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Building Safer Cities

The Future of Disaster Risk

Edited by Alcira Kreimer, Margaret Arnold, and Anne Carlin

The World Bank

Disaster Risk Management Series

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Abbreviations

ACDS	The African Centre for Disaster Studies
ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Center
AIJ	activities implemented jointly
AIUF	additional isolated upper floor
ALOS	Advanced Land Observing Satellite
AMBA	Buenos Aires metropolitan area
ATC	Applied Technology Council
BWDB	Bangladesh Water Development Board
CBA	cost-benefit analysis
CBO	community-based organization
CDM	clean development mechanism
CENAPRED	National Center for Disaster Prevention
CEOS	Committee on Earth Observation Satellites
CEPA-INDEC	Comité Ejecutivo para el Estudio de la Pobreza en Argentina
CER	carbon emission reduction
CERT	citizen emergency response training
CPACC	Caribbean Planning for Adaptation to Climate Change
CRED	Center for Research on the Epidemiology of Disasters
CRID	Regional Disaster Information Center
DMF	Disaster Management Facility of the World Bank
DERC	Disaster and Emergency Reference Centre (the Netherlands)
DIFPP	Dhaka Integrated Flood Protection Project
DIMITRA	International Network on Disaster Management Training in Africa
DRC	Disaster Research Center
DWASA	Dhaka Water Supply and Sewerage Authority
ECLAC	Economic Commission for Latin America and the Caribbean
EIB	European Investment Bank
ENLA	Emergency Network Los Angeles
ENSO	El Niño Southern Oscillation
EOS	earth observation satellites
EPRI	Electric Power Research Institute
EUROMED	European-Mediterranean Partnership
FAO	Food and Agriculture Organization of the United Nations
FDI	foreign direct investment
FEMA	Federal Emergency Management Agency (U.S.)
GAGAN	GPS and geo-augmented navigation system
GATT	General Agreement on Tariffs and Trade
GBM	Ganges-Brahmaputr-Meghna
GDIN	Global Disaster Information Network
GDP	gross domestic product
GEF	Global Environment Facility
GEO	geostationery-earth-orbit
GHG	greenhouse gas
GII	global information infrastructure
GPG	Gauteng Provincial Government
GPS	global positioning systems
GR	greater Resistencia
GSF	greater Santa Fe
IAS	innovative anti-seismic
ICBS	International Committee of the Blue Shield
ICCROM	International Center for the Study of the Preservation and Conservation of Monuments

ICOMUS	International Council on Monuments and Sites
IDB	Inter-American Development Bank
IDNDR	International Decade on Natural Disaster Reduction
IDRC	International Development Research Centre
IEEE	Institute of Electrical and Electronics Engineers
INODEX	Indian Ocean Experiment
IFAD	International Fund for Agricultural Development
IFI	international financial institutions
IFRC	International Federation of the Red Cross and Red Crescent Societies
IIASA	International Institute for Applied Systems Analysis
IMF	International Monetary Fund
INDEC	Instituto Nactional de Estadísticas y Censos
INEGI	National Institute of Statistics, Geography, and Information
INGC	National Institute for Disaster Management (Mozambique)
IOM	International Organization for Migration
IPCC	Intergovernmental Panel on Climate Change
IPCC CZMS	Intergovernmental Panel on Climate Change, Response Strategies Working Group, Coastal Zone Management Subgroup
IPEC	Instituto Provincial de Estadística y Censos
IRI	International Research Institute for Climate Prediction
ISRO	Indian Space Research Organization
JI	joint implementation
JICA	Japan International Cooperation Agency
LDC	least developed country
LEO	low-earth-orbit
LME	London Metal Exchange
MBS	Montserrat Building Society
MIC	methyl isocyanate
MFI	micro-finance institution
NAO	North Atlantic Oscillation
NASDA	National Space Development Agency of Japan
NASSCOM	National Association of Software and Service Companies
NATO	North Atlantic Treaty Organization
NDMC	National Disaster Management Centre (South Africa)
NDPRC	National Disaster Preparedness and Relief Committee (Malawi)
NERC	North American Electric Reliability Council
NGO	nongovernmental organization
NOAA	National Oceanic and Atmospheric Administration
OAS	Organization of American States
OECD	Organization for Economic Cooperation and Development
OFDA/USAID	Office of Foreign Disaster Assistance of the U.S. Agency for International Development
OP	operational program
OSCE	Organization for Security and Co-operation in Europe
PCF	Prototype Carbon Fund
PCUP	Philippine Commission on Urban Poor
PICCAP	The Pacific Islands Climate Change Assistance Programme
PMU	phasor measurement unit
PSDS	Private Sector Development Strategy
PSI	Private Sector Development and Infrastructure Vice-Presidency of the World Bank
PUWC	Pico Union Westgate Cluster
PWV	Pretoria-Witwatersrand-Vereeninging
RAJUK	Capital Development Authority, Dhaka
RAT	rational action theory
RMS	Risk Management Solutions
RPG	Rassemblement du Peuple Guineen
SADC	Southern African Development Community
SIFEM	Sistema Federal de Emergencias
TMG	Tokyo Metropolitan Government
UBN	unmet basic needs

UNCTAD	United Nations Conference on Trade and Development
UNCHS	United Nations Human Settlements Programme
UN/DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNDRO	United Nations Disaster Relief Office
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Affairs Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNFCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
UNHCR	United Nations High Commissioner for Refugees
UN/ISDR	United Nations International Strategy for Disaster Reduction
UNOCHA	United Nations Office of the Coordination of Humanitarian Affairs
UNU	United Nations University
USAID	U.S. Agency for International Development
USGAO	U.S. General Accounting Office
USGS	U.S. Geological Survey
USNRC	U.S. National Resource Council
VAP	Variability and Adaptation Facility
WCC	World Coast Conference
WHO	World Health Organization
WMO	World Meteorological Organization
WTO	World Trade Organization
WWF	World Wildlife Fund

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Editors' Note

Vulnerability to disaster impacts is one of the most underestimated issues in urban development. By 2050, the world population is expected to grow by 3 billion people. Most of this growth will take place in developing countries—and within these countries, in cities and towns—more than doubling urban populations. Large numbers of people will be concentrated in megacities and on fragile lands, making reduction of vulnerability to disasters in metropolitan areas a critical challenge facing development.

Disaster impacts are increasing in severity. Annual direct losses for weather-related events have increased from $3.9 billion in the 1950s to $63 billion in the 1990s. Moreover, a number of ongoing trends have the potential to cause even more severe and broader disaster impacts than ever before. These include increased environmental degradation, the impacts of climate change, population growth in cities, and globalization.

Increasingly, disasters affect communities far beyond the areas of geographic impact as regions are linked in new ways. During the 1999 earthquake in Turkey, numerous textile factories collapsed, bringing to a standstill Turkey's large demand for African cotton. While the September 11 terrorist strikes had devastating impacts in the United States, the greatest economic and human impacts may be felt in Sub-Saharan Africa. The World Bank estimates that the resulting global economic slowdown could kill 20,000–40,000 children, half of them in Africa, as poverty worsens.

While industrialized countries may register higher economic losses following a disaster, there are frequently systems in place to respond to the event to minimize loss of life. Property is often covered by insurance. In developing countries, by contrast, disasters can cause major setbacks to economic and social development, inflict massive casualties, and cause the diversion of funds from development to emergency relief and recovery. Urban areas are particularly vulnerable to disruptions from extreme events, especially in developing countries, where the combination of structural poverty, decaying and substandard infrastructure, high population densities, and the concentration of economic assets and commercial and industrial activities magnify the problem.

The Future of Disaster Risk: Building Safer Cities Conference

In order to increase the awareness of development agencies regarding the urgency of addressing urban vulnerability to hazards, the World Bank's Disaster Management Facility and the ProVention Consortium—a coalition of international agencies, nongovernmental organizations (NGOs), governments, the private sector, and academics—hosted a conference from December 4 to December 6, 2002.

The conference explored a range of issues related to disaster vulnerability and identified priorities for development and disaster prevention activities to ensure safer cities in the future. Papers to serve as conference background materials were commissioned from experts, disaster management researchers, and development practitioners. The papers were complemented by presentations. Discussions revolved around a range of issues facing urban areas, including:

- economic impacts and globalization;
- adaptation to climate extremes and climate change;
- preventive strategies to reduce disaster risk;
- social infrastructure and the vulnerability of the poor;
- social perception of risk;
- the impacts of disasters on critical infrastructure linkages; and,
- threats to megacities from new types of hazards.

Conference Volume

The papers in this volume are organized into four sections: Globalization and the Economic Impacts of Disasters; Environment, Climate Variability, and Adaptation; Social Vulnerability to Disaster Impacts; and Vulnerability of Critical Infrastructure to Disasters. Presentations and related conference proceedings are available on the websites of the ProVention Consortium (http://www.proventionconsortium.org) and the Disaster Management Facility (http://www.worldbank.org/dmf). There is some divergence of views among authors selected for this publication, though we hope their differing viewpoints enrich the debate and highlight the myriad issues surrounding disaster management.

Globalization and Economic Impacts of Disasters

In the first section, Charlotte Benson and Edward Clay explore the relationship between integration in the global economy and sensitivity to natural hazards. They take a macroeconomic perspective illustrated by case studies on Bangladesh, Dominica, and Malawi—three countries with varying degrees of economic diversity and vulnerability to natural hazards. More generally they note that, with reduced barriers to international trade and increased foreign direct investment (FDI), there has been a steady, accelerated movement toward globalization, especially since the late 1980s. They also point out that this increased global economic activity is resulting in environmental degradation that in turn increases the frequency and intensity of natural disasters, making their impacts more devastating. In the three case studies, they explore the complex developmental, economic, and societal factors that affect a country's vulnerability to natural hazards.

Torben Andersen also addresses globalization and notes that, while the frequency of disaster events has quadrupled over the past 30 years, reported economic losses have increased by a factor of 2,000 to 3,000 and insurance losses have increased by a factor of 1,000. These economic losses have by far outweighed economic growth figures for the same period. Andersen notes that these losses hit developing countries hardest and those without post-disaster contingency plans were forced to divert funding from development to disaster relief, stunting the country's growth even more. Furthermore, Andersen argues, some countries do not take steps to mitigate potential hazards since they expect the international community to bail them out in the event of a large disaster. This bailout, however, results in a "moral hazard." Although helping a country following a disaster seems to be the right action to take, this action discourages governments from adequately planning for disasters. Andersen also discusses the importance of countries having diversified economic bases and expert concentrations to help withstand the common shocks that disasters can cause.

Additional positive and negative aspects of globalization on the economies and social development of developing countries are examined by José Miguel Albala-Bertrand. He suggests that globalization has given rise to worldwide economic cycle synchronization that is linked to the performance of industrialized economies. This theory proposes that if industrialized countries are in recession, disaster recovery for developing countries may take longer, since less assistance will be forthcoming and a worldwide recession will make any sort of recovery difficult. He focuses on urban disasters and argues that their effect on the macroeconomy is often negligible because reconstruction and business opportunities brought by a disaster provide opportunities and economic stimulation. Disaster management activities, therefore, should focus on communities and their resilience since the economy will either recover on its own or be subject to greater forces that cannot be controlled.

Several contributors to the volume address the decisionmaking process involved in financing and dealing with disaster risk. For example, Paul Freeman examines the consideration of disaster risk in the privatization process. As part of a development agenda, countries often privatize infrastructure, particularly telecommunications, electricity distribution, and water pipeline systems. As the provision of goods and services is transferred from governments to the private sector, associated risk must also be allocated. Freeman's paper explores the role that privatization can play in shifting the risk of financing post–natural disaster reconstruction from the government to the private sector. Though governments have traditionally been seen as the entity best able to cope with risk, Freeman suggests that natural hazard risk no longer be placed automatically with a government and that this risk be allocated during the privatization process. Freeman identifies several complex issues surrounding risk identification and allocation and states that the risk should be placed with the entity most capable to deal with it. The power of taxation has traditionally made governments best able to cope, but in politically unstable countries and those subject to recurrent disasters, a resource gap may exist. This gap—identified by studying the likelihood of an event, insurance coverage, and a country's ability to raise money through taxes—may mean that a government is unable to sufficiently assume natural disaster risk, and losses might be more efficiently handled by the private market.

Reinhard Mechler also addresses how to account for disaster risk when making development investment decisions. Mechler suggests that cost-benefit analysis (CBA), used in the economic and financial evaluation of public investments, is an underutilized tool that could be better used to account for disaster risk. According to Mechler, using CBA for investment and risk management projects in the context of natural disaster risk improves decisionmaking and the allocation of scarce resources to the most profitable undertakings. This leads to more careful project selection and designs that decrease vulnerability to hazards and secure project benefits. Though cost-efficiency as measured by CBA should not be the sole criterion for assessing investment in development and risk management projects, it provides important information for efforts aimed at reducing potential economic impacts due to natural disasters, thus contributing to more robust economic development.

In a similar vein, Howard Kunreuther discusses whether individuals and businesses have enough economic incentives to carry out socially appropriate levels of mitigation for reducing future disaster losses. He provides several scenarios of interdependent disaster risk illustrated by measures taken (or not taken) by families in adjoining homes to reduce losses from an event such as an earthquake and the possibility of resulting fires, water leaks, or gas explosions that could spread. Kunreuther concludes that such interdependent risks serve as a disincentive for undertaking mitigation measures since one or a handful of families will not invest in mitigation measures if their home will still be at risk due to an unprotected neighbor's home. To encourage mitigation measures, therefore, he suggests greater public-private partnerships that encourage individuals to undertake loss reduction measures and governments to enforce regulations and building codes.

Environment, Climate Variability, and Adaptation

The 20th century ushered in a number of trends that affected the environment and altered its natural rhythms. The industrial revolution, ever-increasing technological innovations, rapid urbanization resulting from the mechanization of agricultural production, and the birth of megacities have put pressure on natural resources and contributed to climate change.

Six authors address urban vulnerability and environmental issues through papers relating to climate change, coastal megacities, flooding, urbanization, and urban land markets. Anthony Bigio's work on climate change promotes the idea that development-financing institutions such as the World Bank, which invest significant amounts in urban areas affected by climate variability, should incorporate adaptation measures into project design. He notes that sea-level rise is the phenomenon exclusively linked with climate change, though climate change also increases the risk of wildfires and storms, impacts fisheries and agriculture upon which urban areas depend, worsens air pollution, and enhances urban heat islands. There are adaptation mechanisms that include improving infrastructure and strengthening defenses, especially in response to sea-level rise, though these changes may impact the environment in such a way that local economic bases are changed.

Climate change in the context of coastal megacities is discussed by Richard Klein, Robert Nicholls, and Frank Thomalla, who note that much of the projected growth in large cities is expected to take place in such locations. Many of these cities have existed for centuries, though it was only during the 20th century that these cities expanded rapidly and began to critically impact natural processes. While weather-related hazards have always been greater for coastal locations, these hazards, combined with human activities and environmental degradation, lead to greater erosion, storm and wind damage, flooding, and salinization of surface waters. Though the threat is global, it is thought to be most severe in South and Southeast Asia, Africa, the southern Mediterranean coasts, and to a lesser extent in East Asia. The authors suggest that, to deal with climate change, desirable policy and management goals should include resiliency and adaptive capacity for weather-related hazards. This framework would have the benefits of linking the analysis of present and future hazardous conditions and enhancing the capacity for disaster prevention and preparedness with disaster recovery.

Hans Günter Brauch focuses more specifically on the potential impacts of climate change in the Mediterranean region, an area of rapid urbanization. He notes that disasters in the region have varying economic and social impacts that have not been adequately addressed at a regional level, since the Mediterranean encompasses diverse communities in Southern Europe, North Africa, and parts of the Middle East. Disasters impact each of these areas differently, and while Southern Europe may be significantly affected by disasters, the preventive measures in place generally prevent extensive loss of life. By contrast, disasters in North Africa and Turkey often result in greater loss of life and property, which may be preventable. Many of these events appear to have greater impacts resulting from a combination of environmental degradation and climate change that increases the frequency and severity of flooding, extreme winter weather, and mudslides. Rapid urbanization in the region also increases the potential for losses in heavily populated areas.

In addition to the rise in sea level, climate change is also thought to affect rainfall, which in turn could result in flooding. Three authors examine flooding by studying causes in Dhaka City and the Río Salado Basin in Argentina, as well as the impact of flooding on urban land markets in Argentina.

Flooding in Dhaka is reviewed by Saleemul Huq and Mozaharul Alam in the context of historical processes. Founded 400 years ago by the Mughal Emperor Jahanagir, Dhaka is surrounded by two major rivers and has experienced flooding for years, including numerous floods throughout the 20th century. Dhaka is now a city of more than 10 million people and recurrent flooding is a problem for residents. Most of the city's low-lying areas and wetlands have been filled in, upsetting the natural water runoff process. The city has implemented a flood protection program including canals, embankments, and pipes to control the flow of water. It is also trying to control the expansion of the city and has forbidden the filling in of wetlands. With an increasing population of urban poor and unsuitable construction in floodplains, the city still faces numerous challenges.

The Río Salado Basin in Argentina covers half of the province of Buenos Aires and is subject to regular flooding. Hilda Herzer writes that socioeconomically it is one of the most important areas in Argentina. It comprises 56 municipalities, and to support its growing population a number of large public works have been carried out, including hydraulic systems to modify the basin's drainage. The basin's primary activities have also shifted from cattle breeding to irrigated farming. As a result, flood and drought cycles now affect agricultural production. The farming and cattle breeding that take place in the basin form an important part of the provincial and national economies. Therefore, the impacts of flooding and drought cycles are not localized and affect the entire country.

Nora Clichevsky also looks at flooding in Argentina, but studies the role of the state as land market regulator in urban areas vulnerable to flooding and the impacts of flooding and flood defenses on land markets. She discusses the competition for desirable urban space in the country and the legal and illegal land markets that arise out of it. With the high rate of urbanization in Argentina and the increase in populated land prone to flooding, this is becoming an even greater issue. There is minimal regulation of the legal land market in Argentina and little control of new housing developments in areas prone to flooding. Clichevsky points out, however, that despite flooding in neighborhoods of all income groups, this does not make a large impact on property values. Evidence of flooding is masked to make property marketable, but the factors most affecting the value are location and neighborhood rather than flood versus nonflood zone.

Social Vulnerability to Disaster Impacts

Of utmost concern in disaster management are the protection of human life and post-disaster recovery that allows individuals and communities to resume dignified lives. Industrialized countries often have the resources and the advance warning systems to evacuate thousands of people and build disaster-resistant structures, all of which save lives. Florida, for example, can be hit by hurricanes that claim few lives and have impacts that destroy only a fraction of local economic growth. Most developing countries are not as fortunate. Disasters still claim tens of thousands of lives each year and destroy livelihoods in an instant.

Katherine Marshall, World Bank Director of the Development Dialogue on Values and Ethics, highlighted the importance of religion as an integral part of social infrastructure. Conference keynote speaker Martin Palmer, Founder and Director of the Alliance of Religions and Conservation, explored this in detail, discussing the unique role that faith-based organizations can play in implementing successful disaster risk reduction strategies. Palmer noted that the 11 major religions of the world control 7 percent of the earth's habitable surface and operate 54 percent of the schools worldwide. With this wide reach, and thousands of years of experience in organizing and motivating people, religious organizations have the potential to influence how people think about risk. Palmer proposed that with the disaster management, development, and environmental conservation challenges of the 21st century, these groups should become more engaged and that the role of religion move from passive to active; to illustrate this point, he cited initiatives in countries such as India and Thailand that have successfully channeled traditional religious values to motivate communities to protect environmental resources. Palmer concluded that harnessing religious values and linking them to development and disaster risk reduction goals is an ancient yet inventive way to increase community involvement, reduce social vulnerability to disaster impacts, and shift perceptions of natural disasters from fatalistic to preventive.

Ben Wisner details diversity in culture and risk perception in two case studies involving four cities: Mexico City and Los Angeles; and Manila and Tokyo. He finds that even in cities that might share similarities, there are vast differences in perceptions of vulnerability and risk. In Mexico City, for example, squatters and children were thought by other city dwellers to be the most vulnerable to disasters. In Los Angeles, by contrast, the elderly and disabled were perceived to be the most vulnerable. Wisner also looked at agencies providing disaster assistance, mainly local governments and NGOs. It had initially been assumed that these two types of institutions could work together and would serve communities well. Wisner found it was not that easy. Though municipalities had the mandate and some funding to assist vulnerable groups, they often lacked in-depth knowledge of social groups and did not have their trust. NGOs possessed detailed knowledge of vulnerable groups and had their trust, but they lacked capacity or a mandate to respond to disaster emergencies. The study highlighted numerous obstacles to their collaboration and it was recommended that additional capacity building in both types of institutions continue.

Enrico Quarantelli also states that risk is a socially constructed concept that can vary vastly from one society to another, though he highlights the emergence of new categories of vulnerables that are a direct result of urbanization and mobility. For example, college students and workers living alone or in quarters, but existing far from families and traditional social support networks, are a group infrequently accounted for in disaster management programs. Notions that slums and squatter communities are disorganized are also challenged, as Quarantelli notes that migrants to cities often live among people of similar ethnic backgrounds and religious beliefs, and are able to organize more effectively than one may think. Quarantelli also discusses the profound effects that urbanization and the development of new technologies is having on the environment, creating newer and more hazardous technologies with impacts that sometimes are not known for years. Suggestions for dealing with such risk include education programs that raise the consciousness of government officials and communities to understand and mitigate risks.

During the conference, Africa was highlighted as a region in serious need of disaster management initiatives. Many African countries are particularly vulnerable when disasters strike urban areas because most countries have only one major city, and many of these are already overburdened. Prvoslav Marjanovic and Krisno Nimpuno submit that, while many African leaders recognize that disasters pose a major obstacle to the continent's efforts to achieve sustainable development, a lack of resources and trained professionals hinders managing disaster risk more effectively. Marjanovic and Nimpuno state that in an attempt to address the shortage of trained professionals, southern African countries have embarked on a number of training initiatives, including three universities in South Africa now offering degree programs in disaster management. South Africa also adopted a new law in 2002, the National Disaster Management Act, which highlights prevention over response, shifting the focus of disaster management activities.

Cultural heritage is also an important component of social infrastructure and quality of life. June Taboroff addresses the impact of disasters upon urban cultural heritage and cites efforts to save historic buildings and precious works of art. In August 2002, flooding in Eastern Europe was featured on the front pages of major newspapers worldwide. Highlighted were not death tolls and injury statistics, but mourning for the loss of irreplaceable treasures and elation at the salvation of others. During disasters in developing countries, cultural heritage is often an afterthought to the emergency response and rarely is it incorporated into disaster management planning. Several international organizations, including UNESCO, are in the process of raising the profile of cultural heritage and working with countries to introduce legislation to protect it under a range of circumstances. While some countries have few resources to devote to preserving cultural heritage, increased awareness is slowly spreading and governments and communities may begin to see value in finding ways to protect cultural heritage for present and future generations.

Vulnerability of Critical Infrastructure to Disasters

Urban communities are dependent upon the infrastructure that supplies them with essential services such as clean water, waste management, electricity, transportation, and telecommunications. Basic services such as these are often the main assets of the urban poor, which assist them to pursue livelihoods and improve their quality of life. Thus, it is essential to protect critical infrastructure from failures in order to prevent families and entire communities from slipping further into poverty.

Several authors addressed the issue of critical infrastructure, retrofitting existing infrastructure, and what happens when infrastructure fails. Hospitals, fire departments, and emergency service stations are also considered essential infrastructure and their proper functioning during an emergency plays an important role in reducing the number of casualties.

Benoit Robert and colleagues discuss critical life support networks and the risks faced from various types of failure including technical malfunctions, sabotage, and natural events. They also weigh the risk of system failure against the level of risk acceptable to the community served by that system. In the case of essential services, they point out that the failure of one system can cause several other critical systems to fail, resulting in a domino effect. Realization of the interlinkages and possible multisystem failures should be taken into account when identifying risks and attempting to mitigate them in the disaster management process.

Lamine Mili identifies similar issues with respect to critical infrastructure, linkages, and possible failure. He focuses on electricity and telecommunications systems and cites examples of massive power failures and their impacts in India, Brazil, North America, and Europe. The power failures were the result of extreme events—a heat surge in India, drought in Brazil, and severe weather in North America and Europe. He also looks at hidden risks that cause system breakdowns, another factor that must be accounted for in planning, since power failures risk lives and negatively impact the economy. Mili emphasizes that the implementation of fault detection, isolation, restoration systems, and plans for survivability of electric power networks following major disturbances is critical to ensure continuously functioning systems. Mili also highlights advances in telecommunications and satellite technologies already being used to monitor severe weather and cites examples of LANSAT-1 ground station linkages with Brazil, China, India, Iran, and Zaire that are able to use this technology.

Mustafa Erdik highlights the devastating loss of life and property that can occur from building failure. The 1999 earthquakes that struck Turkey's industrial belt killed 18,000 and injured 50,000, mostly a result of collapsed buildings. Infrastructure and economic losses ran into the billions of dollars. Erdik states that, though industry losses were better insured than private losses of life and property, the earthquake devastated tens of thousands of families and altered Turkey's industrial landscape. A significant number of skilled workers were killed and many of those who survived would like to move from the area since another, possibly stronger, earthquake is predicted for the coming years. Unfortunately, the greatest lessons from Turkey's tragedy revolved around the revelation of substandard building practices and corruption related to building code enforcement. While building codes had been written and adherence to them could have saved lives, it is too late for the victims of the 1999 earthquakes.

Armenia, situated in a seismically active zone, experienced a similarly devastating earthquake in 1988 that killed 25,000 people and injured 15,000. Since then, there have been improvements in earthquake-resistant technologies, some of them developed locally. Mikayel Melkumyan, an Armenian researcher, developed a system for retrofitting buildings using laminated rubber bearings. Installation of the bearings does not require building evacuation and costs just 35 percent of traditional strengthening materials. The system has been tested over the past five years, and surveys of residents living in retrofitted buildings have revealed that they no longer feel minor earthquakes.

The Way Forward

In synthesizing the various research papers and discussions that took place over the two days of the conference, two main issues emerge: the urgency of addressing increasing disaster vulnerability; and the interdependence of systems at the global, regional, and local levels. Throughout the conference, speakers and participants proposed priorities and solutions for moving forward. Two common threads appear in the numerous approaches discussed: developing innovative approaches to disaster risk reduction and changing people's perception of risk.

John Flora, World Bank Director of the Transport and Urban Development Department, and Orsalia Kalantzopoulos, World Bank Country Director and Regional Coordinator of Southeast Europe, noted that as urban populations have continued to multiply, natural disasters have become bearers of increasing misery, especially for the poor. Additional factors such as climate change, the creation of new hazards, environmental degradation, and rising poverty levels are contributing to the increase in disaster risk. Furthermore, globalization—the increasing interconnectedness of economies, cultures, and the environment—affects the level of vulnerability of developing countries to natural disasters. Natural disaster impacts often span geographic boundaries and must be understood in local, national, and global terms to ensure that appropriate disaster management programs are in place to mitigate and, where possible, prevent major negative impacts on communities and the environment.

This point was reaffirmed during presentations by the concluding panelists: Maritta Koch-Weser, President, Earth 3000; Eva von Oelreich, Head of Disaster Preparedness and Response, International Red Cross and Red Crescent Societies; Helena Molin Valdés, International Secretariat of Disaster Reduction; and, Jean Luc Poncelet, Chief, Program on Emergency Preparedness, Pan-American Health Organization. These panelists recommended areas for leadership and urged conference participants to rise to meet the challenge of preventing future disasters. The panelists also recommended risk management techniques for moving forward, including: investing in improved data and indicators on disaster risk, developing community participation programs, creating new risk transfer and risk reduction mechanisms, and reinforcing partnerships among stakeholders to reduce communities' vulnerability to risk.

Parallel to these important issues, Ngozi Okonjo-Iweala, World Bank Vice President and Corporate Secretary, in her opening remarks and conference discussions iterated the importance of creating innovative approaches to disaster risk management as being crucial to assisting developing countries cope with vulnerability. Several ideas were presented at the conference, including: creative risk sharing and transfer mechanisms, low-cost ways of retrofitting buildings, and techniques for building effective community participation programs. Other speakers discussed innovative uses of standard tools, such as cost-benefit analysis, to integrate disaster risk reduction into development planning.

Along with innovation, a consensus emerged among conference participants that changing people's perception of risk is key to advancing disaster risk reduction. Frannie Leautier, World Bank Institute Vice President, emphasized that communities must understand that they are not helpless in the face of disasters. To empower such groups, education and training were detailed in conference discussions and papers as powerful tools to raise awareness of the importance of preparedness programs and natural disaster risk reduction. From community-level awareness raising and involvement to building a professional-level cadre at senior levels of government and disaster management organizations, learning activities were the most frequently cited solution to creating capacity for disaster risk reduction.

By applying innovative approaches to disaster risk reduction and by empowering people through effective disaster reduction strategies, communities and governments will be more resilient when disaster strikes and better able to protect their lives, homes, livelihoods, and assets. We hope that, by bringing together different stakeholders that do not traditionally interact on the topic of disaster management, this conference made a contribution to advancing the agenda in disaster risk management and will precipitate future collaboration and research among participants. By publishing this volume, the editors hope the dialogue that was initiated at the conference is expanded and its impact broadened.

Flooding after earthquake interrupts commercial activities in Turkey.

Part I

Globalization and the Economic Impacts of Disasters

Chapter 1

Disasters, Vulnerability, and the Global Economy

Charlotte Benson and Edward J. Clay

Two worldwide trends in recent decades are commonly noted and sometimes linked in discussing disasters. First, the reported global cost of natural disasters has risen significantly, with a 14-fold increase between the 1950s and 1990s (Munich Re 1999). During the 1990s, major natural catastrophes are reported to have resulted in economic losses averaging an estimated US$54 billion per annum (in 1999 prices) (Munich Re 1999). Record losses of some US$198 billion were recorded in 1995, the year of the Kobe earthquake—equivalent to 0.7 per cent of global gross domestic product (GDP) (Munich Re 1999).

Second, there is an apparent steady movement toward globalization, with an increasing share of economic activity taking place across countries and regions as barriers to integration are reduced. Between 1987 and 1997, the share of international trade in total output (defined as exports plus imports relative to GDP) rose from 27 to 39 percent for developed countries and from 10 to 17 percent for developing countries (World Bank 2000). Global foreign direct investment (FDI) flows more than tripled between 1988 and 1998 to US$610 billion, and foreign direct investment is now the largest form of private capital flow to developing countries (World Bank 2000). Labor migration and financial remittances to home countries have also been of increasing importance to developing countries and poorer regions within them.

As the World Bank (2000: 1) comments, "globalization is one of the most charged issues of the day.... Extreme opponents charge it with impoverishing the world's poor, enriching the rich and devastating the environment, while fervent supporters see it as a high-speed elevator to universal peace and prosperity." Or, in the words of the 1998 *Siena Declaration*, "rather than leading to economic benefits for all people, it (economic globalization) has brought the planet to the brink of environmental catastrophe, social unrest that is unprecedented, economies of most countries in shambles, an increase in poverty, hunger, landlessness, migration and social dislocation. The experiment may now be called a failure."[1]

But what does globalization imply for vulnerability to natural hazards? Rising disaster losses have paralleled increasing globalization. But are the two trends related—and, if so, necessarily? Or are they coincidental but separate movements? And can differences in the incidence of occurrence and nature of natural hazards influence the form and level of integration of a country into the global economy?

This paper seeks to explore the relationship between integration in the global economy and sensitivity to natural hazards—that is, to events caused by geophysical, hydrological, and atmospheric forces. It takes a macroeconomic perspective and draws on both the wider literature and on evidence accumulated by the authors in a series of studies of the economic impacts of natural disasters. This research includes, most recently, an ongoing study on *The Economic and Financial Impacts of Natural Disasters: An Assessment of Their Effects and Options for Mitigation* undertaken on behalf of the World Bank's Disaster Management Facility, with the financial support of the U.K.'s Department for International Development.[2]

The paper is organized as follows. First, definitions of the key concepts concerning disasters and globalization employed in the paper are given. The next section then considers the implications of various aspects and impacts of globalization for forms and nature of vulnerability to natural hazards. Various aspects of globalization, covering international trade in goods and services; international financial markets; international labor mobility; and international research and exchange of information are considered. The domestic impacts of globalization in certain specific areas—namely, rates of growth, poverty, food security, and environmental conditions—are also discussed.

The potential impacts that risk and disasters, in turn, can have on the pace and nature of globalization are then examined in a section on the implications of natural hazards for globalization, focusing in particular on the issue of whether natural hazards can present a fundamental obstacle to integration.

The next section presents evidence from three countries—Dominica, Bangladesh, and Malawi—illustrating a range of experience in terms of trends in vulnerability, forms that vulnerability can take, and the role of varying external linkages and relations. The case studies also demonstrate that globalization is not a new phenomenon; that it is possible for a country's level of integration into the global economy to decrease, as well as increase, over time; and that the nature of integration can change. The latter two factors, in turn, can have implications for an economy's sensitivity to natural hazards.

The paper concludes with some reflections on the policy and research implications of the complex and changing influences that determine an economy's sensitivity to natural hazards.

The literature relating to both natural disasters and to globalization indicates some diversity in the use of basic terms. At the outset, therefore, it is useful to define how key language is used in this paper:

A *natural hazard* is a geophysical, atmospheric, or hydrological event that has a potential to cause harm or loss. Usually these are both uncommon and extreme events in terms of the range of natural phenomena such as rainfall, tropical storms, flooding, and so forth. Hence the need to determine *risk,* which is understood to be "a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence" (Royal Society 1992: 4).

A *natural disaster* is the occurrence of an abnormal or infrequent hazard that impacts vulnerable communities or geographical areas, causing substantial damage, disruption, and possible casualties, and leaving the affected communities unable to function normally. From an economic perspective, a disaster implies some combination of *losses* in terms of human, physical, and financial capital, and a reduction in economic activity, such as income and investment, consumption, production, and employment in the "real" economy. There may also be severe impacts in terms of financial flows, such as revenue and expenditure of public and private bodies (Benson and Clay 1998). The losses in *stocks* of capital and inventory and reductions in short-term *economic flows* are sometimes confounded in reporting the costs of disaster impacts.[3] These stock losses and short-term flow effects may be so extreme as to result in a modification in the medium- to longer-term trajectory or development path of an enterprise, region, or national economy as well.

Vulnerability is the potential to suffer harm or loss in terms of *sensitivity,* reliance, and reliability. Economic behavior is *sensitive to* a disaster shock. This impact is reflected at a macro or sectoral level in the deviation of economic aggregates from trends that were expected without taking into account the effects of this event. Because economic activity is sensitive to many influences, including other sources of shock, in practice it can be difficult to isolate precisely the impacts of a specific disaster or disasters. The primary objective of our studies has been to seek to isolate and understand these short- and long-term consequences of natural disasters. *Resilience* is the speed of recovery in economic activity, which may involve repair and replacement of lost and damaged capital.

Disaster management literature commonly distinguishes rapid-onset disasters, such as storm surges or earthquakes, which cause immediate loss and disruption, and slow-onset events, notably drought. In our empirical investigations of economic consequences, we have found it useful to distinguish climatic hazards and related riverine and coastal hydrological hazards from geophysical hazards.

Climate-related hazards present threats of varying intensity that are usually recognized at a local or national level, and there is consequently some form of adaptation in terms of economic behavior and the technology in which capital—productive, housing and habitat, or infrastructure—is embodied. The economic, and of course wider social, consequences of both individual events appear to be susceptible to investigation for most lower- and middle-income developing countries. In contrast, potentially catastrophic geophysical hazards may be very rare in occurrence. Even in potentially high-risk geographical regions there may have been no extreme event in living memory or even within the historical record. Consequently, such hazards pose quite different problems of risk perception and economic behavior. However, a global phenomenon—satellite television and linked media information—may be changing that as well.

Globalization is the process through which there is an increase in cross-border economic activities, in the form of international trade of goods and services, foreign direct investment (in turn comprising the financing of new investments, retained earnings of affiliates, and cross-border mergers and acquisitions), capital market flows, and labor migration. It should be noted that greater globalization is not necessarily synonymous with a higher level of GDP, with increasing domestic or regional economic integration, or with market liberalization, although these phenomena are commonly related.

Broader Implications of Globalization for Vulnerability

In this section major aspects of the globalization process are considered in terms of their implications for vulnerability to natural hazards.

International Trade

Reductions in trade barriers and transport and communications costs have resulted in a rapid growth in openness since the mid-1950s, with increasing trade in manufactures (involving more two-way trade) and a fragmentation of the production process (Martin 2001). Initially, developing countries typically liberalized trade more slowly, with a number favoring import substitution policies instead, but since the mid-1980s developing countries have also increasingly reduced barriers to trade, often unilaterally rather than under the auspices of the World Trade Organization (WTO). Average tariff rates in developed countries are now low, although barriers remain in the two areas where developing countries have a comparative advantage: agriculture and labor-intensive manufactures (World Bank 2002). In the case of agriculture, various exceptions have been made for domestic support price schemes under successive GATT negotiations, although negotiations are currently underway in the WTO on a new agreement on agriculture. Quotas have also remained on exports of textiles and clothing, discriminating by country. Indeed, both the World Bank (2002) and others are calling for a "development round" of trade negotiations.

As a result of this broad process of liberalization as well as increased FDI (see the following "External Trade" section) and a relatively high rate of accumulation of human and physical capital, many globalizing developing countries have shifted exports from agricultural to manufacturing products. In 1965, agricultural commodities accounted for about half of developing country exports and manufactures for only around 15 percent. By the late 1990s, around 80 percent of developing country exports were in the form of manufactured items, with agricultural products falling to around 10 percent by 1998 (Martin 2001). Although there is considerable variation in the composition of exports between different developing countries, with some remaining as primarily agricultural exporters, even many of these latter countries have experienced some growth in manufacturing exports. Exports of services from developing countries have also increased significantly.

Different productive activities are potentially differentially sensitive to natural hazards; thus, any change in the composition of production could be significant in terms of the level and nature of risk. Natural hazard events may reduce the availability of particular goods and services for export (either directly or via disruptions to transport and communications networks) while simultaneously increasing imports, to meet both disaster-related domestic shortages and relief and rehabilitation requirements. Ramifications throughout the economy can be significant. Depending on levels of foreign-exchange reserves and on government external borrowing policy, a deterioration in the balance of trade could result in an increase in external borrowing, with implications for future levels of debt servicing and, ultimately, economic growth. Any worsening of the balance-of-payments position could also exert pressure on the exchange rate and, thus, on international competitiveness. There are also potential budgetary implications in so far as government revenue is derived from export and import duties and tariffs. Thus, it is important that a government be aware of the potential sensitivity of its various exports to natural hazards and the possible consequences of any changes in both relative and absolute composition. As liberalization encourages trade, it also encourages shifts in the composition of an economy, with implications for livelihoods, their relative security, and ultimately household vulnerability to natural hazards, a theme explored in further detail below.

At first sight, diversification and the shift toward manufacturing exports would seem a positive development from a natural hazards and balance-of-payments perspective. Renewable natural resource commodities (agriculture, forestry, fisheries) are often among the most directly affected by natural hazards. The sector is particularly susceptible to climatic hazards such as droughts, excessive rainfall causing floods, and cyclones, although the extent and nature of impact depends in part on the timing of a hazard event relative to cropping cycles, and on the severity of the hazard itself. Moreover, it is often difficult to obtain insurance against crop losses. Natural hazards can also have indirect effects via their impact on agricultural equipment and infrastructure, such as drainage and irrigation systems, post-harvest and storage facilities, and boats, as well as generally on transport and marketing infrastructure.

Primary commodity exports, including metals, minerals, and oil, as well as renewable natural resources, are also vulnerable to commodity price shocks. Few countries are price-setters in such markets and thus may experience coincidental contemporaneous fluctuations in international commodity prices, either offsetting or exacerbating balance-of-payments and inflationary impacts of disasters.

That said, there is evidence that efforts have sometimes been taken to dampen the impact of hazard-related falls in agricultural production. In Fiji, for instance, sugar reserves have been used to maintain export earnings and prevent loss of export markets in the aftermath of natural disasters (Benson 1997a). There is probably less scope for using stockpiles of manufactured items to manage risk in this way. Shifts in technology and fashions make many manufactured items rapidly obsolete, while modern management techniques often emphasize just-in-time production processes. Moreover, most manufacturing production is in privately owned enterprises, with, by implication, little regard given to the stability of the broader external sector in undertaking production and export decisions. In contrast, stockpiling agricultural produce was often undertaken by public or quasi-public agencies, in part specifically to stabilize export earnings. Governments need to recognize this change and consider whether new ways of managing balance-of-payments risks—for example, encouraging international financial risk transfer mechanisms or maintaining increased foreign exchange reserves—are required.

The shift into manufacturing products also means that many developing countries are now competing against developed countries for markets. Thus, when disruptions to production occur—particularly where just-in-time production practices are employed—contracts may be lost and future market shares lost. For example, the shift from agricultural to manufacturing exports and thus, at first sight, to an apparently less sensitive form of economic activity, may not in fact have reduced the potential vulnerability of Bangladesh's export earnings to natural hazards. Bangladesh faces severe global competition in the export of ready-made garments. In contrast, it was the world's primary jute producer and, as such, was a price-setter on the international market. Disruption to the production of ready-made garments could result not only in the direct loss of export revenue but also in the longer-term loss of markets overseas.

The concept of vulnerability also entails potential to recover. Again, in some instances agriculture can offer certain advantages, as illustrated by banana cultivation in Dominica (see below), but generally, manufacturing activities can often be restored faster. In the event of hazard-related damage, however, there is a possibility that a particular productive activity will not be re-established at all. Although there has been no research undertaken in this area, it is plausible that manufacturing activities, which are less geographically tied than agricultural ones, could simply be relocated elsewhere, with implied losses to the local economy and, where FDI is involved, to the national economy.

Despite these reservations, the broad shift in composition of exports experienced by many developing countries in recent years is, on balance, almost certainly a positive development from the perspective of sensitivity of exports to natural hazards. However, again from a natural hazards perspective, the fiscal implications of trade liberalization may be less beneficial, to the extent that liberalization reduces earnings from import duties.

Revenue emanating from import duties is typically less sensitive to natural hazards. Import duties are also relatively easy to collect—an important point where a disaster results in administrative chaos and disruption. The precise implication of any reduction in import duties will depend on the precise structure of taxes in a country, including not only the significance of import duties but also the relative rates charged on different categories of imports (food, oil, inputs to industry, luxury items, and so forth).

Finally, over the over the past two to three decades, growth in various service industries linked into the international economy has offered another form of risk diversification as illustrated by the case of Dominica. International financial services and tourism are probably the most significant in this regard. International financial services can be structured in such a way that performance is determined almost entirely by nondomestic factors. The growth of tourism also offers some opportunity to reduce an economy's overall sensitivity to natural hazards. However, efforts are required to ensure that the transport, communications, and tourism infrastructure are hazard-proofed. Tourists themselves also need to be adequately protected in the event of a disaster. It should also be borne in mind that demand is potentially highly sensitive to bad publicity. These are regionally and globally relatively footloose sectors and so investment may cluster in perceived low-risk locations.

Foreign Direct Investment

The globalization process has also involved increasing flows of FDI, as already noted, in part stimulated by a reduction in developing country restrictions on foreign investment (World Bank 2002). The majority of FDI flows go from advanced industrial to advanced industrial countries. Advanced countries accounted for 85.3 percent of total FDI outflows between 1993 and 1997; and for 71.5 percent of FDI inflows over the period 1985 to 1997. However, the share of inflows to developing and transition economies is increasing, jumping from 21.8 percent in 1988–92 to 39.8 percent in 1993–97 (Shatz and Venables 2000).

There are two basic forms of FDI: horizontal and vertical. Much of the intra-industrial country investment is horizontal but, relative to developed-country investment, much of the inflows to developing countries are vertical (Shatz and Venables 2000). Both forms of FDI bring potential benefits in terms of increased supply of capital and access to technology, management expertise, and markets. Each can also alter the nature of sensitivity of an economy to natural hazards.

Horizontal integration, under which a firm supplies a foreign market with its product by producing locally rather than importing, implies that domestic availability of a product may be reduced due to direct damage to the operating plant, potentially placing additional pressure on the balance of payments post-disaster. Domestic production, rather than import, of a particular item also changes the nature of demands on a country's transport network; whether or not this is to the firm's advantage post-disaster remains unclear. Potential post-disaster slumps in an economy could also reduce demand for a particular item, perhaps with implications for demand for labor in the affected industry.

Vertical FDI involves shifting a stage of the production process to low-cost locations, on the basis that "different parts of the production process have different input requirements and, since input prices vary across countries, it may be profitable to split production" (Shatz and Venables 2000: 7). Vertical FDI offers the advantage that demand does not depend on domestic economic circumstances and thus is immune to the consequences of any disaster-related slump, instead continuing to offer employment. However, it can be affected by temporary disruption to transportation and communications networks.

From a natural hazards perspective, both forms of FDI are also potentially significant in spreading risk, both from the perspective of individual producers, who can hold assets in more than one country, and from that of an economy, reducing relative levels of risk borne domestically. Such benefits of foreign ownership were apparent in the case of lime production in Dominica in the past. Large multinational producers involved in the production of primary commodities may be better placed to transfer risk by taking advantage of commodity futures (offering the opportunity to buy and sell forward or reserve the right to do so at a pre-agreed price) and reinsurance markets, by virtue of their greater knowledge and experience.[4]

Foreign investors may also build factories and other buildings to companywide building standards which, where they exist, are often very high, reducing potential physical damage as a consequence of natural hazards. This is not always the case, however. In Bangladesh, for instance, inward investment in garment manufacture seeking low-cost sourcing that exploits potentially temporary tariff loopholes may be associated with low-specification, poor safety designs in high-risk locations (see the following section on Bangladesh).

In summary, globalization in the form of increased FDI flows will alter the nature of risk. The nature of this change will depend on individual circumstances but, on balance, in many cases will probably play a role in reducing broader economic sensitivity to natural hazards.

International Financial Markets

Financial globalization entails the integration of a country's local financial system with international financial markets and institutions. It involves an increase in cross-country capital movement, including the participation of local borrowers and lenders in international markets and in widespread use of international financial intermediaries (in part via their presence, largely in the form of foreign banks, in local markets as well as in the use of those located overseas) (Schmukler and Zoido-Lobatón 2001). The process of financial globalization has been significantly aided by gains in information technology, reducing the importance of geography, as well as by liberalization and privatization of public financial institutions in developing countries.

From a natural hazard perspective, such instruments offer certain advantages. First, firms and households may be able to smooth consumption and investment while meeting rehabilitation costs as they arise. International banking also enables individuals to hold funds with institutions better able to diversify risks. An extreme example of the need to diversify is the case of the Montserrat Building Society during a volcanic emergency (box 1.1).

Increasing international financial integration could also offer a future mechanism for the spread of risk by microfinance institutions (MFIs). MFIs provide financial services to the poor, extending credit and providing savings facilities. The loans they provide are typically very small, are mainly intended for productive purposes, do not require conventional forms of collateral, and are extended on a nonprofit-making basis. MFIs are highly vulnerable to natural hazards because of temporary liquidity difficulties as they try to support clients through difficult periods while also experiencing a temporary drop in flows of debt repayments. Some MFIs are therefore beginning to explore options for disaster insurance to protect themselves and enable themselves to respond to the additional disaster-related needs of their clients. To date, the MFIs that have established such schemes have basically opted for self-insurance, setting some resources aside into a calamity fund for

Box 1.1 Financial fallout from the Montserrat volcanic eruption

The volcanic eruption in Montserrat, which began in mid-1995, resulted in the displacement of 90 percent of the residents from their homes, with more than half eventually leaving the island. One of the financial casualties was the Montserrat Building Society (MBS), the country's only building society, which effectively collapsed. The MBS is largely dedicated to using savings to finance housing. The MBS estimated that, prior to 1995, it had accounted for approximately 90 percent of mortgages on the island as well as for a high proportion of savings by residents and some nonresident migrants. However, following an escalation of the crisis in August 1997, most insurance policies were suddenly canceled by international companies that could easily give up business on an island that was a marginal part of their portfolio. The mortgaged assets held by the MBS immediately assumed a zero value, putting the Society into substantial deficit. Although the MBS remained open, following a temporary three-week closure, depositors were initially only able to withdraw up to 35 percent of their savings while the Society remained in deficit. In early 1999, the MBS announced that savers could withdraw a further 35 percent of their savings. The contrasting behavior of international insurers and a local financial institution illustrates the ambiguities of globalization that can alter but not necessarily reduce disaster risks (Clay and others 1999).

use in the event of an emergency. In the event of a disaster seriously affecting a significant proportion of clients, however, such funds would be grossly inadequate. The alternative—placing the risk externally—would create additional overheads, making the cost of credit itself more expensive. Instead, the solution could lie in some sort of international syndicate of MFIs. Good practice dictates that MFIs should not encourage a culture of default and that, instead, borrowers should ultimately repay any loans. Assuming this occurs and that default—as opposed to deferment—rates are low (as evidenced in, for instance, Bangladesh and Dominica), MFIs could benefit significantly from temporary access to additional resources to smooth fluctuations in demand relative to the availability of funds. Such resources could be provided by other, unaffected, syndicate members.

Globalization has also brought with it increasing possibilities for the use of traditional and newer forms of financial risk transfer. More traditional tools comprise insurance and reinsurance. Newer instruments, developed over the past five years in response to dramatic increases in more traditional ones, entail some form of hedging transaction in capital markets. Weather derivatives involve automatic and immediate payouts (typically available within 72 hours) upon the occurrence of a predetermined trigger event, irrespective of the scale or nature of damage. Catastrophe bonds provide attractive payments to investors unless the specified catastrophic event involves a reduction, and in some cases cancellation, of the principal and/or interest on a bond.

The potential advantages of these various mechanisms include the alleviation of post-disaster pressure on fiscal and external balances; increased government control over the financing of disasters, possibly including the immediate and timely availability of funds; increased capacity for the relevant government to set its own priorities in the management of relief and rehabilitation; increased transparency in the delivery of relief and reconstruction; and provision of a tool for promoting mitigation.

In developed countries there are already well-established markets for insurance against a wide range of natural hazards, including earthquakes, volcanic eruptions, floods, droughts, and cyclones. Newer hedging instruments are also gaining some popularity. However, insurance and capital market instruments have played a relatively small role to date in the transfer of risk in developing countries. Although there is thus scope for benefits of greater financial integration to be reaped, there are also a number of practical obstacles that need to be overcome before coverage can be increased significantly. There is a need to reform the structure and legal and regulatory framework of the insurance industry in a number of countries, including removal of barriers to entry. The cost of insurance also needs to be affordable and stable. At the same time, insurers need to remain sufficiently capitalized to bear any losses, in turn requiring detailed scientific information on current and future risks.

Despite the various potential benefits of financial integration from a natural hazard perspective, as discussed above, it should also be remembered that such integration carries other, more general, risks. Although the World Bank generally favors greater openness to trade and FDI because of its net beneficial implications for economic development and poverty reduction, it is “more cautious about liberalization of other financial or capital market flows” (World Bank 2000: 2). As Schmukler and Zoido-Lobatón (2001: 3) observe, “international market imperfections, such as herding, panics and boom-bust cycles, and the fluctuating nature of capital flows can lead to crises and contagion, even in countries with good economic fundamentals.” Banks and financial institutions can spread a crisis across countries, as demonstrated by the emerging-market crises in East Asia and elsewhere in 1997–98. Natural hazards themselves could even trigger such crises. The city of Tokyo, for instance, lies in a seismically active area. It experienced a major earthquake in 1923 and volcanologists warn that another major event is “long overdue.” As early as 1995, financial analysts were already forecasting that the next major Tokyo earthquake could result in bond and stock market crashes in the United States and a world recession, as well as severe domestic economic difficulties (Hadfield 1995). There is clearly a need to balance risks from different sources and, where possible, to seek to reduce them. The World Bank (2002), for instance, calls for building up supportive domestic institutions and policies to reduce the risks of a financial crisis before becoming involved.

Finally, as with FDI, private capital does not flow to all countries equally. Indeed, the share of flows to low- and middle-income countries (excluding the top 12) has increased over time (Schmukler and Zoido-Lobatón 2001), implying that many hazard-prone developing countries have yet to benefit from potential risk-spreading tools available via financial integration.

Labor Mobility

Increased labor mobility, the third aspect of globalization, allows affected people a radical and socially ambiguous way of coping with disasters. Mobility provides a potential mechanism for spreading risk geographically via the transfer of remittances across borders. As the World Bank (2002:11) states, "geographic factors make it unlikely that capital flows and trade will eliminate the economic rationale for migration. Too many parts of the developing world have poor institutions and infrastructure that will not attract production; at the same time, some of the existing production networks in the North are too deeply rooted to move." Thus, labor mobility looks set to remain as a potentially significant way of reducing sensitivity to natural hazards. However, there are potential costs in terms of loss of skills to the economy.

In the case of Bangladesh, for instance, flows of external remittances provide a significant source of foreign exchange and have played an important role post-disaster. A relaxation of restrictions on out-migration, including professionals such as doctors in government hospitals and medical colleges, was one of the measures adopted in Bangladesh in response to the economic crisis associated with the 1974 floods and famine. Evidence from the 1998 flood again suggests that remittances can increase sharply during times of crisis, rising by 11.9 percent (in U.S. dollar terms) year-on-year in 1998–99 to US$1.7 billion. Most migration is temporary, with migrants eventually expecting to return to Bangladesh (Ahmed and Chowdhury 1998), implying that family ties are strong.

The implications of migration for broad sensitivity to natural hazards are extremely complex in Sub-Saharan Africa, however, to the extent that migration is often to neighboring countries that may be simultaneously affected by drought, a problem of co-variant risk. In such circumstances, the impact depends on the nature of employment of migrants—for instance, agriculture, which is highly weather-sensitive, or mining (a major source of migrant employment in certain southern African countries), which is relatively insensitive to water shortages.

Economic Growth

Many of the countries that have grown fastest in recent decades have also increased their participation in world trade most rapidly (e.g., Dollar and Kraay 2000; Martin 2001). Although the direction of causality has yet to be established, developing countries included in the latest round of globalization, begun in the early 1980s, are experiencing rapid rates of growth and catching up with more developed countries; this mirrors patterns of convergence between OECD countries during earlier waves of globalization (World Bank 2002). This pattern basically reflects improved resource allocation, in part driven by increased competition as well as the removal of distortive tariffs and other barriers to trade that protect domestic production, and improved access to markets, with markets in turn expanding further as per capita incomes rise.

Economic growth is not necessarily synonymous with broader socioeconomic development, but higher per capita countries also tend to be among those countries classified as more developed. Certain broad generalizations can, in turn, be made about the sensitivity of economies at different stages of development—as defined in terms of complexity of intersectoral linkages, levels of physical and human capital, the scale of secondary and tertiary sectors, and so forth—to natural hazards.

In its earlier stages, development tends to alter, rather than reduce, vulnerability. Socioeconomic change associated with development can lead to the breakdown of traditional familial support, declines in traditional ways of life and associated coping measures, and the increased occupation of more hazardous land, a process in part associated with urbanization. The increased provision of infrastructure and services can also alter, even increase, vulnerability. The attempt to foster rapid growth may be reflected in standards of construction unable to withstand extreme conditions. This appears to have happened in Dominica in the 20 years prior to independence. Similarly, private sector investment in conditions of rapid technical and market change often sacrifices safety and durability to short-term profitability. These are conditions in which there may be increased vulnerability to hazards, especially those regarded as extremely unlikely to occur.

At a macroeconomic level, greater domestic integration increases the multiplier effects of adverse performance in a particular sector or regional economy. For example, droughts, floods, or hurricanes may impact the (larger) manufacturing as well as the agricultural and livestock sectors, particularly where initial growth of the manufacturing sector is based primarily around agroprocessing. A notable exception is found in dual economies with largely self-contained extractive sectors that may be relatively insensitive at a macroeconomic level to climatic shocks. Examples are Botswana and Namibia.

As a country begins to develop, the structure of the financial sector is also likely to be more important in shaping the impact of a natural disaster. Intermediate economies typically have more developed economywide financial systems for the flow of funds, including small-scale private savings and transfers, which also diffuse impacts more widely. For example, in Zimbabwe following the 1991–92 drought, the transfer of remittances from urban to rural regions was facilitated by the well-articulated system for small savings. These transfers not only mitigated the impact of the drought in rural areas but also spread the effects more widely (Hicks 1993).

In the later stages of development, evidence suggests that the relative scale of the economic impacts of disasters is likely to decline again. In part, this reflects the smaller role of the particularly hazard-vulnerable agricultural sector in GDP, as a source of employment, a source of inputs to other sectors, and an end user. Other factors also contribute to reduced sensitivity, including typically higher investment in structural mitigation and proofing measures, generally higher building standards and maintenance practices, greater use of financial risk transfer mechanisms (see the FDI section below), fewer foreign exchange constraints, improved environmental management, and lower levels of poverty.

This framework for relating vulnerability to natural hazards to the growing complexity of the economy is a very broad brush. As the three country cases presented later suggest, a wide variety of other factors also determines sensitivity. For example, prevailing domestic macroeconomic and sectoral policies, deliberate changes in policy as a consequence of a disaster, the external policy environment, contemporaneous fluctuations in primary export and import prices, and the timing and nature of other adverse shocks can all be significant.

Nevertheless, the typology serves as a reminder that economic development and growth are not *necessarily* beneficial from a natural hazards perspective. Instead, natural hazards need to be taken into account in the determination of priorities, policies, and strategies, including those relating to integration into the global economy.

Information Gathering and Exchange

Provision of various regional and global public goods—that is, goods and services that are nonrival in consumption (users do not reduce the supply available to others) and nonexcludable—can clearly benefit from improved transnational cooperation and integration. From the perspective of natural hazards, the greatest benefit has almost certainly been felt in the area of scientific monitoring and forecasting. This is most evident within meteorology and climatology (e.g. Lee and Davis 1998; IRI 2001)

There is a growth in regional and international cooperation in climatic forecasting for the three major climatic regions in Sub-Saharan Africa, for instance. This cooperation links into and has been considerably strengthened by research and monitoring of global climatic processes such as the El Niño Southern Oscillation phenomenon by international and industrialized country institutions such as WMO and NOAA, which have global monitoring networks and can draw on all the power of remote sensing technologies.

Regional cooperation on water resources, which relies more directly on the political cooperation of upper and lower riperian states without global partners, is less advanced. Recent disasters such as the devastating extreme 2000 floods in Mozambique and in southwestern Bangladesh have highlighted the considerable scope for progress on system modeling and flood forecasting.[5]

Another example of international cooperation is the global volcanology community. This is very close-knit, with a small team of international experts providing services around the world. The creation of this informal grouping has been greatly facilitated by improved communications and transportation. There are also major research benefits in the sense that the close cooperation has helped facilitate the building of a consolidated body of evidence from volcanoes around the world.

There are other areas where, from a natural hazard perspective, information gathering and exchange are also advantageous; these include crop research, the development of building codes, the development of strategies to control pollution, and the development of mechanisms for protecting the environment. For instance, in the case of the latter, as the World Bank (2002:17) notes, "some environmental issues, such as global warming, are intrinsically global. They require international cooperation, and the habit of such cooperation is easier in an integrated world."

However, a constraint that is emerging as more information that could have important disaster reduction value is generated, is the capacity at country and regional levels to interpret and utilize these data. National meteorological systems provided as a public good, for example, have to compete for recurrent expenditure with all other areas of public spending. In all of the case studies undertaken by the authors, there was evidence of insufficient spending. This was reflected, for instance, in inadequate operation and maintenance of monitoring systems.[6]

Poverty and Vulnerability

Poor and socially disadvantaged groups are usually the most vulnerable to and affected by natural hazards, reflecting their social, cultural, economic, and political environment. Disasters, in turn, are a source of transient hardship and distress and a factor contributing to persistent poverty. At the household level, poverty is the single most important factor determining vulnerability, in part reflecting location of housing (e.g., on floodplains, riverbanks, steep slopes, or contaminated land previously occupied by industrial facilities), primary types of occupation, and level of access to financial and other resources. The poverty-exacerbating nature of vulnerability is attributable not only to post-disaster-related damage, temporary loss of income-generating opportunities, and increased indebtedness, but also to deliberate risk-averting livelihood choices that poorer households may make. For example, poorer households may choose to forgo the potential benefits of higher-yielding crops in favor of more hazard-tolerant ones, implying more stable and secure but, in most years, lower earnings.

The Government of Bangladesh, for instance, identifies natural hazards as one of the factors eroding the income of the poor via crisis-related expenditure and reductions in income-earning capabilities. Furthermore, it recognizes that poverty alleviation cannot be achieved simply by increasing income, but instead requires a range of other measures, including the strengthening of local capacity to protect the poor against shocks (GoB 2002).

Obviously, to the extent that globalization and related economic growth reduce poverty, they may help reduce vulnerability. Globalization tends to encourage growth and creates new job opportunities, potentially allowing people to move to better jobs. According to the World Bank (2002), in the long run workers gain from integration, with wages growing twice as fast in the more globalized developing countries than in the less globalized ones and faster than in rich countries. However, a reduction in either poverty or vulnerability is not inevitable. Indeed, the World Bank (2002:1) states that although "global integration is already a powerful force for poverty reduction… it could be even more effective." For example, skilled wages rise faster, implying that the education system needs to serve all levels of society in order to avoid increasing inequality.

In terms of vulnerability, economic growth and development may not solve problems of risk and vulnerability, as already noted. The declining importance of agriculture—potentially one of the most hazard-sensitive sectors—typically associated with globalization may reduce vulnerability, both directly and as those previously dependent on agriculture take advantage of increasing alternatives. Some 70 percent of the world's poor and food-insecure people currently depend on agriculture for their incomes and food entitlements (FAO 2001). Enhanced opportunities for diversification of household income can also help spread risk. However, traditional coping mechanisms may be simultaneously disrupted. Within the domestic economy, increased competition emanating from globalization can also imply increased entry and exit of firms, at least in the shorter term, implying greater labor market turnover. This can increase sensitivity to natural hazards and other shocks, requiring efforts to ensure that adequate social protection programs are in place. As the World Bank (2002) notes, social protection may also be crucial in encouraging poor people to take the risks involved in entrepreneurship.

Those facing higher levels of risk, such as those emanating from natural hazards, may require particular encouragement and support in recasting behavior from that of risk minimization to profit maximization.

Globalization and associated growth in the manufacturing sector as well as cuts in agricultural tariffs[7] also fuel urbanization. This process is often rapid and unplanned, by implication forcing poorer groups to live in more marginal and hazardous areas such as floodplains, riverbanks, steep slopes, and reclaimed land (IFRC 2002). Sensitive and carefully designed measures are required to help redress associated risks.

Meanwhile, the World Bank (2002) points out that in those countries left out of the globalization process—which contain some 2 billion people—many are facing declining incomes and rising poverty. Whether this is a direct consequence of the fact that they are not globalizers is not clear. However, the fact remains that a significant segment of the world's population, located in these countries, may remain poor and thus particularly vulnerable to natural hazards, despite global trends toward increasing integration and growth.

Food Security

Food security is "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO 2002a).

This emphasis on people's access as the key to food security is a measure of the considerable progress made toward assuring food security at national and international levels that is partly a consequence of the liberalization of external trade and currency markets. Most, but not all, developing countries are now able to acquire additional food imports to respond to temporary deficits. This is in stark contrast to the situation that prevailed in the early 1970s. For example, Bangladesh, a low-income country with sometimes large, temporary additional import requirements, was unable to finance food imports in the famine crisis of 1974 and was further hampered by a U.S. embargo. Subsequently, its government responded to major disasters with a combination of making massive commercial purchases and seeking—usually successfully—large-scale food aid. Finally, the private sector was allowed to cover a large part of the deficit after the floods in 1998. Small open economies like Dominica, marginal to world and regional or global markets, face logistical but not access difficulties to food imports after a disaster. There are still important exceptions, however: countries like Malawi, which is currently experiencing a food crisis, that have difficulty in financing and organizing national food security.

It is well recognized within the considerable body of literature on food security that natural hazard events, in particular droughts, are one of the principal triggers of potential transitory food insecurity for particular segments of a population. In that light, it is relevant to consider the implications of globalization, particularly agricultural trade liberalization, for sensitivity to chronic and transitory food security.

Historically, agriculture has represented a special case, with various exceptions made for domestic support price schemes under successive GATT negotiations, as already noted. However, under the present WTO Agreement on Agriculture, it was agreed that WTO member countries, other than LDCs, should reduce barriers to market access and market-distorting forms of domestic support to agriculture. Developed countries have now implemented this agreement, while the implementation period for developing countries will conclude in 2004. However, there are concerns that liberalization may not result in enhanced food security, as reflected, for instance, in "a common thread through many proposals by developing countries that staple food crops should be exempted from limits on, or reductions in, support under WTO arrangements" (Roberts and others 2002: 40).

In theory, trade liberalization and associated movements in relative prices of different crops should trigger a supply response, with more rational allocation of resources. This may lead to an increase in aggregate agricultural production levels and net incomes. Such responses would be more likely to reduce chronic, poverty-related food insecurity. Furthermore, the supply response could be modified by various constraints relating to access to markets, agroclimatic factors, and the level and availability of assets (including land), skills, and credit. As the 2001 IFAD Rural Poverty Report (IFAD 2001) states, "under globalization, market access becomes increasingly important as only those who have it can exploit the new opportunities. Without market access, the potential benefits of higher product prices and lower input prices are not transmitted to poor households. Remoteness also restricts access to information about new technologies and changing prices, leaving the poor unable to respond to changes in incentives."

Moreover, even if agricultural production does increase, this does not necessarily imply an improvement in food security. Any shifts between food and nonfood cash crops and between tradable and nontaxable can have implications for food security (FAO 2002b). Some people may lose their livelihoods as part of the restructuring process associated with both agricultural and broader liberalization, again with potentially negative chronic food security and related poverty implications. Increased exposure to competition and world price fluctuations in countries where agricultural industries were previously protected from import competition could also expose some farmers to transitory food insecurity. Oxfam (2000), for example, asks whether small-scale farmers can compete in a liberalized environment and whether there is a need to retain some level of protection. Farmers in developing countries also typically have even more limited access to futures markets and other risk management tools (although globalization could help improve access—see section on FDI). In addition, many have few financial reserves. The two factors combined leave farmers more exposed to sudden price fluctuations under more liberalized conditions, potentially restricting their productive capacity the following season (Roberts and others 2002).

Liberalization could cause increased short-run volatility in international grain markets, posing difficulties for importing low-income countries. This possibility was highlighted by the severe price spike in international wheat and coarse grain markets during 1995–96, when there was a rapid reduction in U.S. and other stocks to low levels. Food aid levels plummeted as well. They also coincided and were thought to be associated with the more liberal trade provisions of the 1995 U.S. Farm Bill (Konandreas 2000). These developments significantly increased, for example, the import costs for southern African countries of coping with the 1994–95 drought.

From the perspective of consumers, food security is to a large degree an issue of affordability, food insecurity is mainly associated with poverty, and cheaper imports can be beneficial (Thompson 1999). This is most unambiguously so for the rapidly growing numbers of poor urban consumers dependent almost entirely on market supply. If trade liberalization promotes economic growth and this, in turn, reduces levels of poverty, then this, too, can improve food security, again by increasing access of the poor to food.

In summary, the impact of trade liberalization on food security has been broadly positive at a global level. But the short-term consequences of liberalization are less clear. Food security continues to be a highly country-specific issue, in part depending on the nature and scale of agriculture and the significance of the sector as a form of employment. There will be both winners and losers, and impacts on food security are likely to vary between groups—for instance, between small-scale and commercial farmers and between farmers, rural nonfarm producers, and urban consumers.

In terms of implications for sensitivity to natural hazards, the impacts are, again, likely to vary between countries. From a consumer's perspective, increased access to world markets could dampen disaster-related food deficits resulting from reduced domestic production. To the extent that globalization more generally facilitates the spread of risk associated with a decline in production, it is also positive.

Environment

Finally, concerns have also been expressed about the impact of globalization on the environment. Environmental degradation, both via greenhouse gas emissions and physical destruction, has implications for the scale, frequency, and extent of the impact of natural hazards. There is clear evidence that a number of countries are becoming increasingly vulnerable to natural phenomena as a consequence of environmental degradation, particularly deforestation, and increased cultivation and occupation of marginal lands. Deforestation has disrupted watersheds, leading to more severe droughts and floods. It has also resulted in the siltation of riverbeds, deltas, bays, and gulfs, again increasing the incidence of flooding. Meanwhile, impacts of changes in the composition of the atmosphere on the frequency and intensity of climatic hazards are predicted to vary significantly between regions and subregions but there are expectations of more extreme weather variability, with associated increases in the incidence of droughts and floods, as well as sea level rises, in many parts of the world.

Globalization is widely considered to be a cause of environmental degradation, as illustrated in the quote from the Sienna Declaration cited earlier. In discussing the impact of FDI more specifically, a recent WWF-UK report states that "the past decade has … seen all major trends of environmental degradation accelerate—for example, greenhouse gas emissions, deforestation, loss of biodiversity. Such patterns of environmental damage have been driven by increased economic activity, to which FDI is an increasingly significant contributor" (Mabey and McNally 1998:3). However, there is also a counter argument that globalization does not necessarily directly exacerbate this process. Regarding deforestation, for instance, growth is often associated with reductions in forest area, most obviously where there is a timber export sector and land is being cleared for export-oriented production. However, the World Bank (2002) argues that particularly high rates of deforestation in some countries may not be the direct result of globalization so much as they are domestic factors. In discussing the more general argument that intensification of competition creates a potential for a "race to the bottom" and "pollution havens," with governments perhaps trying to attain a competitive advantage by lowering their environmental standards, the World Bank (2002) also argues that available evidence suggests that this is not happening. Evidently, the costs imposed by environmental regulation are small relative to other considerations, and so their impact upon location decisions between rich and poor countries is minimal. The WWF-UK report refutes this, however, arguing that studies on which such statements are based "have had serious flaws, and an excessive focus on site-specific environmental impacts and emissions of a few industrial pollutants" (Mabey and McNally 1998:3). The report continues on to present "ample empirical evidence that resource and pollution-intensive industries do have a locational preference for, and an influence in creating, areas of low environmental standards" (Mabey and McNally 1998:3).

Implications of Natural Hazards for Globalization

Risk in various forms can have potential implications for the pace and nature of globalization, whether related to such factors as exchange rate instability or natural hazards. This section considers the role of the latter in determining the extent to which countries are integrated into the global economy and, in addition, are able to reap the potential benefits of that integration.

It is beyond the scope of this paper to undertake an empirical examination of factors determining differences in levels of global integration across countries or, in particular, to explore the linkages between disasters, growth, and patterns of globalization.[8] Nevertheless, natural hazards could be another factor preventing the growth benefits of globalization from being achieved and, as discussed in further detailed below, in some cases even inhibiting the pace of integration itself. As the World Bank (2002: 5) states, "while the new globalizers are beginning to catch up, much of the rest of the developing world—with about 2 billion people—is becoming marginalized. Their aggregate growth rate was actually negative in the 1990s" (World Bank 2002: 5).

Disasters, Growth, and Globalization

The direction of causality between high growth and increasing participation in world trade has yet to be established. Nevertheless, it is widely observed that these two phenomena are correlated. More open, export-oriented economies are also more successful in attracting FDI (see later discussion). Again, each affects the other, but empirical analysis by Singh and Jun (1995) suggests that, on balance, openness encourages FDI rather than vice versa.

Increasing integration can occur without raising growth, but this surely implies that some of the major potential benefits of globalization—specifically, growth and related rising per capita income and, hopefully, a reduction in the level of poverty—will be lost. As Roberts and others (2002: 36) comment, "whether such ready movement does in fact occur depends on whether there is sufficient growth in the economy and alternative activities available to absorb resources displaced through trade liberalization," in turn requiring flexible economic structures and sufficient demand for labor and other resources to enable relatively rapid and substantial adjustment between activities.

Natural hazards could be another factor preventing the growth benefits of globalization from being achieved or, depending on the direction of causality, preventing increasing integration into the global economy by restricting growth.

Theories of development place considerable emphasis on the roles of capital and labor growth and productivity (e.g., Solow 1956; Denison 1967). Yet capital assets and other resources can be severely affected by natural disasters while productivity of undamaged capital and labor can be reduced by associated disruptions to infrastructure and markets. There could be significant direct capital losses (except in the case of drought). All major types of disaster, including drought, can also disrupt longer-term investment plans, both in physical and human capital. Governments may divert resources from planned investments to fund the relief and rehabilitation process. Disaster-related external assistance may be extended, but this may not be entirely additional, instead in part replacing development aid flows due to some combination of limited donor resources and local counterpart funding constraints. Other damage may be covered by insurance policies, but there are still opportunity costs relating to the payment of premiums. And some destroyed assets may not be replaced at all. In the shorter term, disasters and hazard risk can also contribute to economic instability and an atmosphere of uncertainty. It is widely observed, for instance, that disasters typically cause a short-term decline in GDP (see, e.g., Benson and Clay 2000; Charvériat 2000). Yet, research indicates that "macroeconomic stability is essential for high and sustainable rates of growth" (Ames and others 2001: 2). Thus, hazard risks combined with post-disaster related economic instability could be a significant disincentive to potential new investment.

A recent research study undertaken by the International Institute for Applied Systems Analysis (IIASA), in conjunction with the World Bank, confirms the potentially adverse long-term impact of natural disasters. The study sought to model the potential implications of natural disasters for future longer-term growth in three countries (Freeman and others 2001). The analysis focused on their potential impact on capital accumulation and quantified the implications, in particular for growth objectives, of various policy options in dealing with disasters. The study concluded that potential catastrophes should be incorporated into economic projections for three reasons: high opportunity costs associated with the diversion of scarce financial resources into post-disaster relief and reconstruction efforts; the havoc imposed by natural disasters on the already-complicated budgetary planning process; and the high demands that natural disasters place on international aid resources, diverting resources away from development uses.

There has been little empirical analysis of historical evidence on the impact of disasters on long-term growth, however. Benson (forthcoming) attempts to address this gap, examining comparative cross-sectional data on real GDP performance for 115 countries over a 34-year period from 1960–93. The study involved regression analysis and an analysis of relative movements in GDP.[9] Rather than attempting a ranking of countries according to natural hazard risk, countries were simply divided into two categories—higher and lower risk—based on evidence on the incidence of disasters over the period of analysis.[10] Analysis was undertaken both including and excluding Sub-Saharan African countries.

The results suggest that, over the past three decades, more hazard-prone low-income countries may have experienced a relatively slower rate of economic growth than their less hazard-prone counterparts who had similar levels of per capita income at the beginning of the period. However, there are fundamental problems in undertaking such analysis, in particular, that less hazard-prone countries were already typically among the set of more developed countries by the latter half of the twentieth century. Thus, the results may simply reflect Quah's (1993) broader finding of polarization toward a bi-modal distribution, with countries beginning at the higher end of the income distribution likely to experience further increases in income. Moreover, a wide range of other factors also could determine rates of growth

Nevertheless, the basic findings, if tentative, are supported by anecdotal evidence from individual countries, with poorer regions of a country also often more hazard-prone. Charvériat (2000), for instance, notes that communities in the northeast part of Brazil and coastal areas of Ecuador and Peru are typically poorer than less hazard-prone parts of the same countries. In part, such patterns reflect differences in opportunities for growth and development as determined by the relative risks faced by different communities. For example, farmers in more hazard-prone regions of Vietnam have been less well placed to take advantage of higher-yielding but less hazard-tolerant strains of rice, while more hazard-prone regions of the country have also received disproportionately small shares in private and public investment and external assistance (Benson 1997b).

Disaster-related budgetary pressures can also affect a country's ability to participate in the global economy in other ways. In the aftermath of a disaster, a government will be obliged to meet potential budgetary pressures by increasing the money supply, drawing down foreign-exchange reserves, or increasing levels of domestic and/or external borrowing. Foreign borrowing can result in an appreciation of the exchange rate, reducing the price of imports and increasing that of exports. In addition, it can place future strains on the economy via higher debt-servicing costs.[11] Natural disasters can also trigger an increase in interest rates charged on new external loans by increasing the risk premia associated with a country's assets. Another option, the rundown of foreign-exchange reserves, is limited by the size of those reserves and entails an appreciation in the exchange rate, with possible associated risks of capital flight and a balance-of-payments crisis (Fischer and Easterly 1990).

External Trade

Many of the nonglobalizers are Sub-Saharan African countries and former Soviet republics, with exports focused on a narrow range of primary commodities, making them highly vulnerable to commodity price shocks (World Bank 2002). Their failure to diversify exports has been attributed to various factors, including poor policies (e.g., product standards and regulations, health and safety regulations, labor and environmental regulations), weak institutions, poor access to information, corrupt governance, limited technology, poor infrastructure, adverse geography (e.g., being landlocked, greater proneness to disease), and climate (Brahmbhatt 1998; World Bank 2002).[12]

Natural disasters may certainly have contributed to some of these constraints, in particular poor infrastructure. Natural disasters could, in fact, be viewed as an aspect of adverse geography, although the literature on globalization and the role of geographical factors in determining growth (e.g., Acemoglu and others 2000; Diamond 1998; Gallup and Sach 1999) tends to ignore them.

In terms of the role of infrastructure, Limão and Venables (2001) argue that, now that recent liberalizations have reduced artificial trade barriers, the effective rate of protection provided by transport costs is considerably higher than that provided by tariffs for many countries. They estimate the elasticity of trade flows with respect to transport costs at approximately 2.5—that is, halving transport costs would increase the volume of trade by a factor of five, or improving infrastructure from the 75th percentile to the 50th would increase the volume of trade by 50 percent. Transport costs depend on various factors including distance, administrative barriers, and the structure of the shipping industry. However, Limão and Venables (2001) find that infrastructure is also quantitatively important. For example, their results suggest that improving one's own and transit countries' (that is, countries through which merchandise travels before reaching its destination) infrastructure from the 25th percentile to the 75th percentile would overcome approximately two-thirds of the disadvantage associated with being landlocked.

Natural hazard events can destroy transport and other infrastructure. Disasters can also result in the diversification of resources away from new investment and into reconstruction, ultimately constraining efforts to upgrade transportation systems. Efforts to improve the efficiency and economy of the Philippines' transportation systems, for instance, are reported to have been only moderately successful because most available resources were redirected in response to calamities, with knock-on implications for the pace of improvement of rural transport linkages (Philippine NLUC 1992). Moreover, disaster-related repairs can disrupt general maintenance operations. In Dominica, unanticipated expenditure on the repair of roads following landslides and storm damage crowds out routine maintenance virtually every year. Obviously, difficult tradeoffs often have to be made between the quality and quantity of infrastructure. Construction of less hazard-resistant roads could facilitate more rapid progress in improving market access.

However, the vulnerability implications of alternative levels of overall quality and strength (e.g., adequate drainage of roads) should also be explored, as hazards could damage and disrupt transport networks.

As already noted, natural hazards can also affect patterns and levels of trade in terms of securing markets. If frequent occurrences affect reliability of supply, then exporting countries could face difficulties in securing and maintaining trading partners.

FDI

The literature suggests that location and related international transport costs, the cost of market access through exports, the quality of infrastructure, possession of raw materials, labor costs, government incentives, political risk, per capita income, the degree of industrialization, and the size of domestic markets are all important in attracting FDI (Shatz and Venables 2000; Singh and Jun 1995; Wheeler and Mody 1992[13]). Generally, more open, export-orientated economies are more successful in attracting FDI, as discussed above. Indeed, the relative size of the export sector is the strongest explanatory variable for FDI flows according to Singh and Jun's (1995) analysis.

There is little hard evidence reported in the literature that natural hazards and related risk have influenced decisions on FDI directly, although there is some anecdotal evidence that this may occur (see section on Dominica below). Again, however, natural hazards and risk may have had some indirect impact on factors determining flows. One of the more interesting lines of investigation from a natural hazards perspective concerns the importance of a hospitable business environment. Singh and Jun (1995) examined this using an operation risk index based on a range of factors including balance of payments performance, economic growth, and infrastructure—all factors that natural disasters can affect. Their results suggest that the business climate is important for high-FDI countries but not for low-FDI countries.

Singh and Jun's (1995) analysis also suggests that, using a broad-based qualitative political risk index, political stability may be important for high-FDI countries, where the stakes are higher, but not for low-FDI countries.[14] They suggest that this reflects the fact that direct investment is likely to be capital-intensive and so requires a relatively more substantive and long-term commitment. Disasters are another form of instability, also potentially threatening the long-term viability of an investment. Singh and Jun's analysis (1995) additionally indicates that work days lost in production, in turn affecting production efficiency, is more significant for low-FDI counties, presumably reflecting the fact that production in these countries is likely to be more labor-intensive. Frequent or extended natural hazard events (e.g., flooding) could affect days worked.

There is some evidence that FDI is spatially more clustered than other forms of production, possibly due to certain incentives to locate close to other firms, including spillovers created by research and development; the development of local networks of suppliers of specialized goods and services; the development of local labor markets with appropriate specialized skills; and confidence, and the possibility that firms "herd," with firms uncertain whether a particular country is a good location for FDI but willing to take the success of one firm as a signal of underlying national characteristics (Shatz and Venables 2000). Again, this herding tendency could discriminate against more hazard-prone countries if potential investors are aware of the possibility of natural hazards, if perceived risk—whether or not correctly so—is high, and if few others have been seen to invest there.

Country Experiences in an Era of Globalization

The general discussion presented earlier indicates that the linkages between globalization and vulnerability to natural hazards are complex and that no easily sustainable generalizations about impacts and effects can be made. Our three most recent case studies suggest that there are important, distinct country type situations. There are therefore likely to be country-specific strategies for disaster reduction. These themes are illustrated by a more detailed account of changing vulnerability for the small, relatively less complex open economy of Dominica. These developments are shown to be country-specific by contrasting developments in Bangladesh and Malawi.

Dominica

Dominica is an important case with which to begin to explore forms of vulnerability and the role of a country's relationship with the global economy, as it exemplifies the type of experience faced by many small island economies. Such economies face a number of special disadvantages associated with their size, insularity, and remoteness (Briguglio 1995), making them highly sensitive to economic shocks of any form, including natural hazards. They are often perceived as some of the countries most vulnerable to natural hazards in the world.[15] Small island economies are typically very open, with relatively limited internal forward and backward linkages, instead relying on international trade to market their outputs and as a source of capital goods, inputs to domestic production, and consumables. Such countries often strive to find niche export markets, concentrating the focus of economic activity accordingly. In so doing, many have secured some form of preferential trade agreement; however, the WTO process is currently eroding the protected status of many such exports.

In the case of Dominica, the level of imports stood at equivalent to 65 percent and exports to 25 percent of GDP in 1997, making the economy very open. Since the 1950s the economy has been reliant on a single export crop, bananas, for which it had preferential access to E.U. markets. Agriculture and agro-processing combined continue to be the major productive sector, although agriculture's share in GDP declined from an average of 37 percent in 1977–78 to 20 percent in 1997–98. Other private sector activity remains small, although experiencing some growth since the mid 1970s. Dominica consistently runs a deficit on its external visible trade account, in part met through tourism earnings. Tourism's contribution to GDP remains relatively low, but by the late 1990s accounted for an estimated 35 percent of external earnings (GoCD 2000).

Dominica is susceptible to a wide range of natural hazards. The most common, probable, and historically significant are tropical storms and hurricanes. The majority of the population and infrastructure are located along the coast, making Dominica particularly vulnerable to strong winds and high seas.[16] There has been a sequence of disasters since 1978: Hurricanes David and Frederick in 1979, Allen in 1980, Hugo in 1989, the cumulative impact of three tropical storms in 1995, and Hurricane Lenny in 1999. Hurricane David, a Category 4 hurricane, directly hit the island and was extremely devastating, with severe environmental and demographic consequences.[17]

There are significant geophysical hazards, as the island is geologically extremely young and almost completely volcanic in origin. There was a volcanic alert in 1998–99, the first since 1880, and scientists indicate a continuing, significant risk of an extreme event in the twenty-first century with a related possibility of earthquakes.

High rainfall in the mountainous, noncoastal areas of the island also results in frequent localized flooding and landslides, which are recurrent annual problems. Other potential hazards include drought, storm surges, bush fires, and tsunamis.

Agricultural Exports

Over time there have been significant shifts in the nature of Dominica's vulnerability to natural hazards relating to changing levels of development and capital investment in the island and changes in economic activity. Shifts in the structure and composition of economic activity, in turn, have been closely tied to international political and economic interests and export market opportunities. In the past, as a colonial plantation cum subsistence economy, the impact of natural hazards was heavily dependent on the sensitivity of the prevailing export crop and the associated structure of production and marketing. In the first half of the 20th century, limes were the dominant crop. Limes are relatively insensitive to high winds. They were also grown on plantations owned by U.K.-based companies able to absorb intermittent losses and associated recovery costs occurring in just one of their countries of operation. This production and marketing structure effectively acted as a geographical risk-spreading mechanism. Meanwhile, small-scale farmers produced much of the island's staple foods, roots and tubers, known locally as "ground provisions."

From the 1950s banana exports, largely grown by smallholders, progressively displaced plantation agriculture. Bananas were exported to the United Kingdom under a preferential access agreement that continued after the United Kingdom joined the E.U. in 1974. This (structural) change increased the overall vulnerability of the agricultural sector to natural hazards. Bananas are highly sensitive to damage from winds of 40 or more miles per hour, so that even the fringe impacts of less severe tropical storms can cause serious damage. Smallholders are also less able to bear heavy losses, because of their lack of assets and access to credit. These changes in the type and structure of production implied increased vulnerability.

Hurricane David in 1979, followed rapidly the next year by Hurricanes Frederick and Allen, demonstrated that sensitivity, causing severe damage to banana plantings. However, this sequence of disasters also led to an increase in the dominance of bananas, which offered a fast, low-investment means of restoring agricultural livelihoods in an assured export market. Recovery only takes 9 to 12 months, even where plantings are totally devastated. In contrast, production of copra, the other major commercial crop, took three to four years to recover.

The rapid recovery in export production after Hurricane Hugo in 1989 again demonstrated the resilience of the banana economy. In this case, the compulsory WINCROP banana crop insurance scheme, jointly introduced in 1987–88 by the banana marketing boards of the four Windward Islands (Dominica, Grenada, St. Lucia, and St. Vincent), also effectively encouraged replanting of bananas by offering partial financial protection in the event of a disaster. The E.U., through STABEX, had also provided the government of Dominica and other associate countries with a partial compensation mechanism for fluctuations in agricultural export earnings. So public finances partially dependent on export earnings were also buffered from the effects of disaster shock.

The dominance of bananas in Dominica and similar monocrop agricultural sectors in other small island economies perhaps exemplifies a progressive adaptation to a specific external economic environment, a process often accompanied by institutional innovation. The structural change from estates to smaller commercial holdings in Dominica resulted in production with relatively low overheads and fixed capital at risk. WINCROP—an outcome of regional cooperation—helps to manage the risks associated with an extremely hazard-sensitive crop. Extension, credit, and marketing arrangements are also closely tied to the specifics of this crop and its production structure. These institutional arrangements become embedded within the economy, and it may be extremely difficult for agriculture to adjust to globalization and less assured markets of uncertain profitability. From the mid-1990s, however, external factors resulted in declining banana production, with falling real prices and the loss of guaranteed preferential access to the European market. The WTO ruling against the E.U. is expected to eliminate preferences on bananas within the decade (Schiff 2002; Roberts and others 2002).

Dominica's future, more diversified, agricultural sector will be more sensitive to natural hazards and other risks. Other subsectors lack the risk-spreading arrangements associated with bananas, namely, WINCROP, STABEX, and a protected export market. Some tree crops also lack bananas' capacity for rapid post-disaster recovery. Thus, a future disaster could be associated with a higher rate of default on agricultural loans, increased demand for credit, and slower post-disaster recovery. This difference in risks has been an obstacle in encouraging agricultural diversification, despite it being official policy throughout the twentieth century and despite the intense efforts of government and NGOs to foster a broader economy.

In parallel with shifts within the agricultural sector, the wider economy's sensitivity to natural hazards has also changed over the past two decades as a consequence of changes in its composition accelerated by the WTO process. Agriculture's share of GDP halved to only 19 percent between 1977 and 1997, while manufacturing, tourism, and international financial services—the latter two by definition closely linked to the global economy—grew and increased their share of GDP. These latter service sectors are less sensitive to all except a catastrophic event, such as Hurricane David. Indeed, if the country's recent expansion into international financial services proves successful, then a further decline in broad economic vulnerability can be anticipated in the future. The international financial services sector has little reliance on physical infrastructure and is not linked in any way to the domestic economy (including domestic financial markets).

Infrastructure

Development of the island's key infrastructure, in particular harbors and the road system, provides another example of changing long-term sensitivity to natural hazards, in this case linked to Dominica's broad level of development rather than the structure and composition of economic activity. Until the 1950s, sea transport was the primary form of intra-island movement, implying rapid recovery of the transport network in the aftermath of a storm. The more recent emergence of roads as the major form of transport, coupled with the mountainous terrain, which forces much of the road network along the coastline, has effectively exacerbated the direct and indirect impacts of storms. The scale of physical damage to the transport network has become far more severe and the pace of recovery much slower, with knock-on implications for the movement of goods and people. Increasing vulnerability of this nature can have extreme consequences in a country like Dominica, with limited capital resources relative to demand and thus a tendency to select least-cost solutions in meeting infrastructure needs; this vulnerability was exposed by the catastrophic Hurricane David.

Similar issues relating to limited capital investment resources have been encountered in constructing port facilities. The expansion of external trade, including highly bulky, refrigerated bananas, and the growth of cruise ship tourism required more extensive port facilities. Funding such investment at apparently acceptable rates of return, however, resulted in compromises in the storm proofing of new facilities in the 1970s and 1980s, with costly consequences. The 1979 and 1989 hurricanes created severe disruption and high repair costs.

Changing Risks

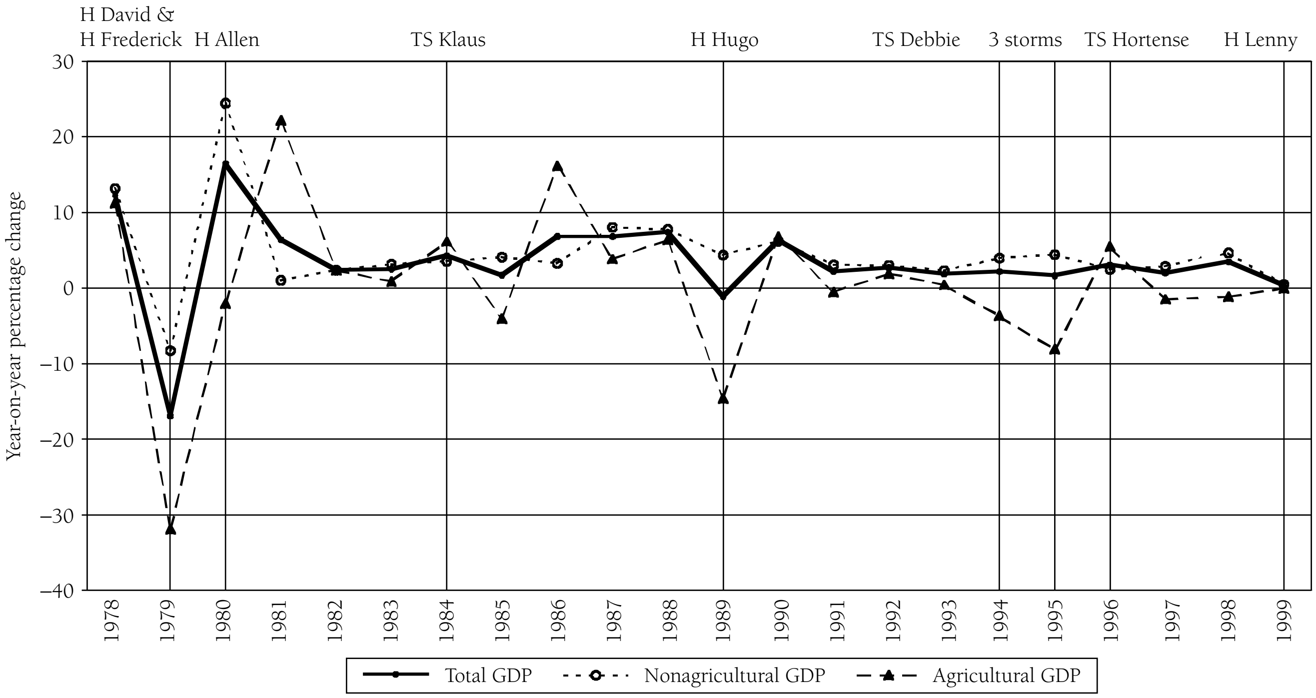
Gradual changes in the character of sensitivity of an economy to natural hazards, such as those described in the case of Dominica, can go unrecognized. Informants for the Dominica study suggested that the impact of Hurricane David in 1979 was in part so severe because the island had not experienced a hurricane for 40 years. Thus everyone was caught unaware. Though Dominica had not experienced a Category 4 hurricane since 1930, however, meteorological records show that there had, in fact, been a number of less severe storms. Instead, it would appear that the changing nature of and apparent rise in the island's vulnerability to storms had not fully impinged on perceptions of risk. Similarly, there was little awareness in government, in the business community, or among the general public of volcano-seismic hazard until the alert in 1998–99. Awareness was heightened by media coverage of the ongoing eruption in nearby Montserrat and the arrival of some Montserratian evacuees.

Hurricane David in 1979 caused severe damage to the whole of the island's capital stock. The population loss from out-migration was not up for 20 years. There was a related unquantified loss of human capital. Tourism, largely uninsured and dependent on local finance, did not recover for almost a decade. Following this catastrophe and subsequent severe storms, there has been piecemeal public investment in more hazard-proof infrastructure and private sector investment in industrial and service sector construction. Nevertheless, Hurricane Lenny in 1999 caused considerable temporary disruption and damage to the infrastructure of ports and roads. The pattern of aggregate macroeconomic impacts of disasters in terms of GDP and sectoral product (as shown in figure 1.1) suggests that vulnerability to climatic hazards had peaked around independence, just prior to Hurricane David. Subsequently the impact of storms has become relatively less severe due to disaster-proofing and structural changes in the economy. Public finances were also in disarray and there were problems of governance in 1979.

What were the longer-term development consequences? Dominica probably lost ground to other islands such as Barbados and St. Lucia on the post-independence tourist and financial services front. It also became a source of less skilled labor to neighboring French and Anglophone islands. It is among the poorest of the smaller Caribbean economies.

There are two important qualifications to the conclusion that vulnerability to natural hazards is declining. First, there are the uncertain consequences of climatic change. Second, the scale of the threat posed by volcano-seismic hazard is increasing. Economic and population growth have been increasingly concentrated in the capital, Roseau, which is in a relatively high-risk zone in the event of a severe eruption. Scientific monitoring has indicated a significant risk of an extreme event in the twenty-first century. This is a real dilemma. Land-use planning and regulation could reduce volcanic hazard risk. However, in a highly competitive regional economy, with many islands seeking FDI in tourism and trying to develop financial services—Dominica's own potential growth sectors—investors could easily be

Figure 1.1 Dominica—Annual fluctuations in agricultural, nonagricultural, and total GDP, 1978–99



Source: Benson and Clay 2001.

discouraged if attention is drawn to Dominica's hazard risks.

Bangladesh

Bangladesh is one of the most disaster-prone countries in the world. Most of its large, densely settled population of 130 million people is at significant risk to more than one form of natural hazard, making it a test case for international efforts in disaster reduction

Hazards and Major Disasters

In terms of area and number of people directly affected, impact on economic activity, and damage and destruction of assets, the types of hazard that have been most important since independence in 1971 are: exceptionally widespread riverine flooding; severe tropical cyclones and associated coastal storm surges; river bank erosion; and drought. According to official estimates, 139,000 people were killed during the 1991 cyclone, and 31 million directly affected by the 1998 floods. Rapid-onset flash flooding, tornadoes, and landslides are frequent causes of more localized but intense human suffering and loss. Severe earthquakes have been rare but are a potentially catastrophic hazard. Around 45 percent of Bangladesh's population is classified as poor and some 23 percent live in absolute poverty. These people are typically living and working in areas most at risk from natural hazards. At the household level, poverty is still the single most important factor determining vulnerability.

River flooding: there have been 4 extreme events in 30 years—1974, 1987, 1988, and 1998. Other very high floods in 1976 and 1984, though less severe when measured in terms of height, maximum flow, and proportion of area inundated, caused widespread suffering and losses and elicited an international emergency response. The implied annual risk of an extreme flood is a high 10–20 percent.

Over 100 years at least 14 very severe storms have impacted Bangladesh with an implied annual risk level of more than 10 percent. The worst storms accompanied by storm surges have been catastrophic. The cyclone of

November 1970 resulted in 300,000–500,000 fatalities; that of May 1991 caused 125,000 deaths.

These events in particular have created a worldwide perception of Bangladesh as one of the world's most disaster-prone countries, described in the mid-1970s by the U.S. Secretary of State as a nonviable "basket case."

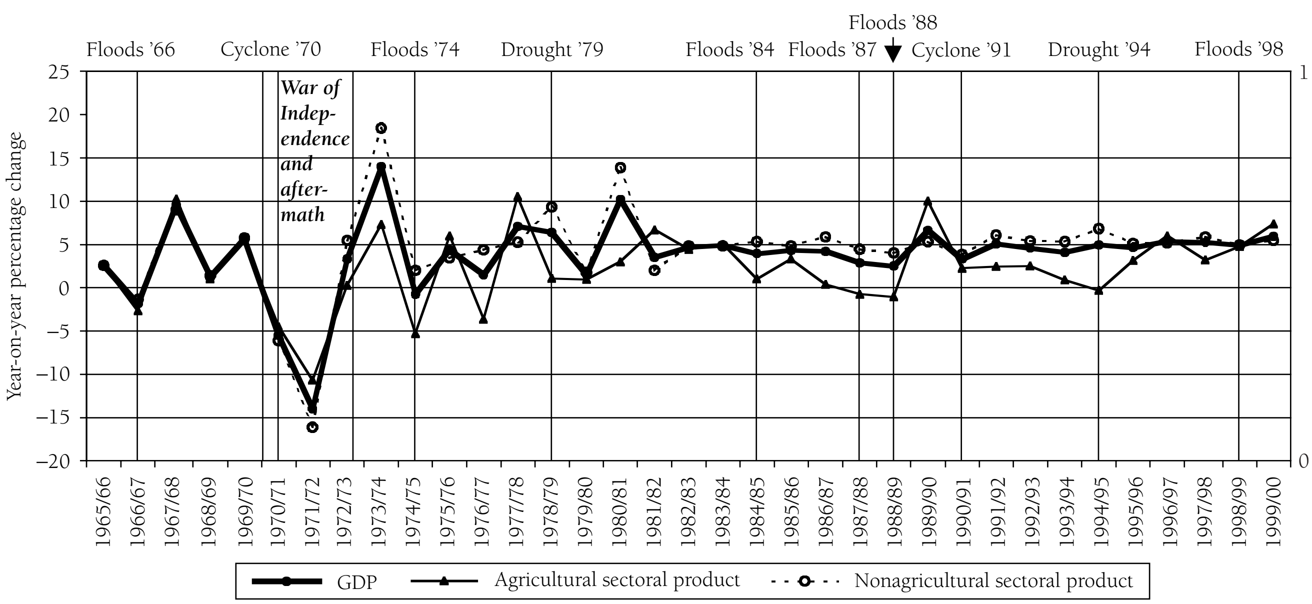
Economic Performance

Since independence, the Bangladesh economy has achieved impressive rates of growth. It achieved rapid recovery in the late 1970s following the devastating effects of natural hazards, war, and famine in 1970–75; and an average real annual growth rate in GDP of 4.2 percent in the 1980s, rising to 5 percent during the 1990s. Average annual per capita GDP growth rose from an average of 1.7 percent in the 1980s to 3.3 percent in the 1990s, reflecting higher GDP growth and declining population growth. At the same time, there has been a change in the structural composition of the economy: agriculture's share of GDP has declined while the industrial and service sectors have expanded, resulting in a sharp shift in the composition of the country's exports. Exports also rose as a share of GDP from 4 percent in 1980 to 14 percent in 2000, while imports rose from 16 percent to 19 percent. A gradual process of structural adjustment and trade liberalization alongside more disciplined monetary management in the 1990s resulted in single-digit inflation and an annual current account deficit below 2.5 percent of GDP. The reforms have also helped increase private sector development and foreign direct investment. Fiscal policy has not been so successful, however. There have been large fiscal deficits, a low tax-to-GDP-ratio, and relatively poor quality spending.

A simple assessment of the sensitivity of Bangladesh's economic performance to major disasters in terms of fluctuations in GDP and rates of growth in agricultural and nonagricultural-sector product as shown in figure 1.2 highlights some key issues:

- From 1965–75 there was extreme volatility in the largely agricultural economy, clearly linked to catastrophic natural disasters.
- With the notable exception of the most recent 1998 floods, major disasters have resulted in a downturn in the agricultural sector's annual rate of growth.
- The impact on the nonagricultural sector looks much less significant, but longer-term impacts of disasters are not reflected in inter-yearly fluctuations: if resources are diverted from productive investment to disaster response, the pace and nature of development will be adversely affected.

Figure 1.2 Bangladesh—real annual fluctuations in GDP, agricultural, and nonagricultural sector product, 1965–2000



Source: Benson and Clay 2002.

- The sensitivity of agricultural and non-agricultural components of GDP to natural hazards appears to be declining over time, suggesting greater resilience.

Declining Vulnerability?

Part of Bangladesh's greater resilience is attributable to structural change in the agricultural sector. Following the 1987 and 1988 floods, the relaxation of restrictions on private agricultural investment and imports of equipment was associated with a rapid expansion of much-lower-risk dry-winter-season rice and, to a much lesser extent, wheat. Since then, highly flood-prone deep water rice and jute have gradually been displaced, and after the 1998 floods, the main monsoon-season transplanted rice finally lost its primacy as the dominant crop.

As Bangladesh approached self-sufficiency in rice, the national staple, internal prices displayed reduced seasonal volatility and moved closer to import-parity price levels with liberalization of the grain import trade. After the floods of 1998 large-scale private sector imports covered the greater part of the temporary food gap, limiting pressures on prices and the public finances (del Ninno and others 2001).

Urbanization is rapidly creating large urban and peri-urban zones, including the capital Dhaka, which is quickly becoming a sprawling, minimally planned megacity with weak, overstretched infrastructure. Since the severe floods of the late 1980s, there has been a de facto shift in flood control investment and protections from rural and agricultural to urban and industrial. This seems to have been at least partially successful. The 1998 floods, of longer duration and with higher river levels than those of 1987 or 1988, did not severely affect the greater Dhaka metropolitan area or the secondary towns that received enhanced protection.

Export-oriented garment manufacture has been the primary motor of export growth as inward FDI, and some local industrialists exploited the trading niche offered by the MFA. In 1998, there was some disruption to supply and export chains, but the industry, largely based in less-flood-affected urban zones, proved resilient. However, for the future it appears that risks have altered rather than been reduced. The industries' markets are far from assured and could be lost if there were a major disaster-related disruption. Manufacturing in coastal Chittagong is exposed to possible cyclones and storm surges, such as that of 1991. There are other risks such as fire, outside the scope of this study. Finally, building standards in facilities with a short life expectancy in this and most other new industrial developments largely ignore seismic hazard.

The third major development has been in the financial system, with some important innovations in financial services. After the chaotic hyperinflation that contributed to the famine of 1974, the government has managed to maintain relative financial stability through periods following disasters. Labor migration has played an important role in financing economic growth through the remittances of incomes. For example, remittances increased by 18 percent in the financial year that includes the 1998 floods. Bangladesh has been a leader in developing microfinance for the rural and more recently urban poor. Microfinance played a significant although limited role in enabling the poor to cope with the costs of the 1998 floods (del Ninno and others 2001). Importantly, the (central) Bangladesh Bank was also able to protect this critically important financial sector through massive refinancing.

The economic impacts do not reflect or parallel the severity of disasters in terms of loss of life and human tragedy. Large, unprotected rural and peri-urban populations, increasing rapidly due to unchecked population growth, remain vulnerable to riverine flooding. The exploitation of ground water for irrigation and human use has had its downside in the widespread problem of arsenic poisoning. Urban flood protection on a flood plain with high population densities poses severe drainage and pollution problems that require unprecedented improvements in management of the urban environment, requiring technical sophistication, investment and operational funds, and improvements in governance. Any major failure in urban flood protection would have massive costs in human and economic terms.

Positively, the construction of a system of cyclone shelters and improvement in storm warnings appear to have reduced the considerable risks to human life posed by tropical cyclones and accompanying storm surges from the Bay of Bengal. But this threat to large populations settled in high-risk coastal areas is by no means eliminated. There are still considerable institutional problems concerning control and access to shelters and the maintenance of coastal embankments that could mitigate the impacts of storm surges (IFRC 2002).

There are also two major sources of increased hazard vulnerability. First, the scale of the threat posed by seismic hazard is increasing. Rapid economic and population growth has been increasingly concentrated in the capital, Dhaka, and other urban centers that would be devastated by a major earthquake. Bangladesh is part of a high-risk region. Minor tremors are common and one of the most extreme events, the 1897 earthquake (8.8 on the Richter scale), had its epicenter in the nearby Shillong Plateau of the Indian State of Megalaya. Local assessments provide only highly tentative risk zoning within the country in map form because of the inadequacies of available data (Ali and Choudhury 2001).

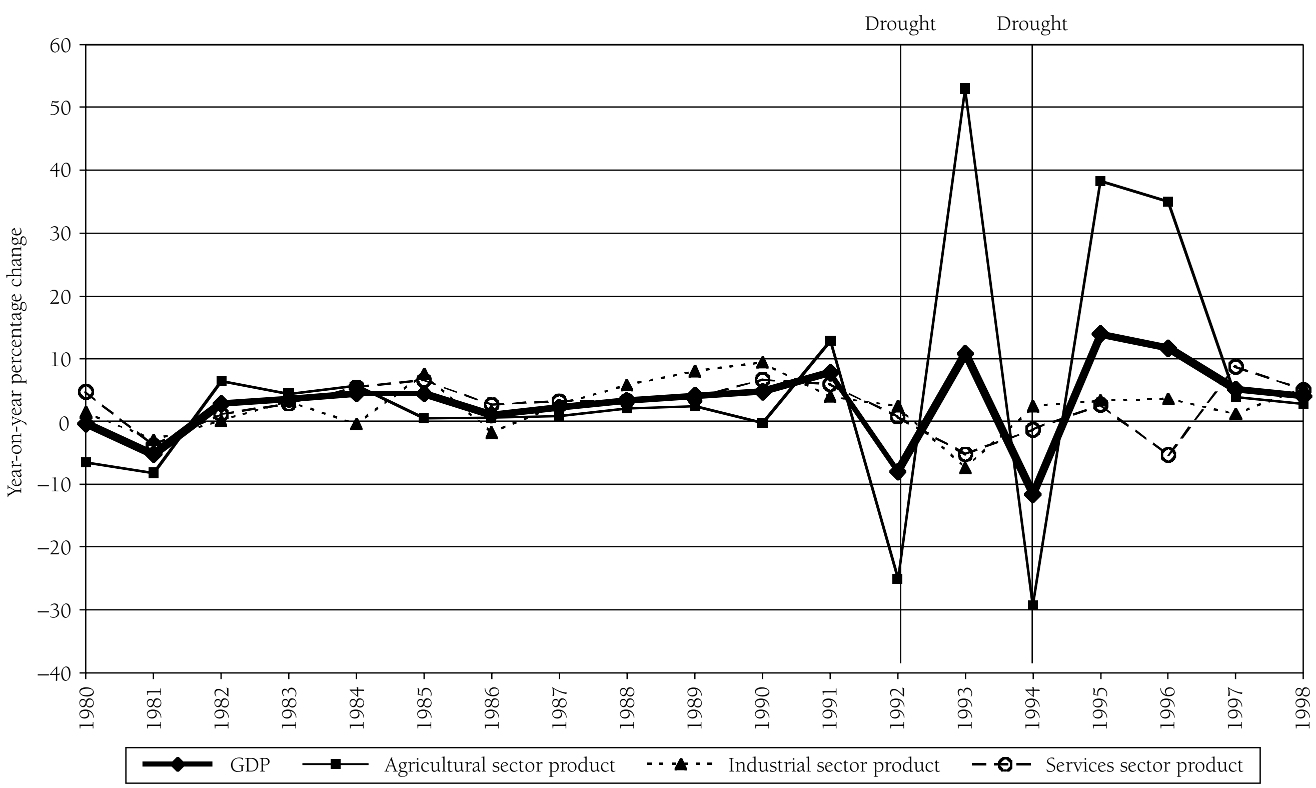
Second, there are the uncertain consequences of environmental change, some recorded and others only so far identified as possible consequences of global climatic change. Human activity in Bangladesh and the immediate region may also be altering the likelihood of specific events as well as the associated effects.

Malawi

Since 1990 Malawi and other countries in Southern Africa seem to have experienced increased economic volatility that is linked with climatic variability (figure 1.3). This apparent increase in vulnerability has occurred during a period of many complex interacting developments in the region—some positive, such as the political reintegration of South Africa and the end to conflict in Mozambique, and others negative, such as the increasing problems of governance in Malawi, Zambia, and Zimbabwe and the HIV/AIDS epidemic, which are undermining the capacity to cope with shocks. These developments are highlighted by what has happened in Malawi.

Malawi, small and landlocked, recorded a population of 10.8 million in 2000. It is one of the poorest countries in Africa, with per capita GDP of US$170 in 2000. Health and social indicators are also among the lowest and declining: average life expectancy fell from 43 in 1996 to 37 in 2000 and Malawi is one of the countries most

Figure 1.3 Malawi—real annual fluctuations in GDP and agricultural, industrial, and services sector product, 1980–98



Source: Clay and others 2003.

severely affected by HIV/AIDS. The loss of human capital and ill health among the economically active population are likely making the country more disaster-prone.

Malawi still has a largely rural economy, with 89 percent of the economically active population classified as rural. Agriculture accounted for some 40 percent of GDP in 2000, compared with 44 percent in 1980. Its share in GDP was declining but rose again in the 1990s, with industrial stagnation and contraction in the public service sectors. Export earnings are dominated by agricultural commodities, largely rainfed tobacco, making the economy sensitive to climatic variability and commodity price shocks.

Although there has been internal liberalization and a reduction in tariffs, the Malawi economy has become relatively less open over time. Exports have declined as a proportion of GDP from 28 percent in 1980 to 24 percent in 2000. Imports fell from 43 percent to 40 percent.

The main source of natural hazard vulnerability in Malawi is climatic variability. The major food staple, rainfed maize, accounting for more than 70 percent of energy intake, is extremely sensitive not only to drought or low rainfall, but to erratic rainfall within the growing season and, as the 2001 season showed, to abnormally high rainfall. There were only two clearly defined droughts in the twentieth century: the drought that caused a famine in 1949 and another that reduced maize production by 60 percent in 1991–92. However, relatively unfavorable conditions such as the widely reduced and erratic rainfall of 1993–94, extremely high rainfall as in 2001, or locally erratic rainfall as in 2002 pose increased food security and wider economic threats to a more vulnerable, less resilient economy.

Riverine flooding is an annual, relatively predictable hazard in the lower-population-density southern districts. Even in 2001, flooding did not have a widespread, catastrophic impact. There are apparently no other significant forms of natural hazard.

Sources of Increasing Vulnerability

A variety of influences has interacted to make the economy and society increasingly sensitive to climatic variability, not just the extreme “drought” events that are widely but simplistically perceived to impact Southern Africa. These influences have included some relating to changes in the external economic environment.

Agricultural development has stalled. Demographic growth averaging 2.6 percent in the 1990s has placed increasing pressure on agricultural systems that are an adaptation of shifting cultivation. Declines in soil fertility on holdings of shrinking size are barely compensated for by increased fertilizer use and other technical improvements that could increase productivity. Liberalization of internal agricultural markets has been relatively unsuccessful. The private sector has been unable to take on and efficiently handle functions that were previously the responsibility of parastatals, especially the agricultural marketing agency, ADMARC.

Conflict in neighboring Mozambique, and more recently, the process of reintegration of South Africa into the regional polity and economy have contributed to the failure of industrialization or service subsectors such as tourism to provide alternative sources of economic growth and employment.

The relative deindustrialization of Malawi shows the need for caution in assuming that regional development will be consistent with broader global trends. The disruption to external communication because of the war in Mozambique from the late 1970s increased transport costs, reducing export parity and raising import parity prices. This favored low-input, self-provisioning rather than export-oriented agriculture, encouraging the development of small-scale manufacturing enterprises, although growth was checked by limited domestic demand. However, the more recent progressive reintegration of South Africa into the regional economy has exposed small-scale manufacture and processing of tradables in Malawi and other “front line states” to a larger-scale, absolutely more efficient competitor. This adjustment effect amounts to de-industrialization, making the economy more exposed to agricultural sector volatility.

Malawi and some neighboring countries have been beset with problems of conflict, governance, and weak public financial management. These have amplified the difficulties caused by economic sensitivity to climatic variability. In 1991–92, the economic effects of drought were intensified by the effects of an influx of displaced people from Mozambique and the halt of bilateral assistance other than emergency relief. In 1994, the effects of an agricultural-sector shock were compounded by weak fiscal and monetary management in a hyperinflationary situation. In 2000–01, there was donor pressure to reduce parastatal debt by reducing grain stocks. Then, as the food security situation deteriorated after the 2001 harvest, there was donor reluctance to respond to aid requests from the government, which could not account for revenues from its grain marketing operations, including local currencies generated by the sale of aid commodities. It is debatable whether the food security crisis that emerged in Malawi during 2001–02 should be categorized as the consequence of a natural hazard. Rather, climatic variability over two years within a range that had not previously been regarded as disastrously destabilizing contributed to a crisis in an economy made more vulnerable by structural changes and other developments that had reduced resilience at all levels. Unfortunately, the onset of an El Niño event in 2002, with its prospect of low and erratic rainfall, increases the risk of a third, disastrous year.

Conclusions

The sensitivity of an economy to natural hazards is determined by a complex, dynamic set of developmental, economic, and societal influences, including powerful external factors. The evidence presented in this paper suggests that increasing integration of economies around the world has significant implications for the nature of sensitivity to natural hazards. In particular, globalization has expanded opportunities for risk diversification and, for nations as a whole, it seems to be a positive trend. However, the question of whether globalization ultimately exacerbates or reduces sensitivity, both of particular economies and individual households, is complicated and depends on specific country circumstances, including public action to reduce vulnerability.

On the downside, globalization exposes countries to new forms of risk, possibly exacerbating the impact of natural hazards when different risk events coincide. Writing about financial globalization specifically, Schmukler and Zoido-Lobatón (2001:18) ask: "Is the link between globalization, crises, and contagion important enough to outweigh the benefits of globalization?" They caution that "in open economies, countries are subject to the reaction of both domestic and international markets, which can trigger fundamental-based or self-fulfilling crises." However, they also note that, although the evidence on the impact of globalization is still very scarce, any observed increase in volatility seems to occur in the short run only, and that volatility decreases in the long term. Indeed, they conclude that there is scope for much deeper globalization, given its potential benefits, but that efforts are also required to seek to minimize associated risks.

This paper draws upon a limited number of in-depth country studies. As such, its findings should be considered as hypotheses for wider testing. Nevertheless, it is striking to note that most of the findings confirm and elaborate conclusions and policy presumptions in the wider globalization literature, which focuses on market-related and financial risks rather than natural hazards.

From a natural hazards perspective, an important objective is to seek ways of using global markets to improve risk management. There may be opportunities in the area of smaller enterprises and consumers, as well as in larger corporations and government. The Montserrat case (box 1.1) and potentially similar risks to narrowly based, locally important, and highly successful financial institutions in Dominica and other smaller, hazard-sensitive economies imply an urgent need to spread risks. Increasing global integration may create opportunities for spreading risks borne by micro-finance institutions as well. Exploiting such opportunities may require international encouragement and support.

In the context of the December 2002 ProVention conference highlighting urban disaster reduction, the country studies suggest that different types of natural hazard risk have distinctive economic dynamics. Developing countries responding more successfully to the opportunities and challenges of globalization are showing some reduction in relative sensitivity (measured as a proportion of GDP or sector product) to more predictable, relatively frequent, climatic hazards such as tropical cyclones in Dominica and extreme riverine flooding in Bangladesh. An important qualification to such trends is the highly uncertain implication of global climatic change for the frequency and severity of natural hazards.

In contrast, the exposure to geophysical hazards appears to be rising. Rapid urbanization—a process often associated with globalization—creates large concentrations of people and physical capital, mostly built with little regard for natural hazards either in choice of location or design. These geophysical hazards typically have relatively low but difficult-to-determine risks, less than 1 percent annually for an extreme earthquake in Bangladesh or a disastrous volcanic event in Dominica. Globally, such increasing hazard exposure implies rising disaster-related losses.

The most worrying position is that of countries and even regions that are apparently being marginalized in the process of globalization. In re-examining the consequences of climatic variability in Southern Africa after almost a decade, there is substantial evidence of greater vulnerability to natural hazards. Natural hazards, in turn, may well be at least indirect compounding factors limiting opportunities and potential for globalization for certain economies, although the precise nature of their role is complicated and, again, often highly country-specific.

For those countries that are becoming more closely integrated into the global economy, risks emanating from all types of natural hazards should be considered in assessing the impacts of reductions in trade barriers and related changes in the composition of economic activity, security of livelihoods, and measures taken to help protect vulnerable groups. More broadly, risks emanating from natural hazards should be taken into account in the determination of priorities, policies, and strategies, with enhancement of resilience to natural hazards as one of the basic objectives of government in hazard-prone countries. It should also be recognized that successful risk management requires not only technical, structural solutions, but also a broader awareness of underlying socioeconomic causes and appropriate action.

Notes

1. *The Siena Declaration on the Crisis of Economic Globalization*. Statement prepared by the Board of Directors of the International Forum on Globalization Siena, Italy, September, 1998. www.twnside.org.sg/title/siena-cn.htm

2. Previous studies have included Benson and Clay (1998) on the economic consequences of drought in Sub-Saharan Africa with a more detailed country study of Zimbabwe (Benson 1998). More recently the economic effects of climatic variability in southern Africa have been reinvestigated in a study focusing more specifically on Malawi (Clay and others 2003). There have been three studies of small island economies: Dominica (Benson and Clay 2001), Fiji (Benson 1997a) and Montserrat (Clay and others 1999) as well as three studies for larger Asian economies, Bangladesh (Benson and Clay 2002), Philippines (Benson 1997c) and Vietnam (Benson 1997b).

3. For example, an official assessment of the costs of the 1998 Bangladesh floods aggregated capital losses, such as damage to infrastructure with rice crop losses. An assessment of Hurricane Lenny in 1999 in Dominica included costs of physical damage and reductions in income from small-scale fisheries.

4. International companies operating in the sugar sector are attempting to take climatic forecasts into account in this way. Private communication from Dr. M. Evans. See also Bohn, forthcoming.

5. In both these cases flows from outside the country contributed to the disaster, and these flows were influenced by the actions of public agencies responsible for water management. There were inadequate warnings to those responsible for flood response in the affected areas. A contributory factor was insufficiently precise understanding of system dynamics and links to exceptionally high rainfall (Akteer Hossain 2001; Christie and Hanlon 2001).

6. For example, there was underfunding of volcano-seismic monitoring in Dominica in 1998 at the outset of a volcanic emergency and no proper wave level monitoring even during Hurricane Lenny in 1999. Bangladesh has effectively been without a seismic monitoring system since the separation of Pakistan and India at Partition in 1947. The meteorological system in Malawi lost access in 1991 to its historical database of climatic information, impeding investigations for over a decade.

7. However, Roberts and others (2002) note that the rural non-farm sector has also been expanding and thus some labor released from farming may remain in rural areas.

8. Even had this analysis been undertaken, the literature on globalization indicates a number of analytical difficulties that arise in comparing relative integration across countries, implying that any findings would have been very approximate at best.

9. After Quah (1993), ratios of per capita income relative to the global average were discretized into intervals at 1/4, 1/2, 1 and 2. Annual one-step transition matrices were then estimated by averaging the observed one-year transitions over every year from 1960-61 to 1992-93. The one 33-step transition between 1960 and 1993 was also analyzed. Analysis was undertaken on the full data set and three subsets (more hazard-prone, more hazard-prone

excluding Sub-Saharan African (SSA) and less hazard-prone countries).

10. A more sensitive ranking according to disaster impact is fraught with difficulties, relating in part to incomplete data.

11. In the Philippines, for instance, the 1990 earthquake and 1989–90 drought were reported to have contributed to a 6.7 percent increase in total external debt, and a 22.4 percent increase in debt from official creditors alone, in 1990 (Ernst and Young 1991). An examination of the impact of the mid-1980s drought on external borrowing in six countries in sub-Saharan Africa revealed that the growth rate in total debt stocks accelerated during the year of most severe drought in five of the countries (Benson and Clay 1998). The one exception, Zimbabwe, had been pursuing a deliberate long-term policy of debt reduction. Disasters can also create additional external debt pressures to the extent that they also destroy infrastructure and other assets funded with still-outstanding external loans.

12. Brahmbhatt (1998) also discusses the role of various structural factors in determining levels of international trade, including country size, factor endowment structure, geographical isolation, and the stage of development. Geographically large countries tend to undertake less trade, in part because of the typically greater diversity of domestic resources and a large home market, the latter implying some reaping of economies of scale even by producing for domestic consumption alone. Countries with a highly specialized structure of factor endowments, for example a relative abundance of natural resources such as oil, will tend to specialize in its production and export, while importing more of their other needs. Meanwhile, richer countries tend to devote a higher share of their output and consumption to services.

13. Cited in Shatz and Venables (2000).

14. Singh and Jun (1995) report that empirical evidence on the importance of political stability reported by others is inconclusive, in part depending on how political stability is defined. It has been variously defined as the number of changes in government, internal armed attacks, riots and so forth.

15. See, for example, Atkins and others 2000; UNDRO 1990; and the authors' case studies for Dominica (Benson and Clay 2001), Fiji (Benson 1997a) and Montserrat (Clay and others 1999).

16. Some 24 percent of the total population resided in the Roseau city area at the 1991 census (GoCD 1999).

17. The historical incidence since 1886 of tropical storms impacting directly on or passing very close to Dominica implies an annual risk of 17 percent of one or more Hurricane Category 1 or above and of 4 percent for Hurricane 4 or above.

Bibliography

Acemoglu, D., S. Johnson, and J. A. Robinson. 2000. "The Colonial Origins of Comparative Development: An Empirical Investigation." Processed. Berkeley, California, Department of Political Science; University of California, Department of Economics; Massachusetts Institute of Technology, Department of Political Science, and Sloan School of Management, Massachusetts Institute of Technology.

Ahmed, K. U., and H. U. Chowdhury. 1998. "The Impact of Migrant Workers" Remittances on Bangladesh Economy." *Indian Journal of Economics* 78 (311).

Akhter Hossain, A. N. H. 2001. "Late Monsoon Flood in the Southwest Region of Bangladesh 2000." *Engineering News* 42. Dhaka.

Ali Md. H., and J. R. Choudhury. 2001. "Assessment of Seismic Hazard in Bangladesh." In K. Nizamuddin, ed., *Disaster in Bangladesh: selected readings.* Dhaka: University of Dhaka, Disaster Research Training and Management Centre.

Ames, B., W. Brown, S. Devarajan, and A. Izquierdo. 2001. "Macroeconomic Policy and Poverty Reduction." *Poverty Reduction Strategy Program.* (Draft. April 2001). World Bank. Available from <http://www.worldbank.org/poverty/strategies/chapters/macro/macr0406.pdf.>.

Atkins, J. P., S. Mazzi, and C. D. Easter. 2000. "A Commonwealth Vulnerability Index for Developing Countries: The Position of Small States." *Commonwealth Economic Paper Series 40*. London: Commonwealth Secretariat.

Benson, C. 1997a. "The Economic Impacts of Natural Disasters in Fiji." *ODI Working Paper* No. 97. London: Overseas Development Institute.

Benson, C. 1997b. "The Economic Impacts of Natural Disasters in Vietnam." *ODI Working Paper* No. 98. London: Overseas Development Institute.

Benson, C. 1997c. "The Economic Impacts of Natural Disasters in the Philippines." *ODI Working Paper* No. 99. London: Overseas Development Institute.

Benson, C. 1998. "Drought and the Zimbabwe Economy, 1980–93." In H. O'Neill and J. Toye, eds., *A World Without Famine?* London: MacMillan.

Benson, C., Forthcoming. "The Economy-Wide Impact of Natural Disasters in Developing Countries." Draft doctoral thesis.

Benson, C., and E. J. Clay. 1998. "The Impact of Drought on Sub-Saharan African Economies: A Preliminary Examination." *World Bank Technical Paper 401*. Washington, D.C.: World Bank.

Benson, C., and E. J. Clay. 2000. "Developing Countries and the Economic Impacts of Natural Disasters." In. Alcira Kreimer and M. Arnold, eds., *Managing Disaster Risk in Emerging Economies.* Washington, D.C.: World Bank: 11–21.

Benson, C., and E. J. Clay. 2001. "Dominica: Natural Disasters and Economic Development in a Small Island State." *Disaster Risk Management Working Paper Series No. 2*. Washington, D.C.: World Bank Available from <http://www.provention-consortium.org/files/dominica.pdf>.

Benson, C., and Edward J. Clay. 2002. "Bangladesh: Disasters and Public Finance." *Disaster Risk Management Working Paper Series 5.* Washington, D.C.: World Bank. Available from <http://www.proventionconsortium.org/files/Bangladesh.pdf>.

Bohn, L.E. Forthcoming. "Climate Forecasts in Swaziland: Perspectives from Agribusiness." In Karen L. O'Brien and C.H. Vogel, eds., *Coping with Climate Variability: The Use of Seasonal Climate Forecasts in Southern Africa.* Aldershot: Ashgate.

Brahmbhatt, M. 1998. "Measuring Global Economic Integration: A Review of the Literature and Recent Evidence." Washington, D.C.: The World Bank. Available from <http://www1.worldbank.org/economicpolicy/globalization/documents/measuring.pdf>.

Briguglio, L. 1995. "Small Island Developing States and their Economic Vulnerabilities." *World Development* 23(9): 1615–1632.

Charvériat, C. 2000. "Natural Disasters in Latin America and the Caribbean: An Overview of Risk." *Research Department Working Paper: 434.* Washington, D.C.: Inter-American Development Bank.

Clay, E. J., and others. 1999. "An Evaluation of HMG's Response to the Montserrat Volcanic Emergency." 2 Vols. *Evaluation Report* EV635. London: Department for International Development.

Clay, Edward J., Louise Bohn, Enrique Blanco de Armas, Singand Kabambe, and Hardwick Tchale. 2003. "Malawi and Southern Africa: Climatic Variability, Economic Performance." *Disaster Risk Management Working Paper Series 7*. Washington, D.C.: World Bank. Available from <http://www.proventionconsortium.org/files/malawi_full_doc.pdf>.

Christie, F., and J. Hanlon. 2001. "Mozambique and the Great Flood of 2000." *African Issues*. Oxford: International African Institute in association with James Currey and Bloomington: Indiana University Press.

del Ninno, C., P. A. Dorosh, L. C. Smith, and D. K. Roy. 2001. "The 1998 Floods in Bangladesh: Disaster Impacts, Household Coping Strategies, and Response." *IFPRI Research Report* 123. Washington, D.C.: International Food Policy Research Institute.

Denison, E. F. 1967. *Why Economic Growth Rates Differ: Postwar Experience in Nine Western Countries*. Washington, D.C.: Brookings Institution.

Diamond, J. 1998. *Guns, Germs and Steel: A Short History of Everybody for the Last 13,000 Years.* London: Vintage.

Dollar, D., and A. Kraay. 2000. "Growth is Good for the Poor." Washington, D.C.: World Bank. Ernst and Young. 1991. "Booming and Busting." *Economic Forecast*. Australia: Asia-Pacific Economics Group.

FAO (Food and Agriculture Organization of the United Nations). 2001. "Some issues relating to food security in the context of the WTO negotiations on Agriculture," in Food Security in the context of the WTO negotiations on Agriculture. Geneva: Palais des Nations.

FAO (Food and Agriculture Organization of the United Nations). 2002a. *The State of Food Insecurity in the World 2001.* Rome

FAO (Food and Agriculture Organization of the United Nations). 2002b. "Trade and Food Security: Lessons of the Past 20 years. Analytical Issues and Framework." Rome. ESCP, Commodities and Trade Division. (Draft).

Fischer, S., and W. Easterly. 1990. "The Economics of the Government Budget Constraint." *The World Bank Research Observer* 5(2):127–42.

Freeman, P. K., L. A. Martin, R. Mechler, and K. Warner. 2001. "Catastrophes and Development: Integrating Natural Catastrophes into Development Planning." (Draft). Laxenburg: International Institute for Applied Systems Analysis.

Gallup, J. L., and J. D. Sachs. 1999. "Geography and Economic Development." *Consulting Assistance on Economic Reform II Discussion Papers* 39. Cambridge, M.A.: Harvard Institute for International Development.

Government of Bangladesh. 2002. *Bangladesh: a National Strategy for Economic Growth and Poverty Reduction*. Dhaka: Economic Relations Division, Ministry of Finance.

Government of the Commonwealth of Dominica. 1999. *Statistical Digest: 21st Anniversary of Independence Publication.* Roseau: Central Statistical Office, Ministry of Finance, Industry and Planning, Government of the Commonwealth of Dominica.

Government of the Commonwealth of Dominica. 2000. *Dominica: Medium Term Strategy, 2000–2002.* Roseau: Government of the Commonwealth of Dominica.

Hadfield, P. 1995. *Sixty Seconds that Will Change the World: How the Coming Tokyo Earthquake Will Wreak Worldwide Economic Devastation*. Second edition. London: Pan Books.

Hicks, D. 1993. "An Evaluation of the Zimbabwe Drought Relief Programme 1992/1993: The Roles of Household Level Response and Decentralized Decision Making." Harare: World Food Program.

IFAD (International Fund for Agricultural Development). 2001. *Rural Poverty Report 2001: The Challenge of Ending Rural Poverty.* Oxford: Oxford University Press.

IFRC (International Federation of the Red Cross and Red Crescent Societies). 2002. *World Disasters Report 2002: Focus on Reducing Risk.* Geneva.

IRI (International Research Institute for Climate Prediction). 2001. "Coping with the Climate: A Way Forward." Preparatory report and full workshop report. A multi-stakeholder review of Regional Climate Outlook Forums, concluded at an international workshop, October 16–20, 2000, Pretoria, South Africa. *IRI-CW/01/1.* Palisades, NY.

Konandreas, P., R. Sharma, and J. Greenfield. 2000. "The Uruguay Round, the Marrakesh Decision and the Role of Food Aid." In E. Clay and O. Stokke, eds., *Food and Human Security.* London: F Cass.

Lee, B., and I. Davis. 1998. *Forecasts and Warnings: Programme Overview.* U.K. National Coordination Committee for the IDNDR. London: Thomas Telford.

Limão, N., and Venables, A.J. 2001. "Infrastructure, Geographical Disadvantage, Transport Costs and Trade." *World Bank Economic Review*.

Martin, W. 2001. "Trade Policies, Developing Countries, and Globalization." Washington, D.C.: Development Research Group, World Bank.

Mabey, N., and R. McNally. 1998. *Foreign Direct Investment and the Environment: From pollution havens to sustainable development*. Godalming, Surrey: WWF-UK.

Munich Re. 1999. "A Year, a Century, and a Millennium of Natural Catastrophes are all nearing their End." Press release of December 20, 1999. Munich: Munich Re.

Oxfam. 2000. "Agricultural Trade and the Livelihoods of Small Farmers." Oxford: Policy Department.

Philippine NLUC. 1992. *National Physical Framework Plan, 1993–2022*. Manila: National Land Use Committee, National Economic and Development Authority.

Quah, D. 1993. "Empirical Cross-Section Dynamics in Economic Growth." *European Economic Review* 37: 426–434.

Roberts, I., B. Buetre, and F. Jotzo. 2002. "Agricultural Trade Reform in the WTO: Special Treatment for Developing Countries." *Abareconomics*.

Royal Society. 1992. *Risk: Analysis, Perception and Management*. London: Royal Society.

Schiff, M. 2002. "Regional Integration and Development in Small States." Policy Research Working Paper 2797. Washington, D.C.: The World Bank, (March). Available from <http://www.worldbank.org/research/trade/archive.html>.

Schmukler, S. L., and P. Zoido-Lobatón. 2001. "Financial Globalization: Opportunities and Challenges for Developing Countries." Washington, D.C.: The World Bank. Available from <http://www.worldbank.org/research/bios/schmucklerpdfs/Financial%20Globalization-Schmukler&Zoido-May30.pdf>.

Shatz, H. J., and A. J. Venables. 2000. "The Geography of International Investment." In G.L. Clark, M. Feldman and M.S. Gertler, eds., *The Oxford Handbook of Economic Geography.* Oxford: Oxford University Press.

Singh, H., and K. W. Jun. 1995. "Some New Evidence on Determinants of Foreign Direct Investment in Developing Countries." *Policy Research Working Paper* 1531. Washington, D.C.: International Economics Department, The World Bank.

Solow, R. M. 1956. "A Contribution to the Theory of Economic Growth." *Quarterly Journal of Economics*, 70: 65–94.

Thompson, R. L. 1999. "Rural development: challenges in the next century." Presentation prepared for the Latin American and Caribbean Association of Agricultural Economics, Port-of-Spain, Trinidad and Tobago, June 30 July 2. Washington, D.C.: Rural Development Department, World Bank.

UNDRO (United Nations Disaster Relief Office). 1990. *Preliminary Study on the Identification of Disaster-Prone Countries Based on Economic Impact.* New York/Geneva.

Wheeler, D., and A. Mody. 1992. "International Investment Location Decisions: The Case of U.S. Firms." *Journal of International Economics* 33: 1–2 and 57–76.

World Bank. 2000. "What Is Globalization?." *World Bank Briefing Paper*. Washington, D.C.: PREM Economic Policy Group and Development Economics Group, The World Bank. Available from <http://www1.worldbank.org/economicpolicy/globalization/ag01.html>.

World Bank. 2002. *Globalization, Growth, and Poverty: Building an Inclusive World Economy*. Washington, D.C.: Oxford.

Chapter 2

Natural Hazard Risk and Privatization

Paul K. Freeman

Increases in natural hazard losses intensify the need for financing dedicated to reconstruction. Multilateral institutions are addressing this issue and establishing new programs. For example, the World Bank recently implemented a Private Sector Development Strategy (PSDS) with the objective of increasing private participation in infrastructure. As noted by the Bank:

> Most poor people in developing countries have little or no access to efficient infrastructure services. Typically, government policies aim at expanding access to infrastructure services and at rendering it affordable. Yet, progress has been slow in a number of the poorest countries. (PSDS 2002:10)

The tool to expanding and accelerating access to infrastructure services is the harnessing of the private market to improve those services, particularly in telecommunications, electricity distribution, and water pipeline systems. The PSDS focuses on activities that increase the use of the private market to provide essential services, including infrastructure.

The process of privatization is complicated. For each project, establishing the macro conditions necessary for privatization and conducting a detailed cost/benefit analysis are required at a national level. Privatization can be described as a process that transfers responsibility for the provision of goods and services from the government to the private sector. The process also allocates risk for the provision of these goods and services from the government to a private party. In exchange, the private party is provided revenue sources.

A difficult task in the privatization process is allocating risk to the participating parties. A key principle of risk allocation is the assignation of risk to the party best able to cope, though the risks associated with privatization are often complex. The identification and allocation of risk are central themes of manuals designed to assist in the privatization process.[1]

This paper explores the role that privatization can play in shifting the risk of financing post-natural-disaster reconstruction from the government to the private sector. This topic has not been explored in detail in the existing literature. Current practice allocates risk of infrastructure loss from natural hazard events to governments. Existing practice is predicated on the long-standing principle that governments are best able to cope with large, uncertain risks—the types of risk that characterize natural hazard catastrophes. Through the power of taxation, governments can efficiently transfer these types of risk to taxpayers.

For a number of developing countries, the risk of loss from natural hazards may be handled more efficiently by the private market. The relative cost of transferring risk to taxpayers may be more expensive than that of transferring risk to the private sector. For these countries, considering natural hazard risk as a part of the bundle of risks transferred and a component of the privatization process may be warranted.

This paper will address natural hazard risk and privatization through discussion of the increasing costs of disasters to infrastructure, detailing the existing justification for allocating natural hazard risk to governments in the privatization process; exploring circumstances in which existing practice may be inappropriate; and discussing areas where additional research is needed.

Natural Hazard Losses to Infrastructure

The losses to infrastructure from natural hazards are significant and continue to escalate at an increasing rate. Research indicates two main factors that contribute to these losses: increasing concentrations of people and assets in hazard-prone regions of the world and increases in the intensity and frequency of severe weather-related events. This section will briefly review these trends.

Rising Total Direct Damages from Extreme Events

The ever-increasing losses from natural hazard events are an important issue for economic development and poverty reduction. Over the last 10 years, economic losses from natural disasters have averaged nearly $580 billion a year (figure 2.1). This is a 7.7-fold increase in losses from the decade of the 1960s (Munich Re 2002). Due to differences in size of the economies in industrialized and developing countries, however, the economic losses per capita were 20 times greater in developing countries (Bendimerad 2000). From 1991 through 2000, 2.1 billion people were affected by natural disasters, an average of 211 million people annually. Of that number, 98 percent lived in medium- and low-development countries as classified by the United Nations (IFRC 2002). Between 1990 and 1998, 94 percent of the world's major natural disasters and 97 percent of all natural-disaster-related deaths occurred in developing countries (World Bank 2001).

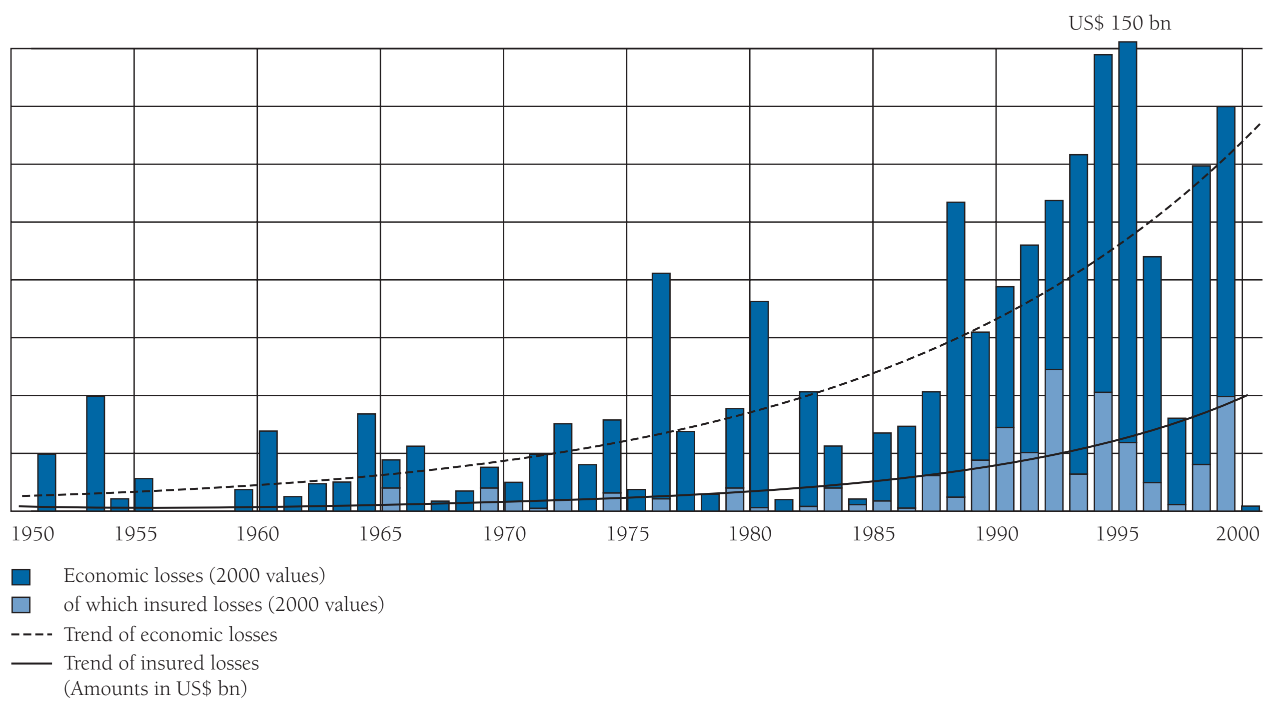
Relationship between Increased Damage and Climate Change

Researchers have isolated several factors that contribute to the rising trend in direct damage from catastrophes. One significant factor is the acceleration in weather-related natural hazard events such as hurricanes, cyclones, and flooding. They account for nearly two-thirds of all losses from natural hazards, while earthquakes account for most of the remaining third. Figure 2.2 divides losses into specific types of events and shows that, while earthquake occurrences have remained relatively stable over time, the incidence of weather-related events has accelerated. The economic costs of rainstorms, floods, droughts, and other extreme weather events have increased 14 times from the decade of the 1950s to the decade of the 1990s (Munich Re 2002).

Socioeconomic Factors and Increased Vulnerability to Natural Hazards

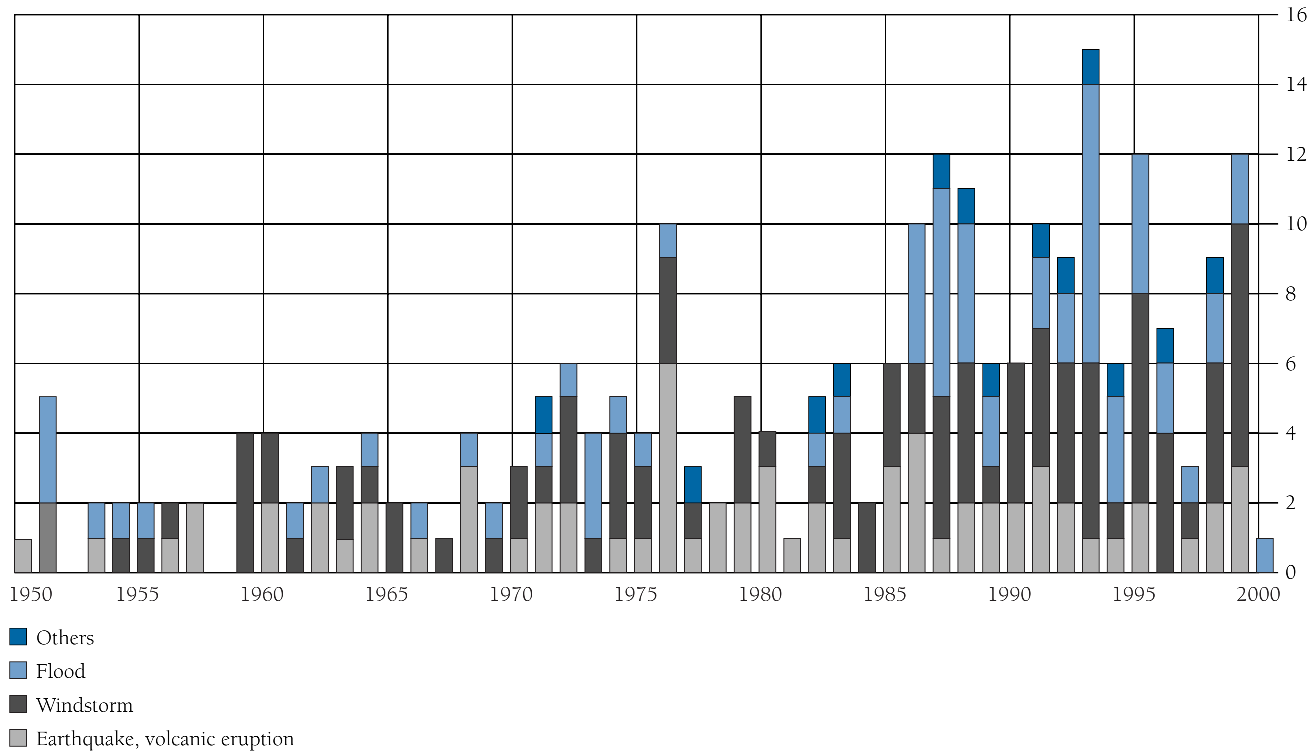
While the increasing frequency and severity of extreme weather events affect the cost of natural hazard risk, the most important variable increasing damage is the

Figure 2.1 Economic losses from natural catastrophes in the 20th century



Source: Munich Re 2002.

Figure 2.2 Natural catastrophe trends in the 20th century



Source: Munich Re 2002.

concentration of human populations and their assets in hazard-prone regions.[2]

It is estimated that natural disaster losses will increase dramatically over the next 50 years. The global cost of natural disasters is anticipated to top $300 billion annually by 2050 (UNISDR 2001). Two broad demographic trends directly impact the increasing losses from natural hazards in the developing world: population growth and the concentration of populations in megacities. In 1999, the world's population surpassed 6 billion. This represents a tripling of population since the beginning of the twentieth century. According to U.S. Census Bureau projections, the world's population will increase to nearly 8 billion by the end of 2025 and reach 9.3 billion by 2050—a 50 percent increase above current levels (U.S. Bureau of the Census 1998). Ninety-nine percent of the global increase will occur in developing countries. In 1960, 70 percent of the global population lived in less-developed regions. By 1999, that percentage had increased to 80 percent (UNFPA 1999), though increases in population do not necessarily translate into increased vulnerability to natural hazards.

Populations are concentrating in urban areas. The movement of people toward cities has accelerated in the last 40 years, with 47 percent of the world's population now living in cities, compared to one-third in 1960. The growth of cities results from births and migration to the cities from rural areas. In developing countries, the proportion of people living in cities has doubled since 1960, with more than 40 percent now living in urban areas. This trend is expected to continue, and by 2030, nearly 57 percent of the population in less developed regions will live in urban areas. In Latin America and the Caribbean, it is projected that more than 75 percent of the population will reside in urban areas by 2030 (UNFPA 1999). Urban concentrations in Latin America are the highest in the world (Charveriat 2000).

Increasing population concentrations in urban regions are primarily located in "megacities" with populations of more than 10 million people. In 1960, only New York and Tokyo had populations greater than 10 million. By 1999, there were 17 cities of that size, 13 of which were in less developed countries. It is projected that by 2015, there will be 26 mega cities, 22 of which will be in less-developed regions of the world. Nearly 10 percent of the world's population will live in these cities, up from just 1.7 percent in 1950 (UNFPA 1999). Urbanization increases risk by concentrating people and investments in limited geographic zones. As a result, natural hazards can inflict substantial damage in a short period of time. Hurricane Andrew inflicted $20 billion in damage in a few hours when it struck Miami in 1992 (Blaikie and others 1994).

Megacities are highly vulnerable to natural disasters. Nearly half of the world's largest cities are situated along major earthquake zones or tropical cyclone tracks (Bendimerad 2000). Floods, earthquakes, and tropical cyclones often strike the same geographic zones more than once, and some of the highest risk areas are also the most populous. India, China, and Southeast Asia are at high risk of seismic activity and floods, hurricanes, and cyclones. [3] Increasing population concentrations in urban areas far outstrip the capacity of cities to absorb this growth. In the 1990s, 60 to 70 percent of urban growth was unplanned (UN/ISDR 2001). Since governments in many developing countries already struggle to provide basic services to burgeoning populations, however, it is already difficult to find resources to decrease the vulnerability of poor residents of megacities to natural disaster risk. The spiraling costs of natural hazard events in developing countries are linked to the increasing number and intensity of events as well as to concentrations of urban poor in hazard-prone regions. Losses from catastrophes will be reflected in increasing infrastructure losses.

Current Infrastructure Losses as a Component of Worldwide Direct Losses

Since total direct damage increased dramatically worldwide over the past decades, it can be assumed that infrastructure damage as a portion of overall losses increased as well. Data from *World Development Indicators* (World Bank 1999) show that 24 percent of invested capital stock is public infrastructure. As of 2001, total direct losses for infrastructure had reached $9.6 billion, though this annual loss figure can vary significantly, depending upon the frequency and severity of weather-related events in a given year. Based on historical data, infrastructure losses in 1995 alone were $32.6 billion (Munich Re 2002).

Research suggests that different types of infrastructure are vulnerable to different types of natural hazard events. Housing and roads are particularly vulnerable to earthquake damage (Albala-Bertrand 1993). Droughts may have minor impacts on infrastructure and productive capacity, but can result in heavy crop and livestock losses. Floods can cause extensive damage to infrastructure and other production capacities, for example, wiping out agricultural yields (Benson and Clay 2000).

In a manual for estimating the socioeconomic effects of natural disasters, the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) provides broad outlines of the most probable types of infrastructure damage by type of disaster. For example, the manual explains how floods can impact clean water supplies; damage buried and semi-buried tanks and dam structures; and harm pump equipment. Floods were considered to cause damage in all infrastructure categories, deteriorating or destroying integral structural components, deforming the land on which infrastructure rests, or rendering it useless when wind and water have deposited extraneous material such as mud, ash, and debris. Droughts tend to impact infrastructure more mildly, though highways can buckle and railroad tracks can misalign when soldered rails become distorted. Windstorms put additional stress on buildings, affecting both structural and nonstructural elements, though only minimally affecting foundations and underground elements (ECLAC 1999).

Because different types of infrastructure are differently affected by disasters, the impacts of climate change are likely to affect critical infrastructure. Increases in flooding and windstorms will have implications for buildings, bridges, roads, and water systems, whereas droughts will affect agriculture and some transportation systems.

Allocation of Natural Hazard Risk in the Privatization Process

The loss of infrastructure due to natural hazard events is well known, though at issue—and the topic of this paper—is finding the most appropriate entity to bear the cost of post-disaster reconstruction. As a general proposition, the risk of loss to government-owned assets is best borne by the government. The justification lies in the ability of governments to use their power of taxation to spread the cost of loss to their taxpayers. Generally, the relative size of the loss to the capacity of the government to spread the loss across taxpayers has made governments the most efficient instrument to manage risk. "It is profitable for all concerned that risks should be shifted to the agency best able to bear them through its wealth and its ability to pool risks. The government, above all other economic agencies, fits this description" (Arrow 1992). The characteristic assumption that a government is the most efficient entity to bear risk underpins decisionmaking about government investments.

Most governments maintain a risk-neutral position: they ignore the risk in making public investment decisions. Justification for this approach is found in the work of Kenneth Arrow (Arrow and Lind 1970). The critical question for Arrow is: "What is the per capita cost of public risk-bearing?" The answer lies in computing individual costs and weighting them against the benefits of public risk bearing. As the cost of risk approaches zero in the hands of each individual, the risk also approaches zero for the government. As the cost of risk per citizen or per person that can be taxed approaches zero, the risk for a country's total wealth decreases. As Arrow states, "when the government undertakes an investment it, in effect, spreads the risk among all the taxpayers."

A second basis for government risk-neutrality is based on portfolio theory. Since risk may be reduced by portfolio diversification as well as by spreading risk over large populations, the government as owner of a wide variety of investments has the potential for the widest portfolio diversification. This theory underpins work by Paul Samuelson on capital investment decisions made by governments, which arrives at conclusions similar to those in Arrow's analysis (Samuelson and Vickrey 1964; Arrow and Lind 1970).

Because of the risk-neutral status of governments, they are the natural entities to which risk is often shifted by societies. In industrialized countries, the government supplies insurance for retirement. In many countries, medical care, particularly for the aged and indigent, is financed by the government (Priest 1996). In regard to natural hazard losses, the government is often the agent to assume the risk of loss for its citizens (Lewis and Murdock 1999).

The risk-neutral status of governments has influenced the behavior of industrialized countries in dealing with natural catastrophe risk in the privatization process. In examining opportunities to privatize energy activities in the United States, the government explicitly retains the risk of natural hazard losses in the privatization process. Guidelines from the U.S. Department of Energy (referenced in footnote 1) state that the risk of loss from natural hazards is less expensive in the hands of the government than any other party. As a result, the government is presumed to be better off by retaining the risk of loss from natural hazards than by attempting to transfer the risk as a component of the privatization process. The same justification has been applied to privatization of government-owned facilities in developing countries (Lewis and Mody 1998).

While the theory of government risk-neutrality may be applicable to most industrialized countries, the use of this theory to justify the assumption of natural hazard risk by governments in all cases is limited. In regard to the privatization of infrastructure projects, the theoretical limits of the policy have a particular application.

Arrow recognized limitations on the general theory of the risk-neutral status of governments (Arrow and Lind 1970). He was particularly interested in projects where the loss would be felt by one specific group, as in the case, for example, of a bridge that serviced a limited geographic region. In this case, it is appropriate that the risk profile of the geographic region dictate how risk for that project should be managed. Another example cited by Arrow concerns government projects directed at a particular population group that receives the benefits of a project and bears its risk of loss. An irrigation project in a defined watershed region would be such an example. In this case, if the risk of loss were to be borne by those dependent upon the project, Arrow maintained that the risk profile of the directly impacted group, not the entire population, would be most relevant. Both of these examples highlight the same principle: if the risk of an investment is borne by a limited group, the risk-adversity of that group should dominate the investment decision (Arrow and Lind 1970).

As to the comparative advantage of the government in diversifying risk through its portfolio strategy, a compelling argument can be made that this is a small advantage when dealing with correlated risk. The risk of loss from catastrophes in smaller countries is correlated, since the catastrophe is likely to impact the entire country at the same time. The core of the portfolio strategy lies in aggregating independent risks, whose error terms cancel out increasing predictive ability. This does not occur when aggregating highly variant risks (Priest 1996).

Several arguments emerge as to why developing countries should be risk-averse. For many, the large size of the potential loss in absolute terms compared to their internal risk-spreading ability means that risk does not approach zero in the hands of the population. Honduras presents such an example: in 1998, Hurricane Mitch caused total losses approaching $5 billion in a country with a total population of 4 million. Seventy percent of the population earns less than $2 per day (World Bank 1999). The average per capita cost of $1,250 per person, therefore, is not insignificant, and the cost of risk does not begin to approach zero for Honduras or countries in similar circumstances.

The mere calculation of per capita cost does not reflect the difficulty countries have in increasing internal tax revenues. Many have only a limited ability to spread the cost of risk internally through taxation (Rodrik 1998). Many countries rely on a system of indirect taxes, the increase of which has political implications for specific segments of society. For these countries, the budgetary adjustment process is difficult and politically costly (Lewis and Murdock 1999). As a result, the process of spreading even small dollar amounts of risk has high political costs (Meier 1995). In addition, shallow financial markets and weak financial systems limit the capacity to access internal and commercial external savings in times of catastrophes (Ferranti and others 2000). Therefore, even if the cost of risk approached zero in the hands of each taxpayer, the barriers to transferring the risk to each taxpayer could be high in many countries.

This raises a critical issue when examining risk spreading. The issue for some governments is not only the absolute size of the risk; it is also the relative ability of a country to dedicate resources to dealing with the risk. In examining external shocks to economies, a growing body of research is emerging to describe why some countries recover from shocks better than others. These studies relate primarily to credit and commodity price shocks (Cornelius 2000). A core factor is that financial markets in many countries remain shallow, and financial systems are weak (Ferranti and others 2000). The imperfections of the financial markets severely limit their ability to diversify risk and reallocate financial resources during times of distress. Another factor of economic recovery is the political will of the country to reallocate costs of adjustment programs within the domestic economy (Rodrik 1998). In a study examining differences in recovery from the recent debt crises in East Asia and Latin America, Rodrik found that countries with the ability to distribute the cost of risk with few political repercussions were able to recover relatively quickly. These countries tended to be located in East Asia. However, countries that lacked the ability to allocate the cost of risk without considerable political turmoil took long periods of time to recover from external shocks to their economies. These countries tended to be in Latin America. In the meantime, economic growth within these slowly recovering countries was significantly curtailed (Ferranti and others 2000). The importance of this observation is that risk aversion at a government level should be influenced as much by the capacity of the country to allocate risk within society as by the relative size of the risk. Since many countries have difficulty reallocating internal resources, reliance on external debt is often the preferred tool to address the need for additional resources (Cornelius 2000). Additional external debt may have the least internal political cost.

As described earlier, it is not clear that governments in smaller countries can efficiently spread highly correlated risk. Since natural disasters tend to recur within geographically defined regions and can impact significant portions of smaller countries, no benefit arises from aggregation of risk at the country level (Priest 1996). This analysis begins to define investment decisions where the traditional assumption of government risk neutrality should be challenged. The first group of decisions includes those for which the risk of loss relative to the capacity of the population to absorb the risk is high. Honduras is a good example of this problem: the risk of loss on a per capita basis is very high.

Risk analysis is different for another group of countries that includes those where the cost of catastrophe losses per capita is small, but the ability to shift the cost of risk to the population is limited. These are countries with fragile taxation systems and those with weak democratic institutions that lack the power to impose costs on entrenched power elites within the country. As described earlier, Rodrik has identified a group of countries that lacked the ability to institute required political change to adjust to noncatastrophe external stocks, despite the considerable costs borne by these countries due to a lack of economic growth. The countries he identified, primarily in Latin America and Africa, would likely lack the political will to allocate the risk of loss internally through taxation. The World Bank has also developed an index that describes countries with imperfect financial markets that tend to magnify rather than absorb the cost of external shocks (Ferranti and others 2000). A third situation arises when investments target the poor. If a specific group benefits from government investment, the risk profile of that group should dictate how risk is handled.

Determining when the government should assume risk associated with past investment decisions has a direct bearing on which risks should be assumed or transferred by governments in the privatization process. As noted earlier, the risk-neutral status of governments in industrialized countries leads them to retain natural hazard risk in the privatization process. The issue of concern for developing countries, particularly for those with high catastrophe exposure, is whether the same theory holds true.

Capacity of Countries to Absorb Natural Hazard Risk

Key principles in the privatization process are the identification and allocation of risks to the parties best able to cover them.[4] With respect to infrastructure projects, a wide variety of risks, including risks during construction, projected use of new infrastructure, the willingness of people to pay to use the infrastructure, and the maintenance and ongoing operations required, must be addressed. As discussed earlier, another risk is the partial or complete destruction of a project by a natural hazard event. Since this risk may be large, and such losses are often difficult to predict, it is a risk generally retained by governments.

Increasingly, research has measured the risk of loss from natural hazards in developing countries and the capacity of countries to manage that risk. In a recent study for the Inter-American Development Bank, a technique that measures the capacity of a government to finance probabilistic losses from natural hazard events was developed. For the Dominican Republic, El Salvador, Bolivia, and Colombia a "resource gap" was developed. A resource gap is a measurement of a country's ability to finance its reconstruction obligations following a disaster. Calculation of the resource gap requires the following computations:

- Country risk from natural hazard losses. The risk is a function of the probability of hazards of different magnitudes impacting a country and the vulnerability to loss of the potentially exposed population and assets.
- The financial responsibility of the government to finance country losses. Primary losses from disasters may be the responsibility of various parties in addition to the government: industry, businesses, homeowners, and individuals. For this analysis, we are concerned about the portion of loss borne by the government.
- The capacity of the government to meet its financial obligations. To the extent that a government lacks the resources to fund its obligations, there is a natural-hazard-resource gap. The required resources may come from international aid, government revenues (taxes), reserves, insurance proceeds, borrowing, and the diversion of resources from other programs.

A natural-hazard-resource gap articulates the ability of a government to meet the needs of financing post-disaster reconstruction. For countries with a resource gap, it means that significant costs to meet the risk of loss to natural hazard risk will be incurred.

Resource Gap

A *natural-hazard-resource gap* is developed for each of the case study countries. The resource gap is a measurement of the inability of a country to finance its reconstruction obligations after a disaster. The measurement of the resource gap requires the calculation of a catastrophe exposure for each country. Catastrophe exposure is determined by combining hazard and vulnerability estimates for each country. The calculated catastrophe exposure estimates are presented in table 2.1:

Table 2.1 Catastrophe exposure in case study countries

Country	*20-year event*	*50-year event*	*100-year event*
Bolivia	200	600	1,000
Colombia	2,000	5,000	8,000
Dominican Republic	1,250	3,000	6,000
El Salvador	900	3,000	4,500

All values in millions of U.S. dollars.

For example, Bolivia can expect direct losses to capital stock of at least $200 million approximately every 20 years; more specifically, there is a 1-in-20 chance every year that there will be a catastrophic event equaling or exceeding $200 million in losses. Likewise, there is a 1-in-50 chance, or 2 percent probability, every year of at least $600 million in direct losses. The magnitude of that figure could double, however, if indirect losses from lost production, tourism, and other services were included.

Because the capacity of governments to finance obligations after a disaster is often limited, it is essential to know the responsibility of the government for a country's catastrophe exposure. Generally, two broad categories of governmental responsibility can be defined: risk to government-owned property and the risk a government assumes from others. In the former, the risk of loss is to government buildings, schools, and hospitals, and infrastructure such as roads, bridges, and airports. The second category is the risk that the government assumes from others. This generally includes the risk to homeowners, agriculture, local and provincial governments, and the poor.

It is estimated that the government will finance 50 percent of the losses in the four countries. Table 2.2 (which is 50 percent of table 2.1) shows the share of losses borne by the government:

Table 2.2 Government financing needs in case study countries

Country	*20-year event*	*50-year event*	*100-year event*
Bolivia	100	300	500
Colombia	1,000	2,500	4,000
Dominican Republic	625	1,500	3,000
El Salvador	450	1,500	2,250

All values in millions of U.S. dollars.

These estimates represent government responsibility for reconstruction of government-owned property, as well as the assumption of risk for private housing, agriculture, and programs targeting the poor during post-disaster periods.

Once an estimate of future financing needs has been determined, the next question addressed is the ability of the government to meet those needs. Is there a gap between the probabilistically determined resources and the ability of the government to fund the required resources? The potential difference is a resource gap. A resource gap is calculated by comparing a government's probabilistic or contingent need for reconstruction funds in the current year with its anticipated access to internal and external funds. Table 2.3 shows the estimated resource gap for the four countries.

The resource gap for each country depends on critical assumptions regarding the ability to access internal and external resources. For example, the resource gap in Colombia is primarily affected by the ability to raise funds through taxation. Historically, Colombia has raised internal taxes as a major tool in financing natural disaster losses. It is assumed that Colombia could raise taxes by an additional $1.5 billion, if necessary. If it has the ability to raise taxes by $2 billion, the resource gap for the 100-year event would disappear. The resource gap also depends on a series of assumptions regarding future financing sources. The report details all assumptions used and the source of the data. The chart raises this question: How are countries able to finance their probabilistic losses from natural hazards? The resource gap provides the basis for evaluating whether a country can efficiently absorb losses to infrastructure. In some cases, transferring the risk of loss from natural hazards to the private market as a component of the privatization process might be the best option for countries with a high resource gap.

Before addressing this option, however, the variations in the resource gap among countries must be understood. According to this analysis, Bolivia can anticipate no resource gap over the range of 20-, 50-, and 100-year events, although Bolivia is the poorest country in South America and would be expected to be the most vulnerable. Its level of hazard risk, however, is so low that it should have sufficient resources (assuming substantially increased borrowing) to respond. Colombia, by

Table 2.3 Resource gap in case study countries

	20-year recurrence			
	Bolivia	*Colombia*	*Dom Rep*	*El Salv*
Direct damages	200	2000	1250	900
Gov responsibility	1000	1000	625	450
Aid	2	17	11	8
Insurancce Payments	5	50	31	23
Budget realloc	250	1500	500	250
New taxes	0	500	0	90
Domestic credit	100	0	150	0
External credit IDB/WB	100	100	100	100
External credit market	0	0	800	800
Resource gap	none	none	none	none
Resource gap w/o IDB/WB	none	none	none	none
Additional debt	0	0	83	80
	50-year recurrence			
	Bolivia	*Colombia*	*Dom Rep*	*El Salv*
Direct damages	600	5000	3000	3000
Gov responsibility	300	2500	1500	1500
Aid	5	43	26	26
Insurancce Payments	15	125	75	75
Budget realloc	250	1500	500	250
New taxes	0	1000	0	180
Domestic credit	100	0	150	0
External credit IDB/WB	200	200	200	200
External credit market	0	0	800	800
Resource gap	none	none	none	none
Resource gap w/o IDB/WB	none	none	none	169
Additional debt	30	0	899	969
	100-year recurrence			
	Bolivia	*Colombia*	*Dom Rep*	*El Salv*
Direct damages	1000	8000	6000	4500
Gov responsibility	500	4000	3000	2250
Aid	9	69	52	39
Insurancce Payments	25	200	150	113
Budget realloc	250	1500	500	250
New taxes	0	1500	0	270
Domestic credit	100	0	150	0
External credit IDB/WB	200	200	200	200
External credit market	0	0	800	800
Resource gap	none	531	1148	579
Resource gap w/o IDB/WB	116	731	1348	779
Additional debt	216	200	1150	1000

contrast, has a very high natural hazard risk, but per capita incomes are high and risks are geographically diverse. The government should be able to absorb the cost of disasters until it reaches a 100-year event. Even then, its resource gap can be covered if the government is able to raise taxes. Alternatively, El Salvador and the Dominican Republic can anticipate resource gaps, given their catastrophic risk exposure. Both countries are small and have limited geographic diversity with respect to risk, a high exposure to large-scale natural disasters, and limited financial resources. For these two countries, there is at least a 1-in-100 chance of being struck by an event that outstrips their ability to raise post-disaster reconstruction funds.

The calculation of a resource gap for countries is the beginning of a process. The resource gap identifies possible sources of financing for losses from natural hazards, but the analysis does not quantify the cost of accessing those resources. As discussed earlier, accessing available resources has a cost. There are political costs to raising taxes and diverting budgetary allocations. The use of increased debt absorbs borrowing capacity that may be better used for other purposes. The borrowing gap calculation frames the issue so that a determination of whether it is more efficient for a government to retain or transfer risk of natural hazard losses as a component of the privatization process can be made.

Conclusions and Future Research

The need to expand the provision of infrastructure in developing countries is clear. The use of privatization as a tool to assist in the extension of infrastructure to the poor is a priority of the international financial community. While myriad issues are associated with privatization, defining and allocating risk as a component of the privatization process to determine the most cost-effective allocation is especially difficult. If risks are large and difficult to control, government retention of the risk might prove the best option. These risks would be extremely expensive to shift to the private sector and, in the worst case, could prove to be a "deal killer." Justification for government assumption of risk is that governments are best able to handle unknown risk through their power of taxation. The ability to spread risk to taxpayers is an enormous efficiency advantage of governments.

Circumstances exist where it may be more efficient for the risk of natural hazard losses be shifted to the market as a component of privatization. The main circumstances are:

- The project benefits a limited geographic area.
- The project assists a limited population group, such as the poor.
- The size of the risk is larger than the capacity of the government to shift the risk efficiently to the population. For those countries with a resource gap, it may not be possible for them to finance the natural hazard risk.
- Countries without a resource gap may have institutional barriers that prevent them from shifting risk to their populations. For countries lacking the ability to develop institutional compromise, the political costs of financing post-disaster reconstruction may make it more desirable to include risk as a component of the privatization process. This may be the case for a number of Latin American countries.

In these instances, the cost of transferring risk to the market should be considered as a component of privatization. It may be that the cost of assigning the risk to the market is too high and the risk must be absorbed by the government, but natural hazard risk should not be placed automatically, as is currently done, in those categories of risk best left with the government. As the losses to infrastructure continue to escalate, the ability to shift natural hazard risk to the market will become increasingly important.

The analysis presented in this paper also applies to other types of risk that may arise from the privatization process. In Eastern Europe, for example, the privatization of state-owned manufacturing enterprises is ongoing. Many of these facilities involve chemical and hazardous waste risk from prior operations. Mechanisms such as environmental insurance exist for market assumption of private enterprises and the risk associated with contamination created from prior business operations, including chemical facilities (Freeman and Kunreuther 1997). It may be that risks from prior hazardous chemical operations may also be more efficiently handled by the transfer of the risk as a component of the privatization process.

Research on the proper allocation and financing of natural and man-made hazard risk for developing countries is in the early stages. For many countries, information about the level of risk to infrastructure has not been systematically developed, although techniques to make the necessary calculations are well understood. The concept of "risk aversion" for governments is not well understood, either. As globalization continues, it may be that the market (including large international corporations) is much more efficient in coping with natural hazard risk. If so, it makes the most sense for that risk to be assumed by the market as a component of the privatization process.

Specifically, the following issues need to be addressed:

- The exposure of an infrastructure project to natural hazard risk.
- The capacity of a country to absorb the risk.
- An evaluation of infrastructure projects to determine their primary beneficiaries and an analysis of the risk tolerance of that particular group.
- The cost of the assumption of the natural hazard risk by the market on a project-by-project basis.

A number of these questions are novel in the context of developing countries. With increased losses to infrastructure from natural hazard events, the efficient assumption of risk will be increasingly important.

Notes

1. In 1998, the United States Department of Energy issued two sets of guidelines for privatization projects that remain benchmarks for work in privatization. The first is a Program-Project Manager's Privatization Guide and the second is a Privatization Cost Estimating Guide. These documents can be found on the website for the Department of Energy (http://www.em.doe.gov/ private/projmangu.html). The Organization of Economic Cooperation and Development (OECD) has a Working Group on Privatization and Governance of State-owned Enterprises with a comprehensive list of documents related to privatization (http://www.oecd.org/EN/document/0,EN-document-80-3-no-20-19549-80,00.html). As relates to work in developing and emerging economies, the Asian Development Bank has a Public-Private Infrastructure Advisory Facility (http://www.adb.org/ Documents/ADBBO/RETA/35078012.ASP) that has examined best practices for privatization in a number of industries.

2. Paul K. Freeman, "Natural Disasters in Developing Countries: Vulnerability from Increasing Population Concentrations," in *Encyclopedia of Population* (forthcoming).

3. Earthquake risk lies along well-defined seismic zones that incorporate a large number of developing countries. High-risk areas include Turkey, Pakistan, Afghanistan, India, China, Indonesia, and the west coasts of North, Central, and South America. The pattern of hurricanes in the Caribbean and typhoons in South Asia, Southeast Asia, and the South Pacific is well established. Floods occur on 1 percent of the worldwide landmass. (Swiss Re 1997).

4. The discussion in this section is based on work done for the Regional Policy Dialogue of the Inter-American Development Bank on Natural Hazard Risk. The resource gap described in this section is based on methodology prepared by Leslie Martin and described in greater detail in Freeman and Martin, "National Systems for Comprehensive Disaster Management: Financing Reconstruction," May 1, 2002. The paper and methodology can be found at the Regional Policy Dialogue website: (http://www.iadb.org/int/drp/).

Bibliography

Albala-Bertrand, J. 1993. *Political Economy of Large Natural Disasters with Special Reference to Developing Countries.* Oxford, U.K.: Clarendon Press.

Arrow, K. J. 1992. "Insurance, Risk and Resource Allocation." In G. Dionne and S.E. Harrington, eds., *Foundations of Insurance Economics: Readings in Economics and Finance.* Boston: Kluwer.

Arrow, K. J., and R.C. Lind. 1970. "Uncertainty and the Evaluation of Public Investment Decisions." *The American Economic Review* Vol. 60: 364–378.

Bendimerad, Fouad. 2000. "Megacities, Megarisk." The Disaster Management Facility, World Bank, Washington, D.C. Available from <http://www.worldbank.org/dmf/knowledge/megacities.htm> accessed June 2002.

Benson, C. and E. Clay. 2000. "Developing Countries and the Economic Impact of Natural Disasters." In Alcira Kreimer and M. Arnold, eds., *Managing Disaster Risk in Emerging Economies.* Washington, D.C.: World Bank.

Blakie, Piers, Terry Cannon, Ian Davis, and Ben Wisner. 1994. *At Risk: Natural Hazards, People's Vulnerability, and Disasters.* New York: Routledge.

Charveriat, Celine. 2000. *Natural Disasters in Latin America and the Caribbean: An Overview of Risk.* Inter-American Development Bank: Washington, D.C.

Cornelius, Peter. K. 2000. "Reforming the Public Sector's Risk Management Emerging Markets." Development Discussion Paper No. 751. Boston: Harvard Institute for International Development.

ECLAC (Economic Commission for Latin America and the Caribbean). 1999. *Manual for Estimating Socio-economic Effects of Natural Disasters*. United Nations International Decade for Natural Disaster Reduction. New York: United Nations.

Ferranti, D., and others. 2000. *Securing Our Future in a Global Economy.* Washington, D.C.: World Bank.

Freeman, Paul K., and Howard Kunreuther. 1997. *Managing Environmental Risk with Insurance.* Boston: Kluwer Academic Publishers.

Freeman, Paul K., Leslie A. Martin, Reinhard Mechler, Koko Warner, and Peter Hausmann. 2001. *Catastrophes and Development: Integrating Natural Catastrophes into Development Planning*. Disaster Risk Management Working Papers Series No. 4. The Disaster Management Facility, World Bank, Washington, D.C.

IFRC (International Federation of Red Cross and Red Crescent Societies). 2002. *World Disaster Report 2001: Focus on Recovery.* Bloomfield, CT: Kumarian Press Inc. <http://www.ifrc.org./publicat/wdr2001/> accessed June 2002.

Lewis, C.M., and A. Mody. 1998. *Contingent Liability for Infrastructure Projects.* Washington, D.C.: World Bank.

Lewis, C.M., and K.C. Murdock. 1999. "Alternative Means of Redistributing Catastrophic Risk in a National Risk Management System." In K.A. Froot, ed., *The Financing of Catastrophic Risk*. Chicago: National Bureau of Economic Research.

Meier, G.M. 1995. *Leading Issues in Economic Development*. New York: Oxford.

Mitchell, James K., ed. 1999. *Crucibles of Hazard: Mega-Cities and Disasters in Transition.* New York: United Nations University Press.

Munich Re (Munich Reinsurance Company). 2002. *Topics: Annual Review: Natural Catastrophes 2001.* Munich: Munich Re.

Priest, G.L. 1996. "The Government, the Market, and the Problem of Catastrophic Loss." *Journal of Risk and Uncertainty* No. 12: 219–237.

PSDS (Private Sector Development Strategy). 2002. "Private Sector Development." World Bank, Washington, D.C. Available from <http://www.worldbank.org/privatesector> accessed June 2002.

Rodrik, D. 1998. "Where Did all the Growth Go? External Shocks, Social Conflict and Economic Growth." Available from http://ksghome.harvard.edu/~.drodrik.academic.ksg/publications.html.

Samuelson, Paul, and W. Vickrey. 1964. “Discussion.” *American Economic Review Proceedings* May(59):88–96.

UNISDR (United Nations International Strategy for Disaster Reduction). 2001. *Natural Disasters and Sustainable Development: Understanding the Links Between Development, Environment and Natural Disasters.* Working Paper No. 5. New York, N.Y.: Department of Economic and Social Affairs.

UNFPA (United Nations Population Fund). 1999. “The State of World Population 1999.” *UNFPA Online*. Available from <http://www.unfpa.org/swp/1999> accessed June 2002.

U.S. Bureau of the Census. 1998. “World Population Profile.” *U.S. Census Bureau Online.* Available from <http://www.census.gov/ipc/www/wp98001.html> accessed June 2002.

World Bank.1999. *World Development Indicators.* Washington, D.C.: World Bank.

World Bank. 2001. *World Development Report 2000/2001: Attacking Poverty.* New York: Oxford.

Chapter 3

Natural Disaster Risk and Cost-Benefit Analysis

Reinhard Mechler

Natural Disaster Risk and Development

Natural disasters constitute a serious challenge, particularly for a number of developing countries where the impacts of these disasters are substantially larger than they are in more developed countries, due to a typically higher degree of vulnerability. Factors contributing to increased vulnerability comprise widespread poverty, high unemployment, distributional inequalities, high population growth, and lack of strong national and local institutions for dealing with disasters (Smith 1996: 42–46; Anderson 1995: 45; ECLAC/IDB 2000: 1). However, natural disaster risk is often insufficiently accounted for in decisionmaking. A major decisionmaking tool commonly used in the economic and financial evaluation of public investments is cost-benefit analysis (CBA). In the context of natural disaster risk, CBA is not used sufficiently. This risk is often neglected in CBA assessments of investment projects, risk management measures to reduce natural disaster risk are often not assessed by CBA, and risk is commonly represented by average values only.

This paper will analyze these shortcomings and their consequences, focusing on the economic impacts of disasters. The next section discusses the impacts of natural disasters and the basic elements of CBA. Then the incorporation of natural disaster risk into CBA is examined, followed by a review of the current shortcomings in using CBA in the context of natural disaster risk and resulting consequences. A short case study illustrates some of the issues discussed. The final section summarizes the findings and provides recommendations for using cost-benefit analysis in assessing natural disaster risk.

CBA and Natural Disaster Risk

Natural Disaster Risk and Impacts of Disasters

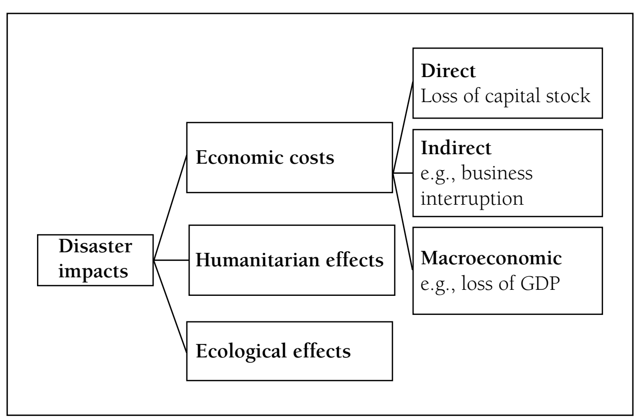
Natural disaster risk can be defined as the following:

> The exposure or the chance of loss (of lives, persons injured, property damaged and economic activity disrupted) due to a particular hazard for a given area and reference period. It may be expressed mathematically as the probability that a hazard impact will occur multiplied by the consequences of that impact (ADPC 2000).

In case of a disaster event, the following effects may occur: humanitarian effects, including the loss of life and persons injured; ecological effects among other damage to ecosystems; and economic effects, the focus of this paper, comprising different effects on the economy and grouped into three categories—direct, indirect, and macroeconomic costs (see figure 3.1).

Direct losses describe physical impacts on capital stock such as infrastructure, machinery, and buildings. They can be caused by the disaster itself or by follow-on

Figure 3.1 Impacts of natural disasters



physical destruction (e.g., through fires). Indirect losses occur as a consequence of these direct stock losses and include production and wage losses due to business interruption. Macroeconomic or secondary impacts comprise the aggregate impacts on economic variables like gross domestic product (GDP), consumption, and inflation due to the effects of disasters as well as to the reallocation of government resources to relief and reconstruction efforts. Because macroeconomic effects reflect indirect damage as well as the relief and restoration effort, these effects cannot simply be added up without causing duplication (Otero and Marti 1995: 16–18). A substantial number of studies on the assessment of these costs exist. A useful source of information is a manual that assesses the various costs of natural disasters developed by the Economic Commission for Latin America and the Caribbean (ECLAC 1999).

Elements of CBA

Cost-benefit analysis (CBA) is an economic technique typically used to organize data, present costs and benefits, and finally estimate the cost-efficiency of projects like building new infrastructure, which are undertaken by governments and public institutions to increase public welfare (Kopp and others 1997: 53). CBA measures the change with and without the specific project. In essence, it compares the costs of a planned project with its benefits and recommends its adoption when benefits exceed costs.

There are three steps to CBA. First, costs and benefits must be identified and estimated. If these are given in physical terms, monetary values need to be assigned (there are several methods for doing this). Next, future costs and benefits need to be discounted to render current and future effects comparable. Last, costs and benefits are compared under a decision criterion to assess whether benefits exceed costs. Several criteria exist: the main ones are the net present value, the cost-benefit ratio, and the internal rate of return (Zerbe and Dively 1994: 177; Dasgupta and Pearce 1978: 165).

The costs in a CBA are the specific costs of conducting a project. First there are the financial costs, the monetary amount that has to be spent for the project. However, of greater interest are the opportunity costs of using these funds—the benefits foregone from not being able to dispose of these funds for other important objectives. Usually, the benefits in a CBA are the additional outcomes generated by the project compared to the situation without the project. In relation to natural disaster risk, additional benefits arise from the savings in terms of avoided direct, indirect, and macroeconomic costs as well as the reduction in variability of project outcomes.

There are several limitations to CBA. One is the difficulty of assessing nonmarket values. Although methods exist, this involves making difficult ethical decisions, particularly regarding the value of human life: CBA should probably not be used for this purpose. Another issue is the lack of accounting for the distribution of benefits and costs in CBA.[1] The general principle underlying CBA is the Kaldor-Hicks-Criterion, which holds that those benefiting from a specific project should potentially be able to compensate those who are disadvantaged by it (Dasgupta and Pearce 1978: 57). Whether compensation is done in practice, however, is often not of importance. Another issue is the question of discounting. Applying high discount rates expresses a strong preference for the present while potentially shifting large burdens to future generations.

However, when keeping these limitations in mind, CBA is a useful tool whose main strength is an explicit and rigorous accounting framework for systematic cost-efficiency decisionmaking. CBA provides a common yardstick with a money metric against which to measure projects for social improvement (Kopp and others 1997: 53). It is a fact that economic efficiency is important to many (government) decisionmakers. For example the United States has "at times dominated the policy debate on natural hazards" (Burby 1991: 154). However, CBA should not be the sole criterion for evaluating policies, but should be complemented by other, noneconomic considerations.

Incorporation of Natural Disaster Risk into CBA

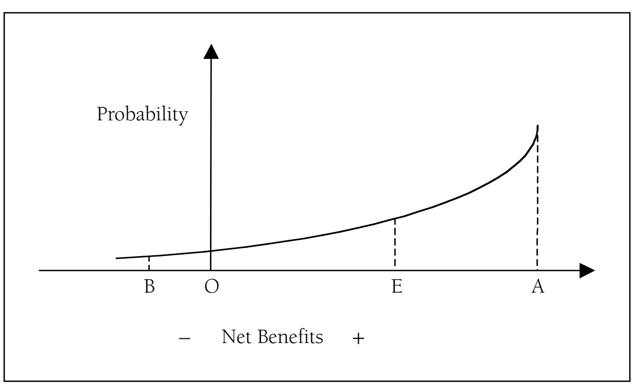
Cost-efficiency evaluations by means of CBA are undertaken in the context of uncertainty which, when it can be measured probabilistically, is called risk, or "measurable uncertainty," according to Knight (compare with Brent 1998: 206).

A number of methods for CBA in the context of risk have been suggested; these are well described in Kramer (1995: 61–76). There are basically two ways to include risk in project analysis: the limited-information approach and the probability-based approach. When no specific information or only partial information on natural hazards and their impacts is available, limited-information approaches are used. Among these, sensitivity analysis is often used, where important variables are varied in an ad-hoc fashion to study the sensitivity of outcomes to these variations. Although natural disasters are rare events and, thus, abundant information on them does not exist, data and software tools that can conduct a fuller probabilistic analysis provide more insight than the limited-information approaches are increasingly becoming available.

A probabilistic approach entails obtaining probability distributions on disaster events and linking them to major economic variables. With that information, a probability distribution of the project outcomes (net benefits) can be generated (figure 3.2).

Assume that *A* is the projected net benefits (i.e., benefits less costs) from a project before natural disaster risk has been included in the assessment. *A* is positive, so this project seems a worthwhile undertaking. If a probabilistic project analysis is conducted and a probability distribution is estimated, the average outcome—the expected value *E*—can be determined. In the case of natural disaster risk, which is a purely downside risk,[2] the expected value will be lower than the originally projected deterministic value *A* that didn't account for risk. However, the average outcome E represents only that value that over a certain time horizon will materialize *on average*. Actual outcomes may lie along the whole range of *A* and *B* (here *B* is assumed to be the worst outcome); net benefits could be negative if a disaster destroys a significant part of the project and only a few benefits materialize while project costs have accumulated already.

Figure 3.2 Project analysis under risk



For a project evaluator, it may be important to examine the probability of net benefits becoming negative, i.e., to determine how marginal a project is. Consequently, if marginality is likely, a decision to abandon the project or site it elsewhere, where hazard exposure is lower, or include risk management components into the project may be necessary.

These risk management measures, or "secondary projects," protect a primary project's outcomes (Brent 1998: 220). Benefits of these projects are the savings in terms of damage avoided and the decrease in volatility in outcomes. Secondary projects may be mitigation projects that reduce risk, or risk transfer projects that cede risk to other parties willing to accept it.

Status of Application of CBA in the Context of Natural Disaster Risk

Natural disaster risk is only one risk among several (including, for example, exchange rate or commodity price fluctuations) that must potentially be taken into account. When a risk is judged to be negligible, it may not have to be considered formally. In contrast, when a risk is found to be large, it needs to be accounted for properly, in order to allow an efficient allocation of resources to these projects.

Natural disaster risk is often not considered sufficiently in CBA. When examining the relevant literature on CBA in the context of natural disaster risk, three issues emerge:

- Natural disaster risk is commonly not accounted for in CBA for investments and primary projects.
- Secondary (risk management) projects are rarely assessed in a CBA framework. When this is done, the focus is on mitigation only.
- Usually, risk is not included explicitly, but by averages.

These issues are further analyzed in the following section.

Natural Disaster Risk Is Not Included in Evaluation of Investment Projects

For a number of countries, natural disaster risk is a serious risk. However, this source of risk usually is not sufficiently accounted for in developmental planning and appraisals of investment projects by governments and multilateral finance institutions (MFIs) (Kramer 1995: 62; OAS 1991: 8). Vermeiren and Stichter remark in an assessment of the costs and benefits of mitigation in the Caribbean:

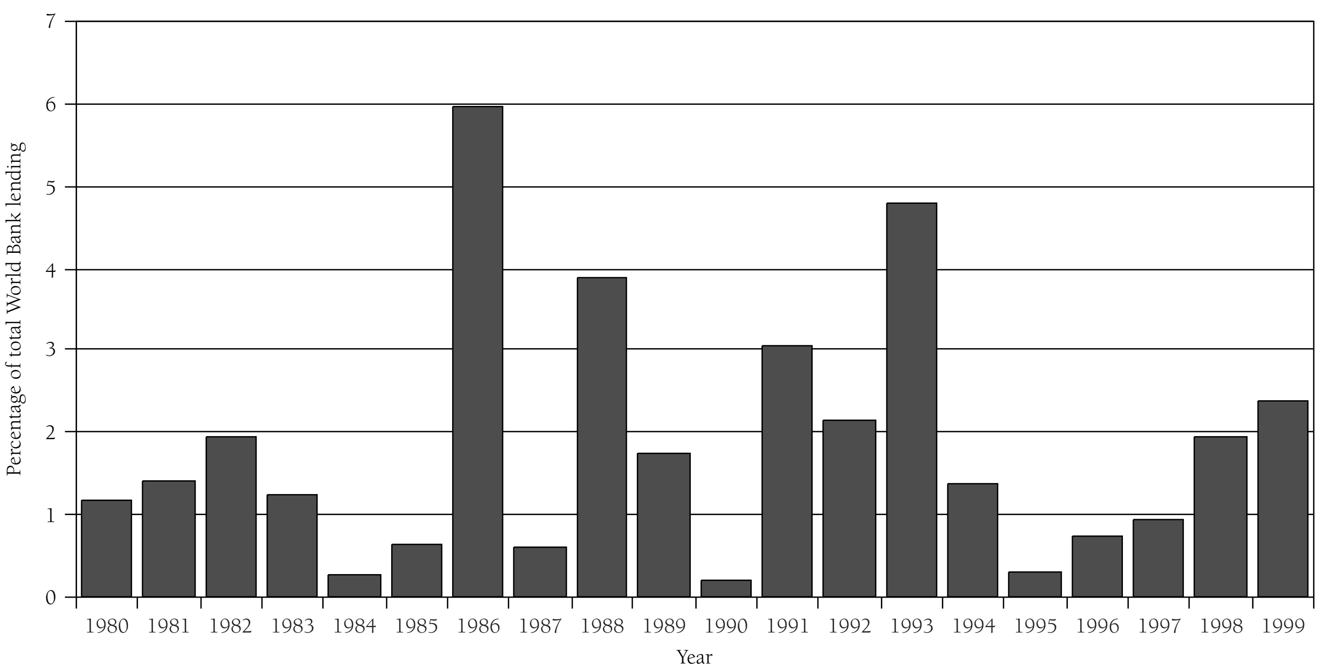
> Contributing to the precarious state of the infrastructure is the region's vulnerability to natural disasters—hurricanes in particular —and the tendency of development decision-makers, in the public as well as private sectors, to make decisions concerning major investment projects without due consideration of natural disaster risk (Vermeiren and Stichter 1998: 1).

As a consequence, the uncertainty in project benefits is thus not duly accounted for, which results in an inefficient allocation of resources. There is the possibility that risky projects may be selected and that projected benefits and investment will be lost when a disaster occurs. Furthermore, investment funds often have to be borrowed externally in developing countries if internal resources are insufficient. In the case of a disaster, this investment is lost and the capacity to service the recently accumulated debt in the future is not increased. Also, funds for continuing these projects or rebuilding lost assets often have to be diverted from other projects, causing large developmental impacts. Finally, if sufficient funds for reconstruction and relief are not available, serious negative long-term impacts on socioeconomic development may result (compare with Freeman and others 2002).

Assistance by MFIs in their capacity as "reinsurers of last resort" is often sought post-disaster. These assistance needs are volatile and rising. For example, between 1980 and 1999, the World Bank, the world's largest multilateral lending institution, financed 102 post-catastrophe reconstruction projects in 56 countries, amounting to a total of about $7.5 billion (Gilbert and Kreimer 1999: 1). [3] In relation to World Bank lending, the total sum over this period amounted to 1.9 percent, with a range from 0.2 to 6.0 percent on an annual basis (see figure 3.3). There was some recurrence: 22 countries have had two or more lending operations over this period.

These figures underestimate the World Bank's reconstruction financing support, as they do not include funds reallocated from other operations. Over the course of the 1990s, the Inter-American Development Bank lent around $2 billion in post-disaster assistance, mainly to rebuild and rehabilitate damaged infrastructure

Figure 3.3 World Bank post-disaster reconstruction loans in relation to total World Bank lending, 1980–99



Note: Word Bank lending includes lending by the International Bank for Reconstruction and Development (IBRD) and the International Development Association (IDA).

Sources: Gilbert and Kreimer 1999, World Bank 2001.

(IDB 2000: 20). From 1996 to 2000 alone, it lent $1.5 billion to affected countries to help recover from disasters, which increased annual average disaster-related lending by a factor of 10 compared to the average over the previous 15 years (IDB 2000: 1).

Also, the supply of donor assistance is becoming increasingly limited as the dwindling amounts of official development assistance (ODA) show.[4] ODA assistance (in constant 2000 U.S. dollar terms) decreased from $69 billion in 1990 to $53 billion in 2000 (OECD 2000; 2001).

Demand for the inclusion of natural disaster risk in project appraisal methodologies has increasingly been voiced (Kramer 1995: 62; OAS 1991: 53). Considering natural disaster risk in project appraisal allows for more careful selection and design of projects as well as the identification and development of secondary risk-management measures to protect the benefits of primary projects. More careful project and development planning is called for when considering loss-increasing trends, such as increased urbanization and high population growth in developing countries, which concentrate crucial assets that may be at risk, and a possible increase in the frequency and severity of natural disasters due to climate change.

CBA of Risk Management Projects Rarely Done

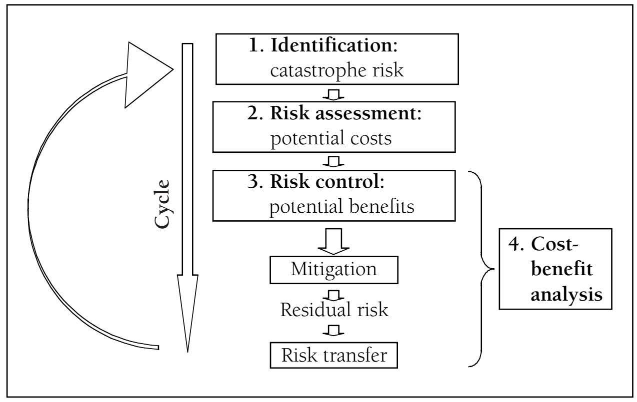
Due to concerns of MFIs about increased spending for reconstruction lending and disaster aid, ex-ante risk-management measures—that is, measures planned and undertaken before the occurrence of disaster events—are increasingly being promoted:

> International aid and development funding agencies, besides sharing consternation at delays, disruptions, and increased costs, have the strong view that wisely planned hazard and vulnerability reduction efforts and financing measures taken before a catastrophe pay excellent dividends in reducing economic impacts. Mitigation expenditures are a tiny fraction of the funds spent on reconstruction in the aftermath of catastrophes (Pollner 2000: 44).

Risk management can be broken down into four components (figure 3.4).

The first step is the identification of risks, followed by an assessment of their potential impacts and magnitudes. If a specific risk is considered large, risk control

Figure 3.4 Risk management of natural disasters



measures should be considered. These may be mitigation measures that reduce risk (e.g., building a dam to prevent floods) or the transfer of risk to other parties (most commonly by means of insurance). For the design and development of risk-control measures, cost-efficiency considerations as conducted by means of CBA are (or should be) an important element of such a risk management process in light of the fact that resources for risk management are generally in short supply. Thus, it is crucial to optimally allocate available resources to those measures where benefits are largest. Ideally, risk management measures are planned and assessed in conjunction with (main) investment projects and routinely included in project appraisals, in the same manner that environmental impact considerations are now included in such appraisals (Gilbert and Kreimer 1999: 44; Vermeiren and Stichter 1998: 8).

Since 1980, the World Bank has lent $6.5 billion for 96 projects that included at least one mitigation component (Gilbert and Kreimer 1999: 51–53). However, as can be discerned from the fact that about half of the top clients for reconstruction borrowing from the World Bank do not appear among the main borrowers for mitigation projects, ex-ante disaster risk management measures cannot yet be said to have sufficiently pervaded development-planning activities.

In a similar vein, the necessity of estimating these *risk management dividends* by means of CBA has only been acknowledged in the past few years, and CBA is still not widely practiced for natural disaster risk management projects (Dedeurwaerdere 1998: 1ff.). When evaluating risk management measures by means of CBA, in general the focus is only on mitigation (Kramer 1995; Dedeurwaerdere 1998). Also, indirect costs and benefits are rarely included in a CBA (Tobin and Montz 1997: 269), while secondary impacts are usually completely neglected. As Gilbert and Kreimer (1999: 37) demand: "There is greater need for an explicit and transparent estimate of all the costs and benefits of natural disaster management."

Several assessments have demonstrated that risk management measures can bring about significant benefits. Dedeurwaerdere (1998) estimated the benefits of different prevention measures undertaken against floods and lahars in the Philippines and calculated benefits of 3.5 to 30 times the projects' costs.[5] Vermeiren and Stichter (1998) calculated potential avoided losses of 2 to 4 times mitigation costs had mitigation been undertaken when building infrastructure like ports and schools in Jamaica and Dominica. Both of these projects limited benefits to avoided direct losses in the appraisal; including indirect benefits would have increased the efficiency of these preventive investments. On a larger scale, it is estimated that the $3.15 billion spent on flood control measures in China over the last four decades of the twentieth century have averted losses of about $12 billion. In addition, the World Bank and the U.S. Geological Survey have estimated that economic losses worldwide from natural disasters in the 1990s could have been reduced by $280 billion if $40 billion had been invested in preventive measures (Benson 1998: 12).

Risk Not Included Appropriately: Necessity of Accounting for Volatility of Natural Disaster Impacts

In cases where probabilistic CBA assessments are conducted, risk is often not included appropriately since average values are used (cf. Kramer 1995: 61; Szekeres 2000; Dedeurwaerdere 1998). The information about costs and benefits contained in the probability distribution is compounded to the expected value measure. Other information from probability distribution (as illustrated in figure 3.1) is not used.

Focusing only on averages can theoretically be justified by the Arrow and Lind theorem (Arrow and Lind 1970), which postulates that governments are usually risk-neutral, i.e., they can neglect risk other than that measured by average values in decisionmaking. The variability of outcomes is not considered of importance in this case, as governments are assumed to be able to pool a large number of risks so that the aggregate cost of risk is negligible (diversification of risk) or to spread risks over a large population base so that the cost of risk to the individual is negligible.

> […] when the risks associated with a public investment are publicly borne, the total cost of risk-bearing is insignificant and, therefore, the government should ignore uncertainty in evaluating public investments (Arrow and Lind 1970: 366).

Arrow and Lind do not argue in favor of completely neglecting uncertainty; rather they argue for assessing average/expected values only: "[...]the government should behave as an expected-value decision maker" (Arrow and Lind 1970: 366) without accounting for volatility. However, there are a number of important qualifications to this theorem, mostly applicable to developing countries (table 3.1).

The qualification of the narrow tax and financing resources base can be illustrated by looking at the impacts of the largest disasters in terms of direct economic losses that have occurred in the United States (Northridge Earthquake 1994) and Honduras (Hurricane Mitch 1998) and comparing these losses to important economic indicators (table 3.2).

For the United States, disaster risk on an *aggregate* level is not a significant risk. In absolute terms, the enormous loss of $45 billion from the Northridge earthquake amounted to only 0.6 percent of GDP and 2.9 percent of tax revenue. In Honduras, on the other hand, the losses due to Hurricane Mitch, the largest disaster so far, have had severe implications, and the resource base for financing the losses was clearly overwhelmed. In terms of GDP, losses from this event amounted to 41 percent and, in terms of tax revenue, they amounted to 292 percent (figure 3.5). Consequently, post-Mitch Honduras experienced significant aggregate economic impacts, with an economic recession in 1999 after years with a growing economy.

On the other hand, when examining only average annual losses in Honduras, the dimensions of this risk are concealed and the impression is provided that it can be handled without major difficulties: the expected

Table 3.1 Qualifications to applicability of risk neutrality–theorem

Qualifications related to risk pooling	
Existence of few and large government projects	Usually, developing countries' governments undertake just a few large investment projects, a course of action that will not result in a highly diversified portfolio of projects; thus risk pooling is not viable (Brent 1998: 217–218).
Large local or regional consequences when assets are lost	Disaster risk is covariant risk: disasters usually will affect whole regions; thus there is loss correlation.
Qualifications related to risk spreading	
Narrow tax and financing resources base for financing losses of projects	In smaller developing countries, the tax base is often too narrow to spread risk sufficiently. Other potential government financing sources such as domestic credit or private sector lending used to spread risk are generally very limited as well.
Distributional impacts	In developing countries, large distributional impacts may occur post-disaster when infrastructure projects whose prime goal is poverty reduction (e.g., through road or sanitation projects) are affected. The poor are the group most affected by a loss of infrastructure.
Irreversibility	If additional funds are not available to continue crucial projects or rebuild assets, there can be irreversible effects, such as on health service provision (Little and Mirrlees 1974: 320).

Table 3.2 Disaster losses and availability of resources for spreading risk for the United States and Honduras

	U.S.: Northridge	*Honduras: Mitch*	*Honduras: Average annual loss*
GDP (million $)	7,834,000	4,725	4,725
GDP/per capita $	29,267	790	790
Aid/GDP	—	6.3%	6.3%
Loss (million $)	45,181	1,946	45
Loss/per capita $	168.8	325.3	7.5
Loss/GDP	0.6%	41%	1.0%
Loss/tax revenue	2.9%	292%	6.8%
Loss/Gross Domestic Savings	3.6%	189%	4.4%
Loss/Net domestic credit	0.7%	165%	3.8%

All values are in current 1997 U.S. dollars, and economic data refer to 1997.

Data sources: World Bank 2001; Freeman and others 2002; Münchener Rück 2000.

loss of $45 million constituted 1 percent of GDP and 6.8 percent of tax revenue in 1997. Thus, it is necessary to look at the extremes rather than the averages, as disasters are by definition low-frequency, extreme-consequence events. Averages do not capture these characteristics well.

The validity of the A&L theorem is generally restricted to more developed countries; a number of developing countries should act in a risk-averse manner:

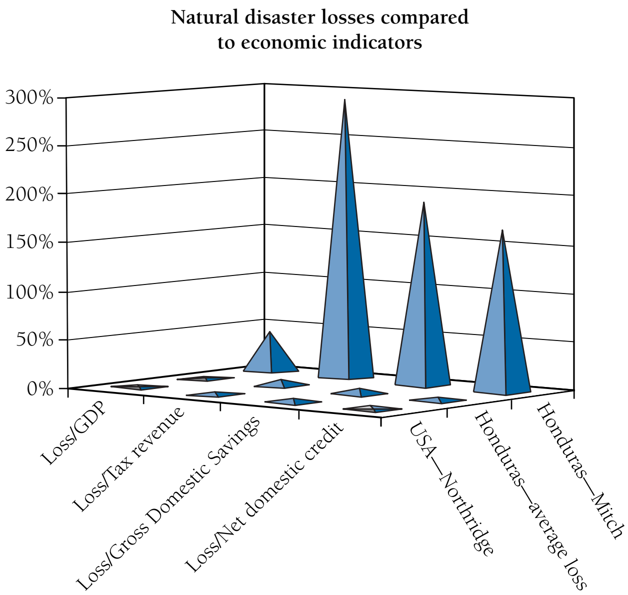
- Countries subject to high natural-hazard exposure.
- Countries subject to high economic vulnerability—that is, those with low tax revenue; low domestic savings; shallow financial markets; and high indebtedness, with little access to external finance.
- Small countries with few large infrastructural assets and high geographical correlation between those assets.
- Countries with concentrated economic activity centers (e.g., large urban agglomerations) exposed to natural hazards.

When discussing the issue of risk-neutrality, the OAS (1991) argued more than a decade ago that:

> The reality of developing countries suggests otherwise. Government decisions should be based on the opportunity costs to society of the resources invested in the project and on the loss of economic assets, functions and products. In view of the responsibility vested in the public sector for the administration of scarce resources, and considering issues such as fiscal debt, trade balances, income distribution, and a wide range of other economic and social and political concerns, governments should not act risk-neutral (OAS 1991: 40).

Adopting a risk-averse perspective and including the volatility of disaster risk in decisionmaking has important implications for the evaluation of primary and risk management projects. In the assessment of primary projects, risk is more appropriately captured, and a more careful project selection can be conducted when the extreme-event character of natural disasters is properly accounted for. For secondary risk management measures there is increased benefit in conducting those evaluations, as benefits in terms of avoided impacts are higher. The latter point will be

Figure 3.5 Important indicators for ability to spread disaster risk for Honduras and the United States



illustrated by the following case study on the evaluation of a risk transfer project in Honduras.

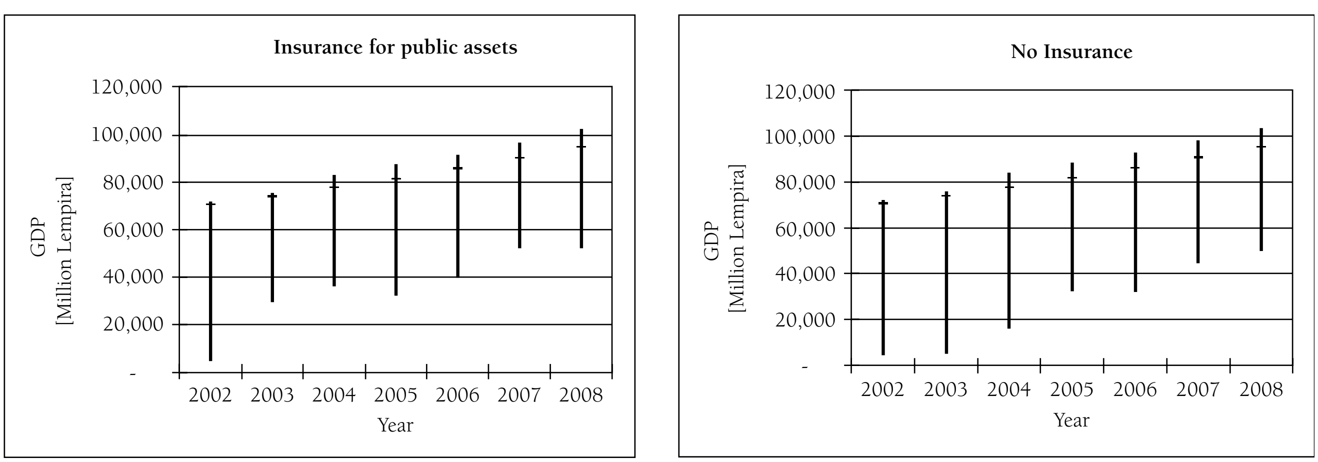
Case Study on CBA of Risk Transfer in Honduras

As discussed, the costs and benefits of transferring catastrophe risk are rarely assessed, and existing analyses focus on mitigation; in addition, the macroeconomic costs and benefits are usually not accounted for in CBA. To shed light on these issues, a recent prospective study undertaken by the author analyzed whether it would be desirable to insure public assets against natural disaster risk in Honduras (Mechler 2002). Honduras is one of the developing countries where insurance against natural disaster risk for public assets (infrastructure, schools, hospitals) has recently been proposed (e.g., Pollner and Camara 2001) and is currently under investigation. The author examined the cost-efficiency of the government's purchasing insurance for the entire portfolio of public assets from a foreign insurer. Costs in this analysis were the opportunity costs due to the premium payment (less government funds available for other important objectives). The benefits arose due to receiving insurance indemnity payments post-disaster to be used for reconstructing critical public assets (roads, bridges) necessary for quick economic recovery. The desirability of this project was evaluated with the change in GDP as the main indicator.

Several strategies for insuring certain risk layers (so-called excess of loss (XL) insurance) and their cost-efficiency were studied while stochastically simulating the occurrence and the resulting economic impacts of storm, flood, and earthquake events, which are the major natural hazards in Honduras.

For example, when purchasing insurance in the form of a risk layer stretching from the 50- to the 100-year catastrophe events (i.e., all disaster events with a return period between 50 and 100 years were insured), projected GDP paths in Honduras over a time horizon from 2002 to 2008 differed from the projections without insurance, as illustrated in figure 3.6 and table 3.3.

Figure 3.6 Projection of GDP paths with and without insurance of public assets in Honduras



Note: Lempira is the currency unit in Honduras. One dollar is approximately 16.50 lempira.

Table 3.3 Assessment of costs and benefits of insuring public assets in Honduras

GDP (million lempira)	*No insurance*	*Insurance*	*Difference: net benefit*	*Difference [% of no insurance case]*
Mean sum of GDP (2002–2008)	411,373	411,239	−134	−0.03%
Standard deviation	18,378	13,999	−4,379	−23.83%

Net benefits as measured by the change in the average sum of GDP over this period due to the insurance arrangement were slightly negative (134 million lempira, 0.03 percent of baseline GDP) compared to the no-insurance case (table 3.3).[6] The fact that this average outcome was negative (albeit only marginally) can be explained by the fact that risk transfer—in contrast to mitigation—does not reduce risk but shifts risk to an insurer who in turn demands compensation in the form of an insurance premium payment every year.[7] Due to the large loss potentials characteristic of a disaster, insurance premia for disaster risks generally exceed the annual average loss substantially (Pollner 2001: 21; Froot 1999: 6–7); thus considerable opportunity costs accrue.[8]

However, a major benefit of insurance in this analysis (and in general) was the reduction in volatility. The large volatility (vertical lines) around the expected values (horizontal lines) was reduced when undertaking insurance. Volatility, as measured by the standard deviation, decreased by about 24 percent. This is of importance for risk-averse countries, where disaster impacts cannot easily be absorbed and the stability of economic development is a major concern. When assessing such a risk transfer project, the benefits in terms of reduced volatility are important and need to be factored in, in addition to the average outcomes.

Conclusions

Although natural disaster risk is significant for a number of developing countries, this risk is not sufficiently incorporated into cost-efficiency evaluations as conducted by means of cost-benefit analysis. Keeping the limitations of CBA in mind (focusing on measurable, mostly economic project outcomes, distribution of costs and benefits not accounted for, discounting of future costs and benefits), undertaking CBA for investment and risk management projects in the context of natural disaster risk improves decisionmaking and the allocation of scarce resources to the most profitable and least risky undertakings.

If possible natural disaster risk should be incorporated into CBA in a probabilistic manner (i.e., data on probability distribution of disasters need to be obtained). Increasingly, the data and tools for such probabilistic analyses are available. With these data at hand, probability distributions for important project outcomes can be assessed to study the impacts of the incorporation of natural disaster risk on the viability of projects.

For new investment projects, accounting for risk in CBA leads to more careful project selection and design, decreasing potential losses when a disaster strikes.

Considering natural disaster risk also allows determination of the need for and efficiency of risk management (secondary) projects that secure the benefits of main investment projects. Benefits of these projects consist of savings in terms of disaster losses averted and a decrease in volatility of the primary project's outcomes. In principle, it would be desirable to integrate risk and risk management measures into project evaluation, just as environmental impact analysis is nowadays routinely conducted when appraising new investment projects.

Furthermore, a number of developing countries with high natural hazard exposure and a limited ability to cope with disaster impacts need to be risk-averse to natural disaster risk. In these cases, natural disaster risk needs to be considered properly, and the volatility of projects' outcomes should be factored into the decision as to whether to conduct a proposed project. Particularly for risk transfer measures, taking volatility of project outcomes into account shows or increases the desirability of such measures.

Cost-efficiency as measured by CBA should not be the sole criterion when planning and assessing development and risk management projects, but it provides important information for a more efficient, less risky allocation of scarce funds and thus can aid in bringing about more robust development. CBA considerations should be an integral element of decisionmaking in a "culture of prevention" and thus may contribute to creating more intangible, but probably even more important, benefits:

> Prevention not only minimizes damage but promotes a stable environment, incentives for investment and enterprises and the sense that people can control their own economic destiny. These are crucial for sustainable long-term development (Anderson 1991: 27).

Notes

1. Methods to account for the distribution of costs and benefits have been proposed, but are not used in practice (Little and Mirrlees 1990: 358–62).
2. As contrasted with *speculative risk* involving chances to gain and lose at the same time.
3. All dollar amounts are U.S. dollars. The World Bank focuses on the financing of investment and productive assets for building infrastructure and institutions fostering socioeconomic development rather than relief operations (Lester 1999: 179).
4. ODA encompasses all financial support given to developing countries in the form of loans and grants with a grant element of at least 25 percent in order to promote economic development and welfare. It is provided bilaterally by the more developed countries and by multilateral finance institutions.
5. Lahars are volcanic mudflows.
6. GDP was discounted at a standard discount rate of 12 percent.
7. Risk could also be transferred to the capital markets (e.g., by means of catastrophe bonds).
8. The insurance premium for catastrophe risk demanded by an insurer is determined by the expected losses to the assets insured (the average annual losses), a surcharge for expenses and profit, and a risk-loading component accounting for the high variability of catastrophe risk. Generally, the premium charged is considerably higher than the expected losses.

Bibliography

ADPC (Asian Disaster Preparedness Centre). 2000. Workshop on Urban Disaster Mitigation. University of Karlsruhe, 23–27 October 2000.

Anderson, M. B. 1991. "Which Costs More: Prevention or Recovery?" In Alcira Kreimer and M. Arnold, eds., *Managing Natural Disasters and the Environment*. Washington, D.C.: World Bank: 17–27.

Anderson, M. B. 1995. "Vulnerability to Disaster and Sustainable Development: A General Framework for Assessing Vulnerability." In Mohan Munasinghe and C. Clarke, eds., *Disaster Prevention for Sustainable Development: Economic and Policy Issues*. Washington, D.C.: World Bank: 41–59.

Arrow, K. J., and R. C. Lind. 1970. "Uncertainty and the Evaluation of Public Investment Decisions." *The American Economic Review* 60: 364–378.

Benson, C. 1998. "The Cost of Disasters." In John Twigg, ed., *Development at Risk? Natural Disasters and the Third World.* U.K. National Coordinated Committee for the International Decade for Natural Disaster Reduction. Oxford: Oxford Centre for Disaster Studies: 8–13.

Brent, R. J. 1998. *Cost-Benefit Analysis for Developing Countries.* Cheltenham: Edward Elgar.

Burby, R., ed. 1991. *Sharing Environmental Risks. How to Control Governments' Losses in Natural Disasters.* Boulder, CO: Westview Press.

Dasgupta, A. K., and D. W. Pearce. 1978. *Cost-Benefit Analysis: Theory and Practice.* London: Macmillan.

Dedeurwaerdere, A. 1998. *Cost-benefit Analysis for Natural Disaster Management - A Case-study in the Philippines*. Brussels: CRED.

Dinwiddy, C., and F. Teal. 1996. *Principles of Cost-benefit Analysis for Developing Countries.* Cambridge: Cambridge University Press.

ECLAC (Economic Commission for Latin America and the Caribbean). 1999. *Manual for Estimating the Socio-economic Effects of Natural Disasters.* United Nations International Decade for Natural Disaster Reduction. New York: United Nations.

ECLAC/IDB. 2000. "A Matter of Development: How to Reduce Vulnerability in the Face of Natural Disasters." Paper before seminar: Confronting Natural Disasters: A Matter of Development, New Orleans, March 25–26, 2000.

Freeman, P. K., L. Martin, R. Mechler, K. Warner, with P. Hausman. 2002. *Catastrophes and Development, Integrating Natural Catastrophes into Development Planning.* Disaster Risk Management Working Paper Series No. 4. The Disaster Management Facility, World Bank, Washington, D.C.

Froot, K., ed. 1999. *The Financing of Catastrophe Risk*. Chicago: University of Chicago Press.

Gilbert, R. and A. Kreimer. 1999. *Learning from the World Bank's Experience of Natural Disaster Related Assistance*. Washington, D.C.: World Bank.

Gramlich, E. M. 1981. *Benefit-Cost Analysis of Government Programs*. Englewood Cliffs, New Jersey: Prentice-Hall.

Hecker, G. 1995. "A Review of the Disaster-Related Activities of the Asian Development Bank: An Economic Perspective." In Mohan Munasinghe and C. Clarke, eds., *Disaster Prevention for Sustainable Development: Economic and Policy Issues.* Washington, D.C.: World Bank: 77–85.

IDB (Inter-American Development Bank). 2000. *Facing the Challenge of Natural Disasters in Latin America and the Caribbean.*

An IDB Action Plan. Washington, D.C.: Inter-American Development Bank.

Kopp, R. J., A. Krupnick, and M. Toman. 1997. *Cost-Benefit Analysis and Regulatory Reform: An Assessment of the Science and the Art.* Discussion Paper 97–19. Washington, D.C.: Resources for the Future.

Kramer, R. A. 1995. "Advantages and Limitations of Benefit-Cost Analysis for Evaluating Investments in Natural Disaster Mitigation." In Mohan Munasinghe and C. Clarke, eds., *Disaster Prevention for Sustainable Development: Economic and Policy Issues*. Washington, D.C., World Bank: 61–76.

Kreimer, A., and M. Arnold. 2000. "World Bank's Role in Reducing Impacts of Disasters." *Natural Hazards Review* 1 (February): 37–42.

Lester, R. 1999. "The World Bank and Natural Catastrophe Funding. The Changing Risk Landscape: Implications for Insurance Risk Management." Proceedings of a conference sponsored by Aon Group Australia Ltd., Sydney, Australia.

Little, I. M. D., and J. A. Mirrlees. 1974. *Project Appraisal and Planning for Developing Countries.* London: Heinemann.

Little, I.M.D., and J. A. Mirrlees. 1990. "Project Appraisal and Planning Twenty Years On." In S. Fischer, ed. *Proceedings of the World Bank Annual Conference on Development Economics.* Washington, D.C.: 351–382.

Mechler, R. Forthcoming. *Natural Disaster Risk Management and Financing Disaster Losses in Developing Countries. Ph.D. thesis*. Karlsruhe: University of Karlsruhe.

Münchener Rück. 2000. Topics: Jahresrueckblick Naturkatastrophen 1999. Munich.

Munasinghe, M., and C. Clarke, eds. 1995. *Disaster Prevention for Sustainable Development: Economic and Policy Issues.* Yokohama: World Bank.

OAS (Organization of American States). 1991. *Primer on Natural Hazard Management in Integrated Regional Development Planning.* Washington, D.C.

OECD (Organization for Economic Cooperation and Development) and D. A. Committee 2000. *Net ODA Flows in 2000*. Paris: OECD. Available from http://webnet1.oecd.org/pdf/M00005000/M00005137.pdf.Internet.

OECD, and D. A. Committee 2001. *Net ODA Flows from 1950 to 1999.* Paris: OECD. Available from http://webnet1.oecd.org/xls/M00002000/M00002883.xls. Internet.

Otero, R. C., and R. Z. Marti 1995. "The Impacts of Natural Disasters on Developing Economies: Implications for the International Development and Disaster Community." In Mohan Munasinghe and C. Clarke, eds., *Disaster Prevention for Sustainable Development: Economic and Policy Issues*. Washington, D.C.: World Bank: 11–40.

Pollner, J. 2000. *Managing Catastrophic Risks using Alternative Risk Financing and Insurance Pooling Mechanisms.* Washington, D.C., World Bank.

Pollner, J., and M. Camara. 2001. *Honduras. Catastrophe Risk Exposure of Public Assets. An Analysis of Financing Instruments for Smoothing Fiscal Volatility*. Washington, D.C.: World Bank.

Reutlinger, S. 1970. *Techniques for Project Appraisal under Uncertainty*. Washington, D.C.: World Bank.

Smith, K. 1996. *Environmental Hazards. Assessing Risk and Reducing Disaster.* London: Routledge.

Szekeres, S. 2000. *La consideracion de desastres naturales en la evaluacion de proyectos federales en Mexico. Analisis y recomendaciones.* Washington, D.C., World Bank.

Tobin, G., and B. Montz. 1997. *Natural Hazards. Explanation and Integration.* New York: The Guildford Press.

Vermeiren, J., and S. Stichter. 1998. "Costs and Benefits of Hazard Mitigation for Building and Infrastructure Development: A Case Study in Small Island Developing States." Paper before conference of The International Emergency Management Society.

World Bank. 2001. *World Bank Development Indicators*. Washington, D.C.

Zerbe, R. O., and D. D. Dively. 1994. *Benefit-Cost Analysis in Theory and Practice*. New York: Harper Collins.

Chapter 4

Globalization and Natural Disasters: An Integrative Risk Management Perspective

Torben Juul Andersen

The increased global exchange of merchandise, services, and capital is a key characteristic of the contemporary business environment. International firms position themselves to gain competitive advantage from opportunities offered in this larger and more open economic system. Similarly, governments reap rewards from firms that establish operations within their borders. There are strong arguments in favor of international trade, foreign direct investment, and globalization since they often promote economic growth. Though there can be significant variance in growth in developing countries, it is recognized that some economic trade and activities are more beneficial than others. Developing countries, therefore, must position themselves to take advantage of opportunities in the global market.

The frequency and severity of natural disasters have increased markedly worldwide. Economic losses associated with natural hazards are increasing exponentially in developing countries, where local risk-transfer markets are generally weak. Hence, natural catastrophes have devastating socioeconomic consequences when they strike populated areas in less developed economies, where they are bound to have adverse impacts on the global competitiveness of exposed countries. Disasters have a negative impact on economic activity and the associated economic uncertainties hamper investment in long-term commercial relationships. Conversely, particular types of economic activity and a truncated policy focus can increase a country's economic vulnerability to natural disasters. These relationships need to be made more explicit and managed more effectively so developing countries are not disadvantaged in the global market.

This paper incorporates perspectives from economics, finance, and strategic management and identifies several links between market globalization and the economic impacts of natural disasters. While a comprehensive analysis of all linkages is beyond the scope of this paper, three areas are explored: (1) the relationship between natural catastrophes, economic development, and global competitiveness; (2) the relationship between global trade and investment, economic growth, and sustainable competitive advantage; and (3) the role of proactive risk management and the potential benefits from global market access.

Natural Catastrophes, Economic Development, and Global Competitiveness

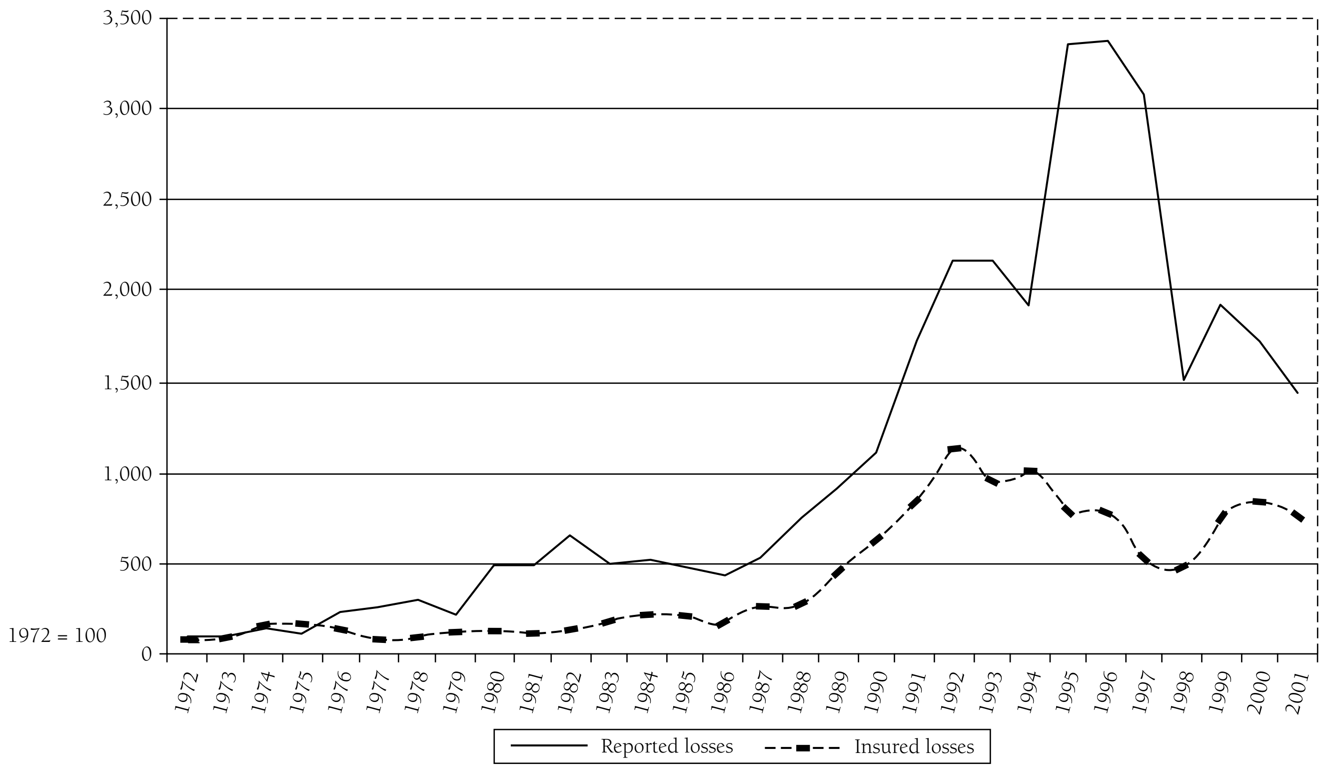
Natural catastrophes reflect the negative economic impacts on human settlements and productive assets from extreme natural phenomena such as windstorms, flooding, and earthquakes. Direct economic losses from natural catastrophes over the past decade exceeded $700 billion[1] (all amounts are in U.S. dollars). These losses are estimated to increase to a total amount of $6 to $10 trillion over the next 20 years, far beyond the growth in aid and development programs (ICRC 2001). Over the past ten years, natural catastrophes have caused more than 800,000 deaths and affected the livelihoods of more than 2 billion people worldwide. Total reported losses from natural catastrophes, ranging from $30 to $190 billion annually, have averaged roughly $65 billion annually.[2] More than 60 percent of the reported economic losses in recent years have related to events in developing countries. Approximately half of the losses in industrialized countries were covered by formal insurance contracts, while only some 5 percent of reported damages in developing countries were covered.[3]

Global catastrophic events seem to be occurring with increased frequency. Over the past thirty years, the number of reported catastrophes has quadrupled, and several factors have resulted in increased economic exposure to natural catastrophes. Climate patterns seem to be changing in ways that increase the frequency of certain natural events. For example, El Niño influences the intensity of storms, rainfall, floods, and landslides in much of the world. At the same time, the population is growing and economic assets are being placed in areas more exposed to natural hazards (Kleindorfer and Kunreuther 1999). This combination of higher hazard frequency and greater exposure of economic assets extends the potential damage that can be inflicted by natural hazards. Though there is no indication that the frequency of earthquakes is increasing, changing climatic conditions seem to be causing more frequent and severe windstorm events. Hence, the combination of a burgeoning world population, increasing urbanization, and an expanding economic asset base extend economic exposure to natural catastrophes.

Whereas event frequency has quadrupled over the past thirty years, reported economic losses have increased by a factor of 2,000-3,000 and total insured losses by a factor of 1,000 (figure 4.1). The implied increase in economic losses associated with natural catastrophes by far outweighs economic growth figures for the same period.[4] The dramatic increase in direct economic losses per hazard event points to the increasing significance of catastrophe risks. If this trend continues unabated, catastrophe risk exposure will seriously challenge the economic sustainability of developing countries that are exposed to natural catastrophes.[5]

The number of victims associated with natural catastrophes, as reflected in the numbers of dead and affected, is heavily skewed toward developing countries. The number of deaths, however, has fallen over the past 30 years, from 2 million during the 1970s to 800,000 during the 1990s. Hence, local risk mitigation and disaster relief efforts may bear fruit, but the number of victims is still large and most are related to events in developing countries. At the same time, the number of people affected by natural catastrophes has increased significantly from 740 million in the 1970s to 2 billion in the 1990s.

Figure 4.1 Development in reported and insured catastrophe losses, 1970–2001 (three-year moving averages)

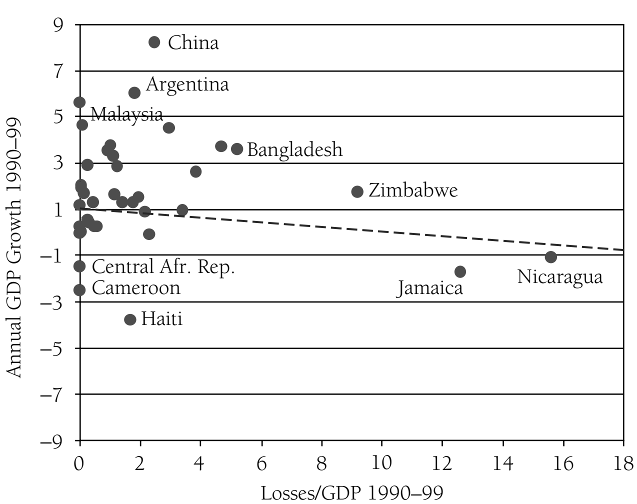


Source: Centre for Research on the Epidemiology of Disasters (CRED) and natural catastrophe losses reported in various issues of *Sigma* (Swiss Re).

Over the past decade, natural disasters have resulted in damage that has constituted 10 to15 percent of an exposed country's annual gross domestic product (GDP). These extreme situations usually apply to relatively small, vulnerable countries with less diversified economies. Such effects can have a significant impact on economic activity and the appropriation of public funds.[6] Economic growth rates typically hover around 1 to 3 percent annually, so a direct-loss impact of 5 to10 percent of GDP can have an abrupt effect on a country's economic development. Studies indicate that real GDP growth decreases in the year of the disaster and then increases the next one to two years, as public and private reconstruction investment boost the growth rate (Charveriet 2000). In many cases, post-disaster reconstruction efforts may actually improve the quality of economic assets and lead to increased productivity (Albala-Bertrand 1993). Therefore, if exposed developing countries take precautionary measures and establish disaster risk financing arrangements, they may be able to reinstate new, and hence more efficient, economic assets after major disasters. However, a sample of developing countries actively engaged in global trade[7] indicates that a high level of catastrophe losses is generally associated with lower economic growth[8] (figure 4.2).

Further analysis of the sample shows a positive relationship between the percentage of the population affected by natural catastrophes and economic growth.[9] This may appear counterintuitive, although in the absence of proactive risk management practices and effective risk-transfer markets, post-disaster financing is typically made available through emergency facilities extended by multilateral institutions and other foreign aid donors.[10] International assistance is often prompted when the number of victims is high. Since disaster-related capital inflows have an economic impetus, they lead to a positive relationship between human devastation and economic growth in exposed countries. This somewhat perverse relationship seems to indicate that the availability of international emergency support and disaster financing shields the countries from the adverse ex post economic impacts of natural disasters while too little is done to prevent the effects of the catastrophes on an ex ante basis.[11] Although unintended, the financing of catastrophe losses through international donations constitutes a powerful disincentive to implement more proactive risk management practices that could help reduce the socioeconomic cost of natural disasters in exposed countries.[12] Prevention is important in reducing human suffering from catastrophes, but political leadership often considers risk management efforts an unnecessary cost rather than an investment in a better environment. Hence, there is a clear need to adopt policy measures that effectively integrate risk assessment, risk mitigation, risk transfer, and emergency preparedness (Andersen and Masci 2001).

Figure 4.2 The relationship between economic growth and catastrophe losses, 1990–2000



Sources: Centre for Research on the Epidemiology of Disasters (CRED), *World Factbook,* and World Bank data.

Since post-disaster economic recuperation in developing countries is typically based on the availability of multilateral relief facilities and humanitarian aid, there are few political incentives to adopt a more proactive risk management approach. This situation makes exposed countries highly dependent on the international community as "lender-of-last-resort" to cope with the worst economic impacts of natural disasters. This bailout hinders the development of disaster prevention and mitigation measures, since leaders are not pressed to make advance arrangements. By contrast, economic entities in industrialized countries obtain insurance and alternative risk-transfer cover in financial markets to ease post-disaster reconstruction efforts. This risk management approach would be beneficial to developing countries, too. Risk management can reduce a country's vulnerability to catastrophe risks and secure reconstruction funding that significantly lessens the economic severity of natural catastrophes.

In the absence of an active risk management approach, developing countries exposed to natural catastrophes are often forced to divert funds from existing development programs to fund temporary disaster relief efforts. This distorts commitments to longer-term economic investment. A country that has insufficient post-disaster financing arrangements often faces delays in compensating economic losses as governments await approval from multilateral credit facilities and other financing sources. Furthermore, disaster relief in the form of bilateral donations typically has conditions that limit the uses of funds. Hence, a lack of risk management reduces the prospects for a more immediate economic recovery after a disaster, particularly when a country's fiscal resources are stretched and critical economic infrastructure has been affected. Economic entities operating in economies that are vulnerable to natural catastrophes have difficulty establishing dependable, long-term business relationships. If these essential stakeholder relationships are jeopardized by excessive catastrophe risk exposure, a country may encounter difficulties in its attempts to support economic activities that have the potential to generate more sustainable competitive advantages.[13] Hence, effective management of catastrophe risk should support competency-based economic activities, thereby increasing the potential economic benefits from international trade. The following section takes a closer look at these relationships.

Globalization, Economic Growth, and Sustainable Competitive Advantage

As restrictions on cross-border transactions have eased in recent decades, the volume of global trade has expanded faster than economic growth in the world economy.[14] The annual compound growth rate in merchandise exports from industrialized countries has averaged 6 percent over the past 20 years.[15] Certain countries, including China, Thailand, Malaysia, Indonesia, and the Philippines, have taken advantage of new global trade opportunities, while other developing economies, including those in Sub-Saharan Africa, have displayed low growth rates. Overall growth in the export of services, which constitutes an increasing share of economic activities, has been somewhat higher, at an annual rate of 7.2 percent, while the volume of foreign direct investment has grown at the phenomenal rate of 17 percent per year during the period.[16]

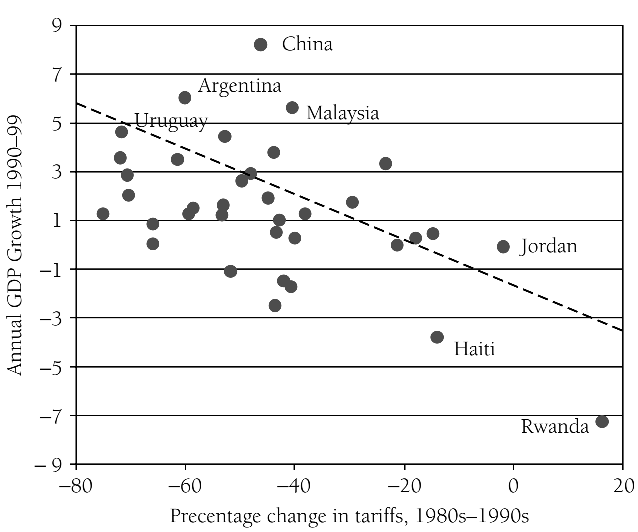
The ability to exchange primary and manufactured goods as well as commercial services across borders has the potential to create economic net benefits because it provides global market access for offerings that constitute comparative advantages.[17] Increased global competition provides new opportunities for companies to improve customer service and increase economic efficiencies. The international mobility of capital can also funnel overseas financial resources to promising business ventures and provide access to risk transfer arrangements in the global financial markets. However, investors' willingness to provide cross-border funding to economic activities in a country depends on the soundness and stability of a country's economic policies, since global investors are lured by promising returns with reasonable risk characteristics.

If the economic arguments for global trade have merit, the evidence should indicate that a higher level of international trade is associated with economic development. For example, if a country is able to exploit comparative advantage in the global exchange of goods and services, then a higher level of trade interaction should lead to higher economic growth in the country. However, in a sample of developing countries with many international linkages, there seemed to be no clear relationship between the ratio of global trade and growth in GDP.[18] Rather, the data seem to indicate a negative relationship between the level of trade and economic growth.[19] These results do not fit with our simple international trade hypothesis. It is possible the discrepancy can be explained by the fact that large countries with more diversified economic bases are better hedged against the negative impacts, including natural disasters, of exogenous shocks to the economy. There seems to be a clear relationship between country size and its concentration on specific export merchandise. Smaller countries, for example, are generally more dependent upon specific export products. This dependency may make them more economically vulnerable to natural catastrophes and other disasters. Hence, it does not seem to be trade volume in itself that matters, but rather the type and diversity of economic activities and global trade transactions a country pursues.

It can also be argued that it is the trade policies pursued by developing countries that influence economic development. If a country has reduced its import tariffs, it reflects a general commitment to international trade and global competition. When protective tariffs are reduced, domestic economic entities are more exposed to global competition, forcing these entities to improve operational efficiencies to thrive and survive.[20] An analysis of the country sample confirms that tariff policies in favor of global trade seem to be associated with higher economic growth. In other words, a reduction in tariffs is associated with lower economic growth rates (figure 4.3).

Hence, trade in and of itself provides little guarantee for sustainable economic development, while economic policy measures that favor a more global and competitive business environment appear to induce economic growth. This suggests that it is the type of merchandise a country exports that matters more than the actual trade volume. Developing countries as a whole have increased their share of manufactured products from 25 percent of total exports to 70 percent over the past two decades. However, the most successful developing countries have had a higher emphasis on market-dynamic product categories, including computer products, electrical equipment, and manufactured garments, that have shown above-normal growth rates in global demand.[21] These product groups represent more skill and technology-intensive merchandise with the potential to achieve further productivity gains than relatively simple, labor-intensive manufactures and factor-based primary goods.

Figure 4.3 Economic growth and changes in tariff rates



Source: World Bank data, Dollar and Kraay (2001).

Global capital flows can take place as investments in marketable financial assets or directly in productive assets through foreign direct investment (FDI). Investment in domestic financial assets provides financial resources to local operators who maintain managerial control over the economic assets acquired. Since many of these investments are placed in tradable securities and syndicated facilities, they constitute relatively mobile capital that can change hands quickly if market sentiments turn unfavorable. This may have repercussions on foreign exchange rates when global market conditions change. By contrast, FDI gains managerial control over business activities through direct corporate acquisitions and investment in economic assets managed by local affiliates. Since FDI constitutes investment in controlled economic assets, it is often considered a more stable source of trans-border financing.

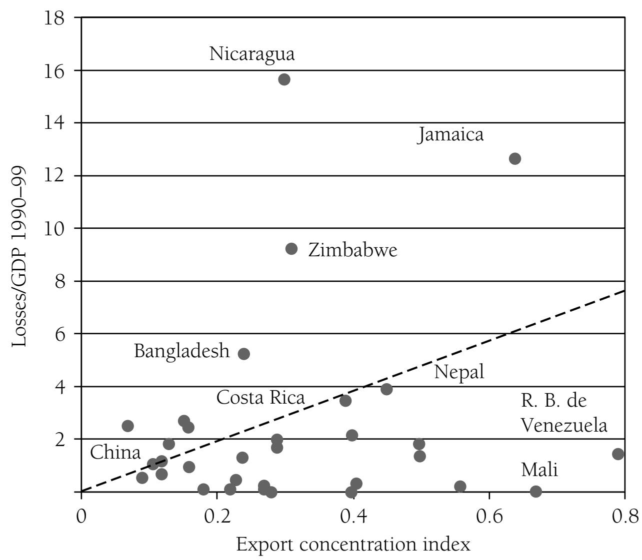
Whereas FDI commits financial resources in support of longer-term commercial activities, there are reservations that this may not always be an advantage.[22] Hence, it is argued that developing countries should not actively seek FDI at any price, but they should consider focusing policy efforts on improving economic conditions to attract capital to a country on the merits of underlying business propositions and the expected returns from genuine economic activities. Developing countries should attract investment that can build country-specific skills and capabilities and create competitive advantages with the potential to drive more sustainable economic growth. FDI made primarily to exploit particular factor endowments in a developing country does not represent the most favorable type of investment. Instead, FDI in support of competency-based economic activities is much more attractive.

The largest FDI amounts have accrued to economies focused on manufactured goods and with relatively low concentrations of particular merchandise exports. Brazil, China, Mexico, and Thailand represent some of the prime recipients of FDI.[23] By contrast, developing countries focused more narrowly on specific types of exports have fared considerably worse. An analysis of the countries in the sample shows a significant negative relationship between the degree of concentration on specific export products and economic growth. Overdependence on the export of specific product groups makes a country's foreign currency earnings vulnerable to changes in global demand and the relative terms-of-trade. Prices for many primary commodities and labor-intensive manufactures have decreased substantially over the past decade, highlighting the risk of high export concentration.[24]

These revelations may guide developing countries in positioning themselves to take advantage of global market opportunities. Lower trade barriers and regulatory restrictions make cross-border business transactions easier and provide greater flexibility in establishing global corporate structures and networks. International companies have taken advantage of the ability to integrate national comparative advantages into their global organization structures. Hence, various corporate functions may be located in countries that represent the highest potential value for the corporation and eventually its customers. For example, labor-intensive operations may be located where there are ample and qualified human resources, product development may be located around centers of research excellence, and global marketing may be coordinated from locations with high concentrations of specialized sales agents.

Evidence from the sample countries supports the contention that a relatively undiversified economic base aggravates the adverse economic impact of natural disasters, since there is a positive relationship between export concentration and the relative size of a country's catastrophe losses[25] (figure 4.4). Countries with a high export concentration are typically more dependent upon factor endowments and developments in global commodity prices than are countries that emphasize the export of competency-based merchandise. To reduce economic vulnerability, these countries must find ways to diversify their economic bases. The ability to diversify the economic base and gear business activities in support of more durable competitive advantage relies on an environment that is conducive to investment in skills and capabilities-enhancing activities. Such an environment requires stable economic policies and managed exposure to catastrophe risk. Governments should

Figure 4.4 Economic losses and export concentration



Sources: Centre for Research on the Epidemiology of Disasters (CRED), United Nations Conference on Trade and Development (UNCTAD), and *World Factbook*.

not only pursue stable and sound fiscal and monetary policies but also engage in risk management practices to stimulate economic activities that have the potential to create more sustainable competitive advantages.

Analysis of the countries sampled shows a positive relationship between FDI and GDP growth.[26] There appears to be evidence of positive development effects from FDI as a means to enhance national comparative advantage. However, that does not necessarily imply that FDI always supports production of competency-based merchandise or enhances development of skills and capabilities. On the contrary, FDI is often made in pursuit of favorable factor cost conditions in host countries. The challenge for developing countries is to minimize dependence upon comparative advantage in one or a few fields and leverage it with the development of more competency-based manufacturing before the initial factor price advantages fade. Analysis of the countries sampled does not show that FDI has a positive influence on the development of competency-based economic activities, however. Rather, there is evidence of a positive relationship between the level of FDI and export concentration.[27] This implies that FDI is positioned to take advantage of favorable factor costs in resource-rich developing countries. It could then be argued that FDI to a large extent supports commodity-based exports. For example, exports from Venezuela, Mali, and Jamaica are highly focused on oil, cotton, and coffee. On the other hand, the largest FDI in absolute dollar terms has been directed to countries like China, Brazil, Mexico, and Thailand, which have more diversified economic bases and a higher ratio of technology-intensive manufactures.

From a corporate perspective, the ability to place functional entities at optimal locations around the globe provides new opportunities for increasing efficiencies and improving innovation by accessing specific skills, capabilities, and knowledge and integrating them into organizational activities.[28] From a country perspective, international corporations' investment dollars might be attracted if special-factor endowments, skills, and capabilities can be used to reinforce economic activities.[29] Companies headquartered in developing countries may also invest overseas to exploit the same advantages in the global markets, thereby attracting new skills and resources to the economy. If local companies have the ability to create their own global corporate structures, this may assist in attracting needed skilled workers to developing countries. Knowledge transfer and capabilities-based commercial linkages arise not only from incoming FDI, but also from outgoing FDI, as local companies learn through their global network relationships. However, many governments in emerging markets are reluctant to ease restrictions on overseas capital investment by domestic entities. This may not be in a country's best interests, however, as this restriction limits the ability of companies to expand and learn from the global marketplace and puts them at a competitive disadvantage.

Hence, governments should understand the comparative advantages that might drive an economy. It is less complicated to exploit existing factor endowments, including primary commodities such as metals, agricultural, raw materials, and labor. This approach is valid as long as the government also encourages the development of skills and capabilities that have the potential of creating longer-term comparative advantages to economic entities operating in the economy. The difficulties with over-reliance on cheap labor is that, once wage levels start to increase, simple comparative advantage erodes and companies move manufacturing facilities to developing countries with even lower wage costs.[30]

From a strategic perspective, business entities are better off if they can establish advantages based on their organizations' inherent skills and capabilities.[31] Such advantages can provide value to customers through unique products, services, and delivery features and value to businesses through the development of economic efficiencies in sourcing and internal processes. Both offer the company competitive advantages. To the extent that a competitive advantage is based on unique and firm-specific capabilities difficult for competitors to imitate, a competitive advantage can become sustainable over time. Governments that establish economies that support local companies and overseas investors and enable them to develop specialized skills and competencies provide countries with the ability to create sustainable competitive advantages. If local and multinational businesses are successful, a stronger economic base for more sustainable long-term economic development will emerge.

Though government planning can provide support for increased economic activity, the development of essential skills and capabilities needed for companies to succeed in the global economy often comes from innovations within a business. Policymakers can support increased commercial activity, however, by establishing a stable socioeconomic environment, improving education, supporting research facilities, and maintaining a well-functioning public infrastructure.[32] Furthermore, government investment programs can support the development of specific skills and capabilities that can shape future core competencies. To achieve this, there is a need to reduce economic vulnerability to catastrophe risk and improve responsiveness to major exogenous shocks to the economy. The next section takes a closer look at this issue.

Risk Management and Global Market Access

The exponential growth in direct economic losses from natural catastrophes has an adverse impact on future economic growth in an exposed developing country, unless the impact is mitigated. Over-dependence on international catastrophe funding and aid aggravates the "moral hazard" (see endnote 16) problem reflected in insufficient risk mitigation efforts and ineffective post-disaster reconstruction. The uncertainty associated with uncontrollable catastrophe exposure and other exogenous economic shocks is detrimental to capabilities-based global linkages that could improve a country's competitiveness. The development of more knowledge-intensive competencies is hampered if economic entities operating in developing countries are considered vulnerable counterparts. Hence, developing countries must become less vulnerable to natural disasters and more responsive to changing economic conditions. A proactive risk management approach would help countries cope better with exogenous environmental and economic shocks.

Vulnerability to risk is a highly individualized phenomenon that depends upon the perceptions of a society to risk. A society that fails to address the risks of possible economic threats caused from such factors as price volatility, global competitive developments, and devastation from natural catastrophes assumes much higher risks than those that take steps toward prevention and mitigation. It is in a country's self-interest to manage key risks in a proactive manner. International businesses and financial institutions sensitive to high levels of risk may avoid investing in such uncertain circumstances. This avoidance further negatively impacts a country's ability to create global linkages and attract funds for new investment.

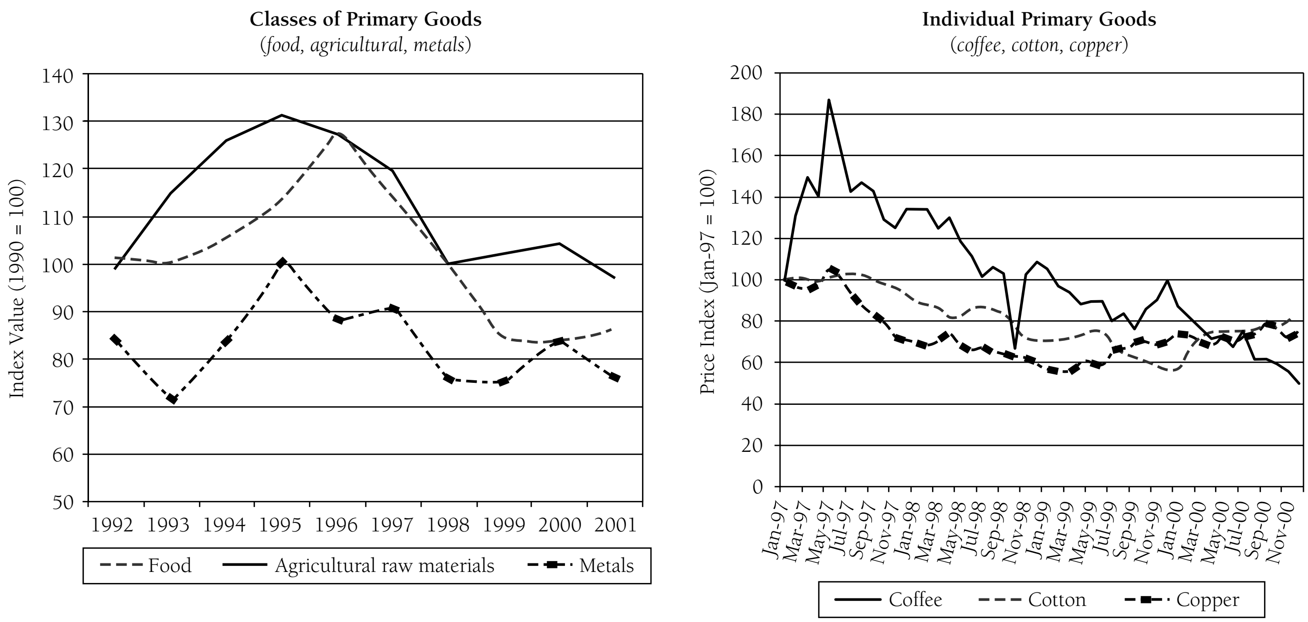
A country that is able to maintain a relatively stable economic environment will attract significantly more FDI than a country with a volatile economy. Economic entities operating in stable countries prove more reliable business partners for international firms and their better risk practices facilitate long-term, knowledge-intensive partnerships that have a greater potential for receiving international funding for new ventures. Risk management facilitates long-term business activities and increases the potential of creating competitive advantages and more sustainable growth. A number of conditions must be satisfied in a stable socioeconomic environment. There must be prudent fiscal and monetary regimes as well as trade and foreign exchange policies that assist foreign entities in establishing skills-based linkages with local companies and supporting domestic companies in their global expansion to overseas markets.[33] There is also equal need to manage the major risk factors that expose a country. These risk factors can have at least three origins: catastrophe risk exposure, extreme price instability, and a deteriorating competitive position in global markets. Since these risk factors are interrelated, risk management should integrate all factors into a country's aggregate risk exposure.

Countries with a high concentration of exports are usually dependent upon specific commodities such as food products, agricultural raw materials, and metals (see figure 4.5). For example, countries such as Costa Rica and Nicaragua are dependent upon world prices for their coffee exports, so falling prices have a severe impact upon livelihoods.[34] Similarly, Mali and to some extent Paraguay, depend upon the price of cotton, while Zambia is highly dependent upon the price of copper. When world prices drop, economic conditions in exporting countries are affected. Extreme dependency upon primary commodities, therefore, provides little resilience for an economy to withstand price declines and closely links these commodity exports with poverty.[35]

Whereas natural catastrophes have a direct economic impact on exposed countries, business conditions can also be affected indirectly by climatic events in other parts of the world that influence supply and demand conditions in commodities markets.[36] When the prices of primary agricultural products increase due to scarcity, this often provides a temporary economic bonanza for producers. But when prices drop on the world market, the decrease in export earnings results in an overall drop in demand for all goods in export countries. Lower commodity prices should represent market opportunities for countries to offer goods more cheaply; however, primary producers are often unable to take advantage of such opportunities because they lack the skills to engage in international product development and global sales initiatives. Hence, successfully engaging national companies in global secondary market activities, including product development, packaging, sales, and distribution, hedges the economy against the adverse effects of deteriorating terms-of-trade.

Primary and secondary industries constitute a diminishing share of total factor income in the global economy, though tertiary service-oriented economic activities are increasing at a much faster rate than conventional industries, particularly in industrialized countries. Thus, a developing country that focuses on the production of primary commodities will likely see their terms-of-trade

Figure 4.5 Commodity price developments, 1990–2000



Sources: International Monetary Fund (IMF), Food and Agriculture Organization of the United Nations (FAO), and the London Metal Exchange (LME).

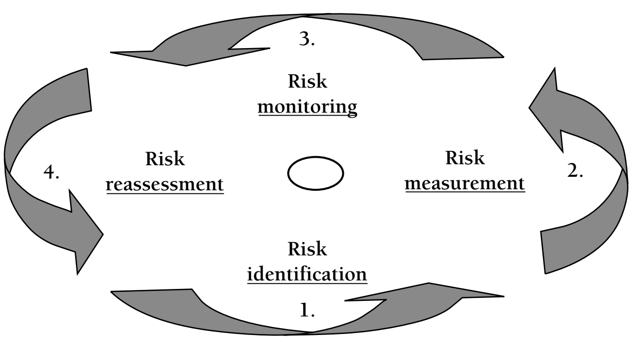
deteriorate in the future. The only way to avoid this vicious commodity price trap is to encourage and support a focus on higher value-added business activities by going beyond an emphasis on primary commodities and engaging in product development and new ways of creating customer value to end users in global markets. Governments may support the development of specific skills and capabilities and encourage local business entities to become further engaged in competency-based economic activities.[37] This may induce FDI that links overseas distributors with domestic supplier affiliates and provides local companies with opportunities to expand overseas and pursue linkages with sales affiliates in global markets. Effective linkages between local companies and foreign affiliates require a mix of skills and technological know-how. This is even more critical when local companies want to expand into overseas markets. There is an equal need to develop basic management skills and international business capabilities to support the overseas expansion of local companies.[38]

The development of competency-based economic activities requires a relatively stable socioeconomic environment. This in turn depends upon the pursuit of reliable and consistent economic policies that maintain fiscal and external trade balances within reasonable boundaries. It also depends upon a country's integrative risk management capabilities that allow a country to cope with the economic effects of natural disasters. Without the ability to manage and dampen the adverse impacts of external shocks, it is difficult to develop a sustainable base for economic value creation. Firms and government entities insure themselves against various kinds of risk that is beyond their control and that otherwise could jeopardize firm survival or severely damage public investment programs. If a firm or government assumes extreme risk exposure, insolvency risk increases and can reach levels where credit becomes scarce and considerably more expensive.[39] Potential restrictions on funding have adverse impacts on economic activity levels that may cause irreparable harm to important stakeholder relationships, e.g., shareholders, employees, customers, suppliers, partners, etc., and strain profitability and future business initiatives.[40] This causes investment activities to drop as viable funding sources dry up or become excessively costly. Hence, a highly disruptive business environment without effective risk-transfer and hedging markets restrains economic growth. Indeed, the ability to identify and manage risk in a proactive manner is heeded as a key characteristic behind the economic success of modern society.[41]

A formal risk management process comprises a number of sequential tasks: risk identification, risk measurement, and risk monitoring. The contemporary risk management paradigm suggests that all relevant risk factors should be considered and integrated into the process and monitored on a continuous basis.[42] Hence, the risk management process in developing countries should address exposure to a number of risk factors that affect economic performance, including market volatility, natural catastrophes, and competitive risks. Different risk exposures require different responses, but a diversified economy focused on competency-based manufacturing is generally more resilient to exogenous economic shocks. A risk management process would typically follow a series of sequential steps performed in a continuous process (figure 4.6). As an initial step in the process, all risk factors that could affect an economy should be identified. Potential sources of risk must be determined up front to devise alternative responses that could counteract the potential adverse effects of the risk exposure. Once key risk factors are identified, economic exposure associated with each factor should be analyzed.

Exposure to each of the risk factors identified can be quantified and measured to assess relative importance. For example, a country's balance-of-payments flows

Figure 4.6 Elements of the dynamic risk management process



Source: Culp 2002.

and factor income development may be sensitive to developments in primary commodity prices, foreign exchange rates, and global demand conditions. Income generation and economic growth are dependent upon the relative competitiveness of economic entities operating in a country and economic indicators in the global economy. The potential direct losses deriving from various natural catastrophes can be determined on the basis of advanced model simulations that are informed by data describing historical meteorological and seismological event patterns and data describing the characteristics of the exposed economic infrastructure. It is also possible to develop econometric models that stipulate the associated secondary effects on economic demand, investment activities, and government finances.

The exposure position of different risk factors can be incorporated into a formal reporting system that allows policymakers to monitor the manner in which a country's overall risk exposure is evolving. As the economic infrastructure, global market conditions, and catastrophe frequencies change, risk exposure reports reflect the consequences of the changed environmental reality. As environmental conditions continue to change, risk management frameworks should reflect an ongoing and dynamic process. Registration and quantification of important risk factors provide the basis for an informative mapping of the risk exposures that influence a country's economic development path. This overview of a country's risk landscape allows decision-makers to evaluate the effects of alternative actions to modify or limit the overall risk profile. The analytical framework also provides a basis for reducing risk exposure by making risk-transfer arrangements.

Depending upon the nature of the risk, residual risk exposure can be hedged through financial derivatives,[43] reinsurance, and alternative risk transfer (ART) instruments. Economic exposure related to changing competitive conditions in the global marketplace cannot be insured in the financial markets. Competitive advantage typically relates to firm-specific, nontradable, intangible factors, so no market-based instruments exist to hedge these exposures. It may be possible, however, to adopt a real options perspective to managing these long-term exposures.[44] The real options concept is the vanguard of strategic risk management, and it provides interesting new ways to respond to idiosyncratic non-marketable economic exposures.[45] New business opportunities planned by economic entities, but not yet implemented, can be conceived as an options portfolio that gives a country economic flexibility and enhances its development path.[46]

Options are not always obvious, however, and sometimes must be innovated. The creation of options depends upon the existence of economic entities in a country that are innovative and able to take on new business initiatives. Governments can support the establishment of an economic environment conducive to serious options creation, such as managing excessive risk exposure, maintaining public security and health standards, building economic infrastructure, and investing in education and intellectual capital.[47] The ability to create options and manage the associated flexibility can add significant value to an economy. The more options available in an economic portfolio, the more responsive and resilient it can be to external shocks, whether from natural disasters or changing conditions in the global market.

A government that manages all risk factors on an integrative basis can cover excessive economic risk exposure by combining a number of risk-transfer techniques to ensure that sufficient funds will be available to retain economic responsiveness and quickly refurbish essential infrastructure in the event of a disaster. Governments should take steps to identify and continuously survey risks that could impact the economy. They should also determine a level of prudent risk exposure and manage the country's risk profile, within limits, through a combination of self-insurance, risk-transfer opportunities, a diversified industrial structure, and an economic options portfolio that builds flexibility into an economy.

Conclusions

Globalization has significantly spurred trade and investment flows over the past decades. At the same time, the frequency of natural catastrophes has increased and associated economic losses have risen at an alarming rate in developing countries. The current approach to multilateral catastrophe funding causes moral hazard problems that leave too few incentives to engage in proactive risk management that could promote more effective risk mitigation and post-disaster reconstruction. There is an urgent need to support developing countries in managing the results of the current trend and assist them in pioneering new integrative risk management practices.

Open international trade relations can benefit all trading partners, but a high export concentration of primary commodities among the world's poorest nations has entrapped them with terms-of-trade that continue to deteriorate. Other industrialized developing countries are trapped by over-reliance on favorable labor costs, which constitute an unsustainable advantage. The poorest developing countries are also hit hardest by the economic devastation of natural disasters that often aggravate an already-strained economic situation. High dependence upon particular commodities provides little room for responsiveness to adverse economic shocks. The obvious response is to create a more diverse industry structure and advance capabilities-based economic activities that have a better potential for creating competitive advantages. This approach requires a stable economic environment founded in sociopolitical stability and active management of exposure to natural catastrophes and other exogenous economic shocks. Prudent economic policies and proactive risk management practices can help developing countries establish a business environment that is more conducive to a sustainable development path.

The paper has sought to derive conclusions from empirical evidence, but the underlying sample of developing countries has its limitations. As the conclusions appear fairly generic, robust further analyses of more comprehensive data sets may be warranted. These studies could consider some of the constructs introduced in this paper and define classes of competency-based business activities, types of competitive advantage, and economic option portfolios. Risk management approaches could also be tested in country-specific pilot studies that specify the direct and indirect economic benefits associated with an integrative risk management process.

Annex 4.1 Reported catastrophe victims and economic losses, 1990–2000

Country	People affected (#)	Total population (mill.)	Affected/ population[1] (%)	Catastrophe losses ($ mill.)	GDP[2] PPP-basis (# bill.)	Losses/ GDP (%)
Argentina	12,979,161	37.38	34.72	8,596	476.0	1.81
Bangladesh	329,090,346	131.27	250.70	10,579	203.0	5.21
Benin	844,000	6.59	12.81	3	6.6	0.05
Brazil	40,863,947	174.47	23.42	5,051	1130.0	0.45
Burkina Faso	2,823,293	12.27	23.01	0	12.0	0.00
Cameroon	810,070	15.80	5.13	2	26.0	0.01
Central Afr. Rep.	79,680	3.58	2.23	0	6.1	0.00
China	1,387,422,101	1,273.11	108.98	112,314	4500.0	2.50
Colombia	2,565,541	40.35	6.36	4,875	250.0	1.95
Costa Rica	1,179,442	3.77	31.26	848	25.0	3.39
Dominica	3,716	0.07	5.23	3	0.3	1.13
Dominican Rep.	2,368,827	8.58	27.61	2,264	48.3	4.69
Ecuador	577,276	13.18	4.38	801	37.2	2.15
Egypt, Arab. Rep.	199,331	69.54	0.29	292	247.0	0.12
Ethiopia	45,315,900	65.89	68.78	19	39.2	0.05
Haiti	4,089,855	6.96	58.73	211	12.7	1.66
Hungary	133,695	10.11	1.32	677	113.9	0.59
India	1,002,191,581	1,029.99	97.30	20,213	2200.0	0.92
Indonesia	7,198,000	228.40	3.15	17,879	654.0	2.73
Côte d'Ivoire	51	16.39	0.00	0	26.2	0.00
Jamaica	1,463,121	2.67	54.90	1,221	9.7	12.58
Jordan	198,744	5.15	3.86	400	17.3	2.31
Kenya	17,441,900	30.76	56.70	12	45.6	0.03
Malaysia	149,869	22.23	0.67	12	223.7	0.01
Mali	1,853,902	11.01	16.84	0	9.1	0.00
Mexico	3,515,773	101.88	3.45	10,203	915.0	1.12
Nepal	5,676,894	25.28	22.45	1,298	33.7	3.85
Nicaragua	2,439,230	4.92	49.60	2,044	13.1	15.60
Pakistan	26,206,278	144.62	18.12	1,341	282.0	0.48
Paraguay	760,652	5.73	13.27	84	26.2	0.32
Peru	5,325,635	27.48	19.38	1,549	123.0	1.26
Philippines	93,468,162	82.84	112.83	5,450	310.0	1.76
Rwanda	1,481,976	7.31	20.27	0	6.4	
Thailand	25,849,910	61.80	41.83	4,218	413.0	1.02
Uganda	1,351,500	23.99	5.63	72	26.2	0.27
Uruguay	37,500	3.36	1.12	30	31.0	0.10
Venezuela, R. B. de	702,581	23.90	2.94	2,088	146.2	1.43
Zambia	4,306,218	9.77	44.08	21	8.5	0.24
Zimbabwe	10,861,153	11.37	95.57	2,598	28.2	9.21

[1] A ratio above 100 percent indicates that a number of people exceeding the entire population have been affected during the period.
[2] Based on purchasing power equivalents as opposed to factor cost converted at current foreign exchange rates.
Sources: Centre for Research on the Epidemiology of Disasters (CRED) and *World Factbook*.

Annex 4.2 National income growth, international trade, and tariffs

Country	GDP Growth 1990–94 (% p.a.)	GDP Growth 1995–99 (% p.a.)	GDP Growth 1990–99 (% p.a.)	Trade/GDP 1990–94 (% p.a.)	Trade/GDP 1995–99 (% p.a.)	Trade/GDP 1990–99 (% p.a.)	Tariffs 1985–89 (avg. %)	Tariffs 1990–94 (avg. %)	Tariffs 1995–99 (avg. %)	Tariffs 1990–99 (agv. %)	Change 1985–95 (%)
Argentina	6.80	5.20	6.00	23.70	32.90	28.30	27.50	13.90	11.00	12.45	−60.00
Bangladesh	3.40	3.70	3.55	18.60	26.70	22.65	92.70	54.30	26.00	40.15	−71.95
Benin	1.40	2.60	2.00	51.80	45.80	48.80	42.80	41.00	12.70	26.85	−70.33
Brazil	0.90	1.60	1.25	13.50	17.90	15.70	45.80	21.00	11.50	16.25	−74.89
Burkina Faso	−0.90	3.20	1.15	43.10	37.90	40.50	60.80	43.00	28.50	35.75	−53.13
Cameroon	−7.20	2.10	−2.55	68.50	65.00	66.75	32.00	18.60	18.10	18.35	−43.44
Central Afr. Rep.	−2.80	−0.20	−1.50	46.90	42.10	44.50	32.00	25.00	18.60	21.80	−41.88
China	8.60	7.80	8.20	30.10	34.20	32.15	38.80	39.90	20.90	30.40	−46.13
Colombia	2.40	0.60	1.50	45.00	58.90	51.95	29.40	16.60	12.20	14.40	−58.50
Costa Rica	2.00	−0.10	0.95	108.30	128.10	118.20	19.50	12.60	11.20	11.90	−42.56
Dominica	1.40	1.80	1.60	118.50	112.30	115.40	31.90	28.00	15.00	21.50	−52.98
Dominican Rep.	1.80	5.60	3.70	56.30	92.30	74.30		17.80	16.20	17.00	0
Ecuador	1.10	0.60	0.85	52.50	57.50	55.00	34.30	10.60	11.70	11.15	−65.89
Egypt, Arab. Rep.	0.10	3.30	1.70	61.60	59.70	60.65	39.70	35.30	28.10	31.70	−29.22
Ethiopia	−1.20	5.00	1.90	22.90	25.40	24.15	29.60	28.80	16.30	22.55	−44.93
Haiti	−7.30	−0.30	−3.80	67.00	98.90	82.95	11.60	11.00	10.00	10.50	−13.79
Hungary	−2.80	3.30	0.25	57.60	74.00	65.80	18.00	9.90	14.80	12.35	−17.78
India	2.60	4.40	3.50	17.00	22.10	19.55	99.40	61.90	38.30	50.10	−61.47
Indonesia	4.30	4.50	4.40	48.60	50.20	49.40	27.90	20.10	13.20	16.65	−52.69
Côte d'Ivoire	−3.40	3.30	−0.05	68.00	76.40	72.20	26.30	23.80	20.70	22.25	−21.29
Jamaica	−0.80	−2.70	−1.75	109.20	125.90	117.55	18.40	19.60	10.90	15.25	−40.76
Jordan	1.40	−1.60	−0.10	162.20	166.20	164.20	16.30	15.80	16.00	15.90	−1.84
Kenya	−0.60	0.60	0.00	51.40	60.70	56.05	39.40	33.30	13.50	23.40	−65.74
Malaysia	5.80	5.40	5.60	173.90	219.80	196.85	14.90	14.30	8.90	11.60	−40.27
Mali	−1.80	2.30	0.25	51.60	51.30	51.45	.	24.00	18.80	21.40	.
Mexico	2.40	4.20	3.30	33.50	49.90	41.70	16.70	12.80	12.80	12.80	−23.35
Nepal	3.00	2.20	2.60	42.00	60.30	51.15	21.80	16.10	11.00	13.55	−49.54
Nicaragua	−2.20	0	−1.10	68.50	85.10	76.80	22.10	12.70	10.70	11.70	−51.58
Pakistan	0.80	−0.30	0.25	34.90	34.50	34.70	69.20	59.80	41.70	50.75	−39.74
Paraguay	1.00	−0.20	0.40	77.30	99.40	88.35	10.90	13.10	9.30	11.20	−14.68
Peru	2.70	3.00	2.85	44.30	52.70	48.50	45.00	19.00	13.30	16.15	−70.44
Philippines	−0.60	3.10	1.25	75.50	106.10	90.80	27.80	24.50	17.20	20.85	−38.13
Rwanda	−14.90	0.30	−7.30	46.50	37.40	41.95	33.00	38.40	38.40	38.40	16.36
Thailand	6.00	1.50	3.75	84.60	94.60	89.60	41.00	36.60	23.10	29.85	−43.66
Uganda	1.60	4.20	2.90	31.40	43.10	37.25	25.00	17.10	13.00	15.05	−48.00
Uruguay	4.90	4.30	4.60	66.40	84.30	75.35	33.70	18.90	9.60	14.25	−71.51
Venezuela, R. B. de	2.30	0.20	1.25	47.20	54.70	50.95	31.10	15.80	12.70	14.25	−59.16
Zambia	−1.40	2.40	0.50	78.90	78.30	78.60	29.90	26.40	17.00	21.70	−43.14
Zimbabwe	0.40	3.10	1.75	59.40	77.10	68.25	9.20	17.20	21.50	19.35	133.70

Source: D. Dollar and A. Kraay, *Trade Growth, and Poverty*, Development Research Group, World Bank, 2001.

Annex 4.3 National income, export concentration, and foreign direct investment

				Foreign Direct Investment			
Country	GDP[1] PPP-basis ($ bill.)	Ln(GDP) Logarithmic transformation	Export[2] Concentration index	1996 ($ mill.)	1999 ($ mill.)	Avg. 1996–99 ($ mill.)	Avg. 1996–99 (pct. of GDP)
Argentina	476.0	6.17	0.13	6,900.0	24,000.0	15,450.0	3.25
Bangladesh	203.0	5.31	0.24	13.5	179.7	96.6	0.05
Benin	6.6	1.89	.	36.0	40.7	38.4	0.58
Brazil	1130.0	7.03	0.09	11,200.0	28,600.0	19,900.0	1.76
Burkina Faso	12.0	2.48	.	17.0	13.0	15.0	0.13
Cameroon	26.0	3.26	0.40	35.0	40.0	37.5	0.14
Central Afr. Rep.	6.1	1.81	.	5.0	13.0	9.0	0.15
China	4500.0	8.41	0.07	40,200.0	38,800.0	39,500.0	0.88
Colombia	250.0	5.52	0.29	3,100.0	1,500.0	2,300.0	0.92
Costa Rica	25.0	3.22	0.39	427.0	669.0	548.0	2.19
Dominica	0.3	.	0.50	17.8	18.0	17.9	5.97
Dominican Rep.	48.3	3.88	.	96.5	1,300.0	698.3	1.45
Ecuador	37.2	3.62	0.40	491.0	690.0	590.5	1.59
Egypt, Arab. Rep.	247.0	5.51	0.27	636.0	1,100.0	868.0	0.35
Ethiopia	39.2	3.67	.	22.0	90.0	56.0	0.14
Haiti	12.7	2.54	0.29	4.1	30.0	17.1	0.13
Hungary	113.9	4.74	0.12	2,300.0	2,000.0	2,150.0	1.89
India	2200.0	7.70	0.16	2,400.0	2,200.0	2,300.0	0.10
Indonesia	654.0	6.48	0.15	6,200.0	2,745.0	4,472.5	0.68
Côte d'Ivoire	26.2	3.27	.	269.0	323.7	296.4	1.13
Jamaica	9.7	2.27	0.64	183.7	523.7	353.7	3.65
Jordan	17.3	2.85	0.16	15.5	158.0	86.8	0.50
Kenya	45.6	3.82	0.28	12.7	13.8	13.3	0.03
Malaysia	223.7	5.41	0.22	5,100.0	1,000.0	3,050.0	1.36
Mali	9.1	2.21	0.67	84.0	19.0	51.5	0.57
Mexico	915.0	6.82	0.12	9,200.0	11,900.0	10,550.0	1.15
Nepal	33.7	3.52	0.45	19.2	4.4	11.8	0.04
Nicaragua	13.1	2.57	0.30	97.0	300.0	198.5	1.52
Pakistan	282.0	5.64	0.23	922.0	532.0	727.0	0.26
Paraguay	26.2	3.27	0.41	149.0	87.3	118.2	0.45
Peru	123.0	4.81	0.24	3,200.0	2,400.0	2,800.0	2.28
Philippines	310.0	5.74	0.50	1,500.0	573.0	1,036.5	0.33
Rwanda	6.4	1.86	.	2.2	1.7	2.0	0.03
Thailand	413.0	6.02	0.11	2,300.0	6,200.0	4,250.0	1.03
Uganda	26.2	3.27	0.56	11.20	222.0	171.5	0.65
Uruguay	31.0	3.43	0.18	136.8	235.0	185.9	0.60
Venezuela, R. B. de	146.2	4.98	0.79	2,200.0	3,300.0	2,750.0	1.88
Zambia	8.5	2.14	.	117.0	163.0	140.0	1.65
Zimbabwe	28.2	3.34	0.31	81.0	59.0	70.0	0.25

[1]Based on purchasing power equivalents as opposed to factor cost converted at current foreign exchange rates.
[2]The index is calculated as the square root of the sum of the ratios of each of the 239 three-digit SITC product groups over total export raised to the power of two. The results are normalized by dividing by the square root of 1 over 239 to create a numerical index range from 0 to 1 (this is a modified Hirschmann index).
Sources: United Nations Conference on Trade and Development (UNCTAD), *World Factbook*, and World Bank data.

Annex 4.4 Correlation Analysis
(Pearson correlation coefficients)

	1. GDP Growth	2. Ln(GDP)	3. Pct. Losses	4. Trade/GDP	5. Tariff ratio	6. Tariff change	7. Conc. index
1. GDP Growth	.	.	.	.	.	.	.
2. Ln(GDP)	0.655**	.	.	.	.	.	.
3. Pct. losses	–0.070	–0.141	.	.	.	.	.
4. Trade/GDP	–0.073	–0.251	0.162	.	.	.	.
5.Tariff rate	–0.021	0.218	–0.200	–0.405*	.	.	.
6. Tariff change	–0.287+	–0.230	0.237	0.201	–0.034	.	.
7. Conc. Index	–0.453**	–0.675**	0.210	0.189	–0.184	0.063	.
8. FDI/GDP	0.133	0.099	0.223	0.308+	–0.337*	–0.194	0.149

Statistical significance levels: **p > 0.01; *p > 0.05; +p > 0.10

Notes

1. This may well underestimate actual damage, since available information on losses associated with natural catastrophes is less than perfect and somewhat incompatible. The key sources for the loss data, e.g., Swiss Re, Munich Re, and CRED, often use different cutoff points in their definition of a catastrophe and they all rely on different external informants such as newspaper articles, news agencies, various multilateral organizations, insurance reports, reinsurance periodicals, and specialist publications.

2. Total reported direct economic losses from natural catastrophes reached close to $190 billion in 1996 and $28 billion in 2000. Source: Centre for Research on the Epidemiology of Disasters (CRED), International Disaster Database, Université Catolique de Louvain, Belgium. Secondary economic effects go unreported although they can be substantial. Reported losses refer to *direct damage* inflicted on private homes, commercial assets, and public infrastructure. Natural catastrophes cause additional *indirect damage* due to reduced economic activities, lost market opportunities, distortion of commercial working relationships, disruption of educational efforts, research and development initiatives, strained public finances, contraction of capital investments, etc.

3. True insurance coverage in developing countries is considerably lower, because natural catastrophe statistics often do not include loss estimates (less than one in three registered natural catastrophes in developing countries reported any loss figures).

4. The loss factors roughly correspond to annual percentage increase in catastrophe losses of around 25 percent in developed economies and 30 percent in developing economies (calculated on a compound rate basis).

5. The *Red Cross World Disasters Report* (2001) refers to these losses as emanating from "un-natural" catastrophes as they escalate due to a lack of focused risk mitigation.

6. Benson and Clay (2001) observe that major disasters influence the composition of public spending and funding patterns, distort short- and medium-term investment plans, and hence adversely affect economic growth potential, particularly in economies that are dependent on public investment.

7. The countries studied in this paper constitute a sample of 39 developing countries that maintain relatively high global trade activities. The sample is taken from Dollar and Kraay (2001).

8. There is a negative correlation between economic growth and catastrophe losses as a percentage of GDP in the sample, but the correlation coefficient is not statistically significant.

9. The correlation coefficient between the percentage of the population affected and annual economic growth is positive in this sample, although not statistically significant.

10. The World Bank has extended more than $7 billion in post-disaster loans and credits over the past 20 years (Gilbert and Kreimer 1999).

11. In the *Red Cross World Disasters Report* (2001), there is a vivid description of how international relief organizations have performed in particular disaster situations that prompted serious questions about "whose needs are best served by aid—those of the donor agencies or their beneficiaries."

12. This is referred to as a "moral hazard" issue because authorities are often less proactive in managing risk exposures when there is an expectation that international organizations will extend emergency assistance. See, for example, *Financial Markets Trends,* No. 76, 2000, OECD.

13. Global competitive advantage can be achieved when an economic entity is able to provide superior value to customers more efficiently than international competitors. The sustainability of competitive advantage depends on the specificity with which an entity is able to create superior value based on unique

product/service features or firm-specific processes that are difficult to emulate. This makes an advantage more sustainable.

14. Various negotiations of the General Agreement on Tariffs and Trade (GATT) have reduced import tariffs on manufactured goods over the years. Trade agreements on goods, services, and intellectual property are now administered by the World Trade Organization (WTO), which also settles trade disputes. The WTO is organizing a series of ongoing negotiations to extend trade rules on such things as agricultural products, textiles, and public procurement.

15. WTO and United Nations Conference on Trade and Development (UNCTAD).

16. There has been a significant increase in FDI in developed economies over the past decade stemming primarily from the ongoing integration of economic activities within the European Union.

17. Comparative advantage can arise from relative differences in production efficiencies. In an open economy, resources would gradually be channeled to companies that maintain relatively high efficiencies when producing particular products and services and they would become a source of exports to global markets, whereas other product and service areas where companies have relatively lower efficiencies would face stiff competition from global imports. Relative production efficiencies can stem from the endowment of production factors in the economy such as oil, minerals, land, agricultural raw materials, and labor, but they can also be rooted in superior skills, capabilities, and knowledge - specialized pharmaceuticals, telecommunications and engineering know-how, manufacturing and management capabilities. Therefore, in a dynamic economic environment, comparative advantage can also be created from innovations in product and service offerings, technological inventions, and continuous improvements in operational processes that create better value for end-users or provide value more efficiently. The latter competency-based sources of comparative advantage are proving to be more profitable, resilient, and durable in the contemporary economic environment compared to pure factor-based advantages.

18. The sample is based on Dollar and Kraay (2001). This paper analyzes variables on a cross-section of developing countries over certain time periods whereas Dollar and Kraay analyze internal country variations over time.

19. There is a negative correlation between trade/GDP and annual GDP growth, but it is not statistically significant in this sample.

20. Collier and Gunnin (1999) find that African countries that have pursued open trade policies have generally achieved higher economic efficiencies.

21. Trade and Development Report, 2002, United Nation Conference on Trade and Development (UNCTAD).

22. See, for example, Mishra, Mody, and Murshid (2001) and Loungani and Razin (2001).

23. See also Financial Market Trends, *Recent Trends in Foreign Direct Investment*, No. 76, June 2000, OECD, Paris.

24. The world market prices for several commodities, such as cotton, soybeans, and wheat, have arguably been depressed by the agricultural subsidies provided within the European Union, the United States, and Japan.

25. There is a positive correlation between the export concentration index and the ratio of registered direct catastrophe losses over GDP, although it is not statistically significant in the current sample.

26. There is a positive correlation between the level of foreign direct investment, both in relative and absolute terms, and the annual GDP growth, although it is not statistically significant in this sample.

27. There is a positive and statistically significant correlation between the level of foreign direct investment over GDP and the export concentration index.

28. See Prahalad and Doz (1987), Bartlett and Ghoshal (1989), Reich (1991), Markusen (1995).

29. This type of foreign direct investment activity is not confined to large multinational corporations. It is also a part of many small to medium-sized companies with the flexibility to take advantage of a global network.

30. *Washington Post*, "Mexican workers pay for success: with labor costs rising, factories depart for Asia," June 25, 2002.

31. See e.g., Barney (2002) and Saloner, Shepard, and Podolny (2001).

32. The new partnership for Africa's development (NEPAD) promoted by South Africa's President Thabo Mbeki is a noteworthy attempt to further such an approach.

33. The major causes of vulnerability to contagion are external imbalances, unrealistic foreign exchange rate regimes, lax fiscal policies, non-credible monetary policies, unhealthy financial sector, the quality of financial reporting, etc., OECD, Financial Market Trends, June 2000.

34. Financial Times, "Coffee republics see their 'grain of gold' lose its luster," June 26, 2002.

35. The Least Developed Countries Report 2002: Escaping the Poverty Trap, United Nations Conference on Trade and Development (UNCTAD).

36. *Wall Street Journal,* "Weather condition El Niño may be returning this year: companies that depend on domestic demand in Asia could be hurt," March 27, 2002.

37. World Investment Report, 2001, Promoting Linkages, United Nations Conference on Trade and Development (UNCTAD).
38. See e.g., Wood (2000).
39. If funding becomes scarce, new and possibly profitable projects will not be funded. As a consequence, a firm will follow a less than optimal growth path. In the country context, a credit crunch will prevent a government from investing in important long-term economic development programs that could otherwise improve the competitive position of economic entities operating in the country. See Froot, Scharfstein, and Stein (1994).
40. If the economic performance of a firm (or a country) becomes excessively volatile, for example, due to uncontrolled risk exposure, the credit risk of a firm (or country) increases and it will be considered a more risky counterpart. It is more risky not only for purposes of credit extension, but also in general economic interactions because the entity's ability to fulfill its future commitments to creditors, customers, and suppliers, is jeopardized. See Miller (1998).
41. See Bernstein (1996).
42. See Barton, Shenkir and Walker (2002) and Dogherty (2000).
43. Financial futures, forwards, and options make it possible to lock in future market rates typically for periods of 6–18 months (Andersen 1993). This hedging technique cannot bypass the consequences of lower-than-expected market rates or continuously deteriorating terms-of-trade, but it can smooth the volatility of earnings flows.
44. A **financial option** is a right, but not an obligation, to buy (call) or sell (put) a particular traded asset at a predetermined price at a future time. Hence, options gives the holder the flexibility to utilize a favorable market situation, or let the option lapse rather than incur a loss. This flexibility has value, which can theoretically be estimated based on the characteristics of market price development of the underlying asset. A **real option** represents that same formal structure except the underlying assets are not traded. They typically constitute an investment opportunity underpinned by firm-specific and unique capabilities. Hence, a new economic venture or business opportunity represents a real option because the firm can utilize the real option when market conditions are favorable and leave or postpone it if conditions are not yet favorable. The flexibility of this options structure has value like that of a financial option. An economy where economic entities have the ability to develop many different types of real options will have more alternatives for expanding economic activity and become more responsive to changes in market conditions.
45. See Andersen (2000).
46. Hence, these real options provide firms with the right, but not the obligation, to pursue new business opportunities.
47. See Boer (2002).

Bibliography

Albala-Bertrand, J. M. 1993. *Political Economy of Large Natural Disasters*. Oxford: Clarendon Press.

Andersen, T. J. 1993. *Currency and Interest Rate Hedging*, Second Edition. New Jersey: Prentice-Hall.

Andersen, T. J. 2000. "Real Options Analysis in Strategic Decision Making: An Applied Approach in a Dual Options Framework." *Journal of Applied Management Studies* 9(2):235–55.

Andersen, T. J., and P. Masci. 2001. "Economic Exposures to Natural Disasters, Public Policy, and Alternative Risk Management Approaches." *Infrastructure and Financial Markets Review* 7(4).

Barney, J. B. 2002. *Gaining and Sustaining Competitive Advantage*. Second Edition. New Jersey: Prentice Hall.

Bartlett, C. A., and S. Ghoshal. 1989. *Managing Across Borders*. Cambridge, MA.: Harvard Business School Press.

Barton, T. L., W. G. Shenkir, and P. L. Walker. 2002. *Making Enterprise Risk Management Pay Off*. New Jersey: Prentice-Hall.

Benson, C., and E. Clay. 2001. "Bangladesh: Disasters and Public Finance." London: Overseas Development Institute.

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

Boer, F. P. 2002. *The Real Options Solution: Finding Total Value in a High-Risk World*. New York: Wiley.

Charveriat, C. 2000. "Natural Disaster Risk in Latin America and the Caribbean." Washington, D.C.: IDB.

Collier, P., and J. W. Gunnin. 1999. "Explaining African Economic Performance." *Journal of Economic Literature* 37(1).

Culp, G. L. 2002. *The ART of Risk Management: Alternative Risk Transfer, Capital Structure, and the Convergence of Insurance and Capital Markets*. New York: Wiley.

Doherty, N. A. 2000. *Integrated Risk Management: Techniques and Strategies for Reducing Risk*. New York: McGraw-Hill.

Dollar, D., and A. Kraay. 2001. *Trade, Growth, and Poverty*. Washington, D.C.: World Bank.

Dollar, D., and A. Kraay. 2002. "Spreading the Wealth." *Foreign Affairs* 81(1).

Froot, K. A., D. S. Scharfstein, and J. C. Stein. 1994. "A Framework for Risk Management." *Harvard Business Review* (November-December).

Gilbert, R. and A. Kreimer. 1999. *Learning from the World Bank's Experience of Natural Disaster Related Assistance*. Washington, D.C.: World Bank.

ICRC (International Red Cross and Red Crescent Societies). 2001. *World Disasters Report: Focus on Recovery.* Geneva.

Kleindorfer, P. R., and H.C. Kunreuther. 1999. "Challenges Facing the Insurance Industry in Managing Catastrophe Risks." In K.A. Froot, ed., *The Financing of Catastrophe Risk*. Chicago: University of Chicago Press.

Lall, S. 2000. "The Technological Structure and Performance of Developing Country Manufactured Exports, 1985–98." *Oxford Development Studies*, 28(1).

Loungani, P., and A. Razin. 2001. "How Beneficial Is Foreign Direct Investment for Developing Countries?" *Finance & Development* 38(2).

Markusen, J. R. 1995. "Boundaries of Multinational Enterprises and the Theory of International Trade." *Journal of Economic Perspectives* 9(x).

Miller, K. D. 1998. "Economic Exposure and Integrated Risk Management." *Strategic Management Journal* 19(5).

Mishra, D., A. Mody, and A. P. Murshid. 2001. "Private Capital Flows and Growth." *Finance & Development* 38(2).

OECD (Organisation for Economic Co-operation and Development). 2000. *Financial Market Trends No. 76*. Paris.

Oxfam International. 2001. "Eight Broken Promises: Why the WTO Isn't Working for the World's Poor." Oxfam Briefing Paper. London.

Prahalad, C. K., and Y. L. Doz. 1987. *The Multinational Mission.* New York: Free Press.

Reich, R. B. 1991. *The Work of Nations.* New York: Vintage.

Saloner, G., A. Shepard, and J. Podolny. 2001. *Strategic Management.* New York: Wiley.

UNCTAD (United Nations Conference on Trade and Development). 2001. *World Investment Report, 2001.* Geneva.

UNCTAD. 2002. *Trade and Development Report, 2002*. Geneva. [CK text]

UNCTAD. 2002. *The Least Developed Countries Report 2002: Escaping the Poverty Trap*. Geneva. [CK text]

Wood, E. 2000. "Aligning Innovation for Dynamic Capabilities and Sustainable Growth in South African Manufacturing." Working Paper. Cape Town: University of Cape Town.

Chapter 5

Urban Disasters and Globalization

J. M. Albala-Bertrand

Disasters and their short- and long-term impacts upon economies and societies have been studied extensively. As globalization spreads, this movement affects global and local economies, implying changes in disaster impacts. This paper looks at the impacts of disasters in urban areas in light of globalization. While not all agree that globalization benefits developing countries, this movement allows certain assumptions to be made based on the performance of industrialized economies and linkages that impact developing countries. Furthermore, it appears that the effect of disaster situations on the macroeconomy is negligible; therefore, disaster management activities should focus on communities and their resilience.

Urban Area and Urban Hazards

Urban Area. A city or urban area is a set of infrastructure, other structures, and buildings that create an environment to serve a population living within a relatively small and confined geographic area. The lives and livelihoods of the population are supported by interrelated systems around which the urban area and society function. Capital stock makes up much of the infrastructure that includes business fixed-capital machinery and equipment, structural capital (plant, infrastructure, overheads, offices, and social-physical capital), and residential capital (dwellings). A disaster can directly affect people and capital stock and, as a consequence, the systemic functioning of both.

Urban Hazard. An urban hazard is a risk that threatens a city, its population, and related socioeconomic activities. If a risk threatens a capital or large city, the risk may resonate beyond the area of impact. In the discussion that follows, the focus is mostly on *major disaster impacts,* since smaller ones are less destructive and more easily absorbed, though much of the discussion is also applicable for smaller disasters. First, a disaster impact is generally defined as major if estimated direct losses approach or exceed the average GDP growth rate of an affected country and/or the damage seriously affects economic activity, even if direct losses from the event are not a significant portion of GDP.

Second, the overwhelming majority of disasters, whether large or small, are geographically and/or economically *localized*, and a disaster impact is unlikely to have negative consequences for the economy as a whole. Third, unless indicated, this paper takes into consideration only *sudden types* of urban natural (earthquakes, floods, hurricanes, etc.) and technological (engineering, chemical, biological, etc.) disasters, with the latter traced mainly to *institutional failure*. Many sudden types of technological disasters are confined to small areas, but they often have larger consequences for the surrounding population and areas not directly affected. The direct effects of these disasters can generally be treated similarly to those resulting from natural disasters, but the responses tend to be different, since the institutional and internal political processes also affect the response.

Furthermore, it has been shown that urban natural disasters, and by extension technological ones, normally have low direct impacts on secondary (industrial) and tertiary (services) sectors. Residential capital tends to bear the brunt of damage and destruction. Social capital, associated with education and health services, does not normally suffer high negative impacts. Damage to service sources and networks is not normally high; therefore, it is short-lived. Social overhead, including infrastructure, is frequently damaged, though transport infrastructure is the most affected, followed by water supply and sewage systems. Within communities, those most frequently killed and injured are the urban poor, who often lose their homes, many of which are constructed with low-quality materials on unstable and disaster-prone land. When accounted for as a percentage of GDP, such losses can be minimal, though the losses are devastating for many families. Rebuilding these areas may not be excessively costly on a per capita basis, but commitment to helping this vulnerable section of the population requires political will. This same population may also suffer when daily wage jobs are lost during a disaster. Ironically, particularly in urban areas, job creation often occurs following a disaster, as emergency and reconstruction activities bring employment, especially in the construction sector.

Considering the above and including substitutions, market reactions, and other endogenous and exogenous responses, the net effect of a disaster situation (considering both impact and responses) normally appears to have *no negative macroeconomic effects*. Expected negative effects on GDP and investment, employment and inflation, the trade deficit and foreign reserves, are largely absent and in the short term there is often an economic upturn of some two years due to the reconstruction and business opportunities brought by a disaster. The public deficit may rise as the government finances rehabilitation and reconstruction activities, but this rarely results in a long-term problem. Hence, one conclusion is that disasters may be "a problem *of* development, but not necessarily a problem *for* development" (Albala-Bertrand 1993a).[1] The question then is whether globalization affects this pattern.

Globalization and the Business Cycle

Globalization involves a wider and deeper merging and interdependence of domestic economies into a worldwide arena of competitive multimarkets and exchanges. It encompasses the flows of goods (trade), capital (finance and direct), information (transparency and access), labor (including human capital), and culture (institutional patterns and dynamics). The expectations of the advocates of globalization are that as more countries, and agents within countries, join this movement, obstacles to access will be reduced, and transportation and information costs will decrease. Participants will have a wider and more penetrating reach in the worldwide arena, and globalization will benefit all.

Opponents, on the other hand, do not doubt that more integration might be economically beneficial, but they have doubts about globalization's pacing, sequencing, and policies. Their concerns arise from worries that quick, unregulated, and socially unaccommodating transitions to advanced stages of globalization can have, and have had, deleterious consequences for the economies of developing countries and the general population, particularly the most vulnerable people. Thus, issues about institutional pre-conditions associated with the protection, pace, and sequencing of reforms to prevent increases in poverty, larger inequalities, and socioeconomic instability cannot be ignored (Stiglitz 2002; Nayyar 2002; Mansoob 2002; World Bank 2001).

The business cycle is a sequence of sustained upturns and downturns in GDP and employment associated with economic shocks and/or agents' decisions that affect aggregate demand that in turn is mediated by a collection of not-well-understood societal factors and expectations of an economic and political nature. Until recently, the seeming absence of a synchronic cycle in OECD countries smoothed and softened the international business cycle, though recently the domestic cycles of OECD countries have become more synchronic and dependent upon phases in the U.S. economy. Business cycles of open developing economies have always been synchronic with that of the main OECD trading partner, but the possibility of diversifying trading partners has existed over time and this has reduced vulnerability to single-partner economic cycles. Globalization could provide similar stability through the diversification of exports and market transparency. It seems, however, that such diversification could become less successful as the cycle becomes more synchronic due to globalization and hence more countries are economically linked; then a major urban disaster in a developing country might have greater domestic impacts than had previously been experienced. The next section looks at this hypothesis within a *disaster situation framework*.

Disaster Situation in Urban Areas

A disaster situation is an analytical framework in which disasters are composed of three interdependent processes of one and the same phenomenon: a disaster impact, a disaster response, and a societal interference wrought by the former two. Thus, globalization and business cycle synchronization may affect any of these phases. Their potential effects can be analyzed by focusing on each of them in turn. A society is a living organism, which by its very nature responds endogenously when disaster strikes. Human and societal responses, associated with in-built institutions, will then occur following a disaster (see Albala-Bertrand 1993a).

Disaster Impact and Effects

A disaster impact is normally the result of a physically or socially uncompensated tension that leads to fatalities, damage, destruction, and the disarticulation of societal frameworks. In the case of natural disasters, the uncompensated tension is due to the physical weakness of structures and societal processes that fail to take into account and plan for extreme natural events. As such, even if the natural event were fully exogenous to society, which might not be the case, physical resistance to the geophysical phenomenon would not be. Resistance depends upon disaster-proof technology and sociopolitical access to it, a mostly endogenous process to society at large. It is similar for technological disasters, but here the inducing phenomenon is also fully endogenous, in-built in social structure and location and management of industrial facilities. Technological failures are associated with institutional failure to ensure the safe production, containment, and use of risky technology. This brings to the forefront the issue of vulnerability.

Generally, vulnerability is the exposure of physical and societal frameworks to violent events. Exposure is in turn associated with the risk of item or framework failure. Societal vulnerability can then be defined more specifically as the exposure of institutions and organized people to violent and extreme events. The main factors influencing vulnerability to natural and technological hazards are *unsafe living quarters* (building quality and location) and *unsafe economic activities* (engineering quality and location of structures and risky processes). In turn, the main societal factors that may increase the likelihood and destructiveness of disasters are *entitlement erosion* (economic and political possessions, access, and rights) and *environmental degradation* (pollution and overcrowding).

The lack of political influence and economic alternatives, poverty, and overall disenfranchisement may be at the root of vulnerability, urban or rural. Increased vulnerability and disaster risk can often be attributed to the wholesale policy rearrangements demanded and imposed by a globalization process indifferent to societies. This indifference is manifested in policy inconsistencies in which institutional rearrangements are imposed with a pace and depth that are faster and more far-reaching than the ability of people, especially the vulnerable, and activities to adapt and re-accommodate with a minimum of stability. This often places people and their livelihoods in a precarious condition and safety vacuum.

Disaster Impact Effects. For all kinds of disasters, once a disaster impact has occurred, two main types of effects ensue: *direct or stock effects* and *indirect or flow effects*. *Direct effects* impact human populations (injury and deaths) and physical and animal stocks (damage and destruction). In turn, indirect effects derive from the former, affecting the interrelation between physical structures and between people. These two types of effects cause losses to society's stocks and flows. For socially made disasters such as complex emergencies and technological hazards, however, there is a third type of effect. This is an institutional effect where institutional failure builds up vulnerability until a triggering event unleashes a devastating breakdown.

Indirect effects can be broken down into four frameworks: *household conditions* (homelessness, shortages, displacement, livelihood erosion); *the states of health and nutrition of the population* (environmental degradation, hygiene problems, disease increase, food scarcity); *the economic circuit* (effects on intermediate markets, final markets, policy, and expectations); and *public activities* (overburden, discontinuities, fragmentation, politicization). These frameworks are not fully independent of each other, but the former two relate more directly to the human condition, including basic needs and welfare, while the latter two relate indirectly to people, but directly to the social system as a whole. With some qualification, these general effects are common to all types of disasters.

Regarding indirect impacts, disasters appear to be more remarkable for the *effects they do not have than for* *those they do*. Especially in urban areas, there is little evidence that a disaster's negative impacts are long-lasting even if the direct effects dramatically affect some vulnerable social strata. Still, only an effective emergency response may guarantee that the disruptions to society and the negative impacts and their potential effects are not only short-lived but the emergency itself is not wasteful (see Albala-Bertrand 1993a; 1993b; 2000a).

How could globalization affect the above potential effects in urban areas? First, urban disasters do not strongly impact exports, since export activities in most developing countries are overwhelmingly associated with primary activities such as agriculture, mining, and fishing. An urban disaster cannot affect these exports directly, and there is little reason to assume that indirect effects on this sector would be significant except in the very short term. The weakness or lack of manufacturing exports in most developing countries is not due to backwardness or general deindustrialization in favor of the service sector, but to clear-cut globalization policies that lead to this result, at least for the foreseeable future (Weiss 2002; Albala-Bertrand 1999; Chang 1996). Therefore, if globalization maintains the same trends, we should expect countries that join globalization to become even more primary-sector dependent than they are now. In terms of this increase in dependency, the issue is whether globalization can create conditions to reduce some of a disaster's direct and indirect effects through the reduction of losses to private and public buildings, dwellings, structures, and machinery and equipment.

The main mechanisms to reduce the physical vulnerability of a built-up environment are regulations, building codes, land use restrictions, and the siting of risky technology. Assuming that the knowledge of these aspects is sound, their effectiveness will depend upon legislation and transparency. Globalization, via dissemination of information about best practices, may contribute positively to a better understanding and drafting of disaster-related legislation. Globalization also assumes an increasingly more open society and greater transparency, which may favor the observance and application of legislation to reduce unchecked corruption. Adoption and implementation of new legislation, however, depend more on a society than on globalization.

There is another, safer area where globalization may play a positive role in reducing potential impact effects. One of the main planks of globalization is the support and development of domestic financial markets to receive foreign investment and tap international funds. Setting aside the issue of domestic regulation of foreign financial flows, a more developed financial market would include mechanisms to spread and reduce risk and vulnerability. If so, the impact of a natural or technological disaster could be reduced or even eliminated through improved loan access and insurance coverage. These mechanisms may help larger businesses and wealthier individuals, though not everyone has the means to borrow following a disaster. Insurance and reinsurance industries, however, are likely to develop significantly due to globalization and risk can be spread more evenly. Even more important, wider availability of insurance would act as a check on construction activities, location, and technology use, as these are generally preconditions for insurance coverage. Corruption in the use of land, materials, and the design of structures might also be reduced. The same would also be true for riskier technologies, where discipline and monitoring could be increased. Globalization therefore might bring a wealth of mechanisms to increase prevention and distribute risk.

But these positive developments are hindered by the ability of all people to afford insurance. Currently, the majority of vulnerable people are excluded from the insurance market. Much of this exclusion is created by the transition costs of globalization, which may not be prepared to protect the real-time losers at any one time. In addition, even if no one were excluded, the experience with natural disaster insurance shows that people and small firms rarely take it up, except after major disasters. People do not normally reflect on the possibility of large losses coming from very unlikely events (Kunreuther 1997; Giarini 1984).

Synchronization of the business cycle may cause some unintended negative effects by reinforcing insurance weaknesses in recessions and ignoring them in upturns. During recessions, access to insurance may be easy, but the capacity to pay policy premiums is reduced. In market booms, the insurance industry may downgrade de facto their standards so as to make inroads in a tight market. Therefore, globalization notwithstanding, the potentially good results in this story would all depend on state backing, tight regulations, and penalty enforcement. In other words, the freer and wealthier the market, the stronger and more all-embracing should be the probity of the state and its regulation of economic activity.

Disaster Response and Mechanisms

Disaster Response. Disaster response can be defined as a wide array of endogenous and exogenous reactions, measures, and policies that mitigate, counteract, and prevent disaster impacts and effects. Response to a disaster can be described as follows: once a disaster has occurred, the impacts stimulate the unfolding of systemic response mechanisms and the creation of specially designed response measures. These two sets of responses aim temporarily to counteract functioning flow losses through emergency relief and rehabilitation activities and permanently compensate stock losses and institutional insufficiencies through reconstruction activities. The impact effects and derived compensatory responses also stimulate an anticipatory response aimed at the prevention and mitigation of future potential disasters (Albala-Bertrand 1993a). These responses generate three main areas of attention, which make up the response side of a disaster situation: (i) response mechanisms; (ii) compensatory response; and (iii) anticipatory response. In addition, as a disaster situation always generates varying degrees of societal interference, we should also focus on response-induced interfering effects.

Response Mechanisms. As introduced earlier, response mechanisms refer to endogenous and exogenous response processes. Endogenous response mechanisms are those channeled through society's in-built institutional processes. These processes represent a series of formal and informal feedback mechanisms that are part of the existing self-regulatory social machinery (e.g., the family, informal finance, the informal sector, formal markets, political and administrative frameworks, cultural norms and customs, psychological attitudes and habits). These involve a wide array of activities that range from highly automatic to nonautomatic in-built responses. For example, extended family solidarity represents a highly automatic endogenous reaction, while the use of the hazard reserve item of the public budget is a planned and calculated response. Likewise, market reactions and emergent coalitions appear to lie somewhere in between. Exogenous mechanisms, in turn, are those channeled via ad hoc, unpatterned, unguaranteed, and irregular processes. They are expressed through actions, measures, and policies that formally fill gaps left by in-built responses, by-pass endogenous channels, shift initiatives away from regular actors, and superimpose alternative structures. This normally implies private and public interventions that go beyond in-built actions and international assistance and aid that goes beyond existing guarantees. In the long run, however, these two response types might not necessarily be independent. This is because the *endogenization* of societally useful *exogenous* initiatives, actions, and behaviors, via education, policy, and social interaction, is the normal way in which society strengthens and develops (see Albala-Bertrand 1993a; Cuny 1983; Davis 1981; Quarantelli, 1978; White 1974; Barton 1970; Dynes 1970; Sorokin 1942; Prince 1920).

Compensatory and Anticipatory Responses. In sudden natural disasters and technological failures, reversing the negative impacts is possible once the emergency response has contained the spread and worsening of indirect effects. These responses normally require a significant amount of public involvement and public finance, and in developing countries, foreign aid and credits are also required (Kunreuther 1997; Albala-Bertrand 1993a). These responses and the inflow of funds, materials, and finances interfere with normal activities that compete for the same resources. In addition, given the societal endogeneity of technological failure, intense critique and reassessment of the control and handling of risky technology, which also prompts an institutional reaction, will also arise. Anticipatory actions in turn may also have strong societal implications as they aim to modify behavior and institutions either to prevent disasters or to respond efficiently when prevention fails. Prevention also includes formal insurance, mortgage, and taxation systems that encourage less risky behavior and a better distribution of risk to reduce negative disaster impacts (Kunreuther 1997; Albala-Bertrand 1993a; Giarini 1984; Cochrane 1975; Dacy and Kunreuther 1969). These actions also include the monitoring of markets, migration, and reactions to maximize response effectiveness and minimize antisocial and speculative behavior.

How can globalization affect the above response mechanisms and their effectiveness? Community, defined as a stable array of institutions that set useful societal interaction and hierarchies within and between particular identity groups, like family, neighborhood, workplace, and formal and informal working relationships, might be the first casualty of fast and unfettered globalization (Stiglitz 2002). There is growing evidence that quick trade liberalization makes small and struggling urban firms uncompetitive and unviable. These would affect formal firms and their workers as well as the informal economic activity that depends on these firms, which may represent the overwhelming majority of urban economic activity in many developing countries (Thomas 1990). In addition, the current globalization push for privatization, deregulation of labor markets, and the general restructuring of firms seeking efficiency and productivity improvements, without heeding the ensuing social costs, will make matters even worse for a precarious social fabric. If there are neither alternative livelihoods nor public protection for potentially affected people and the transition to higher employment and stability is slow, the informal and formal endogenous mechanisms might be badly impaired at the time of a disaster impact.

In addition, the other plank of globalization, the liberalization of capital, is now known to create negative economic shocks and instability associated with unregulated capital flows. If this also comes to the fore, then any respite from poverty will be short-lived. There will also be little in the way of reestablishing the stability and strength of endogenous response mechanisms, let alone of improving them. Therefore, globalization as it has been conducted to date may significantly weaken endogenous response mechanisms at the time of disaster, thus demanding a stronger exogenous response from domestic and foreign sources when disaster strikes.

For example, if a country is facing economic difficulties due to the requirements imposed upon its economy and society by the globalization process, then it is unlikely that the domestic economy and budget would have enough laxity to respond appropriately to a hazard. In an ideal world, we would then expect that foreign aid would flow from institutions in support of globalization. This will not happen, however, unless there is a concerted international effort to improve the soundness and safety of globalization policies as an aim in itself, so that vulnerable people do not suffer as a result of globalization and a disaster.

On the other hand, if globalization makes the business cycle synchronic and there is a recession in the United States and other industrialized countries, then transitional economies would suffer in three ways. First, the recession would reinforce the negative situation described earlier. Second, as export demand, commodity prices, and capital flows fall off, there would be fewer domestic financial resources and already-depressed communities would be further harmed, weakening endogenous response mechanisms. And third, with a worldwide recession, the availability and willingness of countries to give foreign aid might be reduced. (Although if the world economy were in an upturn, international donors might be more generous, but developing countries might also be in better financial positions.) Reconstruction requirements, however, might put a strain on other activities, exportable or not, which might affect the economy indirectly.

A country in recession might have more idle capital resources to serve rehabilitation and reconstruction. Such activities might create a domestic demand stimulus, not limited to domestic activities related to disaster response, and positively affect the whole economy. This possibility is not always the case, however, since most capital is not fungible and cannot be switched to other types of production in the short run or even the medium term. Second, if the economy were significantly open, then most output would be geared for exports. The export sector and its backward and forward linkages would then be operating with significant idle capacity. Domestic demand might normally be satisfied with only a small fraction of these exportable goods, but then the level of domestic demand would also be affected. This would make disaster-induced expenditure less effective as a mechanism to compensate the economy than it would otherwise have been.

Most disaster legislation and arrangements follow major disasters. Fast globalization, of the current type may make the social fabric more unstable and fluid than it would otherwise have been. Fluidity may offer the opportunity and impetus to restructure institutions. Under what type of social contract would these rearrangements be incorporated? This would depend most importantly on the type of society in question, followed by the disaster response. Instability and its results might make it more difficult to set up an organized type of institutional rearrangement, so authoritarian rule might come to the fore; this form of governance does not normally favor the most vulnerable people, hence the overall welfare may be worsened for a considerable period of time.

Visible Response Type and Origin. Notice first that a good deal of the endogenous response is not visible or amenable to quantification, which may normally underestimate the energy and effort made by society itself in the wake of a disaster (Albala-Bertrand, 1993a). The visible response usually comes in the form of finance, materials, technical expertise, labor, and organizations to manage such resources. The main response sources are domestic and foreign. The former can be subdivided into local and national, and the latter into bilateral, multilateral, private financial institutions, NGOs, and remittances. Commonly, the majority of resources are domestic in origin. However, significant expertise and financial resources from international sources are sometimes pivotal in disciplining the general response.

When disaster strikes, the stage of globalization and phase of the business cycle can affect funding sources and mechanisms in various ways. First, a cycle-synchronic recession might significantly affect local and domestic resources. This would also affect informal financial markets, which might become less flexible and effective in the wake of fast globalization, impairing recovery. Second, remittances from abroad would be strongly affected. As this is usually a very important type of informal financial response at the family level, recovery of household and individual livelihood conditions would likely be further impaired. Third, both bilateral and multilateral sources might become strongly procyclical, significantly reducing their role in recessions. Fourth, NGOs depend on donations from a variety of people and organizations. Donations might dry up with a synchronic recession. Finally, international private funding sources might be undergoing excess liquidity, which could contribute to easy, but risky, lending. The latter could be a short-term blessing but a long-term disaster if additional debt were taken on. On the other hand, during upturns, the concerns mentioned might be insignificant, but dependence upon foreign aid would also be less necessary than in downturns.

Conclusions

In the context of a disaster situation, as described above, the following conclusions can be reached:

- Urban disasters affecting large cities and megacities may impose large residential and infrastructure losses, as well as large death tolls and injuries.
- Losses of capital and activities, deaths, and injuries are unlikely to affect the macroeconomy negatively.
- It is unlikely that this pattern would significantly change by virtue of the negative features of globalization, but this does not mean that the people and activities affected by urban disasters would not be victimized.
- The negative features of globalization might make a significant difference for increased victimization, as the endogenous mechanisms of response are likely to be badly impaired.
- Given that globalization appears to make the cycle synchronic and dependent on the U.S. economy, financing disaster response might become procyclical, more adversely affecting a disaster-struck country in the event of a recession.
- Globalization could provide new opportunities for diversifying risk and improving prevention, but the useful incorporation of these opportunities into the economy and polity would depend more on the type of domestic society than on globalization itself.

Furthermore, given that the macroeconomy might not suffer as a result of an urban disaster, communities and activities directly affected should be the main target of response policies. International response organizations can also participate, as they often attempt, in the endogenization of initiatives dealing with preventive and compensatory mechanisms at grassroots and national levels. These initiatives might bring strong political opposition from entrenched political elites who may perceive them as interference, but this should not be a reason to drop them. In addition, organizations that make up part of the globalization movement should take into consideration the social and economic problems that arise as a result of their policies, so that they can design safer and more stable approaches to globalization in general and to hazards in particular.

Notes

1. For an analytical explanation of this situation illustrated by Latin American countries see Albala-Bertrand 1993b.

Bibliography

Albala-Bertrand, J.M. 1993a. *The Political Economy of Large Natural Disasters.* Oxford: Clarendon Press.

Albala-Bertrand, J.M. 1993b. "Natural Disaster Situations and Growth: A Macroeconomic Model for Sudden Disaster Impacts." *World Development* 21(9):1417–1434.

Albala-Bertrand, J.M. 1999. "Industrial Interdependence Change in Chile 1960–90. A Comparison with Taiwan and South Korea." *International Review of Applied Economics* 13(2):161–191.

Albala-Bertrand, J.M. 2000a. "Complex Emergencies versus Natural Disasters. An Analytical Comparison of Causes and Effects." *Oxford Development Studies* 28(2):187–204.

Albala-Bertrand, J.M. 2000b. "Responses to Complex Humanitarian Emergencies and Natural Disasters. An Analytical Comparison." *Third World Quarterly* 21(2):215–227.

Barton, A. 1970. *Communities in Disaster. A Sociological Study of Collective Stress Situations.* Garden City, MI: Anchor, Doubleday.

Chang, H. 1996. *The Political Economy of Industrial Policy*. London: Macmillan.

Cochrane, H.C. 1975. *Natural Disasters and their Distributive Effects.* Boulder, CO: Institute of Behavioral Science.

Cuny, F.C. 1983. *Disaster and Development.* Oxford: Oxford University Press.

Dacy, D.C., and H. Kunreuther. 1969. *The Economics of Natural Disasters.* New York: Free Press.

Davis, I., ed. 1981. *Disaster and Small Dwelling.* Oxford: Pergamon Press.

Dynes, R.R. 1970. *Organized Behaviour in Disaster.* Lexington, MA: Heath & Co.

ECLAC (Economic Commission for Latin America and the Caribbean). 1999. *Manual for Estimating the Socio-Economic Effects of Natural Disasters.* Santiago, Chile.

Giarini, O., ed. 1984. *The Geneva Papers on Risk and Insurance*. Geneva: The Geneva Association.

Kunreuther, H. 1997. "Rethinking Society's Management of Catastrophic Risks." *Geneva Papers on Risk and Insurance* 83:151–176.

Mansoob, M., ed. 2002. *Globalization, Marginalization and Development.* London: Routledge.

Nafziger, W., and R. Vayrynen, eds. 2002. *The Prevention of Humanitarian Emergencies*. Houndmills: Palgrave.

Nayyar, D., ed. 2002. *Governing Globalization: Issues and Institutions.* Oxford: Oxford University Press.

Prince, S.H. 1920. "Catastrophe and Social Change." *Studies in History, Economics and Public Law* 94/1.

Quarantelli, E.L. 1978. *Disaster Theory and Research.* London: SAGE.

Rossi, P.H. and others. 1982. *Natural Hazards and Public Choice*. New York: Academic Press.

Smith, K. 1992. *Environmental Hazards: Assessing Risk and Reducing Disaster*. New York: Routledge.

Sorokin, P.A. 1942. *Man and Society in Calamity.* New York: Dutton.

Stiglitz, J. 2002. *Globalization and its Discontents.* London: Allen Lane.

Stewart, F., F.P. Humphreys, and N. Lea. 1997. "Civil Conflict in Developing Countries Over the Last Quarter of a Century: An Empirical Overview of Economic and Social Consequences." *Oxford Development Studies* 25(1):11–41.

Thomas, J. 1990. *Informal Economic Activity.* London: LSE Publications.

Weiss, J. 2002. *Industrialisation and Globalization*. London: Routledge.

White, G.F., ed. 1974. *Natural Hazards: Local, National, Global.* Oxford: Oxford University Press.

World Bank. 2001. *Globalization, Growth, and Poverty.* Washington, D.C.

Chapter 6

Interdependent Disaster Risks: The Need for Public-Private Partnerships

Howard Kunreuther

Do individuals or businesses have economic incentives to carry out socially appropriate levels of mitigation for reducing future disaster losses? This paper shows that property owners will systematically underinvest in protection due to the presence of *interdependent disaster risks*[1]

These are situations where damage to property or infrastructure creates direct or indirect losses to others. For example, the collapse of a building from an earthquake could cause severe damage to an adjoining structure. Kunreuther and Heal (forthcoming) have demonstrated that this type of interdependency may negate much of the benefits a property owner would otherwise obtain from adopting mitigation measures. The following three questions related to this interdependency are addressed below:

- What incentives do property owners have for investing in protection when their neighbors have **not** done the same?
- What types of public-private-sector partnerships are necessary for the adoption of cost-effective mitigation measures?
- How can one deal with problems of interdependencies in emerging economies such as Turkey's?

Incentives for Investing in Protection

A family is considering investing in a structural mitigation measure to reduce losses from a future earthquake. In making this decision, the family needs to balance the cost of the mitigation measures with the reduction in earthquake damage to its house. As shown below, the incentive to invest in mitigation is greatly diminished if surrounding homes fail to adopt protective measures. The challenge is to find ways to convince all property owners that it is in their best interest to invest in protection.

Suppose there are two identical adjoining homes H_1 and H_2 where there is a probability p that a severe earthquake will occur in their region. Currently both homes are **not** mitigated, so that if an earthquake occurs, the damage to each of the structures will be L. The cost of a mitigation measure is c. If both homes invest in protection, then the damage from an earthquake to each of them is assumed to be 0. On the other hand, if only H_1 invests in mitigation, then there is a probability $q < p$ that H_2 will suffer earthquake damage, which causes a loss L to H_1. This might occur, for example, if a water heater in one house was not bolted, an earthquake caused it to topple over, and the resulting fire spread to the neighboring house. The decision facing each family is whether to invest in mitigation, knowing that the other house may not be protected.

Assume that each homeowner has initial assets of A, perfect information on the risks and costs of protection, and has to make a choice between investing in protection, **Y**, or not to do so, **N**. Table 6.1 shows the outcomes to each individual *A* based on the four possible strategies:

The rationale for these payoffs is straightforward: if both invest in protection (**Y, Y**), then each incurs a cost of c and faces no losses, so each homeowner's net assets is $A - c$. If H_1 invests and H_2 does not [(**Y, N**)—top right entry], then H_1 incurs a cost of c and also runs the risk of a loss emanating from H_2. The probability of H_2 contaminating H_1 is q, so that H_1's expected loss from damage to H_2 is qL. This cost represents the negative

Table 6.1 Expected outcomes associated with investing and not investing in protection

Homeowner 1 (H_1)		*Homeowner 2 (H_2)*	
Y	**N**	**Y**	**N**
$A - pL$,	$A - [pL + (1 - p)qL]$,	$A - c, A - c$	$A - c - qL$
$A - c - qL$,	$A - [pL + (1 - p)qL]$,		$A - pL$

externality imposed by H_2 on H_1. The lower left payoffs (**N, Y**) are just the mirror image of these. If neither house invests in protection, (**N, N**), then both have an expected payoff of $A - pL - (1 - p)qL$.

Now that the outcomes have been specified, one can ask the natural question: under what conditions will the homeowners invest in protection? It is clear from table 6.1 that, for investment in protection to be a dominant strategy so each homeowner will want to invest in protection no matter what the other homeowner does, we need:

$$A - c > A - pL$$
$$\text{and } A - c - qL > A - pL - (1 - p)\, qL$$

The first inequality just says that $c < pL$:, the cost of investing in mitigation, must be less than the expected loss, the normal benefit-cost condition for an isolated home. The second inequality is more interesting: it reduces to $c < pL - pqL = pL(1 - q)$. This is clearly a tighter inequality, reflecting the possibility of damage from the other home to yours. This possibility reduces the incentive to invest in protection. Why? Because in isolation, investment in mitigation buys the homeowner complete freedom from risk; with the possibility of contagion, it does not. Even after investment in mitigation there remains a risk of loss emanating from the other unprotected home. Investing in mitigation buys you less when there is the possibility of contagion from others.

In the two-agent problem with identical costs, one can determine the optimal behavior of each homeowner if they both make decisions simultaneously without any communication. In this noncooperative environment if $c < pL(1 - q)$, then both agents will want to invest in protective measures (**Y, Y**); if $c > pL$ then neither agent will want to invest in protection (**N, N**). If $pL(1 - q) < c < pL$ then there are two Nash equilibria (**Y, Y**) and (**N, N**) and the solution to this game is indeterminate.

The solution concept for two agents with identical costs and risks is illustrated below with a numerical example. Suppose that $p = .1$, $q = .05$, $L = 1000$ and $c = 98$. The matrix in table 6.1 is now represented as table 6.2. If H_2 invests in security (**Y**), then it is worthwhile for H_1 also to invest in security, since without protection its expected losses will be $pL = 100$, and it will only have to spend 98 to eliminate this risk. If H_2 does not invest in security (**N**), then there is still a chance that H_1 will experience a loss even if it protects itself. The expected benefits to H_1 of investing in security will now only be $pL(1 - q) = 95$, which is less than the cost of the security measure. Hence H_1 will **not** want to invest in protection. In other words, either both agents invest in security or neither of them do so. These are the two Nash equilibria.

Table 6.2 Illustrative example: Expected costs associated with investing and not investing in protection

Homeowner 1 (H_1)		*Homeowner 2 (H_2)*	
Y	***N***	***Y***	***N***
A – 100,	A – 145,	A – 98,	A – 148
A – 148,	A – 145,	A – 98,	A – 100

Kunreuther and Heal (forthcoming) show that, as one increases the number of homes subject to damage, the incentive for any house to protect itself against a loss gets progressively worse. Imagine many homes, each one of which could cause a fire if it were unmitigated that would spread to all the other structures in the neighborhood whether or not they had invested in a loss-reduction measure. If there are enough homes that are unprotected, then there is a high likelihood that a protected home may still be damaged from one of these structures. Unless c is very low, there will be no incentive for any homeowner to invest in mitigation if he knows that most neighbors have not done so.

A similar interdependency exists between the damage to a region's infrastructure from a disaster and the decisions by property owners served by these lifelines to invest in mitigation measures. Suppose that a business knows that there is a good chance that if a hurricane wreaks havoc in its area, the electric utilities and/or water supply will be nonfunctional for a considerable period of time. Even if the business invests in mitigation to reduce physical damage to the structure, the owners of the firm know that it faces the risk of business interruption due to damage to the community's infrastructure. This type of contagion will discourage it from investing in some protective measures that it would otherwise undertake had the community lifelines been sufficiently protected to be functional after a disaster.

Need for Public-Private Partnerships

One way to encourage property owners to invest in security when they face the possibility of contagion from others is to internalize the externalities. This section briefly examines the roles that different policy tools—ranging from private market mechanisms to government regulations to collective choice—can play in encouraging agents to adopt protective measures for interdependent security problems.

Kunreuther and Heal (forthcoming) examine the role that different private sector mechanisms can play in encouraging investment in mitigation. They show that private insurance cannot encourage investment in protection because the insurer is only responsible for the damage to its own insured property. One reason for this contractual arrangement between insurer and insured is the difficulty in assigning causality for a particular event. On the other hand, consider a social insurance program that provided coverage to all property owners. It would want to develop a premium structure that encouraged investment in mitigation, since the government would be responsible for covering damage to all insured property.

The possibility of contagion from other units provides a rationale for well-enforced building codes that require property owners to adopt cost-effective protective mechanisms when they would not do so voluntarily. More specifically, building codes solve the coordination problem in the sense that all individual property owners are better off by adopting these loss-reduction measures. When asked whether they would do so voluntarily, they say "no" because they either know or assume that others will be unprotected.

There may also be a need for well-enforced regulations if there were externalities to other parties in addition to the contagion effects between the agents. For example, when a building collapses it may create externalities in the form of dislocations and other social costs that are beyond the economic losses suffered by the owners. These may not be taken into account when the owners or developers evaluate the importance of adopting a specific mitigation measure and, hence, may justify the need for building codes (Cohen and Noll 1981; Kleindorfer and Kunreuther 1999).

One way for the government to enforce its regulations is to turn to the private sector for assistance. More specifically, third-party inspections coupled with insurance protection can encourage property owners to reduce their risks from accidents and disasters. Such a management-based regulatory strategy shifts the locus of decisionmaking from the regulator to the property owners, who are now required to do their own planning as to how they will meet a set of standards or regulations (Coglianese and Lazer 2001; Kunreuther, McNulty, and Kang 2002).

Dealing with Interdependencies in Emerging Economies

Emerging economies face significant challenges in dealing with problems of interdependencies because many buildings have been too poorly designed to withstand the impacts of natural disasters, and the limited governmental personnel are not adequate to enforce building codes and other regulations for reducing future losses. These points are clearly illustrated by the case of Turkey.

The city of Istanbul is very likely to experience strong shaking from a large earthquake in the Marmara Sea during the next 30 years (Parsons and others 2000). Subsequently, most of the current citizens of Istanbul (the majority of the city's population is under the age of 35) are likely to experience this event. Without preparation and prevention, the people of Istanbul face a high risk of suffering significant losses from earthquake damage, including loss of life. The Greater Metropolitan Municipality is taking steps to address mitigation for critical infrastructure, as well as providing public education concerning nonstructural approaches to risk reduction in homes. However, there are no steps in place to address the structural fragility of the city's thousands of residential apartment buildings.

Based on an incomplete engineering inventory, approximately 5,000 of these buildings have been assessed as likely to experience complete structural failure when subjected to strong shaking, risking total loss of life of occupants of these buildings. Another class (40,000+) are likely to experience significant structural damage, also with the potential to cause death or serious injury. Poor performance of buildings in areas east of Istanbul, with similar construction design and quality, was demonstrated in 1999 by two very severe earthquakes. A compulsory earthquake insurance program for homes has been initiated in an attempt to share the expected cost of reconstruction among the population. This financial instrument, however, only deals with losses following a disaster and does not have a premium structure that provides economic incentives for property owners to invest in measures to reduce the risk (Gulkan 2001). The challenge facing Turkey and other emerging economies is how to finance and enforce these mitigation measures. Benefit-cost analyses of retrofitting measures suggest that it will benefit the potential victims and lead to an improvement in social welfare (Smyth and others forthcoming). Institutions such as the World Bank have a stake in promoting cost-effective mitigation measures because such measures promise to save them considerable expenses that they would otherwise incur following a future disaster. Developed countries also have a stake in the outcome because of their interest in ensuring that emerging economies such as Turkey's are on a sound economic footing.

Future Research

The issues discussed above also suggest a number of empirical studies on interdependent security. Given the concern with terrorism both in the United States and the rest of the world, it would be interesting to learn more about what factors lead some individuals and organizations to invest in security and why others are reluctant to do so. What institutional mechanisms would aid the decision-making process of agents considering protective measures in situations where others would be affected? What are the appropriate roles of the public and private sectors in developing strategies that include economic incentives (fines or subsidies), third-party inspections, insurance coupled with well-enforced regulations, and standards?

Proposed solutions depend on the nature of the disaster and the current institutional arrangements in the country or region of interest. They also require data on the likelihood of the event occurring and its consequences, as well as the uncertainties and ambiguities associated with these estimates. In developing strategies for dealing with these problems, one needs to consider the type of available information, the nature of the decisionmaking processes of the key stakeholders, and how their behavior differs from normative models of choice.

Finally, one needs to balance how one allocates resources in an efficient manner with distributional and equity considerations. This issue is particularly important in emerging economies, where explicit ways of dealing with the poverty problem and how to deal with low-income families who cannot afford to invest in mitigation measures unless they are highly subsidized by funds from other sources must be considered.

Notes

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Bibliography

Coglianese, Cary and David Lazer. 2001. "Management-Based Regulation: Using Private Sector Management to Achieve Public Goals." Regulatory Policy Program Working Paper RWP01-047. Cambridge, MA: John F. Kennedy School of Government, Harvard University.

Cohen, Linda and Roger Noll. 1981. "The Economics of Building Codes to Resist Seismic Shocks." *Public Policy* Winter:1–29.

Gulkan, Polat. 2001. "Revision of the Turkish Development Law No. 3194 Governing Urban Development and Land Use Planning." In Paul Kleindorfer and Murat Sertel, *Mitigation and Financing of Seismic Risks: Turkish and International Perspectives.* Dordrecht: Kluwer Academic Publishers.

Kleindorfer, Paul and Howard Kunreuther. 1999. "The Complementary Roles of Mitigation and Insurance in Managing Catastrophic Risks." *Risk Analysis* 19:727–38.

Kunreuther, Howard, Patrick McNulty, and Yong Kang. 2002. "Improving Environmental Safety Through Third Party Inspection." *Risk Analysis* 22:309–18.

Kunreuther, Howard and Geoffrey Heal. Forthcoming. "Interdependent Security." *Journal of Risk and Uncertainty.*

Parsons,T., S. Toda, R. Stein, A. Barka, and J. Dieterich. 2000. "Heightened odds of large earthquakes near Istanbul: An interaction-based probability calculation." *Science* 288:661–65.

Smyth, Andrew and others. Forthcoming. "Probabilistic Benefit-Cost Analysis for Earthquake Damage Mitigation: Evaluating Measures for Apartment Houses in Turkey." *Earthquake Spectra*.

Traffic drives down flooded Manila street, 2002.

Part II

Environment, Climate Variability, and Adaptation

Chapter 7

Cities and Climate Change

Anthony G. Bigio

This was prepared as a background paper for the World Development Report 2003 and was presented at the World Bank's Urban Forum in April 2002. Its four key messages are the following:

a) Cities in developing countries are severely threatened by the impacts of climate change that already cost them billions of dollars and compound other ongoing developmental challenges;

b) Given the limited role of the developing world in the historical accumulation of greenhouse gases, there are increasing expectations that financial assistance for adaptation to climate change should be provided by OECD countries;

c) There is emerging evidence that some of The World Bank's infrastructure projects are vulnerable to the impacts of climate change and as a consequence may be unable to meet their objectives and provide the full range of benefits expected when they were financed; and

d) Given that some 30 percent of The World Bank's investments are in urban areas, an increased ability by the Bank's infrastructure staff to incorporate climate change considerations into project design would play a positive role in assisting cities.

Impacts of Climate Change on Cities

In the latter part of the 20th century, the earth's average temperature rose 0.6° Celsius. Projections for further increases in the 21st century vary considerably, from a minimum of 1.4°C to a maximum of 5.8°C. The increase will depend upon the level of stabilization of carbon emissions, the pace of decarbonization of the global economy, and the patterns of demographic and economic development. Such increases represent a dramatic shift with regard to natural variability in the planet's mean temperature, which has remained within 0.5°C for the last 1,000 years. The latest report from the Intergovernmental Panel on Climate Change (IPCC), "Third Assessment Report: Climate Change 2001" (IPCC 2001b), establishes a direct correlation between the sustained use of fossil fuels (that occurred primarily in industrialized countries), the resulting accumulation of CO_2 and other gases in the atmosphere, and global warming.

Global warming manifests itself in many different ways in the biosphere. The two most relevant to the subject of this paper are the progressive rise in sea level and the increased intensity and frequency of climatic episodes leading to natural disasters. Both represent a significant threat to urban areas in developing countries.

According to several projections, the sea level is expected to increase anywhere from 8 to 88 centimeters during the twenty-first century, mostly due to thermal expansion and the loss of mass from glaciers and ice caps (IPCC 2001b: 16). The frequency and intensity of natural disasters are also growing rapidly worldwide. A recent analysis of great natural catastrophes since 1960 shows an increase in the 1990s by a factor of three, and this seems to be directly correlated with global warming. Economic losses adjusted for inflation rose by a factor of nine (Munich Re 1999).

The rapid pace of urbanization, compounded with an ever-increasing population burden, has also significantly increased the overall vulnerability of urban areas to natural disasters. The location of many urban areas with large populations and critical economic assets in high-risk zones contributes to the increased attention given to impacts in urban areas of disasters induced or enhanced by climate change (Munich Re 2000). In the case of cities in developing countries, the size and vulnerability of informal settlements, generally built in unstable areas such as coastal zones, flood-prone planes and ravines, and geologically unstable slopes, greatly increase their susceptibility to risk. The impacts of a rising sea level and more frequent and intense natural disasters in rural areas will likely generate an additional influx of people to cities. Such "environmental refugees" often become permanent, thus increasing the vulnerability of cities yet again (Hardoy and others 2001).

Developing countries are considered to be particularly vulnerable to climate change, as many are in tropical and sub-tropical zones with economies and societies highly dependent upon the climate and heavily impacted by its variations. Many of the largest cities in Africa, Asia, and Latin America are port cities, historically linked to a colonial past, and directly subjected to the impacts of a rising sea level. The high cost of land in a central city and around ports has often encouraged major commercial developments on land reclaimed from sea and river estuaries that are especially vulnerable to a rise in sea level (Hardoy and others 2001: 205).

The IPCC Third Assessment Report Volume 2: "Impacts, Adaptation and Vulnerability," updates existing knowledge and provides integrated field studies, results of modeling simulations, and other available information on the projected impacts of climate change on urban areas (IPCC 2001a). According to the IPCC report, the main threats to the urban populations and physical assets of developing cities, impacted with more or less intensity based on the actual climate changes that unfold, are the following:

- ***A rise in sea level:*** This is the most fundamental challenge that urban settlements face from global warming. The threat will likely increase due to the ongoing influx of people and economic assets into coastal zones. At risk are entire sections of coastal cities and their infrastructure, beaches subject to erosion, river floors in estuarine zones subject to sedimentation, and wetlands and tidal flats subject to flooding (box 7.1). Furthermore, groundwater risks increased salinization, and coastal aquifers risk diminishing, which affect fresh water supplies and peri-urban agriculture.
- ***Tropical cyclones:*** Increasingly frequent and intense tropical and extra-tropical cyclones will likely cause severe wind damage and storm surges which, compounded with a rise in sea level, are expected to

Box 7.1 Coastal cities and small island states

By mid-century, more than 70 percent of the population in settlements that could be flooded due to a rise in sea level are likely to be located in West and East Africa, along the southern coast of the Mediterranean, and South and Southeast Asia. With a 40-centimeter rise in sea level, the midpoint of the IPCC projection ranges for the end of the century, the world population at risk from annual flooding is expected to increase from the current 10 million to 22–29 million by the 2020s, to 50–80 million by the 2050s, and to 88–241 million by the 2080s (Nicholls and others 2001). The biggest impacts, however, are expected in the small island states of the Atlantic, Pacific, and Indian Oceans.

Cities such as Alexandria, Egypt; Banjul, The Gambia; Tianjin, China; Jakarta, Indonesia; and Bangkok, Thailand will be affected. A 50-centimeter sea-level rise along Egypt's coastal zones would affect 2 million people and 214,000 jobs, and cause land and real estate losses worth US$35 billion (El-Raey 1997). Alexandria's Old City, 12 meters above sea level, is safe from the direct effects of a rise in sea level. However, the port area and newer suburbs are at risk since, with the aid of flood defenses, they were constructed on lowlands. Low marshes and lagoons that surround the city could be lost or seriously contaminated with saltwater due to a rise in sea level. Ultimately, the city could become a peninsula, surrounded by the Mediterranean and only accessible by bridges and causeways (Turner and others 1990).

The average number of people in Africa affected by coastal flooding could increase from the one million of 1990 to a worst-case scenario of 70 million by 2080 (Nicholls 2001: 515). Through coastal erosion and a rise in sea level, Banjul, capital of The Gambia, could disappear by mid-century. East African coastal settlements are also at risk.

In most small island states, coastal planes have provided the best locations for urban centers and population concentrations, physical assets, economic activities, and services. On most Caribbean islands, for instance, more than half of the population lives within two kilometers of the coast. On atolls, the most important infrastructure and population clusters are less than 100 meters from the shoreline. The threats induced or enhanced by climate change will severely affect this group of nations and their cities (IPCC 2001a: 847, 864), which are becoming acutely aware of their vulnerability.

become a severe problem for low-lying coastal regions and cities. Ports and other coastal infrastructure are especially at risk.
- ***Flooding and landslides:*** Expected increases in the scale, intensity, and frequency of rainfall in most developing countries will severely strain or overwhelm the storm drainage systems of many urban centers. This could lead to periodic flooding of low-lying areas as well as landslides and mud-slips on geologically unstable slopes, often subject to informal settlements. Cities built next to rivers and on reclaimed lands in riverbed planes will be prone to additional inundations.
- ***Water quality and shortage:*** Urban flooding damages water treatment works and flood wells, pit latrines, and septic tanks. Sewage treatment systems and solid waste disposal areas can also be affected, contaminating water supplies. Where overall rainfall decreases, droughts will likely compromise the replenishment of the water tables, the normal sources of water supply.
- ***Heat and cold waves:*** Intense episodes of thermal variability could severely strain urban systems by adding an environmental health risk for more vulnerable segments of the population, imposing extraordinary consumption of energy for heating and air conditioning where available, and disrupting ordinary urban activities.

In addition to these major threats, the IPCC report indicates additional risks related to:
- increased possibility of urban fires, severe hail, and windstorms;
- negative impacts on the productivity of fisheries and agriculture, on which some urban economies partially depend;
- worsening urban air pollution exacerbated by increased ground ozone formation;
- enhanced effects of urban heat islands due to higher overall temperatures.

The indirect impacts of such climatic threats are, of course, much wider. They include environmental health problems due to the expected changes in geographic ranges and the incidence of vector-borne and infectious diseases, allergic and respiratory disorders, nutritional disorders due to climate-related food shortages, and the physical damage to and institutional strains imposed upon the health care system (Hardoy and others 2001: 203). Where impacts are felt, urban economic activities will likely be affected by physical damage to infrastructure, services, and businesses. There will also be repercussions on overall productivity, trade, tourism, and the provision of public services.

Economic Valuation of Climate Change Impacts on Cities

Of the major threats to cities described above, only the rising sea level has an exclusive correlation with climate change. The other four threats are natural disasters and climatic episodes that are exacerbated in their intensity and frequency by climate change (box 7.2). Thus, the major attempts at valuating, in economic terms, the impacts of climate change on physical infrastructure generally refer to a rise in sea level and are based on the funds needed to defend the coastal areas and replace physical assets. For instance, the cost of protecting port facilities and coastal structures, raising wharves and quays, and reconstructing water gates

Box 7.2 Natural disasters: what percentage is due to climate change?

In 1982, Peru's GDP declined by 12 percent, half of which was attributable to the El-Niño-related floods of that year. Between 1989 and 1996, China experienced annual losses from natural disasters averaging 3.9 percent of GDP. In 2000, flooding in Mozambique resulted in direct and indirect losses of some 6 percent of GDP (Mimura and Harasawa 2001). Damage and losses from Hurricane Mitch in 1999 equaled 80 percent of GDP in Honduras and 49 percent in Nicaragua (FAO 1999: 409).

These figures have not been disaggregated to show losses that occurred in cities as opposed to rural areas. Nor can we ascertain how many of these disasters or how much of their intensity was due to the inducing or enhancing effects of climate change. However, they help us understand the order of magnitude of the problems faced by cities in developing countries due to climate change. Further detailed analysis is needed, however.

and pumping stations for a one-meter rise in sea level (the high point of the IPCC projection ranges for the end of the century) in 39 prefectures in Japan has been estimated at US$194 billion, or about 7 percent of annual GDP (Mimura and Harasawa 2001).

Conversely, the incremental nature of the intensity and frequency of violent climatic episodes due to climate change is hard to disaggregate from the "baseline," even if scientific evidence has proven the correlation of intensity and frequency with the recent increase in atmospheric temperature. Data on economic losses associated with catastrophic events show that in constant 1999 U.S. dollars, they have increased worldwide from an average of US$71.1 billion in the 1960s to an average of US$608.5 billion in the 1990s (Freeman 2000). Although the economic impacts of these catastrophic episodes are relatively evenly split between developed and developing countries, when related to respective GDP, the economic losses are significantly higher in developing than in developed countries (Sharma and others 2000). Average economic losses in developing countries due to climate change were tentatively estimated at 2 to 9 percent of GDP by the IPCC in its Second Assessment Report, but variability in the underlying assumptions is considered high.

Adaptation of Cities to Climate Change

Throughout history, cities and human settlements have adapted to climate variability, but the intensity and pace of the present and forthcoming climate changes induced by the continued and ongoing use of fossil fuels are already and will increasingly be a major challenge to many of them. Urban adaptation to climate change can be defined as the sum of all physical and organizational adjustments to urban life that will be required to cope with the profound and durable changes in weather and climatic patterns. Determinants of adaptive capacity include the availability of financial resources, technology, specialized institutions and human resources, access to information, and the existence of legal, social, and organizational arrangements (Burton and Van Aalst 1999), all of which are assets that are typically scarce in developing countries and cities. In cities with a proven vulnerability to climate change, investments will likely require:

- *"hardening up" of the infrastructure systems, including storm-drainage systems, water supply and treatment plants with protective physical improvements;*
- *protection or relocation of solid waste management facilities, energy generation and distribution systems; and*
- *consolidation of hydro-geologically fragile areas.*

Coastal cities will likely need to invest in heavy physical infrastructure projects specifically related to sea-level rise, such as:

- *sea-surge protective barriers and dams;*
- *reconstruction of harbor facilities; and*
- *flood barriers and Tsunami-prevention facilities* (IPCC 2001a: 405).

Such expenditures represent a significant burden for the public sector, for private utility companies, and indirectly for urban economies as a whole.

Permanent changes to local ecosystems induced by climate change such as the salinization of ground-water and river estuaries might also alter the local economic base. Adaptation to such changes may be difficult to achieve, but it is essential. An integrated adaptation response might involve coastal zone protection, the creation of new breeding grounds for fish, the expansion of irrigation agriculture, the implementation of new public health measures, appropriate land-use planning, and building codes that internalize climate change constraints (Burton and Van Aalst 1999: 6). While private investment must become part of the strategy, the public sector will have overall responsibility for the adaptation plans and managing such transitions.

In some cities in developing countries, relocation or "managed retreats" (IPCC 2001a: 405) of resident populations and economic activities to less vulnerable sections of urban areas will have to take place over time. This would require a mix of market incentives and public sector planning and investments. Increased awareness of vulnerability to climate change can induce private firms to relocate, especially when the differential costs for insurance and re-insurance, where applicable, represent a powerful incentive to do so. However, this would not apply to the informal sector or to small businesses that do not have the necessary resources. Replacement of ozone-harming assets at the end of their productive lifecycles may create opportunities for adaptation through upgrades or relocation. Land-use planning should channel new residential developments and industrial investments toward less vulnerable areas. However, residents of poor and informal settlements and slums—unless assisted—would in all likelihood lack the tenure and resources to vacate the vulnerable areas in exchange for safer ones.

In the context of scarce financial and technical resources and of competing developmental priorities, investments related to the adaptation of cities—their physical infrastructure, local economy, basic urban services, and residential settlements—to the impacts of climate change will not be popular. They will only be possible if there is an increased understanding of urban vulnerability and the ability to demonstrate that the investments will be targeted at aspects of urban development that require urgent attention. Informal settlements and critical infrastructure such as water supply and drainage systems may be already stretched to the limit and would be first priorities.

Management and institutional aspects of climate change adaptation can be just as challenging, if not more so, than financial ones. These include:

- generation of reliable and comprehensive assessments of risk vulnerabilities for exposed cities and the dissemination of such information;
- establishment of early warning systems and evacuation plans, including emergency preparedness and neighborhood response systems;
- improved efficiency of water supply management, by minimizing leakages and instituting marked-based pricing mechanisms;
- improving health education and institutional capacity in urban environmental management;
- regularizing property rights for informal settlements and other measures to allow low-income groups to buy, rent, or build good-quality housing on safe sites (IPCC 2001a: 405–406).

Mitigation of Greenhouse Gas Emissions in Cities

Cities in developing countries can contribute to the mitigation of global greenhouse gas (GHG) emissions by reducing the volume of CO_2, methane, and other gases that they release. Overall, however, the contribution of developing countries to global emissions is low, estimated at some 21 percent of the total, or 35 percent if the transition countries of the former Soviet Union are included.

Discussions surrounding mitigation have led to a heated political debate between developing and industrialized countries over bearing responsibility for past emissions and regulating current emissions. Developing countries insist that industrialized countries assume the burden of past emissions that led to global warming and that developing countries be allowed unrestricted access to energy generation and consumption, which is considered critical for their future economic growth. They argue that costly mitigation measures are now required on account of the historical accumulation of carbon emissions and the high level of fossil fuels currently consumed by industrialized countries that should henceforth pay the costs of mitigation.

The reduction of GHG emissions has a globally beneficial effect wherever it occurs. The commitment of some industrialized countries to reduce their national global emissions in the future (subject to ongoing negotiations at the international level) and the relatively lower costs of GHG emissions reductions in developing countries provide the rationale for international carbon emissions trading. This represents an opportunity for "win-win" investments in cities in developing countries, provided that the projects financed have sound local *and* global objectives.

In cities, the direct sources of global emissions include energy generation, vehicle use, industrial and point-source use of fossil fuels, and burning of biomass. Indirect sources include electrical energy produced for public lighting, transportation, and industrial, commercial, and household consumption. Added together, these determine overall urban energy demand. Examples of interventions that combine significant local benefits with GHG emissions abatement that can generate revenues for developing cities are:

- ***Improved building materials and energy efficiency:*** Reduce energy requirements for heating, lighting, and cooling and can increase efficiency in the use of building materials and the building cycle itself.
- ***Transport demand management:*** Reduces the total volume of CO_2 emissions of vehicles by promoting greater ridership in mass transportation systems,

pedestrian zones, nonmotorized transportation, and the use of more fuel-efficient vehicles and environmentally friendly fuels.

- ***Methane recuperation from landfills:*** Channels harmful methane gas emissions that would normally be released into the atmosphere into power generation—a viable investment with good economic returns.
- ***Cleaner energy generation:*** Uses carbon sequestration to reduce pollution by switching power plants from coal to natural gas, promoting the use of gas and clean energy sources to replace biomass, and cogenerating heat and electricity—results in significant local pollution abatement.

Financing of Adaptation and Mitigation Projects in Developing Cities

The United Nations Framework Convention on Climate Change (UNFCCC) was established to forge international cooperation in the mitigation of further climate change; therefore, its provisions and implementation mechanisms primarily address opportunities for GHG emissions abatement. The Global Environment Facility (GEF) was set up as the financial mechanism of the UNFCCC to assist developing and transitional countries with four global challenges: biodiversity conservation, ozone depletion, international waters protection, and climate change. In the latter area, GEF has so far exclusively focused on the implementation of projects with GHG emissions abatement or mitigation objectives.

During the 1990s, the climate change community paid relatively less attention to adaptation, while on the other hand, awareness of and preparedness for natural disasters have significantly increased. This may be changing rapidly, however, as the impacts of climate change are beginning to be felt more strongly. Developing countries are now increasingly asking for project and financial assistance from industrialized countries for adaptation projects and their related costs.

Providing funding to developing countries is controversial, however. Many of the problems relating to global warming were caused by industrial countries' sustained use of fossil fuels over the past 150 years, during which accumulated carbon emissions became trapped in the atmosphere. Consequently, it can be argued that the costs of adaptation should be presented as "reparation costs" for which industrialized countries must pay. This is not reflected in the letter or spirit of the UNFCCC agreements, however, and many industrialized countries do not want to address this issue.

Financial provisions for vulnerability and adaptation in the UNFCCC are currently limited to 2 percent of project investments in developing countries, resulting from the trade of Carbon Emission Reduction (CER) certificates. Such trade will start only when the Kyoto Protocol is ratified and the Clean Development Mechanism (CDM), conceived as the certification and clearinghouse for the trading of emissions between developing and transitional economies on one side, and industrialized countries on the other, becomes functional. Ratification of the protocol is expected in 2002 or 2003, after which national regimes for emissions reductions will be adopted.

Several industrialized countries (Canada, Iceland, Norway, New Zealand, Australia, Switzerland, and members of the European Union) are considering the establishment of a Special Climate Change Convention Fund or Adaptation Fund to be administered by the GEF. The fund would make limited financial resources available to developing countries for climate change adaptation purposes. The overall endowment of the fund would be some €450 million annually, and it is expected to become effective in 2005.[1] Least-developed countries would be the primary beneficiaries as their GHG emissions (1 percent of the total) would not entitle them to any significant gains from the Clean Development Mechanism for emissions trading, while their adaptation needs are often the largest. The World Bank's Environment Strategy also refers to the creation of a Variability and Adaptation Facility (VAP), to be financed by donor governments in the near future (World Bank 2001).

In the case of mitigation, on the other hand, UNFCCC financial resources and mechanisms that can be accessed by the public and the private sector to contribute to the abatement of GHG emissions are already in place. Targeted interventions include land-use planning, urban transport, energy generation and efficiency, and urban environmental management.

The UNFCCC has established Activities Implemented Jointly (AIJ), also known as the Joint Implementation (JI), as the formal mechanism for collaboration between industrialized and developing countries to implement projects that have GHG-abatement objectives. Under AIJ, an industrialized country partners with a developing country to provide financial and technical assistance for a project.[2]

GEF Operational Programs (OP) in the climate change area are all highly relevant to cities. These programs co-finance development projects that combine significant local objectives with global ones for which GEF provides grants equivalent to the "incremental costs." These are:

- OP 5: Removal of Barriers to Energy Efficiency and Energy Conservation;
- OP 6: Promoting the Adoption of Renewable Energy by Removing Barriers and Reducing Implementation Costs;
- OP 7: Reducing the Long-Term Costs of Low Greenhouse Gas Emitting Energy Technologies; and
- OP 11: Promoting Environmentally Sustainable Transport.[3]

The World Bank Group-GEF portfolio consists of 62 projects, for which $6.2 billion has been mobilized—$730 million from the GEF and the remainder from The World Bank Group, donors, private investors, and governments (World Bank 2001).

Finally, in the wake of the Kyoto Protocol ratification and the effectiveness of the CDM, the Prototype Carbon Fund (PCF) was established by The World Bank. The PCF is a pilot project to test carbon emissions trading, channel financial resources and information, and build capacity in developing countries on GHG emissions abatement issues. PCF emphasizes the development of renewable energy projects such as wind, small hydropower, solar direct and photovoltaic, landfill gas, and refuse-derived fuel. Additionally, energy-efficiency projects involving buildings and appliances are also financed under the PCF, which has a significant share of such projects in its portfolio (PCF 2001). The capital of the PCF is currently $145 million.

An analysis of the World Bank/GEF portfolio in the area of climate change provides an encouraging example of the proactive work in which the Bank could further engage itself should the Adaptation Funds mentioned earlier become available. The Bank could focus on assisting its client cities by designing programs and projects aimed at relevant local developmental priorities and incorporating climate change objectives—mitigation or adaptation—to be supported by concessional financing at no cost to the client.

Implications for The World Bank's Infrastructure Projects in Urban Areas

A number of key strategies call for the integration of climate change in The World Bank Group's work: the 1999 Energy and Environment Strategy, "Fuel for Thought;" the 2001 Environment Strategy, "Making Sustainable Commitments;" and the 2002 Urban Transport Strategy, "Cities on the Move." Climate change is also classified as a corporate public good priority and forms part of the Millennium Development Goal[4] of ensuring environmental sustainability. While the Bank is active through its lending operations in the mitigation of future climate change, however, vulnerability and adaptation objectives are rarely found as part of the developmental objectives of its projects or as project risks that need to be mitigated through given interventions.

The most comprehensive review to date of the Bank's performance in this area is to be found in "Come Hell or High Water—Integrating Climate Change Vulnerability and Adaptation into Bank Work," by Ian Burton and Maarten van Aalst, Environment Department Paper No. 72, 1999. The review finds the level of integration modest and provides numerous examples of projects that have failed to internalize obvious climate change risks, to the detriment of the Bank's clients and the institution's integrity.

Among the examples provided in the study, an emergency loan for potable water service recovery and restoration and flood protection for the city of Georgetown, Guyana, after the 1997–98 El Niño episode, was reviewed. Despite the fact that a significant portion of the city is below sea level and the emergency loan addressed damage caused by a climatic episode, the intensity of which was enhanced by global warming, no new assessment of the risks was made in project design. This is often the case in hurried emergency operations, making the new investment equally vulnerable to further climate-induced damage.

In the absence of concessional financing for adaptation, it is understood that Bank clients would be unwilling to borrow for climate change, but the authors argue that the Bank—in addition to promoting more awareness of climate change concerns—should at the very least (Burton and Van Aalst 1999: 35):

- ***Address climate change concerns in the Country Assistance Strategies (CAS):*** Currently CASs do not generally cover such risks. Especially for those countries that are known to be particularly vulnerable, the CAS could highlight activities to be avoided or discouraged as well as new activities designed to take advantage of opportunities opened up by climate change if milder climates or increased precipitation affect previously cold or dry regions (Burton and Van Aalst 1999: 13).
- ***Minimize the vulnerability of the Bank's portfolio to climate change:*** Based on examination of the Bank's portfolio in countries with known vulnerability,[5] an average of 37 percent of projects are at some degree of risk due to their location, design, or for failing to have taken into account climate change impacts on water flows, sea-level rise, and related issues.
- ***Maximize the role of the Bank's portfolio on vulnerability and adaptation:*** As part of the same portfolio review, the authors found that 43 percent of the projects could help reduce vulnerabilities to climate change by incorporating adaptive considerations into their designs such as the heights of bridges and embankments, the expected frequency of coastal storms, or other "no regrets" or noncontroversial measures (Burton and Van Aalst 1999: 18).

These recommendations are particularly relevant for the Infrastructure (INF) Vice-Presidency of The World Bank, home to three sectors responsible for the majority of the Bank's urban infrastructure investments: energy and mining; transportation; and water, sanitation, and flood protection. They are also relevant for urban development, an INF theme that carries the overall responsibility for assisting client cities with their development strategies, improving urban livability and reducing urban poverty, through physical investments and policy guidance. The Disaster Management Facility (DMF) and the Cities Alliance are working on closely related issues: the first, as it addresses concerns of disaster awareness, preparedness and reconstruction; the second, as it focuses on the elimination of urban slums and informal settlements built in vulnerable locations.

About 30 percent of the Bank's overall investments, or $6–7 billion, take place in urban areas. Only 5 percent of this is handled directly by urban sector units. Urban projects, in addition to internalizing climate change mitigation and adaptation concerns in the design of their physical components, could also provide opportunities to ensure that such integration occurs as well in all urban projects, regardless of sector.

Some short-term measures to begin to address these issues could include:

- Collection and validation of information on specific vulnerability to climate change in urban areas of countries at risk
- Review of a sample of active projects in urban areas of at-risk countries to identify opportunities for minimizing risks and including "no regrets" measures
- Dissemination of practical information on mitigation measures and financial mechanisms, in an urban context, to urban and infrastructure staff.

As climate change dramatically continues to manifest itself with loss of life and property and affect profound changes to livelihoods in cities of the developing world, The World Bank has the obligation to assess its importance and assist its client cities in addressing these special challenges. While its agenda will still be driven by the mission of reducing poverty and the Millennium Development Goals, the increasing prominence of climate change must be taken fully into account and internalized to design and implement development projects that target the special needs of populated and growing urban areas.

Notes

1. Personal communication with Alan Miller, Senior Environmental Specialist, GEF, January 28, 2002.
2. See http://unfccc.int/program/coop/aij/index.html.
3. See <http://www.undp.org/gef/undp-gef_focal_areas_of_action/sub_climate_change.html programs>.
4. The eight Millennium Development Goals are: eradicate extreme poverty and hunger; achieve universal primary education; promote gender equality and empower women; reduce child mortality; improve maternal health; combat HIV/AIDS, malaria, and other diseases; ensure environmental sustainability, and develop a global partnership for development.
5. Bangladesh, Ecuador, Guyana, Papua New Guinea, Samoa, and Zimbabwe.

Bibliography

Burton, I. and M. Van Aalst. 1999. "Come Hell and High Water—Integrating Climate Change Vulnerability and Adaptation into Bank Work." *ESSD Climate Change Series*. Washington, D.C.: The World Bank.

El-Raey, Mohamed. 1997. "Vulnerability Assessment of the Coastal Zone of the Nile Delta in Egypt to the Impacts of Sea-level Rise." *Ocean and Coastal Management* 37(1):29–40 as quoted in IPCC *Third Assessment Report* Vol. 2, chapter 7.

FAO (Food and Agricultural Organization of the United Nations). 1999. *The State of Food Insecurity in the World* as quoted in IPCC *Third Assessment Report,* Vol. 2:409.

Freeman, K. 2000. "Infrastructure, Natural Disasters and Poverty." In Alcira Kreimer and M. Arnold, eds., *Managing Disaster Risk in Emerging Economies.* Washington, D.C.: The World Bank.

Hardoy, Jorge and others. 2001. *Environmental Problems in an Urbanizing World.* London: Earthscan: 207.

IPCC (Intergovernmental Panel on Climate Change). 2001a. *Climate Change 2001: Impacts, Adaptation and Vulnerability—Contribution of Working Group II to the Third Assessment Report of IPCC.* Cambridge: Cambridge University Press: 383–416.

IPCC (Intergovernmental Panel on Climate Change). 2001b. *Climate Change 2001: The Scientific Basis—Contribution of Working Group I to the Third Assessment Report of IPCC*. Cambridge: Cambridge University Press.

Mimura, N. and H. Harasawa, eds. 2001. *Data-book of Sea-level Rise 2000*. Tsukuba: Center for Global Environmental Research, NIES as quoted in IPCC *Third Assessment Report*, Vol. 2:396.

Munich Re, Press Release March 15, 1999:1.

Munich Re. 2000. "World of Natural Disasters." CD-ROM, Geospecials/Megacities.

Nicholls, R. and others. 1999. "Increasing Flood Risk and Wetland Losses due to Global Sea-level Rise: Regional and Global Analyses." *Global Environmental Change* 9:S69–S87 as quoted in IPCC *Third Assessment Report* Vol. 2, chapter 7.

PCF (Prototype Carbon Fund). 2001. *Annual Report 2001,* Washington, D.C.: The World Bank: 17.

Sharma, M. and others. 2000. "Reducing Vulnerability to Environmental Variability." *Environment Strategy Background Paper.* Washington, D.C.: The World Bank: 5.

Turner, R. and others. 1990. "Cities at Risk." London: BNA International as quoted in Hardoy and others, *Environmental Problems in an Urbanizing World.* London: Earthscan.

World Bank. Environmental and Socially Sustainable Development. 2001. "Climate Change." *Environment Strategy.* Washington, D.C.: World Bank, 175.

Chapter 8

The Resilience of Coastal Megacities to Weather-Related Hazards

Richard J. T. Klein, Robert J. Nicholls, and Frank Thomalla

The 20th century has been characterized by a fundamental change to humanity: we have moved from being a predominantly rural to a predominantly urban species (UN/DESA 2001; UNEP 2002). Further, nearly all future population growth is expected to occur in urban areas as this process of urbanization continues through the 21st century. Part of this process has been the emergence of large cities—larger cities than have ever existed in the history of humanity—which are often termed *megacities* (defined in this paper as cities with a population exceeding 8 million inhabitants). Most of these megacities are found in coastal locations (Nicholls 1995), and their development is raising a range of fundamental management questions (Timmerman and White 1997).

History shows us that some of the world's large cities have a long history of continuous occupancy and importance, even though they have adjusted to changing circumstances. Cairo, Istanbul (Constantinople), and Baghdad began the second millennium as they ended it—among the world's largest cities. Other major cities in 1000 A.D. are now of relatively minor importance (e.g., Kaifeng, China; Nishapur, Persia; Córdoba, Spain) or have even been abandoned (Angkor, Khmer Empire) (Harrison and Pearce 2000), although all of these examples of abandonment are noncoastal cities. Weather-induced hazards are one potential reason for such decline. While the new coastal megacities can command large resources and significant political influence, they are also concentrating increasing populations in potentially hazardous locations, particularly in the new emerging megacities in the developing world. Thus, the development of these cities requires successful mitigation of these hazards.

System resilience is seen as a desirable property in the face of a range of potential stresses, including weather-induced hazards and disaster reduction (UN/ISDR 2002a). According to Costanza and others (1995), coastal ecosystems are highly resilient because of the diversity of their functions and the linkages between these functions. In the same manner, it is argued that coastal economies are more diverse and have multiple niches and that they are inherently more resilient because of the resilience of the ecosystems on which they depend (Adger 1997).

This paper explores the concept of resilience in the context of coastal megacities, and particularly explores its value and utility in the context of hazard management and reduction. First the development of coastal zones and megacities is explored, in order to define the context of the question. This includes defining an explicit set of "coastal megacities" by drawing on data of UN/DESA (2001). Then weather-related hazards in coastal zones and relevant hazard-reduction strategies are considered. This analysis focuses on the hazards that are specific to coastal locations, with particular emphasis on megacity and other large city locations. It also includes an analysis of sea-level rise and climate change, as these are beginning to modify weather-induced hazards in coastal areas, and they are encouraging new thinking on hazard-mitigation strategies. Note that in a parallel paper, Bigio (2002) provides an overview of the challenges that climate change poses to cities. The academic debate over the last 30 years on the meaning of resilience in the context of hazard mitigation and, more generally, environmental management, is then considered. Last, all of this information is synthesized using three questions that are core to this paper:

- Is resilience a desirable attribute of megacities?
- Does enhanced resilience reduce the vulnerability of megacities to weather-related hazards?
- Is resilience a useful concept in the hazard management of megacities?

Coastal Zones and Megacities

Although there is a long history of human settlement in coastal zones, until the 20th century, the level of disturbance to natural processes did not appear to be critical. During the 20th century, coastal populations grew rapidly around the globe because of the many economic opportunities and environmental amenities that coastal zones provide (Turner and others 1996). Low-lying areas near coasts now have the largest concentrations of people on earth (Small and Cohen 1999). The population in the "near-coastal zone" (defined as areas both within 100 meters elevation and 100 kilometers distance of the coast) in 1990 was estimated at 1.2 billion (thousand million), or 23 percent of the world's population (Nicholls and Small 2002).

Nicholls and Small (2002) also showed that most of the near-coastal zone is sparsely inhabited, with the human population being concentrated in a few specific areas of the world's coast. These areas correspond mainly to near-coastal plains in Europe and parts of Asia, and to a lesser extent to densely populated urban areas. Hence, there are wide variations in coastal populations among nations. In many small island nations, all land suitable for human habitation is coastal and also in some large countries, most or all major urban centers are located near the coast (e.g., Australia). In other countries, such as Mexico, Colombia, Russia, and Iran, many larger cities are found further inland, in spite of the countries' long coastlines.

The United Nations medium projection for population growth suggests that the world's population will reach 7.2 billion by the year 2015, 7.9 billion by 2025, and 9.3 billion by 2050 (2000: 6.1 billion; UN/DESA 2001). Growth rates in individual countries will be largely determined by the country's current demographic patterns and fertility rate. Age structures in most developing countries are such that during the coming decades greater numbers of people will come into their prime reproductive years than in industrialized countries. Further, fertility rates are generally higher in developing countries, albeit declining. As a result, all projected population growth until 2050 is expected to occur in the developing world (UN/DESA 2001).

Most of the population growth in developing countries will occur in urban settings and much of this will be concentrated in coastal zones, as has been the case in most industrialized countries. It is projected that by 2015 there will be 33 cities with a population of more than 8 million (UN/DESA 2001). As shown in table 8.1, 21 of these megacities are located in coastal zones. This table, which is an update of the overviews provided by WCC'93 (1994) and Nicholls (1995), also shows that 17 of the 21 largest megacities are coastal and that, with the exception of Tokyo, New York, Los Angeles, Osaka, Paris, and Moscow, all the projected megacities are situated in developing countries. Continued growth of urban areas can be expected after 2015, especially in Africa and Asia (UNEP 2002), resulting in the development of additional coastal megacities to those shown in table 8.1.

Some care should be taken in interpreting the data presented in table 8.1. A certain degree of subjectivity is inevitable in labeling a megacity as "coastal," especially because there are no straightforward definitions of a coastal zone. São Paolo, for example, is not considered coastal because it is situated at an elevation of 800 meters above sea level. However, its proximity to the Atlantic Ocean and the port of Santos has yielded benefits that would not have been available in places further inland (e.g., as a coffee trading capital). On the other hand, cities like Dhaka, Calcutta, and Cairo are situated at some distance from the sea, yet in table 8.1 they are considered coastal because of their deltaic setting. Other cities, such as Los Angeles, Seoul, and Istanbul, have developed on coasts with steeper gradients and hence, parts of their agglomerations extend outside the coastal plain. The predominant criterion to classify a city as coastal in table 8.1 is whether the city has economic and geomorphic characteristics that are typically or exclusively coastal (e.g., seaport, deltaic, or estuarine setting).

Some coastal agglomerations with populations exceeding 8 million people may have been omitted because of the dataset utilized in table 8.1. These include Greater London in the United Kingdom and the Hong Kong-Shenzhen-Guangzhou conurbation in China (Nicholls 1995). More disperse agglomerations are not considered either, such as the Amsterdam-Brussels axis in the Netherlands and Belgium, the Osaka-Nagoya-Tokyo axis in Japan, and "Megalopolis" in the United States, which stretches over 600 kilometers from Boston to Washington, D.C., and has a collective population

Table 8.1 The world's largest cities, with projected populations in 2015 exceeding 8 million

Rank	*Agglomeration*	*Country*	*Population size (million)*			*Expected growth (%)*	*Rank in*	*Rank in*
			1975	*2000*	*2015*	*2000–2015*	*1975*	*2000*
1	Tokyo	Japan	19.771	26.444	26.444	0.00	1	1
2	Bombay	India	6.856	18.066	26.138	44.68	15	3
3	Lagos	Nigeria	3.300	13.427	23.173	72.59	33	6
4	Dhaka	Bangladesh	2.172	12.317	21.119	71.46	43	11
5	São Paolo	Brazil	10.047	17.755	20.397	14.88	5	4
6	Karachi	Pakistan	3.983	11.794	19.211	62.89	16	12
7	Mexico City	Mexico	11.236	18.131	19.180	5.79	4	2
8	New York	United States	15.880	16.640	17.432	4.76	2	5
9	Jakarta	Indonesia	4.814	11.018	17.256	56.62	22	14
10	Calcutta	India	7.888	12.918	17.252	33.55	12	8
11	Delhi	India	4.426	11.695	16.808	43.72	23	13
12	Metro Manila	Philippines	5.000	10.870	14.825	36.38	21	16
13	Shanghai	China	11.443	12.887	14.575	13.10	3	9
14	Los Angeles	United States	8.926	13.140	14.080	7.15	8	7
15	Buenos Aires	Argentina	9.144	12.560	14.076	12.07	7	10
16	Cairo	Egypt	6.079	10.552	13.751	30.32	20	19
17	Istanbul	Turkey	3.601	9.451	12.492	32.18	32	22
18	Beijing	China	8.545	10.839	12.299	13.47	10	17
19	Rio de Janeiro	Brazil	7.854	10.582	11.905	12.50	13	18
20	Osaka	Japan	9.844	11.013	11.013	0.00	6	15
21	Tianjin	China	6.160	9.156	10.713	17.01	19	24
22	Hyderabad	India	2.086	6.842	10.457	52.84	45	31
23	Bangkok	Thailand	3.842	7.281	10.143	39.31	28	27
24	Lahore	Pakistan	2.399	6.040	9.961	64.92	41	35
25	Seoul	Republic of Korea	6.808	9.888	9.923	0.35	16	20
26	Paris	France	8.885	9.624	9.677	0.55	9	21
27	Lima	Peru	3.651	7.443	9.388	26.13	30	25
28	Kinshasa	Dem. Rep. of the Congo	1.735	5.064	9.366	84.95	n/a	40
29	Moscow	Russian Federation	7.623	9.321	9.353	0.34	14	23
30	Madras	India	3.609	6.648	9.145	37.56	31	32
31	Chongqing	China	2.439	5.312	8.949	68.47	40	38
32	Teheran	Islamic Republic of Iran	4.274	7.225	8.709	20.54	25	28
33	Bogotá	Colombia	3.036	6.288	8.006	27.32	35	34
Total (coastal agglomerations)			150.6	254.1	324.1	27.53		
Total (all agglomerations)			217.4	368.2	467.2	26.88		

n/a: not available.
Note: Arrows indicate coastal agglomerations. [Arrows TK: ck. with author]
Source: Population data from UN/DESA (2001).

approaching 50 million people. Such disperse coastal agglomerations may also emerge in the developing world, such as from Accra, Ghana to Lagos, Nigeria, embracing parts of four countries.

Urban populations tend to have higher consumption levels than their rural counterparts, as well as different consumption patterns. The increasing demand for food requires increasing productivity in fisheries and agriculture. However, this is often impeded by the loss of agricultural land to urban expansion and the reduction of fisheries potential because of habitat loss and pollution of rivers and coastal waters from urban and industrial waste.

In addition, the large populations in many coastal areas around the world are, to a greater or lesser extent, vulnerable to hazardous events associated with natural coastal dynamics such as storm surges, floods, and tsunamis. Human-induced climate change and sea-level rise will further increase this vulnerability. These hazards are discussed in the next section.

Weather-Related Hazards in Coastal Zones

Coastal zones and any cities so located are threatened by a wide variety of weather-related hazards, and human activities often modify these hazards. Some of these hazards, such as drought, river floods, and poor air quality enhanced by stagnant air masses and inversion, can affect the entire terrestrial landscape. Other weather-related hazards are more specific to coastal locations and are emphasized here. These hazards are often related and include:

- Erosion
- Storm and wind damage
- Flooding
- Salinization of surface waters.

Table 8.2 summarizes the occurrence of these hazards for the coastal megacities identified in table 8.1, as well as the occurrence of major human-induced subsidence within the city during the 20th century.

Coastal storms can cause significant damage at the coast, including beach erosion (i.e., the physical removal of sediment). These impacts are normally confined to quite narrow areas adjacent to the coast, but erosion can trigger catastrophic flood events if natural barriers such as dunes are breached. Long-term erosion, which is occurring widely around the world's coasts, can cause land loss and will often degrade beach resources that are used for tourism (Bird 1985). The resulting changes in coastal configuration also change the risk of flooding and storm damage. Erosion has been an issue in most coastal cities on the open coast (15 out of 21 megacities in table 8.2). Beach nourishment is becoming a widespread response to this problem (Davison and others 1992; Hamm and others 1998).

Flooding of low-lying coastal areas can occur for a range of sometimes interacting reasons, including storm surges induced by tropical and extra-tropical storm systems, high river flows, and, generally less importantly,

Table 8.2 Summary of the major weather-related hazards and the occurrence of subsidence during the 20th century for coastal megacities as forecast in 2015

		Storm and wind damage		Flooding			
Agglomeration	*Erosion*	*Hurricane landfall*[1]	*Extra-tropical storms*	*River*	*Surge*	*Salinization*	*Major subsidence*
Tokyo	Y	Y (3)	—	Y	Y	?	Y
Bombay	Y	Y (<1)	—	—	Y	?	— ?
Lagos	Y	—	—	—	Y	?	?
Dhaka	—	Y (<1)	—	Y	—	Y	Y ?
Karachi	Y	Y (<0.1)	—	—	Y	?	— ?
New York	Y	Y (<1)	Y	—	Y	?	—
Jakarta	Y	—	—	Y	—	?	Y
Calcutta	—	Y (<1)	—	Y	—	Y	Y ?
Metro Manila	Y	Y (>3)	—	—	Y	?	Y
Shanghai	—	Y (1)	—	Y	Y	Y	Y
Los Angeles	Y	—	Y	—	Y	—	Y[2]
Buenos Aires	Y	—	Y	Y	Y	?	— ?
Cairo	—	—	Y	Y	—	—	— ?
Istanbul	Y	—	Y	—	Y	?	—
Rio de Janeiro	Y	—	—	—	Y	—	—
Osaka	Y	Y (3)	—	Y	Y	?	Y
Tianjin	—	Y (<0.1)	Y	Y	Y	Y	Y
Bangkok	Y	Y (<1)	—	Y	Y	?	Y
Seoul	—	Y (1–3)	Y	Y	—	—	— ?
Lima	Y	—	—	?	Y	—	—
Madras	Y	Y (<1)	—	—	Y	?	?

Y: yes, —: no, ?: uncertain.
[1]The relative frequency of hurricane landfall is indicated by the annual occurrence of tropical storms and cyclones (Beaufort force 8 and above).
[2]Due to oil and gas extraction, rather than groundwater withdrawal.
Sources: Synthesized from Nicholls (1995) and expert judgment.

intense local precipitation in areas with poor drainage. Hurricanes, tropical cyclones, and typhoons (which are different names for the same meteorological phenomena) have produced some of the most dramatic coastal floods over the last few years. These include the cyclones of April 1991 in coastal Bangladesh (139,000 fatalities) or October 1999 in Orissa, India (10,000 people killed and 15 million people made homeless) (UNEP 2002). These coastal storm events comprise more than storm-surge flooding, as they are associated with intense precipitation and strong winds. Hurricane Mitch, for example, caused great damage on the coasts of Honduras and Nicaragua in 1998, but most of the 17,000 fatalities occurred inland of the coastal zone due to flash river floods and landslides. Winds rather than surges were the major cause of property damage during the landfall of Hurricane Andrew near Miami, Florida in 1992. These examples emphasize the need to consider all weather-related hazards and their interrelationships.

Variations in river flow and sea level also lead to movement of the saltwater interface in surface waters. In the strongly seasonal rivers of South, Southeast, and East Asia, saltwater penetrates far upstream in the dry season with even greater penetration during droughts. In cities where the river is the main water supply, salinization can endanger water supplies, although as shown in table 8.2, only limited information is available on this factor.

It should be noted that the aforementioned weather-related hazards are usually directly modified by other human activities in and around urban areas, including:

- Changing sediment supply due to changing land use, hydrological modification or coastal protection and the consequent influence on erosion and deposition (e.g., rapid land loss in the Mississippi delta is increasing the flood risk in New Orleans; Boesch and others 1994);
- Land claim of intertidal areas and deepening of channels for navigation, which often increase extreme water levels and hence flood risk (e.g., London; Kelly 1991); and
- Enhanced subsidence due to groundwater withdrawal, which has reduced land elevation in many large coastal cities, particularly those in deltaic settings in Asia (Nicholls 1995).

Land subsidence due to excessive groundwater withdrawal is a particular problem in many coastal cities built on geologically recent deposits. Rapid growth of cities often triggers accelerated groundwater exploitation. As the water table beneath the city drops, formerly saturated sediments can irreversibly consolidate, the bulk density rises, and the ground surface rapidly subsides (Nicholls 1995). In low-lying coastal areas this leads to a relative rise in sea level as the land sinks. As a result, the erosion, flood, and salinization hazards already described will all be exacerbated. In addition, rapid differential subsidence can cause damage and destruction of infrastructure such as pipelines and buildings. In the extreme, complete submergence of low-lying coastal areas could be the result of subsidence.

At least 8 to 10 of the coastal megacities in table 8.2 subsided during the 20th century with adverse economic consequences. Subsidence rates can be rapid, locally reaching one meter per decade (Nicholls 1995). For instance, land subsidence around Tianjin, China was up to 5 centimeters per year in the late 1980s and locally up to 11 centimeters per year in some periods. On the other hand, in Japan subsidence has been largely stopped with better groundwater management, although large areas in the Osaka-Tokyo conurbation, which are home to 2 million people, are now beneath high-water levels and would be submerged but for the extensive flood defense systems (Mimura and others 1992). The success of better groundwater management in Osaka, Tokyo, and Shanghai has not prevented similar problems developing in other "younger" megacities (e.g., Bangkok, Metro Manila, and Jakarta), and it is likely that during the 21st century other coastal cities will experience similar problems (e.g., Rangoon, Myanmar and Hanoi, Vietnam). Given that the physical causes and socioeconomic triggers of human-induced subsidence are now well understood, such problems are avoidable with appropriate planning and management (Nicholls 1995).

Changing land use also exacerbates human exposure to weather-related hazards. Initial settlements are often built on the most suitable areas and as a city expands, new development has to occur on more hazardous ground. Good examples are the expansion of Alexandria, Egypt and Dhaka, Bangladesh onto low-lying flood-prone areas. Dakar, Senegal evolved on the relatively high and non-erosive land on the Cap Vert peninsula but recent growth has taken place on lower-lying land. Erosion is now becoming an issue and this newly developed land may be flood-prone (Dennis and others 1995). Often the poorest people in cities are found in unauthorized shantytown areas (UN/ISDR 2002b), including Bombay, Lima, Calcutta, Manila, Karachi, Lagos, Bangkok, Jakarta, and Rio de Janeiro (Devine 1992). These shantytowns tend to be built in the least desirable or secure areas, which are often also those areas most exposed to weather-related hazards. For example, in Recife, Brazil the illegal shantytown areas (or favelas) are expanding in mangrove areas, which are by definition at or below normal high water (Muehe and Neves 1995).

It is important to note that weather-related hazards vary with climate variability, such as the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO), and will be modified by climate change. Both climate variability and climate change need to be taken into account when planning hazard responses (see next section). For example, on the eastern seaboard of the United States, significant coastal development and urbanization occurred from 1966 to 1989, increasing exposure during a period when hurricane activity was well below average. The new inhabitants were often ignorant of the hurricane risk, which became manifest with the more frequent and stronger hurricanes that began with Hugo in 1989 (Pielke and Landsea 1998).

Climate change will be of increasing concern to coastal megacity populations, as existing experience of hazardous events will cease to be a guide to future events. Based on the most recent projections of future climate, the Intergovernmental Panel on Climate Change (IPCC) in its Third Assessment Report projects global mean sea level to rise by 9 to 88 centimeters between 1990 and 2100, with a central value of 48 centimeters. The projected sea-level rise is due primarily to the thermal expansion of ocean water (11 to 43 centimeters), followed by contributions from mountain glaciers (1 to 23 centimeters) and ice caps (–2 to 9 centimeters for Greenland and –17 to 2 centimeters for Antarctica) (Church and others 2001). The projected central value of 48 centimeters gives an average rate of sea-level rise of 2.2 to 4.4 times the observed rate over the 20th century. Even with drastic reductions in greenhouse-gas emissions, sea-level rise will continue for centuries beyond 2100 because of the long response time of the global ocean system. An ultimate sea-level rise of 2 to 4 meters is possible for atmospheric carbon dioxide concentrations that are twice and four times preindustrial levels, respectively (Church and others 2001).

A major uncertainty is how the global mean sea-level rise will manifest itself on a regional scale. All models analyzed by the IPCC show a strongly nonuniform pattern of sea-level rise. Some regions show a sea-level rise substantially more than the global average (in many cases of more than twice the average) and others a sea-level fall (Church and others 2001).[1] However, the patterns given by the different models are not similar in detail. This lack of similarity means that confidence in projections of regional sea-level changes is low, although it is clear that they are important with respect to impacts of sea-level rise on coastal zones. For individual cities, rates of subsidence need to be considered, as subsidence will add to global mean sea-level rise and in some cases these changes could exceed the changes due to climate change (see above).

A rise in mean sea level will lead to a decrease in the return period of storm surges; however, it is unclear whether the variability of storm surges itself will change. Changes that are considered possible over some areas are increases in peak wind intensities and mean and peak precipitation intensities of tropical cyclones. Changes in tropical cyclone location and frequency are still uncertain, but it is clear that any changes can have important consequences for many coastal cities, including 16 coastal megacities in table 8.2.

Changes in wind patterns and precipitation in higher latitudes also remain uncertain at local and regional scales. To date, no reliable projections of coastal storm characteristics and tidal range at scales useful for coastal impact analysis exist. The effect of storm surges can also be compounded by increased precipitation on land and associated increased river runoff. Runoff projections of selected rivers are becoming available, allowing their consideration in future impact analysis.

The IPCC Third Assessment Report concludes that recent trends for El Niño are projected to continue in many models (Houghton and others 2001). These trends include a stronger warming of the eastern tropical Pacific relative to the western tropical Pacific, with a corresponding eastward shift of precipitation. Changes in El Niño patterns are likely to be relevant in a number of coastal locations, but they are still too uncertain to be considered in coastal impact studies.

Owing to the great diversity and variation of natural coastal systems and to the local and regional differences in relative sea-level rise, the occurrence and response to sea-level rise will not be uniform around the globe. Coastal environments that are especially at risk include deltaic and low-lying coastal plains, sandy beaches and barrier islands, coastal wetlands, estuaries and lagoons, and coral reefs and atolls (Bijlsma and others 1996); cities in these locations are similarly threatened. The common association of megacities with deltas in Asia suggests that these cities are particularly threatened. Regional and global analyses suggest that, for the regions containing coastal megacities, increased coastal flooding will be most severe in South and Southeast Asia, Africa, the southern Mediterranean coasts, and to a lesser extent, East Asia (Nicholls 2000), which includes 16 of the coastal megacities in table 8.1. However, these general conclusions need to be supported by more detailed city-scale assessments, such as the recent New York assessment (Rosenzweig and Solecki 2001).

Table 8.3 lists the most important socioeconomic sectors in coastal zones and indicates from which of the aforementioned weather-related hazards they are expected to suffer direct impacts. Indirect impacts, for example, impacts on human health resulting from deteriorating water quality, are also likely to be important to many sectors but these are not shown in table 8.3.

In summary, coastal megacities are threatened by a range of specific weather-related hazards, and during the 21st century these will likely be exacerbated by sea-level rise and climate change. While it is recognized that impacts of climate change on coastal megacities are prompted by more than sea-level rise alone, consideration of other factors is constrained by the uncertainties surrounding them, particularly at local and regional scales. Nonetheless, a range of strategies to reduce coastal hazards due to all causes can be implemented, also in the face of uncertainty, as discussed in the next section.

Table 8.3 Qualitative overview of direct socioeconomic impacts of weather-related hazards and climate change on a number of sectors in coastal zones

Socioeconomic sector	*Erosion*	*Storm and wind damage*	*Flooding*	*Salinization*
Water resources	—	—	Y	Y
Agriculture	—	Y	Y	Y
Human health	—	Y	Y	—
Fisheries	Y	Y	Y	Y
Tourism	Y	Y	Y	—
Human settlements	Y	Y	Y	Y

Y: yes, —: no.
Source: adapted from Klein and Nicholls 1999.

Hazard Reduction Strategies

There is a wide range of different strategies for dealing with the weather-induced hazards faced by coastal cities as defined in table 8.4. These can be applied from the level of the individual up to the entire city. Given the focus of the paper on the resilience of coastal megacities, the focus here is on the city-scale response.

In table 8.4, choosing change means accepting the hazard and changing land use, or even the relocation of exposed populations. Reducing losses includes trying to reduce the occurrence of the hazardous event, or, more commonly, reducing the impacts of a hazardous event when it occurs. Accepting losses includes bearing the loss, possibly by exploiting reserves, or sharing the loss through mechanisms such as insurance. Hence the ability to recover from the disaster is of most importance if losses are accepted. Note that these strategies are not mutually exclusive, and hazard reduction within any coastal city might include elements of all three approaches.

Over time, technology is increasing the options that are available for hazard reduction, particularly those strategies that reduce losses (Klein and others 2000). Given the large populations and economic values in

Table 8.4 Generic approaches to hazard reduction based on purposeful adjustment

Purposeful adjustment	*Option*
Choose change	Change location
	Change use
Reduce losses	Prevent effects
	Modify event
Accept losses	Share loss
	Bear loss

Source: Burton and others 1993.

cities, there is usually a bias toward loss reduction, and it can be argued that large coastal cities would not have evolved without the availability of these hazard-reduction strategies. These might include warning systems, defense works, and resistant infrastructure. This approach is most developed in coastal cities around the North Sea, Europe, and in Japan, where flooding claimed many lives up to the middle of the 20th century. Most of the coastal megacities identified in table 8.1 have seen significant action to reduce the effects of weather-related hazards. A particular problem is that, while any strategy to reduce losses (e.g., flood defense) only reduces rather than removes the risk, the measures are often seen as invulnerable and hence encourage further development in what remain potentially hazardous areas (e.g., Parker 2000). Boxes 8.1 and 8.2 discuss examples of hazard-reduction strategies employed over the 20th century for London and Shanghai.

Article 3.3 of the United Nations Framework Convention on Climate Change (UNFCCC) suggests that proactive adaptation (as well as mitigation to reduce greenhouse gas emissions) deserves particular attention

Box 8.1 Responding to coastal flooding in London, United Kingdom

One million Londoners are potentially exposed to coastal flooding. They are defended by a complex system involving fixed flood defenses, the mobile Thames Barrier, which is closed before a surge arrives, and a suite of warning systems that are used to decide when to close the barrier (Gilbert and Horner 1984). While the possibility of a barrier was discussed earlier in the 20th century, the decision to build the present defenses was made in direct response to the 1953 storm surge that killed 300 people and flooded 65,000 hectares of farmland on Britain's east coast. The barrier was completed in 1983—i.e., 30 years after the decision to build was made. Parallel developments in storm surge warning were fundamental to the operation of the barrier. Since the barrier's completion, London's derelict docklands have been regenerated with new homes and businesses, including the new financial district around Canary Wharf. Significant future development is expected in potentially flood-prone sites alongside the tidal Thames.

The design life of the barrier is until 2030, when rising flood levels due to a combination of global sea-level rise and more local changes will reduce the residual flood risk to below a 1-in-1,000-year standard. Given the long lead-time to upgrade the defenses, planning of the flood defenses to 2100 is already in its early stages. This includes consideration for the first time of inland realignment of the flood defense line as a complimentary strategy to raising defenses, and as such reverses a long-term trend of encroachment and land claim into the tidal Thames (Shih 2002).

While the fact that there is residual flood risk even with the existing defenses is not widely appreciated, all insured properties in London still receive flood cover. Therefore, losses would be shared in the unlikely event of failure. However, the U.K. insurance industry is concerned about its exposure to flooding and that flood insurance might be selectively withdrawn: a situation that would arguably reduce the resilience of Britain to major flood events (Clark 1998).

Box 8.2 Responding to human-induced subsidence in Shanghai, China

Shanghai subsided as much as 2.8 meters during the 20th century due to groundwater withdrawal (Han and others 1995; Wang and others 1995). The subsidence was triggered by the growing city and economy in the 1920s and it continued until the 1960s, when groundwater withdrawal was regulated and subsidence rates were reduced to 3 to 4 millimeters per year—rates of subsidence one would expect in a deltaic setting. Therefore, while human action triggered the subsidence problem, it also made it possible to reduce the subsidence to a large degree. Shanghai was flood-prone before the subsidence occurred, but a substantial increase in both the incidence of flooding and the area affected occurred due to the subsidence. A range of new flood protection measures was required, culminating in large new floodwalls built in the early 1990s, which protect the main city to a 1-in-1,000-year standard. However, future subsidence problems remain possible. Anecdotal reports suggest that illegal groundwater withdrawal has increased in Shanghai over the last 10 years, increasing the rate of subsidence again. This illustrates the ongoing nature of managing weather-related hazards.

from the international climate change community given the threat of human-induced climate change:

> The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost.

The threat of climate change is extending the scope of reduction strategies for weather-related hazards and in particular focusing attention over many decades into the future. The Intergovernmental Panel on Climate Change, Third Assessment Report includes a dedicated chapter on adaptation for the first time (Smit and others 2001). Coastal zones are an area where there has been particular interest in adaptation, given the inevitability of global-mean sea-level rise (Klein and others 2000; 2001; Tol and others forthcoming), including some international projects funded by the Global Environmental Facility and others: Caribbean Planning for Adaptation to Climate Change (CPACC); and The Pacific Islands Climate Change Assistance Programme (PICCAP) (see Nicholls and Mimura 1998). Some coastal countries such as Britain and Japan are at the forefront of planning for climate change, including the implications for their major coastal cities (e.g., box 8.1).

In general, proactive adaptation is aimed at reducing a system's vulnerability by either minimizing risk or maximizing adaptive capacity. Five generic objectives of anticipatory adaptation can be identified (Klein and Tol 1997; Klein 2002 forthcoming):

- **Increasing robustness of infrastructural designs and long-term investments**—for example, by extending the range of temperature or precipitation a system can withstand without failure and/or changing a system's tolerance of loss or failure (e.g., by increasing economic reserves or insurance).
- **Increasing flexibility of vulnerable managed systems**—for example, by allowing mid-term adjustments (including change of activities or location) and/or reducing economic lifetimes (including increasing depreciation).
- **Enhancing adaptability of vulnerable natural systems**—for example, by reducing other (nonclimatic) stresses and/or removing barriers to migration (such as establishing eco-corridors).
- **Reversing trends that increase vulnerability** *("maladaptation")*—for example, by introducing setbacks for new development or relocation of existing development in vulnerable areas such as floodplains and coastal zones.
- **Improving societal awareness and preparedness**—for example, by informing the public of the risks and possible consequences of climate change and/or setting up early-warning systems.

As with the approaches listed in table 8.4, these approaches are not mutually exclusive.

Each of these five objectives of adaptation is relevant for hazard reduction in coastal megacities. However, for coastal zones, another classification of adaptation options is often used. This classification, introduced by IPCC CZMS (1990) and still the basis of many coastal adaptation analyses, distinguishes between the following three basic hazard management strategies:

- **Protect**—to reduce the risk of coastal hazards by decreasing their probability of occurrence;
- **Retreat**—to reduce the risk of coastal hazards by limiting their potential effects; and
- **Accommodate**—to increase society's ability to cope with the effects of coastal hazards.

Klein and others (2001) discuss these three strategies in detail and provide examples of technologies for implementing each of them. While the main hazard considered is sea-level rise, their approach is relevant to all weather-related hazards in coastal areas.

The three coastal adaptation strategies roughly coincide with the first three of the five proactive adaptation objectives listed above. Protecting coastal zones against sea-level rise and other climatic changes would involve increasing the robustness of infrastructural designs, and long-term investments such as seawalls and other coastal infrastructure. Efficient management of beach and coastal sediments is also an important strategy to maintain and enhance soft defenses in many coastal cities, which can also sustain recreational and other functions (although this could also been seen as enhancing adaptability).

A retreat strategy would serve to enhance the adaptability (or resilience) of coastal wetlands by allowing them space to migrate to higher land as sea level rises.

Historically coastal ecosystems in urban areas have suffered encroachment and destruction, but in the future, proactive adaptation could allow other development pathways to occur. A strategy to accommodate sea-level rise could include increasing the flexibility or coping capacity of managed systems. Examples include raising buildings above flood levels to minimize flood damage, as is already practiced in the United States, and/or sharing losses via insurance mechanisms. While protection has historically dominated the response to hazards in urban areas, proactive adaptation will present opportunities to retreat or accommodate in some urban settings.

The other two objectives of proactive adaptation, reversing maladaptive trends and increasing awareness and preparedness, are relevant for coastal zones and cities as well. However, given that a whole city built in a low-lying location might be considered maladaptive, the scope for relocation in cities is more limited. Once a large city emerges, there is a large inertia against relocation due to the high level of investment (see box 8.1). Hence, cities tend to develop increasing dependence on artificial measures as they evolve and grow, although some will argue that this is nonsustainable. Therefore, relocation should be integrated into planning future development and exploiting redevelopment opportunities, including proactively exploiting disaster recovery (UNCHS 2001). In this way, disaster recovery and long-term disaster prevention and preparedness can be linked for coastal cities.

Sustaining the functioning of natural coastal systems around cities could also have many benefits, including mitigating weather-related hazards. Thus, hazard mitigation needs to be seen as one goal within integrated coastal zone management, and all hazard mitigation strategies need to address the wider coastal zone context in which they are implemented (cf. Bijlsma and others 1996; Klein and others 1999).

Another key point about the effective implementation of hazard reduction strategies is that they are more than implementing a set of technical measures and need to be thought of as an ongoing process, including planning, design, implementation, and monitoring (Klein and others 1999; 2001). The examples given for London and Shanghai support this point (boxes 8.1 and 8.2). Given that we are discussing a process, and there is a great deal of uncertainty about the future, one approach that is increasingly advocated is adaptive management, or learning by doing (Green and others 2000; Nicholls and others 2000). First suggested by Holling (1973) and developed in subsequent papers (Holling 1986; 1997), it proposes that any intervention should be treated as an experiment from which lessons should be drawn and future interventions made using these lessons. This philosophy has been embraced in other decisionmaking contexts such as coastal management (National Research Council 1995). This approach explicitly acknowledges our incomplete knowledge of the systems that we are trying to manage and can easily incorporate change from whatever cause. It also accepts that the systems that we are managing are open and, hence, optimal solutions in an engineering sense are difficult to define.

The experimental approach of adaptive management makes it explicit that there are risks and uncertainties associated with any decision, including those concerning hazard reduction. The strength of the adaptive management philosophy is that this fact is not suppressed or ignored: rather, it is turned into a learning opportunity, which increases knowledge and improves subsequent decisions. To date, the authors are unaware of adaptive management being applied to hazard-reduction strategies in coastal cities, and there is scope for exploring how this might improve existing practice. Note that many of the ideas concerning adaptive management are linked to the conceptualization of resilience as discussed in the next section.

This brief review shows that there is a range of hazard reduction strategies available for coastal megacities. While continued technology development may further increase the detailed options that are available, new problems and issues will continue to emerge: climate change is only one example of this. Reducing losses/protection has been the main response in the past and this seems likely to continue. However, the implementation of proactive adaptation and the utilization of adaptive management principles raise opportunities to use other approaches as cities develop or are redeveloped, including recovery from disaster. This stresses that hazard reduction is an ongoing process rather than a simple set of technical measures, and it needs to be implemented on this basis. Last, hazard reduction strategies need to be implemented in the wider coastal context and, hence, comprise one issue within the broader goal of integrated coastal zone management.

Resilience Conceptualized

The previous sections of this paper have provided an overview of the context and importance of coastal megacities worldwide, the diverse weather-related hazards that coastal megacities face both now and in the future, and the range of strategies that are available to reduce these weather-related hazards. This section introduces the concept of resilience, as it is assumed that more resilient megacities (as well as other human and natural systems) are less vulnerable to weather-related and other hazards (United Nations International Strategy for Disaster Reduction 2002a). However, for this assumption to be valid and useful, one needs to have an understanding and clear definition of resilience, including by which factors it is determined, how it can be measured, and, most importantly how it can be maintained and enhanced.

As stated in the introduction of this paper, there is no literature that deals specifically with resilience in the context of megacities. However, the concept of resilience has been analyzed for a range of other systems and this literature is reviewed here. The next section discusses the usefulness of the concept in the context of megacities and weather-related hazards.

The *Oxford English Dictionary* defines resilience as: (1) the act of rebounding or springing back; and (2) elasticity. The origin of the word is in Latin, where *resilire* means "to jump back." In a purely mechanical sense, the resilience of a material is the quality of being able to store strain energy and deflect elastically under a load without breaking or being deformed (Gordon 1978). However, since the 1970s, the concept has also been used in a more metaphorical sense to describe systems that undergo stress and have the ability to recover.

Holling (1973) coined the term *resilience* for ecosystems as a measure of the ability of these systems to absorb changes and still persist. As such, it determines the persistence of relationships within an ecosystem. This is contrasted with stability, which is defined by Holling (1973) as the ability of a system to return to a state of equilibrium after a temporary disturbance. Thus, a very stable system would not fluctuate greatly but return to normal quickly, while a highly resilient system may be quite unstable, in that it may undergo significant fluctuation (Handmer and Dovers 1996).

Since the seminal work by Holling (1973), resilience has become an issue of intense conceptual debate among ecologists. The literature provides many perspectives and interpretations of ecological resilience and, despite 30 years of debate, there appears to be no consensus on how the concept can be made operational or even how it should be defined. Alternative definitions have been provided, focusing on different system properties. For example, Pimm (1984) defines resilience as the speed with which a system returns to its original state following a perturbation.

Other ecologists question the core assumption that underpins the concept of resilience, namely, that ecosystems exist in an equilibrium state to which they can return after experiencing a given level of disturbance. They argue that ecosystems are dynamic and evolve continuously in response to external influences taking place on a range of different time scales. Attempts of ecosystem management at achieving stability are therefore bound to fail.

In spite of the relative lack of specificity of ecological resilience (or perhaps as a result of it), the concept has also gained ground in social science, where it is applied to describe the behavioral response of communities, institutions, and economies. Timmerman (1981) has been one of the first to discuss the resilience of society to climate change. In so doing, he links resilience to vulnerability. He defines resilience as the measure of a system's or part of a system's capacity to absorb and recover from the occurrence of a hazardous event.

Dovers and Handmer (1992) distinguish between the reactive and proactive resilience of society. A society relying on reactive resilience approaches the future by strengthening the status quo and making the present system resistant to change, whereas one that develops proactive resilience accepts the inevitability of change and tries to create a system that is capable of adapting to new conditions and imperatives. This is an important broadening of the traditional interpretation of resilience, which is based on the premise of resilience being affected by an initial perturbation. The distinction by Dovers and Handmer (1992) is based on the major difference between ecosystems and societies: the human capacity of anticipation and learning.

Dovers and Handmer (1992) thus link resilience to planning and adaptation to hazards. In a later paper they develop a typology of institutional resilience, which provides a framework for considering the rigidity and inadequacy of present institutional responses to global environmental change (Handmer and Dovers 1996). They argue that current institutions and policy processes appear to be locked into a type of resilience that is characterized by change at the margins. Responses to environmental change are shaped by what is perceived to be politically and economically palatable in the near term rather than by the nature and scale of the threat itself.

This type of resilience, as well as a type that is characterized by resistance to change, provides some level of stability in society, although there is a potentially large risk that this apparent stability is not sustainable and could lead to collapse if society cannot make the social, economic, and political changes necessary for survival. The third type of resilience described by Handmer and Dovers (1996), one that is characterized by openness and adaptation, is more likely to deal directly with the underlying causes of environmental problems and reduces vulnerability by having a high degree of flexibility. Its key feature is a preparedness to adopt new basic operating assumptions and institutional structures. However, there is also a potentially large risk involved in moving toward this type of resilience. Change deemed as necessary could turn out to be maladaptive, rendering a large cost to society.

Adger (2000) investigates the links between social resilience and ecological resilience. He follows Timmerman (1981) in his definition of social resilience: the ability of human communities to withstand external shocks or perturbations to their infrastructure, such as environmental variability or social, economic, or political upheaval, and to recover from such perturbations. Social resilience is measured through proxies of institutional change and economic structure, property rights, access to resources, and demographic change (Adger 1997).

It is argued by many ecologists that resilience is the key to sustainable ecosystem management and that diversity enhances resilience, stability, and ecosystem functioning (e.g., Schulze and Mooney 1993; Peterson and others 1998; Chapin and others 2000). Ecological economists also argue that resilience is the key to sustainability in the wider sense (e.g., Common 1995). However, Adger (2000) observes that, while resilience is certainly related to stability, it is not clear whether this characteristic is always desirable (cf. Handmer and Dovers 1996).

The above overview of conceptual development of resilience shows that what was once a straightforward concept used only in mechanics is now a complex multi-interpretable concept with contested definitions and even relevance. Nonetheless, the concept of resilience is now used in a great variety of interdisciplinary work concerned with the interactions between people and nature, including disaster reduction (UN/ISDR 2002a). The most important development over the past 30 years is the increasing recognition across disciplines that human and ecological systems are interlinked and that their resilience relates to the functioning and interaction of the systems rather than to the stability of their components or the ability to maintain or return to some equilibrium state.

For coastal systems, the self-organizing capacity implied by resilience is considered a desirable property, given the uncertainty about the future (Nicholls and Branson 1998). However, resilience is most easily conceptualized in the case of natural systems. The role of social systems in contributing to resilience and its relationship to the resilience of natural systems is less clear. In a conceptual study on the resilience of the Dutch coast, Klein and others (1998) focus on the functioning of morphological, ecological, and socioeconomic processes in determining coastal resilience. These processes produce a coastal system that is continuously changing, so no original or equilibrium state can be identified. Moreover, perturbations are not isolated events from which a coastal system may or may not recover, but are ever-present and occur at different temporal and spatial scales. Klein and others (1998) define coastal resilience as the self-organizing capacity of the coast to preserve actual and potential functions under the influence of changing hydraulic and morphological conditions. This capacity is based on the (potential) dynamics of morphological, ecological, and socioeconomic processes and the demands for these processes made by the functions to be preserved. The key question about the relationship and exchangeability between the different types of resilience remains to be resolved. A conceptual model of vulnerability to sea-level rise, which combines the concept of resilience with that of resistance, is also presented (see also Klein and Nicholls 1999). This implies that resilience and resistance might be exchangeable, if, for example, a natural soft coast were armored with a seawall, or the opposite process, which is termed managed retreat.

The recognition that human and ecological systems are interlinked has led to the establishment of the Resilience Alliance, a network of scientists with roots mainly in ecology and ecological economics, which aims to stimulate academic research on resilience and inform the global policy process on sustainable development (Folke and others 2002). The Resilience Alliance consistently refers to social-ecological systems and defines their resilience by considering three distinct dimensions (Carpenter and others 2001):

- The amount of disturbance a system can absorb and still remain within the same state or domain of attraction;
- The degree to which the system is capable of self-organization; and
- The degree to which the system can build and increase the capacity for learning and adaptation.

This definition is an amalgamation of the aforementioned definitions of ecological, social, and institutional resilience.

The United Nations International Strategy for Disaster Reduction (UN/ISDR 2002a) uses the term *resilience* as follows:

> The capacity of a system, community or society to resist or to change in order that it may obtain an acceptable level in functioning and structure. This is determined by the degree to which the social system is capable of organising itself and the ability to increase its capacity for learning and adaptation, including the capacity to recover from a disaster.

However, resilience remains at the conceptual level throughout this document and operationalizing the concept is not discussed.

Hence, both in the academic realm of the Resilience Alliance and in the applied realm of the ISDR, the same problems as with previous definitions persist: there is a danger that there is a "motherhood and apple pie" view on resilience, which leaves limited scope for measurement, testing, and formalization. The challenge remains to transform the concept of resilience into an operational tool for policy and management purposes: a challenge that 30 years of academic debate does not seem to have resolved.

Discussion

The vulnerability of megacities to hazards and disasters has been a subject of increasing academic interest, with recent special issues of *GeoJournal* (Parker and Mitchell 1995), *Applied Geography* (Mitchell 1998), and *Ocean & Coastal Management* (Barbière and Li 2001), as well as influential publications by Timmerman and White (1997), Rakodi and Treloar (1997), Mitchell (1999), and Cross (2001). This academic interest has complemented the increasing policy interest, as reflected by initiatives of the International Decade for Natural Disaster Reduction (and now the International Strategy for Disaster Reduction—ISDR) and the Disaster Management Facility of the World Bank.

It is clear that climate change will increase the hazard potential in many cities (Scott and others 2001). In a parallel paper, Bigio (2002) provides an overview of the challenges that climate change poses to cities. This paper has focused on coastal megacities, as they concentrate a growing part of the world's human population in potentially hazardous locations. In 2000, the cities with projected populations exceeding 8 million by 2015 contained about 250 million people (table 8.1), which is about 4 percent of the world's population. Similarly, using 1990 data, Nicholls and Small (2002) identify about 120 million people living in the near-coastal zone at the high-population densities associated with large urban areas (>10,000 people/square kilometer). The strong global tendency to urbanization, both in these large coastal megacities and in the more numerous smaller cities, combined with a general tendency for migration toward the coast, suggests that coastal urban centers will contain a significant proportion of the world's population by 2050, if not earlier (although it is important not to forget the large nonurban coastal population (Nicholls and Small 2002)). Most of these urban centers will be in the developing world, including at least 17 coastal megacities.

Population density and urban centrality make it likely that the disaster problems of large cities will be different from those of rural areas. In large cities, events with relatively small areas of impact affect great numbers of people (Kelly 1995). Nonetheless, the scale, speed, and complexity of urbanization are neglected topics in most investigations of hazard prediction and response. In addition, there is a lack of historical evidence about disasters in very large cities, mainly because such cities are a recent phenomenon (Mitchell 1993).

In spite of the high hazard potential of megacities in general and coastal megacities in particular, there is no compelling evidence that megacities are more vulnerable to hazards than are smaller cities and towns. Handmer (1995) argues that major cities have inherent features that enable them to deal with hazards more effectively than smaller settlements. The immense power and resources of large cities confer considerable capacity to respond (i.e., resilience). Most major cities are able to harness massive financial resources and expertise from within the city, the country, and the rest of the world to combat disaster and aid recovery. Parker (1995) supports this view and argues that the built-in complexities and redundancies characteristic of very large urban systems and the modern global electronic trading systems of which they are part may also enhance resilience.

Cross (2001) also emphasizes the greater resilience of megacities compared to small towns. He argues that the different response capacities of smaller communities profoundly influence the long-term consequences of a disastrous event on the individual victims and whether they receive timely or adequate emergency assistance. Individuals in both small communities and megacities are vulnerable to hazard losses, but losses for residents of large cities are more easily reduced by the warning and protection systems that the cities' concentrated wealth can justify.

On the other hand, as discussed in the earlier section "Weather-related Hazards in Coastal Zones," urbanization in the developing world is also concentrating poor populations in potentially hazardous areas and thus raising the vulnerability of these groups and hence the city as a whole to hazardous events and disasters. This increase and concentration of vulnerability attracts considerable attention in the literature (UNCHS 2001) and is a process likely to reduce the resilience of cities. Hence, while coastal megacities in the developed world might be seen as more resilient than smaller settlements or rural areas, in the developing world there are competing processes influencing resilience and vulnerability, which are dynamic and not fully understood.

Resilience is seen as an important characteristic of megacities that helps to reduce the vulnerability of its citizens to weather-related hazards. However, as shown in the section "Resilience Conceptualized," resilience is a relatively poorly defined concept that has not yet been made operational for policy and management. Following Timmerman (1981), there seems to be a consensus that a resilient city is less vulnerable to hazards but no systematic and reproducible analysis exists to date as to what makes cities resilient and how resilience can be enhanced.

In this section, the authors revisit this consensus view by asking the following questions:

- Is resilience a desirable attribute of megacities?
- Does enhanced resilience reduce the vulnerability of megacities to weather-related hazards?
- Is resilience a useful concept in the hazard management of megacities?

Is Resilience a Desirable Attribute of Megacities?

Whether or not resilience is a desirable attribute of megacities depends on the definition of the concept. The traditional definitions that assume some equilibrium state may be outdated according to some, but they still tend to capture the imagination of many when resilience is mentioned. It is clear that megacities are in a continuous state of flux and that "bouncing back" to the original state after a disaster is impossible. More importantly, if a megacity is struck by a disaster, it follows that the original state was one in which it was vulnerable to disaster in the first place. Going back to this original state is undesirable, as it would leave the city just as vulnerable to the next disaster.

Later definitions of resilience focus on the functioning of systems, including their self-organizing capacity. Resilience interpreted in this manner is desirable in megacities. While it does not help to prevent disasters or reduce their immediate impact, once a disaster happens, it facilitates and contributes to the process of recovery. A resilient megacity thus would be less likely to experience a severe lasting impact from a disaster.

Recently, resilience has also been interpreted as including the degree to which a system can build and increase the capacity for learning and adaptation (Carpenter and others 2001; cf. proactive resilience as defined by Dovers and Handmer 1992). The capacity for learning and adaptation is clearly a desirable attribute, although few would associate intuitively the ability to increase this capacity with resilience. This interpretation of resilience relates to adaptive management and adaptive capacity: two concepts with their own literature and interpretations, but perhaps more operational for policy and management.

Does Enhanced Resilience Reduce the Vulnerability of Megacities to Weather-Related Hazards?

As it was for the previous question, this is a matter of definition. The early interpretations of resilience would not reduce vulnerability; later ones would. However, it is also important to consider who or what would be vulnerable and how this vulnerability would manifest itself. A megacity typically covers a large and often physiographically heterogeneous area, with different exposure and susceptibility to hazards. In addition, the population will be diverse, as will be the conditions under which they live. As a result, while a megacity has a particular vulnerability to hazards, some population groups within the city may be particularly vulnerable due to their high exposure and unfavorable socioeconomic situation.

Resilience interpreted as facilitating and contributing to the process of recovery after a disaster is irrelevant to those who lose their lives during a disaster. Those losing their marginal livelihoods in shantytowns may not benefit as much from being able to display resilience as those who could afford insurance to cover any damage to their property. This shows that equity is an important factor in determining whether resilience reduces the vulnerability of megacities to weather-related hazards.

Is Resilience a Useful Concept in the Hazard Management of Megacities?

The fact that, among others, the United Nations International Strategy for Disaster Reduction (2002a) has adopted the term resilience would suggest that it is a useful concept for hazard management, including that involving coastal megacities. However, the problems with resilience include the multitude of different definitions and turning any of them into operational concepts. The answers to the previous two questions depended on the assumed definitions of resilience, none of which are operational. After 30 years of academic analysis and debate, the definition of resilience has become so broad as to render it almost meaningless. The aforementioned definition by Carpenter and others (2001) includes many issues that are currently en vogue in discussions on sustainable development and hazard management. Rather than the definition providing an explanation of a system attribute that is observed and can be measured, resilience has become an umbrella concept for a range of system attributes that are deemed desirable. The system attributes and the umbrella concepts need to be kept distinct in a conceptual hierarchy.

It is uncertain whether more rigorous academic work will lead to a concept of resilience that does have direct relevance to hazard management. Alternatively, the term resilience should be used only to refer to a system's reactive response to a perturbation. This would correspond to the first two dimensions of the definition by Carpenter and others (2001): the amount of disturbance a system can absorb and still remain within the same state or domain of attraction and the degree to which the system is capable of self-organization. For human systems, this is also referred to as "coping ability" in the hazard management literature.

The proactive type of resilience corresponds to what has been coined "adaptive capacity" by the climate change community. Adaptation in the context of climate change refers to any adjustment that takes place in natural or human systems in response to actual or expected impacts of climate change, aimed at moderating harm or exploiting beneficial opportunities. Planning for adaptation is becoming increasingly important, especially since it has been established that humans are—at least in part—responsible for climate change and that impacts can no longer be avoided only by reducing greenhouse-gas emissions (Arnell and others 2002). Adaptive capacity is defined as the ability to plan, prepare for, and implement adaptation options. Factors that determine adaptive capacity to climate change include economic wealth, technology and infrastructure, information, knowledge and skills, institutions, equity, and social capital (Smit and others 2001). Hence, resilience as defined in the previous paragraph contributes to the overall adaptive capacity.

For two years, the concept of adaptive capacity has been the subject of worldwide interdisciplinary research efforts, aimed at making it operational for the international climate policy process, as well as for national planning agencies (Smith and others 2002). The concept has gained recognition in climate policy and science and is now used outside the climate community as well (e.g., Turton 1999). Climate variability is increasingly considered along with climate change when planning for adaptation, as it is recognized that in many areas the most direct and immediate impacts of climate change will occur through changes in the frequency and intensity of weather-related hazards.

The use of the concept of adaptive capacity by the natural hazard community would not only foster much-needed communication between that community and the climate community. More importantly, it would provide hazard managers with a tool that is similar to resilience in its relationship to vulnerability, but offers greater potential in application, especially when attempting to move away from disaster recovery to disaster prevention and preparedness.

Conclusions

While resilience is widely seen as a desirable property of natural and social systems, including coastal megacities, the term has been used in a number of different ways. Some authors have used it to define specific system attributes, while others have used it to characterize the entire system as an umbrella concept. This leads to considerable confusion. Without an explicit operational definition, resilience only has the broadest meaning and remains a concept rather than a policy or management tool. At the same time, work on adaptation to climate change has developed and is now operationalizing the concept of adaptive capacity, which is defined as the ability to plan, prepare for, and implement adaptation options.

Based on the present knowledge, the authors feel that the definition of resilience is best used to define specific system attributes, particularly:

- The amount of disturbance a system can absorb and still remain within the same state or domain of attraction; and
- The degree to which the system is capable of self-organization.

These specific attributes are more amenable to measurement and monitoring, although questions about the relationship between natural system and social system resilience remain to be fully explored.

In this conceptual framework, resilience is one property that contributes to the overall adaptive capacity of the system in question. The narrower definition of resilience proposed here differs from the approach followed by the ISDR, which uses it in a broader sense that has similarities to the definition of adaptive capacity (UN/ISDR 2002a).

In the case of coastal megacities, maintaining and enhancing both resilience and adaptive capacity for weather-related hazards would be desirable policy and management goals, although based on the hierarchy, maintaining and enhancing adaptive capacity is the overall goal. The framework for resilience and adaptive capacity proposed here has benefits in terms of linking:

- Analysis of present and future hazardous conditions (being addressed by climate change); and
- Enhancement of the capacity for disaster prevention and preparedness with disaster recovery.

This is consistent with the challenges for the future identified by United Nations International Strategy for Disaster Reduction (2002a).

Note

1. This analysis only considers the thermal expansion component of sea level change.

Bibliography

Adger, W.N. 1997. *Sustainability and Social Resilience in Coastal Resource Use.* Centre for Social and Economic Research on the Global Environment, University of East Anglia, Norwich, and University College London, London.

Adger, W.N. 2000. "Social and Ecological Resilience: Are They Related?" *Progress in Human Geography* 24: 347–364.

Arnell, N.W., M.G.R. Cannell, M. Hulme, R.S. Kovats, J.F.B. Mitchell, R.J. Nicholls, M.L. Parry, M.T.J. Livermore, and A. White. 2002. "The Consequences of CO_2 Stabilisation for the Impacts of Climate Change. *Climatic Change* 53: 413–446.

Barbière, J. and H. Li. 2001. "Editorial, Third Millennium Special Issue on Megacities." *Ocean and Coastal Management* 44(4), v–ix.

Bigio, A.G. 2002. *Cities and Climate Change.* Urban Development Division, The World Bank, Washington, D.C.

Bijlsma, L., C.N. Ehler, R.J.T. Klein, S.M. Kulshrestha, R.F. McLean, N. Mimura, R.J. Nicholls, L.A. Nurse, H. Pérez Nieto, E.Z. Stakhiv, R.K. Turner, and R.A. Warrick. 1996. "Coastal Zones and Small Islands." In R.T. Watson, M.C. Zinyowera, and R.H. Moss, eds., *Impacts, Adaptations and Mitigation of Climate Change: Scientific-technical Analyses.* Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, U.K.: Cambridge University Press: 289–324.

Bird, E.C.F. 1985. *Coastal Changes: A Global Review.* Chichester, U.K.: Wiley.

Boesch, D.F., M.N. Josselyn, A.J. Mehta, J.T. Morris, W.K. Nuttle, C.A. Simenstad, and D.J.P. Swift. 1994. "Scientific Assessment of Coastal Wetland Loss, Restoration and Management in Louisiana." *Journal of Coastal Research*, Special Issue 20; v and 103.

Burton, I., R.W. Kates, and G.F. White. 1993. *The Environment as Hazard*. Second Edition. New York: Guilford Press.

Carpenter, S., B. Walker, J.M. Anderies, and N. Abel. 2001. "From Metaphor to Measurement: Resilience of What to What?" *Ecosystems* 4: 765–781.

Chapin, F.S., E.S. Zavaleta, V.Y. Eviner, R.L. Naylor, P.M. Vitousek, H.L. Reynolds, D.U. Hooper, S. Lavorel, O.E. Sala, S.E. Hobbie, M.C. Mack, and S. Diaz. 2000. "Consequences of Changing Biodiversity." *Nature* 405: 234–242.

Church, J.A., J.M. Gregory, P. Huybrechts, M. Kuhn, K. Lambeck, M.T. Nhuan, D. Qin, and P.L. Woodworth. 2001. "Changes in Sea Level." In T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson, eds., *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, U.K.: Cambridge University Press: 639–693.

Clark, M. 1998. "Flood Insurance as a Management Strategy for U.K. Coastal Resilience." *The Geographical Journal* 164(3): 333–343.

Common, M. 1995. *Sustainability and Policy: Limits to Economics.* Cambridge, U.K.: Cambridge University Press.

Costanza, R., M. Kemp, and W. Boynton. 1995. "Scale and Biodiversity in Estuarine Ecosystems." In C. Perrings, K.G. Mäler, C. Folke, C.S. Holling, and B.O. Jansson, eds., *Biodiversity Loss: Economic and Ecological Issues.* Cambridge, U.K.: Cambridge University Press: 84–125.

Cross, J.A. 2001. "Megacities and Small Towns: Different Perspectives on Hazard Vulnerability." *Environmental Hazards* 3: 63–80.

Davison, A.T., R.J. Nicholls, and S.P. Leatherman. 1992. "Beach Nourishment as a Coastal Management Tool: An Annotated Bibliography on Developments Associated with the Artificial Nourishment of Beaches." *Journal of Coastal Research* 8(4): 984–1,022.

Dennis, K.C., I. Niang-Diop, and R.J. Nicholls. 1995. "Sea-level Rise and Senegal: Potential Impacts and Consequences." *Journal of Coastal Research* Special Issue 14: 243–261.

Devine, N.P. 1992. *Urban Vulnerability to Sea-level Rise in the Third World.* M.S. Thesis. New Brunswick, N.J.: Rutgers, The State University of New Jersey.

Dovers, S.R. and J.W. Handmer. 1992. "Uncertainty, Sustainability and Change." *Global Environmental Change* 2: 262–276.

Folke, C., S. Carpenter, T. Elmqvist, L. Gunderson, C.S. Holling, B. Walker, J. Bengtsson, F. Berkes, J. Colding, K. Danell, M. Falkenmark, L. Gordon, R. Kasperson, N. Kautsky, A. Kinzig, S. Levin, K.-G. Mäler, F. Moberg, L. Ohlsson, P. Olsson, E. Ostrom, W. Reid, J. Rockstroem, H. Savenije, and U. Svedin. 2002. "Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations." The Environmental Advisory Council to the Swedish Government, Stockholm.

Gilbert, S. and R. Horner. 1984. *The Thames Barrier.* London: Thomas Telford:182.

Gordon, J.E. 1978. *Structures.* Harmondsworth, U.K.: Penguin Books.

Green, C., R.J. Nicholls, C. Johnson, S. Schackley, and J.W. Handmer. 2000. *Climate Change Adaptation: a Framework for Analysis and Decision-making in the Face of Risk and Uncertainty* Report No. 28. A report produced for NCRAOA as part of Environment Agency R and D Project E2-036. Environment Agency: 87.

Hamm, L., H. Hanson, M. Capobianco, H.H. Dette, A. Lechuga, and R. Spanhoff. 1998. "Beach Fills in Europe—Projects, Practises and Objectives." *Proceedings of the 26th Coastal Engineering Conference* in Copenhagen. New York, N.Y.: American Society of Civil Engineers: 3,060–3,073.

Han, M., J. Hou, and L. Wu 1995. "Potential Impacts of Sea-level Rise on China's Coastal Environment and Cities: A National Assessment." *Journal of Coastal Research* Special Issue No. 14: 79–95.

Handmer, J.W. 1995. "Managing Vulnerability in Sydney: Planning or Providence?" *GeoJournal* 37(3): 355–368.

Handmer, J.W. and S.R. Dovers. 1996. "A Typology of Resilience: Rethinking Institutions for Sustainable Development." *Industrial and Environmental Crisis Quarterly* 9: 482–511.

Harrison, P. and F. Pearce. 2000. *AAAS Atlas of Population and Environment* (American Association for the Advancement of Science). Berkeley, CA: University of California Press, Berkeley: 204.

Holling, C.S. 1973. "Resilience and Stability of Ecological Systems." *Annual Review of Ecological Systems* 4: 1–23.

Holling, C.S. 1986. "The Resilience of Terrestrial Ecosystems: Local Surprise and Global Change." In W.C. Clark and R.E. Munn, eds., *Sustainable Development of the Biosphere*. Cambridge, U.K.: Cambridge University Press: 292–320.

Holling, C.S. 1997. "Regional Responses to Global Change." (Editorial) *Conservation Ecology* 1(1). Available from <http://www.consecol.org>.

Houghton, T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson, eds. 2001: *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, U.K.: Cambridge University Press.

IPCC CZMS (Intergovernmental Panel on Climate Change, Response Strategies Working Group, Coastal Zone Management Subgroup). 1990. *Strategies for Adaptation to Sea Level Rise*. Report of the Coastal Zone Management Subgroup. The Hague: Ministry of Transport, Public Works and Water Management: x and 122.

Kelly, M.P. 1991. Global Warming: Implications for the Thames Barrier and Associated Defences. In R. Frasetto, ed., *Impact of Sea Level Rise on Cities and Regions*. Proceedings of the First International Meeting "Cities on Water" in Venice, Italy, December 1989. Venice: Marsilio Editori: 93–98.

Kelly, C. 1995. "Assessing Disaster Needs in Megacities: Perspectives from Developing Countries." *GeoJournal* 37(3): 381–385.

Klein, R.J.T. (Forthcoming). "Adaptation to Climate Variability and Change: What is Optimal and Appropriate?" In C. Giupponi and M. Schechter, eds., *Climate Change and the Mediterranean: Socio-Economics of Impacts, Vulnerability and Adaptation*. Cheltenham, U.K.: Edward Elgar.

Klein, R.J.T and R.J. Nicholls. 1999. "Assessment of Coastal Vulnerability to Climate Change." *Ambio* 28(2): 182–187.

Klein, R.J.T. and R.S.J. Tol. 1997. "Adaptation to Climate Change: Options and Technologies—An Overview Paper." Technical Paper FCCC/TP/1997/3. United Nations Framework Convention on Climate Change Secretariat. Bonn, Germany: 33.

Klein, R.J.T., R.J. Nicholls, and N. Mimura. 1999. "Coastal Adaptation to Climate Change: Can the IPCC Technical Guidelines be applied?" *Mitigation and Adaptation Strategies for Global Change* 4: 51–64.

Klein, R.J.T., M.J. Smit, H. Goosen, and C.H. Hulsbergen. 1998. "Resilience and Vulnerability: Coastal Dynamics or Dutch Dikes?" *The Geographical Journal* 164(3): 259–268.

Klein, R.J.T., J. Aston, E.N. Buckley, M. Capobianco, N. Mizutani, R.J. Nicholls, P.D. Nunn, and Ragoonaden, S. 2000. "Coastal Adaptation Technologies." In B. Metz, O.R. Davidson, J.W. Martens, S.N.M. van Rooijen, and L.L. Van Wie McGrory, eds., *IPCC Special Report on Methodological and Technological Issues in Technology Transfer*. Cambridge: Cambridge University Press: 349–372.

Klein, R.J.T., R.J. Nicholls, S. Ragoonaden, M. Capobianco, J. Aston, and E.N. Buckley. 2001. "Technological Options for Adaptation to Climate Change in Coastal Zones." *Journal of Coastal Research* 17(3): 531–543.

Mimura, N., M. Isobe, and Y. Hosakawa. 1992. "Impacts of Sea Level Rise on Japanese Coastal Zones and Response Strategies." In J. O'Callaghan, ed. *Global Climate Change and the Rising Challenge of the Sea*. Proceedings of the Third IPCC CZMS Workshop, Margarita Island, Venezuela, March 9–13, 1992. National Oceanic and Atmospheric Administration. Silver Spring, MD: 329–349.

Mitchell, J.K. 1993. "Natural Hazard Predictions and Responses in Very Large Cities." In J. Nemec, J. M. Nigg, and F. Siccardi, eds. *Prediction and Perception of Natural Hazards*. Dordrecht, The Netherlands: Kluwer Academic Publishers: 29–37.

Mitchell, J.K. 1998. "Introduction—Hazards in Changing Cities." *Applied Geography Special Issue* 18(1): 1–6.

Mitchell, J.K., ed. 1999. *Crucibles of Hazard: Megacities and Disasters in Transition*. Tokyo: United Nations University Press: 535.

Muehe, D. and C.F. Neves. 1995. "The Implications of Sea-level Rise on the Brazilian Coast: A Preliminary Assessment." *Journal of Coastal Research* Special Issue 14: 54–78.

National Research Council. 1995. *Science, Policy and the Coast: Improving Decision-Making*. Washington, D.C.: National Academy Press.

Nicholls, R.J. 1995. "Coastal Megacities and Climate Change." *GeoJournal* 37(3): 369–379.

Nicholls, R.J. 2000. "An Analysis of the Flood Implications of the IPCC Second Assessment Global Sea-level Rise Scenarios." In D.J. Parker, ed., *Floods*. London: Routledge: 148–162.

Nicholls, R.J. and J. Branson, eds. 1998. "Enhancing Coastal Resilience—Planning for an Uncertain Future." *The Geographical Journal* 164(3): 255–343.

Nicholls, R.J. and N. Mimura. 1998. "Regional Issues Raised by Sea-level Rise and Their Policy Implications." *Climate Research* 11: 5–18.

Nicholls, R.J. and C. Small. 2002. "Improved Estimates of Coastal Population and Exposure to Hazards Released." *EOS Transactions* 83(2): 301, 305.

Nicholls, R.J., C. Johnson, C.P. Green, and S. Shackley. 2000. "An Adaptive Management Framework for Climate Change." In A. de la Vega-Leinert, R.J. Nicholls, and R.S.J. Tol, eds., *European Vulnerability and Adaptation to Impacts of Accelerated Sea-level Rise (ASLR)*. Proceedings of SURVAS Expert Workshop on A.C. Second workshop in Hamburg, Germany June 19–21, 2000. Flood Hazard Research Centre, Middlesex University, London: 125–139. Available from <http://www.survas.mdx.ac.uk>.

Parker, D.J. 1995. "Hazard Transformation and Hazard Management Issues in the London Megacity." *GeoJournal* 37(3): 313–328.

Parker, D.J., ed. 2000. *Floods*. 2 volumes. London: Routledge: 317, 431.

Parker, D.J. and J.K. Mitchell. 1995. "Disaster Vulnerability of Megacities: An Expanding Problem that Requires Rethinking and Innovative Responses." *GeoJournal* 37(3): 295–301.

Peterson, G.D., C.R. Allen, and C.S. Holling. 1998. "Ecological Resilience, Biodiversity and Scale." *Ecosystems* 1: 6–18.

Pielke, R. and C. Landsea. 1998. "Normalised Hurricane Damages in the United States: 1925–1995." *Weather and Forecasting* 13: 621–631.

Pimm, S.L. 1984. "The Complexity and Stability of Ecosystems." *Nature* 307: 321–326.

Rakodi, C. and D. Treloar. 1997. "Urban Development and Coastal Zone Management. An International Review." *Third World Planning Review* 19(4): 401–424.

Rosenzweig, C. and W.D. Solecki, eds. 2001. "Climate Change and a Global City: The Potential Consequences of Climate Variability and Change—Metro East Coast." Report for the U.S. Global Change Research Program, National Assessment of the Potential Consequences of Climate Variability and Change for the United States, Columbia Earth Institute, New York: 224.

Schulze, E.D. and H.A. Mooney. 1993. *Biodiversity and Ecosystem Function*. Berlin: Springer-Verlag.

Scott, M., S. Gupta, E. Jáuregui, J. Nwafor, D. Satterthwaite, Y.A.D.S. Wanasinghe, T. Wilbanks, and M. Yoshino. 2001. "Human Settlements, Energy and Industry." In J.J. McCarthy, O.F. Canziano, and N. Leary, eds., *Climate Change 2001: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press: 381–416.

Shih, S. 2002. *A Framework for Analysis of Managed Realignment for the Thames Estuary*. MSc Thesis. London: Middlesex University: 88.

Small, C. and J.E. Cohen. 1999. "Continental Physiography, Climate and the Global Distribution of Human Population." *Proceedings of the International Symposium on Digital Earth*. Beijing: Science Press: 965–971. Available from <http://www.ldeo.columbia.edu/~small/ContPhys.html>.

Smit, B., O. Pilifosova, I. Burton, B. Challenger, S. Huq, R.J.T. Klein, and G. Yohe. 2001. "Adaptation to Climate Change in the Context of Sustainable Development and Equity." In J.J. McCarthy, O.F. Canziano, and N. Leary, eds., *Climate Change 2001: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press: 877–912.

Smith, J.B., R.J.T. Klein, and S. Huq, eds. 2002. *Enhancing the Capacity of Developing Countries to Adapt to Climate Change*. London: Imperial College Press, London.

Timmerman, P. 1981. *Vulnerability, Resilience and the Collapse of Society: A Review of Models and Possible Climatic Applications*. Institute for Environmental Studies, University of Toronto, Toronto.

Timmerman, P. and R. White. 1997. "Megahydrolopolis: Coastal Cities in the Context of Global Environmental Change." *Global Environmental Change* 7(3): 205–234.

Tol, R.S.J., R.J.T. Klein, and R.J. Nicholls. Forthcoming. "Towards Successful Adaptation to Sea Level Rise Along Europe's Coasts." *Journal of Coastal Research*.

Turner, R.K., S. Subak, and W.N. Adger. 1996. "Pressures, Trends, and Impacts in Coastal Zones: Interactions Between Socioeconomic and Natural Systems." *Environmental Management* 20(2): 159–173.

Turton, A.R. 1999. "Water Scarcity and Social Adaptive Capacity: Towards an Understanding of the Social Dynamics of Managing Water Scarcity in Developing Countries." MEWREW Occasional Paper No. 9, University of London, School of Oriental and African Studies (SOAS), Water Issues Study Group.

UN/DESA (United Nations Department of Economic and Social Affairs). 2001. *World Population Prospects—the 2000 Revision*. Population Division, Department of Economic and Social Affairs. New York: United Nations: xii, 64.

UNEP (United Nations Environment Program). 2002. *Global Environment Outlook 3*. London: Earthscan: 446.

UNCHS Habitat (United Nations Human Settlements Programme). 2001. *Cities in a Globalizing World: Global Report on Human Settlements 2001*. London: Earthscan: 344.

UN/ISDR (United Nations International Strategy for Disaster Reduction). 2002a: *Living With Risk: A Global Review of Disaster Reduction Initiatives*. Prepared as an interagency effort and coordinated by the UN/ISDR Secretariat, Geneva. Available from <http://www.unisdr.org/unisdr/Globalreport.htm>.

UN/ISDR (United Nations International Strategy for Disaster Reduction). 2002b: *Natural Disasters and Sustainable Development: Understanding the Links Between Development, Environment and Natural Disasters*. Background document for the World Summit on Sustainable Development (WSSD) No. 5. Geneva. Available from <http://www.unisdr.org>.

Wang, B., S. Chen, K. Zhang, and J. Shen. 1995. "Potential Impacts of Sea-Level Rise on the Shanghai Area." *Journal of Coastal Research* Special Issue No. 14: 151–166.

WCC' 93 (World Coast Conference). 1994. "Preparing to Meet the Coastal Challenges of the 21st Century." Report of the World Coast Conference, Noordwijk, The Netherlands, November 1–5, 1993, Ministry of Transport, Public Works and Water Management, The Hague: 49, and appendices.

Chapter 9

Flood Management and Vulnerability of Dhaka City

Saleemul Huq and Mozaharul Alam

Dhaka, the capital and largest city in Bangladesh, was established by the Mughal Emperor Jahangir in 1608 on the banks of the river Buriganga. The city is surrounded by the distributaries of the two major rivers, the Brahmaputra and the Meghna. The surrounding rivers are Buriganga to the south, Turag to the west, Tongi khal to the north, and Balu to the east. The city and adjoining areas are composed of alluvial terraces of the southern part of the Madhupur tract and low-lying areas of the doab of the river Meghna and Lakkha. The combined area of Dhaka East and Dhaka West known as Greater Dhaka covers an area of approximately 275 square kilometers (JICA 1991). The elevation of Greater Dhaka is 2 to 13 meters above the mean sea level, and most of the urbanized areas are at elevation of 6 to 8 meters above the mean sea level. The land area above 8 meters above mean sea level covers about 20 square kilometers. The land ranging from 6 to 8 meters above mean sea level covers 75 square kilometers, while 170 square kilometers of Greater Dhaka is below 6 meters above mean sea level (JICA 1987). The highest lands are located at Mirpur.

The present population of the Dhaka Statistical Metropolitan Area is more than 10 million. The last decadal growth rate was about 70 percent, though the population growth rate was even higher, more than 100 percent in the previous decade (1981 to 1991). Population statistics of Dhaka city show that the annual growth rate was 2.9 percent from 1951 to 1961, 10.2 percent from 1961 to 1974, and 8.1 percent from 1974 to 1981.

By virtue of being surrounded by the distributaries of several major rivers, the city has been subjected to periodic flooding since its early days. Major floods in the Greater Dhaka area have occurred in 1954, 1955, 1970, 1974, 1980, 1987, 1988, and 1998 due to spillover from surrounding rivers. Among these, the 1988 and 1998 floods were catastrophic. In the 1988 flood, it was estimated that about 85 percent of the city was inundated at depths ranging from 0.3 to over 4.5 meters, and about 60 percent of city dwellers were affected. It also disrupted city life, air travel, and communication from the capital city to the outside world. The 1998 flood was most severe in terms of extent and duration. It was estimated that about 56 percent of the city was inundated, including most of the eastern and 23 percent of the western parts of the city. The flood protection embankment and floodwalls along the Turag and the Buriganga rivers protect the western part of the city from river flooding.

The Buckland Flood Protection Embankment along the river Buriganga was the first attempt to mitigate flood damage in Dhaka City. Flood protection plans for Greater Dhaka have been under study and consideration for many years, but the catastrophic flooding that occurred in 1987 and 1988 brought into focus the urgent need to proceed with immediate action. In 1989, construction activities commenced on a "crash program" defined as Phase I work to embank the western part of the city. This has been completed. Flood protection infrastructure for the eastern zone is under active consideration by the government of Bangladesh.

This report on the flood vulnerability of Dhaka city and flood management is organized into five main sections. An introductory section briefly explains the origin, population, flood proneness, and mitigation measures of Dhaka City. The second section provides historical development, emphasizing physical growth of the city and demographic features. The third section of the report highlights flood proneness of the city, including detailed impact assessments from the 1988 and 1998 floods. The fourth section provides information on various measures completed and ongoing to mitigate flood hazards. The concluding section of the report attempts to conduct an analysis of integrated flood management plans for Dhaka city, to protect it from natural disasters with minimum environmental disruption.

Physical and Demographic Development

The physical features, topography, and demographic features of Dhaka City have always influenced its expansion. Political importance and trade played significant roles in the city's expansion during the Mughal and British regime. This section briefly describes the growth and expansion of the city in the scale of time under five major periods: pre-Mughal (before 1604), Mughal (1604–1764), British (1764–1947), Pakistan (1947–1971), and Bangladesh (after 1971).

Pre-Mughal Period (before 1604)

Growth and expansion of Dhaka city in the pre-Mughal period is obscure. The near capital city of Vikrampur was in the limelight from the 10th to 13th centuries. The Muslim occupation of southeastern Bengal can be placed in the late 13th and early 14th centuries, when Sonargaon rose to prominence. This was first as a mint town and an administrative headquarters and subsequently for a short time as the capital under the early Iliyas Shahi Sultans. Sonargaon enjoyed the position of a metropolis in the region in the pre-Mughal period.

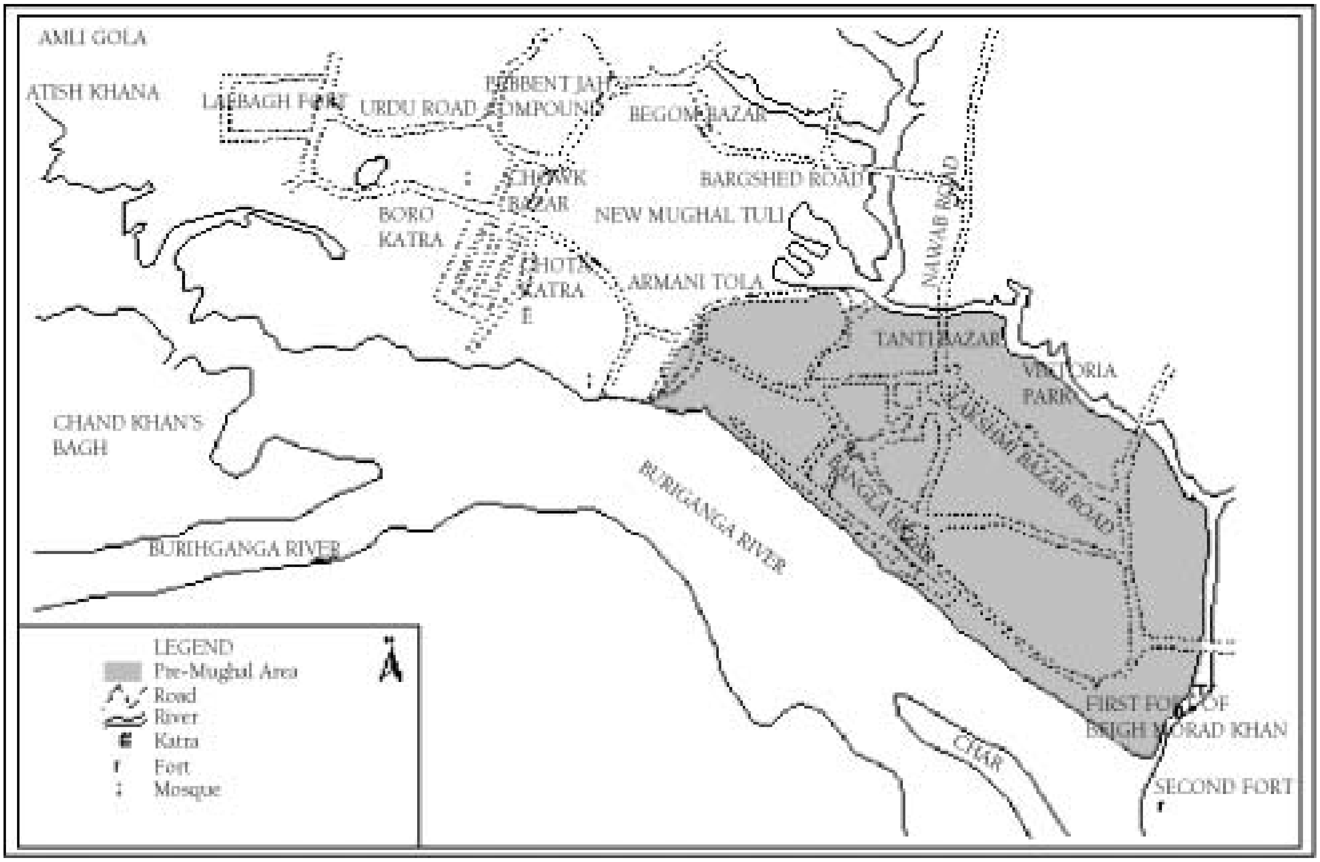
It is evident from the various writings on Dhaka that the areas to the east, northeast, and southeast of Babur Bazar up to the Dulai river on the left bank (northern bank) of the Buriganga formed the old town. The conglomeration of Hindu-named localities in this part of the city bears testimony to the predominance of Hindu craftsmen and professionals in the population of old Dhaka city at that time. The Dulai River possibly formed the northeastern boundary of the old city, though it is difficult to determine the western limit of the pre-Mughal "old city." Considering testimony to the existence of a mosque at that time, however, it can be assumed the city limits went beyond Babur Bazar on the western side (figure 9.1). It is quite likely that, following the course of the Buriganga, settlements grew on the southern, western, and northwestern parts of the city. These, of course, were sporadic growths with the riverbank determining the basis for settlements. The population of Dhaka city at that time is unknown.

Mughal Period (1604–1764)

The "new Dhaka" inaugurated by Islam Khan through the establishment of a fort, Chandnighat and the Chauk, experienced growth under the subsequent Mughal Subahdars until 1717, when the provincial capital was officially shifted to Murshidabad. Dhaka enjoyed status as a provincial capital for slightly more than a century. During this period, administrative and defense needs, coupled with flourishing commercial activities, led to Dhaka's growth from a town to a metropolis. The accounts left by foreign travelers, the extant of the Mughal ruins, and the names of the localities that still survive show the extent of Mughal Dhaka (Karim 1964). It appears from various documents and Muslim sculptures that Mughal Dhaka encompassed the "old Dhaka" within itself. The noteworthy feature of the city was its growth to the northern Phulbaria area. In this period, the expansion to the west and the north was significant. With the fort in the center, the expansion to the west followed the riverbank, and the city spread northward to Phulbaria on the fringe of the Ramna area. The peelkhana (elephant stable) was established at the western end. Residential quarters for officials, government functionaries, and merchants grew in the area between the fort and the peelkhana to the west and the fort and Phulbaria to the north. In this growth of Mughal Dhaka, the general characteristics of a Mughal city were noticeable. The areas to the south and southwest of the fort up to the riverbank grew mainly as commercial areas, while to the north and northeast, residential areas sprouted.

The northern limit of the city extended to the gateway built by Mir Jumla (1660–63), near the present-day mausoleum of three leaders, at the southeastern corner of the Suhrawardy Udyan. Mir Jumla's name is also associated with the construction of two roads connecting Dhaka with a network of forts built for the defense of the capital city. A road headed north to a fort at Tongi-Jamalpur and another toward the east connected Dhaka with Fatullah, where two other defensive forts were constructed. These two roads influenced the growth of the city in these directions.

Figure 9.1 Demarcation between Pre-Mughal and Mughal Dhaka



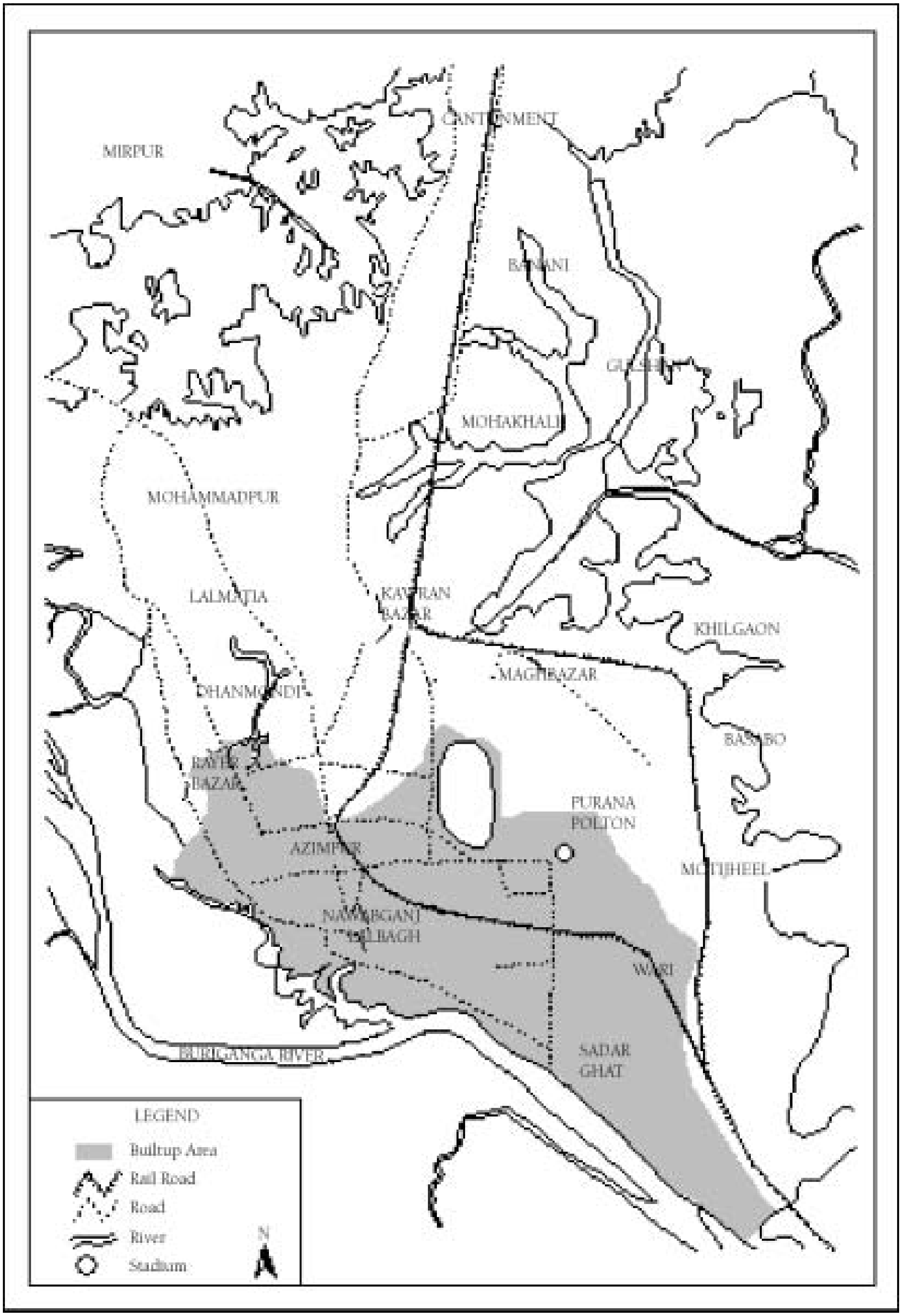
In the available early records of the East India Company (1786 and 1800), the boundary of the city is mentioned as: Buriganga in the south, Tongi in the north, Jafarabad-Mirpur in the west, and Postogola in the east. The expansion of the city in the Mughal period was dictated by nature due to the highlands.

With the establishment of the Mughal provincial capital at Dhaka, the city entered a glorious era and became the chief emporium for products from eastern Bengal. The commercial headquarters was established in the Mirpur area, Shah Bandar. Due to its commercial importance, Dhaka attracted numerous traders—Portuguese, Dutch, English, French, and Armenians—who established trading houses in Dhaka in the 17th century. Factories were also established in the Tejgaon area, which continued to enjoy commercial importance during the next century (figure 9.2). The road built by Mir Jumla formed an axis with European settlements on either side, north of the Kawran Bazar and Amber Bridege (Karim 1964). The physical size of Dhaka was about 50 square kilometers; the population about 0.9 million.

British Period (1764–1947)

After the acquisition of the Diwani in 1765 by the East India Company and the shift of Bengal's capital to Calcutta, Dhaka lost its political importance. Gradually the administrative and commercial importance of the city dwindled, and by 1828 the city was reduced to a mere district headquarters, though it retained its position as a provincial Circuit Court of Appeal. By 1840, this decline had reached its nadir, and most of the former Mughal city had been deserted or fallen victim to the encroaching jungle (Ahmed 1986). The decline affected Dhaka seriously, and during this period Dhaka also suffered physical shrinkage. The jungle-beset city was shown in a topographical map prepared in 1859 as covering an area only a little over three square miles (figure 9.2).

Figure 9.2 The buildup area of the Mughal capital



The second half of the 19th century marked the beginning of the physical renewal of the city. In 1857, India came under the direct rule of the British crown and saw some development of utility services. In 1905, Dhaka became the capital of the new province of East Bengal and Assam. Building the new town started beyond the railroad in Ramna. The only locality developed as a fully planned residential area was Wari. In 1885, Frederick Wyer, the Collector of Dhaka, began developing the area with "broad roads and proper drains." Wari became an upper-middle class area considered "the sanatorium of Dacca."

The Siddheswari area to the northeast of the Race Course was cleared by the government in the early 20th century and the former jungle was developed as a residential area. At the same time, the wasteland around the Dhakeswari shrine was cleared by the local people who felt encouraged to occupy the areas around the newly developed area of Ramna. Thus the "new Dhaka" of the present century had its birth at the hands of the British rulers.

The impetus for growth created by the 1905 partition of Bengal was seriously jolted by the annulment of the partition in 1911, when Dhaka reverted back to the status of a district town. The establishment of the University of Dhaka, which came to occupy many of the buildings of the Ramna area, was the only important event in Dhaka's history until 1947, when Dhaka again attained the status of the provincial capital of the eastern part of Pakistan, initially called East Bengal and later named East Pakistan.

Pakistan (1947–1971)

In 1947, India become independent of British rule and Pakistan was created. Dhaka restarted its life as the capital of East Pakistan. The needs of the officials engaged in administration, the business community, and the residents grew out of the sudden onrush of people to Dhaka. This contributed to the growth of the city in its new role as the provincial capital.

In 1954, the Motijheel area, once desolate and lying on the fringe of marshes and swamps where the Nawabs had built a garden house, was earmarked as a commercial area. By that time, the area north of Nawabpur Railway crossing to the Purana Paltan was developed as the open area of the city with the stadium forming the nerve center of sporting activities. Jinnah Avenue (now Bangabandhu Avenue) was laid to form the main thoroughfare along the western side of this expansive open area.

To cater to the ever-increasing residential needs of the new capital, the Dhanmondi area, adorned with paddy fields in the early 1950s, was developed as a residential area after 1955. The Mirpur Road formed an axis, and the highlands on both sides of the road came to be occupied, right up to Mohammadpur and Mirpur. In the mid-1960s these two areas were developed by the government, mainly to accommodate the migrant Muslim population. The Tejgaon Airport and the Tejgaon Industrial area came under governmental schemes in the early 1950s. In the second half of the 1960s, the decision to have a capital for East Pakistan at Dhaka led to the development of the area to the west of Tejgaon farm and the airport (now known as Sher-e-Bangla Nagar).

With the creation of the Dhaka Improvement Trust (DIT) in 1956 (transformed into the Rajdhani Unnayan Kartripakkha in 1987), greater interest and care were undertaken in road construction and city planning. The DIT developed the Gulshan Model Town in 1961, Banani in 1964, Uttara in 1965, and Baridhara in 1972 (though first conceived in 1962). The Dilkusha Gardens adjacent to Motijheel were eventually engulfed by the ever-growing commercial needs.

In the mid-1960s the main railway line was shifted and directed eastward, after Tejgaon and before Kawranbazar, before rejoining the old track near Swamibagh-Zatrabari cutting through Rajarbagh, Basabo and Kamalapur. The Dhaka Railway Station was moved from Phulbaria to Kamalapur. This eliminated the landmark that had long stood between the "old Dhaka" of the Mughals and the "new Dhaka" of the English. The rapid growth and development of the area between the old railway track and Kawranbazar necessitated this change. The loop through the heart of Ramna had to be abandoned. Since then, the old track has been developed into a broad road connecting Kawranbazar with Phulbaria through Plassey and Nilkhet to the northwest and Swamibagh-Zatrabari through Wari to the north and Narinda to the southeast.

Table 9.1 Area and population of Dhaka City, 1600–2001

Period and year	*Approximate area (sq. km.)*	*Source*	*Population*	*Source*
1600 Pre-Mughal Period	1	Islam, 1974	Unknown	
1700 Mughal Capital	50	Taylor, 1840	900,00	Taylor, 1840
1800 British Town	8	Islam, 1974	200,000	Taylor, 1840
1867 British Town	8	Islam, 1974	51,000	Census of Bengal, 1901
1911 British Town	—	—	125,733	Census of Bengal, 1911
1947 Capital of East Pakistan	12	Islam, 1974	250,000	Census of Pakistan, 1951
1951 Pakistan Period	—	—	335,928	Census of Pakistan, 1951
1961 Pakistan Period	28	Census of Pakistan	550,143	Census of Pakistan, 1961
1971 Capital of Bangladesh	40	Census of Bangladesh, 1974	1,500,000	Census of Bangladesh, 1974
1974 Capital of Bangladesh	40	Census of Bangladesh, 1974	1,600,000	Census of Bangladesh, 1974
1981 Dhaka Municipality	62.4	Census of Bangladesh, 1981	2,475,710	Census of Bangladesh, 1981
1981 Dhaka SMA	155.4	Census of Bangladesh, 1981	3,440,147	Census of Bangladesh, 1981
1991 Dhaka SMA	—		6,950,920	Census of Bangladesh, 1991
2001 Dhaka SMA	—		9,912,908	Census of Bangladesh, 2001

Bangladesh (1971 onward)

The creation of the independent state of Bangladesh in 1971 bestowed glory and prestige on Dhaka, now capital of a sovereign country. This additional factor led to Dhaka's phenomenal growth since 1971. The low-lying areas on the eastern side, such as Jurain, Goran, Badda, Khilgaon, Rampura, and Kamrangir Char, Shyamali, Kalayanapur on the western side came under occupation. Dhaka's growth picked up at a tremendous pace and private initiatives played the dominant role.

The growth of the city followed the pattern set by the Mughal founders. The city was delineated the maximum limit to Tongi in the north and Mirpur in the northwest. The southeastern limit reached Postogola. The riverine surroundings with water-channels, marshes, and lowlands form the western, southern, and eastern boundaries of the city. With increased population pressure, the highlands spreading northward were occupied and built up. The intervening ditches, swamps, and marshes were filled in, not in any planned manner, but as exigencies arose and private initiatives dominated the process. Development under the aegis of the Dhaka Improvement Trust dictated nature, rather than allowing it to direct planned growth. In selecting the sites for the Model Towns of Gulshan, Banani, Baridhara, and Uttara, the method of selecting the highlands on the main Dhaka-Tongi axis road is clearly discernible. No serious effort at reclaiming land under a well-planned scheme to give the city homogenous and cohesive growth is visible. Dhaka has grown on its own in a haphazard manner, and the topography of the area dictated the terms and direction of the growth. Since Dhaka became the capital of an independent country, the pressure on it has been enormous. The permanent inhabitants of the city have registered a steady growth. In addition to this growth, there was a very large floating population, the pressure of which has resulted in the growth of slums on any available vacant land. The recently built high-rise buildings, both in the commercial and residential sectors, occupy the city's highlands and demonstrate ever-increasing pressure on Dhaka as it builds upward, an inevitable and common phenomenon in all modern cities facing population growth. Since the 1990s, Dhaka has been on the verge of change in its urban character, with vertical growth replacing horizontal expansion (Chowdhury and Faruqui 1989). Over the years, most of the low-lying areas of western Dhaka have been filled in to meet the city's residential and commercial demands. The eastern side of the city is being filled in by private intervention. Table 9.1 provides built-up areas and populations from the pre-Mughal period to 2001.

Major Floods in Dhaka

A number of severe floods have struck Dhaka since its early days, and its vulnerability is reflected in the Buriganga River's flood embankments, first built in 1864. Severe floods in Greater Dhaka City are mainly caused by spillover from surrounding rivers flowing to and from the major rivers of the country, as well as internal water logging. In recent history, Greater Dhaka city experienced major floods in 1954, 1955, 1970, 1974, 1980, 1987, 1988, and 1998 due to the overflow of surrounding rivers. Among these, the 1988 and 1998 floods were catastrophic.

Flooding due to rainfall is also a severe problem for certain city areas that may be inundated for several days, mainly due to drainage congestion. The water depth in some areas may be as high as 40–60 centimeters, which creates large infrastructure problems for the city, economic losses in production, and damage to existing property and goods. Impacts of the riverine floods are more severe and disrupt economic activities and livelihoods of people dependent upon urban activities. This section provides causes and characteristics of floods with brief descriptions of their impact from the last two major floods, in 1998 and 1988.

1998 Flood

The main reason for the 1998 flood was excessive rainfall over the catchments area of the Ganges-Brahmaputra-Meghna (GBM) river basin. Three different flood waves passed through the GBM river basin, and the last one was synchronized with the peak flow of the Ganges and the Brahmaputra. In addition, the impact of the lunar cycle and its resulting high tide caused floodwaters to recede slowly, prolonging flooding in the country and the city for two months.

The main causes of flooding inside the protected area were hydraulic leakage, failure to operate the regulators, and lack of timely pumping of accumulated water upstream from the Rampura Regulator. Due to completion of 75 percent of Phase I work of the Dhaka Integrated Flood Protection Project (DIFPP), it was assumed that the Gulshan, Banani, Baridhara, and Tejgaon areas would not be flooded. However, near the Cantonment Railway Station, there are 4 or more drainage pipes of about 4 feet in diameter that connect the Nikunga area with the floodplain on the eastern side. An apparent lack of coordination between the Bangladesh Water Development Board (BWDB) and Dhaka Water Supply and Sewerage Authority (DWASA) to prevent flooding was found. Although DWASA has responsibility for ensuring proper drainage, BWDB is in charge of operating the regulators and gates. In fact, there was neither an operating policy nor person assigned to operate the Rampura Regulator that controls the drainage of 40 percent of the protected area under Phase I of DIFPP.

Balu River Flood in Dhaka East

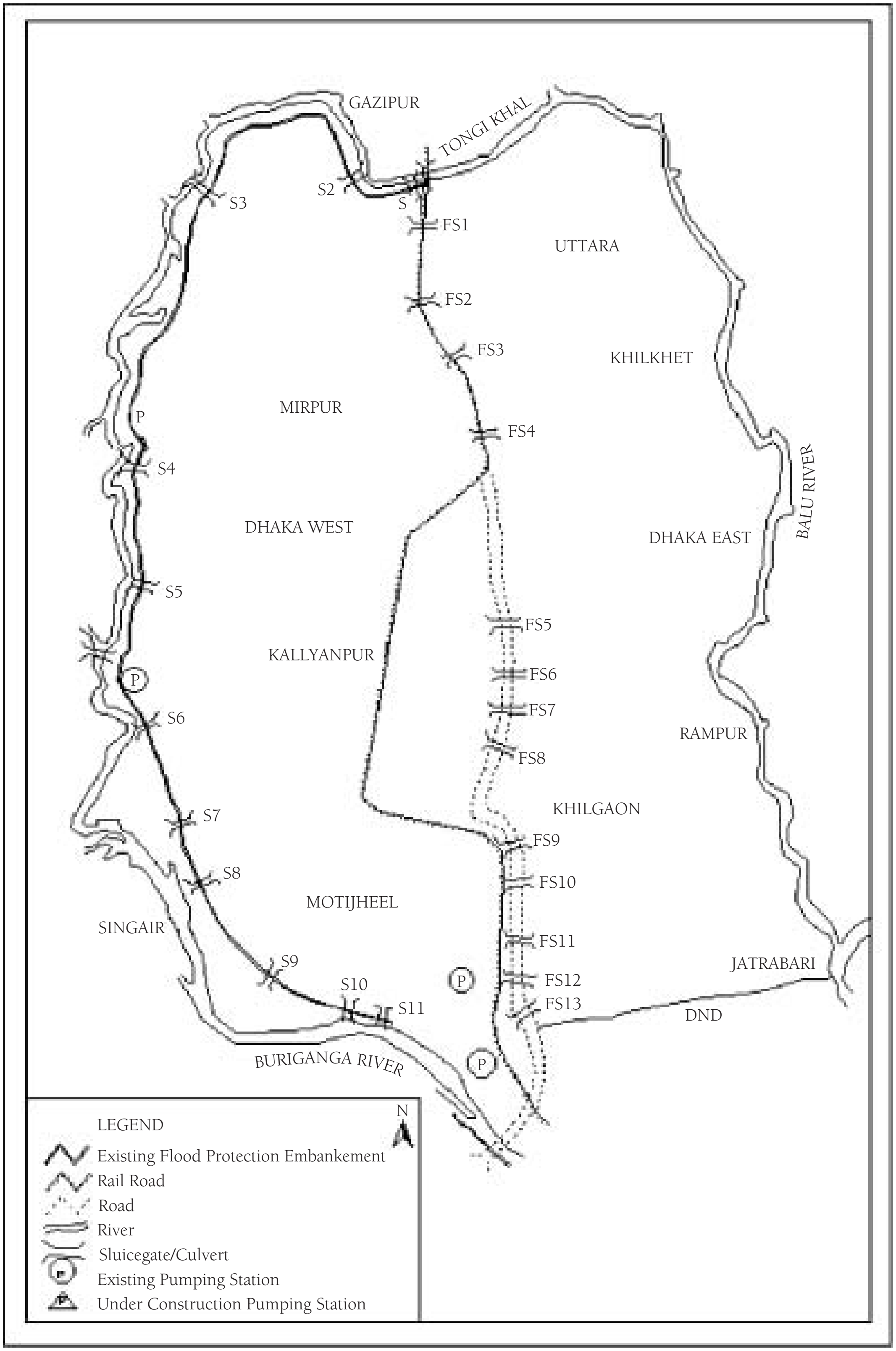
In the 1998 flood, almost all of Dhaka East was flooded by spillover from the Balu River. The flood started around July 22 and continued for some 65 days. The waters peaked on September 12. Residential areas such as Basabo, Mugdapara, Uttar Badda, and Joar Sahara were the worst affected. The ground floors of most buildings were inundated.

Balu River Flood in Dhaka West

As it is protected by the flood control project, it was expected that Dhaka West would remain flood-free, even though the areas adjacent to Mymensingh Road, Progati Sarani, DIT Road, and Biswa Road were submerged during the flood. Mahakhali, Gulshan, Banani, Badda, Baridhara, etc., faced worse flooding problems. The floodwaters remained in the western areas for about 30 days.

The intrusion of floodwater from Balu River to Dhaka East through unblocked culverts and open regulators was considered to be the general cause for river flooding in Dhaka West. It was revealed that three drainage structures, FS8 (Begunbari Khal Rgulator), FS5 (Shajadpur bridge on Pragati Sarani), and FS4 (Khilkhet pipe culvert at Nijunja), served as a flood-carrying channel (figure 9.3). Structure FS4 remained open during the entire flood and caused flooding in Nijunja adjacent to the airport and cantonment areas. Structure FS8 and FS5 were closed after the intrusion of substantial floodwater from the Balu River in Begunbari khal, Gulshan-Banani-Mohakhali Khal, and areas adjacent to the DIT road were submerged. The channel at structure FS5 was closed by an earthen bund. Structures FS9, FS10, and FS11 on Biswa road were responsible for partial flooding in Rajarbag, Gopibag, and Fakirapul before they were closed. Floodwaters in those areas were pumped out by 30 pumps installed at FS12 on Segunbagicha khal at a crossing with Biswa road.

Figure 9.3 Flood and drainage infrastructure of Dhaka



Buriganga River Flood in Dhaka West

The western part of the Dhaka Flood Protection Embankment ends in Lalbag Kellarmore at Swasan Ghat. It has a 2.2-kilometer embankment under construction from Kellermore to the Buriganga Bridge, and it was not closed during flooding, which allowed floodwater to flow into the western part of the city. Flood fighting by local people creating sandbag barriers saved Old Dhaka from flooding, especially in Lalbag Kellarmore. The difference in water levels between the outside and inside at Kellamore point was about 1.5 meters. It was found that the flood protection work started immediately after the flood recession.

Flooding Due to Excessive Rainfall

During the 1998 flood, excessive rainfall in Dhaka caused short-duration flooding in the areas of Shantinagar, Nayapaltan, Rajarbag, Dhanmodi, Azimpur, and Green Road. The runoff generated by rainfall could not flow to the surrounding rivers since the river stage was higher than the inside flow; therefore, the accumulated runoff in low-lying areas remained stagnant until the river stage receded. Extensive water logging occurred in Dhaka West during the flood due to a higher river water stage in the surrounding rivers.

Impacts

It is evident from various studies that damage to infrastructure including roads, water supply, and housing was severe. It was estimated that 384 kilometers of paved roads went under floodwaters, of which Gulshan Thana accounted for a significant amount. Severe damage occurred in Sabujbag Thana, followed by Demra. Severe disruption of water supplies from deep tube wells (DTW) and suspended production occurred in the Cantonment Thana followed by Gulshan and Uttara. Considering the major impacts of floodwaters, it appears that Sabujbag and Gulshan Thanas were worst affected, followed by Demra, Uttara, and Cantonment Thana.

Affected Population: Prof. S. A. Hye (1999) carried out a rapid appraisal of flood-affected people during the flood, dividing the flood-affected area into three categories: most severely affected area, severely affected area, and moderately affected area. It was found that the flood displaced or dislocated 94 percent of families in the most severely affected areas, 52 percent of families in severely affected areas, and 50 percent in moderately affected areas. It was also estimated that the total flood-affected population would likely be 4.55 million. Table 9.2 provides details of affected households and populations.

Effect on Water Supply and Production: It was found that 44 deep tube wells were affected by floodwater; production of 13 of these was suspended. The estimated loss in water production due to suspension was 45 million liters per day.

The remaining tube wells were kept operational by adopting protection measures including the erection of a protection wall around the pump house and raising housing pipes and electrical appliances above floodwater. It was also found that 5 of the 13 suspended tube wells were badly damaged and required replacement. The estimated cost to rehabilitate the water supply system is about 127 million taka, detailed in table 9.3.

Table 9.2 Flood-affected people in Dhaka City by severity of the flood, 1998

Severity of flood	*Affected wards (no.)*	*Total affected households*	*Total affected population (millions)*
Most severe	22	203,000	1.20
Severe	15	150,000	0.90
Moderate	43	409,000	2.45
Total affected	80	762,000	4.55

Source: Hye 1999.

Table 9.3 Cost of rehabilitation and replacement of Dhaka Water Supply System (DWASA), March 1999

Item	*Rehabilitation and replacement needs*	*Estimated cost (million taka)*
1	Repair and cleaning of 600 kilometer water distribution mains	15
2	Replacement of 5 deep tube wells	20
3	Rehabilitation of pump and electrical sub-station of 42 flood-affected DTWs	42
4	Raising level of reconstruction of walls of 42 pump houses	10
5	Installation of 3 low-lift pumps	15
6	Reconstruction of 20 kilometer water mains	25
		127

Source: Ahmed 1999.

Housing Damage: The 1998 flood caused damage to more than 262,000 shelter units, or 30 percent of the 860,552 units in the Dhaka Metropolitan Area; the cost of damage was Tk. 2,311 million. Of these, 32 percent were permanent and semipermanent structures belonging to wealthy or well-to-do households not dependent on assistance for repair and rehabilitation. About 36 percent of shelter units in the katcha-1 type, belonging to lower-middle and poorer classes, suffered damage of Tk. 283 million. Their owners had the ability to cope with repairs but would face hardship. Nearly 32 percent of units of Katch-2 and Jupri types, belonging to the poor and hard-core poor, suffered severe damage and required Tk. 195 million in repairs. The owners were too poor to mobilize funds on their own (Islam and Ali, 1999).

1988 Floods

In 1988, one of the most severe floods in recent history hit Dhaka and inundated 85 percent of the city. Floods of this intensity hit the country approximately once in 70 years. Depths of inundation ranged from 0.3 to more than 4.5 meters, and 60 percent of city dwellers were affected (JICA 1991, 1992). This unprecedented level of flooding disrupted city life and air travel. Communication with Dhaka to the outside world was cut off for about two weeks. Impacts and damage from the 1988 flood were compiled and analyzed according to component 8 of the Flood Action Plan (FAP8).

The entire eastern part of Dhaka and the entire low-lying area of the western part of Dhaka were under floodwater. Parts of Mirpur, Tejgaon, Banani, Shere-Banglanagar, Azimpur, and the Old Town were not flooded.

Impacts

Affected Population: According to available information on impacts of the 1988 flood on Dhaka, it was found that 2.2 million people were affected and the death toll was about 150. The figure for "affected population" was found to be lower than that of the detailed analysis that was carried out by FAP8 based on data collected through the flood damage sample survey (FAP8A).

Affected Houses and Institutions: It is estimated that the number of institutions and houses affected in the 1988 flood was 14,000 and 400,000, respectively. The damage was about Tk. 4 billion for residential buildings and more than Tk. 400 million for institutions.

Comparison of Flood Characteristics of 1988 and 1998

An analysis of water level hydrographs at gauging stations in surrounding rivers and at Noonkhawa on the Brahmaputra River revealed that in 1998, the first flood waves took approximately 6 days to reach Dhaka City from the India-Bangladesh border, while the flood peak required approximately 4 days to reach Dhaka. Due to hydraulic reasons, the flood peak moves faster than the flood trough. Figures 9.4 and 9.5 present hydrographs of surrounding rivers and rainfall in Dhaka City during 1988 and 1998. Table 9.4 presents flood characteristics of the 1988 and 1998 floods in rivers surrounding Dhaka.

Flood Mitigation Measures

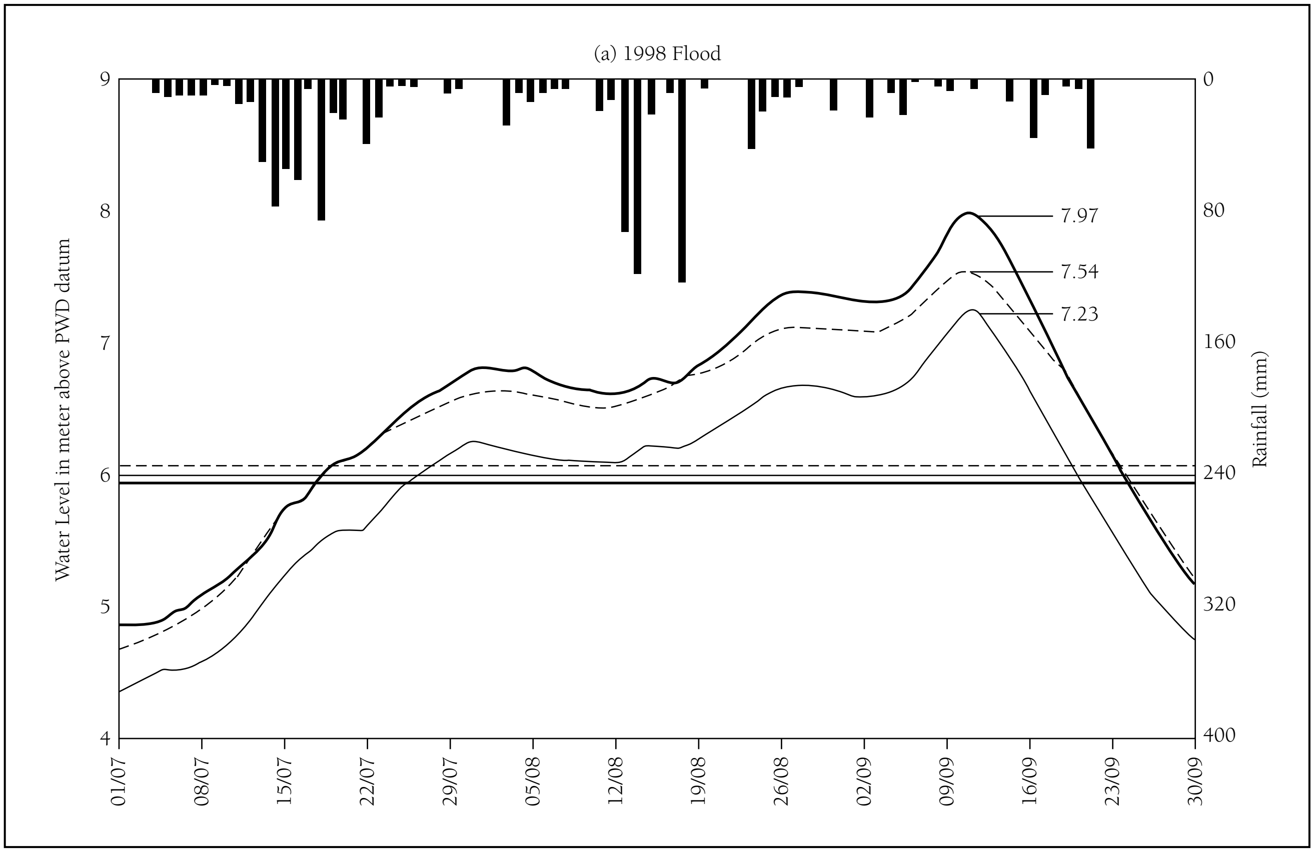
The first flood protection embankment along the Buriganga River was constructed in 1864 to protect the riverbank from flooding and erosion and give a facelift to the riverside. C.T. Buckland, the Commissioner of Dhaka, launched a scheme to construct an embankment (known as the Buckland Bound), which was completed in three phases in the 1880s.

Plans for flood protection for Greater Dhaka have been under study and consideration for many years, but the extreme flooding that occurred in 1987 and 1988 brought into focus the urgent need to proceed with immediate action. Subsequently, the Government of Bangladesh prepared an urgent flood protection and drainage plan, which included enclosing the greater Dhaka area with flood embankments, reinforced concrete walls, and drainage/flood regulation structures such as sluices and pumping stations.

Construction of Flood Protection Embankment

Construction activities commenced with a "crash program" in 1989, and most of the work defined as Phase I has been completed. It provides flood protection facilities to the western half of Dhaka and includes the most highly urbanized areas, covering about 87 percent

Figure 9.4 Water level hydrographs for Turag, Tongi, Buriganga, and Balu Rivers and rainfall in Dhaka during 1998



of the population. Important components of the flood protection measures are:

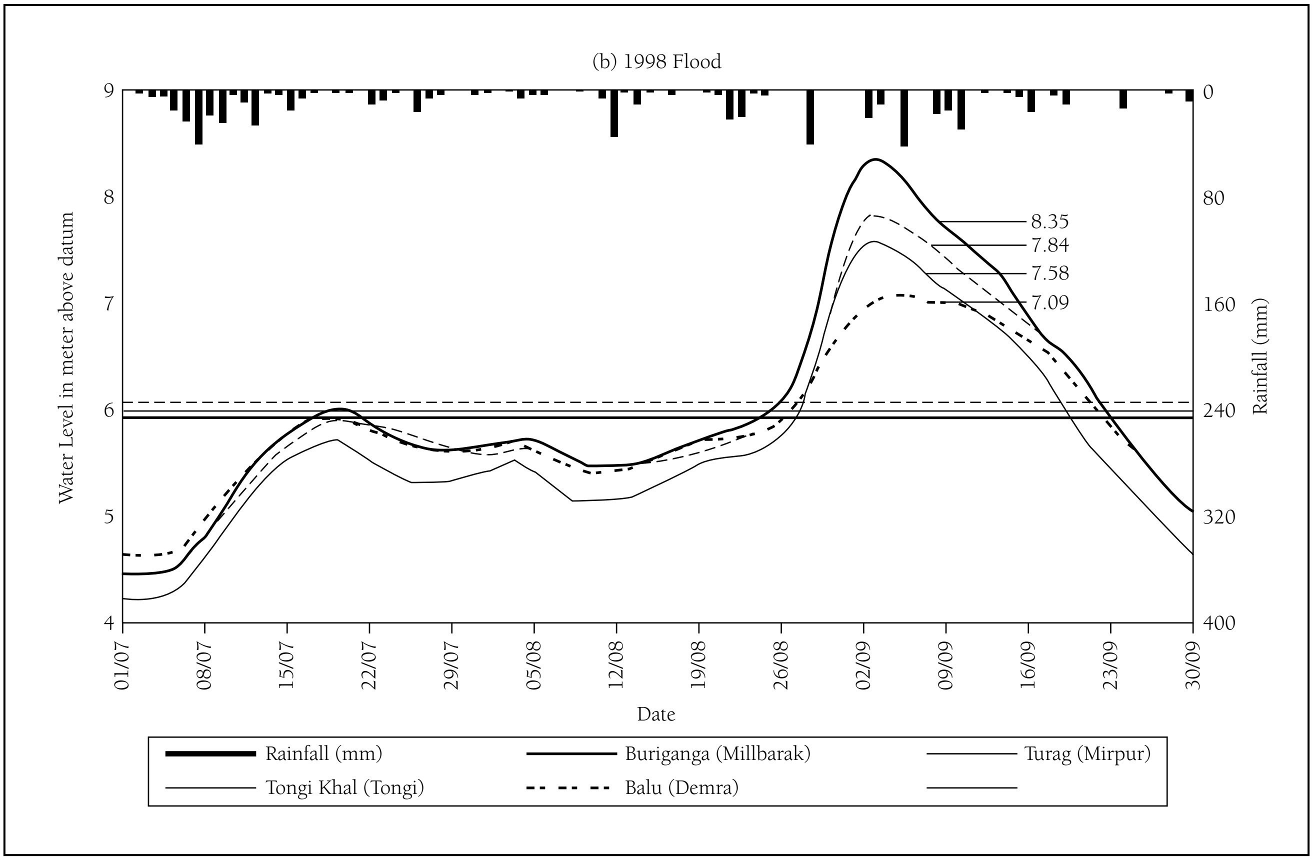
- Approximately 30 kilometers of earthen embankment along Tongi khal, Turag River, and Buriganga River.
- Approximately 37 kilometers of raised road and floodwall.
- A total of 11 regulators at the outfall of khals to the surrounding rivers along the embankment.
- One regulator and 12 sluice gates on the khals at the crossings with Biswa Road, DIT Road, Pragati Sarani, Mymensingh Road, and railway line at Uttar Khan.
- One pumping station at the outfall of Kallyanpur khal to the Turag River, and another one at the outfall of Dholai khal to the Buriganga River. These pump stations are for draining rainwater from parts of Dhaka West.
- A special 10.53-kilometer embankment to surround the Zia International Airport.

A rail-cum-road-embankment that will run along the Balu River for a total length of 29 kilometers is proposed for the eastern part of the city. This will be constructed under Phase II of the Dhaka Integrated Flood Protection Project (DIFPP) to protect the area between Biswa Road and the Balu River. The locations of regulators, sluice gates, pump stations, embankments, and raised roads are shown in figure 9.6. These flood control and drainage works have brought major changes in the flood regime of Dhaka West, including major changes in land use.

Construction of Storm Sewer and Pump Station

To alleviate the internal drainage problems of Dhaka, a storm-water drainage improvement plan was undertaken by Dhaka WASA (JICA 1991). As a part of the plan, many sections of the natural khals were replaced by concrete box culverts. Converted khals include Dhanmondi khal, Paribagh khal, Begunbari khal, Mahakhali khal, Segunbagicha khal, and Dholai khal. These khals are no longer visible. The present storm-water drainage network under Dhaka WASA covers an area of approximately

Figure 9.5 Water level hydrographs for Turag, Tongi, Buriganga, and Balu Rivers and rainfall in Dhaka during 1988



140 square kilometers. Important components of the drainage network are briefly summarized below.

- 22 open canals with widths of 10 to 30 meters and a total length of approximately 65 kilometers.
- 185 kilometers of underground pipes with diameters ranging from 450 to 3000 millimeters.
- 6.5 kilometers of box culvert with sizes ranging from 2.5 meters by 3.4 meters to 6 meters by 4.1 meters.
- 2 storm-water pumping stations with capacities of 9.6 and 10 cubic meters per second at Narinda and Kallyanpur, respectively.
- Recently, Dhaka City Corporation (DCC) constructed one storm-water pumping station with a capacity of 22 cubic meters per second at the outfall of Dholai khal into River Buriganga. Dhaka WASA has taken over the operation and maintenance of the pumping stations.

The Bangladesh Water Development Board is also constructing a pumping station at Goran Chadbari at the outfall of the Degun khal into the Turag River. There are also 65 small pumps with individual capacities of 0.142 cubic meters per second, installed temporarily by Dhaka WASA to drain storm water from various locations.

Moreover, DCC has constructed and maintains at least 130 kilometers of small-diameter underground drains and approximately 1,200 kilometers of surface drains that carry storm water to the main sewer lines. The Capital Development Authority (RAJUK) also constructs underground roadside drainage lines during the construction of new roads.

Conclusions and Recommendations

Two severe floods hit Greater Dhaka City within a decade, causing enormous loss of life and livelihoods and damage to property. Immediately after the 1988 flood, a number of studies were carried out within the general framework of the Flood Action Plan (FAP) that specifically addressed the issue of flooding in Dhaka City. The first

Table 9.4 Flood characteristics of 1988 and 1998 floods in surrounding rivers of Dhaka City

Parameters	*River*	*Gauge station*	*1998*	*1988*
Danger level in meters above PWD datum	Buriganga	Millbarak	6	6.1
	Turag	Mirpur	5.94	5.94
	Tongi Khal	Tongi	6.08	6.08
	Balu	Demra	—	—
Date of crossing-danger-level at rising stage	Buriganga	Millbarak	26/07/98	29/08/88
	Turag	Mirpur	18/07/98	24/08/88
	Tongi Khal	Tongi	22/07/98	28/08/88
	Balu	Demra	—	—
Number of days required by the flood front to arrive at Dhaka City from India-Bangladesh border	Buriganga	Millbarak	7	7
	Turag	Mirpur	6	7
	Tongi Khal	Tongi	6	6
	Balu	Demra	—	10
Number of days required by the highest flood peak to travel from India-Bangladesh border to Dhaka City	Buriganga	Millbarak	4	6
	Turag	Mirpur	4	6
	Tongi Khal	Tongi	5	6
	Balu	Demra	—	8
Height of peak flood level in meters above danger level	Buriganga	Millbarak	1.23	1.58
	Turag	Mirpur	2.03	2.41
	Tongi Khal	Tongi	1.46	1.76
	Balu	Demra	—	—
Duration of flood in days above danger level	Buriganga	Millbarak	56	22
	Turag	Mirpur	69	30
	Tongi Khal	Tongi	65	25
	Balu	Demra	—	—

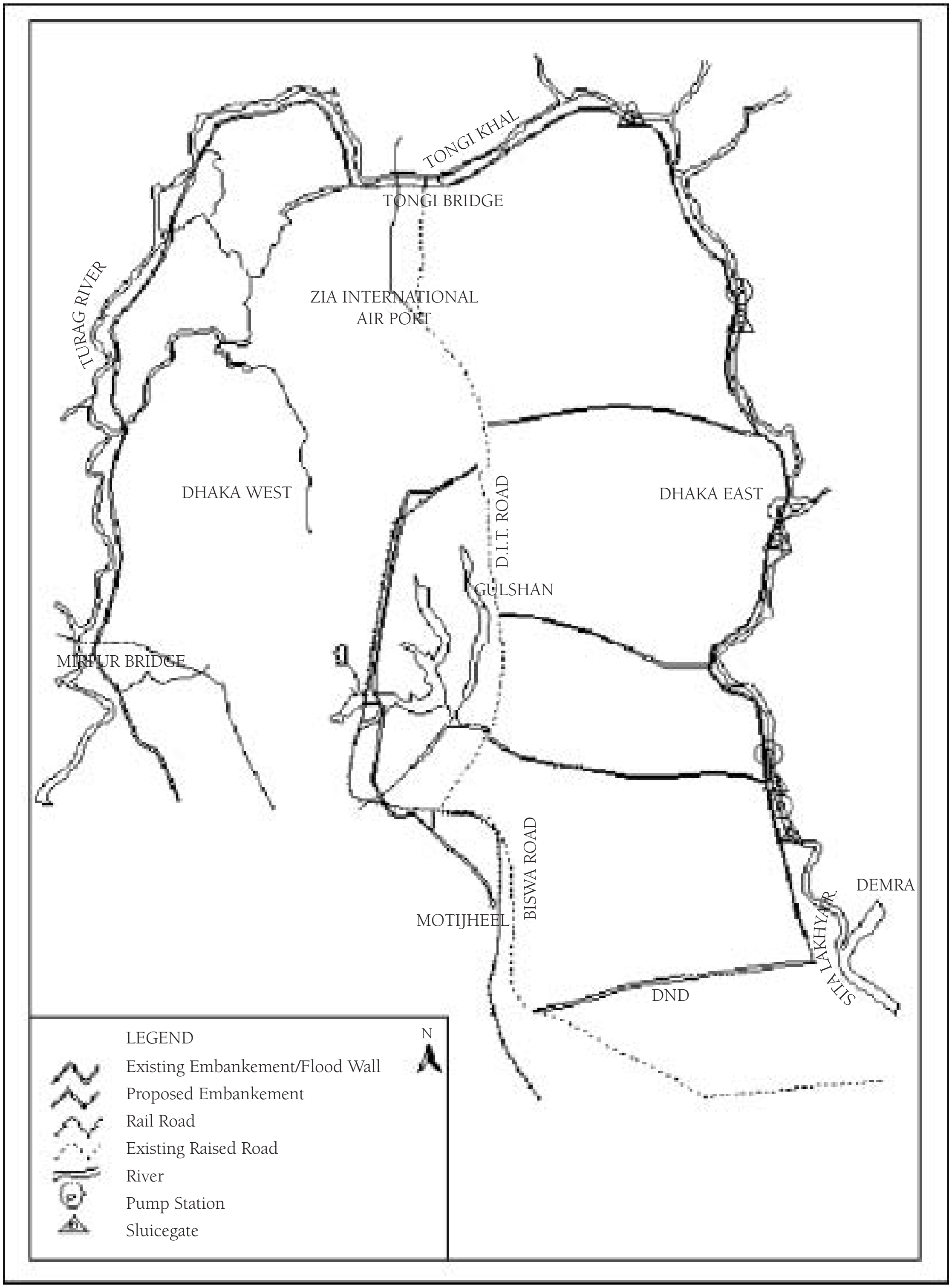
phase of the Greater Dhaka Integrated Flood Protection Project included embankments along the Turag and the Buriganga Rivers to protect Dhaka West. Improvements to the city's internal drainage system had also been completed before the second severe flood in 1998. Moreover, during the 1998 flood some protected areas went under water, indicating that current flood management practices must be improved.

After implementation of the flood-control project in Dhaka West, unplanned and uncontrolled expansion of urban areas stretched rapidly toward the low-lying areas and floodplains adjacent to the flood-protection embankment and river. Residents of these lowlands suffer from inundation due to accumulation of rainwater after heavy rainfall. Land development through land-filling processes in the low-lying areas is causing a drastic reduction in water storage areas. Because of the rapid population increase and scarcity of land in Dhaka West, unplanned expansion is also taking place in Dhaka East at the same pace. It started on the eastern side of Biswa Road, DIT Road, Pragati Sarani, and Mymensingh Road, and is gradually stretching toward the Balu River. The areas where urbanization has already taken place are Mugdapara, Manda, Basabo, Sabujbag, Khilgaon, Goran, and Rampura. Some of these areas were the worst affected during the 1998 flood.

Evaluation of Phase I work revealed that the existing earthen embankment is unstable and cracking in large sections, though some parts have recently been stabilized and other parts of the earthen embankment have been converted to roads. Construction of embankments through low-lying areas without providing adequate drainage facilities has caused internal flooding, adversely affecting the residents in those areas.

The eastern part of the city consists of low-lying floodplains that are submerged during the monsoon season. They still remained unprotected. However, the growing population and land scarcity have forced people to settle in these low-lying areas. Implementation of Phase II of DIFPP will provide flood protection to this part of the city. While designing and implementing the plan, environmental impacts should be kept in mind and an adequate number of drainage facilities should be provided for the proposed embankment. The hydrological data should be analyzed during the design phase of the flood protection infrastructure.

Figure 9.6 Existing and proposed flood control and management infrastructure in Dhaka



Dredging work in the Buriganga, Turag, and Balu Rivers should be regularly carried out to maintain navigability and reduce drainage congestion. In addition to structural measures, nonstructural measures should also be considered to reduce flood damage. These measures include flood zoning, flood forecasting and warning, flood proofing, flood insurance, and evacuation measures. Flood zoning could be one of the most effective measures to ensure that expensive investments are not made in flood-vulnerable areas. It will also help to protect ecologically sensitive areas, natural drainage systems, and the surrounding wetlands that retain water.

Since the western part of Dhaka is already developed, little can be done in this area except protecting the lakes and khals. The government has already issued a decree banning the filling in of any wetland for urban development. In exceptional cases, permission should be secured directly from the prime minister. The eastern part of the city is still largely a floodplain. Proper land development rules should be introduced without delay to minimize the loss from river flooding from the Balu River.

It is anticipated that the city's future flood vulnerability will be aggravated due to climate change. Experts are forecasting that floods with the magnitudes of those in 1988 and 1998 may occur more frequently. Thus, it is imperative that a long-term flood-mitigation and climate-change adaptation strategy be developed for the future management of floods in and around Greater Dhaka City.

Bibliography

Ahmed F. 1999. "Impact on Water Supply Sanitation and Waste Management." In A. Nishat, M. Reazuddin, and others, eds., *The 1998 Flood: Impact on Environment of Dhaka City*. Department of Environment in conjunction with IUCN Bangladesh.

Ahmed S.U. 1986. *Dhaka–A Study in Urban History and Development.* Riverdale: Riverdale Company: 12.

Chowdhury A.M. and S. Faruqui. 1991. "Physical Growth of Dhaka City." In S.U. Ahmed, ed., *Dhaka Past Present Future*. Dhaka: Asiatic Society of Bangladesh.

Hye A. 1999. "Effect on Livelihood." In A. Nishat, M. Reazuddin, and others, eds., *The 1998 Flood: Impact on Environment of Dhaka City.* Department of Environment in conjunction with IUCN Bangladesh.

Islam N. and K. Ali. 1999. "Housing Damage in Dhaka City Due to the 1998 Flood." In A. Nishat, M. Reazuddin, and others, eds., *The 1998 Flood: Impact on Environment of Dhaka City.* Department of Environment in conjunction with IUCN Bangladesh.

JICA (Japan International Cooperation Agency). 1987. "Study on Storm Water Drainage System Improvement Project in Dhaka City." Supporting Report, Local Government Division of Ministry of Local Government Rural Development and Cooperative, Dhaka.

JICA (Japan International Cooperation Agency). 1991. "Master Plan for Greater Dhaka Flood Protection Project." Flood Action Plan 8A, Main Report and Supporting Reports I and II, Flood Plan Coordination Organization (Presently WARPO), Dhaka.

JICA (Japan International Cooperation Agency). 1992. "Feasibility Study of Greater Dhaka Flood Protection Project." Flood Action Plan 8A, Interim and Main Reports, Flood Plan Coordination Organization (Presently WARPO), Dhaka.

Karim A. 1964. *The Mughal Capital*. Dhaka: The Asiatic Society of Pakistan: 8–13.

Nishat A., M. Reazuddin, and others, eds., *The 1998 Flood: Impact on Environment of Dhaka City.* Department of Environment in conjunction with IUCN Bangladesh.

Chapter 10

Flooding in the Pampean Region of Argentina: The Salado Basin

Hilda Herzer

This paper provides information to help in understanding the complexity of flooding processes. Three municipalities in the Pampean Region of Argentina's Río Salado basin were chosen for this analysis: Chascomús, Dolores, and Junín. The study focuses on the impact of farming and cattle-breeding practices and urban and social policies in the development of disasters.[1] A flooded area, whether it is a city or a region, is the expression of relations and conflicts among different areas and diverse socioeconomic groups over time, within the context of natural, economic, social, and political processes. Understanding of this complexity is sustained by the articulation that correspondence between the "causality space" (i.e., the place where causes of socio-natural hazards are produced) and the "impact space" (i.e., the places where they generate an impact over population) is not always necessary.[2]

This idea has two implications: first is the importance of reevaluating the understanding of causality for populations and authorities; and second, the idea defies an institutional notion for environmental urban management that is territorially limited to the city itself. Therefore, it demands the incorporation of the region or basin as the analysis, management, and action unit, both from a research point of view and from its political-administrative organization (Herzer and Gurevich 1996).

Examining the Process

We will describe the Río Salado Basin's natural characteristics that turn it into a region prone to flooding. Among them, it is important to highlight the slope, the type of soil, and the shallowness of the river and its streams that make water drainage difficult during heavy rain. The characteristics of this natural system are superimposed by environmental artificialization and the cities' territorial expansion over time. This is worsened in some cases by anthropic elements such as roads, railways, and canals that hinder the already slow water drainage either because of building defects or lack of maintenance; the construction of a series of canals and embankments (built according to periods of floods or droughts); the changes produced in the area's dominant type of production; and changes in land use and land tenure.

From the standpoint that vulnerability plays an important role in social risk building, the quality and location of built property, land use, the state of infrastructure and services, lifestyles, and political authority and government (ethical, legal, and political frameworks within which a society develops) must be emphasized.

Why the Basin Floods

The Río Salado basin is part of the hydrographic system of the Río de la Plata basin.[3] It covers 186,000 square kilometers, more than half the surface of the Province of Buenos Aires. It includes 56 of its 134 municipalities, and, in socioeconomic terms, is one of Argentina's most important areas.[4] Over centuries, the area was built and rebuilt by human activities that changed its original physical structure, among which we must mention hydraulic works that modified the basin's drainage.

Biophysical Characteristics of the Basin

The basin comprises three main regions, each with its own features: Salado-Vallimanca-Las Flores; Noroeste; Encadenadas del Oeste. The three regions are interconnected by a large plain where drainage conditions are deficient or absent.[5] The Salado-Vallimanca-Las Flores region is the largest, covering 60 percent of the basin, and the three municipalities analyzed are located there.

The Río Salado streams from the southwestern end of the Province of Santa Fe at 75 meters above sea level. It crosses the Province of Buenos Aires from northwest to southeast for 650 kilometers.[6] Its regime is exclusively rainwater. The Río Salado springs from the union of small lakes, and along its course many lagoons and streams pour into it until it reaches its mouth in the Samborombón Bay. There, due to the influence of tides, flows invert when seawater enters. Eastern winds also produce a flow stoppage, and water accumulates in the outlet. In the northwestern region, ancient dunes hinder water drainage to the east and north. Water accumulates on the surface during prolonged rain or due to high phreatic levels. Higher rainfall during the last 20 years also affects the area. Since there is little alternative drainage, surplus water drains to the south, though there is a lot of standing water.

During the last century, the runoff was modified in a large part of the basin due to the canalization of the region's many watercourses. As a consequence, tributaries were intercepted and deviated, while at the same time, the basin's drainage network was extended. Artificial canals were designed to evacuate surplus water that accumulated upstream. However, the system's evacuation capacity is, at present, reduced or inefficient. Since the basin is of an open type, its subsystems are interrelated, and any change in the transport and accumulation conditions in one place necessarily produces changes elsewhere in the basin. This is important when considering the effects of activities carried out anywhere in the basin.

It rains an average of 870 millimeters per year (period 1911–96) in the basin, though the rain regime is irregular and rains are stronger in summer. Winters are dry due to strong western winds. The water balance shows a surplus during the summer and a deficit during winter. March is the dampest and rainiest month. Since the 1980s, there has been a marked increase in mean rainfalls, as shown in table 10.1, below.

The Río Salado basin has a scant slope, the average being 1 centimeter per kilometer, thus limiting the drainage of surplus water. The drainage system is poorly developed and disintegrated; therefore, the amount of water that drains through the rivers is also small, less than 10 percent.[7] It is a low energy system and, consequently, the lack of capacity to evacuate water surpluses produces generalized and prolonged floods. The ground water level increases during prolonged rainfall seasons, rising to the surface and producing floods. Some of the basin's sectors are affected by water salinity because the underground sheet of water is not deep enough and in some cases it reaches ground level, affecting soil quality.

Table 10.1 Average rainfall for each region

Region	*1920–1985*	*Average from 1986 to 2001*
Salado Vallimanca Norte and Sur	800 to 900 millimeters	1000 to 1100 millimeters
Noroeste	750 millimeters	More than 1100 millimeters
Lagunas Encadenadas del Oeste	700 to 900 millimeters	1100 millimeters

Source: Instituto Nacional de Tecnología Agropecuaria.

> The nature of the existing drainage pattern and the nature of rains show that the area suffers frequent, extended, and prolonged floods and inundation. For example, the 1980 and 1985 events lasted from four to five months all along the Río Salado and in 1993 the Río Salado Inferior was affected during three to four months. The Vallimanca stream also suffered prolonged floods lasting about three months, although the streams in the southern region, with sufficient slope, respond quickly. It is also important to consider the temporal development of flood events since, for example, the 1993 flood began in October but all others were during autumn/winter, beginning in March or April (Río Salado Basin Integral Master Plan—Plan Maestro Integral de la Cuenca del Río Salado).

Territorial and Productive Expansion

In 1991, there were 1,300,000 inhabitants in the area, 11 percent of the province's total population. According to the 2001 census, there had been a population increase of only 50,000.[8] This figure represents 10 percent of the province's population. This increase has been very low, approximately 0.5 percent annually from 1947 to 2001.

The urban population represents about 80 percent of the total population; the majority live in the region's main cities. There are around 145 urban centers in the region, which differ in size and importance, since their populations vary from 500 to 92,000 inhabitants. The most populated urban centers are Tandil, Azul, Olavarría, and Junín, which, in 1991, had more than 50,000 inhabitants. Although these cities have not grown in numbers of inhabitants, their territory has expanded.

The urban structure is characterized by intermediate settlements (20,000 to 200,000 inhabitants). They act as linking centers for less important settlements located in their area of influence, within a distance of 150 kilometers.

Many municipalities have lost population, mainly due to two factors: the flood and drought cycles that strongly affect the productive sector and a productive structure that finds it difficult to generate new and stable labor sources in any economic sector.

The whole area has a well-developed transport infrastructure, with an extended network of national and provincial trunk roads, and rural roads. The national ones are important highways that join Buenos Aires with other provinces and only flood in extreme cases due to inadequate transversal drainage or to their very low level. Provincial roads may or may not be paved, and the latter suffer the biggest floods. The rural road network, generally unpaved, floods most; its maintenance is shared by the municipal government and farming and cattle-breeding producer associations.

Farming and Cattle Breeding Production

The provincial farming and cattle-breeding sector, particularly in the Salado basin, fulfills a strategic role in the provincial and national economies. This is due to a combination of several factors: large-scale, mechanized farmland, generally adequate rainfall, a well-articulated road network, proximity to agromanufacturing, and consumer and export centers.

During the 1991–93 period, average agrofoodstuffs exports were US$7.1 million. In 1998, exports reached $15.2 million. This important increase was due to a price decrease in the main technological innovations (fertilizers, agrochemicals, direct sowing, etc.) that led to their generalized use and to an increase in yield per hectare. Out of the total increase, 43 percent corresponds to primary products and nonmanufactured foodstuffs, and 57 percent to manufactured foodstuffs.[9]

The province contributes largely to cereal and oleaginous exports and plays a fundamental role as a cattle-breeding area.[10] Cattle-breeding production decreased in real terms between 1980 and 1996, while agriculture increased by 25 percent. The production of industrial crops (mainly oleaginous) abruptly increased during this period.[11] Its participation in the farming and cattle-breeding gross product increased from 16 percent in 1980 to 34 percent in 1996. Cereals increased from 28 percent in 1980 to 31 percent in 1996. Milk production in 1980 was 18 percent higher than that of 1996, and poultry breeding increased more than 50 percent.

Economic Deregulation and its Effect on Flooding

The transformation suffered from the development model in Argentinean rural areas during the last decade, particularly in the Pampean region, which ushered in a change of rules that became evident as a new farming and cattle-breeding map. Cattle-breeding land was transferred to agricultural uses, and the farming and cattle-breeding frontier expanded, incorporating semi-arid land through the use of new technologies, including irrigation. The productive cycles were also modified, generating intensive tilling that brought about a total production increase.

During the 1990s, the economic deregulation policies in force changed Argentinean farmland (Teubal and Rodriguez 2001). One of the most important measures was the derogation of export taxes. International repayments were tax-exempt and differential exchange rates that reduced prices received by producers were eliminated. Also, the export withholding tax was abolished, although it has recently been re-implemented.[12] These policies enabled concentration in large firms at a detriment to medium and small producers. From the 1990s, "agribusiness" (production in large units with a strong investment in technology) began to develop.

Implementation of the so-called convertibility plan, one of its pillars being the decree deregulating economic activities, implied for the farming and cattle-breeding sector the disappearance of specific governmental organizations that controlled the operation of farming and cattle-breeding markets: Junta Nacional de Granos (National Cereal Board), de Carnes (Meat Board), and others. Tilling, harvest, manufacturing, and commercialization quotas for certain products were eliminated. From a taxation point of view, taxes on farming and cattle-breeding activities, mainly on exports, were abolished. Road and railway networks, and port activities were privatized and deregulated.

The effects of these changes were the establishment of agro-industrial complexes that favor capital concentration, together with the advance of agriculture in areas that had historically supported cattle breeding. These significant changes in land use, added to the absence of any integral basin management, increased flooding risks for some sectors of society and certain cities. This is more visible when an intense rain cycle occurs.

Cattle breeding did not suffer the same shock as agriculture. This is due to price flattening in relation to agriculture and to the absence of technological packages. On the other hand, the agricultural sector readily incorporated technological packages composed of public and private technical assistance, seeds, fertilizers, herbicides, pesticides, artificial irrigation, and satellite information. The new productive cycle extended the productive surface area and increased planting. From 1990 to 1999, there was a more intensified land use and in 1997, fodder areas were replaced with agriculture, constituting the second expansion factor. During the last 12 years, agriculture has advanced considerably in this area due to macroeconomic changes, prices, and export opportunities.

Before the 1990s modernization, the economic structure of the Argentinean Pampean area was predominantly cattle breeding, followed by agriculture and milk production. Cattle breeding was carried out in the open (with some winter reinforcement), and bovine cattle were predominant. Dairy farming was a secondary activity within cattle breeding, but it was important in areas such as Chascomús. Presently, there is mixed land use in the region, where cereal production is combined with cattle breeding. Cattle breeding occupies more than 70 percent of the total surface area in low-level areas with no agricultural use. In areas where the soil is appropriate for agriculture, mixed systems are developed in which both activities rotate with variable intensity according to environmental conditions and soil quality.[13]

Historical Evolution of Flooding

Toward the end of the 19th century and the beginning of the 20th, a damp phase that produced floods in large sectors of the central Pampean region and the Río Salado basin in the Province of Buenos Aires was registered. Floods in 1840, 1854, 1857, 1874, 1877, 1883, 1886, 1800, 1910, 1913, 1914, and 1919 are described by Moncaut and Posadas in their reports on flooding in the region. We must add the references made by Engineer Gandolfo about the flooding of Río Quinto, in which he described the course of the river's overflow in 1915, 1919, and 1923, when it reached the borders of the Province of Buenos Aires.[14]

During the dry phase that dominated the period 1930–1957, the problems were the opposite. The semi-arid strip became marginal for summer tilling. Reservoirs dried up and Río Quinto reduced its reach to the La Amarga swamps and did not surpass, between 1940 and the 1970s, the site of Justo Darat in the Province of San Luis.

Since 1970, a new damp phase has begun. Along a large strip on the western side of the Province of Buenos Aires, the annual average rainfall increased from 600–700 millimeters to 1000–1100 millimeters. This increase, concentrated in the warm season, balanced the agronomic limitations for summer crops and began the expansion of the farming and cattle-breeding frontier toward the west, gradually including traditionally semi-arid areas in eastern La Pampa, Córdoba, and San Luis.

During some years, the limit to that constant surface and yield expansion was simply flooding produced by large volumes of rainfall that accumulated and filtered the soil, raising the underground sheets of water to levels near the surface.[15] This favored the expansion of bodies of water that contributed to flooding during the last 23 years (the consequences were particularly severe in 1980, 1991–93, and 2000–01).[16] The harshness in each area and in each case is related to the distribution and intensity of rainfall and to the presence of works that do not conform to a coherent system.

The Social Actors

A large number of social actors are involved in the basin's flooding problem. We will work with a simple typology: economic, political, and community actors (Herzer and others 1993). It is important to understand that risk-sharing processes and disasters will always be the object of controversial interests. This is so because these processes are built from agreements and oppositions of a variety of social actors and from different rationales, interests, and logic.

Among the economic actors, we find farming and cattle-breeding producers, mainly represented at the Sociedad Rural (Rural Society), and the commercial and industrial associations affected by flooding.[17] The main demand of the commercial and industrial associations, organized into local chambers, is to be included in the emergency benefits during floods.

The farming and cattle-breeding organizations[18] are a permanent reference for local authorities; they constitute the local farming and cattle-breeding emergency committees[19] and certify the producers' claims to obtain the corresponding benefits, with more action capability to channel demands and claims for solutions at various government levels.[20] Their members, as landowners, participate in associations in charge of rural road upkeep and maintenance, necessary to move production out of the fields.

In the cases studied, there was a fluid, although not always a good, interaction with local governments, depending on the municipality's ability to respond to their claims. These actors have their own strategies to face emergency situations. During periods of flood risk, canals are often built on private land without consultation with water authorities.[21] These works are not so much to safeguard the population's well being as to drain water from the land.

The participation of communities is restricted to times of flooding. In the municipalities analyzed, community actions varied from passiveness to mobilization such as road blockages. They also met with authorities to demand answers to their requests and insist upon the execution of flood prevention works that did not fall under municipal jurisdiction.[22] In all cases, it is important to stress the assistance provided by neighbors and their organizations during floods, even if it only means providing shelter in neighborhood associations and participating in the building and vigilance of defenses. Often, neighbors themselves build provisional defenses to protect their homes.

These actors relate with government authorities at three levels: municipal, provincial, and national. Local governments have little capacity to solve problems caused by flooding, and their actions are mainly confined to emergency situations through relief distribution, building defenses and pumping posts, and assisting evacuees. Among the actions that are normally in the hands of local governments, we may consider the implementation of public and private building regulatory instruments. Unfortunately these norms do not exist in some cases; in others, they are not enforced. In the majority of cases, there is no control over their application. For example, in Chascomús, the ordinance approved after the 1985 flood forbidding construction on plots of land under 9.40 meters in elevation was never enforced.

The Civil Defense Municipal Board (Junta Municipal de Defensa Civil) is in charge of coordinating emergency tasks and arranging emergency relief at all government levels. It is integrated by voluntary organizations and municipal government offices qualified to act in emergencies. Actions at the provincial level are coordinated by the Civil Defense Provincial Board (Junta Provincial de Defensa Civil), which collaborates with municipal offices and qualified provincial offices "as much as possible" through the provision of required elements.

Last, coordination at the national level is the charge of the Emergencies Federal System (Sistema Federal de Emergencias) (SIFEM), in which the Emergencies Cabinet (Gabinete de Emergencias) is constituted.[23] This organization was created in 1999, within the jurisdiction of the President's Cabinet Chief. It recently began to depend upon the Internal Affairs Minister. The armed forces, mainly the army, transport people and goods when they are summoned by civil defense. In this particular case, they helped restore road services by setting up a bridge to replace one that was destroyed in the flood.

From another point of view, we can mention the set of institutions linked to water resources that depend upon the National Ministry for Public Works. The Regional Directorate for Provincial Hydraulics (Dirección Regional de Hidráulica Provincial) should control all public and private works in the region. It should be noted here that there are 29 national-level and 19 provincial-level organizations involved in the basin (with an exception made for the basin committees), plus the municipal ones. A common trait that affects all levels is that their actions are limited due to a lack of funding following the recent economic crisis.

Local Government Management in Three Cases

Chascomús

For years, every time there has been a risk of lake overflow, stone and earth embankments are raised to protect the city. Also, public pumping equipment that operates around the clock is installed. Pumping is alternately done in different places, extracting water from saturated underground sheets; this is the only available resource to compress underground sheets.

Although the lake's contour can be controlled with some success, the few rain drains that exist in the city center reverse their flow, flooding streets and homes. This has happened in the past, and it still occurs.

The existing municipal regulations are not enforced.[24] The defense system is always transitory. Each emergency is unique. With each new risk, the municipality summons the mass media to alert citizens about the precautions to be taken in the event of floods or a great storm, and it demands that provincial authorities carry out the works included in the Salado Basin Integral Master Plan.

Repeated flooding, which requires the consolidation and expansion of the defense system and pumping plants, has produced mistrust and uncertainty in the local population. Since the process repeats itself continuously, there should be a permanent risk-management policy to repair the existing fracture, evident because of the impact of flooding, between the central western zone and the promising eastern and southern zones.

It also seems necessary to think about a series of measures to adapt municipal regulations and control measures to hinder the development of new urbanization in areas lacking infrastructure and, in particular, areas that modify the basin's drainage. Both matters are closely linked. It is of little use to concentrate on the consolidation of the city's defenses if the city continues to expand into lower areas.

The interviews conducted revealed the general opinion that, because Chascomús is located on the Salado's lower basin, it is subject to the consequences of actions produced upstream (higher Salado). In this sense, the citizens consider their town as the region's "sewer." This perception produces a passive attitude in local society, inasmuch as only works carried out upstream will limit their suffering. On the other hand, they hope that the local government will solve the situation by building embankments.

Dolores

Water drains from the municipalities of Las Flores, Azul, part of Ayacucho, and part of Tandil toward Dolores, where it accumulates because of the system's scarce capacity. The building of embankments along National Road number 2 affected the producers on the western side, which does not drain. The waterfront extends 25 to 30 kilometers and must drain through a 1-kilometer canal, a bottleneck that stops water from running through. The same thing happens on the eastern fields, which meet the sand dune dikes produced by the building of Provincial Road number 11. In this case, important landowners have not been allowed to open the dunes because this would jeopardize their economic interests.[25] Likewise, since 1920, they have been against the direct drainage of Canal A on a straight line toward the sea. Presently, this is done by a winding, slowly draining canal that affects 30,000 hectares. This situation explains some of the conflicts of interest in the area.

The Dolores cattle breeders do not have great hope that the Master Plan's works will be executed, or that they will produce results. This is so for various reasons; the first and most fundamental is that, with the present economic situation, it is difficult to believe that US$2 billion will be spent on these works. The second is because Dolores gathers water from the higher basin—its northern and central portion—and the only work expected to be carried out in Dolores is the enlargement of Canal A, increasing the drainage capacity of Primary Canals 9 and 1, and improving urban defenses. Other minor but necessary works are not being considered. Third, and perhaps the most interesting, is the lack of political strength of the provincial Hydraulics Directorate (Dirección de Hidráulica), since it does not control the canalization works carried out by producers in their fields and by neighbors in the city. These are illegal works inasmuch as it is forbidden to alter the water's natural flow. Consequently, coordination is difficult when public interests are subordinated to private ones, and what is done on one site affects other social groups.

The Dolores case typifies the lack of general coordination in the basin both public and private, as well as rural and urban, and the consequences that derive from it. The handling of water seems to be nearly out of control, and in this sense it brings to the forefront the absence of the state. Within this panorama, the roles played by the Provincial Hydraulics Directorate and the local government in the siting of housing are not clear, since other municipal offices must bear unbudgeted expenses when providing assistance during emergencies. Furthermore, the lack of social organizations, other than the traditional ones—e.g., Rural Society and the Rotary Club—makes it difficult for community interests to be asserted.

Junín

One of the outstanding questions in the Junín case is the interest in concealing recurrent flooding. Two years ago, the municipality's strategic plan only marginally mentioned flooding in the environmental urban development subprogram. Nor does the preliminary study for the plan mention flooding.

Various critical comments arise from the interviews conducted. One of them refers to the Dirección Hidráulica Provincial's lack of management and control (it is located in the 9 de Julio municipality) over the great number of private works that interfere with water drainage, altering the water's course and affecting those who live downstream. There is an urgent need to appoint an authority to regulate community water use. During the last few years, the municipality also asked the province to study the possible regulation of lakes. The study was completed, and its findings were incorporated into a master plan for water management, but the plan was never executed.

During emergencies, the municipality summons intermediate associations—rural, commercial and industrial—and neighborhood associations to respond. For example, a multisectoral commission was recently formed to address poverty and unemployment. But such integrated planning has no executive continuity the rest of the time. It is important to highlight that the Junín government has been in office since 1983, when the country returned to democracy. The present undersecretary for public works was the previous secretary. The experience gathered during 19 years in office has enabled him to collaborate with the farming and cattle-breeding sectors, although this has been limited by a lack of resources.

Junín, as Dolores and Chascomús, shows a certain complexity regarding its environmental urban-rural problems that puts forward the need to integrate representative public and private actors to address them. As in Dolores, water seems to be out of management and control and, in this sense, it once again highlights the state's absence.

Some of the flooding problems require coordination among national, provincial, and municipal actors to enable the channeling of water without the political and economic conflicts now at stake. The possible execution of the master plan is no guarantee that the rural-urban problems will be solved or that neighborhoods prone to flooding will be safe. In this last case, not only is a new urban code necessary, but also an organization to control its application.

Water Management: Elements of Organization

In a basin with scant or no slope, water drainage will impact other communities. In this sense, there are few plans to coordinate public actions. Moreover, the communities are in no position to coordinate private actions carried out in private fields. The whole set of canals built on private property[26] has never been counted or registered by cartographers. Nor has the task been undertaken by the state.

There is no coordination within levels of government, and there are many levels with shared and overlapping responsibilities in the basin[27]. The provincial government accuses the municipal authorities of indiscriminate action with no coordination within the province when building public works and canals. Municipal governments complain that they lack support from provincial authorities other than what is provided during an emergency.

Between 1998 and 2000, the Salado Basin Integral Master Plan was developed with IDB assistance, diagnosing the need to develop projects, build a series of canals, and carry out a set of defense works—embankments—to limit the flow of water into urban areas. Beyond sharing the proposals established by the Master Plan, no action has been taken.[28] Meanwhile, agricultural producers proposed that the nation and the province implement the infrastructure plan; municipalities should be in charge of secondary canals and producers of tertiary canals. All parties also agreed that a foundation should be created to build other canals, but this has not yet been acted upon.

General Conclusions from the Three Cases

Response to disasters, together with prevention programs and their management, are marked with the indelible seal of political and economic relations built up over time. In this sense, these programs are not alien to a country's political economy; on the contrary, they tend to reproduce it. The political and economic situation at the moment a disaster occurs or when emergency assistance is implemented is not independent of the economic and political interests of the different actors, the state, and the presence or absence of local social organizations.

In the cases analyzed, the producers' organizations, in particular the Rural Society, weigh most heavily in decisionmaking. It is worth noting, in general terms, the absence of urban social organizations, except for the new solidarity networks organized to confront the economic crisis and alleviate hunger through "barter networks" or food assistance. In certain cases, such as Chascomús, Dolores, and Junín, recurrent flooding has not been able to change the vulnerability that existed prior to disasters and, since floods recur, the population tends to be increasingly vulnerable.

The weakness of local governments in the Province of Buenos Aires and their lack of true autonomy facing the provincial and national governments should be noted. There is an economic and financial subordination at each level that is clearly exemplified during emergencies. Municipalities do not have the necessary funds to face disasters; civil defense committees are organized within them, but they depend upon volunteers. The municipality is highly dependent upon provincial or national financial allotments for land acquisition and evacuee assistance. The municipality also depends upon the provincial or federal government to declare a state of emergency that will allow for a temporary tax exemption. In summary, it is a complex web of political, administrative, and financial dependence.

From the local management perspective, municipalities lack the strength to establish regulations and guarantee enforcement, remaining subordinated to the role of spectators of speculative economic processes that induce illegal use of urban land. When disaster arises, they are only able to react to the crisis.

Municipalities should not only produce urban regulations to control risk areas, they should incorporate participative management tools to enable a periodic monitoring of interventions in the territory. Neighborhood community actors could play this role.

The main problems faced by the municipalities during times of flooding were:

- Rivalries with municipalities in the higher basin.
- Lack of financial resources.
- "Dependent" relations with other government levels.
- Lack of awareness about the need for permanent prevention. Work is only done during emergencies.
- Urban expansion patterns that contribute to an increase in the local population's vulnerability.
- Scarce stimulus for the development of policies agreed to with local society.
- Lack of power to discourage private works in urban and/or rural areas, particularly canals that produce negative impacts throughout the basin.
- Lack of experience of the different actors in working together constructively; atomization and a certain weakness in civil society organizations having little management capability; a municipal state that leads urban management according to a traditional model, plus resistance to changing its structures.

Conclusion

The author would like to point out several issues that, in her opinion, still need to be addressed:

- The decantation of water courses proposed by the master plan could be highly dangerous without prior interdisciplinary environmental impact studies to guarantee the benefits of works that will be carried out.
- Works should be compatible with the needs of the various social actors—urban and rural, economic and community, national and local—trying to guarantee that productive systems will adapt to the specific conditions of the environment, both urban and rural.

- Discussion must be promoted among the region's producers about reorganizing their productive systems, and urging them their systems to the existing risk levels. The master plan's formulation does not call for discussions among the three different producers' associations.
- A participative process must be promoted in each municipality, to involve citizens of different affected urban localities.
- Multidisciplinary standpoints must be considered. If economic restrictions only allow for an engineering approach, an integral solution will not be reached and actions that up to now have proved to be insufficient will be repeated over and over again.

Notes

1. We perceive disaster as a process. Its understanding derives from the creation of risk conditions in the course of time, as a result of the interaction between certain unchaining events (hazards) and society's vulnerability.

2. Some examples may be useful to clarify these concepts. Deforestation in a river's high basin may produce flooding in the low basin, due to an increase of the runoff or to the exhaustion of aquifers in the cities, and its impact on droughts in surrounding areas. Upstream refuse stoppage—clandestine refuse dumps—impact on flooding downstream. The social actors involved will not only be different because of their differential capabilities at the political, economic, and social levels, but also because of the different geographical levels of analysis, in which actors develop their actions and the action's impacts.

3. The surface of the Río Salado basin is equivalent to 50 percent of the Nile basin in Egypt. It is similar in surface to the República Oriental del Uruguay (187,000 kilometers^2). It is three-quarters the size of Greece (122,873 kilometers^2).

4. The territory of the Province of Buenos Aires is divided into counties (*partidos*). Unlike other Argentinean provinces, in the Province of Buenos Aires, the counties' limits coincide with those of the municipalities. These are local government units, and the mayor is the elected head of the executive. The counties that integrate the **Salado-Vallimanca-Las Flores** region are: Alberti, Ayacucho, Azul, Benito Juárez (partially), Bolívar, Bragado, Castelli, Chacabuco, Chascomús, Chivilcoy, Dolores, Gral. Alvear, Gral. Belgrano, Gral. Guido, Gral. Lavalle, Gral. Paz, Gral. Viamonte, Junín, Las Flores, Lobos, Leonardo N. Alem, Maipú, Monte, Navarro, Olavarría, Pila, Rauch, Roque Pérez, Saladillo, Suipacha, Tandil (partially), Tapalqué, Tordillo, 25 de Mayo. Those of the **Noroeste** region are: Carlos Casares, Carlos Tejedor, Florentino Ameghino, Gral. Pinto, Gral. Villegas, Hipólito Yrigoyen, Lincoln, Pehuajó, Pellegrini, Rivadavia, Salliquello, Trenque Lauquen, Tres Lomas, and 9 de Julio; and the **Encadenadas del Oeste** region are: Adolfo Alsina, Cnel Suárez, Daireaux, Gral. La Madrid, Guaminí, Laprida (partially), and Saavedra (partially).

5. Since the beginning of the 1990s, because of two hydraulic works, they link directly through the Jauretche–Mercante–Italia canal and the Alsina outlet canal, respectively.

6. For comparison, the Minnesota River runs 539 kilometers across the states of Minnesota, Iowa, and South Dakota.

7. Río Salado Basin Integral Master Plan (Plan Maestro Integral de la Cuenca del Río Salado), November 1999.

8. Data provided by the 2001 Census; they are preliminary and only correspond to total numbers.

9. At present, Argentina contributes 6 percent of world exports of wheat, from 10 to 20 percent of corn, from 8 to 13 percent of vegetable oils, and from 17 to 22 percent of edible oils. Meat exports still represent approximately 9 percent of world exports.

10. The basin significantly contributes to the country's farming and cattle-breeding production. From 1994–97, the production of corn, wheat, sunflowers, and soybeans represented 25 percent of the national total, and meat production was 30 percent.

11. The edible oil industry is mainly located in the provinces of Buenos Aires, Santa Fe, and Córdoba. At present, it is one of Argentina's most competitive industries, with a manufacturing capacity of nearly 18 million annual tons.

12. Given the high oleaginous production level, yield, and export, between January and March 2002, the government withheld 20 percent for farming and cattle-breeding exports.

13. There are practically no recent or reliable data about the number or type of cattle-breeding firms in the area. As an indication, we can mention a study carried out by the Universidad del Centro de la Provincia de Buenos Aires (UNC) that classified producers in the district of Azul as follows:

– Firms or managers with other main income sources; usually absentee cattle producers who employ salaried workers: 32 percent.
– Farming and cattle-breeding firms with their own machinery and salaried workers; some rent large extensions of land; they are usually administered by the owner; they are mainly mixed agriculture/cattle-breeding firms: 29 percent.
– Family firms that suffer loss of capitalization; mainly small cattle-breeding firms but they can rent farming land: half of the producers live on the premises: 25 percent.

– Independent family firms: mainly in arable land areas and they occasionally rent additional land: generally mixed production agriculture/cattle breeding: 12 percent.

14. The lack of official sources about flooding has led us to build our own database.

15. During dry years, the underground sheets of water were at 10 meters.

16. See in adjoining online annex the flooding and drought magnitude index registered between 1978 and 2000.

17. A more detailed characterization would account for their different sizes, localizations in the basin, and positions in high or low areas in the same microregion, since flooding has differential impacts on them.

18. The Rural Society (Sociedad Rural) gathers the largest numbers. Also, the Regional Consortiums for Agricultural Experimentation (Consorcios Regionales de Experimentación Agrícola) and the Agrarian Federation (Federación Agraria) are present.

19. The declaration of a farming and cattle-breeding emergency must be approved by the provincial legislative power and it grants reductions in gross income tax and stops the execution of banking credit debts with the Provincial and National Banks (Banco de la Provincia de Buenos Aires and Banco de la Nación).

20. The local Sociedades Rurales are grouped in a national level organization.

21. During the November 2001 flood in the Municipality of Junín, "anonymous hands" opened a breach in Laguna de Gómez (orchard area) that increased by 0.50 centimeters the Río Salado water level in a very short period, worsening the situation of the bridge that is the only access to the city and nearby neighborhoods.

22. For example, in Junín, the access road to the city is a bridge over Río Salado, built on National Road Number 7, which collapsed during the November 2001 flood. Although the neighbors claimed at the municipality level, this is a national jurisdiction, through the Road Concessions Control Organization (Organo de Control de Concesiones Viales) (OCCOVI), because it was privatized and given in concession to New Roads (Nuevas Rutas).

23. It is presided over by the Cabinet Chief and it is integrated by the following ministers: Internal Affairs, Defense, Economy, Infrastructure and Housing, Health Care and Social Development, and Environment.

24. It is forbidden to build under the 9.40-meters level.

25. Their land is located on the other side of the dunes.

26. Together, these canals can transport large volumes of water.

27. The Basin's Master Plan identifies 29 national and 19 provincial organizations (9 of them are basin committees) involved in the basin.

28. In Argentina, there is a long tradition of facing disasters caused by flooding by means of great plans that imply costly infrastructure works. Beginning with Ameghino's well-known study, the Salado Basin has been the object of the most varied studies since the 19th century. Several national institutions, with international financial assistance, have funded these projects; very few have been implemented, and only partially executed. Each one of these programs criticizes the previous one for lack of coordination and integration. The latest study is the Salado Basin Integral Management Plan, finished in 2000, proposing works for US$2 billion. As an example only, it is worthwhile noticing that the protection projects for urban areas in Chascomús and Dolores cost US$6 million. Given the current recession, spending billions of dollars for flood protection in the basin seems impossible.

Bibliography

Banco Provincia. 1995. *Diagnostico Ambiental de la Provincia de Buenos Aires*, Tomo 1 Aspectos Básicos, Coord. Vega Leandro.

Bianco, M. 1996. *Junín expansión y usos de sus suelos. Aportes a su geografía urbana*. Own Edition.

Bustos, E. 2001. "El asesinato de la Pampa Húmeda." *Le Monde Diplomatique*, año III, n°30 (December), Buenos Aires.

Censos Nacionales de Población y Vivienda. 1980, 1991. INDEC.

Comisión para el Desarrollo de la Zona Deprimida del Salado. 1984. Zona Deprimida del Salado, caracterización y propuesta de desarrollo, Buenos Aires.

Consejo Federal de Inversions. 1980. Aspectos Generales Informe Final (1ra. Etapa), Vol. 1, Buenos Aires.

Consejo Federal de Inversiones. 1980. Estudios Económicos Informe Final (1ra. Etapa), Vol. 3 parte F, Buenos Aires.

"Cuencas Hídricas." 1996. Chapter: Cuenca del río Salado. Instituto Provincial del Medio Ambiente de la Gobernación de la Provincia de Buenos Aires: 35–55.

Domínguez y Carballo, [Initials?]. 1985. "Inundaciones en la Provincia de Buenos Aires durante el período 1972–84." INTA.

Halcrow, W. 1999. *Plan Maestro Integral Cuenca del Río Salado*, Informe Final, Buenos Aires.

Herzer, H. and R. Gurevich. 1996. "Degradación y Desastres. Parecidos y Diferentes. Tres casos argentinos para pensar y algunas dudas para plantear." In M.A. Fernández, ed., *Ciudades en riesgo. Degradación Ambiental, Riesgos Urbanos y Desastres.* Red de estudios Sociales en Prevención de desastres en América latina. Perú.

Herzer, H. and others. 1993. *The management of secondary cities in Latin America.* Nairobi: UNCHS-Habitat.

Municipio de Junín. 2000. Plan Estratégico de Desarrollo.

Natenzon, Claudia and others. 1993. "Inundaciones, producción agropecuaria y agentes sociales de la Cuenca del Río Salado—Provincia de Buenos Aires" Instituto de Geografía, Facultad de Filosofía y Letras, University of Buenos Aires.

PNUD (United Nations Development Programme). 2000. "El mundo del trabajo: los recursos humanos, la inserción laboral y la calidad de vida." Informe Final. Partido de Dolores. Proyecto de Desarrollo Sustentable. Regional. Arg 96/015.

Tauber, Fernando. 1993. *Chascomús. Pautas para una estrategia de desarrollo*. Municipality of Chascomús. Fundación S. Karakachoff.

Tauber, Fernando. 1997. Reflexiones y Datos para una estrategia de desarrollo. Departamento de Publicaciones del Ministerio de Economía de la Provincia de Buenos Aires.

Teubal, M. and Rodríguez. 2001. "Ajuste, reestructuración y crisis del agro." *Le Monde Diplomatique* año III, n°30, (December), Buenos Aires.

Varley, Ann. 1994. *Disasters. Development and Environment*. UK: John Wiley.

Interviews

Department of Production, Dolores: Carlos Alvarez.

Department of Tourism, Chascomús.

Department of Tourism, Dolores

Department of Urban Planning, Dolores: Architect Conti

INCOBYP: José Cornejo (former manager Plan Maestro Cuenca del Salado)

INCOBYP: Horacio Tavecchio

INTECH Water Laboratory, Chascomús: José Fernando Bustingorry.

Provincial Civil Defense Directorate: Operations Director Alberto Ripalna

Red Solidaria of Chascomús: Alicia

Residents of Chascomús, Dolores, and Junín.

Rural Producer, Junín: Omar Girolami

The Rural Society of Dolores: President Germán Galdos

The Rural Society of Junín: President Alejandro Borges

Undersecretary of Public Works: Hugo Fusé

Undersecretary of Public Works, Delores: Engineer Petasi

Vocational Historian: Juan Carlos Pirali

Chapter 11

Urbanization and Natural Disasters in the Mediterranean: Population Growth and Climate Change in the 21st Century

Hans Günter Brauch

This paper analyzes the relationship between urbanization—in relation to population growth and climate change—and natural disasters as outcomes of environmental stress for the Mediterranean space. It includes trends of urbanization up to 2015 and 2030, population growth up to 2050, and models of climate change until 2100 that will increase both the vulnerability to and impact of natural disasters. Based on a medium definition of the Mediterranean space (Brauch 2001; Brauch and others 2003) this paper addresses the increasing vulnerability of major cities to geophysical and hydro-meteorological disasters due to rapid urbanization combined with extreme poverty in most countries of the Middle East, North Africa, and Turkey (Brauch and others 2003). The paper states that in the 20th century an increase in reported natural disasters, fatalities, and affected people could be observed in the Mediterranean space; however, the fatalities diverged between Southern European E.U.-member countries and riparian countries in the Balkans, the Middle East, and North Africa.

After outlining the theoretical and conceptual context, trends in population growth, urbanization, and variations in growth patterns of megacities will be analyzed. Projected regional climate change impacts will also be noted, as well as a survey of reported disasters for the Mediterranean. Two cases of recent urban disasters, Izmit (earthquake of 1999) and Algiers (flash flood of 2001), will also be discussed as well as the impacts of the projected sea-level rise for Alexandria. The paper concludes with suggestions for reducing vulnerability and mitigating the impact of disasters in the Mediterranean.

Rising Vulnerability to Disasters due to Urbanization in the Mediterranean

During the 21st century, urban vulnerability as a result of population growth is expected to rise, as will extreme weather events due to regional climate change impacts, leading to more frequent and intensive hydro-meteorological hazards both globally and regionally. The paper argues that a North-South cleavage in vulnerability to disasters may increase due to these factors:

- *Vulnerability* will increase in megacities if no major progress is achieved on poverty eradication, disaster preparedness, and improved urban building standards.
- The *impact* of extreme weather events will increase in Mediterranean megacities.
- A major obstacle to an effective regional strategy of disaster reduction is that the Mediterranean space is institutionally divided among three continents (Brauch 2001; Baruch and others 2003).

Geophysical and hydro-meteorological disasters share common features, but natural and human-induced regional environmental challenges impact the Mediterranean region differently. While climate change, desertification, and the hydrological cycle have contributed to environmental degradation in this region during the 20th century (Brauch 2001, 2002b), human-induced *demand* factors (population growth, urbanization, agriculture/food demands) will increase pressure on the environment even more during the 21st century. These trends have impacted the vulnerability of urban centers to natural disasters in Europe, the Middle East, and North Africa.

Theoretical Context: Human and Environmental Security from a Grotian Security and an Equity-oriented Ecological Perspective

The reality that we observe is influenced by our intellectual traditions and conceptual lenses (figure 11.1). On international policy, three traditions may be distinguished: a) the *Hobbesian* pessimist, where *power* is the key category; b) the *Kantian* optimist, where *international law* is crucial; and c) the *Grotian* pragmatist, where *cooperation* is vital (Wight 1991; Bull 1977; Brauch and others 2003). On international environmental policy, three positions may be distinguished (Gleditsch 2003; Brauch and others 2003): those of a): a *Malthusian* pessimist, who claims that resource scarcities will rise; b) a *Cornucopian* optimist, for whom plenty of resources will meet with all challenges (Lomborg 2001); and c) an *equity-oriented* pragmatist, who calls for multilateral cooperation in international organizations and regimes. While national measures of disaster reduction and preparedness in the Mediterranean are indispensable, close multilateral cooperation to improve international disaster response is needed. These efforts for disaster reduction, preparedness, and risk management (UN/ISDR 2002) pertain specifically to the environmental dimension and the human level of security. In dealing with environmental security policy issues (figure 11.2), the perspective of a *Grotian pragmatist* may best reflect the perspective of international financial institutions that is also preferred by this author (Brauch and others 2003).

The security concept widened horizontally and vertically (figure 11.2) during the 1990s (Buzan and others 1998). While military institutions and alliances focus primarily on regional and national security through military means, international organizations have used concepts of *environmental* (NATO, OECD, OSCE) and *human security* (UNDP 1994). Environmental security refers to implications of *environmental degradation, scarcity,* and *stress* due to disasters, migration, crises, and conflicts, and on the resolution, prevention, and avoidance of environmental damage (figure 11.3). The chairman of the IPCC, R.K. Pachauri (2000), defined environmental security as "the minimization of environmental damage and the promotion of sustainable development, with a focus on transboundary dimensions." He pointed to several linkages between poverty and natural resource stress that also increase the vulnerability to and impact of natural disasters. Pachauri's interpretation is of relevance

Figure 11.1 Worldviews and environmental standpoints

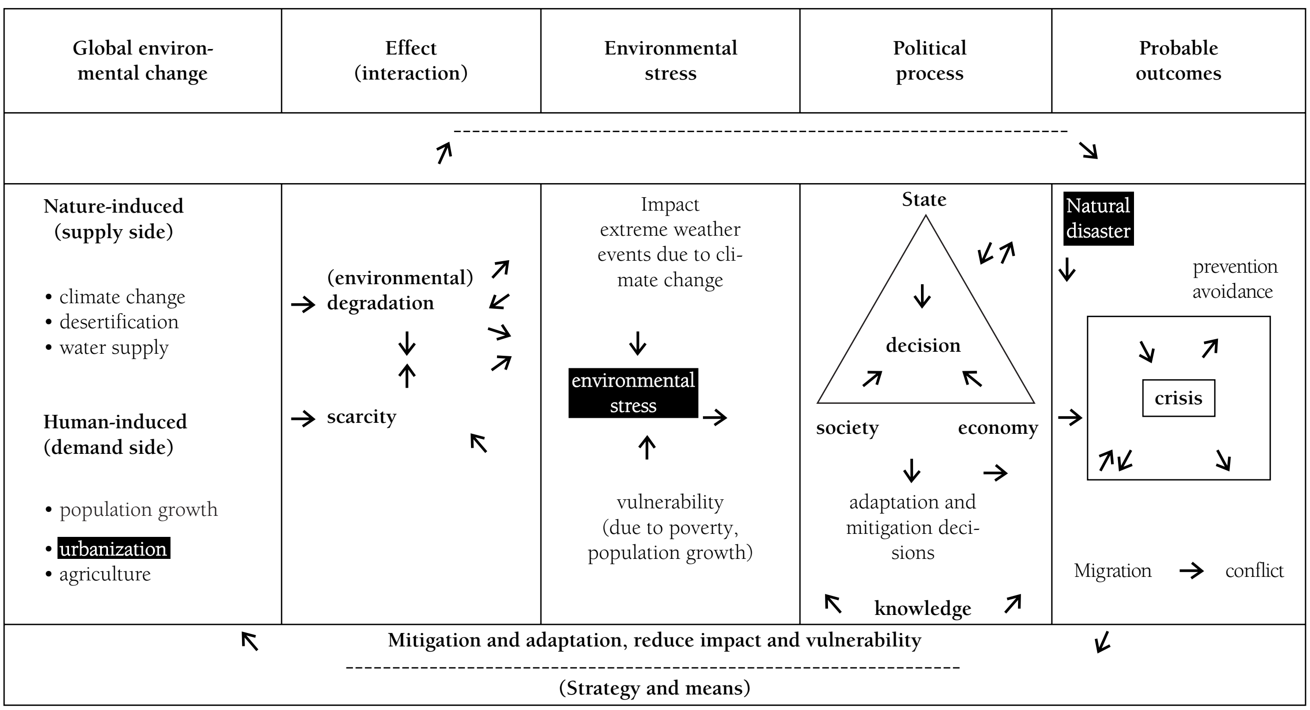
Worldviews/radiations on security (→) Standpoints on environmental issues (↓)	Machiavelli, Hobbes, Morgenthau, (neo)realist pessimist *Power matters*	Grotius, pragmatist *Cooperation is needed and matters*	Kant neo-liberal institutionalist (optimist) *International law matters and prevails (Democratic peace)*
Neo-Malthusian *Resource scarcity* (pessimist)	I Perspective of most MENA states	II ←	III ↙
Equity-oriented reformist *Multilateral cooperation will/may solve challenges* (pragmatist)	IV	V U.N. system World Bank (author's position)	VI
Cornucopian *Technological ingenuity will solve issues* (neo-liberal optimist)	VII	VIII	IX Wilsonian liberal optimism

Figure 11.2 Horizontal and vertical security dimensions

Security dimension ⇒ Level of interaction ⇓	Military	Political	Economic	Environmental ↓	Societal
Human (security)				Urbanization, disasters	
Societal/community					
National	Middle East, North Africa focus		Northern focus (NATO, E.U. countries)		
International/regional					
Global/planetary					

Source: Brauch 2002a, 2003.

Figure 11.3 Causes and outcomes of environmental stress



Source: Brauch 2002b.

for North-South environmental security issues in the Mediterranean. Environmental security issues are often addressed from a *human security* (Newman and Richmond 2001) perspective. For Kofi Annan (2001: xix) human security is a "people-centred concept" that "no country … can achieve … on its own, and none is exempt from risks and costs if it chooses to do without the multilateral cooperation that can help us reach this goal."

Thus, both the *human security* perspective and the *environmental security* dimension are best suited for analyzing the linkages between urbanization and disasters. In the Mediterranean, there have been fundamental differences in the conceptualization of security: while there has been a widening of the security concept in the U.N. family and in most E.U. Mediterranean countries, in the Mashreq (Selim in Brauch and others 2003), in Israel (Kam 2003), and Turkey (Aydin in Brauch and others 2003) the narrow, hard security focus on military and political factors has prevailed. In the North and South, different concepts of sovereignty and security prevail (Brauch 2001).

Model: Global Challenges, Environmental Stress and Outcomes

This model distinguishes between causes and effects of environmental stress and outcomes: a) natural disasters; b) environmentally-induced migration; c) crises; d) conflicts; and e) efforts of environmental conflict prevention and avoidance. In addition to urbanization as the independent variable, the model includes population growth and climate change as two intervening variables. Strategies for disaster reduction must address both *vulnerability* and *impact* for the state, the society, and the economy by enhancing and exploiting available knowledge (figure 11.3).

Disasters (Hewitt 2002; Smith 2001; Abramovitz 2001) may be the result of *purely natural processes* as well as *anthropogenic factors* and of *unintended technological malfunctioning* or *deliberate terrorist attack*. Natural disasters may be a cause for nature-induced migration (UNHCR/IOM/RPG 1996), for distress migration (Meze-Hausken 1998), and for environmental refugees (El-Hinnawi 1985; Myers 1995; Brauch 2000/01); they may also be a cause for domestic or international crises that may escalate into violent conflicts, or that may be avoided by political efforts (Brauch 2002b; 2003). Natural disasters (e.g., Sahel, Bangladesh) have already become one among several triggers for environmentally induced migration, which has led in some cases to domestic crises.

For dealing with disaster reduction and risk management, the political process is vital (UN/ISDR 2002). The state is responsible for the initiation of *adaptation* and *mitigation* measures. However, its resources are constrained by socioeconomic and political factors. Human vulnerability and fatalities can be reduced by capacity building within society, by improved early warning systems, better building standards, success in poverty eradication, and good governance.

Population Growth in the Mediterranean Region (1850–2050)

Urbanization is caused by *push-* and *pull-factors*, the structure of the economy, and the stage of economic development (Rakodi 1997; Lo 1998; Mitchell 1999a; UNCHS 2001a, 2001b). Population growth has been a major driver for the rapid expansion of megacities and for informal housing quarters that are highly vulnerable to disaster (UNEP 2002). Both past and projected population growth (table 11.1) are crucial for assessing future vulnerabilities to disasters.

In the Mediterranean, the demographic data indicate two patterns (Zlotnik in Brauch and others 2003). Due to different stages of demographic transition (Lutz 1994, 1996, 2002), between 1850 and 2000, the population in the five Southern European EU-member countries doubled, while that of the 12 EU dialogue partners (plus Libya) increased 9-fold (table 11.1). From 2000 to 2050, a declining population has been projected in the five Southern (–23.2 million) and Southeastern European (–2.3 million) countries (except Albania), slight increases in Cyprus, and major increases in North Africa (+96.6 million) and in the Eastern Mediterranean (+84.3 million). In the 12 Middle East and North African countries, more people will be added until 2050 than presently live in the five Southern European EU countries (177.3 million). These different population growth patterns will affect vulnerability to disasters.

Urbanization Trends in the Mediterranean Region (1950–2030)

Urbanization trends in the region have differed significantly. While in Southern Europe, the urbanization rate has been projected to increase to 75.2 percent by 2030 (from 44.2 percent in 1950), in North Africa, the urbanization rate has been projected to increase even more rapidly—from 24.7 percent in 1950 to 63.3 percent by 2030. In the Middle East and North Africa, urbanization rates have differed (1950–2000), as have the projections until 2030 (table 11.2). Between 1950 and 2000, the most rapid increase in the urbanization rate occurred in Libya, from 18.6 percent to 87.6, and in Lebanon, from 22.7 percent to 89.7 percent.

By 2030, about 94.6 percent of the population in Israel will be urban, 93.9 percent in Lebanon, and 92 percent in Libya. This compares with 71.6 percent in Greece, 76.1 percent in Italy, 81.6 percent in Portugal, 82.2 percent in France, and 84.5 percent in Spain. While in 1950, the urbanization rate in North Africa was the highest in Egypt, with 31.9 percent, by 2030, at an expected

Table 11.1 Population growth of Mediterranean countries, 1850–2050

	Real population development						*Projection med. var.*	*Changes*	
	1850	*1900*	*1950*	*1965*	*1980*	*2000 (2000 rev.)*	*2050 (2000 rev.)*	*1950–2050*	*2000–2050 (2000 rev.)*
Five southern European E.U. countries									
France	36.0	41.0	41.829	48.753	53.880	59.238	61.832	20.003	**–2.594**
Greece	3.5	4.5	7.566	8.551	9.643	10.610	8.983	1.417	**–1.627**
Italy	25.0	34.0	47.104	52.112	56.434	57.530	42.962	–4.142	**–14.568**
Portugal	3.5	5.5	8.405	9.129	9.766	10.016	9.006	601	**–1.010**
Spain	15.0	18.5	28.009	32.065	37.542	39.910	31.282	3.273	**–8.628**
Total (5)	**83.0**	**103.5**	**132.913**	**150.610**	**167.265**	**177.304**	**154.065**	**21.152**	**–23.239**
Two E.U. candidates and dialogue partner countries									
Cyprus	0.15	0.23	0.494	0.582	0.611	0.784	0.910	0.416	**0.126**
Malta	0.13	0.19	0.312	0.305	0.324	0.390	0.400	0.088	**0.010**
Total (Islands)	**0.28**	**0.42**	**0.806**	**0.887**	**0.935**	**1.174**	**1.310**	**0.504**	**0.136**
Yugoslavia and Albania									
Albania	0.5	0.8	1.215			3.134	3.905	2.690	0.771
Yugoslavia	7.25	9.5	16.345			23.205	20.088	3.743	–3.117
- Bosnia and Herzegovina.			2.661			3.977	3.458		–0.519
- Croatia			3.850			4.654	4.179		–0.475
- Macedonia			1.230			2.034	1.894		–0.140
- Slovenia			1.473			1.988	1.527		–0.461
- FR Yugoslavia			7.131			10.552	9.030		–1.522
Total	**7.75**	**10.3**	**17.560**			**26.339**	**23.993**	**6.433**	**–2.346**
Ten Non-E.U.-Mediterranean dialogue partners (plus Libya)									
Algeria	3.0	5.0	8.753	11.823	18.740	30.291	51.180	42.427	**20.889**
Morocco	3.0	5.0	8.953	13.323	19.382	29.878	50.361	41.408	**20.483**
Tunisia	1.0	1.5	3.530	4.630	6.448	9.459	14.076	10.546	**4.617**
Libya	0.6	0.8	1.029	1.623	3.043	5.290	9.969	8.940	**4.679**
Egypt	5.5	10.0	21.834	31.563	43.749	67.884	113.840	92.006	**45.956**
Only North Africa	**13.1**	**22.3**	**44.099**	**62.962**	**91.362**	**142.802**	**239.426**	**195.327**	**96.624**
Jordan	0.25	0.3	1.237	1.962	2.923	4.913	11.709	10.472	**6.796**
Israel			1.258	2.563	3.879	6.040	10.065	8.807	**4.025**
Palestine Authority	0.35	0.5	1.005	?	?	3.191	11.821	10.816	**8.630**
Lebanon	0.35	0.5	1.443	2.151	2.669	3.496	5.018	3.575	**1.522**
Syria	1.5	1.75	3.495	5.325	8.704	16.189	36.345	32.850	**20.156**
Turkey	10.0	13.0	20.809	31.151	44.438	55.668	98.818	78.009	**43.150**
Eastern Med.	**12.45**	**16.05**	**29.247**	**43.152**	**62.613**	**89.497**	**173.776**	**144.529**	**84.279**
10+1 dialogue c.	**25.55**	**38.35**	**73.346**	**106.114**	**153.975**	**232.299**	**413.202**	**339.856**	**180.903**
Total (12+1)	**25.83**	**38.77**	**74.152**	**107.001**	**154.910**	**233.473**	**414.512**	**340.360**	**181.039**

Sources: McEvedy/Jones 1978 for 1850, 1900; for projections to 2050: UN 2001. The data for 1960, 1980, and for the 1998 UN revisions are from Heilig 1998a, 1998b.

54.4 percent, it would be the lowest. This trend is also reflected in the growth of major urban centers around the Mediterranean (table 11.3).

In Southern Europe from 1950 to 2000, the Mediterranean coastal cities (Rome, Athens, Barcelona, Naples, Marseille) have increased the least (1.1- to 1.8-fold) and will stabilize until 2015. In the Middle East and North Africa, Shubra el Kheima (Egypt) grew 25-fold; Tripoli, Amman, and Rabat grew 10- to 15-fold; Istanbul, Aleppo, Damascus, Beirut, Ankara, Casablanca, Tel-Aviv, and Izmir

Table 11.2 Changes in the urbanization rates of MENA countries (1950–2030)

Ten Non-E.U.-Mediterranean dialogue partners (plus Libya) in percentage									
	1950	*1960*	*1970*	*1980*	*1990*	*2000*	*2010*	*2020*	*2030*
Algeria	**22.3**	30.4	39.5	43.5	51.4	**57.1**	62.2	67.5	**71.7**
Morocco	**26.2**	29.2	34.6	41.3	48.4	**55.5**	61.7	66.7	**71.0**
Tunisia	**31.2**	36.0	44.5	51.5	57.9	**65.5**	71.3	75.2	**78.4**
Libya	**18.6**	22.7	45.3	69.3	81.8	**87.6**	89.7	90.9	**92.0**
Egypt	**31.9**	37.9	42.2	43.8	43.6	**42.7**	44.0	48.2	**54.4**
Only North Africa	**24.7**	**30.1**	**36.3**	**40.4**	**44.8**	**48.9**	**53.4**	**58.2**	**63.3**
Jordan	**35.9**	50.9	56.0	60.2	72.2	**78.7**	80.1	82.2	**84.4**
Israel	**64.6**	77.0	84.2	88.6	90.3	**91.6**	93.0	93.9	**94.6**
Palestine Authority	**37.3**	44.0	54.3	61.1	64.0	**66.8**	70.0	73.5	**76.9**
Lebanon	**22.7**	39.6	59.4	73.7	84.2	**89.7**	92.1	93.1	**93.9**
Syria	**30.6**	36.8	43.3	46.7	48.9	**51.4**	55.4	60.6	**65.6**
Turkey	**21.3**	29.7	38.4	43.8	61.2	**65.8**	69.9	73.7	**77.0**
Western Asia	**26.7**	**35.0**	**44.4**	**51.7**	**62.0**	**64.7**	**67.2**	**69.8**	**72.4**
Urbanization rates for three continents and the world									
Africa	**14.7**	**18.5**	**23.1**	**27.4**	**31.8**	**37.2**	**42.7**	**47.9**	**52.9**
Asia	**17.4**	**20.8**	**23.4**	**26.9**	**32.3**	**37.5**	**43.0**	**48.7**	**54.1**
Europe	**52.4**	**58.0**	**64.6**	**69.4**	**72.1**	**73.4**	**75.1**	**77.6**	**80.5**
World	**29.8**	**33.7**	**36.8**	**39.6**	**43.5**	**47.2**	**51.5**	**55.9**	**60.2**

Source: UN 2002.

Table 11.3 Growth of urban centers in the Mediterranean, 1950–2015 (millions)

City	*1950*	*1955*	*1960*	*1965*	*1970*	*1975*	*1980*	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*	*2015*
Athens	1.8	2.0	2.2	2.4	2.5	2.7	3.0	3.0	3.0	3.1	3.1	3.1	3.1	3.1
Istanbul	1.08	1.37	1.74	2.20	2.79	3.60	4.40	5.41	6.54	7.66	8.96	9.95	10.72	11.36
Ankara	0.54	0.69	0.87	1.09	1.35	1.71	1.89	2.21	2.54	2.83	3.16	3.38	3.58	3.78
Izmir	0.48	0.56	0.66	0.77	0.89	1.05	1.22	1.47	1.74	1.97	2.21	2.39	2.55	2.70
Rome	1.57	1.91	2.33	2.64	2.91	3.00	3.02	2.93	2.81	2.65	2.65	2.65	2.65	2.65
Milan	3.63	4.05	4.50	4.99	5.53	5.53	5.33	4.98	4.60	4.25	4.25	4.25	4.25	4.25
Naples	2.75	2.96	3.19	3.39	3.59	3.62	3.59	3.42	3.21	3.01	3.01	3.01	3.01	3.01
Turin	0.88	1.05	1.25	1.42	1.62	1.64	1.60	1.50	1.39	1.29	1.29	1.29	1.29	1.29
Cairo	2.41	3.00	3.71	4.61	5.33	6.08	6.86	7.67	8.30	8.86	9.46	10.09	10.77	11.53
Alexandria	1.04	1.25	1.50	1.75	1.99	2.24	2.52	2.83	3.06	3.28	3.51	3.75	4.02	4.33
Shubra el Kheima	0.04	0.06	0.10	0.16	0.24	0.35	0.49	0.66	0.77	0.85	0.94	1.03	1.13	1.23
Tel-Aviv	0.42	0.56	0.74	0.88	1.03	1.21	1.42	1.62	1.80	1.90	2.00	2.13	2.27	2.40
Amman	0.09	0.14	0.22	0.30	0.39	0.50	0.64	0.78	0.94	0.99	1.15	1.31	1.48	1.65
Beirut	0.34	0.43	0.56	0.72	0.92	1.06	1.21	1.39	1.58	1.82	2.07	2.28	2.42	2.50
Damascus	0.37	0.46	0.58	0.73	0.91	1.12	1.38	1.56	1.73	1.92	2.14	2.43	2.78	3.17
Aleppo	0.32	0.39	0.48	0.59	0.72	0.88	1.07	1.29	1.55	1.87	2.23	2.62	3.05	3.49
Marseille	0.7	0.7	0.8	0.9	1.1	1.2	1.2	1.2	1.2	1.2	1.30	1.32	1.34	1.36
Algiers	0.50	0.62	0.81	1.07	1.28	1.57	1.62	1.67	1.91	2.30	2.76	3.27	3.74	4.14
Tunis	0.47	0.53	0.58	0.64	0.74	0.87	1.14	1.43	1.57	1.72	1.90	2.07	2.25	2.41
Tripoli	0.11	0.14	0.17	0.24	0.40	0.61	0.80	1.04	1.30	1.52	1.73	1.94	2.12	2.27
Barcelona	1.6	1.7	1.9	2.3	2.7	2.9	3.1	3.0	2.9	2.8	2.73	2.73	2.73	2.73
Casablanca	0.63	0.78	0.97	1.21	1.51	1.79	2.11	2.41	2.69	2.99	3.36	3.78	4.22	4.61
Rabat	0.15	0.18	0.23	0.34	0.49	0.64	0.81	0.98	1.16	1.37	1.61	1.88	2.13	2.34
Fes	0.17	0.22	0.28	0.32	0.37	0.43	0.51	0.59	0.68	0.79	0.90	1.04	1.18	1.30
Marrakech	0.21	0.23	0.24	0.28	0.32	0.37	0.42	0.49	0.58	0.69	0.82	0.96	1.10	1.21

Source: UN 2002.

5- to 10-fold; and Cairo, Tunis, Alexandria, and Algiers 2- to 5-fold. Among the 30 largest urban agglomerations in 1950, two were in the Mediterranean: Milan at number 14 with 3.633 million, and Cairo at number 25 with 2.410 million. In 2000, Cairo was number 20 with 9.462 million, and Istanbul number 22 with 8.953 million. By 2015, Cairo will be number 18 with 11.531 million and Istanbul number 19 with 11.362 million (UN 2002).

Mitchell (1999a: 29) estimated that Cairo's population density was 37,726 inhabitants per square kilometer. Egyptian authors (Yousry 1998: 301) stated an average population density for the Greater Cairo region of 32,000, with the city of Cairo's population density at 78,300 (possibly reaching 87,000 in Dar Elsalam) and Giza's at 51,300 (in Imbaba and Mounira even 84,000) inhabitants per square kilometer. As in many megacities, social problems (inequality, unemployment, crime) associated with the ever-increasing rate of growth in Cairo surpassed the capacity of the government "to cope properly with … and to manage it" (Yousry 1997: 134–137). This rapid urbanization made Cairo highly vulnerable to disasters. On October 12, 1992, an earthquake in Cairo caused 561 fatalities and economic damage totaling US$1,200 billion (Munich Re 1998).

According to UNCHS (2001a: 13), in Arab countries "urban growth rates will remain higher than total population growth rates in the foreseeable future…. Urban growth has been the result of rural-to-urban migration as well as high fertility and declining rates of mortality." The UNHCS notes that "many cities are now going through a critical phase of development, marked by dwindling resources, increasing poverty, and serious environmental degradation."

Both international organizations and individual experts (Mitchell 1995; Ichikawa 1995) noted "the increasing disaster potential of megacities." IDNDR (1996) listed among 17 cases of disasters in urban areas three from the Mediterranean: a) an earthquake in 1980 in Naples, Potenza, Salerno, Avelino with 3,000 deaths; b) an earthquake in 1992 in Erzincan in Turkey that killed 547 and affected 230,000; and c) an earthquake in Cairo that destroyed 5,000 buildings and damaged 12,000. Mitchell (1999b: 475) noted that megacity hazards, such as floods, earthquakes, and windstorms, are the most common damaging phenomena, followed by other risks that trigger disasters. He noted major changes in megacity hazards but also in interactivity, risks, change in exposure, vulnerability and in the efficacy of hazard management. Not only will vulnerability rise, but also the impact of extreme weather events.[1]

Climate Change: IPCC Projections of Extreme Weather Events

According to the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC 2001a: 13), between 1990 and 2100, "the globally averaged surface temperature is projected to increase by 1.4 to 5.8°C and the mean sea level will rise by 0.09 to 0.88 meters." The TAR argued that global climate change increased the probability of some extreme weather events during the 20th century and that, in the 21st century, "more intense precipitation events" and an "increase of the heat index" will become "very likely, over most areas" (IPCC 2001a: 3).

Due to regional climate differences, "expected climate change will give rise to different exposures to climate stimuli across regions." Less-developed regions are severely vulnerable and "in Europe, vulnerability is significantly greater in the south" (IPCC 2001b: 15). This has also been stressed in the IPCC assessments of the climate scenarios for Europe pertaining to the changes in temperature and precipitation during summer periods for the 2020s, 2050s, and 2080s. The projected trend for Southern Europe is obvious: the temperature may increase most and precipitation may decline most in Mediterranean countries. Climate change produces short-term and long-term impacts that can contribute to disasters that vary according to the specific vulnerabilities that may be reduced by both adaptation and mitigation measures.

In response to human activities and the natural environment, Europe and the Mediterranean are sensitive to *extreme seasons* (exceptionally hot, dry summers, mild winters), *short-duration hazards* (windstorm, heavy rain, river-valley flooding), and *slow, long-term change* (coastal squeeze, sea-level rise) (IPCC 2001a: 647). Projected climate change would also be associated with increases in heat waves. The rise in floods "will increase the risk of drowning, diarrhoeal and respiratory diseases, and in developing countries, hunger and malnutrition" (IPCC 2001b: 12). Climate change will also impact on human settlements, and worsen existing trends further. "In such areas, squatter and other informal urban settlements with high population density, poor shelter, little or no access to resources such as safe water and public health services, and low adaptive capacity are highly vulnerable" (IPCC 2001b: 13). The disaster impact is caused by *hazards* whose intensity is influenced by social, economic, physical, and environmental vulnerabilities. According to the ISDR (UN/ISDR 2002: 23) framework, any risk assessment relies on a *vulnerability capability analysis*, a *hazard analysis and monitoring,* and *knowledge development*. Risk assessment contributes to problem awareness, public commitment, the application of risk reduction measures, and to early warning.

Analysis of the Trends in Disasters in the Mediterranean

A survey of natural disasters from 1975 to 2001 (table 11.4) in the Mediterranean indicates that more than half of all the natural disasters were reported for the five South European countries.[2] During these 27 years, most natural disasters were reported in France (86), followed by Turkey (63), Italy (57), Spain (47), Greece (43), Algeria (36), and Morocco (23). With regard to fatalities, Turkey ranked first (27,375), followed by Italy (6,158) and Algeria (4,124), Greece (1,573) and Egypt (1,386). But, for affected persons, Spain was in the lead (6,819,987), followed by France (3,890,759), Albania (3,259,759), Turkey (2,580,392), and Algeria (1,154,355). Around the Mediterranean, most disaster fatalities were the result of earthquakes (Turkey, Italy, Algeria), though drought and famine affected more people.

From the 1980s to the 1990s disaster fatalities increased for Turkey, Egypt, Morocco, Italy, and France, while the affected persons increased most for Spain but also for France (IFRC 2001: 186–197, 2002: 197–203). In Albania the drought of 1991 affected about 3.2 million, while the earthquakes in Turkey in the 1990s affected more than 2 million. In North Africa, the number of people affected by natural disasters increased from the 1980s to the 1990s for Egypt, Morocco, and Algeria, while numbers declined for Tunisia: 96,000 in 1990, 30,000 in 1982, and 2,500 in 1986.

Between 1975 and 2001, geophysical disasters caused the most fatalities (in Turkey, Italy, and Algeria), while the winter storms in France, and drought in Spain, Albania, Syria, and Morocco caused an increasing number of disaster-affected people. The 1999 earthquake in Turkey and the flood in Algeria in 2001, discussed later, demonstrated the vulnerability of urban centers.

Geophysical Disasters: Earthquakes and Volcanoes

The many earthquakes in the Mediterranean are due to repeated collisions between the African Plate, the Eurasian Plate, and several small plates (Arabian, Adriatic, and Iberian). According to Wagner (2001: 213) during the 20th century, about 60 major earthquakes were recorded in the Mediterranean, some 20 in northwestern Turkey. During this period, earthquakes in the Mediterranean caused at least 250,000 fatalities (Wagner 2001: 213).

Hydro-meteorological Disasters: Storms, Floods, and Drought

According to Munich Re (1998: 9) "in terms of frequency of damage and total area affected, storms are, worldwide, the most significant of all natural hazards… [O]ver the period 1988 to 1997, two-thirds of the claim payments (US$130 billion) for natural catastrophes were occasioned by storms." In the Mediterranean severe winter storms and floods have increased in frequency and intensity and, in part due to rapid urbanization, the number of fatalities and economic losses have been rising in the eastern and the southern regions. Due to population growth, the impact of drought differed in the North and South (Mendizabal and Puig in Brauch and others 2003).

In Europe, floods are the most common and the most costly natural disaster. From 1991 to 1995, the economic cost of flood damage has been estimated at EUR 99 billion. A study by the European Environment Agency (2001) stated that "the main areas prone to frequent

Table 11.4 People reported killed by natural disasters by country, 1975 to 2001 (in thousands)

	Total			*Drought/famine*			*Earthquakes*			*Floods*			*Windstorms*		
	Event	*Killed*	*Affected*	*Ev.*	*Killed*	*Affected*	*Ev.*	*Killed*	*Affected*	*Ev.*	*Killed*	*Affected*	*Ev.*	*Killed*	*Affected*
South Europe (E.U.)	**249**	**8,888**	**12,625,625**	**8**	**0**	**6,000,000**	**33**	**6,0077**	**1,765,710**	**71**	**837**	**1,238,417**	**60**	**469**	**3,566,519**
France	86	524	3,890,759	1	—	—	0	0	0	30	143	372,125	34	239	3,504,918
Greece	43	1,573	944,035	1	—	—	17	335	930,925	8	78	10,150	2	48	—
Italy	57	6,158	921,154	0	—	—	15	5,672	834,765	16	319	67,622	9	67	1,119
Portugal	16	132	49,690	2	—	—	0	0	0	4	99	47,220	2	4	70
Spain	47	501	6,819,987	4	0	6,000,000	1	0	20	13	198	741,300	13	111	60,412
E.U. Candidates	**9**	**59**	**4,451**	**2**	**0**	**0**	**2**	**2**	**3,815**	**0**	**0**	**0**	**0**	**0**	**0**
Cyprus	8	59	3,751	2	—	—	1	2	3,115	—	—	—	—	—	—
Malta	—	—	—	—	—	—	—	—	—	—	—	—	—		
Slovenia[a]	1	—	700	—	—	—	1	—	700	—	—	—	—	—	—
Balkans	**50**	**562**	**3,779,928**	**3**	**0**	**3,210,500**	**11**	**187**	**414,405**	**12**	**108**	**145,208**	**2**	**0**	**1,090**
Albania	12	187	3,259,756	1	—	3,200,000	4	36	6,045		4	46,500	0	0	0
Bosnia Herc.[a]	4	6	1,893	1	—	—	—	—	—	—	—	—	1	—	1,090
Croatia[a]	6	41	3,400	—	—	—	1	—	2,000	2	—	1,200	—	—	—
FYR Maced.[a]	4	15	11,500	1	—	10,500	—	—	—	1	—	1,500	—	—	—
Serbia/Mont.[a]	9	15	83,959	—	—	—	—	—	—	5	12	83,008	—	—	—
Yugoslavia[b]	15	298	419,420	—	—	—	6	151	406,360	4	92	13,000	1	—	—
Eastern Mediter.	**95**	**27,613**	**3,700,060**	**5**	**0**	**988,000**	**23**	**26,087**	**2,377,128**	**24**	**505**	**112,858**	**8**	**70**	**104,688**
Israel	11	31	2,029	1	—	—	—	—	—	2	11	1,000	1	3	410
Jordan	11	47	348,956	2	—	330,000	—	—	—	2	17	18,029	3	11	200
Lebanon	4	45	105,575	—	—	—	—	—	—	1	—	1,500	1	25	104,075
Palestinian Auth.	1	—	943	—	—	—	—	—	—	—	—	—	—	—	—
Syria	5	115	662,165	2	—	658,000	—	—	—	2	27	172			
Turkey	63	27,375	2,580,392	—	—	—	23	26,087	2,377,128	17	450	92,157	3	31	3
North Africa	**82**	**6,606**	**2,038,320**	**10**	**0**	**306,400**	**10**	**3,452**	**1,036,210**	**38**	**2,924**	**656,640**	**6**	**69**	**25,188**
Algeria	36	4,124	1,154,355	3	—	—	8	2,881	1,001,212	17	1,201	141,765	2	4	10,117
Egypt	14	1,386	280,342	—	—	—	2	571	34,998	5	673	229,868	3	51	15,071
Libya	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Morocco	23	919	442,973	5	—	275,000	—	—	—	11	873	155,757	1	14	—
Tunisia	8	177	160,650	2	—	31,400	—	—	—	4	177	129,250	—	—	—
Total	**485**	**43,728**	**22,148,384**	**28**	**0**	**10,504,900**	**79**	**35,735**	**5,597,268**	**145**	**4374**	**2,153,123**	**76**	**608**	**3,697,485**

Note: EM-DAT includes events where at least one of these criteria apply: 1) 10 or more people reported killed; 2) 100 people reported affected; 3) a call for international assistance; or 4) a declaration of a state of emergency.

a. since independence in 1991, 1992.

b. for Yugoslavia (1974 until 1991).

floods include the Mediterranean … (where) a major risk factor is the occupation of potential flood areas through uncontrolled building and inadequate land-use planning."[3] While the number of flood events and amount of economic damage have increased from 1992 to 1998, human fatalities have remained low in Europe. The most costly flash flood in November 1995 in Piedmont caused economic damage of US$13 billion but only 64 fatalities. These differences are due to the vulnerability of the victims and the disaster preparedness and response.

Vulnerabilities of Cities to Disasters: Cases of Izmit and Algiers

From the comprehensive analysis of disasters in the Mediterranean during the 20th century (Brauch and others 2003), the following different trends emerged among its four subregions (table 11.4).

- From 1975–2001, the most natural disasters were reported for Southern Europe (249), followed by the Eastern Mediterranean (95), North Africa (82), and the Balkans (50).
- The number of fatalities was highest in Turkey (27,375), followed by Italy (6,158), Algeria (4,124), Greece (1,573), and Egypt (1,386). Most fatalities were from earthquakes.
- Fatalities in the Middle East, North Africa, and Turkey amounted to 34,219 (79 percent of the total).
- About 82 percent of fatalities were from earthquakes (35,737), half from two events in Turkey.
- About 47.5 percent of all disaster-affected people were affected by drought, though more than half of this was the result of a single event—a 1995 drought in Spain. The number of affected persons was highest for Southern Europe, followed by the Balkans, the Eastern Mediterranean and North Africa.
- Of 38 floods with 2,924 fatalities that hit North Africa from 1975–2001, 921 persons (31%) died in the flood that struck Algeria in 2001.

The 1999 earthquake in Turkey and the 2001 flood in Algiers were among the most fatal natural events, where vulnerability was much higher than in Southern Europe. To illustrate this argument, these two recent cases are briefly reviewed below.

The Earthquake in Western Turkey in August 1999

In Turkey, 23 of 63 reported events (1975–2001) were earthquakes that caused 26,087 fatalities and affected 2,377,128. In 1998 and 1999, three earthquakes and one flood in Turkey were among the 100 major worldwide disasters (Munich Re 1999, 2000). The earthquake with the highest economic losses (US$12 billion) and the second-highest fatalities in the 20th century occurred on August 17, 1999, when 17,200 persons died. According to the 2001 ISDR report, the continued high vulnerability of Turkey is attributable to: a) population growth and urbanization; b) the failure to apply existing building regulations consistently; and c) the siting of industrial facilities wherever space is available, with no regard for environmental protection rules. In this earthquake, 321,000 people lost their jobs and about 600,000 became homeless. On November 16, 1999, the World Bank granted two loans totalling US$757.53 million[4] and on February 9, 2000, the European Investment Bank provided a EUR 450 million facility.[5] The impact would be more severe if a future earthquake should strike Izmir, Istanbul, or Ankara due to the high population density and large areas with informal housing. Geologists have predicted that in the next 30 years there is a 62 percent probability of a major earthquake in this area with an intensity of 7 to 7.9 on the Richter scale. At the same time, the populations of these cities are expected to increase (table 11.3).[6]

The Flood in Algeria in November 2001

In North Africa, Algeria was hit most severely by disasters (36 events, 4,124 fatalities, and 1,154,355 affected people), followed by Egypt (14 events, 1,286 fatalities, and 289,342 affected people), and Morocco (23 events, 919 deaths, and 442,973 affected people). Most fatalities in Algeria were due to earthquakes (2,881) and floods (1,201); in Egypt, there were 673 flood victims and 561 earthquake victims in Cairo in 1992. In Algeria, earthquakes affected 1,001,212; in Morocco, drought affected 275,000, and in Egypt, floods affected 229,868. The flash floods that struck Algiers between November 9–13 caused 921 deaths (IFRC 2002), affected 50,423 people, and caused economic losses in the range of US$300 million. According to UNICEF, "the floods have affected over 10,000 families or 40,000 to 50,000 persons, two-thirds of whom are children."[7] The factors contributing to the high vulnerability and high number of fatalities refer to high population density, poorly-built housing in flood-prone regions, severe administrative errors, and lack of implementation of building standards in one of the poorest city sectors.

On August 8, 2002, the World Bank approved a US$89 million loan to Algeria,[8] and on July 24, 2002, the EIB granted Algeria a loan of EUR 165 million for reconstructing flood-damaged infrastructure.[9] According to urbanization projections (table 11.3), Algiers is projected to grow by 50 percent from 2000 to 2015 (2000: 2.76 million, 2015: 4.14 million). While population growth and urbanization contribute to increased vulnerability, climate change may increase the impact of severe weather events, especially in the Middle East and North Africa.

The Projected Impact of the Sea-level Rise for Alexandria

Egypt will be severely affected by the projected sea-level rise in the Nile Delta and in its coastal regions. Sestini (1992) analyzed its implications until 2020. In his view, "the socioeconomic structures of the Lower Nile Delta probably will be affected more by population increase and urbanization, than by climatic changes" (Sestini 1992: 535–536).

Mohammed El-Raey (1991, 1993, 1994, 2000) produced a *Vulnerability Assessment of the Coastal Zone of Egypt to the Impacts of Sea Level Rise*, which concluded: "that a 0.5 meter sea level rise would cause migration of more than 2.0 million people, loss of more than 214,000 jobs and a value loss of more than US$40.0 billion, mainly in Alexandria Governorate."[10] The reports contained detailed vulnerability assessments for Alexandria (El-Raey 1997), Roseta, and Port Said (El-Raey 1997a). El-Raey expects these impacts within the governorate of Alexandria, where 40 percent of Egyptian industry is located: a) increased vulnerability of slum areas to wind and flood damage; and b) changes in the frequency, timing, and duration of heat waves that will affect agricultural yields, and increase insect pests. Secondary regional impacts include: a) increased unemployment that increases immigration pressure on European countries; and b) decreased water resources that increase friction among countries sharing the same water resources, leading to political unrest.

These studies have all projected severe consequences for Alexandria from sea-level rise. Due to high population density, Alexandria and Cairo are highly vulnerable to earthquakes and floods. Alexandria has been projected to grow by 820,000 people until 2015. Food self-sufficiency will decline and import needs will rise significantly (Brauch 2002a, 2002b).

Conclusions: Urbanization and Disaster Preparedness

Drawing Lessons from the Case Studies

The statistical analysis and the two case studies on rapid-onset disasters and projected slow-onset disaster in the southern and eastern Mediterranean have indicated that:

- Rapid urbanization has increased and will further increase the vulnerability to all types of disasters, especially for the poor living in informal housing and in flood-prone areas.
- The probability and intensity of hydro-meteorological disasters have been projected to increase due to climate change impacts. Rapid urbanization may further increase the vulnerability to all disasters and fatalities and affected people in the years to come.

To counter the high fatalities in MENA countries, a dual effort is needed: a) a reduction in human vulnerability; and b) a reduction in disaster impacts.

International Strategy of Urban Disaster Reduction

The IPCC (2001a) observed significant changes in extreme weather events and hydro-meteorological disasters globally. In response, international regimes and epistemic communities (Haas 1993) dealing with disasters have emerged after the International Decade on Natural Disaster Reduction (IDNDR), especially the International Strategy on Disaster Reduction (ISDR) and its Inter-Agency Task Force for Disaster Reduction (IATF), the ProVention Consortium, the emergency and disaster-reduction efforts of UNEP and UNDP, the initiatives by NATO's Euro-Atlantic Disaster Response Coordination Center, and efforts by the EU in the area of civil protection of its member countries on behalf of the European Space Agency.

Mediterranean Strategy of Urban Disaster Reduction

Dealing with disasters in the Mediterranean as a common regional problem has been impeded because this space is institutionally separated among three continents. Efforts at disaster reduction have been launched in the framework of the Euro-Mediterranean Partnership (EMP), and on the scientific level, information networks (MEDIN) and functional organizations exist that involve some non–EU Mediterranean member countries in disaster response, preparedness, and reduction activities. In the Mediterranean these efforts are highly fragmented (Brauch and others 2003). Many EU-sponsored research projects, for example on climate, land-use changes, desertification, and urbanization have focused primarily on Southern Europe.

Two different regional concepts could overcome existing deficits: the geographic perspective of the Mediterranean space contained in the Barcelona Convention (1976), and in the Mediterranean Action Plan (MAP) that includes all riparian countries, and the Euro-Mediterranean space of the Barcelona Declaration (1995) that includes all 15 EU countries and 12 dialogue partners. In October 2001, the 27 Euro-Mediterranean foreign ministers welcomed "the progress made within the Partnership with regard to a system for preventing, alleviating the effects of and managing disasters" and in the Valencia Plan of Action of April 24, 2002, they recognized the "contribution and the experience accumulated by the pilot project on mitigation of natural or manmade disasters." In the *Athens Declaration* of July 10, 2002, the synergies between MAP and SMAP were stressed (Brauch and others 2003), but references to disaster reduction were missing. The pilot project in the EMP context of the EU's Directorate-General External Relations and of civil protection efforts of its Directorate-General Environment could be linked more closely. The joint Global Monitoring for Environment and Security (GMES)-initiative of the European Commission and the European Space Agency could provide data for a joint Euro-Mediterranean regional monitoring of the causes contributing to natural disasters (land-use changes, soil erosion, urbanization) and to the increase in vulnerability, especially of urban centers in the Middle East and North Africa (Sari in Brauch and others 2003). In the EMP context, experts from all Mediterranean countries should join training exercises to cope with disaster impacts.

A Mediterranean strategy for disaster prevention (MSDR) could be launched by the ISDR, and a Mediterranean Inter-Agency Task Force for Disaster Reduction (MIATF) could closely coordinate the regional efforts of existing United Nations, European Union, Arab, and other functional institutions to enhance cooperation, research, and training for disaster reduction. Humanitarian organizations such as the International Federation of the Red Cross and Red Crescent Societies (IFRC-RCS) and the industry could play a role in developing affordable insurance schemes for those countries that have become repeated victims of natural and technological disasters.

From Disaster Response to Disaster Reduction

A disaster-impact assessment and disaster preparedness should become inherent goals of all development projects by international financial institutions (e.g., in the Mediterranean Technical Assistance Programme: METAP), by U.N. institutions, and in the EMP-framework. Risk-reduction measures should be included in regional efforts for environmental management, land-use planning, promotion of improved building standards, and joint monitoring of their proper implementation.

Reducing Vulnerability to and Impact of Disasters

The two basic strategic goals of a Mediterranean strategy of disaster reduction require:

- A reduction in the vulnerability of human beings and economic losses to disasters; and
- A reduction in the impact of geophysical and hydrometeorological disasters.

Reducing the vulnerability to disasters of urban centers in the Mediterranean requires a deliberate strategy of poverty eradication and sustainable development. The EMP (EU) and MAP (UNEP) and international financial institutions in METAP offer existing institutional frameworks. Disaster-reduction goals must be integrated into all national, regional, and urban development plans. This presupposes an enhanced knowledge of risk factors for the whole Mediterranean region for: a) social, economic, physical, and environmental vulnerabilities; and b) all types of hazards and disasters. Societal and political efforts, a higher public commitment, improved urban risk assessments, improved pan-Mediterranean early warning systems, and improved national and urban preparedness would permit a rapid and effective disaster response. In both case studies, major legislative, administrative, and operational deficits were noted. Technical measures can contribute to better disaster preparedness: a mapping of disaster-prone urban regions and the development of specific building codes and instruments for their effective implementation. As urban areas are expected to continue to grow in the Middle East and North Africa, long-term preparedness becomes an essential prerequisite to avoid negative impacts on humans and the environment. Reducing vulnerability requires addressing population growth and reducing the impact of climate change and extreme weather events, including the projected sea-level rise, though remedial action requires a concerted global effort to reduce global warming.

As long as policymakers ignore the linkage between the causes of environmental stress and effects and the most likely outcomes in terms of disasters (figure 11.4), no major progress can be achieved to implement the declared goals of sustainable development. The requirements of the 1998 Cardiff process to include environmental concerns in all sectoral policies provides a political lever to promote the goals of disaster reduction in the framework of the EMP and to realize the goals the 27 Foreign Ministers from EMP countries adopted in the 2002 Valencia Plan of Action for "ensuring sustainable development with a high degree of environmental protection."[11] Whether the dual challenges of both increasing *vulnerability* and *impact* are perceived by the policymakers and the public, and timely and effective countermeasures are launched and effectively implemented, depends on the worldviews and mindsets that determine their political priorities (figure 11.1). Whether governments in the Middle East and North Africa are willing to shift from a hard to a soft security agenda, with human security perspectives on environmental security issues (including disasters), will depend on the resolution of ongoing conflict.

Notes

1. The "Urban Environment Information gateway" of UNEP, GRID, Arendal: "Cities Environment Reports on the Internet (CEROI)," at: <http://www.ceroi.net> does not offer any data on the Mediterranean area. Its extensive list of indicators does not include any disaster-related indicators and could not be used for this paper.

2. While both tables rely on the EM-DAT database, a major difference in both tables applies to data on Syria.

3. See: EU Publication Office: "November 2001 EU topics and new publications-Archive," at: <http://eur-op.eu.int/flash/nfarch/200111_en.htm>: 5-6 of 10, accessed at 23 July 2002. The full report can be downloaded at: <http://reports.eea.eu.int/Environmental_Issues_No_21/en/enviissue21.pdf>.

4. World Bank: "World Bank Provides Earthquake Assistance to Turkey," News Release No. 2000/094/ECA, 16 November 1999, at: <http://www.worldbank.org/html/exdr/extme/094.htm>.

5. European Investment Bank: "EUR 450 million EIB support for earthquake rehabilitation and reconstruction in Turkey," Press release 2000/003, 9 February 2000, at: <http://www.eib.org/pub/press/2000/pa003.htm>.

6. Hanna Ruitshauser and Kemal Gök. Zerstöre, töte die Stadt. Istanbul erwartet ein grosses Erdbeben in: *Neue Zürcher Zeitung* 17/18 August 2002: 61-63.

7. See: UNICEF, 20 November 2001, at: <http://www.reliefweb.int>.

8. World Bank: "Algeria: World Bank Loan To Reduce Impact Of Natural Disaster On Urban Poor," News Release No: 2002/055/MENA, 8 August 2002. at: <http://www.worldbank.org/>, search: "Algeria"; World Bank: "Shielding Algeria from Disaster. World Bank loan will reduce the impact of natural disasters on urban poor", see also for detailed technical annex and environment impact assessments.

9. European Investment Bank: "Algeria EIB lends EUR 165 million for post-flood reconstruction, the Greater Algiers urban road network and a section of the East-West motorway," Press release 2002/061, 24 July 2002, at: <http://www.eib.org/pub/press/2002/2002-061.htm>.

10. See: M. El-Raey: "Egypt: Coastal Zone Development and Climate Change Impact of Climate Change on Egypt," <http://www.ess.co.at/GAIA/CASES/EGY/impact.htm>.

11. See the text at: < http://ue.eu.int/pressData/en/ec/71025.pdf>.

Bibliography

Abramovitz, Janet N. 2001. *Unnatural Disasters.* Worldwatch Paper 158. Washington, D.C.: Worldwatch Institute.

Annan, Kofi A. 2001. "Foreword." In Rob Mc Rae, and D. Hubert, eds., *Human Security and the New Diplomacy. Protecting People, Promoting Peace.* Montreal–Kingston–London–Ithaca: Mc Gill–Queen's University Press: xix.

Brauch, Hans Günter. 2000/2001. "Environmental Degradation as Root Causes of Migration: Desertification and Climate Change. Long-Term Causes of Migration from North Africa to Europe." In Peter Friedrich and J. Sakari, eds., *Policies of Regional Competition.* Schriften zur öffentlichen Verwaltung und öffentlichen Wirtschaft, Vol. 161. Baden-Baden: Nomos: 102–138.

Brauch, Hans Günter and Antonio Marquina, eds. 2001. *The Mediterranean Space and its Borders. Geography, Politics, Economics and Environment*. Collection Strademed 14. Madrid: UNISCI - Mosbach: AFES-PRESS: 25–58, 109–144.

Brauch, Hans Günter. 2002a. "A Survival Pact for the Mediterranean: Linking 'virtual water' and 'virtual sun.'" In TERI, eds., *Global Partnerships for Sustainable Development: Harnessing Action for the 21st Century.* New Delhi: TERI, forthcoming.

Brauch, Hans Günter. 2002b: "Climate Change, Environmental Stress and Conflict." In BMU, ed., *Climate Change and Conflict.* Berlin: Federal Ministry on the Environment, Nature Conservation and Nuclear Safety.

Brauch, Hans Günter, M. Selim, P.H. Liotta, B. Chourou, and P. Rogers, eds. 2003. *Security and Environment in the Mediterranean. Conceptualising Security and Environmental Conflicts.* Berlin-Heidelberg: Springer, forthcoming.

Bull, Hedley. 1977. *The Anarchical Society. A Study of Order in World Politics*. New York: Columbia University Press.

Buzan, Barry, O. Wæver, and J. de Wilde. 1998: *Security. A New Framework For Análisis.* Boulder - London: Lynne Rienner.

El-Hinnawi, E. 1985. *Environmental Refugees.* Nairobi: UNEP.

El-Raey, Mohammed. 1991. "Responses to the Impacts of Greenhouse-Induced Sea-Level Rise on Egypt." In J.G. Titus, ed., *Changing Climate and the Coast,* vol. 2: *West Africa, the Americas, the Mediterranean Basin, and the Rest of Europe.* Washington, D.C.: UNEP and USEPA.

El-Raey, Mohammed. 1993. "Vulnerability of the Coastal Zones." In *World Coast Conference,* Noordwjik, Netherlands, November 1993.

El-Raey, Mohammed. 1994. *Environmental Refugees Case Study: Egypt.* Alexandria: University of Alexandria, Department of Environmental Studies.

El-Raey, Mohammed. 2000. "Egypt: Coastal Zone Development and Climate Change Impact of Climate Change on Egypt." Available from <http://www.ess.co.at/GAIA/CASES/EGY/impact.htm>.

El-Raey, M., S. Ahmed, and E. Korany. 1997. "Remote Sensing and GIS for Vulnerability Assessment of the Impact of Sea Level Rise over Alexandria City and Vicinity." Alexandria, Egypt: Alexandria University, Department of Environmental Studies, Institute of Graduate Studies and Research.

El-Raey, M., O. Frihy, S.M. Nasr, and K. Dewidar. 1997a. "Vulnerability Assessment of Sea Level Rise over Port-Said Governorate, Egypt." Submitted to *Journal of Environmental Monitoring*.

European Environment Agency. 2001. *Sustainable Water Use in Europe, Part 3: Extreme Hydrological Events: Floods and Droughts*. Environmental Issue Report, No. 21. Copenhagen: European Environment Agency.

Gleditsch, Nils Petter. 2003. "Environmental Conflict: Neomalthusians vs. Cornucopians." In Hans Günter Brauch and others, eds., *Security and Environment in the Mediterranean. Conceptualising Security and Environmental Conflicts.* Berlin-Heidelberg: Springer, forthcoming.

Haas, Peter. 1993. "Epistemic Communities and the Dynamics of International Environmental Cooperation." In V. Rittberger, ed., *Regime Theory and International Relations*. Oxford: Clarendon Press: 168–201.

Heilig, Gerhard A. 1998a. *DemoGraphics '96. A population education software developed for the United Nations Population Fund*. Vienna: Heilig.

Heilig, Gerhard A. 1998b. *DemoTables '96.* Vienna: Heilig.

Hewitt, Kenneth. 2002. "Natural Hazards." In T. Munn, ed., *Encyclopedia of Global Environmental Change,* vol. 3. Chichester: John Wiley: 479–493.

Ichikawa, Atsushi. 1995. "Coping with Urban Disasters." In *OECD Observer* 197: 15–16.

IDNDR (International Decade for Natural Disaster Reduction). 1996. *Cities at Risk. Making Cities Safer Before Disaster Strikes.* Geneva: IDNDR.

IFRC (International Federation of the Red Cross). 2001. *World Disasters Report 2001. Focus on Recovery.* Bloomfield, C.T.: Kumarian–London: Europan: 186–197.

IFRC (International Federation of the Red Cross). 2002. *World Disasters Report 2002. Focus on Reducing Risk*. Bloomfield, CT: Kumarian–London: Europan: 197–203.

IPCC (Intergovernmental Panel on Climate Change). 2001a. *Climate Change 2001. The Scientific Basis*. Cambridge–New York: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2001b. *Climate Change 2001. Impacts, Adaptation and Vulnerability. Mitigation*. Cambridge–New York: Cambridge University Press.

Kam, Ephraim. 2003. "Conceptualising Security in Israel." In Hans Günter Brauch and others, eds., *Security and Environment in the Mediterranean. Conceptualising Security and Environmental Conflicts*. Berlin-Heidelberg: Springer, forthcoming.

Lo, Fu-Chen and Y. Yeung, eds. 1998. *Globalization and the World of Large Cities*. Tokyo–New York–Paris: UN University Press.

Lomborg, Bjørn. 2001. *The Skeptical Environmentalist. Measuring the Real State of the World*. Cambridge–New York: Cambridge University Press.

Lutz, Wolfgang, ed. 1994. *The Future Population of the World. What Can We Assume Today?* London: Earthscan.

Lutz, Wolfgang, ed. 1996. *The Future Population of the World. What Can We Assume Today?* Revised and Updated Edition. London: Earthscan.

Lutz, Wolfgang and A. Goujon. 2002. "Demographic transition." In Ted Munn, ed., *Encyclopedia of Global Environmental Change*, Vol. 4: Peter Timmerman, ed., *Social and economic dimensions of global environmental change*. Chichester: Wiley: 211–214.

Mc Evedy, Colin and R. Jones. 1978. *Atlas of World Population History*. London: Allen Lane.

Meze-Hausken, Elisabeth. 1998. "Mass-migration due to climate change? A conceptual layout." Available from: <http://www.nhh.no/geo/prosjekt/em/project98.html>.

Mitchell, James K. 1995. "Coping with natural hazards and disasters in megacities. Perspectives on the twenty-first century." *GeoJournal* 37(3): 303–312.

Mitchell, James K. 1999a. "Introduction." In James K. Mitchell, ed., *Crucibles of Hazard: Mega-Cities and Disasters in Transition*. Tokyo–New York–Paris: UN University Press: 1–14.

Mitchell; James K. 1999b. "Findings and Conclusions" In James K. Mitchell, ed., *Crucibles of Hazard: Mega-Cities and Disasters in Transition*. Tokyo–New York–Paris: UN University Press: 473–502.

Munich Re. 1998. *World Map of Natural Hazards*. Munich: Munich Re.

Munich Re. 1999. *Topics–Annual Review of Natural Catastrophes 1998*. Munich: Munich Re.

Munich Re. 2000. *Topics–Annual Review of Natural Catastrophes 1999*. Munich: Munich Re.

Myers, Norman. 1995. *Environmental Exodus. An Emergent Crisis in the Global Are*na. Washington, D.C.: Climate Institute.

Newman, Edward and O.P. Richmond, eds. 2001. *The United Nations and Human Security*. Basingstoke–New York: Palgrave.

Pachauri, R.K. 2000. "Environmental Security: A Developing Country Perspective." Meeting report of the Wilson Center, Environmental Change and Security Project, Current Events, October 17, 2000. Available from: <http://ecsp.si.edu/archive/rk-pauchari.htm>.

Rakodi, Carole, ed. 1997. *The Urban Challenge in Africa. Growth and Management of its Large Cities*. Tokyo–New York–Paris: UN University Press.

Sestini, G. 1992. "Implications of Climatic Changes for the Nile Delta." In Lubomir Jeftic, J.D. Milliman, and G. Sestini, eds., *Climatic Change and the Mediterranean. Environmental and Societal Impacts of climate Change and Sea-level Rise in the Mediterranean Region*. London–New York–Melbourne–Auckland: Edward Arnold: 535–601.

Smith, Keith. 2001: *Environmental Hazards. Assessing Risk and Reducing Disaster*, 3rd ed. London–New York: Routledge.

UNCHS Habitat (United Nations Human Settlements Programme). 2001a: *Cities in a Globalising World. Global Report on Human Settlements 2001*. Nairobi: UNCHS.

UNCHS Habitat (United Nations Human Settlements Programme). 2001b. *The State of the World's Cities 2001*. Nairobi: UNCHS.

UNDP (United Nations Development Program). 1994. *United Nations Human Development Report, 1994*. New York: UN.

UNEP (United Nations Environment Program). 2002. *Global Environmental Outlook 3*. London-Sterling, V.A.: Earthscan: 270–296.

UNESCAP (United Nations Economic and Social Affairs Program). 2001. *World Population Prospects. The 2000 Revision. Highlights*. Population Division, Department of Economic and Social Affairs, UN Secretariat, New York.

UNESCAP (United Nations Economic and Social Affairs Program). 2002. *World Urbanization Prospects. The 2001 Revision. Data Tables and Highlights*. UN Population Division, Department of Economic and Social Affairs, UN Secretariat, New York.

UNHCR (United Nations High Commissioner for Refugees), IOM (International Organization for Migration) and RPG (Rassemblement du Peuple Guineen). 1996: *Environmentally-Induced Population Displacements and Environmental Impacts Resulting from Mass Migrations*. Geneva: IOM.

UN/ISDR (United Nations International Strategy for Disaster Reduction). 2001. *The Socio-Economic Consequences of the Earthquake at Izmit, Turkey 17 August 1999.* Geneva: ISDR.

UN/ISDR (United Nations International Strategy for Disaster Reduction). 2002. *Living with Risk. A Global Review of Disaster Reduction Initiatives.* Preliminary Version. Geneva: ISDR.

Wagner, Horst-Günter. 2001. *Mittelmeerraum. Geographie, Geschichte, Wirtschaft, Politik.* Darmstadt: Wissenschaftliche Buchgesellschaft.

Wight, Martin. 1991. *International Theory: The Three Traditions*. In Gabriele Wight and Brian Porter, eds. Leicester: Leicester University Press.

World Bank and European Investment Bank. 1990. [What is the publication title?]Washington, D.C.: World Bank; Luxembourg: European Investment Bank.

Yousry, Mahmoud and T. Atta. 1997. "The Challenge of urban growth in Cairo." In Carole Rakodi, ed., *The Urban Challenge in Africa. Growth and Management of its Large Cities.* Tokyo–New York–Paris: UN University Press.

Yousry, Mahmoud, T. Abu-Zekry, and A. Yousry. 1998. "Cairo as a world city: The Impact of Cairo's orientation towards globalization." In Fu-Chen Lo and Y. Yeung, eds., *Globalization and the World of Large Cities.* Tokyo–New York–Paris: UN University Press: 270–313.

Chapter 12

Urban Land Markets and Disasters: Floods in Argentina's Cities

Nora Clichevsky

This paper provides a preliminary presentation of experiences involving the relationship between urban land markets and flooding in Argentine cities within the wider framework of urban vulnerability to disasters such as flooding, landslides, and erosion. The analysis attempts to reveal hidden aspects of two key issues:

- The role played by the state as a land market regulator in urban areas with natural vulnerability to flooding; as a producer of urban land and housing; and as a builder of defenses against flooding.
- Impacts on the land market of flooding and built defenses, as well as access to urban land for different population sectors; land-value increases and decreases in urban areas according to flooding potential; and whether flooding conditions are masked.
- Impacts from the urban dynamics of population, productive activities, and the socio-occupational situations of inhabitants.

This is an exploratory study: therefore, the recommendations present methodological considerations for future work. The urban conglomerates of Santa Fe, Resistencia, and Buenos Aires, and the city of Chascomús were chosen for this study because they are affected by recurrent flooding. These areas have built a number of defenses with differential impacts, and each has its own urban dynamics.

Disasters and Urban Land Markets: A Little-Studied Relation

The localization of cities and the way in which they expand have brought about a series of environmental problems that arise from the relation between the natural environment and human populations. Even areas prone to flooding, vulnerable to erosion, and with scarce potable water are already occupied. Flooding is central to these interrelationships. It occurs due to natural events: a river overflows or there is intense rainfall in an environment not prepared to cope with it.

Urban environment as a particular expression of a relationship established at a given time and space between society and nature has traditionally been considered, in Latin America in general and in Argentina in particular, in a partial, sectoral, and inarticulate way, both in the academic world and in decisionmaking public organizations. This subdivision, evident in studies and policy instruments as well as in the institutional forms adopted by organizations dealing with urban-environmental issues, has defined this field as one of dispute more than of integration. In the few opportunities in which the intention was to treat these matters in an articulate manner, the proposals never went further than talk (Clichevsky 2001b).

If environmental and urban problems in general have hardly been dealt with, land market operations (with their submarkets, legal and illegal), occupation by poor urban population sectors with no access to submarkets, and "disasters" that are generally such due to a high number of affected people in urban centers, have been less so. Neither the impacts on land markets of the above-mentioned disasters, nor the improvements produced by structural and nonstructural measures and their impact on the market and sub-markets, have been studied.

The Competition for Urban Space

The ways in which a city is constructed are directly related to the operation of land markets, legal and illegal. These markets and the related socioeconomic changes of the last decades have resulted in forms of urban segregation, different from previous ones, that have led to more "ghettoized" cities. The land market is the place where private and public agents interact with different objectives in mind. These have changed during the last few decades and are affected by the stage in the land development process, such as production and commercialization. At present, the main agents are: land owners; the financial sector; developers (those who foresee business and propose it to land owners, financial firms, etc.); real estate firms (some of which are present from the beginning of the "business" up to its commercialization); building enterprises; professional teams; the state, acting at several levels; claimant users; and claimant speculators.

The formal or legal land market, divided into submarkets according to types of product, coexists with the informal or illegal market[1] and, with direct land occupation, constitutes different types of informal habitats.[2]

The illegal market comprises clandestine and irregular divisions of land into lots that have not been submitted to authorities for approval and, therefore, will never be legal unless special exceptions are later issued. Irregular lots[3] are those that do not comply with existing laws for production and commercialization[4] in force at the time of sale.

The direct occupation of public and private land generates "villas" (shanty towns) and settlements used as residential areas that are completely unplanned from an urban-environmental view. This often includes land: prone to flooding; without infrastructure; with inadequate access to employment centers, primary education and primary health care services; with ground water pollution and salinity; with proximity to clandestine garbage dumps and brick kilns; and with housing construction that does not meet existing regulations. Illegal settlements have also taken over public areas such as town squares.

The state hardly regulates the legal land market in the production stage,[5] and it is even less involved in the commercialization stage. It operates according to solvent supply and demand (according to profits expected by owners). It is imperfect, with monopolistic or oligopolistic characteristics according to the urban area; it is scarcely transparent;[6] it is related to the international real estate market that is also connected to the financial sector (Clichevsky 2001a); and it is conditioned by other markets such as housing, industry, commerce, and services, generating sub-markets according to the specific demands of urban activities.

The price of land is the deciding factor for a population's access to the portion of urban space where it (or its citizens) can settle: from a legal lot with all urban services to illegal lots with no services; direct occupations (shanty towns, settlements, squatters, and squatted equipment) and various categories of slums, hotels, and boarding houses. It is important to note that the price of land has little relation to the "production"[7] price plus the market's average profit. The price has more to do with rent and the extraordinary benefits that the various market agents are eager to obtain.[8]

Historically, most Argentine cities incorporated land under the logic of "production" using "skipped" subdivisions with the object of keeping interposed lots as a land value reserve[9] until lots further away were occupied. The assumption was that demand would increase and so would the value of the interposed lots. During the past decades, a particular sub-market arose for low-income population sectors, according to the type of land offered (size, services, and so forth), the price, and the availability of housing financing, although this has been disappearing (Clichevsky 2001a).

At the same time, the new economic processes that began during the 1990s brought new investment to the city through the construction of large residential and commercial equipment that covered more than 1,000 hectares. The residential sub-market changed at the same time that social polarization increased. The response was new "merchandise": luxury houses for high-income population sectors, country clubs, gated communities, and even "private cities."[10] These brought environmental territorial changes—even modifying topography due to the removal of large quantities of earth. As a result, new urban environmental problems arose: swamplands were blocked and natural drainage was affected, leading to a greater possibility of flooding than in the past.

There is competition among social population sectors for urban space. For example, if there is interest in investing capital in land that happens to be illegally occupied by a low-income population group, efforts will be made to evict these residents. The state may also want to sell land—possibly during an adjustment and reform period—favoring economic groups who wish to invest in the city rather than using that same land to meet the residential needs of lower-income population groups.

Vulnerability, Land Markets, and Flooding

Vulnerability is the propensity to suffer damage due to the presence of a given force or a potentially destructive energy. It is the inability to absorb through self-adjustment the effects of environmental change due to inflexibility or the inability to adapt to that change (Gómez 2001). Vulnerability is a multidimensional concept, generally associated with a condition (one is vulnerable to) and it includes exposure, sensibility, and resilience (capability to resist or recover). In the social sciences, vulnerability is used to indicate falling beneath the poverty line; and in environmental studies, it is used to indicate vulnerability to flooding, among other meanings.

The concept of vulnerability implies the acceptance of two fundamental matters: on the one hand, it establishes a dialectic relationship between the "outside," the elements that are external to the social group and may turn into risk because they are outside the exposed group's control, and the "inside," the group's cultural and socioeconomic characteristics (Clichevsky 2001b). There is a relationship between natural and social vulnerability. A city is more socially vulnerable because it is prone to flooding, has no services or equipment, no safety requirements (in relation to land market operations), and has a degraded environment. The relationship among the different scales is fundamental for the study of relations between the land market and flooding because both have specific macro, micro, and even neighborhood-level determinations.[11]

Flooding (as any other kind of "disaster") also affects the land market as a whole (even outside the city center) in each of its sub-markets, on a larger or smaller scale according to its dynamics and specific organization (i.e., participating agents who tend to be concentrated and local). A total paralysis may occur in all or some sub-markets, or there may be only a decrease for a specific period in the prices of more important property. The extent of risk, in this case for flooding, also depends upon public and private measures that have been adopted to minimize a disaster's negative impact. For example, "soft" credit will, in turn, lead to impacts on different population sectors demanding land.

Structural and nonstructural[12] measures taken to minimize flooding risk and the possibility of their implementation produce varying impacts on land prices that, in turn, produce impacts on different social population sectors. While some people may benefit, in this case, middle population sectors who can afford a lot in Colastiné, others, such as poor population sectors living in the same area who have been displaced and have to migrate, may be negatively impacted.

The Selected Argentine Urban Areas

Greater Santa Fe (GSF), including Santa Fe, Santo Tomé, San José de Rincón, Recreo, and Sauce Viejo, has a population of some 450,000, according to the 2001 census. GSF is located on the right bank of the Paraná River on a vast plain characterized by difficult water drainage and a corresponding formation of lakes, streams, and swamplands. It is, therefore, prone to recurrent flooding caused by overflow and rainfall due to a lack of adequate drainage.[13]

GSF's traditional economy is based on government services, a university, commerce, and private services, as well as port activities and a handful of food industries, including breweries. According to the October 2001 Permanent Household Survey (EPH), 22.8 percent of the GSF population was unemployed and 14.9 percent was underemployed. It is important to note that, in May 1992, only 9.5 percent was unemployed (INDEC 2001). Income concentration is also important. In 1991, the unmet basic needs (UBN) sector of the population was 16.5 percent. This varied from area to area. In the Guadalupe neighborhood, the number was only 4 percent, while in Alto Verde, the percentage of the population with unmet basic needs was 62 percent (similar to that of Colastiné). In 1980, the UBN population sector in San José del Rincón was 51.2 percent (INDEC 1982).

In the early 1990s, several policies against flooding were implemented in Rincón-Colastiné and other neighborhoods. Provisional defenses were built through the

Flooding Emergency Rehabilitation Program (Programa de Rehabilitación para la Emergencia de las Inundaciones – PREI)[14] and structural works financed by the Flooding Protection Program (Programa de Protección contra Inundaciones – PPI).[15]

Greater Resistencia (GR) comprises the municipalities of Resistencia, Barranqueras, Fontana, and Vilelas and has a population of nearly 360,000. The area includes the Río de la Plata Basin (Cuenca del Plata) and has historically been subject to flooding caused by Paraná River overflow. When the river overflows, its waters flow into the area via the Barranqueras stream and the Negro River. Intense rainfall also impacts flooding, as does the ways in which the territory is occupied.

Until 1920, the main economic activity was timber, later replaced by cotton until 1960, when the world cotton crisis affected the region. Following the 1982–83 floods, industries closed down and productive activities decreased; however, the population continued to increase. Most administrative, commercial, and service activities are concentrated in Resistencia. At present, there is serious economic stagnation and structural unemployment. In October 2001, 15.9 percent of the population was unemployed and 14.4 percent was underemployed (INDEC 2001). Income is strongly concentrated, with 20 percent of the population receiving 50 percent of the income, while the remaining 80 percent receive the other 50 percent. According to the 1991 census, UBN throughout the territory represents 22.7 percent of the population.

To protect this area from recurrent flooding, several defense plans were developed over the past decades. During the 1982–83 flooding, a plan that partially protected the urban area[16] was carried out since the 1983 floodwaters were 8.60 meters over flood level, the highest for the entire twentieth century.[17] After the 1992 floods, PREI constructed a series of defenses such as the Northern Defense (Defensa Norte) and related works; in 1997 when they were taken over by PPI.

Chascomús

Chascomús, in the Province of Buenos Aires, is located in the Lagunas Encadenadas System on the Salado River depression, integrated by the Adela, Chis-Chis, Vitel, Las Barrancas, El Burro, La Tablita, and Chascomús lakes. These waters interconnect by streams or are narrowly separated. They operate by quotas like a very slow river tributary to the Salado River, gathering local water surpluses and transferring them from lake to lake in a southwesterly direction.

Significant population growth has taken place since 1960 and, according to the 2001 census, there are 30,170 inhabitants. The main economic activity in the area is tourism, followed by commerce, administration and services mainly related to farming and cattle breeding, and industry, though factories have been closing. The population is mainly middle class and in 1991 UBN was only 10 percent.

Although Chascomús suffers from recurrent flooding, 2001 saw the most severe flooding in 90 years, reaching a contour elevation reading of + 9.36 IGM. In 2002, lake overflow caused by upstream rainfall in the lakes system caused flooding yet again. Although projects for defense works were prepared years ago, none have been implemented.

The Buenos Aires Metropolitan Area (AMBA) is the result of processes that have operated for more than 400 years, since the city's foundation and its expansion over provincial territory. According to the 2001 census, there are more than 13.8 million inhabitants, unevenly spread throughout a territory consisting of the City of Buenos Aires and 32 municipalities in the Province of Buenos Aires. AMBA is located on the Pampean plain, an area with little slope toward the Río de la Plata, and is cut through by the important Reconquista and Matanza-Riachuelo basins, the encased Maldonado, Medrano, White, Vega, and Cildañez streams, and several even more minor streams.

As Argentina's capital city, Buenos Aires hosts a concentration of all economic activities: industrial, commercial, financial, and administrative. Since the mid-1970s, AMBA as well as the rest of Argentina has gone through important socioeconomic and political changes that produced deindustrialization, unemployment, and impoverishment of its population. In October 2001 (last EPH data; INDEC 2001) unemployment reached 19 percent, while underemployment was 16.5 percent. It is important to note that, in October 1991, unemployment was only 5.3 percent and in 1980, 2.3 percent. Income distribution varies within AMBA and is related to poverty indicators. In 1991, UBN population sectors in the City of Buenos Aires represented 5.9 percent, while in some neighborhoods they were only 2.6 percent (CEPA-INDEC 1994). In the municipalities of Berazategui and Merlo, however, they reached 39.1 percent.

At present, floods due to rain and overflow are the result of urban activities in areas that have always been prone to flooding and of changes in the water system regime produced by land occupation. Flooding recurrence and its severity have increased during the last few years, affecting greater surface areas and people. From 1985 to March 1998, rainfall and sewage overflows caused 26 flooding events in the City of Buenos Aires (Herzer and Clichevsky 2001).

Considerations about the Processes Detected

The urban areas discussed account for multiple interrelations between space occupation, land markets, and flooding. Many of the interrelations are masked and others are not transparent. Urban-metropolitan area economic dynamics—a present and historically determined situation—and a population's socioeconomic situation will define the ways in which urban expansion takes over a natural environment. Urban expansion affects the organization of the land market and its relationship with the state, space occupation by different social population sectors, and vulnerability resulting from settlements on land prone to flooding.

Complex Relations between the State and the Real Market Sector

State policies toward land markets are subject to the influence the real estate sector, including landowners and developers, exerts on the state. This is evident in legal market regulations defined by urban planning organizations, and all forms of exceptions to them, as well as in the definition of "structural" measures in flooding defense programs. It permeates all state actions regarding land use and occupation and has direct implications on the impact that disasters produce by natural effects—in this particular case, flooding—on populations. It is therefore an aspect that must be considered in disaster-management programs.

The State and Real Estate Agents

Historically, land-market agents have felt that their rights were restricted when a state sector implemented stricter regulations on land subdivision, as in AMBA during the late 1940s. At present, they are against any legislation that might constrain their actions on areas prone to flooding. It is interesting to mention the case of Resistencia: the Real Estate Chamber has accused APA of issuing an "expropriating" regulation about land use compatible with natural aptitudes.

The Scarce Effectiveness of Public Policies on Land Market Regulation

Results have been scarce in relation to the quality of urban land that is produced and occupied as a consequence of the previous aspect and of the state's own objectives about the ways policies on the land market are elaborated, approved, and implemented.

The state as a land market regulator in conglomerates with natural vulnerability to flooding has acted in the same way in all of the areas discussed: in Buenos Aires it allowed divisions into lots in areas prone to flooding; in the city of Santa Fe, when a regulation was issued to stop divisions, these were ratified as exceptions. In Greater Resistencia, despite existing legal instruments, municipal authorities have not been able to comply with their role as land use regulators and instead have issued exceptions. The Resistencia City Council, the most important city in this conglomerate, constantly votes for exceptions to its own regulations if they hinder construction proposed by a firm or by a higher state body. Regardless, the exception is implicit (Clichevsky 1994).[18] The natural environment is the outstanding absentee in regulations issued by the municipalities' planning areas (or when municipalities are not autonomous from their respective provinces, as in the case of the Province of Buenos Aires). Legislation is issued on land division, use, and occupation as if it were a flat surface, with no geographical irregularities that might influence the conformation of urban areas.

Although cities were founded historically at higher elevations, later expansions did not take similar measures. There are even extreme situations, as in Resistencia, where the road network was designed over existing lakes and the Planning Code even induced landfills. Furthermore, regulations forbidding divisions into lots to avoid occupation of areas prone to flooding have come too late, as in the case of AMBA municipalities since the 1960s, because urban land prone to flooding had already been approved for division before the regulations came into force. Also, precautions taken regarding contour elevation levels have not been sufficient to contain great floods.[19] During the last few years, these municipalities have changed regulations so that new investments may be located in areas prone to flooding, with the consequent problems caused by changes in drainage, flooding previously safe areas.

Urban Planning Organizations Have a Poor Understanding of Nonstructural Measures in Flooding Prevention Programs

Even "nonstructural measures" designed to improve or minimize flooding risks are implemented by water services organizations (as is the case, for example, of the Provincial Water Administration in Chaco) and not by urban planning organizations. In the best case, these water service organizations support approved regulations. The elaboration of planning instruments—or changes in the existing ones—to consider new situations regarding flooding and defense works are in some cases—as in the Resistencia or Santa Fe conglomerates—either carried out by the organization in charge of programs against flooding, SUPCE Chaco, or jointly between those organizations and the conglomerate's municipal planning area, SUPCE Santa Fe and the capital city, because the other municipalities do not participate. In the case of Buenos Aires, neither the Director Plan for Hydraulic Regulation (Plan Director de Ordenamiento Hidráulico) nor the Environmental Urban Plan (Plan Urbano Ambiental), currently being considered by the legislature, have been jointly—or even partially—carried out. Changes introduced into the Planning Code in August 2000 have not considered the Director Plan, either. Moreover, nonstructural measures either cannot be implemented or can be only partially implemented in consolidated areas prone to flooding.

Absence of Metropolitan Management Organizations

The lack of metropolitan management organizations in the conglomerates under analysis interferes with the possibility of acting on land regulation from a comprehensive flooding-risk standpoint. This is evident in the case of Santa Fe, where the city defined flooding defense regulations for Colastiné and different regulations for the municipality of Rincón, though these areas are supposed to form an urban unit. A similar situation occurs in the City of Buenos Aires and AMBA municipalities located in the Province of Buenos Aires, where the main basins cross over several administrative jurisdictions.

The Role of the State as a Land and Housing Producer

The state as a land and housing producer has also demonstrated how little it is concerned with financing housing estates in areas prone to flooding, and it still sells land to its occupants through various regularization plans in those areas. This has happened in the Santa Fe, Resistencia, and Buenos Aires conglomerates.

Land Markets, Direct Occupation, and Risk

The *legal land market* has been able to operate with very few regulations. Since prices are defined by quality and other factors, areas prone to flooding are cheaper and can be purchased by lower-income population sectors. Those who have no access to the legal market resort to the *informal market* (with no control on land suitability) or *occupy public or private land* in the worst sectors, from an environmental point of view, those with a high flooding risk. This has happened in Buenos Aires, particularly the Matanza-Riachuelo and Reconquista basins; in Santa Fe, in Alto Verde and the western expansion area; in Resistencia, along the course of the Negro River; and in Chascomús, particularly in the Arroyo Los Toldos basin. This increased the exposure of more socially vulnerable populations to the dangers of flooding.

Although it is true that in Resistencia and Buenos Aires, middle population sectors have also settled in areas prone to flooding, the consequences are different because they are less vulnerable. For example, in Resistencia, people can evacuate to the homes of family and friends in higher neighborhoods. Poor population sectors must normally be evacuated to state or NGO shelters. Risks in terms of health care are also different for each social sector.

Land Prices, Flooding, and its Masking

Changes in Land Prices

Regarding land value decreases for areas prone to flooding, there is a difference in land destined for low-income population sectors (areas with other environmental deterioration components or unfit to become urban) and that destined for middle-income sectors or productive activities. Land on the Salado Basin, in Santa Fe, or on the Matanza-Riachuelo and Reconquista basins, in Buenos Aires, where a high percentage of UBN population sectors are located and where prices have always been relatively low, is different from land on the Vega or White streams in the city of Buenos Aires, where middle- and middle-high-income population sectors and commercial activities are located, even though the areas are prone to flooding. In these cases, the risk of flooding does not imply a decrease in land value.

As a hypothesis, we could state that land prone to flooding, located in areas with better access and historically valued by society (as the Buenos Aires North area), undergoes a smaller price decline than land in areas that are socially stigmatized[20] (as the Matanza-Riachuelo and Reconquista basins in Buenos Aires). This relates directly to whether flooding is or is not masked, as described further on.

A study on hedonic prices carried out on the Arroyo Maldonado basin, also in Buenos Aires, where impoverished middle-income sectors and some poor population sectors have settled, established that lots with two years of recurrent flooding only devaluated by approximately 30 percent. This may be due to the fact that this stream's area is at present an urban border between two zones and that middle-income population sectors prefer to settle in other city areas.

Flooding Masking according to Different Social Sectors

Flooding is masked by sectors involved in land markets, particularly owners and real estate agents. In Colastiné and Rincón, in the GSF, rain floods the area despite defenses because the lack of a sewage system is added to atypical climatic phenomena.[21] This situation was masked by real estate agents when lots for middle population sectors were divided. People bought land in this area believing that the defenses would prevent flooding. But defenses built against flooding from overflow do not improve the situation of floods caused by rainfall. This situation was not taken into account when the land was subdivided. People now feel that they have been cheated. The state is also responsible for this situation due to lax regulations, as in the case of Rincón, or to exceptions granted, as in the case of the City of Santa Fe.

Flooding processes are also masked in AMBA, particularly in some Buenos Aires neighborhoods inhabited by middle- and high-income population sectors and where economic activities—mainly commercial ones for middle sectors—are located. A good example of this situation is the case of the commercial and partly residential area of Belgrano on Avenida Cabildo, and, especially, in the residential area of Belgrano and Núñez, on Avenida del Libertador, periodically flooded by the Vega and White streams (Herzer 2001). The flooding situation is masked and property does not suffer land value decrease (except during the time when flooding is severe, though once that passes, prices rise to those found in areas that do not flood). This has been proven through surveys on the price of flats (since this area is completely occupied and there are practically no vacant lots) on Avenidas del Libertador, Monroe, and Cabildo, as well as on adjacent streets.

It is interesting to note the case of Chascomús, because its situation is different from those of the other cities in this study. Chascomús has no permanent defenses. The municipality builds them on an ad hoc basis with the help of neighbors and intermediate associations on the coastal avenue where a large number of commercial, mainly tourist, activities are located. The owners mask the existence of floods, withdrawing all defenses as soon as the water recedes, in order to avoid a negative image with tourists. Since part of the area's industrial activities have closed down, tourism is one of the fundamental activities in Chascomús. The real estate market has also denied that country clubs—some of them already built, others only in blueprint—are in flood-prone areas (although some of them do not as yet have proper authorization to be sold, they were offered and sold until the present economic crisis produced stagnation in this sector).

Resistencia seems to be the only conglomerate in this study where flooding is not masked. For example, during flooding periods, advertisements in all of the local papers (at least through 2001) used expressions such as "high" and "does not flood." This may have changed when the Northern Defense was finished in 2001, but it is hard to know for sure because of the short period of time that has elapsed and because of the economic crisis.

To summarize, middle- and high-income population sectors apparently mask flooding to avoid possible land and property value decreases. They also want to avoid a decrease in economic activities, especially in popular commercial zones like the Avenida Cabildo in the City of Buenos Aires or in Chascomús in heavy tourist areas. It is also true that after the flooding is over, activities return to normal, similar to areas not prone to flooding. We could state, therefore, that areas destined for middle- and high-income population sectors have a higher resilience. But, we must also bear in mind that urban processes are very complex—as are those that generate land prices—and it is therefore necessary to consider a large number of intervening factors, such as the already-mentioned ones of stigma or social value in historical terms, environmental aspects, accessibility, and state investment.

The State as Flood Defense Builder

The state as a builder of flood defenses has promoted a change in some conglomerates' expansion areas, for example, in Resistencia and Santa Fe. The Northern Defense in Resistencia leaves a vast portion of land inside the enclosure, and its occupation will take a long time, depending on the kind of urban regulations for land markets that will be implemented (at present there are none) and the urban dynamics that develop. But this vast enclosure raises some questions: Who benefits from lots that do not flood? What happens to the poor population sectors in Resistencia? What will happen to the vast area enclosed by the Northern Defense that has no urban use? Will the market react by dividing land into lots for that population sector? To date it has not, because in 2001, when the building of the Northern Defense was finished, poor population sectors were putting up settlements on land as their only chance to settle in the conglomerate.

This means that the question does not focus on the existence of land fit according to natural conditions, but to socioeconomic conditions: land market agents cannot produce lots for poor people because, according to regulations in force, they must build infrastructure works that cannot be afforded by certain large population sectors (especially during these last few years of recession and a high increase in unemployment rates). It seems, therefore, that the land value increase in the protected GR area (prices have gone up approximately fourfold since the defense was finished) benefits the original owners and agents who bought land expecting a land-value increase—in the long term, because of present day recession—after the construction of the defense.

In GSF, during an income concentration period when land was considered a lucrative business, the course of defenses in Colastiné-Rincón was "shifted" to increase the number of lots inside the enclosure. There was demand for weekend houses (even for permanent housing in an accessible location), as well as for individual lots and country clubs. Defenses were even built to include land prone to flooding that should have been left out. The land-value increase that resulted from the defense defined not only a change in land use, but also a change in the social sectors that might settle in the area. In Colastiné Norte, Bolivian horticulturists had to leave the area, and a gated community was built.[22] Poor population sectors are being evicted from Colastiné Sur, and they will probably be relocated on the western side of the city of Santa Fe, on land prone to flooding. The same is happening in the neighborhood of La Boca, in Buenos Aires, due to price increases produced by the construction of defenses to prevent flooding caused by southeastern winds ("sudestada") over the Río de la Plata in an area located next to the city center and with a high tourist value. The neighbors—mainly low-income population sectors—are forced by real estate investors to leave their dwellings (in many cases, slums). Although defenses were finished in 1998, the general economic crisis and that in the real estate sector in particular, which began a few years later and has become worse, has partly brought this process to a standstill (Herzer and others 2001).

Vacant Land and Flooded Populations: A Paradox

One of the paradoxes of this subject is the vacancy of a large amount of land suitable for residences and urban activities and the occupation of land prone to flooding.

This can only be explained by the operation of scarcely regulated land markets. In Resistencia, for example, 850 hectares are presented as vacant urbanized areas. If these were subdivided into conventional lots for individual dwellings, the approximate density would reach 100 inhabitants per hectare, with the possibility of settling 85,000 inhabitants. Considering an annual average growth rate of 1.64 percent, the city should limit all urban division extension projects. (Scornik 1998). In Santa Fe, there are also large extensions of vacant land, and in Chascomús some divisions have not yet been occupied. In AMBA there are enough vacant lots to settle people in areas that are safe from floods (1.5 million in 1997), but to achieve this, *the state must take part in the land market with new instruments*, and this requires political will (Clichevsky 2002).

Recommendations

The following recommendations arise from the considerations developed in this study:

- The relationship between land markets and environmental changes must be further explored (disasters such as flooding are part of them) because it is necessary to identify the bidirectional impacts produced by both dynamic processes.
- Present-day climatic changes must be considered because they imply unexpected and scarcely foreseeable impacts in most of the cities studied; also, the need to explore in depth the relationship between those changes and flooding; even more so when, in spite of advances made during the last few years, there is little information as to how some of the areas prone to flooding operate. It is, therefore, necessary to produce new studies to clarify these questions.
- Much is still unknown about the legal land market operation, its interrelations with the illegal market in each urban area, and the complex interrelations with other economic sectors, particularly financial ones, necessary for urban policy decisionmaking. An in-depth analysis is absolutely necessary, although it is known that there will always be a nontransparent area, practically impossible to unveil (for example, where does investment capital originate: from financial capital; narcotics; the weapons market?). Although every study is said to consider metropolitan areas or conglomerates involving more than one legal-administrative area, it is important to stress the need to establish a metropolitan authority to deal with urban space matters as a whole.
- It is essential, particularly at a moment of economic crisis and public adjustment, that the state retrieve, even partially, the land-value increase produced by its actions—through defense works and/or regulations—that are seized by the real estate sector's private agents. This may be implemented through the payment of a land-value increase tax, as is done in other Latin American countries such as Colombia.[23]

In-depth studies must also be carried out about the interrelation between land markets and flooding. For this, it is necessary to consider the time of the study: prior to the commencement of flood-protection programs; during their development; and afterwards; to obtain a wider point of view about the range of possible land-value increases or decreases (for example, through the implementation of nonstructural measures that restrict land uses).

Aspects to be Studied:

- In what type of urban area is the program located: growing or stagnant?
- What is the type of flooding: overflow, rainfall, wind? Recurrence, aggressiveness (a peak that passes), or permanency?
- How many people and which sectors does the program impact?
- What are the various state policies regarding land and housing?
- How is the local land market organized? What are its relations with the regional, national, and international ones (if any)? What are its relations with agents? What are the sub-markets, the type of demand, and its dynamics?
- What is the relationship between land markets and other economic sectors? Relationships with macroeconomic aspects? Is the real estate crisis linked to inflationary periods, to currency devaluation, etc.?
- What will the prices be before, during, and after the program's implementation (both of structural and non-structural measures)?

- What will be the impact of those prices (analyzed according to sub-markets) on different population sectors?
- What are the growth and economic dynamism scenarios for the conglomerate/city to be studied?
- What intervention instruments are proposed in land markets to strengthen flooding prevention; particularly, to implement measures for land markets so that the more vulnerable population sectors may improve their situation? If these are not included in the planning, society's more privileged sectors will again benefit, reproducing and even extending the vulnerability of already vulnerable social population sectors.

Notes

1. The legal and illegal markets are not dichotomous but complementary, even juxtaposed, and with scarcely defined limits. The agents acting in one or the other may be different, or partially or completely the same, according to the place and historical moment.

2. Illegality/informality imply two different means of transgression regarding ownership characteristics and urbanization processes. The former is based on a lack of property deeds (or rental contracts); the latter on non-fulfillment of building standards.

3. They could become legal if they were to comply with regulations over a fairly long period of time.

4. Illegal commercialization may be established also by the type of selling transaction (multiple sales of the same lot, for example). Also, rural land that cannot become urban because of its location has been sold as undivided plots. Cooperative property is built on lots that are smaller than the size established by law for land subdivision.

5. The production process includes the necessary steps that must be taken to turn rural land into urban land. According to state legislation in force in each urban area and at each historic moment, urban land may range from something that only has a subdivision plan with no services or infrastructure to something that has all urban services.

6. For example, it is difficult to know who the owners are because they use figureheads; the real price of transactions; the investments made to "urbanize" rural land. There is no transparency in information; private and state owned land cadastres are only partially updated, and some cities do not even carry registers.

7. The production price is the price paid for rural land plus all subdivision costs (surveying plans) and incorporation of infrastructure. According to legislation in force, it may range from merely the opening of streets to including potable water, sewerage, public and domiciliary lighting networks, and paving.

8. Starting with the original landowners; market operations become more complex with the incorporation of other actors, and the rent they produce benefits not only the owner, but also the developer, the promoter, etc. Agents try to obtain maximum benefits with minimum possible investment, and this defines the way in which they stand vis-a-vis the state: they obtain "favors" regarding compliance to regulations, or they urge, according to their own objectives, the urbanization of certain plots of land, or the granting of certain occupancy factors and uses in areas forbidden by regulations.

9. Obviously, this is not the only explanation for "skipped" subdivisions; they also depend on who the landowners are and on each landowner's logic (Clichevsky 1975).

10. Also, changes in the city's industrial, commercial, hotel, and private recreation sectors have meant a different demand on land.

11. The impact of different "natural disasters," such as landslides, hurricanes, and flooding, is also different according to the economic and social dynamics of the urban center being analyzed. The way in which disasters affect a city will be different than the impact on land markets, which will vary, depending on whether the affected areas are high-, middle-, or low-income residential areas (to simplify) or whether they are commercial or industrial ones. In this case, the use of the concept of social vulnerability is fundamental for the analysis of flooding impacts; the land market response to that impact produces, in turn, a chained impact.

12. The nonstructural measures constitute the environmentally positive actions par excellence, because they aim at maintaining the natural regime of bodies of water. But, it is still difficult to implement such measures (due to poor planning on the part of the planning specialists, and lack of institutional coordination), and this is particularly impossible in already occupied urban areas, where only structural measures can be adopted. The analyzed urban areas account for this situation.

13. The 1982–83 swelling presented, between December 1982 and August 1983, 5 successive peaks with a maximum of 7.33 m. in Puerto Santa Fe. Defenses in the neighborhoods of El Pozo and La Guardia were surpassed and the latter was completely flooded. Colastiné Norte was also flooded. The last important flooding before the present defenses were built occurred in 1992, reaching 7.43 m. during 2 months. These defenses endured the 1998 swelling, which reached 7.24 meters during 6 months.

14. PREI 3521 AR-BIRF. The components are defenses, sanitation, transport and energy, health and education, and housing, as well as technical assistance.

15. PPI 4117 AR-BIRF-JEXIM. It has structural measures components (defenses, drainage, adaptation of bridges), housing and shelters; nonstructural measures and regional environmental programs.
16. The GR Paraná River hydro risk frequency was the result of a statistical study of hydrometric registers in Puerto Corrientes since 1901and in Puerto Barranqueras since 1906 through 1984; it shows that, between 1904 and 1984, out of 30.347 readings taken at the Puerto Barranqueras hydrometer, the swelling was over 6 meters a total of 1264 times. In 970 occasions, the water level was between +6 and +7 meters; in 233 events, between +7 and +8 meters, and 61 times, over 8 meters.
17. After the 1982–83 floods, the Defense Plan approved in Resistencia intended to turn the city into a large enclosure, foreseeing a population growth of up to 500,000 inhabitants, but it was never carried out.
18. The same happened in the City of Buenos Aires, where more than 770 exceptions to the Planning Code were passed between the 1980s and 1991, even when they were forbidden by national law (Clichevsky 1996).
19. It is possible that the basin's regime and the recurrence periods were still unknown.
20. Because, historically, they suffer other environmental problems (proximity to garbage dumps, polluting industries, etc.).
21. Although there are 18 pumping stations in the enclosed area, problems arise because fewer than half of them are working, due to the fact that parts of the systems were stolen from several units.
22. The same happened in the AMBA, toward the end of the 1990s, where gated communities were to be built in land occupied by Bolivian horticulturists in the county of Escobar, although in this case, no defenses against flooding were built.
23. This matter has been discussed, as a possible idea only, by officials working on the subject in Resistencia. In the City of Buenos Aires, it figures in the Environmental Urban Plan Document that is, at present, being discussed at the legislature for its approval.

Bibliography

CEPA-INDEC (Comité Ejecutivo para el Estudio de la Pobreza en Argentina). 1993. "Hogares con necesidades básicas insatisfechas– (NBI) (1980–1991)." Documento de trabajo N.° 3, Buenos Aires.

CEPA-INDEC (Comité Ejecutivo para el Estudio de la Pobreza en Argentina). 1994. "Mapas de la Pobreza en la Argentina." Documento de trabajo n.° 4, Buenos Aires.

Clichevsky, Nora. 1975. El mercado de tierras en el área de expansión de Buenos Aires y su incidencia sobre los sectores populares (1943–1973). Centro de Estudios Urbanos y Regionales –(CEUR), Instituto Torcuato Di Tella (ITDT), Buenos Aires.

Clichevsky, Nora. 1994. "Mercado de tierra y problemas urbanos en ciudades intermedias: réplica del modelo de la gran ciudad? Los casos de La Rioja y Resistencia." Revista URBANA 14-15: 75–90.

Clichevsky, Nora. 1996. Política Social Urbana. Buenos Aires: Espacio Editora.

Clichevsky, Nora. 2001a. El sector inmobiliario en el Area Metropolitana de Buenos Aires. Su dinámica en los años noventa. Copy. Buenos Aires.

Clichevsky, Nora. 2001b. "Pobreza y Políticas Urbano-Ambientales en Argentina," Doc. De Trabajo, CEPAL.

Clichevsky, Nora, ed. 2002. Tierra vacante en ciudades latinoamericanas. Cambridge: Lincoln Institute of Land Policy.

Dirección de Estadística y Censos, Provincia de Chaco. 2002. Censo Nacional de Población, Hogares y Viviendas 2001, Unpublished.

Gómez, José J. 2001. "Vulnerabilidad y Medio Ambiente." Presented at the International Seminar Las Diferentes Expresiones de la Vulnerabilidad Social en América Latina y el Caribe, CEPAL, Santiago de Chile, June 20–21, 2001.

Halcrow Consultora. 2001. "Plan Director de Ordenamiento Hidráulico y control de inundaciones de la ciudad de Buenos Aires." Proyecto Ejecutivo para la Cuenca del Arroyo Maldonado. Préstamo BIRF N° 4117–AR. Tomo III, Capítulo 8.

Herzer, Hilda. 2001. "La participación de las organizaciones sociales." In Alcira Kreimer, David Kullock, and Juan Valdés, eds., Inundaciones en el Area metropolitana de Buenos Aires, Disaster Risk Management Series, N° 3. Washington, D.C.: The World Bank: 166–181.

Herzer, Hilda and Nora Clichevsky. 2001. "Perspectiva Histórica: las inundaciones en Buenos Aires." In Alcira Kreimer, David Kullock, and Juan Valdés, eds., Inundaciones en el Area metropolitana de Buenos Aires, Disaster Risk Management Series, N° 3. Washington, D.C.: The World Bank: 33–45.

Herzer, Hilda, Mercedes de Virgilio, Máximo Lanzetta, Adriana Redondo, and Carla Rodríguez. 2001. "La renovación de La Boca ¿Quiénes pierden?" Vivienda Popular 47, September.

INDEC (Instituto Nacional de Estadísticas y Censos). 1982. Censo Nacional de Población, Viviendas y Familias, 1980. Serie A, Resultados por Localidad, Buenos Aires.

INDEC.1991. Censo Nacional de Población y Vivienda 1991, Gran Buenos Aires Serie B No. 2.1, Buenos Aires.

INDEC. 1992. Censo Nacional de Población, Viviendas y Familias, 1991. Serie A No. 2, Resultados por Localidad, Buenos Aires.

INDEC. 1993. Censo Nacional de Población y Vivienda 1991, por Localidad Serie A No. 2, Buenos Aires.

INDEC. 1994. Censo Nacional Económico 1994. Resultados Provisorios, Buenos Aires.

INDEC. 1997. Encuesta Permanente de Hogares-EPH, Onda Octubre, Buenos Aires.

INDEC. 1998. Encuesta Permanente de Hogares-EPH, Onda Octubre, Buenos Aires.

INDEC. 2001. Encuesta Permanente de Hogares-EPH, Onda Octubre, Buenos Aires.

INDEC. 2001.[CK auth]Censo Nacional de Población, Viviendas y Familias, 2001, Provisional results.

IPEC (Instituto Provincial de Estadística y Censos). 2001. Informe Especial N° 100 Resultados Preliminares de la Encuesta Permanente de Hogares en el Aglomerado Santa Fe, Octubre de 2001, December 13. Gobierno de Santa Fe.

IPEC. 2002. Informe Especial N° 004, February 21, Gobierno de Santa Fe.

Pizarro, Roberto. 2001. La vulnerabilidad social y sus desafíos: una mirada desde América Latina, Santiago de Chile, CEPAL (LC/L,1490-P).

Plan Urbano Ambiental. 2000. Documento Final. Gobierno de la Ciudad de Buenos Aires, Secretaría de Planeamiento Urbano.

Scornik, Carlos. 1998. Diagnóstico Urbano Expeditivo del Área Metropolitana del Gran Resistencia (AMGR), PPI-SUPCE, Provincia de Chaco.

Community clean-up of Auxiliadora Church after Hurricane Mitch, Honduras, 1998.

Part III

Social Vulnerability to Disaster Impacts

Chapter 13

Disaster Risk Reduction in Megacities: Making the Most of Human and Social Capital

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New Research on Old Questions

This paper reports for the first time on the results of a comparative study of urban social vulnerability in four of the world's megacities—Mexico City, Los Angeles, Manila, and Tokyo. Two other cities—Mumbai and Johannesburg—were also included, but their results will be analyzed in a separate paper.[1]

The goal of the study was to elicit and compare from both municipal officials and representatives of civil society definitions of social vulnerability to disasters, sources of information about groups defined as vulnerable, and programs that reduce their vulnerability. The gap between municipality and civil society concerning the understanding of and approach to urban social vulnerability was the major focus of the study.

The main research findings document a paradox. Municipalities and civil society appear to have complementary strengths and weaknesses. Municipalities have the technical expertise and finances required to provide social protection from natural hazards for socially vulnerable groups of people and to assist in increasing the capacity of such people for self-protection. However, municipalities lack detailed knowledge of these vulnerable groups and do not enjoy their trust. The situation of NGOs and other civil society organizations is the opposite. They possess detailed knowledge of vulnerable groups and they have their trust. Rational action theory (RAT) would suggest that partnership would therefore be in the best interest of both municipalities and civil society. The paradox arises because the study revealed many obstacles to that ideal collaboration. Removing these obstacles and providing additional incentives for collaboration between municipalities and civil society should be a priority if the vulnerability to disasters of a growing number of people in cities is to be addressed.

Methods

In each study city interviews were conducted with citizen-based groups and municipal administrators at the level of the constituent "city" level (e.g., the 23 central "wards" of Tokyo, 18 "delegations" of Mexico City's federal district, and 26 municipalities of the State of Mexico into which the metropolitan region sprawls to the North, etc.). Descriptions of methodology are available in Uitto (1998), Velasquez and others (1999), Takahashi (forthcoming), Wisner (2003a). In addition to the published papers and unpublished conference papers by these team members cited below, the author has drawn from interim and final project reports.[2]

Background: The Growth and Hazardousness of Megacities

The second half of the 20th century witnessed the rapid growth of very large cities. There have been primate cities and metropolises for centuries. However, these new urban regions—"megacities" with more than 10 million inhabitants—are relatively recent. The average size of the world's largest 100 cities increased from 2.1 million in 1950 to 5.1 million in 1990. One-sixth of the world's population lived in cities with more than a million inhabitants in 1990. In that year there were 12 cities with more than 10 million people. Worldwide in 1990 there were also 33 cities with five million or more inhabitants and 281 so-called "million cities" (Satterthwaite 1998). In developing countries, cities with more than 1 million people jumped six-fold between 1950 and 1995. Worldwide in 2000, the number of cities larger than 5 million was estimated to be 41 (IDNDR 1996; U.N. 1999). The United Nations believes this number will rise to 59 by 2015, adding another 14 million people to the streets and homes in large cities (accounting for 21 percent of the world's urban growth) (U.N. 1999). In the same year, there were 19 cities with more than 10 million residents, a number believed likely to increase to 23 by 2015.

The megacity poses special challenges for disaster risk reduction for a number of reasons.[3] First, there is their sheer scale and geographic complexity. They sprawl over large areas, and this alone makes the day-to-day monitoring of hazards and vulnerability difficult and adequate provision and protection of lifeline infrastructure problematic. These urban regions have grown over and incorporated a variety of pre-existing villages and towns. Therefore, street patterns are complicated, and interconnectivity within the whole region is a physical challenge for the transport system. The megacity is made up of a number of municipal jurisdictions, so coordinated administration in normal times or emergencies cannot be assumed.

Second, there is the environmental impact, or "footprint," of such large urban regions (Girardet 1992; 2000). These cities require large amounts of energy, water, food, and other "inputs" and create large amounts of solid, liquid, and gaseous effluent and waste heat. Sometimes these characteristics of the urban ecology of megacities (and other large cities) contribute directly to the exacerbation of a natural hazard. An example is the 1995 heat wave in Chicago described in the "social anatomy" of this event authored by Kleinenberg (2002). Seven hundred and thirty-one people (mostly poor and elderly) died. Another example is the mass movement of a mountain of refuse, triggered by intense rainfall, that killed 705 people at the Payatas solid waste site in the northeast of Manila in 2000 (Westfall 2001).[4] However, such environmental aspects as the provisioning of megacities with water and fuel and the removal of waste more commonly have an indirect rather than a direct effect on disaster risk. In an earthquake or flood, these lifelines can be broken. Secondary hazards such as natural gas fires or spillage of hazardous waste can result. Provision of safe water and even food for survivors can also be made more difficult.

Third, many megacities are located in hazardous locations. These include coastal areas or river deltas, where storms and floods are common. Cities such as Manila, Mumbai, Caracas, and Havana are following a worldwide trend. Of the 14 cities with more than 10 million inhabitants in 1995, all but two have coastal locations and 17 of the largest 20 cities are located either on coasts or rivers (Mitchell 1999b: 29). The sprawling growth of some megacities has meant that some are subject to wild fires on their peripheries (Sydney, Los Angeles, Cape Town). Others are located in seismically active zones (Mexico City, Los Angeles, Istanbul, Tokyo) and sometimes near active volcanoes (Manila, Mexico City, Jakarta). Table 13.1 reviews the hazardous locations of several megacities.

Table 13.1 Megacities at Risk (UNU Study Cities in Italics)

City/ Conurbation	*Population 2000 (millions)*	*Hazards to which Exposed*
Tokyo	26	Earthquake, flood
Mexico City	18	Earthquake, flood, landslide
Los Angeles	13	Earthquake, flood, wild fire, drought
Lagos	13	Flood
São Paulo	18	Landslide, flood
Mumbai/Bombay	18	Flood, cyclone, earthquake
Shanghai	13	Flood, cyclone, earthquake
Calcutta	13	Cyclone, flood
Jakarta	11	Earthquake, volcano
Beijing	11	Earthquake, severe winter
Manila	11	Flood, cyclone
Johannesburg-Gauteng	8	Flood, tornado

Notes: "Population 2000": Population estimates for the six UNU project megacities refer to the "greater" metropolitan urban regions. The source is the *World Urbanization Prospects* (U.N. 1999). These numbers are gross estimates. As Mitchell notes (1995: 509), "It is impossible to be sure of the exact population of the world's largest cities. Among others: definitions of cities vary; municipality boundaries vary; the existence, frequency, and accuracy of urban censuses vary; and the rates of population change vary." "Johannesburg-Gauteng": The new 2001 South African census results are not available at the time of writing. The last firm estimate of the population of Gauteng Province (essentially identical with the greater Johannesburg or Pretoria-Witwatersrand-Vereeninging (PWV) urban industrial region was 7.4 million in 1996 (GPG 2001). Using the average African urban growth rate of 4.4 percent per year for 1950–2000 calculated by U.N. (1999: 4), one can estimate between 8–8.5 million in the year 2000, and a total population approaching 9 million in 2002. Since the end of apartheid in 1994, there has been a series of spatial-administrative reorganizations in and around South Africa's large cities, resulting in the case of greater Johannesburg of a consolidation of 51 municipalities into 15 (GPG 2002). Therefore, comparable data are difficult to obtain. Since the former PWV urban region (greater Johannesburg) already had 7.5 million inhabitants in 1990 (Wisner 1995: 337), use of the administrative area of Gauteng Province as a surrogate for the megacity may produce an underestimate. In short, it could well be that the greater Johannesburg megacity reached 10 million in 2002.
Source: Adapted from United Nations 1999.

Finally, megacities are highly diverse socially. In them live some of the richest and poorest people on earth. There is typically significant linguistic, ethnic, and religious diversity, and there is usually a population of recent immigrants, some foreign, and some undocumented or illegal. "Illegality" and "irregularity" also can extend to the nonimmigrant population, where extensive squatter settlements have grown (Fernandes and Varley 1998).

Social Capital and Urban Social Vulnerability Reduction

It is this last characteristic of the megacity, its social diversity, that presents both problem and opportunity. A four-year study (1997–2001) supported by the United Nations University revealed a rich mosaic of social networks, coping and support systems, and citizen-based initiatives in six megacities. However, this study also revealed that there was a large gap in understanding and approach to urban social vulnerability on the part of municipal officials and civil society groups. Often they carried out parallel or even conflicting risk-reduction activities. At the extreme there was sometimes animosity and distrust between them. Certainly in no case were the possible synergisms between civil society resources and those of the municipalities maximized. The study showed that municipalities had technical knowledge and financial resources that could benefit socially vulnerable groups of people, but they lacked detailed knowledge of these groups and were not trusted by them. By contrast, nongovernmental organizations (NGOs) and other institutions and groups within civil society knew a great deal more about these groups of vulnerables (e.g., the homeless, the frail elderly, street children, the disabled, those in squatter settlements) and had their trust, but lacked the technical and financial resources.

Cities need institutions of civil society to provide a "bridge" or "interface" between municipal administrations and the 600 million people (possibly closer to a billion) who live in unplanned, self-built, unserviced, and legally unrecognized settlements (Toepfer n.d; Lee 1994: 396).[5] The study discussed in this paper was an attempt to understand the obstacles in the way of improving that bridging function.

Before entering into the detailed results of this study, several key terms require definition. *Social capital* is a term that comes from the so-called "livelihood approach" in development studies and development policy (Sanderson 2000). It is used here in two ways. First, more conventionally, social capital refers to the access to resources and information that households have by virtue of their noneconomic social relations with other people. These may be based on kinship, friendship, common religious adherence, membership in cultural and sports clubs, shared hometowns, etc. Studies of the ways households cope with the stress of drought, flood, and other hazards have shown that socially mediated access and mutual aid play an important part in coping strategies and, in turn, the resilience of livelihood systems (Blaikie and others 1994: 67–68). This is true in urban as well as rural circumstances.

By extension, the term social capital is also used in a second way. To the extent that institutions of civil society such as NGOs and CBOs (citizen-based organizations) can provide a bridge between the formal agencies of disaster management in governments and urban dwellers, these institutions themselves form "social capital."

Despite some reservations, the term has been adopted as a shorthand for a wide variety of socially facilitated opportunities and capabilities (see below) for ease of communication with development policy experts. The phrase "social capital" has, indeed, been criticized as depoliticizing the essentially conflictual nature of development. Critics believe the term confuses the real differences in political and economic power in most societies between a minority elite who control the means of production and financial capital and the majority who may enjoy "other" capitals—"human," "social," etc. (Harriss 2001).

There are similar problems surrounding the use of the term *human capital*; however, again, for ease of communication with policymakers and for brevity, it refers to local knowledge of the built and natural environment and the skills, formally and informally acquired, that are collectively called *capacity* in disaster-management circles (see below).

Vulnerability is a term that occurs with a general meaning in livelihood literature and a more precise significance in disaster management. The more general meaning refers to susceptibility to harm or loss due to external shocks or stresses on the livelihood system (e.g., extreme price swings such as the current coffee price decline, political regime changes, extreme natural events such as drought or flood, seasonality, etc.). In this paper, and in the UNU study, a more precise definition was adopted. In words employed by the author and coauthors in 1994, "By 'vulnerability,' we mean the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard" (Blaikie and others 1994: 9).

The author understands and defines vulnerability as the absence or blockage of capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard. Others have juxtaposed vulnerability and capacity in this way (Anderson and Woodrow 1999; IFRC 1999). These capacities (in his work, Sen (1993) refers to them as "capabilities") include an array of skills, knowledge, and networks through which one gains access to information, knowledge, and material resources. In short, vulnerability/ capacity is a function of the livelihood system in its entirety, including social capital.

In this approach, vulnerability makes up one of three components of disaster risk. In addition to vulnerability, there are hazards (an event in nature) and mitigation (measures taken by households or collectivities to reduce the impact of the hazard).[6] These four essential elements of disaster management and prevention are related in a systematic way. **Risk (R)** is a function of the frequency and magnitude of natural events, often called **hazards (H)**, the **vulnerability (or capacity)** of people (V), and the ability of government agencies, other groups and institutions, or households to prevent or mitigate, and prepare for, hazard events (**M**, as the shorthand for all these activities, is usually "**mitigation**"). These relationships can be expressed schematically:

$$\mathbf{R = [H \times V] - M.}$$

A final term that needs defining is *civil society.* This term is used to signify all institutions and organized activities in society that are nongovernmental and outside direct control of the government, political parties, and businesses. Nongovernmental organizations and citizen-based organizations are part of civil society.

Megacity Profiles

Comparing four of the UNU study megacities gives an impression of the range of geographic and socioeconomic conditions in them. Table 13.2 summarizes some striking similarities among these four large urban regions. First is their size. They all fall squarely into the strictest definition of "megacity," with well over 10 million people in their metropolitan areas. They are all extensive, but Los Angeles far exceeds the others in sprawl, and has the lowest average density. The other three are densely populated, with Tokyo exceptionally so. Los Angeles is the youngest city region among them. The others are each twice as old, or nearly so, even dating Mexico City from the Spanish conquest and not from its Aztec origins (given in brackets).

All four urban regions contain considerable flood-prone flatlands, even though Mexico City is the only one without a coastal location. Three have over many years augmented their coasts with considerable landfill that shares with the drained lakebed under the historic center of Mexico City soil conditions subject to subsidence and liquefaction. In all cases, there are hills adjacent to or intermixed with these flatter parts. Therefore, despite their differences in climate, in all cases there are times in the year, or particular climate events, during which one can expect landslides.

Social Vulnerability: Perception and Policy Comparisons in Four Megacities

Despite these important similarities in the geography of hazardousness, the UNU study found different definitions or perceptions of who the highly vulnerable social groups are and what policies best address their needs.

Two-by-two comparisons of the megacities reveal both convergence and difference. Before overall patterns and their policy implications are discussed, two such sets of comparisons will be presented: Mexico City versus Los Angeles and Manila versus Tokyo.

Mexico City versus Los Angeles

In Mexico City, the more detailed breakdown by age, gender, and socioeconomic status was generally thought by officials in the Delegations of the Federal District (DF) and the Municipalities of the *Estado de Mexico* to be an academic luxury of a rich country (see table 13.3). While a small number of respondents acknowledged that some of these groups face additional risks and problems

Table 13.2 Comparison of four megacities

Characteristics	*Greater Los Angeles*	*Metro Manila*	*Greater Mexico City*	*Metro Tokyo*
Population	13	11	18	26
Size (000 km^2)	87	15	22	14
Density (pop/ km^2)	149	733	818	1,857
Age since foundation (years)	220	430	477 (666)	398
Situation	Coastal and inland valleys	Coastal peninsulas between bays	Inland valley on plateau	Coastal, running north and west into hills
Topography	Mix of flood plain, canyon, coastal cliff, and estuary	Coastal plain, river flood plain, hilly to East	Center over ancient lakebed, many ravines to North, West, and South, flatter to Northeast	Flat in much of ward (*Ku*) area, more relief in *Tama* area to West
Climate	Semi-arid	Tropical	Semi-arid	Temperate
Political and economic importance	Regional economic role, Pacific Rim and Latin America, Regional economic and political role in U.S.	Nationally primate and sub-regional economic role in Asia	Nationally primate in economic and political terms, regional economic role in the Americas	Nationally primate in economic and political terms, world an regional economic center
Percent poor	25	50	60	10
Percent in informal settlement or illegal migrant	5–10	30	40	2–3
Natural hazards	Earthquake, fire, flood, landslide	Earthquake, flood, landslide, typhoon	Earthquake, flood, landslide	Earthquake, flood, typhoon
Last major disasters	Northridge earthquake 1994; wildfires 1995	Payatas garbage dump flood, fire, and landslide 2000	Earthquake 1985	Earthquake and fire 1923

Sources: Manila and Tokyo: Fuchs and others (1994), Lo and Yeung (1996), Tayag (1999), Velasquez and others (1999); Tokyo: Takahashi (1998; 1999; 2003), Tokyo Metropolitan Government (1995); Manila: Tayag (1999); Mexico City: Gilbert (1994; 1996), Townsend (2000), Puente (1999a and 1999b), Eibenschutz and Puente (1992); Los Angeles: Wisner (1999a; 1999b; 2003a), Bolin and Stanford (1991; 1998); General: U.N. (1999).[7]

Table 13.3 Groups perceived by disaster management professionals to be highly vulnerable to disasters (Percent officials)

Mexico City	*Los Angeles*
Squatters (67 %), especially	Elderly persons (100 %)
Living in ravines	
Living over ancient mines	
Living near hazardous industries	
Children (23 %)	Disabled persons (93 %)
	Children (93 %)
Legal immigrants (16 %)	Persons with special medical needs (86 %)
Disabled persons (14 %)	Mentally ill (54 %)
Elderly (14 %)	Illegal immigrants (29 %)
Homeless (11 %)	Foreigners/ foreign-born (29 %)
Mentally ill (5 %)	Homeless (21 %)
Persons with special medical needs (5 %)	Street children (14 %)
Illegal street vendors (5 %)	People living near oil refineries (7 %)
Artisanal fireworks producers (5 %)	People living near water pumping stations (4 %)
Street children (2 %)	People living in mobile homes (4 %)

Notes: "Percent Officials": Percentage of 44 disaster-management officials interviewed in greater Mexico City and 28 interviewed in greater Los Angeles. "Legal immigrants": This includes people from the rural areas of the country where indigenous people live. "Foreigners/foreign-born": This was said to be mostly to do with lack of knowledge of English.

during disaster recovery, the consensus was different. Most believed that illegal or informal squatters, who most commonly live in ravines over ancient mines on some of the surrounding slopes, were generally vulnerable. They thought that everyone in such a living situation was vulnerable without finer distinctions. The exception to this concerned a more common belief that children needed special protection.

In greater Los Angeles, there was nearly universal acknowledgement of the special vulnerability faced by the elderly, disabled persons, children, and people with special, chronic medical needs (e.g., those on oxygen or ventilators at home or those in need of frequent dialysis). The mentally ill or disabled were also recognized in more than half of the interviews with disaster management officials in greater Los Angeles. A smaller group of municipalities believed that the legality of immigrant status, language ability of foreigners or the foreign born, and homelessness create situations in which people can suffer increased vulnerability to disaster.

Despite differences in the way that social vulnerability is defined and understood by municipal disaster managers, their approaches to planning and to the acquisition of information is similar. Table 13.4 summarizes these data.

Mexico City officials and their counterparts in greater Los Angeles try to involve neighborhood groups and NGOs in the planning process, but more try to do so in the Mexico City megacity (Carrasco and Garibay 2000). This difference is due in large part to the history of social and political organization in the two urban regions. In Mexico there is a long history of political party patronage and clientalism that manifests itself in the form of a variety of local associations and groups that rely on such support. There is also a tradition of opposition and protest in Mexico that gives rise to other groups that do not enjoy party political support.

It is striking, however, that despite claims of involvement of citizens in the planning process, few municipalities in greater Mexico City actually obtain information about socially vulnerable groups from neighborhood groups (where the fine-grained and detailed information exists).

At the level of the municipal jurisdiction, both sets of officials, in Mexico City and Los Angeles, claim a high degree of intersectoral cooperation. This turns out in practice to be a matter of legal formality—attending the same planning meetings, signing off on the same planning documents. However, more than half in both cases claim to obtain information about socially vulnerable groups from other departments in the same

Table 13.4 Knowledge of vulnerable groups and planning of programs to reduce vulnerability in Mexico City and Los Angeles
(Percent officials)

Mexico City	*Los Angeles*
Involve neighborhood groups in planning (71 %)	Involve neighborhood groups in planning (50 %)
Obtain information from neighborhood groups (9 %)	Obtain information from neighborhood groups (21 %)
Involve NGOs in planning (43 %)	Involve NGOs in planning (21 %)
Intersectoral coordination at municipal level (91 %)	Intersectoral coordination at municipal level (100 %)
Information from other government departments in municipal government (68 %)	Information from other government departments in municipal government (61 %)
Information from national agencies (30 %)	Information from national agencies (14 %)
Experience problems using social data (66 %)	Experience problems using social data (71 %)

Notes: "Involve neighborhood groups...": Many of these take the form of groups formed around someone who has taken the free 18-hour course called Citizen Emergency Response Training (CERT) made available to citizens. The inspiration for this kind of training came from the experience of spontaneous citizen action after the 1985 earthquake in Mexico City, where L.A. Fire Department Chief Frank Borden had gone as an observer. The course included fire suppression, light search and rescue, first aid, transportation of the injured, communication, and team leadership. "Involve NGOs in planning": One of the six municipalities that involves NGOs is the City of Los Angeles, where there is an active network of 70 NGOs with official status in the planning and emergency-response system called the Emergency Network Los Angeles (ENLA). There is a great contrast between a city like the City of Los Angeles and its relationship with NGOs through ENLA, and other, much smaller, municipalities that have no process for involving NGOs with the exception of the two national, quasi-governmental bodies, the American Red Cross and the Salvation Army. "Intersectoral coordination...": Universal claims of coordination are explained by the legal requirement in California to follow what is known as the Standard Emergency Management System (SEMS), which mandates plans and exercises that involve multiple sectors and mutual aid contingency arrangements among cities and counties. "Information from national agencies": This was most commonly information from the National Center for Disaster Prevention (CENAPRED) or the National Institute of Statistics, Geography, and Information (INEGI).

municipal government. This sharing of information takes coordination beyond mere formalism.

A most striking result was how few municipalities take advantage of the many publications and electronic information sources made available by their respective national government agencies. In part, this is due to a lack of financial resources and time by understaffed, small municipal offices. It is also a reflection of the background and lack of specific training in social sciences for those working on disaster management at the municipal level. In greater Mexico City, most have engineering backgrounds or come from the construction industry. In greater Los Angeles, they either have had careers in law enforcement or fire fighting. In neither case do managers find it easy to use social data.

These results provide support for the general finding mentioned earlier: municipalities generally have the technical resources to meet the needs of socially vulnerable groups, but they lack detailed information about them.

Social Capital and Civil Society in Mexico City and Los Angeles

The starting point of this research project was the hypothesis that civil society (NGOs and CBOs) can provide a vital link or bridge between highly vulnerable populations and municipal governments. In the ideal world, such groups would have information about and trust relationships with marginalized people who the city finds it difficult to understand or to approach. The UNU research partially supported the hypothesis. However, there are at least three factors that seem to limit the ability of civil society to function in this mediating, bridging manner.

The first limiting factor concerns the structure and function of NGOs themselves. Most NGOs have their own fairly narrow and well-defined agendas and areas of expertise and concern (Foreman 1998; Carrasco 2000; Benson and others 2001). In part this is a natural result of how NGOs are formed and remain funded. They carve out niches in the urban ecology. Focused concerns include housing, legal empowerment, women's rights, and sanitation. The problem observed is that such groups see disaster management and the process of vulnerability reduction through the prism of their established agenda. For example, in Los Angeles neither the Mothers of East L.A. nor the Community/Labor Strategy Committee—two NGOs with long histories of activism on air quality problems—concerned themselves with the fact that low income Blacks and Hispanics are more likely to live in flood-prone areas.

There were a few, predictable NGOs whose mandate specifically addresses aspects of risk communication or more general disaster management: these include the Red Cross in both cities, or Emergency Network Los Angeles (ENLA) and the Salvation Army in Los Angeles and CARITAS in Mexico City. Ironically, however, these NGOs have been so fully officialized and incorporated into the metropolitan systems of disaster management that they do not function as conduits to and from the poorest of the poor and other special-needs groups.

In a similar way, there are some specialized disaster-oriented CBOs, such as the neighborhoods in central Mexico City trained by the Association of Retired Fire Fighters[8] and those in Los Angeles that have had Citizen Emergency Response Training (CERT). These suffer from narrowness of mission and, in the case of Los Angeles, a definite class bias. Most of the roughly 20,000 CERT-trained individuals in the City of Los Angeles are white and middle-class. These groups are not oriented toward dialogue with marginal, socially vulnerable groups of people because their mission is defined as preparedness and response (not prevention and mitigation) and because of the socioeconomic class position of leaders and members of these groups.

The second limiting factor concerns politics. In a number of interviews, municipal officials indicated that they believed that NGOs involved themselves in relief and post-disaster recovery work to further their own political ends. They were not trusted and collaboration suffered. From the NGO side, there was as often a history of antagonism with the government. Mistrust from the NGO side could have deep roots and center around larger societal issues such as human rights and corruption—giving rise to such epochal changes as the electoral loss of Mexico City by the PRI political party. Mistrust could also be focused on feelings of neglect and social exclusion by the communities served by the NGO, as was the case of the Pico Union Cluster near downtown Los Angeles. This is a low-income residential district populated by Hispanic immigrants, especially from El Salvador and Guatemala, many of them undocumented. The housing stock comprises five- and six-story brick tenements and poorly maintained, subdivided wood-frame Victorians that date from an earlier, more affluent period in this districts' settlement history.

Because damage from the Northridge earthquake in 1994 was not expected as far from the epicenter as the Pico Union district, little official assistance arrived for several days, despite appeals by a consortium of 40 service NGOs called the Pico Union Westgate Cluster (PUWC). PUWC provided improvised shelter and food for the displaced. Later, antagonism continued to build as the Spanish-speaking field workers dispatched by FEMA turned out to be Puerto Rican and Miami Cuban, whose Spanish idiom, body language, and attitude toward the residents was considered disrespectful. Soon PUWC also found itself lobbying to call back city engineers whom residents believed had inadequately inspected some structures in the neighborhood, a problem of perception and communication exacerbated by the well-known reluctance of Central Americans to trust buildings that have suffered earthquake damage.

Four different kinds of trust (or lack thereof) are evident in these examples.[9] First, localities (neighborhoods) are often heterogeneous in their social composition: socioeconomically, ethnically, in terms of age ranges, stages of life, etc. This makes it difficult or impossible to treat localities in a unitary way as "communities" (Morrow 1999; Buckle and others 2000; Wisner 2003b). One cannot assume that individuals and households trust one another. Second, there is trust or a lack of it between institutions of civil society and formal institutions of governance. Moreover, it was observed that CBOs might trust one agency within the state apparatus but not another, one level of government (e.g., the local municipality) but not another (e.g., national). Third comes the issue of trust between individuals and households and organs of formal governance. In Los Angeles, undocumented immigrants and other marginal groups of people (e.g., homeless youth, squatters) avoid contact with officials because they fear deportation or eviction. Frequently, there are also linguistic and cultural barriers. In Mexico City there are similar obstacles to productive contact between government and such groups as street vendors, street children, squatters, and illegal immigrants from Central America and from the rural homelands of Mexico's many indigenous minorities. Fourth, the question of trust arises in the relations between groups of people and NGOs/CBOs. While it was generally found that specialized NGOs had reasonably frequent contact with their constituents (e.g., the frail; low-income elderly; the homeless; street children; street youth; undocumented immigrants; etc.), a relationship of trust cannot be assumed. This depends on the history and credentials of the NGO. For example, in parts of greater Los Angeles where the main citizen-based vehicle for disaster-risk management is the Neighborhood Watch—originally and primarily set up to prevent crime—youth gangs, a significant group of people, exclude themselves.

The third limiting factor concerns continuity and capacity building. In numerous cases, NGOs that had formed spontaneously in response to disasters such as the 1985 earthquake in Mexico City or the 1994 Northridge earthquake in Los Angeles did not persist beyond the early stages of recovery. If the whole point of developing a "culture of prevention" is to build networks at the neighborhood level capable of ongoing hazard assessment and mitigation at the micro level, preparedness training, and the identification of vulnerable individuals, then the organizational base is weakened or even lost each time "emergent" NGOs rise and fall in response to specific events.

There were some exceptions in Mexico City. A few organizations stand out for effective response to the 1985 earthquake and continuous efforts since then without becoming dependent on political parties. CARITAS was directly involved in providing temporary housing and medical attention, as well as longer-term housing reconstruction and employment generation. They acted as intermediary for housing grants, built 2,240 new houses, and bought 288 buildings and 1,308 plots of land for housing (Puente 1999a). They have stood by the families involved in post-earthquake recovery through a subsidiary organization formed for the purpose, *Apoyo a la Comunidad*. Hence, in this case, there is still the connection with the community and the potential for broader, continuous capacity building. CARITAS is unusual because of its independence from the system of political patronage in the city. This is because CARITAS is the local branch of a worldwide official Catholic charity. The political and economic independence of the Catholic Church in Mexico dates from the Mexican Revolution in the 1920s.

In a similar way, the Tenants' Association of the government housing complex at Tlatelolco had had a long history of activism before the 1985 earthquake, and a strong sense of shared identity. One respondent proudly noted that Tlatelolco was the location of the last stand of Aztec warriors against the Spanish in 1521. More recently, these center-city apartment dwellers witnessed the massacre of 400 university students by the Mexican army in 1968 in the Plaza of the Three Cultures. They protected many other students in their homes, and some of these bystanders were beaten by the army. Thus, after the 1985 temblor brought down one of Tlatelolco's 18 tower blocks, there was not only the usual outpouring of solidarity and mutual aid characteristic of *Chilangos* (citizens of Mexico City). Rather unusually, the tenants remained organized in order to fight government attempts to demolish the whole complex and re-house tenants on the outskirts of the urban region. Partly as the result of this successful struggle, the tenants' association has remained active in disaster-risk education and preparedness. They hold workshops on preparedness for the residents and have collaborated with the Civil Protection authorities of the Federal District in developing specific disaster plans. However, despite this collaboration with one arm of government, the Tlatelolco residents remain critical of others. For example, in 2001 they organized a successful campaign to stop plans by the Judicial Police to use a former community center building in the apartment complex as a holding prison. The tenants' association argued that this would put residents at risk.

Continuity was also a problem in Los Angeles. The premier NGO involved in building low-cost housing and brokering assistance from the government for low-income, ethnic minority people after the Northridge earthquake, *Mano a Mano*, was not able to maintain its funding base after the initial recovery period and was supplanted by the well-established NGO, Habitat for Humanity. Ironically, *Mano a Mano* had acted as "cultural broker" and go-between for Habitat in relations with Spanish-speaking people during the emergency (Bolin and Stanford 1998).

Manila versus Tokyo

The contrast between Manila and Tokyo is similar to that between Mexico City and Los Angeles, only more extreme. Residents of urban informal settlements in Manila were regarded by the majority of the officials interviewed (87 percent) to be the social group at highest risk (67 percent shared this view in Mexico City). The elderly and disabled were universally seen as the groups in Tokyo who are most vulnerable. Indeed, a highly nuanced typology of the vulnerable elderly emerged from interviews there in the 23 central wards.

These differences may well mirror the macroeconomic conditions prevailing in the two cities. As in Mexico City, national patterns of poverty give rise to migration to informal settlements in the countries' major economic centers. The resulting urban marginality creates a population of homeless children and youth. These were the second most commonly mentioned in Manila.

Reflecting its role as a destination for many legal foreigners with little knowledge of Japanese, such people were considered potentially at risk by 70 percent of disaster planners in Tokyo. This has more to do with Tokyo's role as a global business and financial center and less to do with illegal working-class immigration, although there are some of the latter who arrive from mainland China, the Philippines, and North Korea. Table 13.5 presents these data.

Despite very large economic and political differences between Manila and Tokyo, there is a similar approach to knowledge of disaster vulnerability and planning. Indeed, all four megacities show the same pattern. All four attempt to involve neighborhood groups in planning. All four also claim high degrees of intersectoral coordination and connections with other jurisdictions within the megacities. However, none of the four cities is particularly good at involving nongovernmental organizations in planning. Finally, disaster planners in all four cities had difficulties using social data.

However, there are important differences within these generally similar patterns. Manila and Mexico were better at the municipal level in acquiring information about vulnerable groups of people from neighborhood groups (65 percent and 57 percent of municipal level respondents saying they did). In Los Angeles, only one in five planners could count on this source of information, and a mere 9 percent in Mexico City.

Another commonality between Manila and Tokyo is the existence of legally established, strong, and well-financed metropolitan government structures that

Table 13.5 Groups perceived by disaster management professionals to be highly vulnerable to disasters (Percent officials)

Metro Manila	*Central Tokyo*
Squatters (87 %)	Elderly persons (100 %) Bed-ridden elderly (61 %) Elderly living alone (48 %) Elderly in general (26 %) Demented elderly (13 %)
Street children (71 %)	Disabled persons (100 %)
Elderly (13 %)	Legal foreigners (70 %)
Disabled persons (7 %)	Infants (39 %)
Young children (7 %)	Persons with special medical needs (35 %)
Others (3 %)	

Note: Percentage of 31 disaster-management officials interviewed in metro Manila (action officers responsible for disaster planning in the 16 administrative subunits of metro Manila plus 5 at primary district (*barangay*) level, and 10 in a variety of government commissions; and 23 disaster-management officials in the 23 central wards in the case of Tokyo. "Street children": However, these respondents believed that they were not responsible for dealing with the vulnerability of street children, as their welfare falls under the Department of Social Welfare and Development. Five officials believed that street children are too mobile and transient to be the responsibility of any municipal jurisdiction. "Disabled persons": In the case of Tokyo, this included both physical and mental disability. "Legal foreigners": Officials mentioned only legal non-Japanese residents, who may have difficulty understanding Japanese language warnings and instructions. While the growing presence of illegal immigrants, especially among those doing casual labor, was recognized, no official believed that they were a group of vulnerable people for whom special disaster planning should be done. Likewise, the homeless in Tokyo subway stations, in parks, and along the Sumida River were acknowledged to exist, but they "did not count" for planning purposes. See Wisner (1998). "Others": There were single mentions among the 31 officials (3 percent) of orphans, students living in boarding houses, women (battered, pregnant, or lactating), mentally disabled (due to drug use), persons in flood-prone areas.

embrace a large portion of the megacity. In Mexico City and Los Angeles there are no overarching metropolitan coordinating structures. The existence of metropolitan-wide institutions explains the high degree of intersectoral and inter-city coordination claimed by respondents. Coordination was only diminished in the case of Tokyo by a countervailing process—the strict interpretation of privacy laws that prevents one department's sharing of social data with another, even at the level of a single ward.

Finally, municipalities in both Manila and Tokyo used information made available by national-level institutions such as the Philippines' Presidential Commission on Urban Poverty and Japan's National Land Agency. No similar widespread utilization of nationally generated information takes place in Mexico City (ironically, since the National Center for Disaster Preparedness—CENAPRED—is located in Mexico City). Table 13.6 presents the data on sources of knowledge and planning in Manila and Tokyo.

Social Capital and Civil Society in Manila and Tokyo

In all four cities, civil society has a double history as both critic and opponent of government and its partner (Heijmans and Victoria 2001). In Manila this was seen dramatically in the use of what was called "people's power" to remove nonviolently both Presidents Marcos and Estrada. Less dramatic, day-to-day manifestations of this same tension exist in the work of the legal aid network in Manila that provides support for squatters. Recently they represented a group of fishermen and their families threatened by eviction from riverside homes in Malabon (part of Manila), where large-scale channel modifications were scheduled in aid of flood control. Legal aid volunteers also represented the survivors of the Payatas garbage dump disaster mentioned earlier. On the other hand, Manila also has a dense network of non-profits and citizen-based organizations that work in partnership with municipal governments. In contrast to the conflictual relocations of people with river and ocean-based livelihoods in the municipality of Malabon, its counterpart municipality, Marikina, was able to achieve a negotiated relocation away from the flood plain with the financial assistance of the Philippine Commission on the Urban Poor (PCUP) (Tayag 1999).

As noted above, 11 (65 percent) of the 17 Disaster Action Officers interviewed in metro Manila acknowledged assistance from neighborhood associations and NGOs in disaster management. However, as observed in Mexico City and Los Angeles, most of this involvement focuses on response and recovery (help with communications, transport, evacuation, rescue, provision of house repair grants and loans) and does not address vulnerability as such.

Tokyo has a highly developed social infrastructure of citizens' organizations at the neighborhood level that serve various functions such as firefighting, first aid, hazard mitigation, and education about earthquakes. The volunteer fire corps (*shobodan*) dates from 1718.

Table 13.6 Knowledge of vulnerable groups and planning of programs to reduce vulnerability (Percent officials)

Metro Manila	*Central Tokyo*
Involve neighborhood groups in planning (73 %)	Involve neighborhood groups in planning (100 %)
Obtain information from neighborhood groups (65 %)	Obtain information from neighborhood groups (57 %)
Involve NGOs in planning (18 %)	Involve NGOs in planning (22 %)
Intersectoral coordination at municipal level (100 %)	Intersectoral coordination at municipal level (100 %)
Obtain information from other departments in municipal government (100 %)	Obtain information from other departments in municipal government (13 %)
Obtain information from national agencies (100 %)	Obtain information from national agencies (100 %)
Experience problems using social data (71 %)	Experience problems using social data (100 %)

Notes: "Involve neighborhood groups in planning" (Manila). The 1992 Local Government Code specifies that local citizen groups must be represented in special bodies such as health boards, but not all municipalities have managed to involve neighborhoods in disaster planning. "Involve neighborhood groups in planning" (Tokyo): There is a centuries-long tradition of urban neighborhood groups based on ceremonial functions and other more practical activities such as fire fighting. Tokyo's neighborhood fire brigades date back to the 18th century. However, many groups are merely formal and not active. Fifty-seven per cent of officials expressed concern about the level of participation of citizens at the neighborhood level, and 83 percent characterized their ward's neighborhood groups as "formal." Only four wards (17 percent) said they had very active neighborhood groups. "Involve NGOs in planning" (Manila): Excluding the Philippine National Red Cross, which is present and active in all municipalities and treated as part of government for planning purposes. "Involve NGOs in planning" (Tokyo): The Japanese Red Cross was referred to in eight wards (35 percent), and *Shakai Fukushi Kyougikai*, an umbrella organization to coordinate social welfare organizations dealing with visual impairment, physical disabilities, and mental retardation in seven wards. However, only five wards claimed to have active involvement of NGOs in their plans. "Intersectoral coordination…" (Manila): Via the Metropolitan Manila Development Authority and its Metro Manila Disaster Coordinating Council. "Intersectoral coordination…" (Tokyo): Via the Tokyo Metropolitan Council. "Obtain information from other departments…" (Tokyo): Strict interpretation of privacy laws in all but three wards meant that there was very little sharing of information about vulnerable groups of people from one department (e.g., that dealing with the elderly, for example, or the disabled) and the department of disaster planning. "Obtain information from national agencies" (Manila): Particularly the Presidential Commission on Urban Poverty and the Department of Social Welfare and Development. "Obtain information from national agencies" (Tokyo): The Tokyo Metropolitan Council provides many maps and planning materials, as does the National Land Agency.

Local groups that work to identify and mitigate hazards in their neighborhoods (*machizukuri kyo gikai*) are said to have numbered 56,000 in 1991, covering 37 percent of all households (Kaji 1991: 222). Likewise, the Japanese Red Cross strongly advocates the importance of local knowledge in disaster management (Higashiura 1994). Indeed, the Tokyo Metropolitan Government (TMG) officially advocates "Reinforcing citizens' disaster prevention groups" and "[e]nsuring the safety of especially vulnerable citizens" (TMG 1995: 78). However, despite the existence of this social capital, in practice, the UNU study found that neighborhood groups find it hard to recruit young people, and their activities are narrow and formalistic. As noted earlier concerning CERT-trained neighborhood groups in Los Angeles and the formal outreach by Civil Protection authorities in Mexico City's Federal District, there is a middle-class bias also in Tokyo that excludes the homeless, mentally ill, and illegal immigrants.

Volunteerism has increased rapidly since tens of thousands of young people converged on Kobe after the earthquake there in 1995. However, this spontaneous activism has not yet been channeled into the revitalization of moribund neighborhood groups. Nor is there crossover to concern with urban social vulnerability to disasters from the environmental activism in greater Tokyo that has seen years of protest over the expansion of Narita airport or chemical and radioactive hazards.

The problem of formalism also affects metro Manila. Since 1992, the Local Government Code has required the NGOs be represented in local health boards and other specialized bodies in the 17 administrative jurisdictions that make up the megacity. However, by the time of the UNU study, this requirement had been implemented in only four of metro Manila's constituent cities. Nevertheless, some good practice does exist as a basis for further progress. For example, in the city of Muntinlupa, in the extreme south of the megacity region, there is an arrangement similar to the relationship of NGOs to the City of Los Angeles Division of Emergency Preparedness. In the Muntinlupa case, several emergency response NGOs[10] are integrated into local government plans although they are do not sit on the local government council (Tayag 1999).

General Conclusions about Social Capital and Urban Disaster-Risk Reduction

Urbanization since 1950 can be understood as a necessary result of a succession of development models adopted by policy makers. So, too, the growing social abyss between rich and poor in these cities and between those labeled "illegal" and their "legal" neighbors has resulted from development policies. As a result, social and human capital are grossly underutilized in disaster-risk reduction activities. Ignorance and mistrust blocks the emergence of the "hybrid" management of risk that would merge the science, technology, and engineering available to municipalities with local knowledge and coping practice and social networks available among "illegal" urban dwellers and in squatter settlements.

In the words of Dr. Suvit Yodmani, Executive Director of the Asian Disaster Preparedness Center in Bangkok (Yodmani 2001):

> A paradigm shift in the development sector from income poverty to human poverty has been paralleled in the disaster management sector by a shift from seeing disasters as extreme events created by natural forces, to viewing them as manifestations of unresolved development problems.

One such "unresolved development problem" is the lack of articulation and integration of the social institutions of civil society with those of national and subnational, formal governance. This is not a simple "technical" problem of decentralization, but a deeper problem of trust. It involves issues of accountability and representation, and, ultimately, the question of legitimation of the state.

If the municipalities in this study of four megacities are at all typical, then urban social vulnerability remains a serious problem as yet insufficiently faced by municipal, metropolitan, or other higher orders of government. Among the specific problems documented are:

- Fragmented and uncoordinated responsibility for different at-risk groups
- Legal barriers to access to social data
- Staffing shortages and lack of training in the use of available social data, resulting in little use of existing sources
- Limited or sometimes no planning at the municipal level for longer-term recovery issues
- Limited or ritualistic use of community or neighborhood groups
- Political hostility toward NGOs
- Funding shortages and high turnover in NGO staff.

The last three of these problems are very common and block the effective use of social capital to reduce risk. Socially vulnerable and marginal groups in cities have needs but also capacities. Their local knowledge and coping as well as their needs can be communicated to government agencies through NGOs and CBOs. City agencies have systems of risk reduction that may benefit socially vulnerable groups. Here again, it is the bridge, mediation, or interface[11] provided by organs of civil society that can provide access to official risk reduction. The exponential growth of CBOs and NGOs during the decades of the 1980s and 1990s has expanded the basis—with all the pros, cons, and difficulties mentioned earlier—for much deeper and systematic relations between cities and civil society.

Viewed from this more optimistic perspective, the UNU study revealed at least in a few of the constituent cities of the four megacity regions the following:

- Innovative use of existing neighborhood groups for preparedness or even for hazard and vulnerability mapping
- Some cases of excellent coordination between municipalities and NGOs
- Improvements in risk communication and increased sensitivity on the part of some municipalities to the needs of foreigners, both legal and illegal.

The main conclusion, therefore, is that the social basis for disaster-resilient cities must be continued capacity building across the whole of these heterogeneous populations (Eade 1997; Plummer 1999). Revitalized democratic participation in the governance of cities, better education systems, employment generation, broader inclusion of women, minorities, and youth all contribute to this (Gilbert and others 1996; Freire and Stren 2001).

Notes

1. The present paper utilizes the data from only four of the six study cities. This is for three reasons. First, the pair-wise comparisons of Tokyo/ Manila and Los Angeles/ Mexico City provide sufficient insight into the common results and differences encountered. Second, since the main surveys were conducted

in all six cities (1999–2000) there have been significant new events that have radically altered the relations among municipalities and civil society in Johannesburg and Mumbai. These new conditions cannot be addressed in the space I have been allocated and deserve separate, extensive treatment. In the case of Johannesburg there has been a reorganization of the administrative structure of the city as part of the dismantling of the system of apartheid in South Africa (see: Beall and others 2002; Bond 2000; Wisner 1995). In addition, there have been several urban upgrading initiatives in parts of greater Johannesburg as the result of the visibility anticipated by authorities with 60,000 delegates due to arrive for the World Summit on Sustainable Development (August–September 2002) (see Bond forthcoming; Alexandra Renewal Project 2002; World Bank 2001; Greater Johannesburg Metropolitan Council 2000). "Upgrading" has in some cases involved forced evictions that may be seriously affecting relationships between civil society organizations and the municipal state (Magardie 2002; AFROL 2001). In the case of Mumbai, the reaction to the devastating earthquake to the North in Gujarat (2001) stimulated the creation of an ambitious multi-sectoral disaster preparedness plan and the realignment of relationships among municipal government, business, and civil society around it (see Rowell 2002; Sinha 2001). Thirdly, the additional complexities in Johannesburg and Mumbai require further detailed follow-up, which is under way, in order to understand how recent dramatic events in both cases may have modified the patterns of municipal state-civil society relations shown in data collected earlier (1999–2000).

2. The author would like to acknowledge the efforts of the team involved in the United Nations University research project coordinated during 1997–2001. The team comprised: G. Berger (video documentary consultant), R. Bolin (Los Angeles consultant), M. Luna (Manila consultant), W. Pick (Johannesburg coordinator), S. Puente (Mexico City coordinator), S. Takahashi (Tokyo coordinator and Los Angeles consultant), J. Tayag (Manila coordinator), J. Uitto (UNU academic officer in charge, 1997–1999), J. Velasquez (UNU academic officer in charge, 2000–2001), and B. Wisner (overall project coordinator and Los Angeles coordinator).

3. On disaster risk in cities, see Hardoy and Satterthwaite (1989), Hardoy and others (1990), Hardoy and others (1992), Mustow (1995), IDNDR (1996), Mitchell (1999a), Mansilla (2001).

4. Two hundred and five bodies were recovered, and 500 were missing and presumed dead (Westfall 2001).

5. Among these are those who are potentially the beneficiaries of implementation of the Millennium Target 11, "to achieve a significant improvement in the lives of at least 100 million slum dwellers by the year 2020" (UNDP 2002). Reducing vulnerability to volcanic eruption and lahar flow, earthquake, flood, storm, and landslide can be done in ways that also increase livelihood options and resilience among such people. The converse is also true. All efforts to implement this Millennium Target can be wiped away in an extreme natural event, as has occurred recently in the case of hurricane Mitch (1998), flood and landslides in greater Caracas (1999), earthquakes in Gujarat, India and El Salvador (2001), landslide in Algiers (2001), and volcanic eruption that destroyed much of Goma, Congo (a city of 500,000 people) in 2001.

6. Mitigation is sometimes also referred to as a combination of personal and social protection (Cannon 2000; Wisner and others 2003).

7. "Age since Foundation": All the megacities were predated by small settlements, some occupied for a long and undetermined period. In the case of Mexico City, two ages are given. The first uses the date of the establishment of the Aztec settlement of Tenochtitlan (1325 or 1345). The second uses the date of the defeat of the Aztecs by Cortez (1524). The banks of the Pasig River in present-day Manila were inhabited long before the Spanish colonial period, but the age provided uses the date of Spanish control of Manila (1571). "Percent Poor": Percent below locally defined poverty line. Clearly, one is dealing with relative and not absolute poverty in these comparisons; however, in all cases among the "poor," there is little or no surplus for financial investments in self-protection because of the relative expense of food, shelter, utilities, and transport. "Percent Informal Settlement or Illegal Immigrants": There is little squatter or informal settlement in greater Los Angeles or greater Tokyo except for some semipermanent encampments of homeless individuals and the illegal use of condemned buildings ("squats"). In areal extent and numbers of inhabitants, these are not at all comparable to the large informal settlements in greater Mexico City and greater Manila. However, when one considers the numbers of illegal or undocumented persons in the urban population, a different but related percentage can be estimated for Los Angeles and Tokyo. The commonality between the two measures is "illegality" and the challenge for risk reduction that that produces. "Last Major Disaster": The fire bombing of Tokyo during the Second World War is not included, although more recent than the 1923 earthquake and fire, because it was not triggered by an extreme natural event. While the catastrophic mass movement of solid waste, and subsequent fire, that buried homes and people at Payatas, Manila, is partly the failure of a human artifact (a solid waste dump site), the trigger was heavy rainfall.

8. This *Associacion de Bomberos en Retiro* was unknown to municipal authorities, and was unregistered as an NGO, prima facie evidence that it was not the product of client-patron politics so often encountered among nominally independent NGOs in Mexico City.

9. In the literature on environmental risks and technological hazards, the concepts of trust and credibility have received much attention (Douglas and Wildavsky 1982; Brown 1987; Wynne 1987; Slovic 1993; Bujra 2000; Slovic 2000; Barnes 2002). Treatment of trust in this literature extends to discussions of it philosophical roots and implications for social theory (e.g., Beck 1992; Beck and others 1994; Giddens 1992). Unfortunately, there has not been a parallel exploration of these concepts in the context of the study of natural hazards (with Kasperson and Pijawka (1985) as one of the rare exceptions).

10. These NGOs are: *Brigada LAKAS*, *Lakas ng Kababaihan*, *Kabalikat Civiscom*.

11. The term "interface" was used in this context by Rowell (2002).

Bibliography

AFROL 2001. "Moving Alexandra Squatters Good for Environment." Available from <http://www.afrol.com/News2001/sa008_alex_environ.htm>.

Alexandra Renewal Project. 2002. Available from <http://www.alexandra.co.za/>.

Anderson, M. and P. Woodrow. 1999. *Rising from the Ashes: Development Strategies in Times of Disaster.* London: IT Publications.

Barnes, P. 2002. "Approaches to Community Safety: Risk Perception and Social Meaning," *Australian Journal of Emergency Management* 17 (1): 15–23.

Beall, J., O. Crankshaw, and S. Parnell. 2002. *Uniting a Divided City: Governance and Social Exclusion in Johannesburg*. London: Earthscan.

Beck, U. 1992. *Risk Society: Towards a New Modernity*. Trans. M. Ritter. London: Sage.

Beck, U., A. Giddens, and S. Lash. 1994. *Reflexive Modernization: Politics, Tradition and Aesthetics in the Modern Social Order*. Cambridge: Polity.

Benson, C., J. Twigg, and M. Myers. 2001. "NGO Initiatives in Risk Reduction: An Overview." *Disasters* 25 (3): 199–215.

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

Bolin, R. and L. Stanford. 1991. "Shelter, Housing and Recovery: A Comparison of U.S. Disasters." *Disasters* 15 (1): 24–34.

Bolin, R. with L. Stanford. 1998. *The Northridge Earthquake: Vulnerability and Disaster*. London: Routledge.

Bond, P. 2000. *Cities of Gold, Townships of Coal*. Trenton, NJ: Africa World Press.

Bond, P. Forthcoming. *Sustainable South Africa? Environment, Development and the Post-Apartheid State* (provisional title).

Brown, P. 1987. "Popular Epidemiology: Community Response to Toxic Waste-Induced Disease in Woburn, Massachusetts," *Science, Technology, and Human Values* 12 (3 and 4): 78–85.

Buckle, P., G. Marsh, and S. Smale. 2000. "New Approaches to Assessing Vulnerability and Resilience." *Australian Journal of Emergency Management* 15(2): 8–14.

Bujra, J. 2000. "Risk and Trust: Unsafe Sex, Gender and IDS in Tanzania." In: P. Caplan, ed., *Risk Revisited*. London: Pluto Press: 9–84.

Cannon, T., 2000. "Vulnerability Analysis and Disasters." In D. J. Parker, ed., *Floods*, Vol. 1. London: Routledge: 45–55.

Carrasco, F. P. 2000. *Participación Comunitaria y Cambio Social*. Mexico City: Instituto de Investigaciones Sociales (UNAM) and Plaza y Valdes Editores.

Carrasco, F. P. and B.A. Garibay. 2000. *Guia communitária para la prevención de desastres*. Mexico City: Government of the City of Mexico and Institute of Social Research, National Autonomous University of Mexico (UNAM).

Douglas, M. and A. Wildavsky. 1982. *Risk and Culture: An Essay on the Selection of Technical and Environmental Dangers*. Berkeley: University of California Press.

Eade, D. 1997. *Capacity-Building*. Oxford: Oxfam.

Eibenschutz, R. and S. Puente. 1992. "Environmental Degradation, Vulnerability, and Urban Development in Developing Countries: A Conceptual and Operational Approach." In A. Kreimer and M. Munasinghe, eds., *Environmental Management and Urban Vulnerability*. Washington, D.C.: The World Bank: 78–79.

Fernandes, E. and A. Varley, eds. 1998. *Illegal Cities: Law and Urban Changes in Developing Countries*. London: Zed Press.

Fernandez, M., ed. 1999. *Cities at Risk: Environmental Degradation, Urban Risk, and Disaster.* Quito: A/H Editorial.

Foreman, C. H. 1998. *The Promise and Peril of Environmental Justice*. Washington, D.C.: Brookings Institution Press.

Freire, M. and R. Stren, eds. 2001. *The Challenge of Urban Government*. Washington, D.C. and Toronto: The World Bank Institute and The Centre for Urban and Community Studies, University of Toronto.

Fuchs, R.J. 1994. "Introduction." In Fuchs, R.J., E. Brennan, J. Chamie, F. Lo, J.I. Uitto, eds., *Mega-city Growth and the Future*. Tokyo: United Nations University Press: 1–13.

Fuchs, R.J., E. Brennan, J. Chamie, F. Lo, J.I. Uitto, eds. 1994. *Mega-city Growth and the Future.* Tokyo: United Nations University Press.

Giddens, A. 1992. *The Transformation of Intimacy*. Cambridge: Polity Press.

Gilbert, A. 1994. *The Latin American City*. London: The Latin America Bureau.

Gilbert, A., ed. 1996. *The Mega-city in Latin America.* Tokyo: United Nations University Press.

Gilbert, R., D. Stevenson, H. Girardet, and R. Stren. 1996. *Making Cities Work: The Role of Local Authorities in the Urban Environment*. London: Earthscan.

Girardet, H. 2000. "Cities and the Culture of Sustainability." In F. Dodds, ed., *Earth Summit 2002*. London: Earthscan: 202–211.

Girardet, H. 1992. *The Gaia Atlas of Cities: New Directions for Sustainable Urban Living*. New York: Anchor Books.

GPG (Gauteng Provincial Government). 2001. "Stand Up and Be Counted." *Gauteng News: Newsletter of Gauteng Provincial Government*, July–August. Available from <http://www.gpg.gov.za/>.

GPG (Gauteng Provincial Government). 2002. *Department of Development Planning and Local Government Annual Report 2000/2001*. Available from <http://www.gpg.gov.za/>.

Greater Johannesburg Metropolitan Council. 2000. "Report on the Interactive Planning Workshop for Johannesburg." In World Bank, *Upgrading Urban Communities: A Resource Framework.* Washington, D.C.: World Bank. Available from <http://www.mit.edu/urbanupgrading/upgrading/case-examples/>.

Hardoy, J. and D. Satterthwaite. 1989. *Squatter Citizen: Life in the Urban Third World*. London: Earthscan.

Hardoy, J., S. Cairncross, and D. Satterthwaite. 1990. *The Poor Die Young: Housing and Health in Third World Cities*. London: Earthscan.

Hardoy, J., D. Mitlin, and D. Satterthwaite. 1992. *Environmental Problems in Third World Cities*. London: Earthscan.

Harriss, J. 2001. *Social Capital and the De-Politicization of Development*. London: Anthem.

Heijmans, A. and L. Victoria. 2001. *Citizen-Based and Development-Oriented Disaster Response*. Quezon City: Center for Disaster Preparedness.

Higashiura, H. 1994. "Community Vulnerability and Local Knowledge." *The World Conference on Natural Disaster Reduction*, Yokohama, May 23–27, 1994, Technical Session A: Vulnerable Communities.

International Decade for Natural Disaster Reduction (IDNDR). 1996. *Cities at Risk: Making Cities Safer … Before Disaster Strikes*. Geneva: IDNDR.

International Federation of Red Cross and Red Crescent Societies (IFRC). 1999. *Vulnerability/ Capacity Analysis*. Geneva: IFRC.

Kaji, H. 1991. "Promotion of People's Participation in Disaster Management: The Japanese Experience." In United Nations Centre for Regional Development (UNCRD), *Regional Disaster Management in the Latin American Region*. Report and Summary of Proceedings of the UNCRD-CISMID International Workshop on Regional Disaster Management, Piura, Peru. Nagoya: UNCRD: 23–26, 222.

Kleinenberg, E. 2002. *Heat Wave: A Social Autopsy of Disaster in Chicago.* Chicago: University of Chicago Press.

Lee, Y. 1994. "Myths of Environmental Management and the Urban Poor." In R. Fuchs, E. Brennan, J. Chamie, F. Lo, and J. Uitto, eds., *Mega-city Growth and the Future*. Tokyo: United Nations University Press: 390–411.

Lo, F. and Y. Yeung, eds. 1996. *Emerging World Cities in Pacific Asia*. Tokyo: United Nations University Press.

Mansilla, E. 2001. *Riesgo y Ciudad*. Mexico City: LA RED.

Magardie, K. 2002. "Home Improvements in Alexandra." BBC News. Available from <http://www.bbc.co.uk/1/hi/world/africa/2166764.stm>.

Mitchell, J.K. ed., 1999a. *Crucibles of Hazard: Mega-cities and Disasters in Transition*. Tokyo: United Nations University Press.

Mitchell, J.K. 1999b. "Natural Disasters in the Context of Mega-cities." In J. Mitchell, ed., *Crucibles of Hazard: Mega-cities and Disasters in Transition*. Tokyo: United Nations University Press: 15–55.

Morrow, B. H. 1999. "Identifying and Mapping Community Vulnerability." *Disasters* 23 (1): 1–18.

Mustow, S., ed. 1995. *Megacities: Reducing Vulnerability to Natural Disasters*. London: Thomas Telford.

Plummer, J. 1999. *Municipalities and Community Participation: A Sourcebook for Capacity Building.* London: Earthscan.

Puente, S. 1999a. "Natural Disaster Risk Management and the Geography of Urban Vulnerability: the Case of Mexico City." Annual Meeting of the Association of American Geographers, Honolulu, Hawaii.

Puente, S. 1999b. "Social Vulnerability to Disasters in Mexico City: An Assessment Method." In J. Mitchell, ed., *Crucibles of Hazard: Mega-cities and Disasters in Transition*. Tokyo: United Nations University Press: 295–334.

Rowell, J. 2002. *Mainstreaming Risk Management in the Slums of Mumbai: A Livelihood Perspective*. Final Dissertation, MSc in Disaster Management. Cranfield Disaster Management Centre, Cranfield University.

Sanderson, D. 2000. "Cities, Disasters and Livelihoods." *Environment and Urbanization* 12(2): 93–102.

Satterthwaite, D. 1998. "Why Half the World's Population does not Live in a City." In IFRC, *World Disasters 1998*. Oxford: Oxford University Press: 11 (box 1.2).

Sen, A. 1993. "Capability and Well-Being." In M. Nussbaum and A. Sen, eds., *The Quality of Life*. Oxford: Clarendon: 30–54.

Sinha, R. 2001. "Report on a Meeting of Government, Business, and NGOs to Consider the Mumbai Disaster Preparedness Plan." Available from <http://www.anglia.ac/geography/radix>.

Slovic, P. 1993. "Perceived Risk, Trust and Democracy." *Risk Analysis.* 13 (6): 675–682.

Slovic, P. 2000. *The Perception of Risk*. London: Earthscan.

Takahashi, S. 1998. Social Geography and Disaster Vulnerability in Tokyo. *Applied Geography* 18 (1): 17–24.

Takahashi, S. 1999. "Urban Social Vulnerability to Hazards in Tokyo." Annual Meeting of the Association of American Geographers, Honolulu, Hawaii.

Takahashi, S. Forthcoming. "Coping with Urban Social Vulnerability to Hazards in Tokyo: Current Status of Disaster Mitigation Plans and its Implications." In S. Sassen, ed., *Sustainable Cities*. *Encyclopedia of Life Support Systems*. Paris: UNESCO.

Tayag, J. 1999. "Urban Social Vulnerability to Hazards in Metro Manila." Annual Meeting of the Association of American Geographers, Honolulu, Hawaii.

Toepfer, K. n.d. "The Urban Revolution." U.N. Center for Human Settlement (UNCHS/Habitat). Available from <http://www.unchs.org/unchs/english/feature/urbanrev.html>.

Townsend, R. 2000. *The Aztecs.* London: Thames.

Tokyo Metropolitan Government (TMG). 1995. *Tokyo and Earthquakes*. Tokyo: TMG.

Uitto, J.I. 1998. "The Geography of Disaster Vulnerability in Megacities: A Theoretical Framework." *Applied Geography* 18(1): 7–16.

United Nations. 1999. "Key Findings." *World Urbanization Prospects: The 1999 Revision.* New York: United Nations.

United Nations. 2002. "Key Outcomes of the Summit." *Johannesburg Summit 2002: World Summit on Sustainable Development*. Johannesburg, South Africa, August 26– September 4, 2002. Available from <http://www.johannesburgsummit.org>.

Velasquez, G., J. Uitto, B. Wisner, S. Takahashi. 1999. "A New Approach to Disaster Mitigation and Planning in Megacities: The Pivotal Role of Social Vulnerability in Disaster Risk Management." In T. Inoguchi, E. Newman, and G. Paoletto, eds., *Cities and the Environment: New Approaches for Eco-Societies.* Tokyo: United Nations University Press.

Westfall, M. 2001. "On-Site Integrated Urban Upgrading for Vulnerable Slum Communities of Payatas." Project Overview. Manila: Asian Development Bank.

Wisner, B. 1995. "Bridging 'Expert' and 'Local' Knowledge for Counter-Disaster Planning in Urban South Africa." *GeoJournal* 37(3): 335–348.

Wisner, B. 1998. "Marginality and Vulnerability: Why the Homeless in Tokyo Don't 'Count' in Disaster Preparations." *Applied Geography* 18(1): 25–33.

Wisner, B. 1999a. "Urban Social Vulnerability in Greater Los Angeles." Annual Meeting of the Association of American Geographers, Honolulu, Hawaii.

Wisner, B. 1999b. "There Are Worse Things than Earthquakes: Hazard Vulnerability and Mitigation Capacity in Greater Los Angeles." In J.K. Mitchell, ed., *Crucibles of Hazards: Mega-cities and Disasters in Transition.* Tokyo: United Nations University Press: 375–427.

Wisner, B. 2003a. "Urban Social Vulnerability to Disaster in Greater Los Angeles." In S. Sassen, ed., *Sustainable Cities*. *Encyclopedia of Life Support Systems*. Paris: UNESCO, forthcoming.

Wisner, B. 2003b. "The Communities Do Science! Proactive and Contextual Assessment of Capability and Vulnerability in the Face of Hazards." In: G. Bankoff, G. Frerks, and T. Hilhorst eds., *Vulnerability: Disasters, Development and People*. London: Earthscan, forthcoming.

Wisner, B., P. Blaikie, I. Davis, and T. Cannon. 2003. *At Risk: Natural Hazards, People's Vulnerability, and Disasters*. 2nd edition. London: Routledge.

World Bank. 2001. "The Johannesburg Story." In *Upgrading Low-income Settlements: A Regional Roundtable for Africa*. October 3–5, 2000, Johannesburg, South Africa. Available from <http://www.worldbank.org/urban/upgrading/afrnd/>.

Wynne, B. 1987. *Risk Management and Hazardous Waste: Implementation and the Dialectics of Credibility*. Berlin: Springer-Verlag.

Yodmani, S. 2001. "Disaster Risk Management and Vulnerability Reduction: Protecting the Poor." Paper presented to the Asian Development Bank's *Asia and Pacific Forum on Poverty*. Available from <http://www.adpc.ait.ac.th/infores/adpc-documents/PovertyPaper.pdf>.

Chapter 14

Living with Risk: Toward Effective Disaster Management Training in Africa

Prvoslav Marjanovic and Krisno Nimpuno

In recent years, the world has witnessed a succession of disasters—floods, wildfires, storms, earthquakes, volcanic eruptions, and landslides. These claimed many thousands of lives, caused material losses in the billions of dollars, and inflicted a terrible toll on developing countries in particular, where disasters divert attention and resources from development needed desperately to escape poverty.

It is a well-known fact that today's disasters are often generated by, or at least extended by, human activities. At the most dramatic level, human activities are changing the natural balance of the planet and interfering with the atmosphere, oceans, polar ice caps, forest cover, and the pillars that make our world what it is.

Population growth and associated pressures cause more people to live in flood plains or in areas prone to landslides. Inadequate land-use planning, poor environmental management, and a lack of appropriate institutional and legislative arrangements increase the risk and multiply the effects of disasters.

Living with risk is the order of the day, and we must learn to reduce these risks through appropriate measures focused on planning, forecasting, and mitigation. We need to build a world of resilient people, communities, and nations.

In recent years, there has been a major conceptual shift in how people seek to cope with disasters that arise from natural hazards. While humanitarian response capacities are vital and need continued attention, the focus on addressing risk underlines the recognition that human intervention designed to reduce the vulnerability of communities and assets can reduce the impact of disasters. Gradually, environmental and development stakeholders are becoming more involved in the management of risk and vulnerability reduction due to their close interaction with natural resources management.

The African Ministerial Statement to the World Summit on Sustainable Development states that the increased incidence of natural disasters in Africa poses a major obstacle to the African continent's efforts to achieve sustainable development, especially in view of the region's insufficient capacities to predict, monitor, handle, and mitigate natural disasters. Reducing the vulnerability of the African people to natural disasters and environmental risks is mentioned as a requirement to achieve the poverty-reduction goals of the Millennium Declaration alongside other basic requirements, including economic growth, access to sources of energy, and basic health services. Extreme weather events such as floods and droughts induced by climate change are singled out.

Following the meeting of the Council of Ministers of SADC (South African Development Community), held in August 2000 in Windhoek, it became apparent that the SADC region is not well prepared to deal with disasters and that a major drive toward an effective training program in disaster management and vulnerability reduction is necessary. The University of the Witwatersrand has responded to this need and, in partnership with Disaster and Emergency Reference Centre from the Netherlands (DERC) and the National Disaster Management Centre of South Africa (NDMC), has initiated activities to support the needs of the region and the soon-to-be-established Disaster Management Facility within the SADC structure.

The creation of the disaster-management structure within SADC is primarily driven by the events that unfolded in February 2000 with the advent of Cyclone Eline. In the initial phase of the flooding disaster, SADC was reduced to a spectator while the international aid providers took center stage. Even when SADC managed to intervene, the thrust was not as focused as it could have been. Such a level of regional unpreparedness is untenable and should not be repeated in the future. The general view emerged that SADC ought to have a disaster-management structure backed by vibrant and sustainable support from which to draw resources to assist stricken member states. The events in February 2000 also demonstrated that the focus on relief will not be sufficient to provide long-term and sustainable means for dealing with disasters. The preparedness measures need to focus on vulnerability reduction; relief should not be viewed as a panacea to all problems associated with major disasters.

While there is always a crucial role to be played by the international community in its humanitarian assistance following major disasters, it should be stressed that SADC countries do not have intimate experience in dealing with aid agencies. Obstructive "red tape," with officials clinging to rules and regulations that frustrate the efforts of the aid provider, is common, and failure to realize the magnitude of the disaster skills—which are different from the "business as usual" approach—that are needed is often at the core of effective management of disasters. Equally, the skills for preparing disaster management plans are just as lacking, despite a legal requirement for such plans to be prepared in many of the SADC countries. The assessment of risk and damage is yet another area in which there is a lack of capacity within SADC.

There is therefore a profound need for an effective and accelerated training and education program to ensure adequate preparedness for natural disasters, which, statistically, are on the increase. South Africa has prepared a Disaster Management Bill, which was promulgated and has become a national Disaster Management Act. The principal agency for the implementation of the Act is the National Disaster Management Centre. As a part of this initiative, a Disaster Manager has been appointed in each of the local authorities in South Africa, with the task of preparing a Disaster Management Plan for his area. It quickly became evident that the capacity to meet the requirements of the new policy and legislation is lacking and particularly so in areas most vulnerable to disasters. It became evident that training and capacity building in disaster management are a prerequisite to effective implementation of the new policies and legislation.

This paper presents the initial results of a joint initiative between the University of the Witwatersrand and the National Disaster Management Centre to address the training and capacity building needs that have been identified.

The Status of Disaster Management in SADC Countries

Before one can assess the training and capacity-building needs for disaster management, it is necessary to review the current status of disaster management in some SADC countries.

Zimbabwe

- Major hazards include drought, flooding, epidemics, public transportation accidents, industrial accidents, forest fires, and environmental degradation.
- The central government initiates disaster-preparedness programs through relevant sector ministries with local administrations taking the responsibility for implementing and maintaining their effectiveness.
- The Ministry of Local Government, Public Construction and National Housing is charged with the coordination role, as stated under the Civil Protection Act No. 5 of 1989.
- Civil Protection Act No. 5 also established a National Civil Protection Fund, which receives money from the government and the public to be applied to enhancing civil protection measures through research, training, and the acquisition of materiel, among other applications. This act is under review and will address the legislative gaps in the areas of fire and ambulance services, and the enforcement of sectoral preparedness planning.
- A National Civil Protection Coordination Committee is responsible for civil protection functions and is comprised of senior officers selected from government ministries and departments, parastatals, and NGOs. Similar multisectoral representation is maintained at the provincial and district levels. All three levels have functional subcommittees with responsibilities according to specialty.
- Mission Statement: "to provide for and ensure optimal emergency preparedness and disaster prevention at the individual, community, sectoral, local authority,

and national level through regulatory mechanisms and coordinated strategic planning for emergencies."

- Constraints and needs: equipment, including rescue, communications, and early warning; inadequate funding; legislative gaps; and staff development.

Zambia

- Types of disasters include drought, floods, epidemics, refugees, fires, pest infestations, internally displaced persons, persons with HIV/AIDS, transportation accidents, water hyacinth, industrial accidents, and mining accidents.
- Institutional framework allows for a national disaster committee, technical committees, specialized subcommittees, provincial disaster committees, and district disaster committees.
- DMMU consists of a secretariat and three regional offices with the functions of coordination, vulnerability/risk assessment, training/capacity building, advocacy, stockpiling, resource mobilization, needs assessment, impact assessment, and research.
- The Disaster Management Training Centre offers a three-week disaster-management course at the SADC-level.
- Funding: annual budget allocation of approximately US$200 million.
- Stakeholders include the government, United Nations system, NGOs, community, and the private sector.

Tanzania

- Major hazards faced are drought, floods, landslides, epidemics, pest infestation, earthquake, accidents, fire, and civil strife, which create flows of refugees into Tanzania.
- Tanzania has legislation covering disaster management; however, it needs an amendment in order to focus on the management of disaster activities rather than on relief coordination.
- Other government approaches to preparedness include crop and food security monitoring by the Ministry of Agriculture and the Department of Meteorology; a national policy to conserve land from overgrazing, soil compaction, and erosion; a national environmental policy to control degradation and raise public awareness; and policies to control population growth, reforest lands, improve storage and rainwater harvesting, ensure sound management of the environment, and discourage people from living in flood plains.
- The government has established strategic grain reserves.
- With UNDP assistance, Tanzania has prepared a draft disaster-management policy and enabling legislation; carried out a training needs assessment and risk assessment/vulnerability analysis; developed a framework for a disaster-management plan; created an MIS; and started a public awareness program.
- Further requirements for disaster management in Tanzania include strengthening the disaster-management department through training; preparing sectoral-, regional- and district-level disaster management plans; inventorying resources; mapping temporary shelter areas and sources of relief goods; increasing public awareness; and establishing national and regional emergency committees.

South Africa

- Events/disasters occurring in South Africa include droughts, floods, wildfires, fires in informal settlements, industrial accidents, displacement, high winds, and disease outbreaks and epidemics.
- In January 2000, South Africa launched a "White Paper on Disaster Management," which presented an approach that prioritizes prevention rather than focusing primarily on relief and recovery efforts. The White Paper emphasizes the importance of preventing human, economic, and property losses, and avoiding environmental degradation. The White Paper also placed special emphasis on pursuing international and regional cooperation with vigor.
- The Disaster Management Bill was published for public comment on 21 January 2000, while the final draft of the bill was introduced into parliament in early 2001.
- The National Disaster Management Act was adopted by parliament in 2002.
- The cabinet established an Inter-Ministerial Committee on Disaster Management in 1997, which consists of nine cabinet ministers and their deputies. An Interdepartmental Disaster Management Committee was also established, comprising representatives of national

and provincial government departments, national associations and institutions, the private sector, and NGOs. Similar structures exist on provincial and local government levels.

- The National Disaster Management Centre was established in 1999 and continues to have responsibility for coordinating actions during all phases of a disaster, with a focus on information management.
- Local authorities are responsible for disaster preparedness, but may seek assistance at the provincial level if resources are not sufficient at the local level.
- Shortcomings and/or needs include stockpiling equipment; training and capacity building; simulation exercises; vulnerability assessments; and communication and early-warning systems.

Seychelles

- The National Disaster Committee is chaired by the Principal Secretary of Environment and falls under the aegis of the Cabinet of Ministers, which is lead by the vice president. The committee consists of senior members of various ministries, NGOs, and the private sector.
- Seychelles has a national disaster plan, which outlines the roles and responsibilities of each relevant organization. Additionally, several ministries have their own response plan, i.e., the health sector.
- Weaknesses: not much emphasis is placed on preparedness, and the concept of disaster management is not well established; public awareness of disaster management is low.
- Positive aspects: good communication systems; small population; some personnel have been trained in disaster management; the risk of disasters is minimal.
- Seychelles would like the following to be addressed on a regional scale: organize disaster-management training; evaluate disaster-management capabilities in each country and carry out vulnerability assessments; serve as focal point for information collection and dissemination of knowledge related to disaster management; organize simulation exercises.

Mozambique

- Mozambique is undergoing a process of rapid sociopolitical, economic, and institutional transformation.
- Mozambique has suffered from a wide range of natural and man-made disasters. Since its independence from Portugal in 1975, Mozambique has been victim to drought, floods, cyclones, massive war-provoked population displacements, coastal oil spills, erosion and landslides, wildfires, pests, epidemics (cholera, bubonic plague, meningitis), forest fires, and large transportation accidents. The three hazards mentioned first—droughts, floods, and cyclones—are a priority for disaster reduction.
- After successive floods in the Limpopo Valley (1976–77), the Buzi and Pungue Valleys (1978), and the Zambezi Valley (1979), it became evident that Mozambique needed to develop an integrated Disaster Management Policy that combined prevention, mitigation, preparedness, and response in the context of post-war reconstruction and development. Mozambique is prone to continuing and recurrent natural disaster threats. Lack of planning and preparation in anticipation of such hazards increases the loss of life and exacerbates the vulnerability of the population when disaster strikes. Mozambique currently lacks an integrated disaster-management policy and structure.
- The now-established institutional framework provides for an interministerial Disaster Management Council chaired by the prime minister. A free-standing National Institute for Disaster Management, INGC, is the secretariat for the council and the principal body for disaster management at a national level. Provincial and local-level structures will be established. INGC replaces the former council, but still reports to the Ministry of Foreign Affairs and Cooperation.
- INGC is responsible for developing a Disaster Management Plan that includes prevention, mitigation, preparedness, and response. In the absence of a Disaster Management Plan, the roles of various partners in civil protection have so far not been defined. Consequently, there is little coordination between them in mitigation matters. The coordination mandate of INGC is now seen as taking responsibility for control of all bilateral- and multilateral-supported disasters.
- Although INGC keeps these institutions informed of current disaster issues, there is little tangible activity that coordinates disaster-prevention programs. The various ministries continue their individual mitigation

efforts without the benefit of a civil-protection framework or a disaster-response plan.

- The Ministry of Public Works tries to follow and promote the existing building and planning regulations, and the Ministry of Health strengthens its general public health services, which currently, under donor pressure, focus above all on AIDS prevention information.
- The structure of disaster responsibilities in Mozambique leaves much to be desired. INGC, the intergovernmental committee, is the coordinator for sector ministries, U.N. agencies, provinces, and the private sector, and reports to the prime minister through the Ministry of Foreign Affairs.
- Seven task force subcommittees exist and have well-defined roles and responsibilities.
- Contingency planning, from the national to the district levels, is in place; the degree of its effectiveness is not known.

Mauritius

- The dominant threat, by far, is cyclones—few miss the island nation. Consequently, the government has developed sophisticated planning, preparedness, early warning, and responder responsibility systems. Despite the frequency and severity of cyclones in Mauritius, no lives have been lost in many years.
- Mauritius uses a standardized system of cyclone terminology and classes of cyclone warnings, familiar to all citizens.
- The government convenes a planning session of relevant ministries, departments, and essential services, which comprise the Central Cyclone Committee. This annual meeting is two weeks long. Local cyclone committees also meet annually.
- The warning system for the population is a simple system of red or blue (termination) flags, displayed on public buildings, police stations, fisheries posts, and the like.
- Relief operations are conducted by the government through a standing cabinet committee.
- Other hazards include torrential rain and flooding, as well as landslides.
- Mauritius has a thriving NGO community and many U.N. specialized agencies; therefore, it has a congenial climate for strengthening disaster preparedness.

Malawi

- The Department for Coordination and Disaster Management, Relief, and Rehabilitation has the responsibility for disaster-management issues in Malawi; the most frequent hazards are flooding, drought, epidemics, and refugee flows.
- Malawi has national legislation establishing the institutional framework for disaster management. The legislation also provides for a National Disaster Preparedness and Relief Committee (NDPRC), which includes relevant ministries and departments, as well as some NGOs. This committee provides policy guidance to the Commissioner for Disaster Preparedness, Relief, and Rehabilitation.
- District Development Committees are the local government equivalent of the NDPRC; the chief executive of each district assembly is responsible for the local disaster management program, assisted by NGOs.
- With the help of UNOCHA, the Government of Malawi has prepared a draft national disaster-management plan; an accompanying manual is planned when funds are available to complete the planning process.
- The government is now turning its attention to disaster mitigation, prevention, and reduction. This approach recognizes that a disaster can wipe out decades of development efforts.
- Malawi's primary short-term needs are in the area of communications: radios, communications vehicles, and satellite phones.

Namibia

- National disaster preparedness in Namibia is in an emerging stage, with much left to be done.
- Since drought is endemic to Namibia, the country has a National Drought Policy. Some strategies being implemented under that policy include pest, drought, and flood management. The government has established a National Drought Fund for implementation.
- The Ministry of Health and Social Services runs a Disaster Surveillance and Epidemic Management Section; it also conducts public awareness campaigns on epidemics such as HIV/AIDS.
- Environmental disaster mitigation activities are being carried out by the Ministry of Environment and Tourism; some national policies are in place.

- The Directorate of Maritime Affairs is implementing a national oil-spill contingency plan.
- A search and rescue center is being established, lessening Namibia's dependence on South Africa for airborne operations.
- Twenty-three regional trainers have been trained in disaster preparedness and management; other training has also been carried out.
- Namibia's needs in disaster management include training; equipment, including boats and helicopters; and medical equipment.
- Namibia feels that SADC member nations would benefit from a common ground (terminology, etc.) for training.

Botswana

- The body responsible for Disaster Management in Botswana is the National Disaster Preparedness Committee, which is chaired by the Deputy Permanent Secretary. Representatives include the Deputy Permanent Secretaries from the line ministries, the Botswana Defense Force, the Botswana Police Service, and the Botswana Red Cross. The National Disaster Management Office was established in 1998, and is the secretariat to the NCDP. Its mandate is to coordinate all disaster management activities. District Disaster Management Committees chaired by district commissioners are also in place.
- Botswana is characterized by an inadequate level of preparedness; inadequate search and rescue capability; poor information management systems; and bureaucratic red tape.
- The most common disaster in Botswana is drought. Botswana is also reported to have the highest rate of HIV/AIDS infection in the world, which makes management of the pandemic a government priority. In February 2000, the cyclones originating in the Mozambique channels resulted in the heaviest floods ever recorded in Botswana's history.
- Other disaster include floods, veldt fires, epidemics, animal diseases, vectors such as malaria-carrying mosquitoes and tsetse flies, pest infestations, cyclones, strong winds, earthquakes, transport accidents, refugee influx, industrial accidents, and chemical spills.
- The disaster management structure for Botswana is at three levels.
- The needs identified are: a finalized disaster profile and National Disaster Management Plan, which will form the basis for a legal framework; capacity building at the national and local levels; training; development of a strategic plan and budget; and decentralization of basic stockpile items.

Angola

- Very little is in place for effective disaster management in Angola. An ad-hoc technical group has been created to assist in preparing a disaster management plan.
- In 1999, Angola suffered damage from heavy rains in Benguela, and desertification and drought affected the provinces of Luanda, Bye, Moxico, Kuando-Kubango, and Namibe, as well as other parts of the country. The overuse of land causes landslides in Moxico and the northern and southern sides of Luanda.
- The government has made available some financial resources to fund small projects, but the amount of funding is insufficient.
- Angola supports a regional coordinating mechanism for disaster management.

It is also of interest to summarize the recommendations of the SADC Disaster Management Steering Committee to the Council of Ministers made in 2002. The Terms of Reference for the SADC Disaster Management Mechanism should be as follows:

- Act as an information and communications hub linking individual national centers, regional sector structures, related NGOs, training and research institutions, and other existing capacities in a two-way communication system
- Facilitate regional collaboration for all aspects of disaster management
- Coordinate any regional response to disasters as requested by member states
- Promote and, where necessary, implement and manage disaster-management programs within the region in collaboration with member states
- Mobilize resources, facilitate appeals for assistance, and undertake fundraising for disaster management and disaster response

- SADC should develop a protocol on disaster management in the region
- SADC should develop disaster-management standard operating procedures
- The Council of Ministers should ensure that each member nation clearly indicates one focal point for disaster management in each country
- Member states should promote and encourage the active participation of civil society and the private sector in all aspects of disaster management
- Member states should be encouraged to promote in-country seminars and workshops to capacitate local communities and stakeholders
- Member states should be proactive and should sensitize government officials and communities to the importance of disaster prevention or mitigation and preparedness
- The SADC region should work collectively to undertake staff development, to include:
  - Creating a coordinated staff training program in disaster management, taking appropriate measures to develop and retain staff in order to ensure institutional memory and providing the resources and facilities that allow disaster management personnel to maximize their performance
  - The region should work collectively to create a common language and procedures for disaster management
- SADC should commit to assisting member states in undertaking disaster vulnerability assessments and risk mapping
- SADC member states should ensure that there is close collaboration between and among SADC institutions and other organizations involved in similar disaster management activities in the region
- Member states should promote the appropriate, timely, and effective dissemination of accurate information to all stakeholders, particularly disaster managers and high-risk communities.

Training and Capacity-Building Needs for Disaster Management in SADC

From the above summary, it is evident that the training and capacity building needs are extensive, diverse, and multidisciplinary, and that no single training institution or program can meet all needs. It is thus evident that a cooperative network approach is essential to ensure that effective training and capacity building in disaster management can be developed and implemented. In addition, it is also evident that any training and capacity-building effort has to be established bearing in mind two main factors:

- The urgent short-term need to provide basic training for all those involved in the first line of disaster-management activities and to do so as quickly as possible
- The need to establish a stable and sustainable training and capacity-building program to respond to the long-term needs of the region.

The first of the above factors requires an extensive series of short courses to address short-term needs and would focus on fundamentals of disaster management from a practical point of view, while the second factor requires the establishment of formal regional training programs in disaster management, which will lead to formal qualifications at undergraduate and postgraduate levels. The short-term needs can only be met through "mobilization" of all available resources and will require international cooperation and regional effort.

The long-term needs, on the other hand, require thorough planning and development and are best suited to a network approach similar to the one taken by WaterNet (a regional initiative for a regional Masters Program in Water Resources Management) to develop a regional educational program in Disaster Management and Vulnerability Reduction.

The long-term training and capacity-building objectives should be:

- Reducing the incidence and impact of crisis and disaster occurrences
- Eliminating risks and vulnerability to such events
- Promoting effective national and regional strategies in crisis and disaster prevention, preparedness, mitigation, response, and recovery
- Efficiently coordinating and collaborating all phases of crisis and disaster management, between and among national and international partners
- Making effective and efficient institutional and legislative arrangements
- Developing appropriate planning and intervention strategies focused on vulnerability reduction rather than relief

- Fostering international cooperation and sharing of resources and experiences
- Building effective information bases and other resource management
- Utilizing regional resources and focusing efforts on developing sustainable regional capacity to deal with disaster management.

Disaster Management Training Initiatives in South Africa

In South Africa there is a widely recognized need for disaster management training and capacity building. Three main initiatives are worth mentioning: the University of Free State Initiative, the Potchefstroom University Initiative, and the University of the Witwatersrand Initiative.

The University of Free State Initiative

The University of Free State has introduced formal education (Magister and an Advanced Diploma in Disaster Management) as well as informal training and an education program (short courses). The formal program has three formal contact sessions each year of five days each. During the first contact, session students are oriented and receive all course material for the first year. The course consists of eight compulsory courses, two electives, and a research project reported in a mini-dissertation format. The course can be taken over a minimum period of two years (full-time). However, students will be allowed to take the course over a three-year period (part-time). Compulsory courses are: Research Methodology, Hazards of Disaster Management, Strategic Management, Advanced and Specific Disaster Management Principles and Practices, Advanced Disaster Risk Management, Information Technology in Disaster Management, Public Health, and Management of Disasters (Natural and Man-made). Elective courses include: Trauma Management, Political Strategic Planning, Information Management, Ethnic and Cultural Conduct, Media Liaisons, Environmental Degradation, Disaster Vulnerability, and Risk Assessment. Admission is in accord with the university's admissions policies.

The Potchefstroom University Initiative

The African Centre for Disaster Studies (ACDS) was established in January 2002 at the Potchefstroom University for Christian Higher Education within the School for Social and Government Studies. The explicit aim of the ACDS is to address the need for education and research in disaster-related activities within Southern Africa and the wider African context. At the time of writing, the ACDS center is planning to offer:

Certificate Course in Disaster Studies (to start in 2003) The objective of the certificate course in Disaster Studies is to provide the student with skills and competency in the management of hazards, risks, vulnerability, disasters, and their associated secondary effects. The main emphasis of the course is on disaster-risk reduction through the use of vulnerability-reduction techniques and hazard assessment and mitigation, within the context of sustainable development and sustainable livelihoods. The program lasts one year and consists of the following modules: Disasters: A Theoretical Perspective; Disaster Risk Reduction; Disaster Planning; Disaster Recovery; Disasters and Sustainable Development; Disaster Information Management and Communication.

Short Courses in All Aspects of Disaster Studies (to start in 2003) The short courses currently planned are: Basic Course in Disaster Management; Integrated Development Planning and the Municipal Disaster Plan; Disaster Preparedness Planning.

An Undergraduate Degree in Disaster Management (to start in 2004) Details of the program are not known at this time.

The University of the Witwatersrand Initiative

The University of the Witwatersrand has responded to the urgent needs for training and capacity building in disaster management by partnering with DERC and the NDMC to offer a series of short courses and develop a new postgraduate and research program in Disaster Management.

The Disaster Preparedness Training Program (short courses) has been developed as a basic training program for municipal and district disaster managers. The first training cycle of six modules, developed for the municipal disaster managers of Limpopo province, was implemented in 2002, January through October. The next cycle of short courses will be offered during 2003 and regularly thereafter. The short courses have been certified by the NDMC and are currently in the process of verification by the South African Qualifications Authority.

The six training modules aim at developing a good understanding of the principles of disaster reduction and impart skills in disaster mitigation as well as in disaster response. Three modules address mitigation planning and three modules focus on emergency response. The program is also suitable for senior NGO staff. The program consists of six modules of one week each, which are conducted at two months intervals. A short description of each of the modules is given below:

Module 1. Introduction to Disaster Management

This module places disaster management in the framework of development planning and identifies strategy options to reduce disasters. Introductions to the main natural hazards, to conflict and displacement-related emergencies, and technological hazards are presented. Introductions to natural disasters cover the underlying phenomena of meteorology, hydrology, and seismology that pose hazards. An overview is given of the legal and administrative measures that societies take to ensure safe and sustainable development. Public perceptions of emergencies and existing disaster myths and their influence on emergency responses are studied. Human behavior, both individually and collectively, form a major factor in the development of disasters. The critical factors affecting human health during emergencies are presented and mitigation options are reviewed. Several case studies of major emergencies are presented.

The various phases of disasters—prevention, mitigation, preparedness, emergency response, relief, recovery, and rehabilitation—are reviewed and the roles and actors in disaster interventions are identified. The multi-disciplinary nature of disaster management, in particular, earth sciences, physical planning, public administration, sociology, and health, is discussed. The common options for disaster reduction are presented. The factors that increase and decrease disasters' impacts are analyzed.

Module 2. Hazards and Vulnerabilities

The module reviews hazard profiles and possible effects and impacts of hazards. It shows that hazards are not the cause of disasters, and establishes the causative links between disasters and vulnerabilities. These vulnerabilities prove to be the causes of natural disasters, technological disasters, and civil strife. De facto disasters are failures in development planning. They are events that can be avoided, which is the essence of disaster reduction.

For each hazard a profile is presented, related to location, frequency, and intensity, and the forces causing these hazards are explained. Threat recognition elements are studied. Social, economic, physical, and managerial vulnerabilities to various hazards are reviewed, with a variety of case studies. The course reviews administrative, technological, legal, and cultural aspects of disaster reduction and emphasizes the importance of community participation in all public efforts in this field. Vulnerability mapping is an important activity for guiding disaster-reduction efforts, and remote sensing as well as field monitoring are presented as options in this respect.

Module 3. Mitigation Planning

The principles of disaster mitigation, in particular those related to prevention and preparedness, are studied as the main tools in disaster reduction. The focus of these efforts is to address vulnerabilities. The historical process of devising mitigation strategies is illustrated by various case studies and demonstrates that disasters can be prevented. Hazard-specific preparedness and mitigation measures are reviewed for relevant locations. Such mechanisms relate to international monitoring (e.g., by remote sensing), by national agencies (e.g., volcano observatories), or by community organizations (e.g., river level monitoring or pre-cyclone shuttering of buildings). Specific impacts of hazards are countered by various protective measures, while monitoring mechanisms are developed for threat recognition and warning. The purpose and effect of mitigation measures are reviewed. Choices and priorities in mitigation are identified and elements of mitigation planning are reviewed in relation to the community in question. The training needs of such actors are assessed and plans for appropriate materials are developed, while the role of mobilization and public information is stressed. A collective memory and hazard consciousness are needed at all levels. Mitigation planning is presented as a variety of safety measures, which depend on a culture of safety and participation.

Module 4. Emergency Response

Preparedness to take action when hazard threats occur is the prime instrument in reducing impacts. Development of response capacities and the availability of logistics and supply resources are fundamental. Planning of intervention alternatives, schemes for management of public behavior, and the determination of various alert phases allow organized interventions under conditions of potential chaos. Coordination between security, rescue, and logistics services, and public initiatives and responses are to be vested in an agreed decision-making process. Crisis management emerges therefore as an important technique to maximize the effect of the allocated resources that can bring order into potential conditions of chaos. The importance of establishing Emergency Operation Centers is stressed. The role of relief, especially of international NGOs, is analyzed, with particular attention to its disruptive effects on the regular development process. The differences between local and international relief are studied and mechanisms to reduce negative effects are discussed. The mobilization of local response capacities is a central theme.

Module 5. Displacement and (Re-) Settlement

Refugee influxes and various types of internal displacement have become major issues in Africa. The causes of displacement due to war, civil strife, environmental degradation, and economic changes are reviewed. The social consequences and the issues of settlement, shelter, health, and economic survival are reviewed. The present policies and planning methods in emergency settlement are studied, while options for sustainable settlements are presented. Early site selection is a key activity in proactive planning. Innovative "Self Help" building technologies are studied. Much attention is paid to the environmental impact of emergency settlements. Site selection, self-help housing, phased infrastructure, and central services are covered, with particular attention to site selection, availability of building materials, and water supply. The UNCHS manual for resettlement forms the basis for this section. Camp management issues, logistics, security, and social services are addressed, and relief programs of NGOs in food supply, fuel, water and sanitation, education, and health services are covered.

Module 6. Developing Disaster Plans

Disaster plans are administrative instruments for the effective deployment of the necessary response resources, through command and control measures. They clarify mandates and clear lines of command. The plans identify which resources are needed, where they may be found, and how they can operate smoothly in a coordinated response. They confirm collaboration agreements that in times of emergency make all necessary resources available for deployment and stipulate requisition procedures. Both government and nongovernment agencies are included, while the necessary responses from the affected populations are channeled and controlled. Communication systems are of critical importance and allow a rapid decision-making process that facilitates smooth operations. Public regulations and a legal basis for the plan are essential, but smooth implementation of the plan depends above all on good cooperation and trust.

Mitigation plans are incremental development plans for decreasing, and possibly eliminating, vulnerabilities. They form a key element in development planning, but require constant improvement and monitoring by safety specialists. The appointment of municipal and district mitigation officers is presented as an important element in disaster reduction.

In addition to the above, a number of short courses have been delivered outside of South Africa, including:

- Kenya: Introductory Disaster Management training courses were conducted in Kenya, for leading NGOs in the field of relief, which expressed a desire to develop proactive disaster reduction programs (e.g., CARE Kenya and the Anglican Church).

- Tanzania: Several training workshops were conducted in two national educational institutes, with participation from neighboring countries. A draft disaster plan was developed for the Ministry of Health.
- Mozambique: A training program is being developed, as part of an ongoing U.N. project on flood mitigation, addressing community needs in flood-prone areas. Surveys of vulnerability factors in informal urban settlements have been concluded.
- Ethiopia: In collaboration with U.N. Habitat, a training course on earthquake-resistant adobe housing was conducted at the University of Addis Ababa.
- Egypt: An introductory workshop on vulnerabilities in informal settlements was conducted at the Center of Planning and Architectural Studies, a nongovernmental human-settlements planning institute.

The postgraduate program in Disaster Management is focused on two main areas of activity:

- A research program with a focus on understanding disasters in Africa
- A graduate diploma and a Master's Program in Disaster Management.

The research program was initiated during 2002 with support from the Ford Foundation. Two research projects have begun: droughts in Southern Africa and wildfires in Southern Africa. Two Masters of Science theses are expected to be completed by the end of 2002 and one doctoral thesis is to be submitted in 2003. The research program is expected to grow in other areas of interest and will include but not be limited to problems such as information management and dissemination, remote sensing and disaster management, and institutional aspects of disaster management.

The proposed programs leading to a graduate diploma and/or Master of Science in Disaster Management are currently going through the University Academic Structures for approval. A blended learning approach, combining in-class teaching, project work, and field and action learning is adopted. It is anticipated that the first students will register for degrees in January 2004. The programs are to be offered in partnership with the relevant faculties of the university using Wits School for the Environment as a conduit for cross-disciplinary studies. The graduate diploma in Disaster Management will consist of six modules similar to those currently offered as short courses but with more theoretical background and an in-depth analysis included in the curricula. The program will be based on extensive materials developed by DERC, materials currently in use by the U.N. agencies and universities in the United States, Asia, and Europe, with appropriate modifications to suit South African and regional needs.

In accordance with the requirements of the National Qualifications Framework and the South African Qualifications Authority, the programs will be outcomes-based and will undergo normal verification and quality assurance processes. Entry into the program will be in accordance with the university's admissions policies, which also include recognition of prior knowledge. Master's degree program students will be required to take additional courses and submit a research thesis equivalent to six months of full-time engagement.

In addition to the three initiatives discussed, a number of technikons in South Africa are currently developing appropriate disaster-management programs, some of which will be offered through distance learning.

The University of Cape Town also has an active program in disaster management but details about it were not available at the time of writing.

International Network on Disaster Management Training in Africa—DIMITRA

The International Network on Disaster Management Training in Africa—DIMITRA—is an initiative aimed at mobilizing the limited resources in Africa and extending training and capacity-building initiatives to the continent. It is envisaged as a Pan African initiative open to all with a focus on vulnerability reduction and learning to live with risk. The initiative was launched with support from the World Bank's Disaster Management Facility and the ProVention Consortium at an International Disaster Management Training Workshop conducted in parallel with the WSSD in August 2002 during the CEMSA 2002 International Conference on Environmental Management and Sustainable Development in Africa. Participants from 10 countries (Botswana, Egypt, Kenya, Nigeria, Netherlands, South Africa, Tanzania, Thailand, U.K, and Zimbabwe) deliberated for three days on the training and capacity-building needs in disaster management and have developed an action plan that forms the basis for future DIMITRA activities. Fund raising is currently in progress to support the implementation of the DIMITRA Action Plan.

DIMITRA is a network of university departments and research and training institutes specializing in disaster management and vulnerability reduction. Member institutions will be asked to endorse Vision for Risk-Free Environments, currently under development and aimed at regional integration and economic benefits for present and future generations in Africa.

The mission of DIMITRA is to enhance regional capacity in disaster management and vulnerability reduction through training, education, research, and outreach by sharing the complementary expertise of its members. DIMITRA member institutions will share expertise in various aspects of disaster management and vulnerability reduction. The ultimate objective is to develop and implement a regional post-graduate program in disaster management and vulnerability reduction aimed at educating a new generation of disaster managers in Africa to address the complex and integrated nature of disaster problems facing Africa.

DIMITRA Structure

DIMITRA is envisaged as a membership organization. DIMITRA members will meet during the Annual General Meeting. The first DIMITRA annual general meeting will be held in the first quarter of 2003 to discuss and adopt the constitution of DIMITRA. The AGM elects members to the steering committee that will oversee the DIMITRA secretariat. The University of Witwatersrand currently hosts the secretariat and is driving the initiative until funding is secured for DIMITRA to function on its own.

Membership of DIMITRA is open to institutions in Africa that are involved in training, education, and research in fields directly related to disaster management and vulnerability reduction, preferably at graduate and postgraduate levels. The primary requirements of members are to subscribe to the principles of DIMITRA; to commit to further integrated management and prevention, rather than relief, through sharing expertise and facilities with other members; to contribute to the development and maintenance of selected course modules; and to allow peer review. DIMITRA will also have "supporting members," strategic partners and donors who will sit on the DIMITRA Steering Committee and guide its activities.

Conclusions

Disaster risk management needs to be led and based within governmental authority, but its success cannot be accomplished without the benefits of the widespread participation of many others. While policy direction is crucial and legal foundations assure a continuing legitimacy, it is the professional and human resources delivered on the ground that are the measure of success. In Africa the focus must thus be on the development of human resources, which are so lacking; in addition, focused efforts on an international scale are urgently needed.

For this to happen, there must be coordinated effort and a systematic approach to establish sound foundations and larger administrative and resource capabilities. The burden is too large for any individual country or government to handle—international efforts based on mobilizing locally available resources are required. This is amenable to a broad network such as DIMITRAN, the one recently initiated, and actions are needed to make such a network effective. This will in turn require funding and buy-in from policy makers. The University of the Witwatersrand considers supporting such initiatives to be its social responsibility and is taking the initial responsibility to make such initiatives a success. But we cannot do it alone and support and contributions from others are needed and welcome. We look forward to a rewarding future.

Bibliography

Anderson, Mary B., and Peter J. Woodrow. 1989. *Rising from the Ashes: Development Strategies in Times of Disaster.* Boulder, CO: Westview Press.

Asian Disaster Preparedness Center, Bangkok. 1999. *Managing Disasters in Asia and the Pacific*. A Review of Lessons Learned during the International Decade for Natural Disaster Reduction.

"Balancing the Environment and the Economy: Approaches for Mitigation." 2001. S01-13, Natural Hazards Center Research and Applications Workshops, session summaries, August.

Blaikie, P., T. Cannon, I. Davis, and B. Wisner, B. 1996. *At Risk: Natural Hazards, People's Vulnerability, and Disasters.* London and New York: Routledge.

Christoplos, Ian, J. Mitchell, and A. Liljelund. 2001. "Re-framing Risk: The Changing Context of Disaster Mitigation and Preparedness." *Disasters* 25 (3): 195.

Disaster Management Bill. 2001. Pretoria, South Africa. Government Printer.

Gilbert, Roy and Alcira Kreimer. 1999. "Learning from the World Bank's Experience of Natural Disaster Related Assistance." Disaster Management Facility of the World Bank, Urban and Local Government Working Paper Series N°2. Washington, D.C.

Green Paper on Disaster Management. Pretoria, South Africa. Government Printer. 1998.

IDNDR (International Decade for Natural Disaster Reduction). 1999. *Proceedings*, IDNDR Programme Forum.

ISDR (International Strategy for Disaster Reduction). 2002. "Disaster Reduction and Sustainable Development." ISDR Background document for the World Summit on Sustainable Development (WSSD) N°5.

SADC (Southern African Development Community). 2001a. "Disaster Management Strategy." Secretariat, Gaborone.

SADC. 2001b. "Strategy for Flood and Drought Management in the SADC Region." SADC, Water Sector Coordinating Unit. Maseru.

UNEP (United Nations Environment Programme). 2002. "Global Environmental Outlook" (GEO-3 Report). A series of UNEP.

Chapter 15

Urban Vulnerability to Disasters in Developing Countries: Managing Risks

E. L. Quarantelli

Some argue that the world is much riskier than it used to be (Beck 1995, 1999). However, our age is not more dangerous, but the balance of risks and dangers has shifted. We live in a world where hazards created by ourselves are as threatening, or more so, than those that come from the outside (Giddens 2000:52).

"Risk" is always socially constructed by humans and has no objective existence. "All perceptions of risk, whether lay or expert, represent partial or selective views of the things and situations that threaten us" (Jasonoff 1998:91). Consistent with this is the observation that "the empirical results suggest that the social processes that construct and maintain risk in the public eye are at least as important as, if not more important than, the physical and psychological dimensions of risk" (Rogers 1997:745).

Perceptions of risk can differ dramatically. Indigenous residents of Bangladesh's Brahmaputra-Jamuna River islands view the annual flooding in their region as part of a natural cycle that benefits the environment. The indigenous residents have developed a stock of local knowledge and strategies to cope with the environmental conditions and take advantage of them for agriculture, their main source of income. Western engineers, on the other hand, define the flooding as an event that needs to be controlled to protect the 30,000 "helpless" inhabitants forced regularly from their homes (Schmuck-Widmann 1998:1).

This difference in perception has been observed by several researchers (Kraus and others 1992; Flynn and others 1993; Tierney 1999). The differences between disaster "experts" and lay people often lead to a dismissal of lay people's perceptions. The director of risk communication for the Harvard Center for Risk Analysis summarized the views of experts in the following manner:

> Billions of dollars and countless hours of effort will be wasted unnecessarily—all because we're afraid of the wrong things.… In a frenzy of fear, we're pouring millions … into protecting ourselves from the West Nile virus, and spending only a fraction of that sum on public education encouraging people to wash their hands, which would eliminate far more disease than killing every mosquito in America.…
>
> In many areas, science can identify the physical hazards, tell us how many people are likely to be affected by each one, what various mitigations will cost and how effective we can expect them to be. We can rank risks and remedies and put things in perspective. But we don't. Instead, we make policy based more on fear than fact.
>
> This irrational response kills people … the principal underlying cause of wasteful choices is fear. But society must be more rational than that …. Why not create … an independent nongovernmental agency … to provide credible guidance on risks? The institute would rank hazards so we could know which are most likely to occur, classify risk according to their consequences, and conduct cost-benefit studies to rank mitigation choices by cost and effectiveness.… How do we make policymaking more rational? (Ropeik 2000.)

Policymakers should incorporate the views of ordinary people into disaster analysis and planning. Such a strategy would further strengthen the partnerships needed to plan for and respond to major disasters—consistent with the philosophy that one should plan *with* people and not *for* them.

Urbanization

Urban population growth. The world's population continues to increase, with 96 percent of this growth in developing countries (UNFPA 1991:3). The United Nations projects that by 2010 there will be 511 metropolises exceeding one million inhabitants and, for the first time, more than 50 percent of the world's population will dwell in cities (Jones 1991:5). In addition, 40 large cities will be added every five years, so that by 2025 there will be 639 metropolises with more than one million residents. Seventy-six percent of these will be in developing countries. The metropolitan explosion will be greatest in Africa and Latin America. Currently, 77 percent of Latin Americans, 41 percent of Africans, and 35 percent of Asians live in urban areas (UNFPA 1991:10).

Population growth alone does not account for all urban growth, however. Urban migration also plays a large role:

> Declining mortality rates in rural areas of most developing nations have not been matched with corresponding fertility declines. The resulting increase of population cannot be sustained by stagnating rural economics, which leads to growing demographic-employment opportunity imbalances in the countryside. Migration becomes the only mechanism to relieve this imbalance. Rural migrants pour into the cities, exacerbating already overcrowded conditions in urban subareas. The age selectivity of rural migrants (largely teenagers and young adults) further contributes to city growth through new family formation and natural increase (Dogan and Kasarda 1988:19).

Over the next 20 years, urban areas must absorb one billion *additional* residents—as many urban residents as there were *in total* in 1990 (Fuchs and others 1994:1). There has also been a fundamental shift in the roles of cities. Once centers for collecting and processing resources and raw materials brought in from the hinterlands, cities are now symbols of national identity and pride and the locus of a country's power.

The urbanization process increases vulnerability to natural disasters through the concentration of people and assets. Increasing pressure to expand housing and commercial space has also accelerated the pace of vulnerability. Housing complexes and industrial parks are being rapidly constructed on unused land, formerly swamps or wetlands, in and near cities. Such land is unstable for construction and property in these areas is some of the first damaged during floods and earthquakes.

Hillsides provide another unstable foundation. The 1999 rains and mudslides near Caracas, Venezuela killed thousands. Many of the victims had cleared forest land and built homes within the boundaries of the Avila National Park overlooking the valley of Caracas. By contrast, a torrential rainstorm in the same area in 1952 did not result in a disaster since the area had been virtually uninhabited and the park's slopes amply forested.

An unwillingness to seek safer housing is often difficult or impossible, however; "people who are already barely eking out an existence will not avoid a risky flood plain or the shadow of a volcano any more than they will eschew the squatter settlements around a pesticide factory in Bhopal or a liquefied gas facility in Mexico City. In short, the poorest of the poor are probably likely to reside in the path of both natural and technological hazards" (Bowonder and Kasperson 1988:104).

Industry concentration. Much of the population concentration is due to the concentration of industry. In developing countries, one or two cities often house the bulk of a country's industrial production. Mexico City, for example, generates one-third of Mexico's gross national product; São Paulo, with 10 percent of Brazil's population, contributes 25 percent of the net national product; Bangkok, with 10 percent of Thailand's population, contributes 86 percent of the nation's gross national product in producer services and 74 percent in manufacturing (Kasarda and Crenshaw 1991:473). These concentrations of services and industries make disasters in a city, a relatively small area with respect to a country's total area, particularly catastrophic for a city and a country.

In addition to the risk of losing a country's industrial base during a single natural disaster, this concentration of industry in and near population centers holds additional risks. "Hazardous industries are not randomly distributed within cities. Industrial zones in general, and hazardous industry sites in particular, tend to be located in less-affluent areas characterized by low socioeconomic residents less able to capably deal with, or respond to, crises" (Britton 1991). Once again, it is the poor who face additional risks to their life and health by the mere fact of their poverty.

Even when there are efforts to protect people, however, reality often intervenes. Rioters in New Delhi torched buses and blocked roads in November 2000 to protest the closure of 90,000 small factories blamed for polluting residential areas. Rioters demanded that the government ignore a Supreme Court order to close the factories that employed close to one million people (Dugger 2000).

Urban vulnerability—a reality. A decade ago, an analysis of the world's 100 most populous cities found that 78 percent were exposed to one of four major natural hazards—earthquakes, tsunamis, volcanoes, and windstorms (not including flooding)—and 45 percent faced being struck by more than one. In developing countries alone, 86 percent faced more than one threat (Degg 1992:203–204).

With their population densities and commercial and industrial centers, cities have characteristics that can magnify the impact of disasters to which they are prone. In developing countries in particular, many cities have substandard construction, large slums, poor health care, inadequate water and sanitation services, crumbling transportation networks, pollution, increasing unemployment, and high crime rates. These challenges, coupled with the fact that natural occurrences will continue to happen, put developing countries at a further disadvantage. Even the 1995 earthquake in Kobe overwhelmed the Japanese, who had some of the best disaster-management policies and programs in the world.

Growth of slums and informal settlements. A United Nations report states that in 1990, roughly one billion people lived in slums and squatter settlements. These informal settlements increasingly make up large sections of many cities: Dar es Salaam 60 percent, Lagos 58 percent, Mumbai 57 percent, Mexico City 40 percent, Calcutta 40 percent, Nairobi 34 percent, and São Paolo 32 percent (Oberai 1993:2). When technological and natural disasters strike these urban areas, the human and social costs are greater because a large percentage of the population is already less protected from the elements and struggling for daily survival. Furthermore, in many cities, these informal settlements are considered illegal, therefore, government officials have not included them in urban planning. Scarce resources are normally first allocated to official neighborhoods and there is often little remaining for squatter settlements. The squatters' lack of political and municipal voting rights puts them at an additional disadvantage, making disaster planning formidable in areas where existing social, economic, political, and technical constraints are severe (Davis 1987:6).

Though these unofficial settlements may appear disorganized and chaotic to the casual observer, studies have revealed that people often move into specific areas to live among a similar ethnic or religious group (Alba 2000). This affiliation allows people to maintain ties with their tribes and rural areas of origin, providing a sense of security to migrants (Gilbert and Gugler 1992:157). A study in Nigeria found that "the evidence is overwhelming that virtually all respondents maintain significant relationships with their rural home community" (Gugler 1997:66). Though these migrants may be ethnically, religiously, and socially different from the dominant group or groups in a city, understanding the makeup of shantytowns and squatter settlements aids in developing appropriate disaster-management plans that incorporate all urban dwellers.

Social dimensions of vulnerability. Women and children are most likely to be victims of disasters by the simple fact that they typically comprise at least 70 percent of the population in developing countries. Until recently, however, women went relatively unnoticed in disaster research and it was assumed that their behavior was similar to that of men. That is not necessarily the case. If caring for a household with its young and elderly occupants, women must concern themselves with saving the lives of others and themselves. A typical "family" in some countries may include several generations, as well as kin normally considered "distant" in the West. When the subject of women and disasters was finally studied, it was found that women have access to fewer support systems following a disaster, are less likely to be involved in mitigation and prevention activities, are not always reached by warning systems, and have not been recognized as necessary players in terms of disaster prevention, management, and assistance.

The same can be said for street children, an estimated 30 million worldwide (Laquian 1994:203). A study following Hurricane Mitch found that street children fared relatively worse than the general population and made up a disproportionate number of the victims. Those housed in temporary shelters following the hurricane suffered from severe physical, psychological, and psychosocial problems (*Reconstruction* 1999:14). Furthermore, in some cities, there may be a large number of individuals such as students or laborers living alone or rooming with nonrelatives. These unique social and living patterns make up a city and must be adequately taken into consideration in planning disaster response.

Disabled and especially vulnerable individuals. Countries in conflict or recovering from protracted conflicts often have an unusually large population of disabled people who may need special assistance during times of crisis. Such communities may also be situated near unmarked landmines or other hazards that make the delivery of assistance and travel to and from the affected areas particularly dangerous. Large concentrations of war widows with children may also need special attention during and following a disaster.

The AIDS epidemic has also created new classes of vulnerables. Those who are severely ill are especially vulnerable to disasters, as are concentrations of AIDS orphans. In South Africa, some 20 percent of the population is already HIV-positive, and it is estimated that 42 million African children will lose one or both parents to AIDS by the year 2010. In addition, the gross domestic product in many countries is expected to decline by as much as 20 percent as a result of the deaths of working-age adults (Nelson 2000; Wade 2000). In addition to the social and economic devastation, the disease means there are fewer adults and resources to deal with other disasters that strike.

Natural Disasters and Human Influence

A. C. Bradley wrote nearly one hundred years ago, "[C]alamities ... do not simply happen, nor are they sent: they proceed mainly from actions, and those the actions of men" (1906:11 cited in Hewitt 1997:ii). Floods, earthquakes, and other "natural" disaster agents have social consequences *only* because of the activities of communities before, during, and after a disaster. High-density population concentrations in floodplains, inadequate and unenforced building codes, housing on volcanic slopes, and inadequate warning systems increase damage from natural occurrences. If we think that the number of natural disasters has been increasing, that is not necessarily true. What seems to be happening is that the same number of natural occurrences are resulting in more costly remedies because humans have put themselves in nature's way. Property and economic loss, psychological stress, and disruption of daily life are concerns for most people rather than the actual hazards themselves.

Changing environment. In an attempt to mitigate what we call a disaster, humans have tried to control nature through dams, levees, and filling in swamps and wetlands. Not only has flooding not been controlled, but in some cases, the severity has increased and the ecological balance been upset. The Rhine River is one example:

> The severity of flooding … has been strongly influenced by many changes occurring to its floodplain since the beginning of the 19th century. Moors and bogs have been drained, cultivated and settled…. Since steamship navigation began in 1836, the meandering stream has been straightened. Artificial cut-offs through meander bends reduced the length of the Danube and caused it to incise its bed, thus increasing its fall and decreasing its width. The construction of levees began in 1884, with the aim of confining floodwaters to a narrower path…. These modifications led to a loss of floodwater retention space, as stagnant waters have been cut off and drained and the land filled. Rhine River forests have been eliminated, wetlands drained and the infiltration capacity of both soils diminished by field clearance (Geipel 1993:112).

Water is also channeled for drinking and industrialization. Chronic water shortages affect many countries, particularly developing ones. "Freshwater resources are being used up at such rapid rates that groundwater supplies are dwindling and surface waters are fouled with pollutants from industries, municipalities and agriculture. In much of Sub-Saharan Africa, the Middle East and parts of Asia, water consumption will reach 30–100 percent of available reserves in 10–15 years—a result of population growth and inefficiencies in use" (UNFPA 1991:5).

The water supply is also affected by droughts. While droughts used to be thought of as a rural agricultural problem, this is no longer the case (Glantz and Mason 1994; Vogt and Somma 2000). In Kenya, a lack of water to power hydroelectric dams resulted in the imposition of strict power rationing in 2000 with most homes having electricity only three or four nights a week and factories receiving power every other day (Fisher 2000). Increasingly, urban and metropolitan localities are finding themselves faced with shortages or reduced water supplies. In June 2000, the residents of São Paulo, Brazil, were told that their water would be rationed for five months, with some three million residents required to follow the two and one plan: two days with water, one day without (*Wilmington News Journal,* June 1, 2000:A15).

Soil erosion due to increased agricultural production also affects the environment and the impacts of disasters.

The use of heavy agricultural machinery compresses soils and increases surface runoff. Crops like corn, sugar beets, and turnips, which are planted in rows, increase the potential for soil erosion, especially during the spring floods, when once-scarce vegetation covers the fields. In recent decades the area planted with these crops has increased. "The sectors where the levees were breached along the Rhine River in 1988 contained hand-built dikes … constructed to reclaim land for pasture and cultivation" (Geipel 1993:113).

Air pollution from automobiles and industry has also been blamed for increasing the severity of natural disasters. Twenty-five years ago, it was suggested that automobile pollution exacerbated the incidence of tornadoes in cities (Isaacs and others 1975). Although the research has not been universally accepted, recent studies suggest that air pollution may intensify the effects of hurricanes, also. It is thought that if the atmosphere's carbon dioxide content doubles, hurricane intensity could rise 40 to 50 percent generally and up to 60 percent in the Gulf of Mexico. The National Center for Atmospheric Research predicts that the atmosphere's carbon dioxide content will double between 2035 and 2080, suggesting an accompanying increase in hurricane intensity.

Technological risks. In addition to humankind's ability to influence the impacts of natural disasters, we have added threats entirely of our own creation. Chemical and nuclear risks are now present globally—in and around facilities and in distant localities when transported by road, rail, and ship. Some 12 percent of all cargo in Russia is considered hazardous (Vorobiev 1998:33) as is 5 to 15 percent of cargo on American roads. It has been estimated that more than a million residents of the former Soviet Union live in contaminated areas in and around 300 towns where chemical weapons were once produced, stored, tested, and destroyed (Shargorodsky 1993).

Over the past century, the chemical industry grew exponentially and has gained political power. In the United States alone, the industry generates more than $200 billion per year through the manufacture of more than 4.5 million different chemicals—20,000 of them produced annually in amounts exceeding one million pounds. Ensuring the safety of products that can explode, burn, asphyxiate, poison, corrode, and generally wreak havoc on humans and the environment is not easy, and some hazards were not immediately recognized until after they had been in use for several years. Chemicals have become part of everyday life in cities, however, and are used to treat such essentials as drinking water. Wastewater treatment also protects humans and the environment, though such processing can lead to the production of toxic sludge, further treatment of which results in methane gas and carbon dioxide that contribute to global warming.

The increased use and production of chemicals has resulted in an increase in accidents. Between 1917 and 1979, there were 39 chemical disasters resulting in 20 or more fatalities. In just the next five years, however, there were half as many disasters, including the pesticide leak from the Union Carbide plant in Bhopal, India where 1,600 people died and 70,000 more were affected (Freitas and others 2000:21). And in February 2000, the dike of a gold-extraction operation in northwest Romania broke, spilling millions of gallons of cyanide-polluted water into the Tisza River, which eventually carried the pollution hundreds of miles into Hungary and Yugoslavia (Savic 2000:2).

Responding to technological disasters is often more difficult than other disasters because the proper response to chemical poisoning and radiation contamination is specialized and can strain emergency medical services more than an "ordinary" disaster. This was the case in Bhopal, India, where the local system was overwhelmed with the numbers affected and the types of medical problems faced. The city's biggest hospital, Hamidia, admitted 1,900 seriously ill patients the first day and eventually treated more than 70,000 victims, though it had only 760 beds (Bowonder and others 1985:32).

Compounding the chemical risks has been an increase in the sizes of trunks and tankers to transport chemicals, oil, and nuclear waste. The shipping tonnage of oil tankers has expanded sevenfold since 1960. Accidents involving these large tankers have resulted in significant environmental damage as illustrated by the 1978 *Amoco-Cadiz* oil spill off the Brittany coast, the 1989 *Exxon Valdez* oil spill near Alaska, and the 1982 *Aegean Sea* tanker oil spill and fire at the harbor of La Coruña, Spain, a city of 250,000 people. Port cities face myriad risks in addition to oil spills, however, since a large tanker carrying liquefied natural gas carries the energy equivalent of 55 Hiroshima-type atomic bombs (Lovins and

Price 1981:64). Moreover, the West has begun exporting its hazards by sea to developing countries, which are desperate for the income generated.

Nuclear hazards. The nuclear industry has a shorter history than the chemical industry, but its disasters can be even more deadly. While most nuclear risks are associated with cheaper and so-called "cleaner" electricity, running a plant and disposing of spent nuclear fuel rods create significant hazards. Twenty-three nuclear incidents were reported in the former Soviet Union between 1951 and 1991, though undoubtedly there were others that went unreported (Gentleman 2000:134). Incidents not immediately reported nor appropriately responded to include the 1957 explosion of a tank that spewed 70 to 89 tons of radioactive waste in and around a nuclear weapons plant near Chelyabinsk. At least 270,000 people were exposed to the radioactive cloud, although the resulting health impacts were difficult to ascertain precisely. Twenty-three villages had to be razed and 10,000 residents permanently resettled, although that was not undertaken until a year later. Seventeen thousand acres of polluted farmland were turned, ironically, into a nature reserve (Monroe 1992:535–536). This is considered the most contaminated spot on the planet.

Even in developed countries with strict controls, nuclear plants are not entirely risk-free. In Japan, the Mihama nuclear power plant released radioactivity after a steam pipe ruptured, forcing the emergency system to flood the reactor to prevent a meltdown (Sanger 1991). In the United States, the near meltdown at the Three Mile Island facility in 1979 proved that such facilities were not as risk-free as claimed.

The global arms race also ensures the proliferation of nuclear hazards. North Korea, Iran, Libya, Iraq, Israel, India, and Pakistan face global scrutiny for their capabilities and activities. The former Soviet Union is attempting to decommission some of its nuclear weapons, but lacking adequate funding, the United States has stepped in at some facilities to ensure weapons are properly destroyed and components are not sold on the black market.

Cleaning up nuclear facilities is difficult if not impossible, and lingering contamination spreads easily. A 2000 report by the U.S. National Research Council states, "Of 144 facilities that played a role in the U.S. nuclear weapons program, the Energy Department has concluded that 109 will never be clean enough to permit unrestricted use by the public" (Kempster 2000:A5). Radiation fallout from the 1986 Chernobyl nuclear accident affected European countries that in turn exported contaminated milk to Malaysia, Nepal, and Ghana (Adams 1998:206). In Belarus, just across the border, the incidence of thyroid cancer was found to be 24 times higher in contaminated areas than other parts of the country in 1999 (ICRC 2000:94). Western Europeans have expressed concern for the safety of their own nuclear plants and the deteriorating facilities in Eastern Europe, particularly the six Kozlodui nuclear plants in Bulgaria (U.S. GAO 2000). While natural disasters may destroy buildings and alter the physical environment, technological disasters can contaminate and render areas unfit for inhabitation.

Other technologies. Computer technology is not inherently hazardous, although the use, or rather misuse, of technology can be. Hackers can create disasters and major inconveniences by disrupting computer-dependent systems such as power and water supplies, and nuclear facilities. They can also create viruses that interrupt normal systems functioning. Though many technologies are recent, people have become so dependent upon them that when they fail, so do other systems. For example, in a chemical disaster where the computer monitoring system failed, the surrounding population received the warning late since there was no backup system. In precomputer days, the warning would have been issued verbally hours earlier (Quarantelli and others 1983).

Telecommunications infrastructure is also vulnerable. In 1991, 11 widespread phone system outages affecting major metropolitan areas occurred in the United States. In the report accompanying those figures, it was noted that "modern fiber optics carry 10,000 times more calls than the old copper cables they replaced. An accidental cut of a single fiber optics cable can cut off entire metropolitan areas" (Lee 1992:8).

Technology also allows us to build bigger and taller skyscrapers, but this represents another increase in vulnerability, as was tragically evident with the World Trade Center towers where some 2,800 people died. These were not the first tall buildings to burn, however. Devastating fires in high-rise buildings have also occurred elsewhere. In 1974, 189 died in a 25-story building in

São Paolo, Brazil. Such fires have prompted discussions of protective measures such as wider stairways to use in the event of an emergency, construction of heavily fire-proofed refugee floors where evacuees could gather, and banning underground parking garages where terrorists could strike.

Some technologies are more scientific than infrastructure-related, making planning by the average person in the event of an emergency more difficult since the threat is often not understood. In 1979, biological toxins were accidentally released at a Soviet research center. As many as 1,000 workers were killed, and a 20-square-mile area around the city of Svardlovsk was contaminated by highly toxic anthrax spores (Thompson 1987:11A; Oberg 1988). Like nuclear and chemical facilities, manufacturing facilities for biotechnological purposes also have significant risks associated with the production, storage, transportation, distribution, and use of the products involved. (For biotechnological hazards in agriculture in developing countries, see Dommelen 1999; the spread of biotechnology in developing countries is discussed in Acharya 1999.)

Genetic engineering may also hold risks not yet fully understood. For example, oil and chemical waste-eating bacteria have been created that can be used to help clean up oil spills, although these organisms could also attack lubricants on machinery. As a National Science Foundation report has stated, however, "no hazard particular to genetic engineering has yet surfaced" (Schmeck 1987:7).

Super disasters. With an increase in technological hazards and the transportation of chemicals and hazardous waste, it logically follows that there will be an increase in such disasters. Magnifying them could be the effects of natural disasters (Showalter and Myers 1994). In 1987, a powerful tornado created 14 toxic chemical sites around Edmonton, Canada. California's Northridge earthquake caused: one train to derail and spill sulfuric acid and diesel fuel; nine pipeline ruptures; 35 breaks in natural gas transmission lines; 717 breaks in distribution lines; and 15,201 natural gas leaks that resulted in three street fires, 51 structural fires, and the destruction of 172 mobile homes (Lindell and Perry 1995:8,11; Lindell and Perry 1998:287). In Russia in 1961, windstorms in the Lake Karachay region in the Southern Urals spread contamination when radioactive plutonium and strontium from an earlier nuclear disaster was blown to other areas (Porfiriev 1991). Cognizant of the chain of events, disaster risk management is increasingly taking into account the possibility of hazardous chemical releases and spills after earthquake shocks (Tierney 1990).

Disaster Planning, Mitigation, Response, and Recovery

Disaster planning. The degree and type of disaster planning in place in developing countries varies considerably. In India and Iran planning is significant, while in countries such as Venezuela and Taiwan there are no national-level disaster plans. In Turkey, until recently, there was no single national coordinating agency for disaster management, although there was a blueprint for action and assignment of responsibilities (Gulkan and Ergunay 1999:176). The existence of government agencies, however, says nothing about the quality of their operations in either planning or managing. There must also be public interest in addressing risks. Seoul was flooded in 1966, 1972, 1984, 1987, and 1990 (Kim 1999:92) though little action has been taken to address the recurrent flooding.

There is also considerable variation in planning for technological disasters. A survey of mitigation and other preparations for disasters in developing countries in Asia and the Pacific found that while there was at least minimal planning for natural disasters, there were almost none for technological disasters (ADB 1991). A survey of national disaster plans of developing countries suggests that governments give less attention to technological disasters than natural disasters. Mexico City, for instance, paid little attention to planning for technological disasters until after the 1985 earthquake.

It is generally accepted that the best disaster planning and management involves the following (Sorensen 1988:241–260; Quarantelli 1991):

- Views disasters as different from accidents and minor emergencies;
- Views catastrophes as different from disasters;
- Focuses on multiple hazards and is generic rather than agent-specific;
- Includes all four time phases of the planning process: mitigation, preparedness, response, and recovery;

- Aims at multiple rather than single-hazard or risk-reduction goals;
- Focuses on general principles rather than specific details;
- Highlights a continuing process rather than an end product, such as the production of a written plan or a document for mitigation;
- Builds on research findings derived from systematic data in addition to personal experience;
- Emphasizes the need for coordination both within and between organizations and segments of the community, rather than "command and control"; and
- Distinguishes between planning and managing, between the strategies and the tactics necessary.

Disaster planning includes developing a set of activities and systems to prepare for and predict disasters. Forecasting and warning systems, community education, emergency operations centers, and medical and food stockpiles are part of the preparation. This can be difficult in urban areas that are struggling to develop and where basic infrastructure and municipal services are lacking. Funding infrastructure and activities in these areas for events that may never occur may seem like a waste of precious financial resources. Urban communities should put disaster preparedness planning on their community agendas, however, and link it to overall developmental planning since such investments need to be protected. This is especially important in developing countries where disaster management agencies and awareness at the local level are rare.

Mitigation. The concept of "mitigation" in the event of a disaster has been around since ancient Egypt and China, perhaps since 4000 B.C. (Qingzhou 1989: 193–194; Waterbury 1979). More recently in the United States, mitigation has involved structural mitigation such as dams and levees to reduce flooding.

"Mitigation" tends to be used in two major but differing ways in research and professional disaster literature. In the United States and several other countries, it generally refers to "away from and prior to impact period" measures and includes activities to eliminate and lessen risks. Examples include improved building codes, consciousness-raising about risks and disasters, targeted educational programs, relevant zoning and land-use rules, insurance purchase (Britton 1991), and compliance and enforcement of safety regulations. Successfully implemented mitigation measures can in part explain the great difference in the number of casualties between the earthquake in Armenia (10,000 to 25,000 deaths) and Northridge, California (61 deaths). Appropriate construction materials and the enforcement of housing codes in the United States resulted in few casualties during the earthquake (Poghosyan 2000), while damage was heaviest in recent construction in Armenia and Mexico City as buildings collapsed (Krimgold 1992:217).

An initial requirement for mitigation planning is community awareness of probable disasters in their urban locality. This may seem obvious, but for many communities a major disaster is a one-time occurrence in the course of a generation. Studies in the United States indicate that the majority of citizens have never directly experienced a major disaster. This is not true of disaster-prone cities such as Buenos Aires, which was flooded 37 times in the past 15 years (Herzer and Clichevsky 2000:34), nor is it the case for Bangladesh and some Pacific island nations. Without personal experience, however, people generally do not believe they are at risk from a disaster. An ongoing Disaster Research Center (DRC) evaluation study in the United States called "Project Impact" reports that, "Repeatedly, DRC researchers have heard from [Project Impact] community leaders ... that it would be necessary to have a disaster hit their communities in order to focus attention on the need to support mitigation activities" (*Disaster Resistant* 2000:25). Even after a disaster, people can dismiss the event as a one-time occurrence. Thus, disaster planning, especially for mitigatory measures, must take into account the experience of disasters in an area over time—perhaps over two generations.

While some communities are unaware of their vulnerability, others are very aware, but take little action because the pattern of disasters has not been studied and no reliable predictions are made. Dhaka, Bangladesh, has been the site of numerous floods that have inundated much of the city. Two-thirds of all slum dwellings were flooded in 1987 and the next year 77 percent of the city was flooded (Huq 1999:130). A recent analysis offered the following observation: "Historical data on hazards and disasters in Dhaka are almost totally lacking. This makes it difficult to project likely patterns of risks and potential losses in the expanding city of the future" (Huq 1999:125). This lack of data and inadequate preparedness of citizens has led residents to respond in the only way they thought they could save themselves—prayer. In a survey of two coastal communities in Bangladesh struck by a cyclone, it was found that "praying to Allah" was undertaken by 73 percent of residents in one village and 90 percent in another. In both localities, it was the most frequent precautionary measure taken (Haque and Blair 1992:225).

Awareness of potential disasters is the first step, although knowledge about possible disasters must be accompanied by a willingness and an ability to implement mitigation measures, since awareness does not automatically translate into action. In a recent survey of disaster planning in Tehran, Iran, it was noted that the area has a history of earthquakes of magnitude 7.0 and higher. Though a comprehensive plan for disasters has been developed by officials, "The steps that people can take to protect themselves are not known and the demand of the community to have themselves protected is not forthcoming" (Nateghi-A. 2001:210). The same seems to be true for the threat of floods in Seoul, Korea. City officials are aware of potential disasters, but neither flood-risk zoning nor land-use control is practiced, partly because of citizen "indifference" and also because in a densely populated, fast-growing city all available land is used and low-lying areas filled in (Kim 1999:112).

Though a community may want to minimize its exposure to potential disasters, hazards are sometimes thrust upon them. Multinational corporations, often the investors in chemical and nuclear facilities, generally deal with a central government. As a result, local authorities frequently have little say on the siting and inspection of facilities, particularly in developing countries where community input is ignored (Towfighi 1991:107). Multinationals have the added complication of public relations and avoiding bad publicity, which could hinder disaster response. In Bhopal, for example, civil authorities called the factory, but the staff did not confirm the chemical leak, thus delaying evacuation and causing confusion among civil authorities and police trying to respond (Bowonder 1985:250) to the mounting disaster.

At the community level, there should be insistence upon appropriate mitigatory measures, the use of safety technology, and an effective regulatory system. Technology can increase the probability that key installations are properly designed and run and that monitoring systems are in place and used. A regulatory system monitored by community authorities can increase social pressure for proper maintenance and procedures. In the United States, however, some have contended that this had led to over-regulation, particularly in the nuclear industry. This may seem like a strong counter-argument, but the result of "over-regulation" has been a safety record where there has never been a nuclear accident in the United States resulting in casualties outside the facilities.

Restrictive land-use measures and zoning codes also reduce risk, but there must be socioeconomic and sociopolitical support for such measures. In Brazil, vested interests in rapid economic growth result in weaknesses in institutional strategies for the reduction of accidents. Risk analysis, land-use planning in the siting of hazardous facilities, mandatory accident notification, disaster planning, and information dissemination about risks and response measures for crisis situations are frequently ignored (Porto and Freitas 1996:20). Even in developed countries, it is not the absence of knowledge about floodplains that causes problems, but an unwillingness to use this knowledge in community planning.

A local risk assessment provides the starting point for understanding the most immediate threats and preparing appropriately. The risks and preparedness measures identified must be communicated to the local population. Risk awareness, however, does not translate automatically into preparedness. Especially for chemical and nuclear risks, specific measures must be taken to protect the population and contain the threat. For example, there have been instances of fire departments provoking explosions and fires by spraying water on otherwise inert chemicals. In Bhopal, medical personnel, the government, and local communities should have been briefed that methyl isocyanate (MIC), a toxic substance, is inactivated when people breath through a moist towel. This would have saved a number of lives (Bowonder 1985:96).

Disaster response. When a disaster can be predicted or is spreading, evacuation is often the official recommendation, though it is not always followed (Perry 1985; Vogt and Sorensen 1987). People are often reluctant to leave their homes and farms, which might represent their life savings. In a 1991 cyclone in Bangladesh, half of the households in two coastal villages, all of whom received early warnings of the threat, did not leave to seek shelter (Haque and Blair 1992:217). One hundred and thirty-nine thousand people died in the storm. Chemical and nuclear disasters also result in large-scale evacuations even when fatalities are expected to be minimal. For example, a 1985 toxic sulfur trioxide release in New Delhi, India forced 100,000 to evacuate and a 1989 crude oil explosion resulted in 200,000 evacuees from Guadalupe, Mexico, though neither case resulted in a significant number of deaths (Cutter 1991:280).

Once a disaster strikes, the overwhelming majority of search and rescue activities are carried out by friends, relatives, and neighbors. It is impossible to predict how people will respond, but knowing of risks and preparing communities to face them can improve response. Though some activities such as rescuing people from collapsed buildings may require heavy equipment, urban officials in earthquake and other disaster zones should ensure that equipment and trained crews are available. A review of disaster plans from a number of urban Asian cities, however, found that, with the exception of Singapore, few cities addressed the idea of collapsed buildings in preparedness planning.

In many countries, the military is often the key respondent to a disaster (Walker 1992). Ironically, however, military organizations have not been systematically approached for an analytical perspective on disaster response. Neither have religious organizations. Relief provided by churches and organized religious groups frequently ranks very high as a major source of aid. At the international level, appeals are often made to smaller congregations, who donate generously. As urban officials prepare disaster plans, they should encourage the participation of these experienced groups in their planning.

Disasters result in loss of life, homes, livelihoods, and economic activity. Industrial areas, business districts, crops, and livestock are frequently ravaged during disasters. Businesses and economic entities often face not only the loss of a place of business, inventory, and income during the days of the disasters, there are numerous lingering impacts. Suppliers may be delayed in delivering products, people may have lost the means to patronize a business, and employees and customers may be suffering from a lingering trauma that hampers a business' return to normality. Small businesses are typically hardest hit since protective measures may be prohibitively expensive. Corporations tend to have more measures in place and multinationals are often best equipped to pay for and carry out mitigation strategies.

Some businesses recover in the long run, although those that were marginal in the pre-disaster period often fail or do not reopen in the aftermath of a major disaster. Surprisingly, prior preparedness planning seems to have little effect on recovering from a disaster, although this might be due to poor preparedness planning that did not take into account the special needs of businesses from the start. There is also no clear relationship between disaster recovery and disaster assistance provided by government agencies. In fact, "there was no relationship whatsoever between the number of aid sources businesses relied on during the post-disaster period and the extent to which they recovered" (Webb and others 1999:16).

When Disaster Strikes

Even though some communities have put disaster management plans in place, difficulties in implementing them can be illustrated by the following observations made in Ecuador, Peru, and Bolivia during 1997 and 1998:

> While the civil defense organizations in the respective countries were the nominal "national emergency organizations" … each was rapidly pushed to the sidelines by one or more new but temporary governmental organization charged with supposedly managing the response. The result was 1) confusion and duplication at the institutional level, and 2) a serious loss of credibility and morale in each country's civil defense structure. This is hardly the combination one would seek for optimizing institutional readiness (Olson and others 2000:5).

The same scenario occurred after Hurricane Mitch, though local agencies knowledgeable about an area should assume a lead role, especially if they have prepared for such an event. The strengthening of their capacities for all levels of a crisis means that fewer crises will become emergencies, fewer emergencies will become disasters, and fewer disasters will become catastrophes. If these agencies are adequately prepared, they will be able to respond appropriately and call in reinforcements and additional expertise as necessary. Civil defense organizations should also accept that disasters and catastrophes are likely to become political and plan for that eventuality (Olson and others 2000:36). This also applies in the disaster mitigation process for, as has been said, "The decision-making process about the acceptability of risks is essentially a political process" (Porto and Freitas 1996:24).

With local organizations at the helm, the resumption of essential services, with which they are most familiar, can more easily resume and be balanced with the provision of emergency services. A general disaster planning and management principle is that organizations should stick to their mandates and attempt to return an area to normal life as soon as possible. However, in all major disasters, new behaviors and groupings will emerge as people and organizations cope with the multiple contingencies created that cannot be handled by routine service delivery. In fact, the greater the disaster, the more improvisations will appear, accompanied by pluralistic decision-making in tasks ranging from evacuation and the provision of emergency medical services to inter-organizational coordination and community priority-setting (Quarantelli 1996).

Events that disrupt communities are not all of the same magnitude, since a disaster is more than an everyday emergency. In a disaster, the core emergency and response facilities can be destroyed. In recent catastrophes in developing countries, small towns have had their medical and police personnel wiped out. Outside agencies later responded, though their response times were longer, they were unfamiliar with the area, and there were "turf wars" as agencies staked out their territories.

The following describe some of the differences in organizational response that can be expected in disasters and catastrophes as opposed to regular emergencies (noted in Quarantelli 1998a:5–8):

- Organizations must relate quickly to a number of familiar and unfamiliar groups. For example, a research team studying a massive fire near Nanticoke, Canada, identified 346 organizations inside the evacuation perimeter of the fire—all of whom had to pass through a police checkpoint (Scanlon 1992:9). Even for a plane crash in Detroit, the DRC found 241 organizations responding, including 59 fire departments and 69 agencies represented at the Emergency Operations Center. In contrast to disasters, everyday emergencies do not bring about such a massive convergence of groups.
- Organizations must adjust to a loss of autonomy and freedom of action. Minor emergencies are often managed by public sector organizations such as fire and police departments, private organizations, and the private sector. Individuals may also be required to surrender individual and property rights to "the greater good" as search and rescue is carried out and access to some areas is restricted.
- Performance standards and norms for organizations often change drastically during disasters. What is appropriate during periods of normalcy or minor emergencies typically becomes less relevant during the management of a major crisis. There is often a deliberate slowdown in organizational activities that does not occur in everyday emergencies.
- A catastrophe can have even graver consequences than a disaster, since most or all of a community is heavily impacted. In a DRC field study, it was found that Hurricane Hugo destroyed or heavily damaged more than 90 percent of all homes in St. Croix, U.S. Virgin Islands. The near total destruction made it impossible for displaced victims to seek shelter with relatives and friends. By contrast, the 1985 Mexico City earthquake destroyed less than 2 percent of residential housing stock and only 4.9 percent of the population reported significant damage to their homes. Of those displaced, most found accommodation with relatives.
- Catastrophes have longer recovery periods than disasters. Massive destruction of buildings may make it impossible for some to return, while others might have lost their places of work. This was true in the 1988 Armenian earthquake. For years afterward, there were few inhabitable buildings. The population of Leninakan dropped from 230,000 to 120,000; Kirovakan from 170,000 to 74,000; and Spitak from 18,000 to 3,000 (Poghosyan 2000). While it is difficult to prepare for such a massive quake, there are useful lessons to be found in the recovery since the areas are thriving once again.

Once a disaster has occurred or the threat seems to have passed, the end of the evacuation period is often announced. This can be more controversial than evacuation, however (Stallings 1991:193). Estimating the remaining danger and ensuring a measure of safety are often impossible. Some people may feel it is safe to return home while officials may disagree, not wanting to incur expensive re-evacuation costs if the area proves unsafe. In other cases, a government may have run out of funds to assist evacuees and wants people to return home—even though, in the case of nuclear or chemical hazards, the area may not be safe from invisible threats and the effects might not be known for years (Stallings 1991:195).

Recovery management. Recovery deals with activities undertaken after a crisis response period is over in an attempt to return an area to normal. In the short term, the focus is on restoring infrastructure and service delivery. In the long term, the attempt is to restore community life. Specific measures can include providing financial and technical assistance to farmers wanting to clean up contaminated farmland, setting up of counseling services for victims, restoring urban services, and rebuilding damaged and destroyed facilities (see Mitchell 1996). There may also be calls for such an event never to be allowed to happen again.

In the aftermath of a disaster, citizens may be outraged that certain "avoidable" incidents took place and local officials did not sufficiently protect or warn them. People often organize following a disaster and political activists take advantage of such an opportunity to politicize people around this and other issues. Where recurrent threats are possible, citizens groups are even more likely to emerge (Quarantelli 1988). Activist groups appeared in Mexico City after the 1985 earthquake (Dynes and others 1990), Bhopal after the chemical poisoning, and Turkey after the 1999 earthquake. Groups may also seek out those who should or are thought to be responsible for augmenting the disaster. The discovery of building codes unenforced, warning messages not passed along, and delays in disaster response can provoke the wrath of disaster victims.

Once politicized, citizens may insist upon the passage of laws and regulations to prevent similar disasters in the future. Activist groups and NGOs may also try to prepare the local population for future threats. Taking advantage of public interest and partnership opportunities, governments can channel resources of these groups to be better prepared in the event of other emergencies.

In the longer term, disasters have been found to have impacts upon the political process. A study of 12 countries struck by rapid-onset natural disasters between 1966 and 1980 found a positive relationship between disaster severity and subsequent political unrest (Olson and Drury 1997; Drury and Olson 1998). Studies of Africa and Latin America found a relationship between regime type, mismanagement, and levels of disaster damage (Davis and Seitz 1982; Seitz and Davis 1984). In a recent study, Shefner (1999) looked at whether the sewer explosions in Guadalajara, Mexico had any political fallout. Although he found that the political activists who emerged after the disaster had nearly disappeared two years later, there were longer-term effects in later elections.

Political issues also arise out of uncertainties. Victims of technological disasters often find themselves with health concerns for which there is no ready remedy. Their daily existence becomes a stressful guessing game of identifying symptoms and disease, and the uncertainty increases the duration of the disaster. This post–traumatic stress affects an unknown number of victims of technological disasters, although just 3.8 percent of victims of natural disasters appear to be affected with this psychological trauma (Brody 2000:D8).

Sometimes psychological stress is the "disaster." For instance, there were no casualties and little property damage in Mississauga, a suburb of Toronto, when 217,000 residents had to be evacuated following a train derailment that threatened the release of toxic chemicals (Scanlon and Padgham 1980). Though no one was killed, the threat and evacuation disrupted the lives and routines of nearly a quarter of a million people for several days and caused psychological, social, and indirect economic impacts. Similarly, the Three Mile Island nuclear threat "provided a dramatic demonstration that factors besides injury, death, and property damage impose serious costs." Although it caused not a single death and few if any latent cancer fatalities, it devastated the utility that owned and operated the plant and imposed $500 billion in costs and sanctions on the nuclear industry and society. Following the incident, stricter regulations, reduced operation of reactors worldwide, greater public opposition to nuclear power, increased reliance on more expensive energy sources, and increased costs of reactor construction and operation resulted (Slovic 1987).

An even more unusual example occurred in Goiania, Brazil, where a cancer treatment machine abandoned in a junkyard released cesium 137. The radioactivity killed four people and seriously affected 44 others. But far more consequential was the perceived risk to the town's 1.2 million residents. Over 100,000 residents underwent Geiger counter examinations to detect possible contamination, and some 8,000 formal certificates were issued stating that the person was not a carrier of hazardous radiation. Anxiety over contamination also led hotels in the country to cancel the reservations of people from Goiania, buses and airplanes to refuse to take Goiania residents as passengers, and some doctors and dentists refused new patients who did not have the formal certificates. Conventions in Goiania were also cancelled. One estimate was that regional tourism fell 40 percent and it was reported that property values fell, with sales levels for the entire city and state being affected. Some 50 percent of the state's export sales were lost for one month because the area's agricultural products were boycotted (or purchased at 50 percent of value). Even textiles and clothing manufactured in Goiania were affected, with some items losing nearly 40 percent of their value (Petterson 1987: 3–4, 8–9, 12).

Recovery is often a complex economic and social process, and it becomes protracted when a disaster has contaminated and polluted buildings, their contents, and the surrounding air, land, and water. While this is more likely in technological disasters, it can also happen with volcanic eruptions like Mount St. Helens and floods such as the one that struck eastern India in August 2000, where the flood waters contaminated vast supplies of drinking water (Kim 2000). To the extent possible, contamination needs to be contained, but having the appropriate quick response is not often possible.

Agencies and groups involved in recovery also tend to be different from those that participate in the preparedness and response phases of disasters. Police and fire personnel, emergency medical teams, and emergency and crisis managers are typically the major players during the preparedness and response phases. City officials such as community planners, and building and housing inspectors, as well as members of the private sector such as insurance agents and bankers, are more active during the recovery period. These two groups do not always communicate during the normal course of business and expecting them to suddenly work together amicably is unrealistic. If these groups are involved during the planning phases, however, and get to understand each other's agendas, the recovery period will run smoother.

Additionally, to improve future disaster risk planning, recording a disaster and response to it can provide valuable lessons. In Bhopal, authorities and medical personnel were never told of the threat that lurked in the Union Carbide plant. When chemicals leaked, hospitals gave only symptomatic treatment for the unknown poisoning (Bowonder 1985:86). In both the Three Mile Island and the Chernobyl nuclear accidents, iodine pills that could have reduced some of the effects of radiation had neither been stored in sufficient quantities nor adequately distributed during the crisis. These provide clear lessons for authorities working in areas where there are chemical or nuclear plants.

Economic Impacts

Economic loss is often the determinant of whether an event is described as a disaster or a catastrophe. Looking at total dollar amount alone is not enough, however since "the economic costs of disasters in poor countries often exceed 3 percent to 4 percent of the gross national product…. In … economically vulnerable East African countries … the costs exceeded over 20 percent of GNP at various times during the 1980s. In contrast, the $24 billion loss from the 1992 Hurricane Andrew disaster in South Florida, which was at the time the costliest disaster in the history of the United States, represented an almost undetectable proportion of the country's $6 trillion economy" (Berke 1995:372). Others have noted that the Managua earthquake of 1972 resulted in $5 billion in damage, nearly 40 percent of Nicaragua's GNP, while the $8 billion in damage from the Loma Prieta earthquake represented only 0.2 percent of the GNP of the United States (Hohn 1995:573). What is "disastrous" in a developed country might be "catastrophic" in a developing one.

Disasters in developing countries often affect large numbers of people, also. It will forever remain unknown whether Hurricane Mitch directly affected 24.2 percent of the population in Honduras or 19.5 percent in

Nicaragua (Reconstruction 1999:13), but clearly a significant percentage of the population was impacted in one way or another. The recent floods in Mozambique affected 27 percent of the population (Swarns 2000:9). By contrast, the U.S. Federal Emergency Management Agency (FEMA) reported in 1998 that from 1993 to 1998, at least 1,400,000 Americans were impacted in federally declared disasters and that at least hundreds of thousands of other people were impacted by events managed entirely at state or local levels. This indicates that, over a six-year period, only half of one percent of the American population was affected.

Though disasters in developing countries affect greater numbers of people and can destroy a greater percentage of the domestic economy, the impacts of disasters are no longer restricted to the areas they strike. Globalization now increases vulnerability for everyone. When a 1999 earthquake destroyed a number of Turkish weaving factories, cotton production in Sub-Saharan Africa was affected. The market for cotton was drastically reduced and unemployment rose in several African countries. Similarly, when an earthquake hit Taiwan in 1999, the sales of computers in the United States were impacted, since critical computer components were manufactured in Taiwan. Also, following an explosion at the Nisshin chemical plant in Japan, there were difficulties for the global semiconductor industry, since the company provided the world's main source of hydroxylamine, a chemical vital to photoresist stripping of semiconductors (Kallender 2000).

Tourism, often a significant source of revenue and foreign exchange in developing countries, is commonly another victim of disasters. In Indonesia, fires created such thick smoke pollution in 1997 that Brunei, the Philippines, and other Southeast Asian countries were affected (Khandekar and others 2000) and the Thomas Cook travel agency refused to book vacations in affected areas, since poor visibility due to the smog curtailed, delayed, and canceled flights (Tourism 1997). A number of nations lost their share that year of Southeast Asia's annual $26 billion tourism industry (Mydans 1997:3).

Due to complex social links in the modern world, future disasters could have catastrophic potential even if they do not result in casualties or physical impact. There is a tendency to equate disasters with casualties and property damage. However, events that are catastrophic in terms of such losses are relatively rare. For example, earthquakes are infrequent. "Over 70 percent of the approximately 1.3 million earthquake related deaths since 1900 have occurred in 12 single events…. In the United States, only an estimated 1,600 deaths have been attributed to earthquake since colonial times" (Jones and others 1993:19, 20).

Improved Disaster Risk Management

Little distinction should be made between preparedness for natural and technological disasters. Researchers summarizing the discussions at a recent international conference held in Japan on natural-disaster reduction noted that the core issues in risk management for natural disasters are similar for all disasters and the involvement of people in developing strategies for disaster mitigation is crucial (Herath and Katayama 1994:1).

Current disaster theorists argue that all disasters can be attributed primarily to human actions and that no distinction between "natural" and "technological" disasters is significant for general disaster-risk-management purposes. Recently, several authors from six different countries and social science disciplines agreed that the distinction has been increasingly abandoned by most scholars in emergency management operations worldwide (Quarantelli 1998b:248). However, others—Kroll-Smith and Couch (1991), Baum and Fleming (1993), Freudenburg (1997), Picou and Gill (1999), and Picou (2000)—write that technological disasters are unique since they result in long-term social impacts not seen in natural disasters.

Yet another objection to making a natural/technological distinction is that there are disasters where no agent is clearly identifiable. Famines are the best example of this. Also, for newer types of disasters such as computer system breakdowns, the source of the problem can be natural, technical, or social. That is, computer systems can be brought down by earthquakes, power outages, or hackers. The stock market crash of October 1987 was a disaster whose occurrence did not directly result in any fatalities, but with a one-third decline in the Dow Jones Industrial Average, $1 trillion vanished in four days (Barro and others 1989:127). Resulting economic losses around the world brought the total significantly higher. Natural and technological disasters are nowhere near this costly in such a short period.

Taking Action

It is sometimes thought that the solution to better disaster planning and management lies in more and better technologies. Even when addressing natural disasters, there is a tendency to fall back on technological and engineering solutions. In Florida, six million people now live in counties along the ocean shore where there were 500,000 residents 60 years ago. Though hurricanes regularly hit this area, the loss of life has steadily declined. This is attributed to better warning systems and evacuation plans (Ingelton 1999:30) as well as improved construction materials. Developing countries do not have such resources, however, and there are calls by environmental groups to halt construction in disaster-prone areas.

Globally, some changes have already occurred or are in the process of being established, although overall strategies are still lacking. *International Strategy for Disaster Reduction* 1999 (UN/ISDR 1999) newsletter describes the following range of activities and programs:

- Numerous agencies and groups in the region are now involved in disaster planning and management;
- A variety of educational activities have been initiated;
- A number of partnerships and links have been created;
- Information networks have been established;
- Relevant guides and reports have been published;
- Numerous disaster-related meetings and conferences have been held;
- Legislation for disaster prevention has been passed or advocated; and
- Warning systems have been planned or put in place.

Global disaster networks offer opportunities for information sharing. The Global Disaster Information Network (GDIN) and the Disaster Research Center (DRC) are two organizations engaged in studying disasters and bringing together professionals from the field of disaster management. Increased use of the Internet worldwide makes their research available to a growing audience and improves access to information that can be used in disaster planning.

The mass media also play a role in disasters, especially global news organizations such as the BBC and CNN, whose reporting brings global sympathy and assistance to devastated regions of the world. These media provide the lens through which most of the world views disasters (Seydlitz and others 1991; Baum and Fleming 1993). As Rosenthal, Comfort, and Boin suggest, “If CNN defines a situation as a crisis, it will indeed be a crisis in all its consequences. Mediazation will be one of the driving forces in the world of future disasters and crises” (forthcoming:7). Such reporting is generally not sufficient in planning for disasters, however, since planning for a disaster is not “news.”

Disaster management officials should take advantage of the penetrating reach of local and national media to involve them in disaster planning and management. Not only can the media carry warnings of immediate threats, they can broadcast other aspects of disaster preparation and management and provide information to people who are unable to read newspapers and disaster-management handouts.

Education. At a formal level, scientists and social scientists plan for and deal with disasters. Following Hurricane Mitch in Central America, projects to train more meteorologists in weather forecasting were implemented (Reconstruction 1999:47). Schools at the primary and secondary levels are also good venues for spreading awareness messages, since children can bring this information home to their families.

Standardizing terms and concepts can also improve disaster management, especially with regard to statistics. The Regional Disaster Information Center (CRID) in San Jose, Costa Rica, has created a thesaurus of standardized descriptors used in its documentation database (CRID 2000:4). Also, the Centre for Research on the Epidemiology of Disasters (CRED) has undertaken major efforts to improve the data it obtains and processes, especially for its database containing information on more than 12,000 disasters that have occurred globally since 1900. Their efforts have led to attempts to standardize terms so that statistical compilations do not combine incompatible phenomena.

Improving disaster statistics rather than documenting hazards can also help researchers understand the negative impacts of disasters. Officials and NGOs in developing countries should be trained in data collection so that statistical databases of deaths, injuries, property damage, and social disruption can be created and lessons learned. The statistics are useful in monitoring trends and predicting future disasters in hopes of saving lives and property.

Government and community action. Some communities emerge stronger and spur governments to action to better prepare for or prevent future disasters. As stated earlier, respondents to disasters can only work with the existing infrastructure and social systems so change must come before the next disaster, not after. If a flow of communication is needed to respond to a disaster and that communication is absent under normal circumstances, it will not jump into existence during a disaster. Improved technologies cannot help either, unless people are trained to use them. Better radios, for example, do not translate into better communication unless put into use earlier as part of a normal functioning system.

There are several stages in the overall disaster-risk-management-planning process, as follows:

- Formulation of emergency response policies;
- Adoption of policies by government and social service agencies;
- Development and adoption of appropriate region-specific programs;
- Identification of target audiences for each level of an emergency response program (these could range from village women to higher levels of national governmental bureaucracies);
- Program implementation by government and private organizations;
- Application of both general and specific disaster principles;
- Obtain feedback on whether the desired results are achieved; and
- Take into account social changes that may affect the newer threats and vulnerabilities that might occur (adapted from Wenger and Drabek 1987; see also WHO 1999).

Recommendations for Developing Countries

As recently as a decade ago, approximately 80 percent of the population lived beyond the outskirts of cities with populations of 100,000 or more (Kasarda and Crenshaw 1991:472). As discussed earlier, the shifts in population have altered this demographic. Some countries have not recognized that, although they were once primarily rural, they are becoming more urbanized each day. This lag is illustrated by the fact that government departments dealing primarily with agricultural issues are still the main organizations responsible for national-disaster planning and management, even where the population has become urbanized.

There are several recommendations developing countries and international groups might want to adopt to improve disaster readiness. The governments of developing countries currently have various levels of disaster planning, although most are not fully ready to address their vulnerabilities in the event of major natural or technological disasters. There should be a commitment by policy and decisionmakers to put disaster planning at the top of their agendas. A passive willingness to accept disaster planning is not enough. There must also be follow-through measures, particularly financial support. Olson and his colleagues note that, while a national law addressing disaster planning had been proposed five years earlier in Nicaragua, it was not until the 1999 legislative session that a disaster fund, with a corresponding budget allocation, was provided (1999:56). Disaster-related laws without financial support are ineffective. Countries have to look at all resources—local, regional, and national—to fund disaster-management programs. Even in the United States, Superfund legislation to clean up toxic sites is political and subject to budget cuts from Congress.

There is a need for specific risk analysis of the possible disasters in each country. To study natural disasters, new tools such as Geographic Information Systems (GIS) can be used in conjunction with social networks to understand the dynamics of a particular area. The Global Disaster Information Network and the Disaster Research Center, mentioned earlier, serve as forums for exchanging information about disasters—useful to those with Internet access. A British satellite developer announced plans to launch in 2002 a constellation of five satellites devoted to monitoring natural and manmade incidents. A number of other technological advances have been made that can benefit disaster-management organizations, provided they have access to emerging technologies (Richharia 2001: 23; Hofmann-Wellenhof and others 1994).

Disaster planning should be part of developmental planning and should be discussed at local and national levels. More than two decades ago, Long (1978) argued that disaster planning should be linked to national development planning, but as John Mitchell notes, "Until recently, disaster relief and long-term development tended to be seen as distinct entities" (1998:14). It is perhaps equally important to look at those developing countries where such a link has been made.

Evidence suggests that emphasis on disaster-management planning and coordination at the national level is the most effective (Dynes 1990). Once a policy has been articulated, the center can work with local governments to plan regional contingencies. The responsibilities of the numerous local public and private emergency response organizations can be spelled out in advance and backed-up by the resources available at the national level. The Federal Emergency Management System (FEMA) in the United States is an example of an organization that coordinates responses to natural and technological disasters and makes federal disaster assistance available to severely affected communities. FEMA also has a data bank of disaster planning and response materials.

Finally, more attention needs to be paid to extreme disasters in two respects. First, there is a need to plan for a catastrophic disaster that could massively impact a society and be truly national in scope. Some developing countries have experienced such events. The impact of Hurricane Mitch on Honduras was catastrophic. The same is true of the 1988 earthquake in Armenia (see Poghosyan 2000:26–29 for reasons why official statistics on casualties and property losses, though high, might have been underestimates). Likewise, monsoon rains in India in August 2000 left millions homeless in three eastern states and wiped out whole villages (Farooq 2000). Second, increasingly, there will be major disasters whose origins will be distant from where they eventually impact. Such circumstances present difficulties for disaster managers who must grapple with an increasing number of variables.

Recommendations for International Financial Institutions

In the last decade, several international financial institutions (IFIs) have taken significant steps with respect to addressing disasters. These improvements include establishing environment departments, explicitly building prevention requirements into recovery loans made to developing countries, and markedly raising the disaster consciousness of their own personnel.

IFIs can play a significant role in disaster planning and management since they operate in most developing countries. The following offer several suggested courses of action:

- Raise the consciousness of officials at all levels of government on disaster-management issues;
- Raise community awareness of disaster planning and mitigation measures;
- Link disaster management to development objectives;
- Assist in the development of databases through the collection, analysis, and storage of standardized data on disaster losses. Assist developing countries in linking national disaster systems into larger networks;
- Promote global approaches to disasters and involve multinational corporations that cross national boundaries;
- Focus attention on the social aspects of behavior that cause disasters; and
- Conduct follow-up assessments several years after disaster policies, programs, and plans have been put in place.

The globalization of culture should also be taken into account, since knowledge of natural and technological disasters and lessons learned from other disasters often comes from the global media. And, since people generally experience no more than one disaster in a lifetime, people should be prepared and not have to be victims of such an experience to mitigate, prepare for, and respond quickly to a disaster.

Bibliography

Acharya, Rohini. 1999. *The Emergence and Growth of Biotechnology: Experiences in Industralised and Developing Countries*. Chelton, England: E. Elgar.

Adams, Barbara. 1998. *Timescapes of Modernity: The Environment and Invisible Hazards.* London: Routledge.

ADB (Asian Development Bank). 1991. *Disaster Mitigation in Asia and the Pacific.* Manila.

Alba, Richard. 2000. "Ethnicity." In Edgar Borgatta and Rhonda Montgomery, eds., *Encyclopedia of Sociology.* NY: Macmillan.

Barro, R., E. Fama, D. Fischel, A. Meltzer, R. Roll, and L. Telser. 1989. *Black Monday and the Future of Financial Markets.* Homewood, IL: Dow Jones-Irwin.

Baum, A. and I. Fleming. 1993. "Implications of psychological research on stress and technological accidents." *American Psychologist* 48: 665–672.

Beck, U. 1995. *Ecological Politics in an Age of Risk.* Cambridge, England: Polity Press.

Beck, U. 1999. *World Risk Society*. Cambridge, England: Polity Press.

Berke, Philip R. 1995. "Natural-hazard reduction and sustainable development: A global assessment." *Journal of Planning Literature* 9: 370–375.

Bowonder, B. 1985. "The Bhopal incident: Implications for developing countries." *The Environmentalist* 5: 89–103.

Bowonder, B. and Jeanne Kasperson. 1988. "Hazards in developing countries: Cause for global concern." *Risk Abstracts* 5: 103–109.

Bowonder, B., J. Kasperson, and R. Kasperson. 1985. "Avoiding future Bhopals." *Environment* 27: 6–13, 31–37.

Britton, Neil. 1991. "Hazardous industries and risky technologies: A new role for insurance?" Unpublished paper.

Brody, Jane. 2000. "When post-traumatic stress grips youth." *New York Times.* March 21, 2000: D8.

"CRID standardizes disaster terminology." 2000. *Disasters: Preparedness and Mitigation in the Americas* 81 (July): 4.

Cutter, Susan. 1991. "Fleeing from harm: International trends in evacuation from chemical accidents." *International Journal of Mass Emergencies and Disasters* 9: 267–285.

Davis, Ian. 1987. "Safe shelter within unsafe cities: Disaster vulnerability and rapid urbanisation." *Open House International* 12: 5–14.

Davis, Morris and Steven Seitz. 1982. "Disasters and governments." *Journal of Conflict Resolution* 26: 547–568.

Degg, Martin. 1992. "Natural disasters: Recent trends and future prospects." *Geography*: 198–209. *Disaster Resistant Communities Initiative: Evaluation of the Pilot Phase Year 2. Year 2 Report.* 2000. Newark, DE: Disaster Research Center, University of Delaware.

Dogan, Mattei and John Kasarda, eds. 1988. *The Metropolis Era: Mega-Cities*. Beverly Hills, CA: Sage.

Dommelen, Ad Van. 1999. *Hazard Identification of Agricultural Biotechnology: Findings From Relevant Questions.* Utrecht, The Netherlands: International Books.

Drury, A. and Richard Olson. 1998. Disasters and political unrest: An empirical investigation. *Journal of Contingencies and Crisis Management* 6: 153–161.

Dugger, Celia W. 2000. "A cruel choice in New Delhi: Jobs vs. a safer environment." *New York Times* November 24, 2000.

Dynes, Russell R. 1990. "Community emergency planning: False assumptions and inappropriate analogies." Preliminary Paper # 145. Newark, DE: Disaster Research Center, University of Delaware.

Dynes, Russell R. Forthcoming. "Social science research: Relevance for policy and practice." In Claire Rubin, ed., *Study on Improving Earthquake Mitigation*. Report to FEMA:105–124.

Dynes, R., E. L. Quarantelli, and D. Wenger. 1990. *Individual and Organizational Response to the 1985 Earthquake in Mexico City.* Newark, DE: Disaster Research Center, University of Delaware.

Farooq, Omer. 2000. "Monsoon rains leave millions homeless in India." *Wilmington News Journal* August 28, 2000: A2.

Fisher, Ian. 2000. "Brownouts in Kenya highlight its chaos and misrule." *New York Times* June 25, 2000: 10.

Flynn, James, Paul Slovic, and C. K. Mertz. 1993. "Decidedly different: Expert and public view of risks from a radioactive waste repository." *Risk Analysis* 13: 643–648.

Freitas, Carlos, Marcelo Porto, and Jorge Machado, eds. 2000. *Acidentes Industriais Ampliados: Desafios E Perspectivas Para O Controle E A Prevencao.* Rio de Janiero, Brazil: Editora Fiocruz. (In Portuguese).

Freudenburg, W. R. 1997. "Contamination, corrosion and the social order: An overview." *Current Sociology* 45: 19–40.

Fuchs, R., C. Brennan, J. Chami, F. Lo, and J. Vitto, eds. 1994. *Mega-city Growth and the Future.* Tokyo: United Nations University Press.

Geipel, Robert. 1993. "The River Danube flood of 27 March 1986." In J. Nemec, J. Nigg, and F. Siccardi, eds., *Prediction and Perception of Natural Hazards. Proceedings of Symposium.* Dordrecht: The Netherlands: Kluwer Academic Publisher: 111–118.

Gentleman, Amelia. "Russia averts nuclear disaster." *Wilmington News Journal* September 18, 2000: A5.

Giddens, Anthony. 2000. *Runaway World*. New York: Routledge.

Gilbert, Alan and Josef Gugler. 1992. *Cities, Poverty, and Development: Urbanization in the Third World.* Oxford: Oxford University Press.

Glantz, Michael and Melanie Mason. 1994. "Urban drought." In Stanley A. Changnon, ed., *The Lake Michigan Diversion at Chicago and Urban Drought*. Boulder, CO:UCAR:163–186.

Gugler, Josef, ed., *Cities in the Developing World: Issues, Theory, and Policy.* Oxford: Oxford University Press. 1997.

Gulkan, Polat and Oktay Ergunay. 1999. "Case study." In Jon Ingleton, ed. *Natural Disaster Management: A Presentation to Commemorate the International Decade for Natural Disaster Reduction (IDNDR) 1990–2000.* Leicester, England: Tudor Rose: 176.

Haque, C. Emdad and Danny Blair. 1992. "Vulnerability to tropical cyclones: Evidence from the April 1991 cyclone in coastal Bangladesh." *Disasters* 16: 217–229.

Herath, S. and T. Katayama, eds. 1994. *Proceedings of the Workshop. Towards Natural Disaster Reduction.* Tokyo, Japan: International Center for Disaster-Mitigation Engineering.

Herzer, Hilda and N. Clichevsky. "Floods in Buenos Aires: Learning from the past." 2000. In Alcira Kreimer and Margaret Arnold, eds., *Managing Disaster Risk in Emerging Economies.* Washington, D.C.: World Bank: 32–45.

Hewitt, Kenneth. 1997. *Regions of Risk*. Essex, England: Addison Wesley Longman.

Hofmann-Wellenhof, B., H. Lichtenegger, and J. Collins. 1994. *Global Positioning System: Theory and Practice*. New York: Springer-Verlag.

Hohn, Uta. 1995. "Issues in Urban Earthquake Risk." *GeoJournal* 37: 386.

Huq, Saleemul. 1999. "Environmental hazards in Dhaka." In James K. Mitchell, ed., *Crucibles of Hazards: Mega-Cities and Disasters in Transition.* Tokyo, Japan; United Nations University Press: 119–137.

ICRC (International Committee of the Red Cross and Red Crescent Societies). 2000. *World Disasters Report*. Geneva.

Ingleton, Jon, ed. 1999. *Natural Disaster Management: A Presentation to Commemorate the International Decade for Natural Disaster Reduction (IDNDR) 1990-2000.* Leicester, England; Tudor Rose.

Isaacs, J., J. Stork, D. Goldstein, and G. Wick. 1975. "Effect of vorticity pollution by motor vehicles on tornadoes." *Nature* 253: 254–255.

Jasanoff, S. 1998. "The political science of risk perception." *Reliability Engineering and System Safety.* 59: 91–99.

Jones, Barclay. 1991. "Population growth, urbanization and disaster risk and vulnerability in metropolitan areas: A conceptual framework." Unpublished paper.

Jones, N, P., E. Noji, G. Smith, and R. Wagner. 1993. "Casualty in earthquakes." In Kathleen Tierney and Joanne Nigg, eds., *Socioeconomic Impacts: 1993 National Earthquake Conference.* Memphis, TN: Central United States Earthquake Consortium: 19–68.

Kallender, Paul. 2000. "Disaster could endanger chip industry." *Electronic News* 46 (July 3, 2000): 1–27.

Kasarda, John and Edward Crenshaw. 1991. "Third world urbanization: Dimensions, theories and determinants." *Annual Review of Sociology* 17: 467–501.

Kempster, Norman. 2000. "Nuclear sites never will be safe, study says." *Wilmington News Journal* August 8, 2000: A5.

Khandekar, M., T. Murty, D. Scott, and W. Baird. 2000. The 1997 El Nino, Indonesian forest fires and the Malaysian smoke problem: A deadly combination of natural and man-made hazard. *Natural Hazards* 21: 131–144.

Kim, Dwi-Gon. 1999. "Flood hazard in Seoul: A preliminary assessment." In James K. Mitchell, ed., *Crucibles of Hazard: Mega-Cities and Disasters in Transition.* Tokyo: United Nations University Press: 92–118.

Kim, Susan. 2000. "Millions homeless in India flooding." *Disaster News Network* August 29, 2000.

Kraus, Nancy, A. Torbjorn, and Paul Slovic. 1992. "Intuitive toxicology: Expert and lay judgments of chemical risks." *Risk Analysis* 12 (1992): 215–232.

Krimgold, Frederick. 1992. "Modern urban infrastructure: The Armenian case." *Environmental Management and Urban Vulnerability.* Washington, D.C.: The World Bank: 215–218.

Kroll-Smith, J. Stephen, and Stephen Couch. 1991. "What is a disaster? An ecological-symbolic approach to resolving the definitional debate." *International Journal of Mass Emergencies and Disasters* 9: 355–366.

Laquian, Aprodicio. 1994. "Social and welfare impacts of mega-city development." In R. Fuchs, E. Brennan, J. Chamie, F. Lo, and J. Uitto, eds., *Mega-city Growth and the Future.* Tokyo: United Nations University Press: 192–219.

Lee, Leonard. 1992. "Making the connection." *Disaster Recovery* 5: 8–9.

Lindell, Michael and Ronald Perry. 1995. "Identifying and managing conjoint threats: Earthquake induced hazardous materials releases." Unpublished paper.

Lindell, Michael and Ronald Perry. 1998. "Earthquake impacts and hazard adjustments by acutely hazardous materials facilities following the Northridge earthquake." *Earthquake Spectra* 14: 285–299.

Long, Frank. 1978. "The impact of natural disasters on Third World agriculture: An exploratory survey of the need for some new dimensions in development planning." *American Journal of Economics and Sociology* 37: 149–163.

Lovins, Amory and J. H. Price. 1981. *Energy Policies for Resilience and National Security*. San Francisco: Friends of the Earth Inc.

Mitchell, James K. 1996. *The Long Road to Recovery: Community Responses to Industrial Disaster.* New York: United Nations University Press.

Mitchell, John. 1998. "Protecting development." In John Twigg, ed., *Development at Risk? Natural Disasters and the Third World.* London: The U.K. National Co-ordination Committee for the International Decade for Natural Disaster Reduction: 14–19.

Monroe, Scott. 1992. "Chelyabinsk: The evolution of disaster." *Post-Geography* 33: 533–545.

Mydans, Seth. 1997. "Its mood dark as the haze, southeast Asia aches." *New York Times* October 26, 1997: 3.

Nateghi, Fariborz. 2001. "Earthquake scenario for the mega-city of Teheran." *Disaster Prevention and Management* 10: 95–101.

Nelson, Benjamin. 2000. *Global Health: The U.S. and U.N. Response to the AIDS Crisis in Africa.* 2000. Available from <http://www.gao.gov>.

Oberai, A. S. 1993. *Population Growth, Employment and Poverty in Third-World Mega-Cities*. New York: St. Martin's Press.

Oberg, James E. 1988. *Uncovering Soviet Disasters*. New York: Random House.

Olson, Richard and A. Cooper Drury. 1997. "Un-therapeutic communities: A cross-national analysis of post-disaster political unrest." *International Journal of Mass Emergencies and Disasters* 15: 221–238.

Olson, Richard Alvarez, B. Baird, A. Estrada, V. Gawronski, and J. Prieto. 1999. *Disaster and Institutional Response: Hurricane Georges in the Dominican Republic and Hurricane Mitch in Honduras and Nicaragua, September-October 1998.* Folsom, CA: Robert Olson Associates.

Olson, Richard, Juan Pablo Sarmiento Prieto, Robert A. Olson, Vincent T. Gawronski, and Amelia Estrada. 2000. *The Marginalization of Disaster Response Institutions: The 1997–1998 El Nino Experience in Peru, Bolivia, and Ecuador.* Boulder, CO: Natural Hazards Research and Applications Information Center, University of Colorado.

Perry, Ronald. 1985. *Comprehensive Emergency Management: Evacuating Threatened Populations.* Greenwich, CT: JAI Press.

Petterson, John. 1987. "The reality of perception: Demonstrable effects of perceived risk in Goiania, Brazil." *Practicing Anthropology* 10: 3–4, 8–9, 12.

Picou, J. S. 2000. "The "talking circle" as sociological practice: Cultural transformation of chronic disaster impacts." *Sociological Practice; A Journal of Clinical and Applied Sociology* 2: 77–97.

Picou, J. S. and D. A. Gill. 1999. "The *Exxon Valdez* disaster as localized environmental catastrophe: Dissimilarities to risk society theory." In M. J. Cohen, ed., *Risk in the Modern Age.* London: Macmillan: 143–170.

Poghosyan, G., ed. 2000. *Ten Years of Loneliness*. Yerevan, Armenia: Noyan Tapan.

Porfiriev, Boris. 1991. "Environmental dimensions of national security: A trial of systems analysis study." Newark, DE: Disaster Research Center, University of Delaware.

Porto M. and C. Freitas. 1996. "Major chemical accidents in industrializing countries: The socio-political amplification of risk." *Risk Analysis* 16: 19–29.

Qingzhou, Wu. 1989. "The protection of China's ancient cities from flood damage." *Disasters* 13: 193–227.

Quarantelli, E. L. 1988. "Future disasters in the United States: More and worse." Preliminary Paper #125. Newark, DE: Disaster Research Center, University of Delaware.

Quarantelli, E. L. 1991. "Criteria for evaluating disaster planning in an urban setting." In Francesco M. Battisti, ed., *La Citta e l'Emergenza*. Milan, Italy: Franco Angeli: 39–63.

Quarantelli, E. L. 1996. "Just as a disaster is not simply a big accident, so a catastrophe is not just a bigger disaster." *The Journal of the American Society of Professional Emergency Planner*: 68–71.

Quarantelli, E. L. 1998a. "Major criteria for judging disaster planning and managing: Their applicability in developing societies." Preliminary Paper # 268. Newark, DE: University of Delaware.

Quarantelli, E. L., ed. 1998b. *What Is a Disaster? Perspectives on the Question.* London: Routledge.

Quarantelli, E. L., Brenda Phillips, and D. Hutchinson. 1983. *Evacuation Behavior: Case Study of the Taft, Louisiana Chemical Tank Explosion Incident.* Newark, DE: Disaster Research Center, University of Delaware.

Reconstruction and Transformation of Central America After Hurricane Mitch. 1999. General Secretariat Central American Integration System.

Richharia, M. 2001. "Mobile Satellite Communications: Principles and Trends. New York: Addison-Wesley.

Rogers, George. 1997. "The dynamics of risk perception: How does perceived risk respond to risk events?" *Risk Analysis* 17: 745–757.

Ropeik, David. 2000. "Let's get real about the risks we fear." *Wilmington News Journal* August 19, 2000.

Rosenthal, Uriel, Louise Comfort, and Arjen Boin, eds. Forthcoming *From Crises to Contingencies: A Global Perspective*.

Sanger, David. 1991. "A crack in Japan's nuclear sangfroid." *New York Times* February 17, 1991.

Savic, Misha. 2000. "Cyanide spill killing all life in Tisa River." *Wilmington News Journal* February 13, 2000: 2.

Scanlon, Joseph. 1992. *Convergence Revisited: A New Perspective on a Little Studied Topic*. Boulder, CO: Institute of Behavioral Science, University of Colorado.

Scanlon, Joseph and Massey Padgham. 1980. *The Peel Regional Police Force and the Mississauga Evacuation.* Ottawa: Canadian Police College.

Schmeck, Harold. 1987. "Panel discounts special hazards in gene splicing." *New York Times* August 15, 1987: 1, 7.

Schmuck-Widmann, Hanna. 1998. "Floods in Bangladesh: Disaster or part of the life world? European engineers' perception, knowledge and techniques in comparison to local and indigenous knowledge and strategies." Unpublished paper.

Seitz, Steven and Morris Davis. 1984. "The political matrix of natural disasters: Africa and Latin America." *International Journal of Mass Emergencies and Disasters* 2: 231–250.

Seydlitz, Ruth, J. William Spencer, Shirley Laska, and Elizabeth Triche. 1991. "The effects of newspaper reports on the public's response to a natural hazard event." *International Journal of Mass Emergencies and Disasters* 9: 5–29.

Shargorodsky, S. 1993. "A lethal Soviet legacy." *Wilmington News Journal* December 24, 1993: 2.

Shefner, Jon. 1999. "Pre- and post-disaster political instability and contentious supporters: A case study of political ferment." *International Journal of Mass Emergencies and Disasters* 17: 137–160.

Showalter, Pamela and Mary Myers. 1994. "Natural disasters in the United States as release agents of oil, chemicals or radiological materials between 1980–1989: Analysis and recommendations." *Risk Analysis* 14:169–182.

Slovic, Paul. "Perception of risk." *Science* 236 (1987): 280–285.

Sorensen, John. 1988. "Society and emergency preparedness: Looking from the past into the future." In Andrew Kirby, ed., *Nothing To Fear: Risks and Hazards in American Society.* Tucson, AZ: University of Arizona Press: 241–260.

Stallings, Robert. 1991. "Ending evacuations." *International Journal of Mass Emergencies and Disasters* 9: 183–200.

Swarns, Rachel L. 2000. "Mozambique confronts huge flood losses but sees ray of hope." *New York Times* April 30, 2000: 9.

Thompson, Mark. 1987. "Toxin killed 1,000 in U.S.S.R." *The Philadelphia Inquirer* March 25, 1987: 11A.

Tierney, Kathleen. 1990. "Risk of hazardous materials releases following an earthquake." Preliminary Paper #152. Newark, DE: Disaster Research Center, University of Delaware.

Tierney, Kathleen. 1999. "Toward a critical sociology of risk." *Sociological Forum* 14: 215–242.

"Tourism in southeast Asia hurt by fires in Borneo and Sumatra." *New York Times* September 26,1997.

Towfighi, Parviz. 1991. "Integrated planning for natural and technological disasters." In Alcira Kreimer and Mohan Munasinghe, eds., *Managing Natural Disasters and the Environment*. Washington, D.C.: Environment Department, World Bank: 106–110.

UNFPA (United Nations Population Fund). 1991. *Population and Environment: The Challenges Ahead.* New York.

UN/ISDR (United Nations International Strategy for Disaster Reduction). 1999. *ISDR: Newsletter for Latin America and the Caribbean* 15: 1–40.

U.S. GAO (United States General Accounting Office). 2000. *Nuclear Safety: Concerns with the Continuing Operation of Soviet-Designed Nuclear Power Reactors.* Washington, D.C.

Vogt, B. and J. Sorensen. 1987. *Evacuation in Emergencies; An Annotated Guide to Research*. Oak Ridge, TN: Oak Ridge National Laboratory.

Vogt, Jurgen and Francesca Somma, eds. 2000. *Drought and Drought Mitigation in Europe.* Dordrecht: Kluwer.

Vorobiev, Y. L., ed. 1998. *Disasters and Man: Book 1 The Russian Experience of Emergency Response.* Moscow: AST-LTD Publishers.

Wade, Nicholas. 2000. "Global disasters in the making." *The New York Times* July 18, 2000 Available from <http://www.nytimes.com/library/national/science/071800sci-week.html>.

Walker, P. 1992. "Foreign military resources for disaster relief: An NGO perspective." *Disasters* 16: 153–159.

Waterbury, John. 1979. *Hydropolitics of the Nile Valley*. Syracuse, NY: Syracuse University Press.

Webb, Gary, Kathleen Tierney, and James Dahlhamer. 1999. "Businesses and disasters: Empirical patterns and unanswered questions." Preliminary Paper # 281. Newark, DE: Disaster Research Center, University of Delaware.

Wenger, Dennis and Thomas Drabek. 1987. "Emergency preparedness and response planning: An overview of seismic policy related issues." Preliminary Paper #121. Newark, DE Disaster Research Center, University of Delaware.

WHO (World Health Organization). 1999. *Community Emergency Preparedness: A Manual for Managers and Policy-Makers.* Geneva.

Chapter 16

Natural Disasters and Urban Cultural Heritage: A Reassessment

June Taboroff

In August 2002, central Europe saw some of the most devastating floods of the last 200 years. Newspapers, radio, and television heralded the extreme threats to the historic towns of the Czech Republic, Germany, and Hungary by the *Jahrhundertflut*. The heavy rains and high floodwaters forced the evacuation of thousands of people as cities and towns were submerged and lives were lost. Estimates by re-insurers for total flood damage in Germany, Austria, and the Czech Republic reached $14.7 billion.

These floods struck some of central Europe's top cultural attractions and most valued historic urban environments. The World Heritage towns of Cesky Krumlov and Prague were damaged. Media coverage of the disaster left no doubt that the protection of cultural heritage is of concern to society at large. BBC News commented from Dresden, "The people here have been as concerned for their own properties as they are for the future of their historic buildings."[1] Numerous news reports highlighted the significant losses to the Czech and German economies from the closure of cultural sites and cancellation of tourist visits due to the floods.

Dresden, destroyed by Allied bombing in 1945, came under siege once again in August 2002 when floodwaters swelled the Elbe to five times its normal flow, poured into the city, and submerged seven districts. Despite the efforts of thousands of volunteers, army personnel, and relief workers to sandbag the river, flood waters advanced through the old town and other parts of the city. The city's Royal Palace was hit by floodwater. Many of the city's historic squares were under water. In one of the swiftest salvage operations ever mounted to save priceless works of art, museum staff, government officials, firemen, policemen, and volunteers moved about 20,000 works of art from Dresden's galleries and museums to upper galleries and buildings hoped to be flood-proof. One of the most spectacular rescue efforts occurred the night of August 13, when more than 4,000 paintings from the Old Master's gallery at the baroque Zwinger Palace were shifted in just seven hours. One of the rescue efforts involved attaching over-sized paintings to the ceiling with ropes.

It will take months, if not years, to repair the damage. The workshops and tools that would normally be used to restore Dresden's art treasures were swept away by the floods. The greatest risk now is for buildings: "Nobody knows what the damage is exactly. It will be months and months to wait and millions and millions to pay."[2] These are the same historic buildings that were lovingly and faithfully restored after being firebombed during World War II. They have since become major tourist attractions and a source of reborn civic pride for the city.

In Prague, another cultural treasure house, officials at museums, palaces, and archives are coping with the worst flooding of the city since 1890. Some palaces close to the Vltava River were flooded. Storage facilities of the National Museum were heavily affected: books from the National Museum Library were soaked and the lower floors of historic buildings damaged. The architecture archive of the Prague University of Technology was under 10 feet of water, flooding 90 percent of this important archive of Czech architecture. In 1940 the archive had been relocated to the ground floor of this historic building. Thanks to the enormous effort of volunteers, most documents were removed from the building and frozen in order to allow for possible future restoration. An SOS Architecture Archive fund has been launched to restore the drawings and documents.

Less dramatic than the floods of August 2002 but cumulatively as damaging are the annual floods in Venice.

In the 20th century, the relative sea level increased by more than 23 centimeters, and the number of tides over 100 centimeters has surged. In contrast to the decade after 1923, when there were just 7 tides over 100 centimeters, in the decade after 1990, 114 floods measured over 100 centimeters, and in 2000 there were 19. Recent archaeological studies have shown that the city is sinking much faster than previously thought. Using new carbon dating techniques, a team of archaeologists calculated the rate of relative sea-level rise over 1600 years. They found layer upon layer of pavements and foundations laid over the centuries in a constant effort to keep the city above water.[3] Such additional infrastructure increases costs to the city and property owners.

Much of Venice, especially St. Mark's Square, has a severe dampness problem. This main square lies lower than other parts of the city and begins to flood when the tide is higher than 70 centimeters. Green algae grows on the porous brick and stone work of the palaces along the Grand Canal, causing further damage. After 50 years of neglect and indecision, Italian authorities have finally begun dredging canals, raising city pavements, and repairing damaged sea walls. The cost is estimated at more than $40 million per year, however. The deeper and more frequent the annual floods become, the fiercer the debate grows about how to stop them. Meanwhile, tour operators study the tides, as do shopkeepers and residents to calculate the opportunity and physical costs of flooding.

Urban Heritage at Risk

These recent examples present a vivid picture of what is at stake when natural disasters strike urban areas with significant cultural sites. They also highlight several key points:

- Do not underestimate the vulnerability of cultural heritage to natural disasters. Recent experience in central Europe starkly shows that environmental degradation, the inability to manage fluctuations in the volume of rivers, and other weather-related natural disasters are on the increase in many parts of the world and can destroy precious heritage sites.
- Ensure that individual site management plans are adequate for disaster scenarios by establishing priorities, improving the security of collections and buildings, and training staff. Although many cultural institutions in industrialized countries have their own emergency plans, they are often based on the case of fire, not floods or other types of disasters. All emergency plans need to be revised to address a range of disasters.
- Coordinate crisis management at both the institutional and urban/regional level. Experience indicates that institutional coordination has worked quite well, for example at national museums, but regional coordination within urban and other geographic areas has been less successful (as demonstrated by recent events in Prague).
- Inform the public about the risks to cultural heritage and the need for investment in protecting heritage from natural disasters. This will create an active constituency to support preventive measures. As was evident in central Europe, the public at large, through their work as emergency volunteers, was responsible for helping to save many treasures.

The subject of urban cultural heritage is important for several reasons. First, the severity and frequency of natural disasters is arguably on the increase. Whether weather-related disasters or geophysical processes, there are enormous costs associated with inadequate preparedness and post-disaster reconstruction. Recent episodes of extreme weather include the high winds that toppled trees in Versailles and the historic gardens of Paris, and the severe winter storms in 1999 that damaged buildings in Europe. Earthquakes regularly shatter urban areas of Iran and India, destroying temples, housing, and other elements of the historic environment.

Second, cultural heritage tends to be concentrated in urban areas where intense trading and business activities spawned displays of religious, civic, and private creativity and wealth. A vast majority of such cities are located in coastal areas or along rivers and are therefore vulnerable to flooding and landslides. A tally of the World Heritage list shows that, of the cities listed, most are situated in coastal or riverine areas. There are also cities in mountainous areas, such as Cuzco or Katmandu, that are in seismically active zones.

Third, both capital and secondary cities are at risk. Capital cities such as Prague and Dresden are often the focus of attention in times of disaster, and may be better able to respond to emergencies. Provision of disaster information, organization of emergency services, and access to funds for reconstruction tend to be better in such cities. In smaller towns such as Cesky Krumlov, where half of the buildings in the town's historic center were flooded in the August 2002 floods, the physical and economic consequences can be equally profound or even greater, though resources for reconstruction are often fewer.

But even in capital cities, current procedures for protecting cultural heritage have been shown to be inadequate. A cultural heritage expert from the Czech Republic filed this report:

> We were not prepared sufficiently. Most of the state museums, galleries and castles opened to the public had evacuation plans for the case of fire… In most cases a detailed program for the evacuation of the collections was prepared (the priority, the succession of individual items)…. Nevertheless nobody was prepared for a flood of such immense scale. What failed completely and tragically was the forecast and quick information on the real extent of the danger (personal e-mail communication, October 2, 2002, from Jana Polakova, ICOMOS Czech Republic, to June Taboroff).

With few exceptions, authorities responsible for safeguarding cultural heritage, most often governmental bodies but also private museums and cultural institutions, have yet to be sufficiently prepared to respond to natural disasters.

Perceptions of Risk

Natural disasters, such as flooding and hurricanes, are recurrent rather than single events. Nevertheless, perceptions of risk to cultural heritage are highly variable and provide a good indicator of readiness to tackle disaster prevention and mitigation. The following international sample of current work on risk and vulnerability gives an overview of thinking about heritage.

The View from Southern Africa

Contributors to the 2001 World Bank-sponsored consultative workshop on culture in Africa, held in Kimberley, South Africa, were asked to comment on risks to heritage. Representatives of 10 countries prepared national profiles and drew up preliminary lists of heritage at risk. Only in the case of South Africa was the issue of risk preparedness mentioned. "Disaster management plans for cultural property in case of fire, floods and even the occasional earthquake, etc. are imperative."[4] Natural disasters were cited in two reports. The Ghana report mentioned sea-level change in coastal areas as the cause of heritage loss. One example cited was encroachment of the sea at Katar in the Volta region, where Fort Peasantine has fallen victim to the waves. The Mali report cited drought and the southern spread of the Saharan region as risk factors for built heritage, as they provoke population flight and the abandonment of buildings. For Nigeria, Cameroon, Kenya, Zambia, Zimbabwe, Uganda, and Botswana, risks that were identified were attributable to human causes: environmental degradation (usually unspecified); uncontrolled development; and lack of awareness. Thus, for the majority of countries in southern and eastern Africa represented at the workshop, averting the risks of natural disasters was overlooked in a discussion of heritage at risk, despite the fact that these countries are prone to severe natural events.

Europe and the G8

In western and central Europe, the United Kingdom, North America, and Japan, disaster-prevention measures and plans are a relatively high priority for institutions charged with safeguarding cultural heritage. The rapid rescue of thousands of works of art by heritage and civil protection workers, assisted by large numbers of volunteers in Dresden, Prague, and elsewhere in Germany, the Czech Republic, and other affected Central European countries is an inspiring demonstration of disaster coordination. In California after the earthquake of 1989, many museums and libraries were closed and rebuilt to conform to earthquake safety standards or torn down and replaced with earthquake-resistant buildings. In the United States, institutions typically have individual emergency plans that are coordinated at a city- or state-wide level. In the United Kingdom, English Heritage has the remit to advise the public on ways to conserve and protect the historic built environment. It has produced, among other things, guidance on disaster preparedness and first aid measures to be taken in the aftermath of floods. The organization can also deliver assistance through its regional offices and London headquarters.

Mediterranean Archaeological Sites

A recent effort to address risk assessment for archaeological sites in the Mediterranean, financed by the European Commission's Euromed Heritage I Programme, examined natural and human risk factors (EUROMED 2002). Natural factors included were earthquakes, volcanism, hydro-geological phenomena, coastal erosion, change in seacoasts, water erosion, climatic factors, and biological factors. For the nine sites examined, of which five were in urban areas, the natural risk factors of significant importance were identified as hydrogeological (Tharros, Italy; Lixus, Morocco; Jericho, West Bank); seismic (Jericho, West Bank); climatic (Tharros, Italy; Lixus, Morocco); and volcanic (Pompeii, Italy). The report was concerned with probability of risk, and gave only minimal attention to preparedness and mitigation, except in general terms such as the need for physical strengthening measures for standing structures and the need for orchestration of effort with government authorities. For these sites, representative of the archaeological richness of the Mediterranean, little in the way of protection measures for natural disasters is being put in place. As a result, they remain highly vulnerable.

The International Council on Monuments and Sites Review of Risk

The ICOMOS Heritage at Risk 2001–2002 report provides a view of the opinions of heritage professionals. It is based on 75 reports received from ICOMOS members, national committees, international scientific committees, and affiliated groups. The 2001 report elaborates categories of sites that are most threatened: rural and vernacular architecture; 20th century heritage sites; industrial heritage; religious heritage; archaeological sites; and cultural landscapes and gardens. Attention is concentrated on human risks, namely, new construction, change of ownership, and lack of maintenance. There is only occasional mention of natural disasters, however, one example being Turkey's report on natural threats, and there is little attention paid to risk preparedness. The authors remark,

> Natural disasters are affecting the heritage in different ways. The flooding of Antakya, ancient Antioch, caused serious damage to the service facilities of the historic town. In 2001 there were several earthquakes in Turkey…. The damage inflicted on monuments and urban areas by the earthquakes of 1999 in Izmit and Duzce continue; some of the damaged buildings have not received any care for 2 years …. Unfortunately some monuments are being repaired without expert advice…. (ICOMOS 2002).

ICOMOS Report on Risk-Preparedness for Cultural Heritage

At the behest of UNESCO, ICOMOS prepared a report in 1997 to assess the degree of protection to which cultural heritage is integrated into disaster management ("Risk-Preparedness for Cultural Heritage," ICOMOS 1997). Based on responses from 14 countries, the majority being industrialized countries with the exception of Jordan, Pakistan, Zambia, and South Africa, certain patterns were detected:

- Disaster management agencies do not generally distinguish cultural heritage from property.
- Disaster management for cultural heritage is handled differently in each country. In some cases the Ministry of Culture or its equivalent works closely with law enforcement or civil defense agencies. In countries such as New Zealand, each government institution is required to establish disaster management procedures and care for cultural heritage. In Sweden, the state administration is responsible for cultural heritage at the regional level; the disaster management agencies responsible for cultural heritage list cultural heritage to be protected under the Hague Convention.
- Interest by the disaster management community in integrating cultural heritage concerns into its activities varies. Some countries display high concern for the protection of cultural heritage in case of emergencies: Sweden has done so since the 1960s. Other countries may have general interest, but little in terms of follow-up procedures.
- Opportunities for improving protection include new legislation, coordination, and cooperation among

agencies, and the creation of one national body to monitor emergencies.

- Obstacles that were cited include incomplete legal frameworks; lack of equipment; lack of trained staff; and fragmented responsibilities.
- There are few fora where disaster management and cultural heritage professionals collaborate.
- Guidelines and methodologies for protecting heritage to improve risk preparedness are not generally available. In Belgium a special methodology was developed for archives.
- The type of disaster determines which professionals carry out emergency response plans. This is at the discretion of the Ministry of Interior or agency charged with disaster response, advised by heritage professionals. In Sweden, the Swedish Agency for Civil Emergency Planning is the focal point for discussions among armed forces, planners, heritage specialists, and other concerned groups.
- There are few evaluations of emergency response for cultural heritage.

The low response rate to the questionnaire (7 percent) suggests that many countries are not yet convinced that disaster preparedness is a priority. Although cultural institutions often have emergency response plans—usually for fire—few countries have developed comprehensive disaster management plans, institutional structures, and guidelines.

This evidence from the field of cultural heritage shows that developing countries are even less ready to deal with natural disasters than wealthier countries. The Operations Evaluation Department of the World Bank said in a 1998 evaluation of disaster assistance:

> When the devastation caused by storms or other natural disasters in industrial and developing countries is compared, the injury and death rates can be up to 100 times higher in the poorer developing countries…. Lack of mitigation is itself an indicator of underdevelopment, one that the Bank can help overcome (World Bank 1998).

Behavior of Denial

In many countries, behavior with respect to cultural heritage is not unlike that of property owners in the United Kingdom. In a 2002 survey conducted by the U.K. Environment Agency, many of those most at risk still deny that they could be flood victims, despite disturbing images of recent floods. In the autumn of 2000, 10,000 properties were flooded in storms, although flood defenses are believed to have protected 280,000 properties. The survey reports that, while 95 percent of people in an area at risk agreed that flooding was a serious issue, fewer than half accepted that it related to them. Only one person in 20 had taken any action to prepare for floods.[5] A possible explanation for this behavior is that potential flood victims are reluctant to protect themselves against flood damage for fear it could reduce the value of their property.

Certainly there are exceptions of disaster planning in the field of heritage protection, but many governments and institutions begin to put in place preparedness measures only after being hit by a disaster. Otherwise, the possibility of a disaster striking is considered a remote phenomenon.

After the Deluge?

When disaster strikes cultural heritage, there are special measures to take for historic buildings and sites. These measures are extremely important because they can reduce further damage. The general rule is that "remedial" work can be more damaging than the original disaster. While each type of disaster results in specific types of damage, there are certain principles that guide conservation interventions. They concern recording, analysis of damage, and impacts on living heritage.

A key preventive factor is to record incidents. Various cultural heritage authorities have their own forms.[6] For example, with flood damage it is essential not to dry out old buildings too quickly with the application of heat. Timber paneling, boarded floors, and doors may warp and twist; salts will burst out of old stone, and plasterwork and painted surfaces will peel and flake. The best general advice is to dry the building slowly through ventilation and with the aid of dehumidifiers. This can take several months but it is better than destroying original historic fabric that may be even more expensive to replicate. Photographic recording and removal of important timber elements to a cold store for freeze drying is recommended for very important building elements.

In the case of earthquakes and other severe physical damage, documentation followed by analysis of building structure and engineering is necessary before solutions are proposed. The introduction of steel frames into masonry construction can cause additional and sometimes fatal damage. A case in point is the Feyzullah Efendi Madrasa in Istanbul, dating from the 18th century, which was inappropriately repaired after the 1999 earthquake.

It is also important to highlight the human consequences of disasters for both physical and nonmaterial culture. The living heritage of urban centers can be severely harmed by disasters, as they interrupt or erase traditional customs, such as festivals, markets, craft production, etc. The ICOMOS Heritage at Risk report (2002) remarked,

> But the effects on heritage places, monuments and sites of the loss and on indigenous language and the traditional values, skills and knowledge that language embodies are more difficult to assess. The loss of understanding of the spiritual, intangible and cultural values of places is as difficult to document as it is irreplaceable.

Recent Activities

At the international level, there have been recent initiatives motivated by the need to address disaster prevention. They are aimed at informing and motivating national governments and heritage institutions that are the guardians of heritage. Of particular interest are the following reports, meetings, training sessions, and activities sponsored by international agencies, professional organizations, and training centers:

- ICOMOS Heritage at Risk annual reports. These reports include individual commentaries by 75 national committees. They are an important effort to assemble information and examine trends. ICOMOS also set up an International Committee on Risk Preparedness to develop professional guidance on risk management as an integral part of conservation practice.
- The International Committee of the Blue Shield (ICBS). Created in 1996 by the four nongovernmental organizations that represent professionals in the fields of archives, libraries, monuments and sites, and museums, the ICBS works to protect cultural heritage threatened by natural disasters and war. Though the ICBS has asked that national committees be formed, this initiative cannot go far beyond good intentions, since its lack of funding relegates it to a clearing house and forwarder of information.
- UNESCO has sponsored several meetings on the subject of disasters. Most recently, it convened the Conference on World Heritage Mountain Cities and Natural Hazards from September 25–27, 2002. UNESCO is discussing convening a roundtable on risk preparedness in 2003.
- The International Center for the Study of the Preservation and Conservation of Monuments (ICCROM) has supported several training courses on risk preparedness. Among these was a course in Central America after Hurricane Mitch.
- The World Bank has directly financed several projects with components targeting disaster preparedness and reconstruction. These include the China Yunnan Earthquake Reconstruction Project and the Honduras ProFuturo project, both of which intervened in historic urban areas. Under the Yunnan project, improved seismic resistance was incorporated into historic buildings in Lijiang, a World Heritage city.

Despite the individual merits of these activities, however, many sites remain unprotected and systems are not yet in place to effectively reduce risk to heritage from natural disasters.

Trends in Natural Disaster Preparedness

As the number of devastating weather-related and geophysical disasters and processes increases—flooding in the United Kingdom, earthquakes in Turkey—the toll of urban heritage lost and damaged rises. Integrating cultural heritage concerns into national preparedness planning is the exception rather than the rule, especially in developing countries.

An example of good practice is the Swiss Federal Office for Civil Protection, which includes a heritage section.[7] The Swiss Federal Office has been entrusted with two priority missions: providing aid in the event of disaster and other emergencies; and protecting the public in the event of armed conflict. Civil protection also protects cultural heritage and participates in a regional context and in cooperation with organizations specialized in disaster rescue and relief and transfrontier rescue operations. The Swiss Committee for the Protection of Cultural Property serves as an advisory body to the Confederation, to the Federal Department of Defense, Civil Protection and Sports, and to the Federal Office for Civil Protection. The committee has a maximum membership of 25 individuals, all with an interest in the protection of cultural property. In Switzerland implementation is the responsibility of the cantons in cases where responsibility does not lie directly with the confederation. They are expected to contribute financially to the protection of cultural property and take the following measures:

- Create the necessary legislative framework at the cantonal level
- Designate an office responsible for the protection of cultural property
- Draw up an inventory of cultural property
- Create documentation to safeguard cultural property
- Determine the form of organization required at the local level
- Train the staff responsible for the protection of cultural property.

The requirement of the Swiss authorities for localities to make financial contributions to heritage protection is especially forward looking. Sweden and the United Kingdom are other countries where advances have been made in planning for prevention.

Public commitment to protecting heritage during disasters is increasing in some parts of the world. In central Europe heritage professionals, bolstered by emergency services and the public at large, helped save important treasures. In the United States a major tourism magazine, *Travel and Leisure,* has initiated a new feature page on heritage at risk after the recent floods.

Improving Prevention through Policies and Planning

In an earlier paper, "Cultural Heritage and Natural Disasters: Incentives for Mitigation" (in Kreimer and Arnold 2000), I discussed measures and incentives that could be adopted to better protect heritage. It is worthwhile to re-examine and update these measures and incentives. Key strategic elements that are suggested by current experience are:

- Update and review inventories of historic places, paying particular attention to condition and change in vulnerability due to sea level rise, etc. Knowing the extent, location, and condition of heritage is the first step in its protection.
- Put in place risk-minimization procedures such as moving archives and collections from the basements of buildings in flood-prone areas, upgrading museum storage and display cases to meet seismic standards, and other measures to address known risks.
- Enforce building codes, especially in seismically active zones, to reduce the likelihood of collateral damage.
- Ensure that heritage professionals are included in national and local disaster and civil defense committees to ensure they are notified of impending disasters and are able to work in close collaboration with fire and safety authorities.
- When training civil defense and emergency workers, include modules on the special needs of heritage, including aftercare for important heritage objects and sites.
- Evaluate the current experience of disaster response for cultural heritage to draw lessons and avoid ad-hoc decisions.

Today the realization that natural disasters could affect cultural heritage is still not widespread. Governments are slow to mount preventive measures, and urban risk preparedness does not always take heritage needs into account. Many organizations are prepared for little more than fire emergencies. Experience in other areas of risk management suggests that "costs force customers to become aware of risks. They change behavior."[8] The cost of loss may prove to be a persuasive argument for national policymakers, especially when the cost of one lost masterpiece can climb to millions of dollars. Loss of income from tourism can also be crippling, and the loss of sense of place when historic areas are destroyed is beyond dollar calculation.

The Way Forward

Cultural heritage needs to be factored into overall disaster mitigation and management approaches. Cultural heritage professionals should make themselves known to disaster mitigation professionals and disaster mitigation professionals should invite the participation of heritage professionals in designing response systems. Effective preparedness and mitigation strategies will depend upon government agencies, heritage professionals, and emergency services working together to:

- Ensure that legislation affords heritage the necessary protection in the event of disaster
- Coordinate with disaster relief planners at local and national levels
- Determine the necessary organization for delivery of heritage protection
- Prepare emergency plans at institutional, municipal, regional, and national levels
- Create emergency teams representing a mix of professionals
- Provide documentation and training materials for the protection of cultural heritage
- Design mitigation measures to ensure that heritage is properly conserved.

These are lessons that the World Bank and other international development institutions, bilateral donors, governments, the voluntary and private sector, and the ProVention Consortium can promote in their disaster preparedness and mitigation work. Let us not wait until the next disaster disrupts lives and livelihoods and destroys the cultural heritage of mankind before preparations begin.

Notes

1. BBC News Website, News Front Page, Saturday 17 August 2002. Available from <http://news.bbc.co.uk/hi/world/europe/2200048.stm>.

2. Museum curator, BBC News Website, Front Page, Saturday 17 August 2002. Available from <http://news.bbc.co.uk/hi/world/europe/2200048.stm>.

3. *The Christian Science Monitor* Website. “Plan to save Venice from the sea draws praise, doubts.” August 21, 2002. Available at <http://www.csmonitor/2002/0821/p07so1-woeu.html>.

4. Conference Proceedings of the Kimberley Consultative Workshop on Culture in Africa, November 2001.

5. *Financial Times* Website. “Residents fear costs of opting for flood defences.” September 23, 2002. Available at: <http.ft.com/search/article.html?id+020923000129&query=Floods&vsc-appld=tot>.

6. For an example, see <http://www.resource.gov.uk>.

7. <Available at: http://www.civilprotection.ch/e/kulturgueterschutz/organisation.html.>.

8. “Ready for anything, even meteorites.” *Financial Times*, May 20, 2002: 12.

Bibliography

BBC News Website. Available from <http://news.bbc.co.uk>.

The Christian Science Monitor Website. Available from <http://www.csmonitor.com>.

Financial Times Website. Available from <http.//www.ft.com>.

ICOMOS (International Council on Monuments and Sites). 2002. *H@R!: Heritage at Risk ICOMOS World Report on Monuments and Sites in Danger 2001–2002*. Paris.

Kimberley Consultative Workshop on Culture in Africa. (forthcoming). Conference Proceedings. Kimberley, November 2001, Government of South Africa, Government of Norway and the World Bank.

Kreimer, A. and M. Arnold, eds. 2000. *Managing Disaster Risk in Emerging Economies*. Washington, D.C.: The World Bank.

World Bank. 1998. “Disaster Assistance.” World Bank Operation Evaluations Department Precis 174, Autumn. Washington, D.C.

Landslide destroys
buildings in Venezuela.

Part IV

Protecting Critical Infrastructure from Disaster Impacts

Chapter 17

A New Structural Approach for the Study of Domino Effects between Life Support Networks

Benoît Robert, Jean-Pierre Sabourin, Mathias Glaus, Frédéric Petit, Marie-Hélène Senay

Life support networks allow the delivery of essential services such as energy, water, telecommunications, etc. They are the guarantees, for a society, of properly functioning socioeconomic activisties, in respect to health and safety of the general population. These networks are constituted of a multitude of interrelated infrastructure, which, upon the failure of one component, can provoke, by the domino effect, the failure of other components up to the point of a network-wide failure. Therefore, the network can no longer carry out the operations for which it was designed. This domino effect can also be observed between several networks that are interconnected. The goal of this report is to present a methodology for the evaluation of these domino effects among life support networks.

This work is in line with the current international trend toward establishing efficient and effective management plans for life support networks based on the antagonistic concepts of maximum production and minimum risk. This approach is complex because the consequences are great for populations and socioeconomic activities upon failure of these networks. Thus, the need to have operational emergency measures based on an exhaustive evaluation of risks makes itself felt following the appearance of increasingly frequent catastrophes. Analysis of the needs of emergency response managers of life support networks established that the behavior of these networks should have been studied for the entire set of possible failure conditions, not only for the most extreme events. Finally, the evaluation of the domino effects between life support networks demands an extremely multidisciplinary work and the integration of technical, economic, and social expertise. Therefore, a very real problem of risk communication exists.

In order to respond to the limitations of emergency measures and the evaluation of risks as a function of the domino effect between several life support networks, a new structural approach was developed at the *Centre risque et performance* of the École Polytechnique de Montréal. It is based on the characterization of the essential elements of the network, which allow it to carry out the operations it is allocated. This approach focuses on the identification of the consequences of poor efficiency of the network, then on the evaluation of its vulnerabilities. Thus, the domino effects can be identified and studied. This approach will be explained in general terms after presenting the overall context of emergency measures and risk.

This report is composed of five major parts. First, the problems faced by life support networks will be presented. Second, the general notion of risk will be explained in order to define the diverse challenges that the managers of these networks must face. Work is currently being done on risk and life support networks. They will be fully explained and analyzed in order to define the characteristics of the new structural approach, which will be presented in the last chapter. This will be completed by a demonstration of the potential uses of the structure of this approach for risk studies, emergency response measures, and risk communication. Finally, the application of such an approach in developing countries will be presented.

Context

Life support networks are made up of a multitude of civil infrastructure, which ensure the correct functioning of industrial activities and provide essential services for citizens (Selcuk and Semih 1999; O'Leary 1997). Life support networks composed of civil infrastructure can be grouped according to the following categories (Isenberg 1991; Lau 1995):

- Electricity (generation, transportation, distribution infrastructure, etc.)
- Natural gas and liquid fuels (storage, transportation, distribution infrastructure, etc.)
- Potable water and wastewater (collection, treatment, storage, transportation, distribution infrastructure, etc.)
- Telecommunications (broadcasting, cable transmission, distribution infrastructure, etc.)
- Transportation (road systems, public transportation systems, etc.).

Thus, these networks fulfill fundamental roles for the proper functioning of a society by ensuring essential services concerning the health and safety of populations and the proper functioning of the economy. When a life support network fails, the human and socioeconomic repercussions are very significant. Therefore, they cannot be ignored (Hubbert and Ledoux 1999).

Life support networks are made up of a set of strongly interrelated components. The components, which are directly related to the role of the network, form a primary network, but parallel or secondary networks—such as remote control and computer networks—exist. The set forms an integrated system whose reliability depends on the set of its components. As soon as one component exhibits a failure, the impact on the system not only depends on the importance of the component but also on the importance of the components linked to the faulty one. In addition, the components of several networks can be linked, provoking repercussions by way of the domino effect (Allen 1997; Plate 1996; Moses 1998; Lemperiere 1999).

A good understanding of the dynamics of these networks is therefore essential in order to avoid benign malfunctions transforming into major crises. The numerous catastrophic events observed throughout the world over the last few years demonstrate just how much the safety of the human and the natural environment depend on the proper functioning of infrastructure. In addition, the events of September 11th, 2001 in the United States show that infrastructure is vulnerable to varied acts of malevolence.

Various life support networks are currently being studied by way of risk studies, the risk being the product of the *probability of recurrence* of an event by the *consequences* that the event begets (Kaplan 1997). These studies generally only consider precise events (scenarios) that can provoke a failure (CAN\CSA 1991). They are normally focused on obtaining a unique result (economic, technical, or industrial risk) and base themselves on the study of a finite number of natural or technical events (Stedinger and others 1996).

Nevertheless, analysis of past catastrophes indicates that the actual methods of risk evaluation only partially reflect the real risk of failure of these networks. The origin of the events is rather of an *anthropic* nature; in other words, they combine natural events with technical malfunctions and human intervention. In effect, not only are the life support networks subject to unforeseen natural turns of events, but equally the infrastructure that they are made up of differ in age, state, nature, design, etc. The management methods used call upon both automated systems and human intervention; however, several catastrophes are due or amplified by human error (Hubbert and Ledoux 1999; Reason 1990).

On the other hand, current risk studies aim, for the most part, to put a figure on the risk of failure, so that the identified consequences must, generally, be expressed as a number, often a dollar value. Social impacts, although quite tangible, are broached very lightly or not at all, while environmental impacts, even more intangible, are often ignored. This approach, therefore, has a tendency to minimize the consequences of a potential failure of a life support network. It does not permit a realistic portrayal of the situation or the development of efficient and effective emergency and mitigation measures. In addition, the interrelations between several life support networks are often neglected because certain links that unify these networks are not identified.

Finally, the current risk studies are generally carried out without regard for the highly multidisciplinary nature of these works. In effect, to realize these works adequately, it is important to gather experts from all technical, social, and emergency measures disciplines (as much from the life support networks being studied as from the communities affected by failures of the networks) as well as the various competent authorities (BIT 1990) and the other interconnected life support networks.

Unfortunately, the communication between these concerned parties is underestimated during the course of these studies.

Risk: General Concepts

The notion of risk encompasses several concepts, which must be clarified. This section sets out the general guiding principles of the management, evaluation, perception, and acceptability of risks. They allow a clearer view of the context of the problem presented by risk communication, which is essential in the study of domino effects between life support networks.

Risk Management

Risk management is a complex process during which decisions concerning risks are made by reconciling notions of analytic procedures that are necessary for the efficient management of risk and the human, legal, administrative, political, and organizational dimensions of the decision-making process (Covello 1986). Furthermore, efficient risk management corresponds to efficient allocation of limited resources (Dynes 1994). It is a question of identification, estimation, evaluation, reduction, and control of risks (Petts 1992), allowing the reinforcement of the ability of those involved to interact in an organized manner during the prevention and preparation phases. In this way, the goals of risk management can be to control and reduce the risks to an acceptable level, to reduce the level of uncertainty in the decision-making process regarding risks, and to increase the confidence of the public or other concerned parties in the decisions taken (Gutteling and Wiegman 1996).

A life support network is a risk generator. It can be considered the starting point of this approach; the information the network possesses confers upon it a major, even essential, role. Moreover, it is faced with an imperative: its mission. In this context, it tries to reconcile its obligations and constraints with the interests of the community where its production facilities are located.

The identification and the estimation of risks take from, without contradiction, the technical and scientific domains. From a managerial point of view, expertise coming from other disciplines, such as economics, law, and communication, must be taken into consideration.

Risk Communication

Risk communication is generally described as an exchange (Covello and Merkhofer 1994; Leiss 1990), bilateral (CAN/CSA 1997) or interactive (U.S. NRC 1989), of information, perceptions, opinions, and preoccupations. “As a discipline, risk communication tries to achieve an adequate understanding of the communication processes in the risk area, an understanding that responds to its inherent complexity and array of participants. In terms of its practical orientation, risk communication seeks to improve the workings of these processes, and so to reduce the level of mistrust among participants. The ultimate objective is to assist in the formation of the reasonable consensus in contemporary society on how to assess and manage risk” (Leiss 1989).

There are two types of information circulation: within a domain or a network and between several domains or networks. Furthermore, a model proposed by Leiss (1989) suggests that the difficulties of communication will be even more considerable once information passes from one domain to another. This process of communication is channeled, constrained, by the nature of risk itself, but also by the institutional communication channels already in place. In this way, the circulation of information relies on two approaches: structured and nonstructured. The structured approach translates into committees with sitting members being government representatives, risk generators, experts, and representatives of the public. The nonstructured approach relies on the circulation of information arising from the routine contact between those involved. These routine contacts are a good starting point to put into motion a more complete approach. However, they are not enough for the risk communication approach and must be enriched for a greater efficiency.

Communication must, therefore, play a role in mediation that serves the entire group of concerned parties, where each one gains by integrating into this mediation space if it wants its point of view known and if it wants to exert some influence on the overall process of risk management. This mediation, based on the exchange of information and perceptions, represents the very essence of risk communication. The explanation of the nature of risks, as well as the preventive and response measures put in place for the concerned public, will be accomplished in a language understood by all and previously validated by representatives of concerned parties. "In the revealed-preference and risk compendia approaches favored by technical experts, a technology is judged to be socially acceptable if the risks of death associated with it do not exceed the risks of death associated with comparable technologies. These approaches, therefore, yield an absolute number of "acceptable" fatalities (a so-called 'acceptable risk' level)" (Covello and others 1986).

It becomes clear that the formation of committees intended to improve the communication and the management of risk must include technicians and specialists capable of judging the scientific and technical data (expert sphere), as well as citizens (public sphere) capable of rigorously validating the proposed measures. "While expert knowledge of many different kinds is called upon to address the complexity of such risks, non-experts are also called upon to approve or disapprove, ultimately through political processes, decisions based on accumulated facts and reasoning" (Leiss 1989).

The task of clear communication is further compounded by the presence of not one, but many publics, characterized by a public mood that fluctuates, a public perception that is inconsistent throughout the population, and a public view that is difficult to measure (Middlekauf 1989). Despite these constraints, a democratic society must find ways to place specialized knowledge into the service of public choice. Moreover, it must be perceived to do so (Powell 1996).

Acceptability and Perception of Risks

Generally speaking, the notion of perception is associated with the public, media, and special interest groups belonging to the public sphere. It is defined as an intuitive judgment regarding the nature and importance that a risk presents for health. Nevertheless, it can be defined and characterized by factors that influence it, such as the level of understanding of the risk in question, the fear resulting from the expected rate of death and disease, as well as the size and the characteristics (e.g., children) of the threatened population (Covello and others 1994; U.S. NRC 1989; Leiss and Chociolko 1994).

Therefore, the domain of risk perception depends on the social context, the political decision-making process, and the influence of the population on the competent authorities that are part of the process of risk management. The public sphere gathers interested parties who are normally more reactive when facing risks and the actions or inactions of governments or risk generators. The understanding of the public, in the face of risks, is generally limited by the perception of these risks, resulting from their disturbing nature and from the way this information is presented.

The acceptability of risks relies upon the presumption that there is a probability that an event might not occur. Thus, the population, tacitly or explicitly, accepts the existence of these risks if they are below a certain threshold and if the benefits related to their existence exceed the perceived risks (Leiss 1994). It seems that the population pays more attention to the qualitative characteristics of the risk, while the sphere of expertise is more concerned with the assessment of the level of death and disease potentially linked to the risk (Covello 1986). Moreover, the population seems effectively ready to accept a certain level of risk if they perceive it as being justified or if the risk allows them to reach some goal or provide certain advantages (e.g., generate a job). Alternatively, it will be much more difficult for a risk to be accepted if it seems to be imposed or if it is in opposition with certain values. Therefore, the acceptability of risks will be part of the negotiation between the interested parties, according to their respective perceptions of risks (Renn 1998).

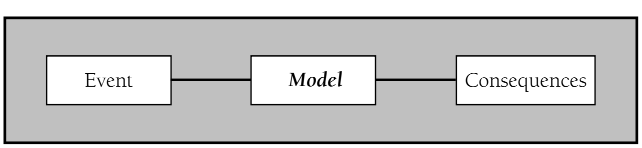
The decisions coming from the competent authorities will be made while considering the acceptability and perception of risks by society in an economic, social, and political context. To not take into account the acceptability and the perception is to risk controversy and failure. In addition, two types of language are used regarding risk, namely technical language and perceptible language. Competent authorities are straddled between these two languages that they must master. Thus, they have an essential role to play in the understanding of the scientific and technical problems of risk, while paying attention to the perceptions of the public sphere (BIT 1990). The competent authorities have no choice other than to consider the risk in question in a social, human, technological, political, and economic global perspective (Leiss 1989).

Risk Studies: Traditional Approach

Risk definitions found in literature are numerous and diverse, and content themselves to rule on the nature of risk (Seidou 2002). Among these definitions, that of Rowe (1997) best summarizes the approach used at present. In this approach, risk is defined as being the potential of incidence of unwanted and negative consequences of an event. In technical fields, definitions include a clause allowing the calculation of a value, generally by multiplying the probability of occurrence of harmful events by the severity of these events, expressed, generally, in monetary units. These formulas can apply themselves to sequences of events (scenarios) by summing, for all the events, the products of the consequences and the probability (Kaplan 1997; CAN\CSA 1991; Stedinger 1996). Even though the use of probabilities to assess risks related to extreme events is currently questioned (Zielinski 2001; Robert and others 2002a), the approach that studies a finite number of scenarios remains largely privileged in a highly linear process (figure 17.1).

This approach is based on the prior establishment of boundary conditions. For every modification of the initial conditions, the process is repeated, thus establishing as many scenarios (Law and Kelton 1991). Overall, this approach consists in first defining the source event of the potential risk. The characteristics of the event make up the source data of the model. This model is established in order to simulate the behavior and the effects of the event in a specific context (study area, delimited geographical space, etc.) with specific objectives (scale of representation, time progress, etc.). The results of the simulation show the consequences engendered by the event in the study area (city, region, potable water supply network, etc.). These results can be illustrated using maps or balance sheets (Quach and others 2000).

Figure 17.1 Risk scenario: a linear process



Conventional risk analysis mainly focuses on extreme events, of which the probability of occurrence is extremely low. In such a context, the event is considered a hazard, which is defined as being an unforeseeable or a disruptive event (United Nations 1984). Within the framework of risk analysis, a hazard can be defined as a generic class gathering a potential set of causes, or as a source of causes. For example, a hurricane is a hazard that can generate causes like flooding of an underground public transportation network, or strong winds that can damage power lines.

Hazards

A risk or a hazard is an event. A cause is defined as being the origin, the reason, for which an event occurs. It is generally accepted that causes are of a natural or an anthropic origin. The term "natural" refers to the physical world, except for humans and their works, and to what occurs spontaneously in the universe without the intervention of calculation, reflection, or will, which are considered the prerogative of humans. The term "anthropic" relates to human industry, that which is made by humans, that which is due to the existence and the presence of humans. Based on these definitions, it is possible to say that an anthropic cause, due to the existence of humans, is the cause that will bring about an event (failure, malfunction) affecting the studied sector. A natural cause, contrary to an anthropic cause, is not at all influenced by human activities.

Today, it is increasingly difficult to define an exceptional event as exclusively of natural origin (IPCC 2001). Risks are in interaction with one another (Zielinski 2001; Denis 2002). In this context, no event said to be natural can be completely independent from human activities, particularly with regard to extreme weather phenomena (tornadoes, hurricanes, ice storms, torrential precipitations, floods). It is, however, admitted that a natural event can be considered a trigger, where the human activity and the anthropic risk that result from it are defined as aggravating elements. In addition, the anthropic causes are mostly internal to a system, while natural causes are external to it.

Although risk studies of either of the two types of events (natural or anthropic) follow the same generic approach, it appears important to make a distinction in their specific treatment. Effectively, this distinction allows the differentiation of hazards coming from outside a life support network from those propagated inside this same network.

Natural Events

Particularities of exceptional natural events lie in their low predictability. Therefore, the evaluation of natural causes is essentially carried out using quantitative and predictive methods based on statistical analyses and stochastic modeling (IPCC 2001; Zielinski 2001; Bier and others 1999). In this case, the establishment of a model draws, on the one hand, on physical laws that govern the components of the event (e.g., hydraulic laws in the case of a flood) and, on the other hand, on the analysis of prior recorded events in order to validate the model. Historical, morphological, and cartographic studies as well as studies more specific to the studied phenomenon (seismic risk, floods, etc.) are fundamental in order to collect data necessary to the proper operation of stochastic models. It is a matter of better understanding phenomena in order to better predict them.

Consequently, it is possible to simulate a multitude of synthetic events (scenarios). The results of these stochastic models are generally illustrated as maps, graphs, and tables (RNC 2002). They allow reporting of the effects of the event upon the studied geographical site. As an example, table 17.1 shows three cases of the evaluation of the consequences of natural causes.

These generic results are generally obtained in the form of maps that integrate, for example, water levels, tornado corridors, and wind speeds or even seismic zones. This way of expressing the results has the advantage of offering a global vision of the expected impacts of the hazards in a given territory. However, the approach generally followed during these evaluations does not integrate, a priori, the concerns of the managers of the life support networks located in the studied territory (figure 17.2)

Therefore, for those in charge of the networks (participants B and C, figure 17.2), the risk evaluation for their infrastructure requires a specific approach for the interpretation of the generic results obtained by participant A. This process of nonintegrated sequential

Figure 17.2 Evaluation of the impacts of a natural hazard and use of the results

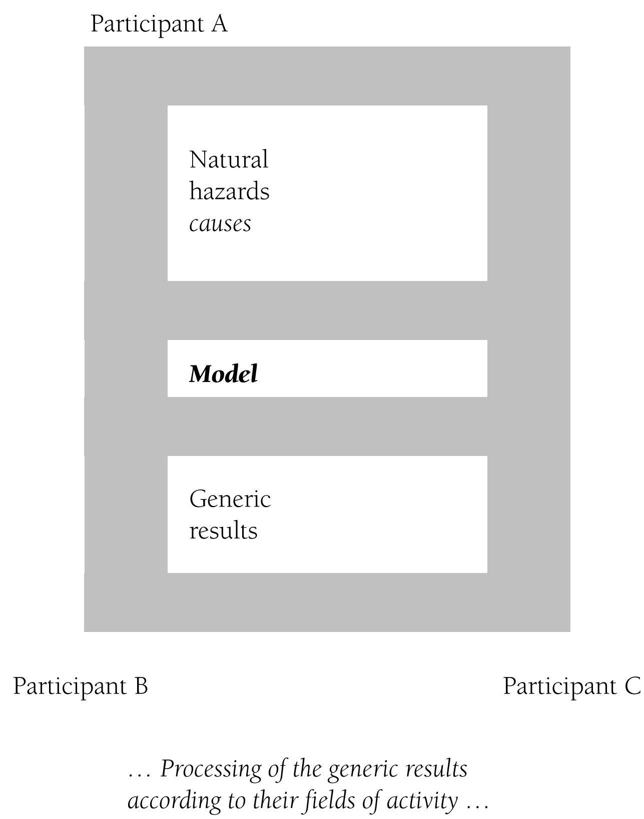


Table 17.1 Cases of evaluation of consequences of natural events

Official	*Application*	*Model(s)*	*Reference*
U.S. Geological Survey	Earthquakes in the United States	Mississippi Embayment reference model	http://www.ceri.memphis.edu/usgs/model/index.shtml
U.S. Federal Emergency Management Agency	National Flood Insurance Program (NFIP)	Numerical models accepted	http://www.fema.gov/mit/tsd/en_modl.htm
National Hurricane Center	Tropical cyclone track and intensity guidance models	Operational track guidance models	http://www.nhc.noaa.gov/aboutmodels.html

steps highlights two main limitations. The first is related to the single-sequence approach, generally observed by authors of natural hazard studies (participant A). The second limitation is related to the need of those in charge of life support networks (participants B and C) to evaluate not only the most unfavorable scenario, but also the set of potential situations with which they can be confronted, in order to be able to understand the dynamic behavior of their network and thus anticipate some mitigation or emergency measures.

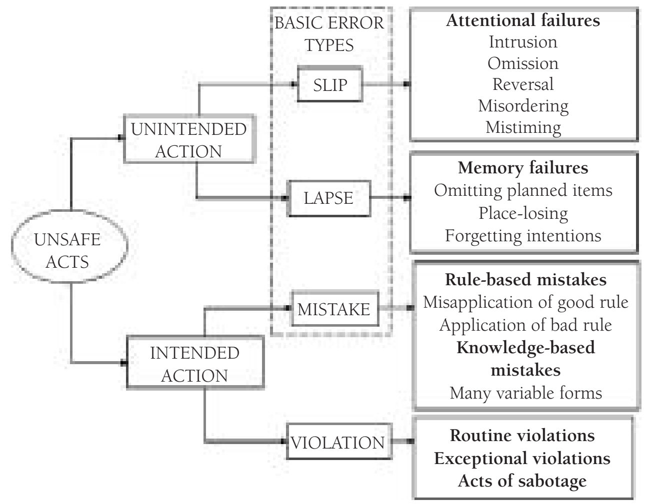
Anthropic Events

Anthropic events refer to two main categories: technical malfunctions and human reliability. If the first category is relatively well known and integrated into analyses, the second one is in many regards minimized in risk studies.

It is, however, important to differentiate between reliability and human error (Nicolet and Celier 1985). Human reliability is the probability that an individual, a team, or a human organization, will accomplish a mission, under given conditions, within acceptable limits, within a certain length of time. A human error is a behavior that exceeds acceptable limits (variation between what has been done, perceived, understood and what should have been done). These two definitions demonstrate that the study of human errors takes place after the event occurs. In contrast, studies of human reliability take place before the event takes place.

The study of human reliability is complex since it can be approached in two different ways. A first approach consists of defining human reliability as the gathering of human errors, violations, and positive actions that could be carried out by participants. Human errors arise from intended actions (mistakes) and unintended actions (slips, lapses). As shown in figure 17.3, drawn from Reason (1990), a slip corresponds to a failure of attention, while lapses are failures of memory. Mistakes refer to the incorrect application of a good rule or to the correct application of a bad rule. Violations, according to Reason (1990), "...can be defined as deliberate, but not necessarily reprehensible, deviations from those practices deemed necessary to maintain the safe operation of a potentially hazardous system. Therefore, the border between violations and faults is often difficult to determine."

Figure 17.3 Summary of the psychological varieties of unsafe acts



Source: Reason 1990.

A second approach consists of differentiating latent malfunctions from active malfunctions (Reason 2000). Active malfunctions have almost an instant effect and are often related to the operators of the system being considered. Latent malfunctions, as their name indicates, are more insidious since they can go by unnoticed until an event or a combination of events makes them active. This last type of malfunction is related to individuals, such as managers, who are remote from the control interface (Reason 2000). Due to their nature, latent malfunctions, which are more likely to affect a system, are more difficult to assess than active errors. Therefore, many studies tend only to consider active failures in their evaluation methods. This differentiation between types of malfunctions presupposes that only a series of latent and active human malfunctions can lead to the failure of the system.

When it becomes a matter of integrating anthropic events as causes of potential risk, the approach proves to be complex. However, these events can be taken, not only as a direct cause, but also as a potential technical cause. Technical malfunctions are principally found at the design, construction, operation, and maintenance stages. These malfunctions are related to human factors. It is not easy to differentiate between the two, and for this reason, the notion of sociotechnological risk is often employed (Denis 1998). Even in the case of a mechanical breakdown, human intervention cannot be disregarded, because it may be the result of an error in design or maintenance. Therefore, the theoretical approach normally relates human causes with technological causes.

In this category, there exists a multitude of tools, which are more or less specialized and dedicated to activities such as design, operation, maintenance, and management of a network. In particular, certain models permit the simulation of a technological risk (for example, breakdown of a transformer station in a power grid) and the measurement of the behavior of the network faced with the risk. The organizations responsible for civil infrastructure generally have at their disposition these models, which allow the simulation and operation of their networks.

Limitations of Current Risk Studies

Profiting from the never-ending increase in performance of computers, these software tools allow a large number of parameters and variables to be taken into account. Nevertheless, the limitations of these models have less to do with the computing power than with fundamental understanding of natural phenomena, such as meteorological events (hurricanes, tornadoes, or cyclones). Models of natural phenomena collide with the complexity of the interactions, between environmental elements as much as between technological elements. At present, models are mathematical relations simplified from the rules of behavior of natural phenomena. In effect, the majority of models rely on a combination of empirical and theoretical relations (Tyagi 2001), which by their very nature imply incertitude as much for the input values as for the algorithm of the model being used. Therefore, these sources of uncertainty are reflected in the results (output).

In addition to the incertitude engendered by the ignorance of the behavioral mechanisms and interrelations between different components, conditions of a scenario are defined by historical data and the statistical analysis of this data. However, certain authors (Bier and others 1999) highlight the specific character of extreme events. They define them as events that are at once severe and outside the normal sequence of occurrence of the system in question. This statement highlights the uncertainty that exits in the area of the study of extreme events (data and models). Presently, the form under which risk study results are presented makes it difficult to take into account this fundamental dimension of uncertainty. For example, analysis of the risk of dam rupture (technological event potentially engendered by a natural hazard) allows the establishment of a flood map for the regions downstream of the infrastructure as a function of a fixed scenario. However, taking into account sources of expressed uncertainty, the results (water levels) do not allow the managers of essential infrastructure, potentially affected by the flood, to grasp the entire set of potential effects of the event on the components of their infrastructure in order to evaluate the consequences on the different missions of the essential infrastructure. For example, the mission of a potable water network is to deliver a volume of water, of sufficient quality, with a minimum pressure.

Analysis, a posteriori, of so-called natural catastrophes shows, more often than not, that extreme events, which on one hand are difficult to foresee according to the models being used and the previously defined boundary conditions (recovery time, initial conditions, etc.), can combine with other events (technological risks, etc.), which amplify the effects and the consequences (Lavallée 2000). Scenarios consider, in general, single-event conditions (simple hazards). This characteristic is implicitly required for the statistical treatment of previous events. So studies of catastrophes highlight the synergetic effect that can exist between generators of natural, technological, and human risks (Denis 2002). For example, a hurricane engenders not only direct consequences on populations, but also on essential infrastructure (flood of an underground public transportation network, felled telecommunication relays or electric power distribution pylons, etc.). Out of service or malfunctioning parts of the infrastructure, by definition, have negative effects on one another and finally on the functioning of civil society. This statement and the resulting consequences are repeated more and more often, particularly in industrialized societies with essential infrastructures that are increasingly complex and interrelated. However, even if there are differences between societies in industrialized countries and developing countries, the development of life support networks always tends toward an increased complexity and interdependence.

To be able to treat overall the multiple and complex relations that encompass tangible and intangible parameters, one of the advocated approaches is to refocus the analysis on essential infrastructure. In effect, simulation of natural hazards does not integrate, a priori, the expectations of the managers of these infrastructures. In this context, the reference should no longer be the causal event, but the infrastructure itself, which, if it does not fulfill its mission completely or in part, engenders consequences on civil society, and other infrastructure. From here, research of potential causes that generate deviation from the missions is accomplished with respect to the preoccupations of the managers, regardless of the type of risk: natural, technological, or human. In this context, study of the domino effects between life support networks is clearly necessary in order to be able to evaluate the risk and to contemplate emergency measures in order to respond adequately to catastrophes.

New Structural Approach

The classical approach, which consists of analyzing a life support network from a finite number of potential failure causes, does not allow consideration of the entire set of situations. In addition, the domino effects between networks are rarely identified and considered. With regard to the very nature of life support networks, which have human and socioeconomic consequences resulting from their failure, it is dangerous not to have a complete picture of the possible situations. To respond to this disquieting situation, a new approach is proposed to carry out an exhaustive study of life support networks. This analysis will act as a catalyst for the study of the domino effect between several life support networks.

The proposed approach relies on a precise characterization of the functions of a life support network, its modes of operation, and the infrastructure that composes it. The analysis of a life support network is based on two study methodologies. The first is an evaluation of the consequences of failure of the network, while the second is a determination of its vulnerabilities. All of this information will serve the study of the domino effects between several life support networks. Case studies carried out by the École Polytechnique de Montréal will illustrate the proposed methodologies; the confidentiality of these results has been maintained by removing all information that could identify the zones studied.

Characterization of a Life Support Network

Fundamentally, a life support network is created in order to fulfill certain missions or functions directly related to human activity. To do this, certain operations are available to managers of this network. In terms of engineering, a network is composed of a set of important infrastructure components, of which some are essential in terms of vulnerability of the network. A network fails once one mission cannot be fulfilled in whole or in part, following the failure of one or several operations or of infrastructure. Therefore, there is a notion of degree of efficiency of a mission. The description of the three principal elements—mission, operation, and essential infrastructure—follows below.

- Mission: the mission of a life support network corresponds to a function for which it was designed and built.

  As an example, the mission of a potable water supply network is to:
  - maintain a quality of water suitable for human consumption;
  - provide water (volume and pressure) in order to fight fires;
  - provide a volume of water;
  - etc.

  The mission of an electrical network is to:
  - maintain constant electrical power;
  - maintain a minimum electrical power;
  - provide at least some organizations (hospitals...) with electrical power;
  - etc.
- Operation: an operation is a technical process allowing direct or indirect actions on part or all of the network in order to accomplish the mission; these actions can be automated or manual.

  As an example, the operations of a potable water supply network include:
  - pumping;
  - treatment;
  - storage;
  - etc.

The operations of an electrical network include:

- energy generation;
- transportation;
- distribution;
- etc.

- Essential infrastructure: infrastructure corresponds to installations that are necessary to accomplish the operations. Infrastructure is essential when it has a primary role in the proper functioning of the network.

As an example, the essential infrastructure of a potable water supply network is:

- ozonator;
- reservoir;
- pump;
- etc.

The essential infrastructure of an electrical network is:

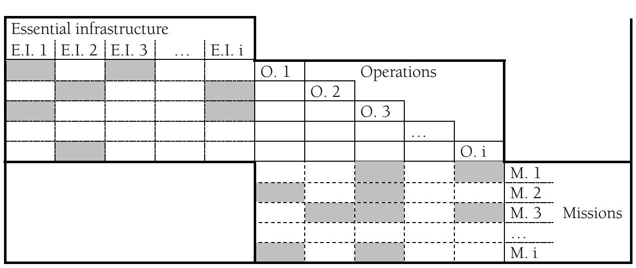
- transformer station;
- hydroelectric generating station;
- high voltage power lines;
- etc.

To fulfill a mission, several operations are available; an operation uses a certain amount of essential infrastructure. Figure 17.4 shows a schematic of these elements and their potential interrelations. For example, the essential infrastructure (E.I. 1) allows the network to fulfill its mission (M. 2) using the operations (O. 1 and O. 3).

These operations depend on the specificity of each life support network and must be established with the managers, design engineers, and the technical and operations managers. The correct identification of these elements is essential to defining their efficiency and their importance. These notions can be defined as follows.

- Efficiency: an element is 100 percent efficient when it adequately fulfills the task for which it was designed.

Figure 17.4 Diagram of the characterization of a life support network



If an element cannot fulfill all of the tasks, its efficiency decreases. When an element is out of service, its efficiency becomes zero. Therefore, efficiency can vary between 100 percent and zero. This efficiency is evaluated differently depending on the elements:

- *Mission:* a mission is 100 percent efficient if all of the conditions that characterize it are present and the set of clients affected by the mission is served.
- *Operation:* an operation is 100 percent efficient if the management procedures are valid, adequately applied, and known by all of the personnel.
- *Essential infrastructure:* an essential infrastructure is 100 percent efficient if it is in good condition, functions correctly, is used within the design norms, was designed according to the existing norms, etc.

- Importance: characterizes how an element is essential for a network
  - *Mission:* a mission is essential if it represents a priority that whose fulfillment is imperative; some missions can be secondary.
  - *Operation:* rules of operation are essential if they ensure a minimum level of service, while some rules of operation can be identified as refinements or can be used to ensure an optimization of operations.
  - *Essential structure:* the importance of an essential structure is a direct measure of its role in the network. In the case of a failure, or cessation of services, the consequences on the correct functioning of the network and the accomplishment of the missions are significant.

Thus, a network is functional if the entire set of its missions is fulfilled with a degree of efficiency of 100 percent. Once a mission is no longer efficient, the network fails. A failure results from a vulnerability of the network, in other words, once an operation and/or an essential infrastructure is no longer efficient. The size of the vulnerability depends on the importance to the mission of the nonefficient elements.

There are two distinct notions, in terms of analysis, related to correct functioning of the network: failure and vulnerability. Failures of a network provoke consequences on populations and socioeconomic activities and will, therefore, be studied from the angle of the study of consequences. Vulnerability of a network will be analyzed by way of the study of vulnerabilities, which allows the affected elements to be established. These two studies are described in the following pages.

Consequence Studies

Analysis of current risk studies shows that the approach by scenarios is too restrictive for studying life support networks. In effect, these scenarios generally advocate a macrosequential approach, based on the evaluation of past events, composed of natural or technological risks, where human reliability is rarely integrated. Finally, they consider extreme events to the detriment of the intermediate situations that affect a set of well-defined infrastructure, usually coming from one network. These studies bring about a generalization of knowledge, whereas only a part of the entire set of possible situations has been analyzed. It follows that there is an apparent gap in the evaluation of vulnerabilities of a network and the domino effects resulting from the multiple failures that can arise. To alleviate these major weaknesses, during risk studies and the planning of emergency measures, a new approach is proposed: the study of consequences (Robert 2001b, 2002b).

A study of consequences is based on the following fundamental principles:

- A life support network fails when one of the missions for which it was designed is no longer fulfilled with an efficiency of 100 percent.
- The reduction of efficiency of the mission of a life support network is studied without consideration for the causes that could have provoked the reduction.
- All of the degrees of efficiency of a mission are analyzed from 100 percent to zero, in a manner that covers all of the possible situations.

From the preceding principles, a study of consequences of a life support network is carried from the six principal steps, described generally below:

1. Evaluation of variations in efficiency of missions

   Each mission of a life support network is analyzed in technical terms in order to identify experts who should be involved in the project to characterize the failures and evaluate the consequences.

2. Sequential evaluation of missions according to their importance

   Prioritization of the study of consequences as a function of the their importance. This step will allow evaluation of the resources to establish those that are available and those that must be sought.

3. Failure study related to the variation of efficiency of a mission

   Once a mission is not respected, the potential failures are numerous. For example, the mission of a potable water supply network can be inefficient following multiple failures, such as chemical, biological, or bacteriological contamination, etc. The identification and characterization of these failures are important in order to evaluate the potential consequences properly. Failures can be grouped as a function of consequences. Equally, failures can be described in terms of variation between no failure and maximum failure, with respect to the variation of the efficiency of the mission.

4. Exhaustive evaluation of the consequences

   A study of consequences is focused on the complete analysis of a failure and the set of resulting consequences. The entire set of possible and plausible situations is studied while considering all of the graduations of the failure. Such an exhaustive approach allows a progressive picture of the repercussions or the consequences generated by the occurrence of a failure to be established. For example, following the failure of a hydroelectric reservoir, a flood is created. A study of the consequences covers all the water levels between the start of the flood and the maximum water level. The progression of the flood is therefore studied as well as the increase in the resulting consequences.

5. Drawing of consequence curves

   The results of a study of consequences are presented in the form of curves or diagrams in order to show the progression of the phenomena studied.

6. Identification of life support networks affected by the failures

First, life support networks affected by the failure of a network are identified. The conditions of failure of the first network are also identified in order to establish the initial conditions provoking the domino effects. Communication mechanisms between these networks are initiated in accordance with the concepts of risk communication.

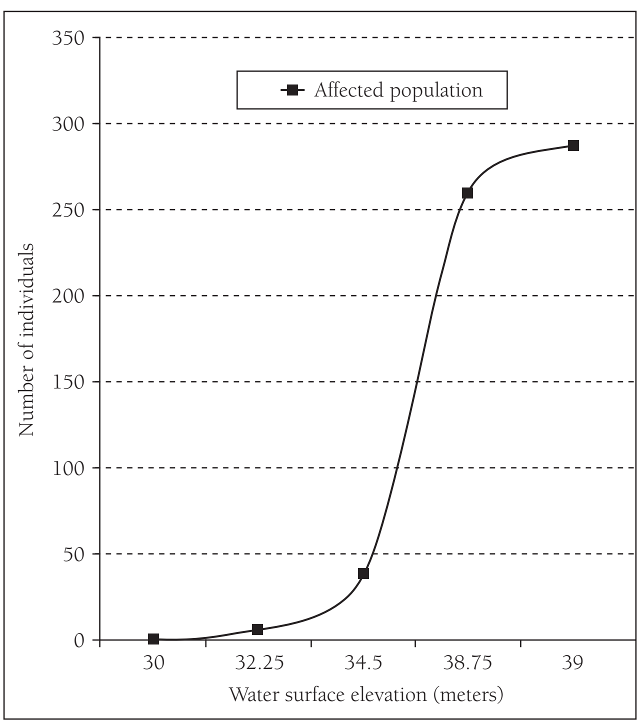
Actually, the consequence curves are established to cover the human socioeconomic consequences of the failure of a life support network. These curves were established principally for the municipal emergency measures managers directly affected by consequences for their citizens and municipal affairs. Some examples of produced curves:

- Number of people affected by the failure (flood and water contamination)
- Damage to buildings (flood)
- Number of sensitive elements (hospitals, schools, daycare centers, etc.) affected by the failure (flood, contamination, loss of electricity)
- Dangerous industries affected by the failure (flood, loss of electricity)
- Public transportation affected by the failure (flood, loss of electricity).

Figure 17.5 presents an example of a consequence curve for a municipality expressed in terms of number of people affected by a flood. Analysis of such a curve, in addition to providing all the knowledge for a good plan of the mechanisms of evacuation, allows the establishment of the levels of severity of the emergency generated by these consequences (Robert 2001b).

These graphical results, coming from a progressive and systematic approach, are easily used in a risk study based on specific events. In effect, such risk studies allow a result representing a precise state of vulnerability, which corresponds with a point on the consequence curve, to be obtained. For the different planning stages of emergency measures, these graphics allow the entire set of potential situations to be covered and establish thresholds that correspond to the emergencies.

Figure 17.5 Consequence curve for a municipality



Vulnerability Studies

The failure of a network is a unique event generally resulting from the conjunction of several distinct causal chains. Therefore, the proposed approach consists of studying the potential failures of the missions of a network in order to define their causes, both natural and anthropic. The goal is not to determine a probability of occurrence of an event, which often proves to be subjective, but to define the series of hazards that can lead to the failure of the network. For example, for the bacteriological contamination of a water supply network, it is a matter of determining the contamination points of the network while taking into account the operating procedures, the condition of the network, and the possible contamination of groundwater by natural phenomena or technological accidents.

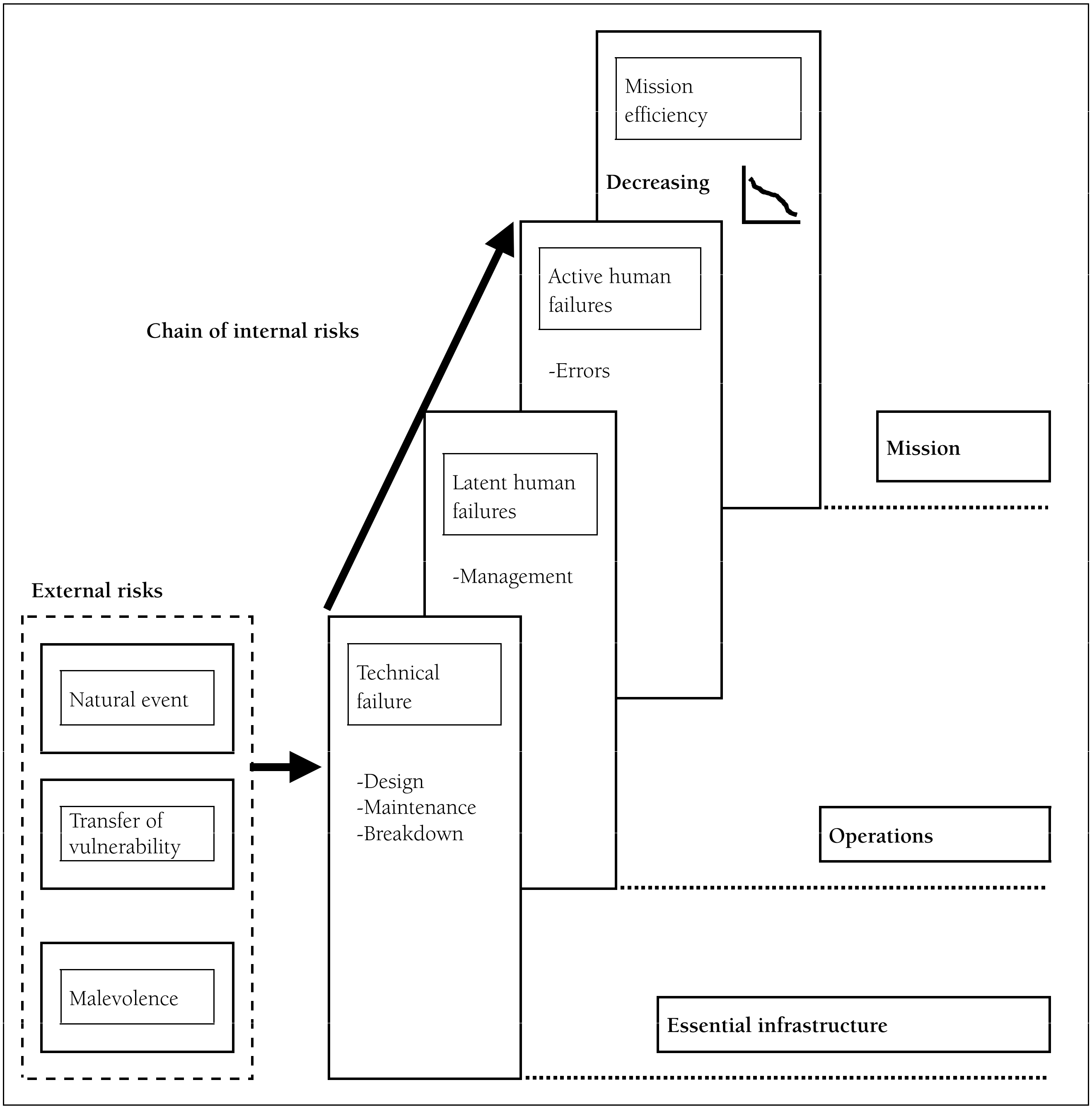
First, the methodology of the study of vulnerabilities is presented overall. It is based on the identification of the vulnerabilities of a life support network. Explained next are the general concepts of evaluation of the possibility of the vulnerabilities, since these data are essentially for the study of risk.

Methodology

Network engineers must determine the conditions necessary to reach a certain state, taking into account that external risks can arise and that components of the network (operations and essential infrastructure) can become inefficient. Figure 17.6 diagrams these conditions, which are described below.

- External hazards: act as triggers by affecting the network at the level of essential infrastructure. Three causes of external hazards have been identified.
  - Natural causes: subdivided into two groups:
    - Instantaneous phenomena, such as earthquakes

Figure 17.6 Diagram of the conditions for decreasing the efficiency of a mission



- ◦ Predictable phenomena, such as the seasonal surge of a river.

  In all cases, the natural events studied are exceptional phenomena.
- External technical malfunctions: correspond to the transfer of vulnerability between life support networks following the domino effects between them.
- External human causes: are exclusively active human failures such as acts of malevolence (sabotage).

▪ Decreasing efficiency of the components of a network: can only have two origins, either technical or human.

The methodology of evaluation of overall vulnerability is presented because it requires highly multidisciplinary work, with a whole set of technical, managerial and human resource participants. The concept of risk communication will serve to identify the participants and the precise structure of the steps to follow as a function of the specifics of each life support network. Three main steps can be identified.

1. Evaluation of vulnerabilities

The analysis of consequence curves allows the identification of the missions where efficiency has decreased. Therefore, it is a matter of determining the causes bringing about the decrease in efficiency. To do this, each element linked to the inefficient mission is analyzed.

- First, the operations are studied. It is a matter of evaluating whether human error can diminish the efficiency of an operation. For this, how and where human interaction takes place must be identified. Next, management procedures must be analyzed in terms of response to an exceptional situation.
- Essential infrastructure is then analyzed in terms of internal efficiency. To do this, it is a matter of evaluating whether the actual condition of an infrastructure is satisfactory, then establishing the potential conditions for diminished efficiency, for example the minimum level of maintenance necessary to affect an infrastructure.
- External hazards are then studied. It is a matter of establishing the natural events that can arise and affect the efficiency of the infrastructure, while assuring that the entire set of possible situations is covered.

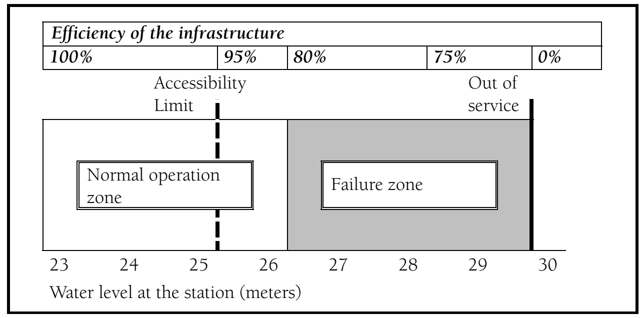
  Technological causes coming from the failure of another life support network are analyzed from the failure curves of the network and from the transfer function as described in the section on domino effects. This transfer of vulnerability allows direct evaluation of a decrease in efficiency of infrastructure.

  Acts of sabotage must be considered possible, requiring an evaluation of the protection of the infrastructure.

The result is an exhaustive evaluation of the elements related to a mission, with the following information for each one:

- A description of the conditions bringing about a decrease in efficiency; and
- An evaluation, numerical or not, of the possibility of occurrence of these conditions.

Figure 17.7 Vulnerability curve for a transformer station



Next, an overall analysis is carried out in order to obtain a complete picture of failure possibilities. The variation in efficiency of a mission is analyzed to know the progression of the magnitude of the failures.

2. Creation of vulnerability curves

The results of the evaluation of vulnerabilities can be presented in the form of curves or diagrams that illustrate the progression of the phenomena. These curves are associated with procedures of operation and essential infrastructure. They indicate variation in the degree of efficiency. Figure 17.7 gives an example of a vulnerability curve of a transformer station, essential infrastructure of a hydroelectric network, having to control floods as a mission (Robert 2001b).

3. Identification of domino effects between several life support networks

Consequence studies highlight the life support networks affected by failures of a first network. At this stage, it is a matter of identifying the essential infrastructure, which has links with other life support networks, and evaluating at which threshold the efficiency of the first network affects the second.

Possibility of Occurrence of Vulnerabilities

To carry out a risk evaluation, it is necessary to evaluate the possibility of the occurrence of a hazard. Numerous techniques exist for evaluating overall reliability (human and technical) (Dhillon 1985, 1989) of a system as well as the effects of natural events on it. Based on the classification proposed by the *Institut de Sûreté de Fonctionnement* (ISDF 1994), it is possible to define five major classes of methods:

- Quantitative and predictive methods (Kirwan 1994; El Shahhat and others 1995);
- Descriptive analysis methods (Hadipriono and others 1986; Leverenz and others 1996);
- Combination approaches (Suokas 1993; Ridley and Andrews 2000);
- Structural and descriptive analysis methods (NASA 1995; Modarres and others 1999); and
- Systematic design analysis methods (Garin 1994; Cazaubon and others 1997).

The objective of quantitative and predictive methods is the evaluation of the probability of occurrence of human errors, technical failures, and natural events that are observable under the given conditions. The majority of these methods call upon the opinions of experts, which allows the various aspects—both natural and anthropic—that can bring on a failure to be considered. However, from these methods, probabilities that are often subjective result, since they are strongly correlated to the opinions of the experts who participated in working them out and to the variables used.

The objective of descriptive analysis methods is to tackle the origin of the decrease in efficiency of a mission and provide reliable collection and failure analysis tools. These methods are used once the event has arisen, which is at the same time their strength and their weakness. In effect, they allow the hazards bringing about a decrease in efficiency to be described, but they cannot serve to evaluate the network before the failure.

The objective of combination approaches is to describe and analyze in order to anticipate and even predict failures. These methods, such as cause/consequence trees, are very interesting. Starting from a potential consequence, it is possible to rebuild the series of hazards that have or could bring about a decrease in efficiency of a mission.

The goal of structural and descriptive analysis is to identify the structural characteristics of a network, in other words, its boundaries, components, and interconnections. Because of their mode of representation in block form, the use of such methods can be problematic, even impossible, for complex systems such as life support networks. However, these methods are interesting for defining, in an efficient manner, the entire network and its interrelations with other systems.

The objective of systematic design analysis methods is to consider an entire design project as much from a technical as an organizational plan. These methods take both human and technical factors into account at once.

It is important to note that several methods can obviously be combined according to the situation and desired result, as long as they integrate into a common approach.

The classical approaches to risk analysis advocate probabilistic evaluations of risk, which essentially rely on quantitative and predictive methods. These methods rest on the use of elaborate scenarios built from data collected during observed decreases in efficiency of networks. The proposed approach distinguishes itself from the scenario approach by addressing the problem with the study of consequences of the decrease of efficiency of a mission. Defining risks remains important, notably for the design criteria and mitigation measures, without associating probabilities, which often prove to be subjective.

Different risks are strongly dependent upon one another. Therefore, it appears necessary to define an overall methodology integrating all of these causes to better predict and manage the risks that can affect the network being studied. This approach will have to combine the evaluation methods of three large risks. Certain methods integrate two of the risks (natural and technological, technological and human), but none integrating the three seem to have been developed. Another difficulty lies in the integration of the evaluation of different simultaneous natural phenomena, like for example, the probability of occurrence of an earthquake and a flood. Therefore, it must be determined, among the large group of previously presented methods, which technique or group of techniques would be the most appropriate for evaluating the set of risks, both anthropic and natural, that could lead to the failure of a life support network. While allowing the combination of different factors, the chosen evaluation methods must be easily understood, quickly put into place, and adaptable to networks of different natures. Methods with a low degree of subjectivity will have to be found, from which mitigation measures can be implemented.

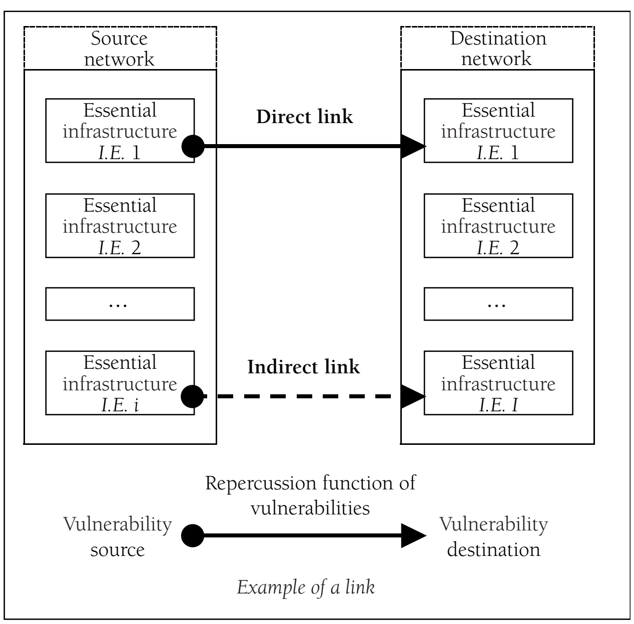
An overall methodology for risk evaluation will have to be based on a good understanding of the network being studied, its vulnerabilities, its environment, impacts that could affect it in case of decreased efficiency of another network, and equally the infrastructure that it could influence in case of a failure (vulnerability transfer). The evaluation of events that can engender risk must be carried out in a systematic manner, not to eliminate risk, but to diminish the vulnerability of the set of life support networks.

Study of Domino Effects between Life Support Networks

Consequence and vulnerability studies highlight that the failure of a life support network can provoke consequences on another network by affecting its essential infrastructure (external technological risk). The links uniting several life support networks are numerous and varied. A good understanding of the dynamic of these networks is therefore essential to avoid benign malfunctions transforming into major crises (Allen 1997; Hubbert and Ledoux 1999; Lemperiere 1999). Figure 17.8 illustrates this principle of links.

A methodology was developed at the École Polytechnique de Montréal to study the links that united several life support networks (Robert 2001a, 2002b). It is based on the idea that these links, which represent a connection between different networks, allow vulnerabilities of one network to reflect on another through a function

Figure 17.8 Definition of links



of repercussion of vulnerabilities. These links are directional, defined by a source and a destination. The source is associated with an essential infrastructure specific to the originating network, whereas the destination is associated with an essential infrastructure of the destination network. Two types of links can be identified: (1) a direct link if the two components are physically or mechanically connected (like an electric cable); and (2) an indirect link if there is no clearly identifiable connection. The type of link directly influences the repercussion of vulnerabilities function. However, the methodology for the study of these links is the same. It uses the following three steps.

1. Definition of the source vulnerability

   The source vulnerability represents a combination of consequence and vulnerability studies carried out on the source life support network. The consequences of multiple failures of the network are identified as well as the other life support networks affected by way of the links between these networks.

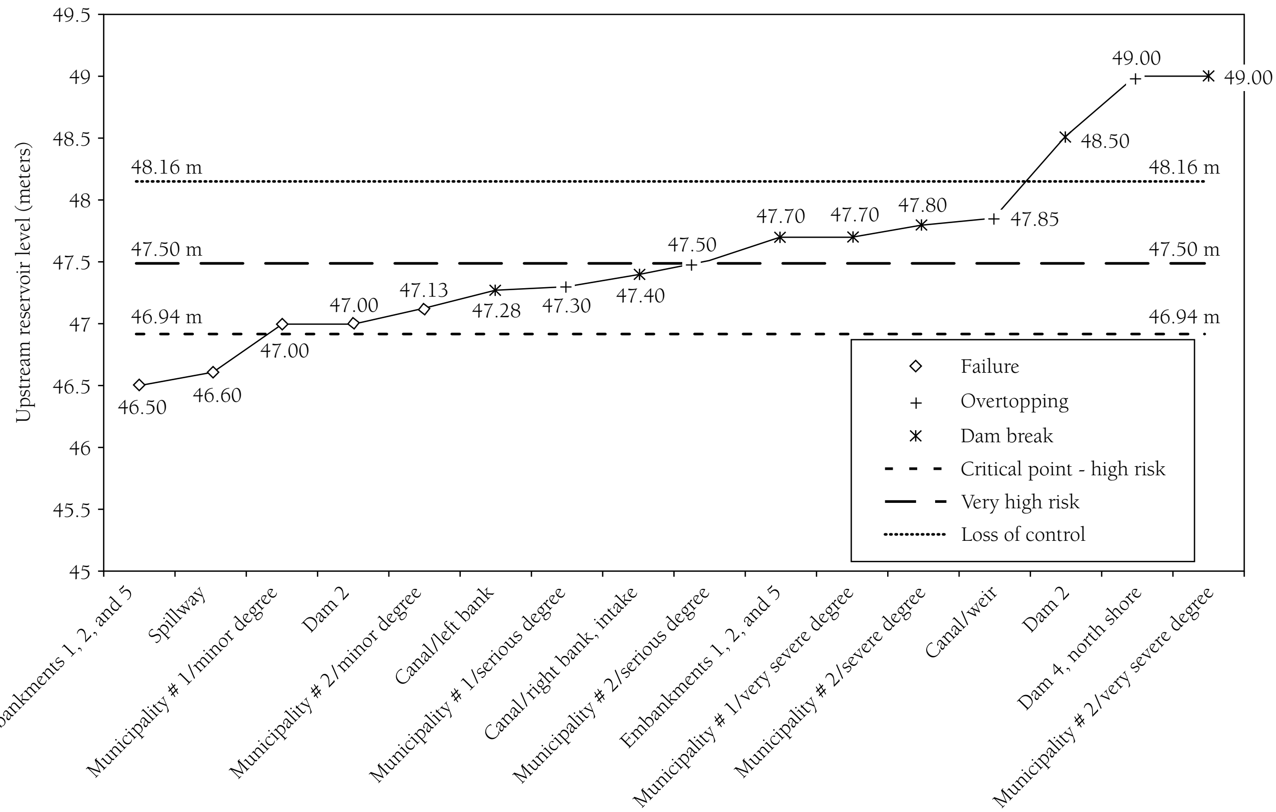
   The study of vulnerabilities of the source network allows the essential infrastructure where the efficiency has decreased to be identified. If this infrastructure is the source of a direct or indirect link, there is a potential domino effect.

   The set of degrees of efficiency of the essential infrastructure must be analyzed and passed on to the destination network. Equally, it is important to integrate the consequences of these variations of efficiency. A graphical representation illustrates this graduation of the vulnerability of a network. Figure 17.9 shows an example of a vulnerability curve for a hydroelectric installation. On this curve, the different components are identified and characterized in terms of technical efficiency. In addition, the multiple consequences of these failures are represented. Such a curve synthesizes all of the information that must be communicated to the other networks affected by these failures.

2. Definition of the repercussion function

   The consequences of the variations in efficiency of the source essential infrastructure must be propagated, modified, or transformed before reaching the destination component. The repercussion functions are generally established by simulations, which attempt

Figure 17.9 Affected components as a function of the water level rise in the upstream storage basin



to evaluate the consequences—direct or indirect—of variations in the efficiency of the infrastructure on the environment. The type of link, direct or indirect, influences these studies.

a. Direct link: the repercussion function depends on the physical nature of the link. For electrical links, the function can be a variation in power. In general, these functions are well documented, numerically modeled, and known by the network managers and engineers.

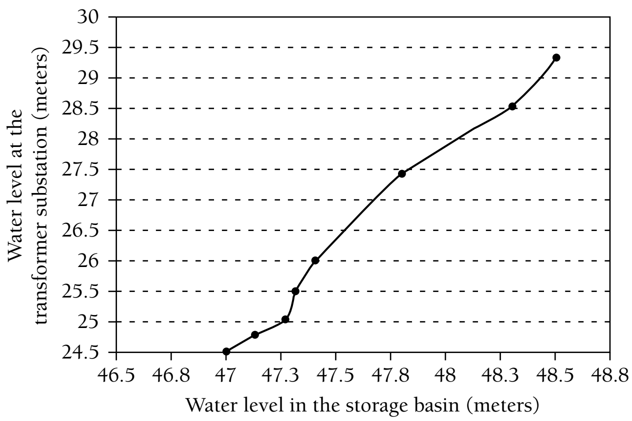
b. Indirect link: the definition of a repercussion function for an indirect link is more complex in terms of technical expertise, because it requires specific studies and calculations, which are not regularly carried out by network managers and engineers. For example, for a hydroelectric installation, source vulnerability is shown in figure 17.9. The repercussion function of this vulnerability characterizes the behavior of water that overflows a reservoir and affects the infrastructure of the other network affected by the same flood. Therefore it is important to know the flooded areas. Graphically, this function is shown in figure 17.10, which shows a curve relating water levels between a reservoir and a transformer station.

3. Definition of the destination vulnerability

The source vulnerability transferred to the essential infrastructure of the destination network is considered an external technological risk that is going to influence its efficiency as described in vulnerability studies. Figure 17.7 shows the result obtained on a transformer station.

The study of domino effects between several life support networks demands the collaboration of multiple experts and requires complex studies, especially for indirect links. It is a multidisciplinary work, which will have to be carried out so that the entire set of human and socioeconomic consequences can be considered in the establishment of efficient and effective emergency measures and the performance of complete risk studies. The diverse uses of these studies are presented below.

Figure 17.10 Example of a repercussion function: relationship between the water level in a storage basin and at a transformer substation



Applications and Uses

The results of these studies are particularly well suited for risk studies and planning of emergency measures. For risk studies, two methods are possible: an approach by scenario and an approach by consequences. The choice of the method depends on the desired use of the results. For emergency measures, the proposed studies are particularly useful for the planning and identification of mitigation measures. A section specific to risk communication will be presented, since it acts as the basis for the previous activities by ensuring the involvement of all concerned parties. The diverse uses of these studies will be presented below.

The applications described below allow the evaluation of risks related to life support networks facing natural hazards. In the context of financing these networks, the quality of the information obtained from consequence and vulnerability studies will allow a better evaluation of the opportunity to develop these networks with regard to consequences during a failure. It will also be possible to evaluate whether the structures and the networks, as planned, are adequate in terms of risks and especially in terms of consequences for populations. Alternative solutions can therefore be proposed and developed. Proactive solutions for the protection of populations can also be directly associated with the financing of networks by way of imposed emergency measures centered on the network missions and the mechanisms of risk communication. The initial planning of these measures permits them to be integrated into financing mechanisms and therefore ensures their existence and efficiency.

Risk Studies: Scenario Approach

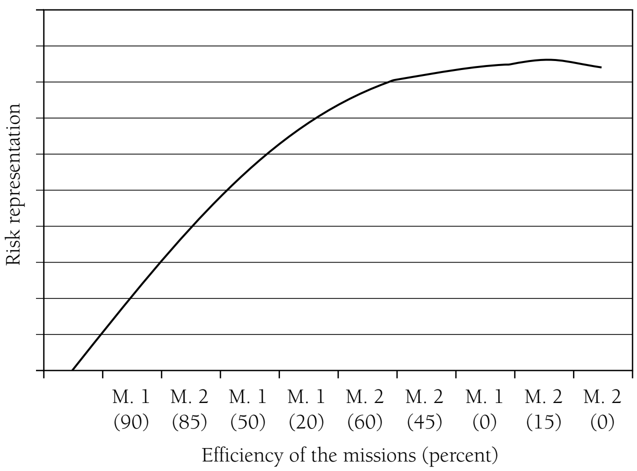
A risk study based on the consideration of a finite number of scenarios does not allow the entire set of possible situations to be considered, but maintains a certain utility, especially in establishing the data necessary for design and rehabilitation. Equally, it can serve to evaluate a set of similar infrastructure in a given territory. This type of risk study is widely used for hydroelectric installations (Plate 1996; Lemperiere 1993; Quach and others 2000). The result of such a risk study is generally represented by the product of the probability of occurrence of a scenario and the consequences, as defined at the beginning of this report.

The proposed vulnerability studies coupled with the precise definition of a scenario will permit the probability of a scenario arising to be established with much greater precision. In effect, the scenarios studied can be situated among a set of potential situations, which is a plus when the sum of the probabilities must remain equal to 1. Once the scenarios have been studied and simulated, the potential consequences generated by the scenarios will have been exhaustively studied by consequence studies, including the domino effects on the other life support networks. Therefore, the uncertainties of risk calculations will be minimized.

Risk Studies: Consequences Approach

A way of evaluating the overall risk related to a life support network is to study the entire set of potential situations. In the face of infinite possible solutions, a finite number of conditions can be analyzed to trace a risk curve that corresponds to the variation in efficiency of a mission. To determine the study points for this risk curve it is a matter of analyzing the consequence curves and establishing different levels of progression. Each level corresponds to a significant and abrupt increase in the consequences, therefore a network failure and a decrease in the efficiency of a mission. Vulnerability studies allow the vulnerabilities of the network that provoke the decrease in efficiency of a mission to be determined. They identify the concerned elements at the

Figure 17.11 Schematization of a risk curve



operations level and the essential infrastructure. Therefore, it is possible to evaluate the plausibility of occurrence of these causes and to calculate a risk in terms of the couple of plausibility of occurrence and consequences (this result can be purely numerical or can have a symbolic value). This risk calculation is carried out for each mission of a network. A set of risk values is therefore associated with decreases in efficiency of missions and the results can be expressed, if necessary, as a graph. Figure 17.11 shows a risk curve established for two missions (M. 1 and M. 2).

Such a risk study allows the maximum risk of a network to be determined, and also the total risk, which represents the sum of all the intermediate risks. These results can serve the network managers, and also the insurers, the financial organizations, and the competent authorities for the evaluation of the risks.

Emergency Measures

Consequence studies and consequence curves produced are particularly well suited to emergency measures. In effect, they synthesize the information to be used for the preparation of an emergency plan. For the manager of a life support network, preparing for an emergency means evaluating all possible situations to ensure the best protection to the people potentially touched by a failure of this network, however remote the chance of such a situation occurring. In effect, the human and socioeconomic consequences are too important to neglect a potential situation. It is one of the principal drivers of the study of consequences.

Concerning the establishment of mitigation measures, a combination of consequence and vulnerability studies is necessary. Similar to the risk studies done according to the consequences approach, levels of consequence must be established. These levels are determined from an evaluation of consequences that are *unacceptable* for the population. Next, vulnerability studies allow vulnerable elements at the operations level and the essential infrastructure to be identified. It is, therefore, possible to determine the corrective measures to apply—whether they are structural or not, permanent or not—as much on the essential infrastructure level as for the operational procedures, all the while considering external risk.

Risk Communication

Several studies have attempted to prove that the management of risks, as well as the process of risk communication that accompanies it, reduces uncertainty and increases the acceptability of risks. According to a systematic approach, risk communication allows the risks to personnel, populations, and material, industrial, technological, and financial resources to be reduced (Bates and Fitzpatrick 1994).

In the proposed structure of life support networks, as soon as the domino effects have been identified at the level of consequence and vulnerability studies, a structure for risk communication must be created. It ensures the transfer of information between concerned networks, with the goals of planning emergency measures, and reducing and controlling risks. Of course, it must not be forgotten that these networks are part of a larger set of networks and that information concerning risks and their consequences will have to be exchanged with partners.

Risk communication must ensure an interactive exchange of structured information between concerned parties. Therefore, setting up a Risk Management Committee seems like an essential tool for exchange, dialogue, mediation, and decisionmaking. All aspects relative to prevention and preparation will be treated there.

The Risk Management Committee is composed of representatives of the two networks: source and destination, as well as representatives of the concerned authorities. The committee must consist of different hierarchal levels and expertise. It is also advisable to create working subcommittees for precise domains of expertise, whose results are submitted to the committee for discussion and approval.

The Risk Management Committee will have to first approach certain points, which are described below.

- Prevention: the first responsibility of the committee is to ensure that the steps of vulnerability transfer are adequately carried out and then establish the level of acceptable consequences for the concerned parties. Finally, the important question concerning the disclosure of the risks to the population must be addressed. If the anticipated consequences predict a direct danger for the population, it will have to be brought to the attention of the committee.
- Preparation: each life support network has the responsibility of reaching a level of preparedness that permits it to maintain or re-establish, in the shortest possible time, the functions that allow it to fulfill its mission during a disaster or catastrophe. Certain elements of this preparation must be planned jointly with the partners of the Risk Management Committee, including:
  - Criteria and warning processes in case of an incident
  - Protocol for these exchanges between networks
  - Channels of communication used in such cases
  - Encoding and decoding of transmitted information as well as the feedback process
  - The implementation of mitigation measures at the level of operations and infrastructure
  - The decisionmaking levels required and involved in these exchanges of information.
- Intervention: unlike the prevention and preparation phases, where information to be exchanged and discussed passes via the Risk Management Committee, the protocol for information exchange is very different during intervention. Therefore, direct links between managers and experts must be anticipated in order to allow an exchange of precise information and to favor coordination between networks. The preferred channels of communication must adhere to certain precise criteria:
  - Transport high-quality, concise, precise, and tangible information
  - Transmit information quickly and without distortion
  - Transmit information that sets mitigation measures in motion
  - Transmit information that integrates with the operations of the destination networks
  - Establish a direct link between personnel of the same hierarchical and operational levels
  - Create robust, redundant, and compatible links between the networks. All mechanical and electronic means can be considered.

  The committee will have to look into the nature of the information needing to be transmitted, and assure itself of the robustness of these preferred communication links.
- State of readiness: the committee has the responsibility for maintaining the systems and functions put in place. Therefore, the division of responsibilities must be agreed upon for:
  - Maintenance of the communication channels
  - Verification of the robustness of these channels
  - Training of personnel who intervene in emergency situations
  - Preparation of joint exercises, allowing the readiness of all participants to be verified.

Application to Developing Countries

Current State of the Problematic

Independent of the location and the operation and maintenance conditions, each type of life support network has its own behavior. In effect, the accomplishment of the missions of a life support network is based on the needs (potable water, electricity, etc.) of the community it serves. This statement defines the structural as well as the functional aspects of the network. The goal of the current work is to put into place a theoretical basis for a methodology to understand life support networks in terms of potential failures and to evaluate their consequences on other life support networks. Therefore, this approach can be applied successfully in developed and developing countries. However, the use of this approach in developing countries requires the prior acceptance of the three principles described below.

- Life support networks with a certain degree of complexity must be present. This condition, as a general rule, corresponds to large urban zones, which are particularly sensitive to the failure of these networks. "The concern over the risk to megacities, particularly in the developing world, is their growing vulnerability caused by their hyper-concentrations of population, dependence on complex and aging infrastructure, and unprepared local institutions" (Bendimerad 2000).
- The use of this method requires a regional methodological approach. For example Hurricane Hugo hit the Caribbean and the Carolinas in 1989 (Badolato and others 1990; Denis 2002). Blackouts caused the stoppage of potable water treatment plants; the lack of water lasted from three days to two weeks. The telephone network on the island of St. Croix, Virgin Islands was totally destroyed, and rebuilding took several months.

  To evaluate the consequences on populations, emergency plan measures and the establishment of adequate mitigation measures are necessary to analyze regional networks. A national approach does not permit such a refinement of knowledge.
- The study of these networks, as advocated, implies the consideration of exceptional but noncatastrophic events. In effect, if the natural events that trigger the failure of these networks inflict considerable damage on populations and destroy all social infrastructure, it is illusory to specifically study life support networks. In this case it is preferable to concentrate on the essentials, the protection of populations. Therefore, there must be a global vision of the risks, which cover all possible scenarios, not only extreme ones. In terms of planning and preparation of emergency and mitigation measures it is important to prepare for intermediate emergency situations so that they do not become exceptional situations. The 1995 Sakhalin earthquake in the Russian Far East (Porfiriev 1996; Denis 2002) is an example where the consequences of a large noncatastrophic natural event (rated intermediate) were strongly amplified due to poor knowledge of the communication and energy distribution networks and the domino effects resulting from their destruction.

Fundamentally, the difference between life support networks in developed and developing countries resides in the physical characteristics of the infrastructure (age, resistance, grid density, etc.) as well as on a sufficient knowledge of the aforementioned to ensure adequate planning of network management and operations.

> The recent development of disaster management programs by a number of countries emphasizes establishing national policies and initiatives but seldom targets the specific conditions pertaining to large cities. In most cases, the central government retains the authority for disaster management programs that are often focused on developing response capabilities, instead of proactive mitigation. With the regulatory environment concentrating decisionmaking authority and resources at the central level, the difficulty in predicting, assessing, and controlling the impact of catastrophes on large cities, with competing priorities and limited resources, and local government officials deferring decisions and responsibility to the central government, the result is that local government action for disaster management is often ineffective.
>
> Yet experience and modern disaster management practice recognize the importance of a strong and well-structured local disaster management capacity, and the need for decentralized authority to achieve an effective response. During a disaster, local governments are immediately confronted with the responsibility of providing relief to victims but often do not have the means or adequate legislative authority to mobilize these resources. Local governments also have difficulties in accessing mitigation funds because funding and relief agencies typically work directly with central governments. Reaching out to local governments to help them build local capacity, acquire knowledge and resources and providing them with authority for decisions are essential policies for reducing losses (Bendimerad 2000).

> Risk Reduction: Avoiding hazards and reducing vulnerability to disasters result when an extreme natural or technological event coincides with a vulnerable human settlement. Reducing disaster risk requires that all stakeholders change their perceptions and behavior to place a high priority on safety in planning and development. Effective risk reduction involves mitigation measures in hazard-prone developing countries. Such measures include land use planning, structural design and construction practices, and disaster warning systems. In addition to employing scientific and technical knowledge, risk reduction may also involve overcoming the socioeconomic, institutional and political barriers to the adoption of effective risk-reduction strategies and measures in developing countries. This may be accomplished through projects analyzing the possible roles of government, nongovernment, and private sector organizations in risk reduction, local and regional workshops and conferences aimed at heightening

the awareness of stakeholders to the threat of natural disasters and what can be done about it, and educational and training activities that increase the understanding of policymakers, decision makers and practitioners about disaster management" (World Bank 2000).

The proposed approach for the study of domino effects is perfectly consistent with this perspective.

Answer to the Problematic of Developing Countries

It becomes apparent that the principal differentiation between life support networks in developing countries and those in developed countries resides in the physical characteristics and the planning of emergency measures. These two principal differences will be identified below and the answer provided by the method of the study of domino effects will be made explicit.

Physical Characteristics

Life support networks are in variable condition, designed according to nonuniform criteria by multiple contributors originating from varied countries. The situation varies according to the country, even the region. Therefore, contrary to developed countries, there is often a lack of homogeneity in the design and operational criteria of the life support networks that serve the same community.

In this context, the proposed approach adapts itself perfectly to the problematic because it is centered on the definition of the missions of a life support network, the principal characteristics of the network being linked to these missions. It is possible to adapt itself very precisely to the specifics of a country.

Populations must know the missions of the life support networks and their importance to understand the inherent risks. The competent authorities, managers, and technical support personnel of these networks can, in association with the populations, foresee mitigation measures in the event of failure. These measures must be in agreement with the local resources and social particularities. In terms of emergency measures, in a crisis situation, multiple actors, governmental and others, often from abroad, are called on location. The initial knowledge of *all* the missions the networks allows, in the absence of an emergency plan, permits minimal measures to be put in place to protect populations and ensure a quick return to normalcy.

Thus, in this context, it is possible to systematize this approach by missions by simplifying the information to be transmitted to take into consideration the resources available for the collection of this data. Table 17.2 presents the essential information for gathering and collating. The information must be provided by the local actors responsible for the management of the networks and completed by the engineers that designed or rehabilitated them. In the table, fictional examples taken from several different networks are presented by way of illustration. The essential information is described below.

- Identification: the life support network is identified.
- Mission: this information is primary as it forces all actors to define it together. It is a multidisciplinary work that puts in place the basis for future activity for planning emergency measures.
- Essential infrastructure: it is a matter of determining, with the engineers, the infrastructure that is essential for the network to function. For example, one identification criterion would be that, faced with a total loss of this infrastructure, the efficiency of the mission would be reduced by at least 75 percent. The list of these essential infrastructure components should be limited. Operations are not considered at this stage, since the focus is on infrastructure without regard to human intervention, which is more complex to study.
- Links with other networks: The most important, or essential, direct and indirect links should also be identified and associated with the mission to which they are attached. As for essential infrastructure, only the links that significantly influence the networks in question need to be identified. It is a matter of identifying the type of link (direct or indirect) and the network connected to this link (destination network). The consequences for the destination network can be expressed globally. Next, the people responsible for this destination network can be identified.
- All basic information found in this table is available after the completion of consequence studies, without regard to the causes of the failures or the probability that they occur. Obtaining this information does not require significant resources, and it is available locally. In addition, the studies or steps necessary to

Table 17.2 Example of essential information relative to life support networks

Network being studied:	**Potable water supply**			
Mission:	Maintain a minimum pressure			
Essential infrastructure:	▪ Pumping station ▪ 5 main conduits (no. 1, no. 2, no. 3, no. 4 and no. 5)			
Links				
Identification	Type (D/I)	Connected networks	Consequences	Responsible personnel
Main water conduit no. 3 (secondary road X Facade of building Y)	I	gas	A leak in a main conduit provokes the destruction of a gas conduit, which creates a risk of explosion.	Mr. Smith
Mission:	Provide quality water			
Essential infrastructure:	▪ chlorination pool ▪ reservoir			
Links: none				
Network being studied:	**Electrical power supply**			
Mission:	Maintain a minimum voltage			
Essential infrastructure:	▪ Thermal power plant ▪ 3 transformer stations (no. 1, no. 2, and no. 3) ▪ 2 main transmission lines (no. 1 and no. 2)			
Links				
Identification	Type (D/I)	Connected Network	Consequences	responsible personnel
Transformer station no. 2 (near the water treatment plant)	D	Potable water supply	The loss of electrical power in the transformer station provokes the cessation of treatment of water. There is no electrical transmission line backup to the treatment plant. There is a generator at the treatment plan, but it is not in good condition.	Mrs. Smith

obtain this information require contributions from the principal actors, who must be gathered for the planning of emergency measures and crisis management.

Planning Emergency Measures

It becomes apparent that knowledge of life support networks is not enough to plan emergency measures adequately. Basic information, such as the minimal example presented in table 17.2, also shows the basic information necessary for planning emergency measures.

The preceding information issuing from consequence studies is fundamental because it identifies the essential infrastructure and the domino effects between life support networks. These results allow, at the very least, to alert those in charge to problems and put in place adequate protection measures and emergency measures. Minimal studies of vulnerability and repercussion functions can be carried out on the essential infrastructure affected by the domino effect.

This information allows *concrete and tangible mitigation measures* to be established, as much at the level of essential infrastructure as at the level of links generating the domino effect. In effect, the establishment of any prevention and mitigation measures requires a better understanding of the consequences. The protection of essential infrastructure and the identified links corresponds to minimal but indispensable (considering the consequences for the population) emergency measures. In effect, the failure of these networks following exceptional natural events will greatly amplify the consequences for the populations at risk.

Preferred channels of communication between those in charge of networks (identified in table 17.2) should be put in place to ensure that concrete measures are taken. They will be based on routine contact between the individuals identified. Later, they can be enriched and serve as a basis for real risk communication. These steps represent a minimal measure of protection for populations, especially as the favored measures essentially aim to reduce socioeconomic impacts.

The principles of communication and management of risk do not change, whether we are in a developing country or not. Analysis and management methods and the principle of information exchange remain the same. Only the techniques of information transmission during an emergency situation can cause a safety problem. Dialogue must be instituted based on local practices and structures and a minimal exchange of information must be carried out between life support networks, despite the level of sophistication of existing means of communication.

The development (including construction and rehabilitation) of a life support network in a developing country should consider, from the start, not only the possible consequences of a failure of this network for other networks, but also the consequences of failures of other networks on this network. Also, measures designed to improve the network's own robustness should be anticipated with the principle that the missions of each network can be ensured. The identification of information needing to be exchanged therefore relies on the consequence criteria: what must be demanded from the risk generator? The risk generator must carry out a risk and consequence study and provide the results. At a minimum, national and regional authorities must be made aware of the potential domino effects of certain risks on other life support networks.

The Role of International Financial Organizations

Organizations that finance these networks can play an initiating role in putting into place, maintaining, and refining the information presented in table 17.2, and in developing concrete, efficient, and operational actions of emergency measures planning.

Better control of risk ensures a substantial reduction in costs and better protection of populations in the event of a catastrophe. This is also true in developing countries, which are often subject to large-scale natural hazards with considerable socioeconomic consequences. It is therefore mandatory for the people who develop and finance life support networks in urban areas vulnerable to natural hazards to begin working to protect populations and avoid network failures provoking a significant amplification of consequences.

Finally, systematic steps are actually carried out to reduce natural risk in developing countries. The ProVention Consortium is an example. "The ProVention Consortium (2002) is a global coalition of governments, international organizations, academic institutions, the private sector, and civil society organizations aimed at reducing disaster impacts in developing countries. The Consortium functions as a network to share knowledge and to connect and leverage resources to reduce disaster risk. It focuses on synergy and coordination so that efforts, and benefits, are shared." The consequence studies complete the work of these groups that focus on natural hazards. However, in our approach these hazards correspond to external trigger events that affect essential infrastructure and the links between networks. From that point, the socioeconomic consequences are evaluated more rigorously and actions for a return to normal are better planned. Information on essential infrastructure, links, and consequences permit the planning of replacement actions in response to total or partial destruction. This planning includes the hierarchical classification of the infrastructure to be rehabilitated to ensure minimal efficiency for missions judged to be of primary importance; technical, human, and financial resources necessary for the replacement of infrastructure and direct links; and the timeframe for a return to normal activities.

This process requires will on the part of the international community and local actors to work together to establish minimal efficient and operational emergency measures to cope with potential failures of the multiple missions of life support networks.

Conclusions

Understanding risks relative to life support networks is fundamental for populations to establish protection measures in the face of potential failures. When considering the interconnection of life support networks, the domino effects between them are supplementary phenomena to which a certain importance must be attached. Traditional risk studies based on scenarios composed of extreme natural events do not allow the entire set of possible situations to be considered.

The proposed structural approach to life support networks is innovative in the sense that it is based on the study of the missions that the networks must fulfill. If these missions are not respected, the consequences will be analyzed and synthesized without regard for the causes, allowing operational and efficient emergency measures to be put in place. For risk evaluation, knowledge of the vulnerabilities of the network is critical. The proposed structure allows not only the infrastructure in question to be evaluated, but also the operation of the network that can diminish system efficiency.

It is essential to foresee that life support networks are subject to external and internal risks. External risks, combinations of natural events, technological events by way of the domino effect, and acts of malevolence act as triggers, which affect the network at the essential infrastructure level. These result in a decrease in operational efficiency of the network's mission. This approach, combining natural and anthropic events, is in line with a new international tendency in risk studies that does not uniquely consider scenarios based on natural events of a known frequency. The domino effects between life support networks can now be studied systematically by transferring the vulnerability of a network, the source of failure, to another network. Thus, this transferred failure becomes an external technological cause that influences the efficiency of one or sets of essential infrastructure of a destination network. This structural approach allows, finally, risk communication mechanisms between life support networks, structured by way of Risk Management Committees, to be put in place. These committees complete the emergency measures by bringing together the concerned networks and assuring efficient transmission of precise and tangible information, allowing mitigation measures to be put in place during a crisis.

This structural approach is particularly well suited for developed countries with complex life support infrastructure and emergency measures. The results of this work will allow the state of preparedness of the various participants to improve. Concerning developing countries, situations vary from country to country. Life support networks are in various conditions and designed according to nonuniform criteria. Emergency measures are not always efficient. The proposed approach, in this context, offers several interesting alternatives.

Focusing the analysis of a network on the missions that it must fulfill offers numerous advantages relative to the particular context of these networks. In effect, the construction, reconstruction, and rehabilitation of life support networks are generally considered large projects, and their financing comes from multiple international organizations. The management and maintenance of these networks involves diverse authorities and often nongovernmental organizations (NGOs). Therefore, it is important that all participants know an infrastructure's mission and its relevance to other infrastructure. It is the same for all people affected by these networks. This knowledge allows missions to be optimized and avoid becoming contradictory or ill-suited for a local social context and to adapt financing to local realities.

Knowledge of consequences allows better planning of minimum emergency measures. In effect, consequence studies being a representation of human and socioeconomic risks, it is thus possible to concentrate on the essential, as much on the level of protection provided for populations as for the mitigation measures to put in place. For organizations that finance these networks, knowledge of these basic consequences allows the costs that will be assumed for rehabilitation and reconstruction following a failure to be evaluated. A basic consequence study for each mission of a life support network should be systematically carried out, especially considering that it does not require significant resources.

The proposed approach focuses on the missions of life support networks, coupled with consequence and vulnerability studies, and has to its credit the ability to identify the sensitive points of networks to put minimum emergency measures in place. For the competent authorities who participated in financing these networks, this approach offers a concrete picture of the potential risks and, therefore, favors the implementation of efficient mitigation measures for populations.

Bibliography

Allen H. 1997. "Making a business of dam safety." *International Water Power Dam Construction* 49(8): 20–21.

Badolato E.V., J. Bleiweis, J.D. Craig, and H.W. Fleming. 1990. *Hurricane Hugo: Lessons Learned in Energy Emergency Preparedness*. Clemson, South Carolina: The Clemson University

Strom Thurmond Institute of Government and Public Affairs.

Bendimerad F. 2000. "The risk of natural disasters occurring in megacities is growing. Proper planning by local governments can reduce the human and financial loss to cities." Available from <http://www.worldbank.org/dmf/knowledge/megacities.htm>.

Bier V.M., Y.Y. Haimes, J.H. Lambert, N.C. Matalas, and R. Zimmerman. 1999. "A Survey of Approaches for Assessing and Managing the Risk of Extremes." *Risk Analysis* 19(1): 83–94.

BIT (Bureau International du Travail). 1990. *Prévention des accidents industriels majeurs*. Genève:: 117

CAN\CSA. 1991. *Risk analysis requirements and guidelines: quality management. A national standard for Canada*. Conseil canadien des normes, Association canadienne de normalisation, CAN\CSA Q850: 49.

CAN\CSA 1997. *Gestion des risques : Guide à l'intention des décideurs, Norme nationale du Canada*. Conseil canadien des normes, Association canadienne de normalisation, CAN\CSA-Q850-97: 49.

Cazaubon C., G. Gramacia, and G. Massard. 1997. "Management de projet technique: méthodes et outils." Collection technosup, génie de production. Paris: Ellipses: 182.

Covello, V.T., J. Menkes, and J. Mumpower. 1986. *Risk Evaluation and Management*. New York: Plenum Press: 435–457.

Covello, V.T. and M.W. Merkhofer. 1993. R*isk Assessment Methods: Approaches for Assessing Health and Environmental Risks*. New York: Plenum Press: 319.

Denis H. 1998. "Comprendre et gérer les risques sociotechnologiques majeurs." Éditions de l'École Polytechnique de Montréal: 342.

Denis H. 2002. *La réponse aux catastrophes, quand l'impossible survient*. Montréal, Canada: Presses Internationales Polytechnique: 318.

Dhillon B. S. and S.N. Rayapati. 1985. "Analysis of redundant systems with human errors." *Proceedings of the Annual Reliability and Maintainability Symposium*, Philadelphia, PA: 315–321.

Dhillon B. S. 1989. "Modeling human errors in repairable systems." *Proceedings of the Annual Reliability and Maintainability Symposium*, January 24–26 1989, Atlanta, GA: 418–424.

Dynes, Russell S. 1994. "Community Emergency Planning: False Assumptions and Inappropriate Analogies." *International Journal of Mass Emergencies and Disasters* 12 (2): 141–158.

Dynes, R. and K. Tierney, eds. 1994. *Disasters, Collective Behavior, and Social Organization*. London and Toronto: University of Delaware Press, 71–84, 145–159.

El-Shahhat A.M., D.V. Rosowsky, and W.F. Chen.1995. "Accounting for human error during design and construction." *Journal of Architectural Engineering* 1(2): 84–92.

Garin H. 1994. "AMDEC/AMDE/AEEL: l'essentiel de la méthode." Association française de normalisation, Paris: 39.

Gutteling, J. M. and O. Wiegman. 1996. *Exploring Risk Communication*. University of Twente: Kluwer Academic Publisher: 213.

Hadipriono F. C., C.L. Lim, and K.H. Wong. 1986. "Event tree analysis to prevent failures in temporary structures." *Journal of Construction Engineering and Management* 112(4), December, 500–513.

Hubbert G. and B. Ledoux. 1999. *Le coût du risque... L'évaluation des impacts socio-économiques des inondations*. Paris: Presses de l'École Nationale des Ponts et Chaussées: 232.

IPCC (Intergovernmental Panel on Climate Change). 2001. "Climate Change 2001: The Scientific Basis." Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. J. T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P. J. van der Linden, and D. Xiaosu, eds. Cambridge: Cambridge University Press: 944.

ISDF (Institut de Sûreté de Fonctionnement). 1994. "L'état de l'art dans le domaine de la fiabilité humaine." Octares éditions, collection ISDF: 446.

Isenberg J. 1991. "Performance of lifeline and emergency response in Watsonville, CA, to Loma Prieta earthquake." Proceedings of 4th US Workshop Earthquake Disaster Prevention Lifeline System: 381–390.

Kaplan S. 1997. "The world of risk analysis." *Risk analysis* 17: 407–417.

Kirwan B. 1994. *A guide to practical human reliability assessment*. London: Taylor and Francis: 592.

Lau D.L. and others. 1995. "Performance of lifeline during the 1994 Northridge earthquake." *CJCE* 22(2): 438–451.

Lavallée D., C. Marche, and T. Quach. 2000. "De nouvelles approches pour quantifier le risque de rupture d'une retenue d'eau." *Canadian Journal of Civil Engineering* 27:1217–1229.

Law, Averill M. and David W. Kelton. 1991. *Simulation Modeling and Analysis*. Columbus, OH: McGraw Hill: 221.

Leiss, William. 1996. "Three phases in risk communication practice." In *Annals of the Academy of Political and Social Science, Special Issue, Challenges in Risk Assessment and Risk Management*. Thousand Oaks: 15–30.

Leiss, W. and C. Chociolko. 1994. *Risk and Responsibility*. Montreal: McGill-Queen's University Press: 405.

Leiss, W. and D. Krewski. 1989. *"Risk Communication: Theory and Practice."* In W. Leiss, ed., *Prospects and Problems in Risk*

Communication. Waterloo: University of Waterloo Press, Waterloo: 90–111.

Lemperiere F. 1993. "Dams that have failed by flooding: an analysis of 70 failures." *International Water Power Dam Construction* 45(9–10): 19–24.

Lemperiere F. 1999. "Risk analysis: What sort should be applied and to which dams?" *International Journal of Hydropower Dams* 6(4): 128–132.

Leverenz F. L., Chadwell G. Bradley, and S.D. Unwin. 1996. "Process event tree based hazop studies." Battelle Memorial Institute. http://www.battelle.org/environment/irm/pdfs/pet-hazop.pdf.

Middelkauf, R.D. 1989. "Regulating the safety of food." *Food Tech* 43: 296–307.

Modarres M., M. Kaminskiy, and V. Krivtsov. 1999. *Reliability Engineering and Risk Analysis. Quality and Reliability*. New York: Marcel Dekker: 542.

Moses F. 1998. "Probabilistic-based structural specifications." *Risk Analysis* 18(4): 445–454.

NASA. 1995. "System reliability assessment using block diagramming methods." Preferred Reliability Practices, Practice No. PD-AP-1313: 5.

Nicolet J. L., and J. Celier. 1985. *La fiabilité humaine dans l'entreprise*. Collection le nouvel ordre économique. Paris: Masson: 302.

O'Leary S. 1997. "Concrete rehabilitation for dams." *Proceedings of International Conference on Hydropower* 1610–1622.

Petts, J. 1992. "Incineration risks perception and public concern: Experience in the UK improving risk communication." *Waste Management and Research* 10: 169–182.

Plate E.J. 1996. "Dams and safety management at downstream valleys." *Proceedings International NATO Workshop Dams Safety Manage Downstream Valley*: 27–43.

Porfiriev B.N. 1996. "Social aftermath and organizational response to a major disaster: the case of the 1995 Sakhalin earthquake in Russia." *Journal of Contingencies and Crisis Management* 4(4): 218–227.

Powell, D. 1996. *An Introduction to Risk Communication and the Perception of Risk*. Ontario: University of Guelph: 17.

ProVention Consortium. 2002. <http://www.proventionconsortuim.org/objectives.htm>.

Quach T.T., J. Gagnon, B. Robert, and C. Marche. 2000. "Upper Ottawa River: A Four Step Risk Assessment." *20th Congress, International Commission on Large Dams*, Beijing, China, September 19–20, 2000. Q76-R32: 479–498.

Reason J. 1990. *Human Error.* Cambridge: Cambridge University Press: 302.

Reason J. 2000. "Human error: models and management." *British Medical Journal* 320: 768–770.

Renn, O. 1998. "The role of risk communication and public dialogue for improving risk management." *Risk Decision and Policy* 3: 5–30.

Ridley, L.M. and J.D. Andrews. 2000. "Reliability of Sequential Systems Using the Cause-Consequence Diagram Method." *Proceedings of the 14th Advances in Reliability Technology Symposium,* Manchester, November. Available from <http://www.lboro.ac.uk/departments/ma/preprints/papers01/01–26.pdf>.

RNC (Ressources Naturelles Cananda). 2002. "Programme de Séismologie des Tremblements de Terre (PSTT)." Ressources Naturelles Canada. Available from <http://www.seismo.emr.ca/zoning/haz_f.html>.

Robert, B. 2001a. "A Method for the Study of Cascading Effects Within Lifeline Networks." Workshop on Mitigating the Vulnerability of Critical Infrastructure to Catastrophic Failures, Alexandria, Virginia, September 10–11. Available from <http://www.ari.vt.edu/workshop/>.

Robert, B. 2001b. "Outils d'aide à la décision pour les plans de gestion des aménagements hydroélectriques." *Proceedings of CDA Annual Conference.* Fredericton, Canada, October: 39–46.

Robert, B., C. Marche, and J. Rousselle. 2002a. "Computerization and use of flood impact curves." ICLR Research, Paper Series XX. Institute for Catastrophic Loss Reduction, April.

Robert, B. 2002b. "Étude des risques et des effets domino produits par la défaillance d'un aménagement hydroélectrique." *Proceedings of Annual Conference of the Canadian Society for Civil Engineering*, June.

Rowe, W.D. 1997. *An Anatomy of Risk*. Wiley Series in System Engineering and Analysis. New York: John Wiley and Sons: 256.

Seidou, O. 2002. "Intégration du risque dans les modes de gestion des systèmes hydriques." Philosophiae Doctor Thesis (Ph.D.), École Polytechnique de Montréal, Canada: 251.

Selcuk A.S. and Y.M. Semih. 1999. "Reliability of lifeline networks under seismic hazard." *Reliability Engineering System Safety* 65(3): 213–227.

Stedinger, J.R., D.C. Heath, and K. Thompson. 1996. "Risk analysis and safety evaluation: hydrologic risk." Report No. 96-13-16:51. Institute of Water Resources.

Suokas J. and V. Rouhiainen. 1993. *Quality Management of Safety and Risk Analysis*. Elsevier Science Publishers BV: 296.

Tyagi A. and C.T. Haan. 2001. "Reliability, Risk, and Uncertainty Analysis Using Generic Expectation Functions." *Journal of Environmental Engineering* 127(10), October: 938–945.

United Nations. 1984. "Proceedings, Engineering Foundation Conference: Maintenance and Rehabilitation of Dams." Water Resources Series No. 58. New York: United Nations: 117.

US NRC (United States National Research Council). 1989. "Improving risk communication." Committee on Risk Perception and Communication. Washington, D.C.: National Academy Press: 332.

World Bank. 2000. *World Development Report 2000/2001: Attacking Poverty*. Available from <http://www.worldbank.org/poverty/wdrpoverty/report/>.

Zielinski, P.A. 2001. "Flood frequency analysis in dam safety assessment." *Proceedings of CDA Annual Conference,* Fredericton, Canada, October: 79–86.

Chapter 18

Mitigating the Vulnerability of Critical Infrastructure in Developing Countries

Lamine Mili

Critical infrastructure is a collection of facilities and institutions that provide vital services to people and economies. Its disturbance would impair the defense or economic security of a country. It includes the following systems:

- telecommunications
- electric power
- gas and oil storage and transportation
- water supply
- transportation
- banking and financial services
- emergency-service institutions, including hospitals, police stations, fire and rescue departments
- government institutions.

The previous definition applies to any country, industrialized or in the process of industrialization. Here the telecommunication systems comprise not only the cable and wireless telephone networks, but also the communication and earth observation satellite systems and computer networks, including the Internet. This infrastructure can be regarded as the backbone of the economies of developed and the developing countries worldwide since they provide material support for the delivery of basic services to all segments of a society. Their maintenance, expansion, and protection against all types of threats, manmade, technological, or natural, are of great concern to state executives and government constituencies (Clinton 1996).

In this report, attention is restricted to telecommunications and electric power systems. Their key role in economic growth in developing countries and growing vulnerability to technological failure and extreme natural hazards due to the global warming are highlighted. To substantiate these claims, the genesis and development of the Brazilian energy crisis of 2001 that stem from the combined effects of the energy policies undertaken by the Brazilian government since the 1980s and the severe drought that steadily reinforced its grip on several regions of the country since 1998 are analyzed. Specifically, the lack of diversification in energy resources and the meager investment in transmission and generation expansion since the late 1980s exposed the Brazilian electric power infrastructure to a series of system-wide blackouts while leading the country to a painful energy rationing. The latter will certainly have a negative impact on economic growth in the years to come.

To increase the security and efficiency of the power infrastructure at a minimum cost, we advocate: (1) the implementation of a defense plan against catastrophic failures through islanding initiated by special protection systems; (2) the development of a fault detection, isolation, and restoration scheme for the power distribution system that aims to decrease the time of recovery after a blackout; and (3) the installation of computer-aided software programs at control centers to seek the best topology of the distribution network and yield minimum electric losses.

Finally, we promote the development of a global information infrastructure that provides effective disaster risk management against extreme weather conditions at a global scale. Using satellite technologies and the Internet, this infrastructure links together disaster centers strategically located around the globe to enable the twin tasks of: (1) detecting any incipient disasters by processing the huge volume of data received from the earth observation satellites; and (2) broadcasting early warnings to a wide public through the Internet and other telecommunications media.

Positive Impact of the Electricity and Telecommunication Services

As indicated by the recent World Bank report (World Markets Research Center 2001: 119) entitled "World Infrastructure and Development," electricity and telecommunication services in developing countries can significantly contribute to economic development by providing new opportunities for small businesses to develop and grow, and therein to propose new jobs and services. Not only can the local market enlarge and consolidate its direct geographical basis, but it may also find ways to improve the productivity of its workforce to the point that it can compete at the regional and the national level. It may even target the global economy via the Internet and the multitude of services that it conveys should computer infrastructure exist. This is exemplified by the US$8.3 billion software industry in India whose exports, mainly to the United States and Europe, have shown impressive growth rates since 1995 to reach US$6.2 billion in 2001, placing it in fourth place after Microsoft, Oracle, and SAP (Ravisankar 2002). This industry employs more than 500,000 professionals and accounts for nearly 2 percent of the Gross Domestic Product (GDP) of the country (NASSCOM 2002). While China also has a fast-growing software industry, it cannot yet compete with that of India.

Tourism industries, traditional handicraft businesses, and educational institutions are also taking advantage of the Internet to market their products worldwide. Three successful initiatives have been undertaken by the Naushad trading company of Kenya (Naushad 2002), the Internet Bazaar of India (Internet Bazaar 2002) and the African virtual university, which links 25 learning centers in 15 African countries, a project funded by the World Bank in Kenya (Phombeah 2000). Many other businesses mushroomed throughout Africa, Asia, Latin America, and the Caribbean thanks to the PAN Networking Program initiated and funded by the International Development Research Centre (IDRC), Ottawa, Canada (IDRC 2002). The PAN networking groups provide basic training and financial support to rural businesses in information technologies and Web site development, among other activities.

For poor communities, another beneficial impact of electricity and telecommunication services is the enhancement of social welfare. The availability of these services provides a cleaner living environment since electric pumps deliver running water to communities. They also reduce the time spent on household chores and increase opportunities for learning since electricity allows people to read more easily at night and access broadcast information and cultural programs offered by radio, television, and now, the Internet.

Since electricity is instrumental in the development of national economic markets, most developing countries have implemented ambitious programs of rural electrification since the early 1970s. Distribution power networks have been expanded to reach rural towns and villages. The installations of decentralized renewable electric energy sources have flourished where the cost of power grid connection is too high (World Energy Council 1999). In China, small hydropower stations with a total capacity of 17 GW supply nearly 20 percent of rural electricity. In Kenya, a dynamic private sector has so far provided more than 1 MW of photovoltaic panels to 20,000 households. With the financial help of the World Bank, the government of Argentina has recently encouraged the emergence of a private competitive market consisting of small distributed electric energy resources. The latter comprise solar photovoltaic panels, micro-hydropower units, small wind-powered stations, and diesel generating units. These are only a few examples of a long list of success stories in Asia, Africa, and Latin America and the Caribbean.

Low Level of Rural Electrification in the Developing Countries

Despite significant efforts undertaken so far, the vast majority of rural populations in developing countries are still relying on wood, dung, agricultural wastes, and other biomass as accessible cheap fuel for cooking, heating, and lighting (World Energy Council 1999). One extreme case is provided by Sub-Saharan Africa, where fewer than 8 percent of households are electrified. In fact, this figure masks a wide disparity between countries, between rural areas and cities, and between poor and rich people (World Markets Research Center 2001). India provides another instructive example. Power networks there reach about 80 percent of all the villages, though only 31 percent of households can afford the connection costs. Poor maintenance of equipment and excessive energy losses, which may be as high as 30 percent or more if unpaid electricity usage is included, afflict the power industry and raise the cost of production and distribution of electric energy (Word Bank 1998).

To diversify the cost of electrification, thereby allowing the poor to afford its service, some economists have questioned the high quality standards that have been enforced by most developing countries, which are often simple copies of those adopted in developed countries. As indicated by the World Bank Infrastructure Forum of May 2001 (World Markets Research Center 2001), this diversification of price could be accomplished by replacing the monopolies of the electric energy sector with private energy providers that would compete to sell power at least cost. In fact, such competitive electric markets are currently emerging worldwide as a result of aggressive restructuring policies enacted by an increasing number of governments of both developed and developing countries. The main motivation of the latter is to create a favorable market environment that would encourage private national and international companies to invest in the expansion of the electric power system. This expansion responds to the important increase in consumption that results from the economic and population growth in these countries.

The Need to Reconcile Economic Development and the Environment

Unfortunately, the form of economic development currently adopted worldwide comes at the expense of the environment. It not only induces deforestation and desertification over vast regions of the globe, but also gives rise to enormous air pollution. This pollution stems from the release into the atmosphere of large volumes of greenhouse gases such as ozone, dioxide, and carbon monoxide, among others. As recently discovered, it also results from a huge amount of anthropogenic aerosol, termed the Asian brown cloud (Topfer and Ramanathan 2002). This is a three-kilometer-deep haze of dust, black carbon, and sulfates, which stretches over a large part of Asia. Its existence has been uncovered by an international team of scientists working under the umbrella of the Center for Clouds, Chemistry and Climate on the Indian Ocean Experiment (INDOEX) project commissioned by the United Nations Environment Programme (UNEP).

Such pollutants pose a serious threat to the health of exposed populations, primarily children and the elderly. They have been blamed for hundreds of thousands of premature deaths in poor suburbs and rural areas of Africa, India, China, and Southeast Asia. They are also destabilizing the planet's climate through the greenhouse effect that deflects sunlight from the earth's surface and traps heat. These undesirable effects in turn may cause in the near future a significant decline in agricultural productivity, jeopardizing the economic growth of many countries, especially in South and East Asia. In India, a decrease of 5 to 10 percent in rice productivity is anticipated shortly (Topfer and Ramanathan 2002).

In view of the increasing number of extreme events occurring on the planet, climate change is undoubtedly taking place (Working Group II of IPCC 2001). Long-lasting droughts and extreme hot weather are afflicting many developing countries, putting exceedingly high stress on their water reserves and electric power infrastructure. Western Asia and North Africa are suffering from severe water shortages, while Brazil and India experienced large-scale blackouts in 2002 due to an overload of their electric power systems. Of a more destructive nature are the cyclones and floods that recently ravaged Central America and some parts of Asia. These natural hazards are occurring with unprecedented magnitudes and frequencies as testified by the four successive hurricanes that struck countries of Central America and the Caribbean from August 1998 to November 1999. These were Hurricanes George, Mitch, Floyd, and Lenny in August 1998, October 1998, July 1999, and November 1999, respectively. Of these four, Hurricane Mitch was the most destructive. It devastated large segments of the Honduran and Nicaraguan transportation and communication infrastructure, the reconstruction of which was still underway two years later (USGS 1998). By the magnitude of its impact, Hurricane Mitch ranks among those that occur once in one or two centuries (USAID 2001). According to climatologists, El Niño, La Niña, and the Asian Brown Cloud are to be blamed for the high frequency and magnitude of these natural disasters.

In the light of the foregoing discussions, a burning question arises: How to reconcile economic development with the preservation of the environment? Are these two incompatible? This issue is at the center of most of debates taking place in workshops and conferences sponsored by the United Nations and the World Bank. Two key concepts are emerging: (1) adaptation to climate change, and (2) economic sustainability. The former calls for the implementation of technological, economic, and social measures to mitigate the impact of extreme events, while the latter requires the adoption of new forms of economic development that promote environmentally-friendly technologies and the eradication of extreme poverty in the world. Any proposed solutions will revolve around key questions related to the development of critical infrastructure, maintenance, and access to all. In the next sections, we will focus mainly on the former problem by proposing mitigation measures for electric power and telecommunication infrastructure.

The Growing Vulnerability of Critical Infrastructure

Main Characteristics of Networked Infrastructures

Critical infrastructure systems such as water, energy, telecommunications, computer, and networked banking are becoming increasingly interdependent as the digital society matures on a global scale. Consequently, the vulnerability of these stratified networks is raising major concerns worldwide. For instance, the normal operation of water, telecommunications, and banking systems is maintained only if there is a steady supply of electric energy. On the other hand, the generation and delivery of electric power cannot be ensured without the provision of fuel, water, and various telecommunications and computer services for data transfer and control purposes to the power plants and networks. These interdependencies are strengthening their grip as the usage of the Internet and other computer networks becomes prevalent.

Energy and telecommunications infrastructure each form a complex interconnected networked system that stretches over a large geographical area to reach in principle every household and economic entity in a region. Their functions in a society are similar to those of arteries and veins that branch out through the human body to nourish every cell with vital nutrients. Infrastructure's covered geographical areas may include a continent or even the whole world. In fact, the public telephone system can be regarded as the first infrastructure to reach a global scale since a point-to-point connection can be established between any pair of telephones around the world. This is achieved via an adequate combination of cables and wireless technologies, including several constellations of satellite systems at low, medium, and geostationary earth orbits. Computer networks have a similar propensity to globalization as more and more countries equip themselves with Internet technologies.

While being recognized as the most complex system ever built by human beings, electrical power systems have not yet attained a global scale. However, some such as the North American and European interconnected power systems, reach continental size. Note that the latter system can be regarded as a single system servicing not only Western- and Eastern-Continental Europe, but also the United Kingdom, Scandinavia, and Russia. In addition, it is now expanding its reach through the Strait of Gibraltar and the Bosphorus to interconnect in the near future with all power grids in the Mediterranean region. The first phase of this project has already been completed with the installation of a 400-kV AC submarine cable between Spain and Morocco (Janssens and Kamagate 2002). Future projects to link the Russian power system to the high-voltage power grid of Japan and Alaska (Koshcheev 2001) also exist. However, we should recognize that the advantages brought by these interconnections also come with possible technical problems such as sustained loop flows around seas and mountains and low-frequency oscillations across long transmission lines connecting generating units to remote load centers. The latter is more thoroughly outlined in the emerging technologies section of this paper.

Increasing Vulnerabilities to Extreme Natural Hazards

Newspapers report daily the devastating effects of cyclones, floods, and droughts on people and infrastructure worldwide. These extreme events strain critical infrastructure in countries most at risk, especially less developed countries. In Central America, floods and hurricanes that take many lives and damage infrastructure in these mostly developing countries have been recurring at a higher rate than usual since the early 1990s. India experiences small-scale blackouts on a regular basis throughout the country. This adversity does not spare its frenetic capital, New Delhi, where electricity cuts lasting several hours are not uncommon. However, from time to time, a huge blackout occurs across several Indian states, affecting millions of people and producing large economic losses. This was precisely the case during the blackout of July 30, 2002, which spread over five states of Western India. It was due to a heat surge that followed several months of intense drought that afflicted many regions of the country. The blackout was triggered by a load increase that went beyond the maximum capability of the transmission system (Rediff News 2002). One of its victims was the Indian railway system, where service was interrupted for several hours.

The fate of India is not isolated. Brazil faces similar difficulties due to the lasting drought the country has suffered from since 1998. The drought has induced an energy crisis resulting from the heavy reliance of the Brazilian power system on complex water reservoirs feeding numerous hydroelectric plants placed in cascade which account for more than 90 percent of the installed generation capacity (Augusto and others 2002). Despite a strict rationing of 20 percent of its electric consumption, instated with the active participation of the population from June 2001 to February 2002, ten states located in the south, southeast, and center-east of the country experienced widespread blackouts on January 21, 2002 (Latin America Regional Reports 2002). These are the most populous and industrious states of the country. Because the energy crisis may jeopardize its economic growth in the long run, Brazil is seeking to diversify its electric energy production, mainly by boosting the construction of gas-fired plants (The Economist 2002; Prates 2001). The Brazilian energy crisis will be further analyzed in a later section.

Developed countries are also facing unusually harsh weather conditions that expose critical infrastructure to the risk of partial or total destruction. For example, in North America, an ice storm of an unprecedented magnitude knocked down a sizable segment of the electric transmission grid of Canada and the North Eastern region of the United States from January 5–10, 1998. The restoration of the Canadian network took months and cost the taxpayers several billion dollars. In Europe on December 17 and 26, 1999, two consecutive waves of fierce windstorms hit France, Germany, Switzerland, Spain and several other Western European countries, killing dozens of people and damaging infrastructure. The impact of the wind was so intense in France that it inflicted considerable damage to the French public transport network and the electric power networks, leaving millions of people without electricity for several days (ABC News 1999). Like the Canadian disaster, the restoration of the French power system required several weeks to complete and came at a high price.

Increasing Risks of Cascading Failures Triggered by Local Disturbances

The integrity of critical infrastructure is at risk worldwide not only because of the growing frequency of extreme events of natural causes, but also because they are increasingly vulnerable to local disturbances. This is in part due to the strong reliance of critical infrastructure systems on one another, which may turn a local disturbance in one system into a large-scale failure via cascading events that has catastrophic consequences on society as a whole. It is also in part due to the current trend to operate critical networked systems closer to their stability or capacity limits. One compelling reason for this practice is, of course, economics. Providing this infrastructure with some degree of resiliency comes at a price, which is entailed by the required level of redundancy in the equipment that needs to be achieved. This is even more true in developing countries, where the expansion of critical infrastructure systems does not keep pace with rapid growth in demand.

Another reason for the degradation in infrastructure reliability is the detrimental role played by hidden failures in the equipment (Thorp, Phadke, Horowitz, and Tamronglak 1998). Hidden failures are hardware or software failures that are only exposed when a system or a portion of a system is highly stressed due to congestion or fault. In other terms, hidden failures cannot be revealed before the system is perturbed. In particular, routine maintenance testing may not detect them or even worse, may induce them. This was precisely the case in the 1977 New York blackout (Sugarman 1978; Wilson and Zarakas 1978) where a protection relay was damaged during a testing procedure a few weeks before the power system failure. Another cause of hidden relay failures is the present practice in electric power systems to favor dependability over security in relay settings to ensure the isolation of a fault with high probability while allowing the tripping of non-faulty devices from time to time. Hence, it should not come as a surprise that a North American Electric Reliability Council report (NERC 1988) blamed hidden failures in the protection systems for aggravating the situation in 73.5 percent of significant disturbances that were investigated in the U.S. electric power transmission network. This is a sizable portion of major failures in power systems that should call out for the development of mitigation measures not only in the United States, but also in other developed and developing countries.

Another example of a hidden failure that wreaked havoc with the normal operation of critical infrastructure was a software bug that existed in the switching systems of the AT&T long-distance public telephone network before its general breakdown via cascading failures on January 15, 1990 (Neumann 1995, 1998; Mason 1990; Travis 1990). The triggering event was a failure in a switch whose detection was passed to all its neighbors. As a result, the latter switches correctly took action not to forward calls through the failed one. Unfortunately, a software bug in all of the switches prompted each of them to mistakenly notify their neighbors that they were failing and calls were not to have been forwarded through them. This domino effect resulted in the interruption of the long-distance telephone service in the United States for nine hours.

Satellite and Information Technologies for Natural Disaster Risk Management

The Earth Observation Satellites

The management of natural disasters consists of five main tasks that need to be achieved in a cyclic manner: prevention, mitigation, warning, response, and recovery (Wood 2002). Prevention and mitigation require assessing the risk of various potential hazards and taking action in the long- and mid-term to mitigate their harmful impacts. A premise of the disaster-risk management process is the availability of good models of the earth's climate and geological systems. The development and validation of these models rely on the accessibility of a comprehensive measurement set of all variables that affect the present and future states of these systems. Fortunately, these measurements are becoming available as more Earth Observation Satellites (EOS) are placed in orbit. These space platforms measure such things as cloud cover, crust tectonics, ocean movement, polar ice surface and displacement, vegetation density and coverage, and soil moisture level.

In 1972, NASA launched LANSAT-1, the first earth observation satellite. Because NASA made the images taken by LANSAT-1 available to the public, many developed and developing countries built and operated ground stations to receive them. Developing countries that were able to take advantage of the images included Brazil, Zaire, India, Iran, and China. Since then, many EOS satellites were put into orbit by the United States, Japan, France, and other members of the European community. As an example, figure 18.1 shows the Advanced Land Observing Satellite (ALOS) of Japan (NASDA 2002). Among developing countries, only China and India have so far founded their own satellite programs that include EOS. Brazil and Argentina have established space agencies, while Kenya hosts the United Nations Environment Programme and South Africa has established the Satellite Application Center/Council for Scientific and Independent Research. All process the huge database created from the measurements sent by EOS, which entitle them to be members or associates of the prestigious and very active Committee on Earth Observation Satellites (CEOS). Since its foundation by the Group of 7 at the 1984 Summit of Industrialized Nations, about 40 EOS were put into orbit and more than 50 more missions are anticipated in the near future (CEOS 2002).

There are two types of EOS: low-earth-orbit (LEO) satellites and geostationary-earth-orbit (GEO) satellites. The former revolve on polar orbits at an altitude that ranges from 500 to 1000 kilometers and carry either optical sensors that cannot penetrate clouds or microwave sensors that have the ability to operate in a cloudy and foggy environment. Among these sensors, synthetic aperture radars provide the best image resolutions, which can be as high as one inch. On the other hand, the GEO satellites are placed on a 24-hour equatorial orbit that allows them to remain stationary with respect to the earth's surface at an altitude of 36,000 kilometers. These are meteorological satellites that take images in the visible or infrared spectrum at intervals of 15 minutes for U.S. satellites GOES-8 and GOES-10 and 30 minutes for all the others, including the Indian National Satellite, INSAT (Wood 2002).

The Communication and Navigation Satellites

Two other types of satellites, communication and navigation satellites, play a key role in disaster management, especially during the warning and relief phases. Their advantage over alternative technologies comes from the fact that they are less prone to failure during the impact of natural disasters. As their name indicates, communication satellites retransmit electromagnetic signals that they receive from and to a ground station or another satellite. On the other hand, navigation satellites, commonly known as Global Positioning Systems (GPS), allow a GPS receiver to calculate its position, velocity, and time. Since 1995, the most accurate receivers have provided measurements within 16 meters of a position, 0.1 meters per second for velocity, and 100 nanoseconds for time (Graham 1995). The GPS systems form a constellation of 24 geostationary-Earth-orbit satellites that have a 12-hour revolution at an altitude of 20,900 kilometers. These satellites consist of six groups of four platforms placed on six 55°-inclined orbital planes 60° apart. This configuration allows four satellites to be visible any time from any location on earth.

The GPS systems found broad application worldwide. In particular, GPS receivers are placed on board military and civil aircraft, ships, and land vehicles. Following in the steps of developed countries, India recently announced that its Civil Air Navigation system will be based on a GPS- and GEO-Augmented Navigation system, called GAGAN (Singh 2002). However, a recent report released by the Office of the Assistant Secretary for Transportation Policy of the U.S. Department of Transportation warned the general public of potential vulnerabilities in the transportation infrastructure that relies on GPS. It indicates that GPS signals are prone to various intentional and unintentional interference, including atmospheric interference. To mitigate these vulnerabilities, the report calls for the usage of backup systems.

One important application of GPS is the Geographical Information System (GIS). This is a computer software program that processes and displays spatial images and maps that are geographically referenced. For disaster-risk-management applications, these images are those provided by the EOS satellites and other remote-sensing technologies. They are extremely useful during the warning and disaster relief phases, since they allow rescue personnel to have handy spatial views of predicted or current impacts of hazards.

Development of a Global Information Infrastructure for Disaster Management

In an informative paper, Jayaraman, Chandrasekhar, and Rao (1997) of the Indian Space Research Organization convincingly argued that the EOS and communication and navigation satellites in addition to the Internet could greatly help in managing natural disasters on a global scale. To this end, they called for the development of a Global Information Infrastructure (GII) with the capability to transfer via satellite to disaster management centers at high speed large volumes of data sensed by the EOS. The feasibility of this technology was recently demonstrated by the Trans-Pacific High-Data-Rate Satellite-Communications experiments. These experiments were conducted by the Disaster-Observation-Satellite working group as one of the many tasks of the Japan-U.S. cooperation in space projects. Distributed at strategic locations around the globe, the GII centers will process satellite data to detect any incipient disasters and widely disseminate the information to governments and research institutions, which in turn should make them available to a broad public via the Internet and other telecommunication media.

The GII will also help doctors practice telemedicine during the disaster response and relief phases. Telemedicine is being successfully applied in India to overcome the acute lack of health infrastructure and medical personnel in 600,000 villages (Harris 2002). The country has a ratio of only 1 bed for 1,333 Indians. This is significantly less than the 1-bed-to-600-people ratio in the Philippines, for example. Thanks to the initiative of the Indian Space Research Organization (ISRO) and the Ministry of Information Technology, 200 telemedicine sites interconnected via 128-kbps integrated-service digital networks and communication satellites are already operating in the country. As a first step in the extension of this network nationwide, ISRO is targeting the state of

Orissa to develop an ambitious statewide telemedicine network in the near future. A successful story of the application of telemedicine was provided by the Gujarat earthquake of January 27, 2001. During and after that earthquake, telemedicine was used by medical doctors in Ahmedabad to provide their services to patients in remote areas.

Vulnerability Assessment of the Brazilian Electric Power Infrastructure

Positive Impact of the Power Industry Reforms in South and Central America

Since the early 1990s, a steady degradation in the reliability of electric power systems in developing countries, especially in South America and Asia, has taken place. There are several reasons why this has happened. First, the expansion of electric power generation assets and high-voltage transmission networks has not kept pace with the significant increase in load demand pushed higher by robust economic growth and an improvement in the standard of living for the middle class. This is mainly due to the national debt crisis that struck many of these countries in the early 1980s. The crisis prevented them from borrowing from the international financial market at a favorable rate to finance capital-intensive investment in their power infrastructure. Second, climate change, described as the El Niño effect, has also affected these countries. The latter forced the Colombian Government to decree electric energy rationing from 1992 to 1993 following a surge in load demand induced by unusual weather conditions (Rudnick and others 1998). Third, there is poor management of electric power assets by public utility companies that showed a lack of interest in bringing productivity and efficiency to international standards. In many developing countries, energy losses in distribution networks have been extremely high, productivity of the workforce too low, and unpaid electric energy consumption endemic. The latter may vary from 20 percent to 50 percent in some utilities in Venezuela and India.

To improve capital and human productivity at electric utilities and encourage the national and international private sector to take part in badly needed investments in generating units and the expansion of the transmission and distribution networks, a growing number of countries have embarked on a structural reform of the power industry geared toward the emergence of competitive markets. The first to take action was Chile. As early as 1982, the Chilean government enacted a law that dismantled public utilities into three independent businesses and allowed private companies to enter the market. A privatization program was put in place that prompted the Chilean private pension funds and multinationals to play a greater role. U.S., Spanish, French, U.K., and Canadian companies have responded favorably to the appeal. A few years later, some Chilean companies strengthened their financial positions to the extent that they could expand throughout South America in countries that had opened their markets to competition.

The positive experience of Chile has found many emulators not only in South America, but also in Europe, North America, Asia, and the Pacific region (Einhorn and Siddiqi 1996; Ilic, Galiana, and Fink 1998; Hunt and Shuttleworth 1996; Tabors 1996). This trend was enforced by the World Bank through a strict policy of binding loans to the initiation of reforms. Argentina then followed Chile's example and deregulated its power market in 1992. Peru deregulated in 1993 and Bolivia and Colombia in 1994. Most Central American countries followed in 1997.

Brazil initiated its reform process with the privatization of its distribution companies enforced by Law 8987, enacted February 13, 1995. In just two years, 73 percent of distribution companies were divested (Rudnick and others 1998). However, despite this success, several genuine attempts made by the Brazilian government to encompass generation plants in this reform failed. As of 2002, only a tiny fraction of the public fleet was sold, a not very encouraging prospect for private investors. In fact, this meager accomplishment stems from the existence of strong political opposition to the whole reform process that gained strength as the energy crisis worsened. The energy crisis in California and the severe drought of 2001 finally prompted the government to interrupt the privatization process in 2001 and, via the revitalization committee, revise the general regulatory schemes by incorporating market-based rules (Prates 2001; Barroso and others 2002). Because of its impact on the future economic growth of the entire region, the Brazilian energy crisis will be examined.

From a broad perspective, it is generally recognized that the reform of the electric power sector in South America has been a great success. Besides a non-negligible capital investment performed by private companies and funds, competition and stringent quality standards enforced by laws in many countries have brought a noticeable improvement in the operational efficiency and reliability of electric power systems. This improvement accompanied a decrease in the price of electricity, especially in the wholesale market. According to Rudnick, Varela, and Hogan (1997), Chilean companies were able to cut energy losses by half in seven years while Argentinean companies achieved this level in three years following the reforms. The latter dramatically ameliorated workforce productivity and enhanced the efficiency and reliability of generating units via an improvement of their maintenance programs and the usage of better technologies such as combined-cycle units. This in turn has raised their availability for operation from 47 percent to 70 percent just two years after the reforms. Therefore, it came as no surprise that the monthly wholesale electricity prices in Argentina went down by more than 40 percent. In Brazil, too, productivity of the newly privatized distribution companies rose significantly while energy losses decreased by 9 percent (Prates 2001).

Figure 18.1 Major regions and river basins in Brazil

(Courtesy of Jardini and others, IEEE Power Engineering Review 2002, ©2002 IEEE)

Structural Vulnerabilities of the Brazilian Electric Power System

Following the external debt crisis of the 1980s, the Brazilian government decided not to invest heavily in the expansion of power systems. No major project was undertaken except the interconnection of the north-northeast to the south-southeast power grids that were completed in 1999 (see figure 18.1 for the four main regions of Brazil). Following enactment of the reform laws of 1995, 1996, and 1998 that provided a legal framework for implementation of the privatization process and creation of a wholesale market managed by an independent system operator, the government anticipated that the private sector would rapidly take the lead in the investment in generation and transmission expansion to respond to a forecasted load growth ranging from 5.3 percent to 6.5 percent for the next 10 years (Jardini and others 2002). Unfortunately, the involvement of private companies has not met government expectations. Three main reasons may be put forward to explain this lack of enthusiasm: (1) the nonexistence of a competitive market in generation that would have allowed private companies to sign long-term contracts with load-serving entities and therein secure returns of investment; (2) the implementation of large devaluations in the Brazilian currency that have put generation companies at great financial risk, since they have to sell electricity in the national currency while buying the fuel in U.S. dollars; and (3) the presence of a transitional business environment characterized by precarious rules and regulations. By 1999, this unfavorable environment had resulted in the delay or suspension of many planned projects. In May 2001, one of the last companies to suspend all investments was the U.S.-based AES (Business News Americas 2002). As warned by the Brazilian planners, the security of the national power infrastructure was in jeopardy and the imminence of a shortage in electric energy production loomed ahead.

Another major vulnerability of the Brazilian electric power system is the lack of diversification in energy sources since the power generation system is overwhelmingly dominated by a host of reservoir-based hydroelectric plants in cascade along major river basins of the country. As of early 2001, the installed capacity of the hydroelectric generating units amounted to 59.6 GW for a total capacity of 65.7 GW, yielding a percentage of 90.7 percent. The remaining capacity was shared between conventional thermal-power units at a modest level of 6.4 percent and nuclear units at 2.9 percent. Being aware that the structural vulnerabilities of the power infrastructure might escalate into a major energy crisis, the government initiated in early 2000 an emergency plan termed the Thermoelectricity Priority Plan. This plan advocated the construction by 2003 of 12 GW of gas-fired power plants mainly fed by the Bolivian-Brazil gas pipeline (Jardini and others 2002). Unfortunately, this plan came too late to prevent the energy crisis from striking, following a severe drought in early 2001.

Causes of the Brazilian Energy Crisis of 2001–02

From 1998 until 2001, the November to April wet season resulted in steadily declining water inflows into the reservoir systems. Due to a severe drought during the 2000–01 wet season, the water inflows to the northeast/southeast reservoirs were seriously insufficient. By the end of April 2001, the reservoir was only one-third of its maximum capacity, well below the recommended half-capacity level. To avoid depleting the reservoirs and facing blackouts during the dry season, the Brazilian government called for the rapid implementation of an electricity rationing plan, effective June 1, 2002. This plan advocated an energy reduction of 20 percent for the residential and commercial sectors, including office buildings, 15 percent to 25 percent for the industrial sector, and 35 percent in public street illumination (McClellan 2001; Wheatley 2001).

Interestingly, while the northern and southern regions received enough water during this period, they were unable to transfer the excess electric power to the other two energy-starved regions because of a lack of available capacity in the transmission lines. As result, a great deal of water was spilled. The situation was exacerbated by the failure of one 1500-MVA transformer in the São Paulo area and by a delay due to environmental constraints of the third high-voltage transmission line that would have connected the Itaipu hydroelectric plant located in the south to the national power grid (Jardini and others 2002).

Fortunately, thanks to the active participation of the population, the objectives of rationing were met and major blackouts were avoided. The end of the drought and the return to more normal rainfall levels during the 2001–02 wet season prompted the government to declare an end to the rationing in February 28, 2002. Also, to overcome a glaring lack in electricity production, the government began a new program of generation expansion on July 6, 2001. By 2003 this is expected to increase capacity by 26 percent, including 15 thermal plants of 6.4 GW. The U.S. power company AES decided to reconsider its decision to pull out by contributing to the national effort with a US$1.2 billion investment in a set of 3000-MW thermoelectric plants (Business News Americas 2002). However, this good news came with a warning signal that announced the fragility of the Brazilian power system: the warning took the form of a major blackout on January 21, 2002.

The Blackout of January 21, 2002, in Brazil

The blackout spread in the south, southeast, and center-west regions and caused large economic losses in 10 of the most populated and industrialized states. Business News Americas (2002) revealed that the system breakdown was triggered by a fault on a transmission line belonging to the company CTEEP. It consisted of a sequence of cascading outages that originated from the faulted line and spread sequentially from one location to the other over an increasingly larger region of the network via the tripping of the protection relays. In the course of their actions, the latter isolated many electric generation plants in a sequence that started with the Itaipu hydroelectric plant, followed by the CESP Parana's plant and then the Angra nuclear plants.

The details of these cascading events have not yet been made available to a broad public. However, one typical scenario could be as follows. The triggering event could have resulted from a short-circuit that occurred on one of the network's transmission lines. The relays of that line sent tripping signals to its circuit breakers. Before the faulted line opened, the short-circuit current was sensed by a certain number of relays located within the region of influence of the fault. The latter region is defined as the union of the regions of vulnerability of all the relays whose hidden failures are exposed by the fault. Consequently, each of these relays may have unnecessarily opened an unfaulty line if it suffered from a hidden failure. Therefore, in addition to the faulted line, we may have two, three, or more simultaneous line openings, usually (but not necessarily) located in the vicinity of the fault. As a result, the power that used to pass through the tripped lines found its way through other links in the network, which in turn may have overloaded some of them. If any of the overloaded currents is larger than the setting of the overcurrent relays, then the latter will open the associated unfaulty line, putting additional stress on the network. As a domino effect, this sequence of line tripping followed by line overloading may propagate throughout the network until either the line overloading vanishes, or the stability limits or the voltage collapse limits are reached.

The risk of these cascading events leading to blackouts increases dramatically when the power system is operated closer to its stability limits, which was precisely the situation of the Brazilian power system. The system has small reserves in generation and transmission, making the congestion and equipment overloading likely to occur following major disturbances and contingencies.

Impact of the Energy Crisis on the Brazilian Economy

Electricity rationing has had an immediate negative impact on Brazilian society, and its effect has changed the economic and political trends for the years to come—but by how much? To get a sense of the magnitude of the disaster, McClellan (2001) referred to a study that anticipates the loss of 800,000 jobs if the decrease in energy is pursued. Another study revealed that economists contemplate a decline in economic growth from a previously projected 4.5 percent to less than 3 percent. In a poll conducted in São Paulo, 65 percent of manufacturers said that they would shrink or postpone investments and 25 percent are contemplating layoffs. Wheatley (2001) mentioned that on May 25, 2001, Flextronics International Ltd., a Singapore-based company, announced the cancellation of an $85 million addition to its industrial plant at Sorocaba, a suburb of São Paulo, thereby erasing the prospect of 500 new jobs. Fortunately, the impact of the crisis on the automobile industry, an important component of Brazilian GDP and exports, seems to be minor since Anfavea, a consortium of well-known multinational automakers such as VW, GM, Fiat, Ford, and Honda announced that it would maintain its forecasted production of 1.9 million vehicles for 2001, an increase of 14 percent with respect to 2000 (McClellan 2001). In response to the energy shortage, many automobile manufacturers are shifting or will shift to gas, a more abundant energy source. The future is therefore not as dim as it might appear at first glance.

Risk Mitigation of Blackouts in Electric Power Systems

New Technologies for Power System Transmission and Generation

The shift toward a competitive electricity market was made possible by technological advances not only in telecommunications and computers, but also in power generation, power electronics, fiber optics, and sensors. The economies of scale that once characterized large power plants were no longer valid with the advent of smaller and more efficient generating units in the 1980s. This cleared the way for growing use of small-scale distributed generation technologies such as combustion turbines, small hydro-turbines, wind turbines, photovoltaic panels, and fuel cells. These are generally owned by independent power producers that compete among themselves to provide generation and auxiliary services at both the distribution and the transmission levels.

The power electronics technology is not a newcomer to power systems. In the mid-1970s, Static Var Compensators were already being utilized for voltage control and to a certain extent for stability control. Also, HVDC converter stations and high-voltage DC lines have been incorporated into the transmission grid to allow for the transfer of large amounts of power over long distances and to allow the coupling of two power systems with different frequency regulations (i.e., the East-West European connections as indicated in the IEEE Subcommittee on International Practices, 1996). However, the 1990s have witnessed the advent of a broad range of power-electronic apparatuses, termed Flexible AC Transmission System (FACTS) devices by Hingurani (1993). These devices meet the urgent need of utility companies to increase the loadability of their transmission network following the environmental regulations imposed around the world. Issued in the late 1980s, these regulations impose stringent limitations on the construction of new overhead transmission lines, which in turn increase the stress put on the existing transmission network. As a result, the power systems are being pushed dangerously closer to their operating limits, making the occurrence of major disturbances more likely. This is substantiated by the growing number of incidents recently reported in the literature such as voltage collapses, angular instabilities, and cascading outages leading to brownouts or blackouts (IEEE Working Group on Voltage Stability 1990; Van Cutsem and Vournas 1998; IEEE Working Group on Special Stability Controls 1990).

Driven by the rapid development of the microprocessor and fiber optic technology, protection and sensors are also experiencing technological improvements. For example, computer relays are replacing the old electro-magnetic and electronic protection devices as they become less costly (Phadke and Thorp 1988). One important feature that makes them attractive is a higher reliability due to a self-checking and self-monitoring capability. Also, in the event of a detected defect, they can take themselves out of service after informing a central control system. Another interesting feature is their ability to adapt to different operating conditions of a power system by changing their settings, yielding the so-called adaptive relaying. Algorithms may also be implemented on their microprocessors to perform filtering, fault location, and various network calculations for control purposes (i.e., damping oscillations). Fiber optics are advocated as the most effective medium to transfer a large volume of data to a central location without any electro-magnetic interference.

Another computer device that is attracting growing attention is the microprocessor-based phasor measurement unit, or PMU (Phadke and Thorp 1988). Invented at Virginia Tech in the mid-1980s, they are presently installed on the transmission grids of many electric utilities in the United States. These utilities are interested in the ability of the PMUs to measure and time tag with great accuracy all the voltage and current magnitudes and phase angles of the buses where they are located. Because they sample at a sufficiently high rate the various nonlinear oscillations that can take place in the system, the PMUs are being incorporated in various control schemes for damping inter-area oscillations and steering the system away from transient instabilities or voltage collapse.

Enhancing the Efficiency of a Distribution System via Distribution Automation

Distribution automation is being incorporated in the distribution management system of an increasing number of utilities worldwide (His and Chen 1998; Su and others 2000; Humphreys 1998; Choi and Kim 2000). Typically, distribution automation consists of a collection of functions that act either on the utility feeders and equipment or on the customer appliances and metering system (Williams and Walden 1994; IEEE Communication Protocols Subcommittee 1995). The feeder automation functions seek to improve the performance of the distribution system through switching and other control actions. One common control action is the switching of circuit breakers to reconfigure the distribution network in order to transfer loads among feeders to minimize network losses while maintaining phase imbalance at a reasonable level during peak and off-peak periods. This switching may also be initiated to isolate the smallest possible segments of the network during fault conditions, known as fault detection, isolation, and restoration schemes. These network reconfigurations must be carried out regularly due to the diversity and time-varying characteristics of the load (Huddleston 1990); a configuration that is optimized at peak load may do poorly at off-peak load and vice versa.

Another contribution of distribution automation is in the area of power quality. Research in power quality enhancement has resulted in the development of a variety of devices to mitigate the effects of transients on customer equipment and utility transmission and distribution networks. Transients include voltage sags and swells, flickers, surges, and harmonics. They may cause interruption of service or have a damaging effect on utility and customer equipment. Presently, the focus is on finding solutions for voltage magnifications and voltage sags (Adams and others 1998; Middlekauff and Collins 1998). Induced by capacitor switching, voltage magnifications may cause the loss of audio signals and a loss of power to video signals of local television stations. Several devices that can cope with these problems are being developed and marketed (Adams and others 1998; Nelson and others 1995).

Overcoming the Transmission Capacity Shortage via Distributed Resources

According to the U.S.-based Electric Power Research Institute (EPRI), it is anticipated that by 2010 more than 20 percent of U.S. growth in electricity will be supplied by distributed resources. This trend is also foreseen in Europe and many developing countries. This is a sizable amount of newly installed power capacity that would put a significant strain on the distribution networks since many of these units will be connected along distribution feeders, down to the low voltage levels. Obviously, the design of this network should be rethought completely (Hadjsaid and others 1999). A shift toward a more meshed network is probably required for stability and security. The redesign should also account for the inclusion of various distribution automation devices such as fault detection, isolation and restoration; automatic voltage controllers; distribution static compensators; and dynamic voltage restorers for power quality purposes. Monitoring and control of the distribution system, including the use of automated mapping facilities, would require the design and installation of a distributed architecture of remotely distributed control centers spread across the service areas. These centers would communicate among each other and share a common database through fast communication links such as fiber optics, radio communications, and low orbit satellites. The design of such distributed computer architecture has already been envisioned by researchers in Taiwan, yet without including a large number of distributed resources and automatic devices (Lu and others 1997; His and Chen 1998; Su and others 2000).

Technology Deployment for Disaster Risk Management in Electric Power Systems

The deployment of the technologies previously outlined, coupled with advanced control schemes, has the ability to enhance the resiliency of a power system to catastrophic failures and decrease the time of recovery following a blackout. Furthermore, they may improve the efficiency and the quality of service of the transmission and distribution grids. A priority list of actions includes the following:

- Implementation of a plan of defense for the survivability of electric power network transmission following a major disturbance. This defense plan aims at confining the cascading failures to a small region via the breakup of the transmission grid into islands. This breakup should achieve, as far as possible, a balance between power generation and load demand in every island. It should be carried out by a collection of special protection schemes having objectives that range from the prevention of angular and voltage instabilities to the relief of overloaded lines and transformers. To meet these requirements, protection schemes may initiate generation and load shedding and line switching across the network. Interestingly, a pioneer implementation of such a defense was recently carried out by the Taiwan Power Company following a series of blackouts in Taiwan, the last one occurring July 29, 1999 (Hsiao and others 2002).
- Implementation of the fault detection, isolation, and restoration scheme for the distribution system to decrease the time of recovery after a blackout. One important component of this computer-based scheme is the Outage Management System (OMS). Currently implemented by a growing number of U.S. utilities, the OMS makes use of the geographical information system to map the location of all devices that compose the distribution network and achieve functions such as customer call management, connected circuit models, switching, outage/regulatory, and remote-user access (Blew 2001).
- Implementation of computer-aided software programs at control centers that seek the best topology of the distribution network associated with minimum electric losses. These losses constitute a sizable fraction of the total losses in an electric power system. Their minimization will result in millions of dollars of savings per year while simultaneously improving the quality of service of the system.

Bibliography

ABC News. 1999. "France, Austria Battered Again," Paris, Dec. 28. Available from <http://abcnwes.com/sections/world/DailyNews/eurowea991228.html>.

Adams, R. A., S.W. Middlekauff, E. H. Camm, and J.A. McGee. 1998. "Solving Customer Power Quality Problems Due to Voltage Magnification." Paper No. PE-384-PWRD-0-11-1997, *IEEE Transactions on Power Delivery* 11.

Adibi, M. M. 2000. *Power System Restoration: Methodology and Implementation Strategies*. IEEE Press.

Barkovich, B. R. and D.V. Hawk. 1996. "Charting a New Course in California." *IEEE Spectrum* July: 26–31.

Barroso, L. A. N., M. V. F. Pereira, R. Kelman, P. Lino, and J. Rosenblat. 2002. "Can Brazil Learn from California?" *IEEE Power Engineering Review*, August.

Blew, D.S. 2001. "Outage Management Systems: Surviving the Implementation." *Proceedings of the Workshop on Mitigation of the Vulnerabilities of Critical Infrastructures to Catastrophic Failures*, Alexandria Research Institute, Virginia Tech, Alexandria, Virginia, September 10–11. Available from <http://www.ari.vt.edu/workshop/>.

Business News Americas. 2002. "Latin America Electric Power Weekly Wrap-Regional." *Financial Times Information,* January 25. Available from <http://www.bnamericas.com>.

Cauley, G., P. Hirsch, A. Vojdani, T. Saxton, and F. Cleveland. 1996. "Information Network Supports Open Access." *IEEE Computer Applications in Power* July: 12–19.

CEOS. 2002. Working Group on Information Systems and Services. Available from <http://wgiss.ceos.org/ceos.htlm>.

Choi, J.-H. and J.C. Kim. 2001. "The Online Voltage Control of ULTC Transformer for Distribution Voltage Regulation." *Electric Power and Energy Systems* 23: 91–98.

Clendenin, M. 2001. "After Plague of Blackouts, Hsinchu Hears Vow of Better Power in 2001." *Electronic Engineering Times,* CMP Media, Inc., Jan. 8.

Clinton, W. J. 1996. "Executive Order 13010-Critical Infrastructure Protection." The White House, July 17. Available from <http://www.ciao.gov>.

Dana, P. H. 2000. "Global Position System Overview." Colorado University. Available from <http://www.colorado.edu/geography/gcraft/notes/gps/gps_f.html>.

Economist, The. 2002. "A Struggle for Power." February 2.

Einhorn, M. and Siddiqi, R., eds. 1996. *Electricity Transmission Pricing and Technology*. New York: Kluwer Academic Publishers.

EPRI (Electric Power Research Institute).1999a. "Power Delivery in the 21st Century," *EPRI Journal*, Summer issue: 19–25.

EPRI (Electric Power Research Institute). 1999b. "Utility Communications Go Into Orbit," *EPRI Journal*, Fall issue: 18–27.

Graham, J. F. 1995. "Space Exploration From Talisman of the Past to Gateway for the Future." NASA.

Hadjsaid, N., J.-F. Canard, and F. Dumas. 1999. "Dispersed Generation Impact on Distribution Networks." *IEEE Computer Applications in Power* 12 (2): 22–28.

Harris. 2002. "India: Telemedicine's Great New Frontier: An Indigenous Technology Effort is Wiring Up its Healthcare System." *IEEE Spectrum*, April: 16–17.

Hingorani, N. G. 1993. "Flexible AC Transmission." *IEEE Spectrum* April: 40–45.

His, P.-H. and S.-L. Chen. 1998. "Distribution Automation: Communication Infrastructure." *IEEE Transactions on Power Delivery* 13 (3): 728–734.

Hsiao, T.-Y., C.-N. Lu, and Y. Liu. 2002. "Defense Plan Design in a Longitudinal Power System." *Proceedings of the 14th Power Systems Computer Computation*, Paper 5 of Session 25, Seville, June 24–28.

Huddleston, C.H., R. P. Broadwater, and A. Chandrasekaran. 1990. "Reconfiguration Algorithm for Minimizing Losses in Radial Electric Distribution Systems." *Electric Power Systems Research* 18: 57–66.

Humphreys, S. 1998. "Substation Automation Systems in Review." *IEEE Computer Applications in Power* April: 24–30.

Hunt, S. and S. Shuttleworth. 1996. "Unlocking the Grid." *IEEE Spectrum*, July: 20–25.

IDRC (International Development Research Centre of Canada). 2002. Ottawa, Canada. <http://www.idrc.ca>.

IEEE (Institute of Electrical and Electronics Engineers) Communication Protocols Subcommittee. 1995. "IEEE Tutorial Course: Communication Protocols." IEEE Power Engineering Society, Report 95 TP 103.

IEEE (Institute of Electrical and Electronics Engineers) Subcommittee on International Practices. 1996. "East and Central European Policy on Electricity Infrastructure, Interconnections and Electricity Exchanges." IEEE Report 96 TP 113-0.

IEEE (Institute of Electrical and Electronics Engineers). 1990. Working Group on Special Stability Controls. *Eigenanalysis and Frequency Domain Methods for System Dynamic Performance*. IEEE Special Publication 90TH0292-3-PWR.

IEEE (Institute of Electrical and Electronics Engineers) 1990. Working Group on Voltage Stability. *Voltage Stability of Power Systems: Concepts, Analytical Tools, and Industry Experience*. IEEE Special Publication 90TH0358-2-PWR.

Ilic, M., F. Galiana, and L. Fink, eds. 1998. *Power Systems Restructuring: Engineering and Economics.* New York: Kluwer Academic Publishers.

Internet Bazaar. 2002. Available from <http://internetbazaar.org>.

IPCC (The Intergovernmental Panel on Climate Change) Working Group II. 2001. "Climate Change 2001: Impacts, Adaptation and Vulnerability." Available from <http://www.ipcc.ch/pub/tar/wg2/005.htm>.

Janssens, N. and A. Kamagate. 2002. "Loop Flows in a Ring AC Power System," *Proceedings of the 14th Power Systems Computation Conference.* Paper 2 of Session 09, Seville, June 24–28.

Jardini, J.A., D. S. Ramos, J.S.C. Martini, L. B. Reis, and C.M.V. Tahan. 2002. "Brazilian Energy Crisis," *IEEE Power Engineering Review*, April: 21–24.

Jayaraman, V., M. G. Chandrasekhar, and U.R. Rao. 1997. "Managing the Natural Disasters from Space Technology Inputs." *Acta Astronautica* 40 (2–8): 291–325.

Koshcheev, L. A. 2001. "Basic Principles of Interstate Electrical Power Links Organization in Northeast Asia Region." *Proceedings of the Workshop on Power Grid Interconnection in Northeast Asia.* May, Beijing, China.

Latin America Regional Reports: Brazil. 2002. "State Intervenes in Troubled Sector." *Latin American Newsletters, Ltd.* Section Energy: RB-02-02, February: 7.

Lu, C. N., K.T. Chen, M.C. Lin, and Y.T. Lin. 1997. "Performance Assessment of an Integrated Distribution SCADA-AM/FM System." *IEEE Transactions on Power Delivery* 12 (2): 971–978.

Mason, C. 1990. "Software Problem Cripples AT&T Long-Distance Network," *Telephony* January 22: 10.

McClellan, B. 2001. "In the Dark: Brazil's Auto Industry Struggles with Energy Crunch." *Manufacturing South-America.* Intertec Publishing Corporation, August.

Middlekauff, S. W. and E. R. Collins. 1998. "System and Customer Impact: Considerations for Series Custom Power Devices." *IEEE Transactions on Power Delivery* 13 (1): 278–282, January.

NASDA (The National Space Development Agency of Japan). 2002. "Earth Observation satellite." Available from <http://www.eoc.nasda.go.jp/guide/satellite/sat_menu_e.html>

NASSCOM (National Association of Software and Service Companies). 2002. July 29. Available from <http://www.nasscom.org/it_industry/indian_scenario.asp>.

Naushad. 2002. Available from <http://www.ntclimited.com>.

Nelson, R.J., N.H. Woodley, and E.M. Gulachenski. 1995. "Requirements for Dynamic Voltage Restoration to Relieve Distribution System Voltage Sags." *Proceedings of the American Power Conference,* 57th Annual Meeting, Chicago, IL.

NERC (North American Electric Reliability Council). 1988. "NERC Disturbance Reports, 1984–1988." New Jersey. Available from <http://www.nerc.com/dawg/database.html>.

Neumann, P.G. 1995. *Computer-Related Risks*. Boston: Addison-Wesley Publishing Co.

Neumann, P.G. 1998. "Computer-Related Risks and the National Infrastructures." In *The Role of Computer Security in Protecting U.S. Infrastructures*. Hearing, 105th Congress, 1st Session, No. 33: 64–99.

Phadke, A.G. and J.S. Thorp. 1988. *Computer Relaying for Power Systems*. New Jersey: John Wiley and Sons.

Phombeah, G. 2000. "Feeding Hungry Minds in Africa." BBC News, July 27. Available from<http://news.bbc.co.uk/1/hi/world/africa/854610.stm>.

Prates, J. P. 2001. "Brazil's Energy Crisis Complicates Progress in Gas, Power Markets, but Outlook Brightening." *Oil & Gas Journal* 99 (42): 77.

Ravisankar, R. 2002. "Moving Up the Value Chain: From Services to Products," July 29, *i-flex solutions Ltd.* Available from <http://www.iflexsolutions.com>.

Rediff News. 2002. "Major Power Breakdown in Western India." July 30. Available from <http://Rediff.com/news/2002/jul/30power.htm>.

Rediff News. 2002. "Indiscipline by Madhya Pradesh Caused Grid Collapse: PGCIL." July 30. <http://Rediff.com/news/2002/jul/30power1.htm>.

Rudnick, H. 1996. "Pioneering Electricity Reform in South America." *IEEE Spectrum* August: 38–44.

Rudnick, H., R. Varela, and W. Hogan. 1997. "Evaluation of Alternatives for Power System Coordination and Pooling in a Competitive Environment." *IEEE Trans. on Power Systems* 12 (2): 605–613.

Rudnick, H., N. de Franco, T.J. Hammons, L.V. Sbertoli, C. Chahin, J.G.A. do Nascimento, J.W. Marangon Lima, and P. Gray. 1998. "Latin America Deregulation Processes." *IEEE Power Engineering Review* December: 10–23.

Singh, S. 2002. "India to Use Global Positioning in Civil Air Navigation System." *IEEE Spectrum* (April).

Su, C.-L., C.-N. Lu, and M.-C. Lin. 2000. "Wide Area Network Performance Study of a Distribution Management System." *Electric Power and Energy Systems* 22: 9–14.

Sugarman, R. 1978. "New York City's Blackout: A $350 Million Drain." *IEEE Spectrum* 15 (11): 44–46.

Tabors, R. T. 1996. "Lessons from the UK and Norway." *IEEE Spectrum* 33(8): 45–49.

Task Force on Harmonics Modeling and Simulation. 1996. "Modeling and Simulation of the Propagation of Harmonics in Electric Power Networks." Part 1s and 2, *IEEE Transactions on Power Delivery* 11 (1): 452–474.

Thorp, J.S., A.G. Phadke, S.H. Horowitz, and S. Tamronglak. 1998. "Anatomy of Power Systyem Disturbances: Importance Sampling." *Electrical Power & Energy Systems* 20(2): 147–152.

Topfer, K. and V. Ramanathan. 2002. "Impact Study—The Asian Brown Cloud: Climate and Other Environmental Impacts." The Center for Clouds, Chemistry, and Climate. UNEP report, April 8. Available from <http://www.rrcap.unep.org/abc/impactstudy>.

Travis, P. 1990. "Why the AT&T Network Crashed." *Telephony* January 22: 11.

USAID (United States Agency for International Development). 2001. "Hurricanes in Central America and the Caribbean." *USAID Status Reports* (February 6). Available from <http://hurricane.info.usaid.gov/>.

USGS (United States Geological Survey). 1998. "Central America Disaster Overview." USGS Center for Integration of Natural Disaster Information (November 17). Available from <http://cindi.usgs.gov/hazard/event/mitch/briefing/brief5.html>.

Van Cutsem, T. and C. Vournas. 1998. *Voltage Stability of Electric Power Systems*. New York: Kluwer Academic Publishers.

Wheatley, J. 2001. "What's Blacking out Brazil's Growth." *Business Week International Editions*. June 11. *The McGraw-Hill Co.* Available from <http://businessweek.com/ index.html>.

Williams, B. R. and D. G. Walden. 1994. "Changing the Momentum: Distribution Automation Strategy for the Future." *IEEE Computer Applications in Power* (July): 16–21.

Wilson, G. L. and P. Zarakas. 1978. "Anatomy of a Blackout." *IEEE Spectrum* 15 (2): 38–46.

Wood, H. 2002. "The Use of Earth Observing Satellites for Hazard Support: Assessments and Scenarios." Final Report of the CEOS Disaster Management Support Group. Available from <http://disaster.ceos.org/legal.cfm>.

World Bank. 1998. "Meeting India's Future Power Needs: Planning for Environmentally Sustainable Development." Washington, D.C. Available from <http://www.worldbank.org>.

World Energy Council. 1999. "The Challenge of Rural Energy Poverty in Developing Countries." Available from http://www.worldenergy.org/wec-geis/publications/default/launches/rural/rural_info.asp.

World Markets Research Center. 2001. "World Infrastructure and Development." May. Available from <http://www.wmrc.com/businessbriefing/infrastructurebriefing/contents/Infra2001/Index.html>.

Chapter 19

Damage to and Vulnerability of Industry in the 1999 Kocaeli, Turkey, Earthquake

Mustafa Erdik and Eser Durukal

Over the past 10 years, Turkey has been hit by several moderate to large earthquakes that caused significant loss of life and property. These took place in: Erzincan, 1992; Dinar, 1995; Adana-Ceyhan, 1998; and Kocaeli and Duzce, 1999. Adana-Ceyhan and Kocaeli are the most industrialized regions in Turkey, and the earthquakes of 1998 and 1999 resulted in extensive losses to industry in these regions.

On August 17, 1999 a magnitude MW 7.4 (MW is moment magnitude) earthquake struck Turkey's northwestern Kocaeli and Sakarya provinces, a densely populated region in the industrial heartland. The earthquake nucleated at a depth of about 15 kilometers, some 10 kilometers east of the town of Gölcük. The earthquake was associated with a 120-kilometer rupture involving four distinct fault segments on the northernmost strand of the western extension of the 1300-kilometer-long North Anatolian fault system. Predominantly right-lateral strike-slip offsets were in the range of three to four meters over a significant length of the fault. Another segment at the eastern end of the fault break ruptured on November 12, producing the MW 7.2 Duzce earthquake. The August 17, 1999 (MW 7.4) Kocaeli and November 12, 1999 (MW 7.2) Duzce earthquakes resulted when a wedge of continental crust known as the Anatolian Block was squeezed between the Arabian and Eurasian plates. This motion was accommodated by two major strike-slip faults: the North and East Anatolian faults.

The 1999 Kocaeli and Duzce earthquakes caused considerable damage to residential and commercial buildings, public facilities, and infrastructure, and caused significant casualties in an area 20 kilometers by 200 kilometers. The number of condemned buildings after the earthquakes totaled 23,400. Some 16,400 of these, encompassing 93,000 housing units and 15,000 small business units, collapsed or were heavily damaged. Another 220,000 housing units and 21,000 small business units experienced lesser degrees of damage. Widespread building collapse in the two earthquakes resulted in a substantial number of casualties. Deaths numbering 18,373 were recorded, and 48,901 people were hospitalized for injuries; 40 percent of them will be left permanently disabled.

The two major earthquakes that took place in 1999, namely the MW 7.4 Kocaeli, Turkey and the MW 7.6 Chi-Chi, Taiwan (China), earthquakes, caused comparable economic and insured losses. In the Kocaeli earthquake, the economic losses were estimated to have been \$10–40 billion, while insured losses were estimated at \$550–750 million. The Chi-Chi earthquake resulted in economic losses of \$8–14 billion and insured losses of \$500–\$850 million (Johnson 2000). It is worth noting, however, that there is an order of magnitude difference in the human losses in these earthquakes. The Kocaeli earthquake resulted in more than 18,000 deaths and nearly 50,000 injuries, while in Taiwan there were 2,405 deaths and 10,718 injuries.

The Kocaeli earthquake is considered the largest event to have damaged an industrialized area since the 1906 San Francisco and 1923 Tokyo earthquakes. In the earthquake, 70 percent of total insured losses related to direct damage and 30 percent was due to business interruption. Estimations in U.S. dollars (all dollar amounts in this paper are U.S. dollars) by the insurance industry of total insured losses were in the order of \$1.5–\$3.5 billion (RMS 1999) as compared to the \$550–\$750 million estimated to have been paid by the industry (Johnson 2000).

The epicenter of the 1999 Kocaeli earthquake was the main site of Turkey's heavy industry. Major industries located there include: automobile manufacturing;

petrochemicals; motor and railway vehicle manufacture and repair; basic metal works; production and weaving of synthetic fibers and yarns; paint and lacquer production; tire manufacturing; paper mills; steel pipe production; pharmaceuticals; sugar processing; cement production; power plants; and tourism.

The region affected by the earthquake is geographically extensive, economically dynamic, and the industrial heartland of Turkey. The four districts most severely affected (Kocaeli, Sakarya, Bolu, and Yalova) contribute more than 7 percent of the country's GDP and 14 percent of industrial value-added. Per capita income is almost double the national average. With only 4 percent of the nation's population, the region contributes more than 16 percent of budget revenues. The districts immediately surrounding the area (Bursa, Eskisehir, and Istanbul) were indirectly affected because of their close economic linkages, since industries and small businesses supply services and material inputs to each other's production processes. The greater region now realizes that it shares a seismic risk and faces magnified uncertainty for the future. Taking all seven cities together, the wider earthquake region accounts for 35 percent of national GDP and nearly half of the nation's industrial output. Building losses reportedly amounted to $5 billion. Damage to lifelines is estimated to be some $1 billion. Industrial facilities and small business losses are $2 billion and $1 billion, respectively. If we assume that indirect socioeconomic losses will be as much as direct physical losses, the total loss figure is in the vicinity of $16 billion (about 7 percent of Turkey's GDP). Most industrial losses were covered by insurance.

Private and public sector estimates of damage to industry as a whole range from $1.1 to $4.5 billion. The value-added loss in manufacturing is estimated at $600 to 700 million. The State Planning Industry estimated that value-added losses stemming from damage to industry were $700 million. The losses may have resulted in a 1.6 percent decline in the growth of the production sector in Turkey. Other sources put this loss figure as high as $2 billion. According to the Kocaeli Chamber of Industry, 214 enterprises (about 19 percent of all enterprises in the province) reported significant damage totaling $2.5 billion in capital losses. Many major facilities faced extensive business interruptions; however, the biggest loss was that of qualified manpower. Most industrial losses were covered by insurance. Payments of claims were reported to have totaled $600 to $800 million. The State Planning Organization estimates a loss of $880 million just for the 19 state-owned enterprises located in the region (mainly in Tupras, Tuvasas, Igsas, Petkim, Seka, and Asil Celik). The State Planning Organization also estimates that the loss of business in these industries may have amounted to $632 million. The tourism industry (based in Yalova) was virtually destroyed and has yet to pick up even three years after the earthquake. A fundamental regional restructuring in the tourism industry may be needed.

Rahnama and Morrow (2000) note that older, heavy industrial facilities, especially those with taller structures, that partially to totally collapsed, were more affected by the earthquake than newer facilities. It was observed that any type and quality of anchorage improved the performance of machines and equipment, except very sensitive equipment such as assembly line sensors in the automotive industry and rotary kilns in cement plants. Losses associated with business interruption were more severe for these types of facilities. For light industrial facilities, building damage turned out to be the primary reason for direct and indirect losses. As was the case in the 1998 Adana-Ceyhan earthquake, the poor performance of precast concrete structures was observed. For refineries and other chemical processing facilities, nonbuilding structures turned out to be the most vulnerable, with tanks being the most susceptible to earthquake and fire damage. It was observed that damage to industrial facilities was more severe and extensive than that seen in earthquakes with similar peak ground acceleration levels. This observation was attributed to the duration and long-period ground motion of the earthquake (MCEER 2000). Most industrial facilities damaged by this earthquake were within 10 kilometers of the fault rupture and in intensity zone IX.

In general, the earthquake damage at industrial facilities in Turkey was not significantly different than that observed in other earthquakes worldwide. Large storage tanks, pipelines, transmission lines, and precision machinery are generally susceptible to damage from earthquakes. Due to the high relative value of contents, their vulnerability and dependence on structural performance are key in assessing loss potential, especially for heavy manufacturing facilities. Port and harbor facilities are particularly susceptible to sub-marine landslides or ground settlement due to liquefaction that may occur during earthquakes. In addition, all processes that involve a substantial risk of explosion, such as those in the petrochemical industry and processes involving molten metal, should be examined carefully.

Earthquake vulnerability is the measure of damage a building or structure is likely to experience when subjected to ground shaking of a specified intensity. The dynamic response of a structure to ground shaking is a complex behavior that is dependent upon a number of inter-related parameters that are often difficult, if not impossible, to predict precisely. These include: the exact character of the ground shaking that the building will experience; the extent to which the structure will be excited by and respond to the ground shaking; the strength of the materials in the structure; the quality of construction and condition of individual structural elements; the interaction of the structural and nonstructural elements of the industrial facility; the weight of contents in the facility at the time of the earthquake; and other factors. Most of these factors can be estimated, but never precisely known. As a result, it is typically necessary to define vulnerability functions for buildings within levels of confidence.

In addition to physical vulnerabilities, the socioeconomic vulnerabilities of industrial facilities need to be assessed in terms of casualties, social disruption, and economic losses. Casualties in earthquakes arise mostly from structural collapse and other collateral hazards. Lethality per collapsed building can be estimated by a combination of factors representing the number of people per building, occupancy at the time of the earthquake, occupants trapped by collapse, mortality at collapse, and mortality post-collapse. Lethality for collateral hazards is difficult to generalize and may require facility-specific assessments.

It is generally known that losses due to collateral hazards and indirect economic losses constitute a major portion of total earthquake losses in industrial systems. Indirect economic losses arise from shutting down damaged facilities and include: production and sales lost by firms in damaged buildings; production and sales lost by firms unable to get supplies from other damaged facilities; production and sales lost by firms due to damaged lifelines; lost tax revenue; and increased unemployment compensation. Partial quantification of these indirect economic losses can be found in ATC-25 (1991).

An industrial facility consists of many integrated components and processes. As such, operation of a facility depends upon the performance of its critical components. The greatest risk from an earthquake is that to life safety. Building code requirements in most counties, including Turkey, are written with the objective of protecting lives. A building is allowed to be damaged, but it should not collapse and people should be able to evacuate even under extreme conditions. However, in large earthquakes, industrial buildings and related machinery and equipment damaged may be costly to repair and there may be additional damage from fire and chemical spills. Since most revenue generated by industrial facilities is related to the products and services they provide rather than the physical assets of the company, any significant interruption in the production of these goods and services will have an adverse effect on business. The risk of business interruption is a critical economic reason for controlling earthquake and post-earthquake damage. As such, the design (or seismic retrofit) of industrial facilities should preferably be based on performance-based methodologies with the objective of controlling structural and nonstructural damage.

Bibliography

ATC-25 (Applied Technology Council). 1991. "Seismic Vulnerability and Impact of Disruption of Lifelines in the Coterminous United States, ATC-25." Redwood City, California.

Johnson, Laurie A. 2000. "Earthquake Loss Modeling Applications for Disaster Management: Lessons from the 1999 Turkey, Greece and Taiwan Earthquakes." Proceedings of *EuroConference 2000 on Global Change and Catastrophe Risk Management: Earthquake Risk in Europe*. Laxenburg, Austria. Available from <http://www.iiasa.ac.at/Research/RMS/july2000/>.

MCEER (Multidisciplinary Center for Earthquake Engineering Research). 2000. "The Marmara, Turkey Earthquake of August 17, 1999: Reconnaissance Report." Charles Scawthorn, ed. University of Buffalo, New York.

Rahnama Mohsen, and Guy Morrow. 2000. "Performance of Industrial Facilities in the August 17, 1999 Izmit Earthquake." *Proceedings of the 12th World Conference on Earthquake Engineering.* On CD. Paper No: 2851, Auckland, New Zealand.

RMS (Risk Management Solutions). 1999. "Event Report, Kocaeli, Turkey Earthquake." San Francisco, California.

Chapter 20

The Behavior of Retrofitted Buildings During Earthquakes: New Technologies

Mikayel Melkumyan

Five years have passed since buildings were retrofitted under the World Bank–financed Armenia Earthquake Zone Reconstruction Project. During this period several earthquakes of varying intensities occurred in northern Armenia. Intense usage of these buildings has been taking place as all are occupied. Considering these factors, there are lessons that can be drawn from the retrofitting, which uses new technologies, to learn whether these technologies can be applied to critical facilities.

Different types of laminated rubber bearings were used to improve earthquake resistance in numerous buildings. Following the earthquakes, these bearings were examined and their performance was evaluated. Lessons learned from the experience should now be passed along to decisionmakers responsible for construction policies. Also, if the new technologies are deemed appropriate, they should be applied to critical facilities. The study of these retrofitting measures also included analysis of the sustainability and effectiveness of the new technologies for critical facilities such as schools and hospitals.

On the basis of the study, a report was prepared on the findings outlined below. The conclusions reached and recommendations made can be supported by the data received and working papers submitted that are kept in a permanent file.

Project Scope

The objectives of the assignment were to assess the behavior of retrofitted buildings, to learn lessons based on the consequences of earthquakes of different intensities, and to justify the possibility of the practical application of new technologies to critical facilities. More specifically, the study required the following:

1. Visual inspections of three isolated buildings in Vanadzor (one building with base isolation and two buildings with isolated upper floors). Possible damage in isolation systems and to structures below and above was to be revealed and assessed.
2. Instrumental investigation of dynamic characteristics of the buildings. The values of vibration periods and damping factors were to be obtained and compared with the design values at small deformations.
3. Based on visual inspection and instrumental investigations, assess the technical conditions of the buildings.
4. Survey the tenants regarding the behavior of buildings during the various earthquakes that occurred in the last five years.
5. Based on the findings, assess the behavior of buildings during earthquakes and draw lessons from retrofitting using new technologies.
6. Justify the possibility of the practical application and effectiveness of new technologies to critical facilities.
7. Prepare recommendations to influence decisionmakers in construction policy for further implementation of new technologies in Armenia and other countries where similar projects are financed by the World Bank and other international financial institutions.

In addition to the above scope, a similar study was carried out for one building in Spitak.

This paper was written with the participation of A. Azaryan, T. Nersesyan, S. Saroyan, A. Avagyan, G. Goulanyan, A. Ghevondyan, A. Karapetyan, G. Voskanyan, K. Avanesova, and M. Begumyan.

Visual and Instrumental Inspection of Three Buildings in Vanadzor and One in Spitak: Assessment of the Technical Conditions

The three buildings in Vanadzor were strengthened within the framework of the "strengthening" subcomponent of the World Bank-financed Earthquake Zone Reconstruction Project. "This subcomponent funded the strengthening of structures damaged and weakened by the 1988 earthquake that could be made habitable through retrofitted structural reinforcing or seismic isolation systems. Also this subcomponent has established new technologies for the strengthening of existing structures, notably new techniques for installing seismic isolation systems in new and existing occupied buildings. The project is the worldwide pioneer for several techniques, and two project pilot structures have attracted international professional attention by establishing appropriate low technology methods for the strengthening of existing structures."[1]

In the proceedings of the 7th International Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control of Vibration of Structures (Assisi, Italy, 2–5 October, 2001) it is mentioned:

> As far as the ordinary apartment buildings are concerned, the number of new applications of the Innovative Antiseismic (IAS) techniques … is particularly large in Japan and the P.R. China and Armenia…" (page xxiii); "…with regard to the interest in the IAS techniques …it is now extending to new countries like, for instance, Turkey, Iran and India. Some other countries are beginning to follow the excellent example of Armenia…, where seismic isolators are locally manufactured also for foreign markets, like Syria" (page xxv); "Very interesting on-site tests of … an existing bank building at Irkutsk-City in Russia, retrofitted by applying the technology invented by Prof. M. Melkumyan in Armenia…" (page xxv).

The building inspected in Spitak was constructed under the terms of the World Bank project. It is a four-story apartment building on Shahumyan Street with reinforced-concrete bearing walls. This is the first newly constructed building in Armenia using the seismic (base) isolation system. Following the 1988 Spitak earthquake, no buildings over two stories were constructed. With base isolation, however, a four-story building was constructed for the first time after the earthquake. Presently, where the isolation system is located, renovation work is going on with the purpose of establishing a museum dedicated to the 1988 Spitak earthquake. This project was initiated by the Armenian Association for Earthquake Engineering.

A visual inspection was carried out for three buildings in Vanadzor (one building with base isolation and two buildings with Additional Isolated Upper Floor (AIUF)) in addition to the building with base isolation in Spitak. Hairline cracks were found in some reinforced-concrete elements below and above the isolation system and some violations of the rules of exploitation were revealed in the building Yerevanyan #149. While the cracks are not dangerous for the building, the violation of rules of exploitation in the form of filled seismic gap by stones, mortar, soil, and wood is absolutely inadmissible. All filled materials that restrict the displacement of the isolation system must be removed immediately.

The roof layers and some parts of exterior nonbearing structures in the building Isahakyan #4 were significantly damaged due to violation of the rules of exploitation of the building by tenants. As a result, the seismic isolators of AIUF were immediately influenced by atmospheric precipitations, seriously deteriorating the surface of six isolators. Also in buildings Isahakyan #4 and Cherkassi #1, the seismic isolators are not appropriately protected from low temperatures. The roof and nonbearing exterior structures of the Isahakyan #4 building must be repaired and six seismic isolators must be replaced. All isolators in both Isahakyan #4 and Cherkassi #1 buildings must be taken into special jackets due to light insulation materials. The estimated cost for jacketing, replacement of isolators, and repair work for both buildings is about US$15,000.

No damage was revealed in reinforced-concrete structures below and above the isolation system of Shahumyan building. Seismic isolators were also in a normal technical state.

Instrumental investigations of all four buildings were carried out. The rubber hardness and dynamic characteristics of buildings were measured. The increase in rubber hardness due to low outside temperatures was observed in the Isahakyan #4 and Cherkassi #1 buildings. The dynamic characteristics of the Yerevanyan #149 and Shahumyan buildings fully correspond to the design values of total initial stiffness of isolation systems. The dynamic characteristics of the Isahakyan #4 and Cherkassi #1 buildings are 1.4 times less on average than the design values as a result of increased rubber hardness. The proposed jacketing of seismic isolators of AIUF in both buildings will help to avoid disturbing their tuning in order to keep effective seismic protection of the buildings.

Based on visual and instrumental investigations, the technical conditions of the buildings were assessed. It is stated that in three buildings, Yerevanyan #149, Cherkassi #1, and Shahumyan, all systems that provide increased earthquake resistance are in satisfactory condition from a technical point of view. Nonbearing structures of AIUF and some seismic isolators in Isahakyan #4 building are in bad technical condition.

Table 20.1 Short form of the European Microseismic Scale EMS-98

EMS intensity	*Definition of earthquake*	*Description of typical observed effects (abstracted)*
III	Weak	Felt indoors by a few people. People at rest feel a swaying or light trembling.
IV	Largely observed	Felt indoors by many people, outdoors by very few. A few people are awakened. Windows, doors, and dishes rattle.
V	Strong	Felt indoors by most, outdoors by few. Many sleeping people awake. A few are frightened. Buildings tremble througout. Hanging objects swing considerably. Small objects are shifted. Doors and windows swing open and shut.

Data on the Earthquakes Recorded in Northern Armenia from 1996 to 2002

Practically all of the territory of Armenia is situated in a seismically active zone. The size of earthquakes ranges up to $M = 7.1$ (according to historical and paleoseismic estimations). Focal depth is, on average, 10 kilometers. All sources are located on active faults with an average slip rate of about one centimeter per year. During the last seven years, more than 20 earthquakes were recorded in northern Armenia. By geographical location of the epicenters of the earthquakes, the distances between the epicenters and the cities of Vanadzor and Spitak were calculated and the maximum possible intensity values in Vanadzor and Spitak were in the range of III to V. Such seismic impacts are not a hazard for the buildings inspected, but they cause distress in the population. From this point of view, the opinions of the buildings' tenants are important for assessing the behavior of buildings during earthquakes. The behavior of people for each level of intensity from III to V is described in table 20.1.

Survey of the Tenants of the Four Buildings Examined

A survey among tenants of apartment buildings with base isolation or AIUF was carried out on February 6, 2002 in the cities of Vanadzor and Spitak. The objective of the survey was to find out how safe the tenants feel in the buildings that were newly constructed or retrofitted by new technologies, and to ascertain the advisability of applying AIUF and base isolation not only to apartment buildings but also to schools, hospitals, kindergartens, and other critical facilities. Appropriate questionnaires were elaborated to carry out the survey (a sample questionnaire is given below).

An analysis of the results showed that 94 percent of all respondents were aware of the advantages of their building over others, 77 percent felt safe during earthquakes, and 93 percent would like to apply seismic protection systems if constructing their own houses. One hundred percent of tenants considered the application of seismic protection systems to critical facilities to be a priority and 100 percent wished to see an increase in the number of buildings with seismic protection systems to reliably protect people from earthquakes in Armenia.

Other comments from respondents included:

- Usually we learn from tenants of neighboring buildings that an earthquake has occurred.
- We have felt few earthquakes in this building during the past several years.
- We are glad to live in this type of building.
- We feel safe and protected.
- If I don't experience any vibration during earthquakes, it means I am safe.
- We bought this apartment because we knew the building was improved with a seismic protection system.
- We believe that the existence of the seismic protection system makes the building safer.
- We invite our neighbors from close apartment buildings to take refuge at our place when an earthquake occurs.
- I have learned about earthquake occurrences only from the radio.

- When there is noise and lights are switched on in the front building, I assume that an earthquake occurred.
- We believe that schools, hospitals, and kindergartens should be seismically isolated first of all.
- We would like all of the buildings in our city to be safe, and all people to feel safe.
- I am safer here in this house than in the temporary dwelling-wagon.

Sample Questionnaire for Tenants of the Nine-Story Apartment Building #4 with AIUF in Isahakyan Street, Vanadzor

Several buildings in Vanadzor were provided with base isolation or other seismic protection systems from 1995–97. We would like to know your opinion on the advisability of applying such seismic protection systems. This research is being carried out under a World Bank contract. Your sincere answers will help to make our research effective.

Thank you in advance.

1. Where were you when the earthquake of 1988 occurred?
   Out of Armenia ☐ In Armenia ☐ In the Earthquake Zone ☐
2. For how long have you been living in this building?
   a) more than 14 ☐ b) 6-14 years ☐ c) up to 6 years ☐
3. Do you know the advantage of your building over the others?
   Yes ☐ No ☐ Find difficulty in responding ☐
4. How many times have you experienced earthquakes or have you heard that an earthquake has occurred?
   a) have experienced ....times ☐ b) have not experienced ☐ c) have heard ....times ☐ d) have not heard ☐ e) find difficulty in responding ☐
5. If 4a). Did you feel safe at home during the earthquakes?
   Yes ☐ No ☐ Find difficulty in responding ☐
6. What kind of apartment (building) did you live in before the earthquake of 1988, and what is the difference between it and the one you live in now?
   ____
   ____
   ____
7. If you would construct your own house, would you like to apply seismic protection systems?
   Yes ☐ No ☐ Find difficulty in responding ☐
8. Do you consider seismic protection systems advisable to be applied not only to apartment buildings but also to schools, hospitals and other critical facilities?
   Yes ☐ No ☐ Find difficulty in responding ☐
9. What can you say about your neighboring apartment buildings tenants' behavior during the earthquakes?
   ____
   ____
   ____
10. Based on your experience would you like to see increase of the number of buildings with seismic protection systems in Armenia?
    Yes ☐ No ☐ Find difficulty in responding ☐

Floor ______ apartment # ______

Age ______ Sex: Male ☐ Female ☐

Education: Secondary ☐ Technical college ☐ Incomplete higher ☐ Higher ☐

Thus, in the course of the last seven years, the buildings studied were struck by some 10 earthquakes of different intensities in the range of III–V by EMS-98. No serious damage was evident in bearing structures and isolators. Therefore, the behavior of buildings was assessed based on the tenant survey. The results obtained demonstrate that the seismic isolation and seismic protection systems implemented behaved during the earthquakes in the manner envisaged at the design stage.

The results of the study represent a strong argument for the further use of seismic isolation, not only for apartment buildings but also for critical facilities. In an article published in the newspaper "AZG Armenian Daily #219," November, 29 2001, Professor Nazaretyan, who conducted an independent study of the building, wrote that, "During the 1999 Spitak earthquake with an intensity of 5–6, the tenants of the Shahumyan Street building in Spitak and the Yerevanyan #149 building in Vanadzor did not feel the earthquake, while people from neighboring buildings ran outside."

Lessons Drawn from Retrofitting Existing Buildings and from Constructing New Buildings Using Seismic Isolation and Protection Systems

1. Retrofitting existing buildings with seismic (base) isolation or constructing new seismic (base) isolated buildings can be realized in a relatively short time. Building Yerevanyan #149 in Vanadzor was retrofitted in one year and the Shahumyan building in Spitak was constructed in just over one year. For comparison, it should be noted that strengthening a building similar to Yerevanyan #149 by conventional methods takes more than two years.

2. Retrofitting existing buildings using new technologies (seismic isolation or AIUF) does not require interruption of the use of the buildings. While performing the retrofitting, tenants can stay in their apartments. On the contrary, strengthening by conventional methods requires evacuation.

3. The cost of retrofitting with new technologies is significantly cheaper (two-thirds less) than the cost of conventional strengthening. It is even cheaper when funds for temporary housing are factored in.

4. The cost of construction of new buildings using seismic isolation technologies is around 30 percent less than the cost of construction of conventional buildings.

5. Seismic (base) isolation provides high reliability for all structures and the buildings with seismic isolation are virtually safe from earthquakes. AIUF in comparison with base isolation provides less reliability, but earthquake resistance is still increased 1.6–1.8 times.

6. People feel very safe in the buildings protected by seismic (base) isolation or by AIUF. In their opinion, the new technologies must be used extensively and not only for apartment buildings but also for schools, hospitals, and other critical facilities.

7. During earthquakes of different intensities, buildings protected by seismic isolation or AIUF exhibit the behavior envisaged at the design stage. This is an objective reality showing that seismic isolation technologies will provide high efficacy in retrofitting existing or constructing new critical facilities.

8. Maintaining buildings with the application of seismic isolation technologies, as for any other type of building, is an important factor. Unsatisfactory maintenance decreases the effectiveness of seismic protection.

Justification for the Possibility of Practical Application and Effectiveness of New Technologies to Critical Facilities

After completion of the World Bank–financed Earthquake Zone Reconstruction Project and successful implementation of new technologies in 1995–1997, the application of seismic isolation continued in Armenia. Moreover, technologies developed in Armenia were also implemented in Russia and Syria. Armenian factories, namely "Nairit" and "Yerevan Factory of Rubber Technical Articles" (YFRTA), are now able to manufacture seismic isolators and bridge rubber bearings at a high quality and to international standards. The life expectancy of the bearings is guaranteed by the factories for 45 years. After the guarantee period, the bearings should be inspected. If the elastic properties (hardness) of the rubber are unchanged, they can continue to be used. Bearings should also be inspected following strong earthquakes.

From 1998–2001, 14 seismic-isolated buildings were designed in Armenia. Included were 12 apartment buildings for the new Huntsman Village in Gyumri city, one house for a single family in Proshyan, and one school in Vanadzor, which will be retrofitted using seismic isolation. The school project in Vanadzor is actually the first application of new, advanced seismic isolation technology to a critical facility. Building construction in Huntsman Village was financed by American John Huntsman. The construction of the single-family house was financed by the owner, an Armenian citizen. This is the first application of base isolation in private construction in Armenia. The retrofitting of the school in Vanadzor was financed by Swiss CARITAS.

An important factor for the application of such technologies in Armenia is the presence of Armenia's chemical industry, which is able to locally manufacture high-quality isolators. Another factor is the presence of scientific and engineering sources capable of designing, investigating, testing, and improving the systems using new technologies. It is appropriate to note that retrofitting technologies were developed, designed, and implemented for the first time in Armenia. This fact is recognized by the international scientific and engineering community. Although the buildings studied were struck by medium-strength earthquakes, the experience showed that seismic isolation technology is extremely reliable. For example during the destructive 1995 earthquake in Kobe, Japan, the two seismic-isolated buildings were not affected at all, while a very large number of conventionally designed buildings collapsed.

AIUF as a seismic protection method is very efficient for tall, flexible structures where base isolation is inappropriate. Although AIUF increases the seismic resistance of flexible buildings less than base isolation increases the seismic resistance of rigid buildings, the application of AIUF provides resiliency to buildings during future earthquakes. AIUF is the only method currently developed in Armenia that allows increasing seismic resistance of existing occupied flexible buildings.

With such capabilities, the retrofitting or construction of ordinary (apartment) buildings and critical facilities using seismic isolation costs much less than conventionally designed buildings. For example, a comparative analysis was carried out for the Huntsman Village Project. Some average results of that analysis are given in table 20.2 for a four-story building. Two situations are considered: one building is designed with an ordinary type of foundation (conventional design), and the other is seismic-isolated.

The cost of the bearing structure of this building (defined through a tender) is around $270,000. Based on this amount, it can be concluded that, with seismic isolation, costs can be reduced by 30 percent. Almost the same results were obtained for the school project in Vanadzor. In this case, seismic isolation reduced building materials by 15 tons of steel and 250 cubic meters of concrete. Generally, the Armenian experience has shown that savings due to seismic isolation for retrofitting of existing buildings could be much higher, some 2 to 2.5 times, in comparison with conventional strengthening. Also, seismic isolation allows acceleration of the whole construction process. These factors encouraged Swiss CARITAS, donors for the school project, to undertake seismic isolation for this critical facility. Presently the Huntsman Village, as well as a school in Vanadzor, are under construction.

Thus, the successful implementation of new technologies during the last eight years; the presence of capable industry that can locally manufacture seismic isolators; the presence of capable scientific and engineering sources locally developing and designing seismic isolation systems; the possibility of retrofitting by seismic isolation without interruption of facilities use; the low cost of retrofitting and new construction using seismic isolation; the possibility of accelerating the whole construction process; and high reliability of seismic isolation fully justify further practical application and effectiveness of

Table 20.2 Results of comparative analysis of seismic-(base)-isolated and fixed-base (conventionally designed) buildings

Name of parameter	*Fixed-base building*	*Seismic-isolated building*
Total shear force (kN)	40800	10200
Required reinforcement (ton)	360	104
Required reinforcement per 1 m^2 of the area of the building (kg)	110	32
Distance between the reinforcing bars in the walls (cm)	20 × 20	40 × 40
Grade of the concrete	B20 (M250)	B10 (M150)
Required cement (ton)	810	428
Required cement per 1 m^2 of the area of the building (kg)	250	132
Cost of reinforcement	$144,000	$41,600
Cost of cement	$32,210	$17,550
Cost of seismic isolators	—	$24,700
Total cost of bearing structure	$270,000	$177,640
Cost of bearing structure per 1 m^2 of the area of the building	$83	$55

Seismic isolation will cost in U.S. dollars: ($144,000 + $32,210) – ($41,600 + $17,550 + $24,700) = $92,360 the advanced seismic isolation technologies to critical facilities.

Recommendations Influencing Decisionmakers for Construction Policies for Further Implementation of New Technologies

1. It is recommended that International Financial Institutions (IFIs) implement the new advanced technologies in relevant projects in Armenia and other countries. Such technologies were born within the framework of the World Bank Earthquake Zone Reconstruction Project in Armenia, and it would be desirable to encourage the use of these technologies, especially for critical facilities.

2. It is recommended that IFIs encourage the Government of Armenia and others involved in construction financing to continue the application of new advanced technologies, not only for apartment buildings but for critical facilities as well. A booklet briefly describing all of the advantages of these technologies could be prepared and distributed among the interested parties.

3. IFIs should be consistent in insisting that construction funded includes reliable earthquake-resistant technologies. Special attention should be paid to construction companies, since many are reluctant to use new technologies and are not interested in obtaining smaller contracts.

4. A series of lectures should be organized to train those in construction companies, the Ministry of Urban Development, design institutes, and donor organizations about the new technologies.

5. A Center of Anti-Seismic Technologies should be established, possibly at the American University of Armenia. Such a center could train people working in the construction industry to deal with the development of new designs and further improve new technologies and their application to critical facilities.

6. Guidelines for seismic isolation and the protection of buildings and structures should be developed and published to promote further implementation of new technologies in the country (and in the region).

7. The experience of Armenia with retrofitting and seismic isolation should be shared with authorities in other countries with similar earthquake risk.

8. Local authorities and tenants of buildings where new technologies were implemented should be well trained in building maintenance to ensure that the technologies perform well during earthquakes. The Government of Armenia and donors should provide funds for jacketing isolators and repairing nonstructural elements in some buildings.

9. The 8th World Seminar on Seismic Isolation, Passive Energy Dissipation and Active Vibration Control of Structures will take place in October 2003 in Yerevan. This decision was made in recognition of the work undertaken in Armenia in the field of seismic isolation. The participation of decisionmakers in construction policy from Armenia and other countries should be encouraged in that high-level forum.

Note

1. See World Bank ICR No. 17255, Armenia Earthquake Zone Reconstruction Project, December 1997.

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