Integrated Disaster Risk Management

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Economic Consequence Analysis of Disasters

The E-CAT Software Tool

Springer

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About the Series

Just the first one and one-half decades of this new century have witnessed a series of large-scale, unprecedented disasters in different regions of the globe, both natural and human-triggered, some conventional and others quite new. Unfortunately, this adds to the evidence of the urgent need to address such crises as time passes. It is now commonly accepted that disaster risk reduction (DRR) requires tackling the various factors that influence a society's vulnerability to disasters in an integrated and comprehensive way, and with due attention to the limited resources at our disposal. Thus, integrated disaster risk management (IDRiM) is essential. Success will require integration of disciplines, stakeholders, different levels of government, and of global, regional, national, local, and individual efforts. In any particular disaster-prone area, integration is also crucial in the long-enduring processes of managing risks and critical events before, during, and after disasters.

Although the need for integrated disaster risk management is widely recognized, there are still considerable gaps between theory and practice. Civil protection authorities; government agencies in charge of delineating economic, social, urban, or environmental policies; city planning, water and waste-disposal departments; health departments, and others often work independently and without consideration of the hazards in their own and adjacent territories or the risk to which they may be unintentionally subjecting their citizens. Typically, disaster and development tend to be in mutual conflict but should, and could, be creatively governed to harmonize both, thanks to technological innovation as well as the design of new institutions.

Thus, many questions on how to implement integrated disaster risk management in different contexts, across different hazards, and interrelated issues remain. Furthermore, the need to document and learn from successfully applied risk reduction initiatives, including the methodologies or processes used, the resources, the context, and other aspects are imperative to avoid duplication and the repetition of mistakes.

With a view to addressing the above concerns and issues, the International Society of Integrated Disaster Risk Management (IDRiM) was established in October 2009.

The main aim of the IDRiM Book Series is to promote knowledge transfer and dissemination of information on all aspects of IDRiM. This series will provide comprehensive coverage of topics and themes including dissemination of successful models for implementation of IDRiM and comparative case studies, innovative countermeasures for disaster risk reduction, and interdisciplinary research and education in real-world contexts in various geographic, climatic, political, cultural, and social systems.

More information about this series at http://www.springer.com/series/13465

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To our families

Foreword to the IDRiM Book Series

In 2001, the International Institute for Applied Systems Analysis (IIASA) and the Disaster Prevention Research Institute (DPRI) joined hands in fostering a new, interdisciplinary area of integrated disaster risk management. That year, IIASA and DPRI initiated the IIASA–DPRI Integrated Disaster Risk Management Forum Series, which continued over 8 years, helping to build a scholarly network that eventually evolved into the formation of the International Society for Integrated Disaster Risk Management (IDRiM Society) in 2009. The launching of the society was promoted by many national and international organizations.

The volumes in the IDRiM Book Series are the continuation of a proud tradition of interdisciplinary research on integrated risk management that emanates from many scholars and practitioners around the world. In this foreword, we briefly summarize the contributions of some of the pioneers in this field. We have endeavored to be inclusive but realize that we have probably not identified all those worthy of mention. This foreword is not meant to be comprehensive but rather indicative of major contributions to the foundations of IDRiM. This research area is still in a continuous process of exploration and advancement, several of the outcomes of which will be published in this series.

Japan

Disaster Prevention Research Institute

The idea of framing disaster prevention in risk management terms was still embryonic even among academics in Japan when Kobe and its neighboring region were shaken by the Great Hanshin–Awaji Earthquake (GHQ) in 1995. For example, Okada (1985) established the importance of introducing a risk management approach to reduce flood and landslide disaster risks. Additionally, it was not until late 1994 that the Disaster Prevention Research Institute (DPRI) of Kyoto University

Table 1 Conventional disaster plan vs. 21st century integrated disaster planning and management

Reactive	Proactive
Emergency and crisis management	Risk mitigation plus preparedness approach
Countermeasure manual approach	Anticipatory/precautionary approach
Pre-determined planning (if known events)	Comprehensive policy-bundle approach
Sectoral countermeasure approach	Adaptive management approach
Top-down approach	Bottom-up approach

had reorganized to add a new cross-disciplinary division of Sogo Bosai, or "integrated disaster management."

The new division of DPRI undertook a strong initiative among both academics and disaster prevention professionals to substantiate what is meant by integrated disaster management and to communicate to society why it is needed and how it helps. Many of these efforts were based on evidence and lessons learned from the GHQ. Japan's disaster planning and management policy changed significantly thereafter. Table 1 contrasts the approaches before and after that cataclysmic event. The current approach stresses strategies that are proactive, anticipatory, precautionary, adaptive, participatory, and bottom-up. The rationale is that governments in Japan had been found to be of relatively little help immediately after a high-impact disaster. Lives in peril had more often been saved by the actions of individuals and community residents than by official governmental first responders.

To understand a significant change in disaster planning and management in Japan, one must understand the contrasts among Kyojo ("neighborhood or community self-reliance"), Jijo ("individual or household self-reliance"), and Kojo ("government assistance"). Realizing limitations in the government's capacity after a large-scale disaster, Japan has shifted more toward increasing both Kyojo and Jijo self-reliance roles, and to depend less on the former, which in the past was the major agent to mitigate disasters.

One of the additional lessons learned after the 1995 disaster was to address the need for a citizen-led participatory approach to disaster risk reduction before disasters, as well as for disaster recovery and revitalization after disasters.

International Collaboration

In 2001, the International Institute for Applied Systems Analysis (IIASA) and DPRI started to join hands in fostering a new disciplinary area of integrated disaster risk management. That year, IIASA and DPRI agreed to initiate the IIASA–DPRI Integrated Disaster Risk Management Forum Series. Eight annual forums were held under this initiative, helping to build a scholarly network that eventually evolved into the formation of the IDRiM Society in 2009.

These activities, which were designed to be cross-disciplinary and international, have seen synergistic developments. Japan's accumulated knowledge, led by DPRI, became merged with IIASA's extensive expertise and became connected with inputs from the USA, the UK, other parts of Europe, Asia, and other countries and regions.

Major Research Contributions

Among many, the following contributions merit mention:

Conceptual Models Developed and Shared for Integrated Disaster Risk Management Okada (2012) proposed systematic conceptual models for understanding the Machizukuri (citizen-led community management) approach. Figure 1 illustrates the multilayer common spaces (an extension of the concept of infrastructure) for a city, region, or neighborhood community as a living body (Okada 2004). This conceptual model has been found to be useful to address multilayer issues of integrated disaster risk management at various scales. For example, in the context of this diagram, Machizukuri is more appropriately applied on a neighborhood community scale rather than on a wider scale, such as a city or region. Applied to a neighborhood community in the context of a five-storied pagoda model, it starts with the fifth layer (daily life), followed by the fourth (land use and built environment) and the third (infrastructure). By comparison, Toshikeikaku (urban planning) focuses mainly on the fourth and third layers. Another point of contrast is that Machizukuri requires citizen involvement to induce attitudinal or behavioral change, while this issue is not essential for Toshikeikaku.

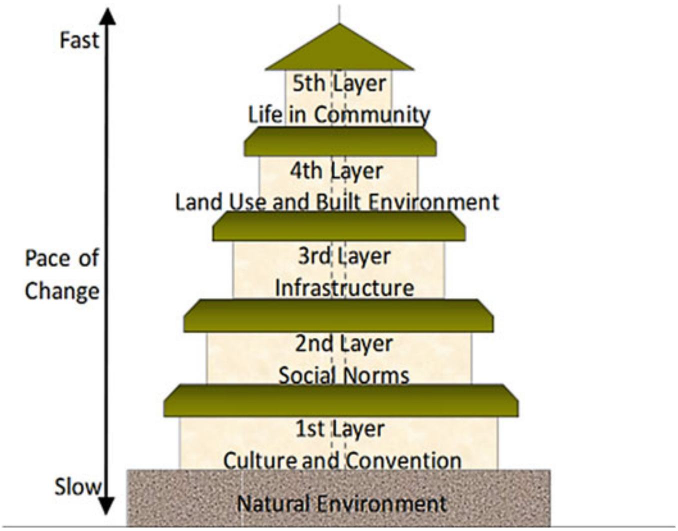

Fig. 1 Five-storied pagoda model (Source: Okada 2006)

Economic Modeling of Disaster Damage/Loss and Economic Resiliency Extensive research has been carried out by Tatano et al. (2004, 2007) and Tatano and Tsuchiya (2008) to model and analyze economic impacts of disruptions to lifelines and infrastructure systems caused by a large-scale disaster. For instance, simulating a hypothetical Tokai–Tonankai earthquake in Japan, a spatial computable general equilibrium (SCGE) model was constructed to integrate a transportation model that can estimate two types of interregional flows of freight movement and passenger trips. Kajitani and Tatano (2009) investigated a method for estimating the production capacity loss rate (PCLR) of industrial sectors damaged by a disaster to include resilience among manufacturing sectors. PCLR is fundamental information required to gain an understanding of economic losses caused by a disaster. In particular, this paper proposed a method of PCLR estimation that considered the two main causes of capacity losses as observed from past earthquake disasters, namely, damage to production facilities and disruption of lifeline systems. To achieve the quantitative estimation of PCLR, functional fragility curves for the relationship between production capacity, earthquake ground motion, and lifeline resilience factors for adjusting the impact of lifeline disruptions were adopted, while historical recovery curves were applied to damaged facilities.

Disaster Reduction-Oriented Community Workshop Methods The Cross-Road game developed by Yamori et al. (2007) proceeds as follows. During a game session, a group of five players read 10–20 episodes that are presented on cards one at a time. Each episode is derived from extensive focus group interviews of disaster veterans of the GHQ and describes a severe dilemma that the veterans of Kobe actually faced. Individual players are required to make an either/or decision (i.e., yes or no) between two conflicting alternatives in order to deal with the dilemma.

The Yonmenkaigi System Method (YSM) by Okada et al. (2013a, b) is a unique participatory decision- and action-taking workshop method. It is composed of four main steps: conducting a strength–weakness–opportunity–threat (SWOT) analysis, completing the Yonmenkaigi chart, debating, and presenting the group's action plan. The YSM is an implementation- and collaboration-oriented approach that incorporates the synergistic process of mutual learning, decision-making, and capacity building. It fosters small and modest breakthroughs and/or innovative strategy development. The YSM addresses issues of resource management and mobilization, as well as effective involvement and commitment by participants, and provides a strategic communication platform for participants.

Collaborative Research and Education Schemes Based on the Case Station-Field Campus (CASiFiCA) Scheme Acknowledging that diverse efforts have been made for disaster reduction, particularly in disaster-prone areas (countries), many professionals have been energetically and devotedly engaged in field work to reduce disaster risks. They recognize also that more community-based stakeholder-involved approaches are needed. A crucial question arises as to why we cannot

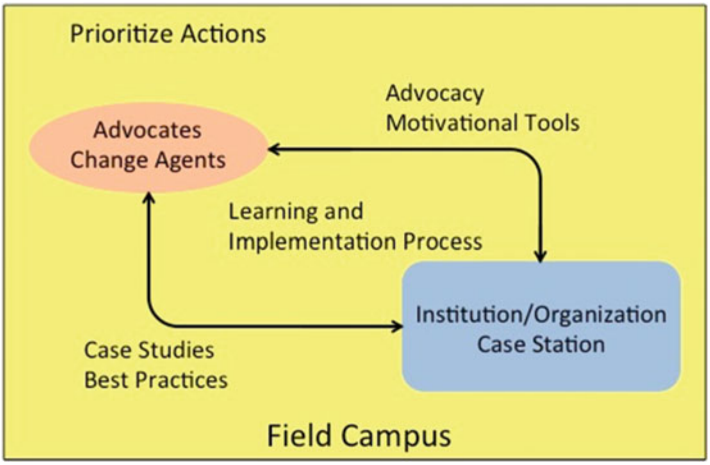

Fig. 2 Case Station-Field Campus scheme

conduct field work more creatively. One promising solution might be the CASiFiCA scheme originally proposed by Okada and Tatano (2008). As diagrammed in Fig. 2, the CASiFiCA scheme is characterized by a set of local case stations and field campuses and their globally networked linkages that are expected to operate synergistically to achieve the following objectives: promotion of IDRiM education at all levels, multilateral knowledge sharing and knowledge creation, and implementation of knowledge and gaining knowledge from implementation.

Europe

Integration via Regulation: European Union Experience

The integrated risk management of technological and natural hazard-triggered technological accidents (known as Natechs) has been a major theme addressed during the IIASA–DPRI Integrated Disaster Risk Management Forum Series since the first forum in 2001. In 2007 and 2008, the forum was hosted by the Major Accident Hazards Bureau at the Joint Research Centre of the European Commission in Italy, further strengthening the need for integration across natural and technological disaster risk management.

Integration was not (and, generally, still now *is not*) a self-evident concept when the first European Union Conference on Natural Risk and Civil Protection was launched in 1993, in Belgirate, Italy (Horlick-Jones et al. 1995). As the rapporteur-general wondered:

> Whilst one objective of the conference was to encourage dialogue between researchers and practitioners, it quickly became clear that the group structure was rather more complex than simply comprising natural scientists and civil protection experts. The 'tribes' present included natural hazard scientists, civil protection theorists – mostly social, behavioural and management scientists, industrial risk specialists, protection administrators and civil protection practitioners. The hazards and civil protection 'community' included a number of professional groups with distinct traditions and cultures. The term 'tribe' is used in an attempt to capture some sense of how strong is this divide.

Communication between the groups was rather difficult and most surprising for people not directly involved in scientific disputes. The discovery of the strong opposing views existing between different research directions within the same "hard" discipline (e.g., in seismology the debate on earthquake predictability) made even the agreement on an agenda for the conference challenging. These difficulties were unanticipated, because previous events concerning industrial hazards—organized in a similar manner on emergency planning (Gow and Kay 1988) and risk communication (Gow and Otway 1990)—found a rather cooperative atmosphere.

Despite the fact that the organization of the conference involved three directorate-generals of the European Commission (Research and Education, Environment, and Joint Research Center), natural hazards activities were not covered by an institutional legal basis. Also, at the time, there was no mutual assistance/compensation agreement in the case of a natural disaster, but only an initial exchange of experiences among emergency response services of EU member states. On the other hand, the existence of a sound regulatory process that obliged the different actors to be involved in the risk management framework was the reason for the successful cooperation in the latter mentioned events.

The new regulatory process for chemical accident prevention is an example. The process was reactive rather than anticipatory. It was triggered by a number of major accidents—e.g., the dioxin release at Seveso (Italy) in 1976 and the explosion at Flixborough (UK) in 1974. These had in common the features that local authorities did not know what chemicals were involved and in what quantities. They did not know enough about the processes to understand what chemicals/energy could be produced or released under accident conditions, and there was a general lack of planning for emergencies. Given this background, the first 1982 Seveso I Directive (82/501/EEC) was largely concerned with the generation and the control of an adequate and sufficient information flow among the different actors in the risk management process (Otway and Amendola 1989). This covered industrial activities that handle hazardous materials and introduced an integrated risk management scheme with identification of the actors and their obligations (control/licensing authorities—operators) or rights to know (the public). It requires that potential major accidents involving hazardous materials be identified, adequate safety measure be taken to prevent them, and on-site emergency plans be implemented. The competent authorities (CAs) have to control the adequacy of such measures and provide for external emergency plans. The public should be "actively" informed of the safety measures and how to behave in the event of an accident. The operator is required to report any major accident to the CAs, and the CAs have to notify the European Commission, which keeps a register of accidents so that member states can benefit from this experience for the purposes of prevention of future accidents.

The Seveso I Directive was the background for further discussions at the international level, such as the Organisation for Economic Co-operation and Development (OECD) and the United Nations Economic Commission for Europe (UNECE), which resulted in further recommendations and conventions on trans-boundary effects related to major accidents (United Nations 1992).

Reacting to the tragedy in Bhopal, India and other issues identified during its implementation, the need for a revision was identified, particularly concerning the lack of provisions for land-use planning (De Marchi and Ravetz 1999), resulting in the Seveso II Directive (96/82/EC). It completed the transparency process, beginning with the obligation of disseminating information to the public on how to behave in case of an accident, and, in a relatively short time, changed the "secrecy" in most countries surrounded by chemical risks into unprecedented transparency (for the "evolutionary construction of a regulatory system" for an extensive discussion of all Seveso II requirements, see Amendola and Cassidy 1999). It established that the public should be consulted for land-use planning and emergency planning with respect to accident risks and therefore should be more directly involved in risk management decisions. Furthermore, the safety report and accident reporting systems became accessible by the public.

The Seveso II Directive focused much more on the socio-organizational aspects of the control policy:

- The concept of an industrial *establishment* was introduced, characterized by the presence of dangerous substances. The focus is on the interrelations among installations within such an establishment, especially those related to organization and management. Further, attention is given to situations liable to provoke so-called *domino effects* between neighboring establishments. This led to integrated assessments of industrial areas. Furthermore, it implicitly called for the analysis of external threats, such as natural hazards.
- The socio-organizational aspects of an establishment were strongly affected by the introduction of the obligation for a major accident prevention policy (MAPP), to be implemented by means of safety management systems (SMS) (Mitchison and Porter 1999). These provisions were introduced after the awareness that most of the major accidents of which the commission was notified over the years under the major accident reporting system (MARS) had root causes in faults of the management process (Drogaris 1993).
- The introduction of the obligation for a *land-use planning policy* with respect to major accident hazards has had important socio-organizational consequences, as a broader body of authorities, especially those dealing with local urban planning, are becoming involved in decisions about the compatibility of new development with respect to existing land use (Christou et al. 1999). This has been integrated with the requirement that the public shall be consulted in the decision-making process. This has also led to integration of planning policies with respect to other kinds of hazards, such as natural ones, assuring that appropriate distances are

kept between establishments, residential areas, and areas of particular "natural sensitivity."

- The provisions for *emergency planning* and *public information* have been reinforced, as the *safety report* becomes a public document, and the public must be consulted in the preparation of emergency plans.

The Seveso II Directive also approached management as a continuous process, because it did not limit the regulatory action to providing a license or a permit to operate. Instead it assigned the obligation to the operator to adopt management systems as a continuous process for feedback in the procedures relating to operating experience and managing the changes over time. Also, land-use planning addresses not only "siting" a new establishment but also considers the compatibility of major changes with the existing environment as well as the control of urbanization around an establishment. Furthermore, it promoted common efforts among authorities, operators, and risk analysts to improve the risk assessment procedures and achieve better risk governance processes (Amendola 2001).

As mentioned above, the Seveso II Directive called for the analysis of external hazards as part of the hazard assessment process. Both domino effects and land-use controls are of particular importance when addressing the risk reduction of chemical accidents triggered by external natural hazard events (Natechs). In fact domino effects may be more likely during natural disasters than during normal plant operation (Cruz et al. 2006; Lindell and Perry 1997). Their likelihood will depend on the proximity of vulnerable units containing hazardous substances, and the consequences will undoubtedly increase with the proximity of residential areas. The European Commission published guidelines to help member states fulfill the requirements of the Seveso II Directive (see Papadakis and Amendola 1997; Mitchison and Porter 1998; Christou and Porter 1999). However, the guidelines do not provide specific actions or methodologies that should be taken to prevent, mitigate, or respond to Natechs (Cruz et al. 2006).

In 2012, the European Commission published the Seveso III Directive, which amended and subsequently repealed the Seveso II Directive. The major changes included in the Seveso III Directive included strengthening of a number of areas such as public access to information and standards of inspections. Furthermore, the latest amendment now explicitly addresses Natech risks and requires that environmental hazards, such as floods and earthquakes, be routinely identified and evaluated in an industrial establishment's safety report (Krausmann 2016).

International Institute for Applied Systems Analysis (IIASA)

"Risk" has been part of IIASA's activity profile since the institute's foundation. This theme is critical, as the prospect of unintended consequences from technological, environmental, and social policies continues to stir intense debates that shape the future of societies across the world. Relying on probability calculations, risk became a theoretical focus designed to bolster a scientific, mathematically based approach toward uncertainty and risk management.

Early controversies in the 1970s and 1980s on nuclear power, liquid natural gas storage, and hazardous waste disposal—all early research topics at IIASA—made clear to the expert community, however, that probabilistic calculations of risk, although essential to the debates, are not sufficient to settle issues of public acceptance. In response, IIASA has pioneered research on risk perception (Otway and Thomas 1982), objective versus subjective assessments (Kunreuther and Linnerooth 1982), systemic cultural biases (Thompson 1990), and risk and fairness (Linnerooth-Bayer 1999).

As a critical part of this history, IIASA is widely recognized for its advances in stochastic and dynamic systems optimization (e.g., Ermoliev 1988), treating endogenous uncertainty and catastrophic risks in decision-making processes (reviewed in Amendola et al. 2013) and advancing statistical methods for probabilistic assessment (e.g., Pflug and Roemisch 2007). The hallmark of IIASA's risk research is the integration of these multiple strands of mathematical and social science research.

One important in-house model taking an integrated perspective in the RISK program at IIASA is the so-called Catastrophe Simulation (CatSim) Model, which focuses on the government and its fiscal risk in the face of natural disaster events. It is a mainstay of the program's methodological and policy research and was first developed to aid public officials in developing countries to assess catastrophic risks from natural hazards and analyze options to enhance their country's financial resiliency. The model takes a "systems approach" by integrating catastrophe risk modeling with financial and economic modeling. It enables users to explore the impact of traditional and novel financial instruments, including reinsurance and catastrophe bonds, in terms of the costs of reducing the risk of a financing gap. CatSim has proven useful in other contexts as well, e.g., for allocating climate adaptation and development funds to support disaster resilience in the most vulnerable countries. Based on the model framework, assessed exposure and financial vulnerability to extreme weather events on the global scale can be performed as well (Hochrainer-Stigler et al. 2014).

Beyond modeling, IIASA has pioneered the exploration of novel financing instruments to provide safety nets to vulnerable communities and governments facing climate risks (Linnerooth-Bayer and Amendola 2000). These instruments now feature prominently on the agendas of development organizations and NGOs, and they are also gaining attention in the climate change adaptation community (Linnerooth-Bayer and Hochrainer-Stigler 2015). In an early influential policy paper, IIASA scientists argued that donor-supported risk-transfer programs, some based on novel instruments, would leverage limited disaster-aid budgets and free recipient countries from depending on the vagaries of post-disaster assistance (Linnerooth-Bayer et al. 2005).

As a final mention, IIASA's contributions to integrated disaster risk management have included the design and implementation of new forms of bottom-up governance, most notably stakeholder processes which co-design policy options with experts and explicitly recognize large value differences.

The USA

Multidisciplinary Center for Earthquake Engineering Research

The National Center for Earthquake Engineering Research (NCEER) was established at the State University of New York at Buffalo in 1986, with funding from the US National Science Foundation (NSF), the state of New York, and industrial partners. NCEER's original vision focused on multidisciplinary research and education aimed at reducing earthquake losses. Although the Center's main priority was to support research in structural, civil, and geotechnical engineering, it also provided funding for research in the fields of economics, urban planning, regional science, and sociology. Despite NCEER's ambitious vision, much of the research conducted during the 10-year period of initial grant support remained discipline-specific, although with the passage of time there was greater integration across disciplines, particularly in areas such as earthquake loss estimation, which required collaborative approaches.

When NCEER leaders decided to enter a new competition for NSF funding in the mid-1990s, there was general agreement that investigators should step up their multidisciplinary collaborative efforts based on an understanding that earthquake risk reduction and risk management require contributions from a range of areas of expertise beyond traditional engineering fields. This was made explicit when the leadership decided to change the Center's name to the Multidisciplinary Center for Earthquake Engineering Research (MCEER). Participation in multidisciplinary teams was strongly encouraged as MCEER investigators increasingly tackled problems that were beyond the scope of individual disciplines. Experts in remote sensing and in structural engineering worked together on the development of building inventories and, later on, rapid post-earthquake damage assessment methods using remotely sensed data. Engineers, economists, and sociologists worked on improving earthquake loss estimation methods, focusing, for example, on estimating potential damage to urban lifeline systems as well as resulting direct and indirect economic losses. Collaborating teams developed earthquake recovery models and explored the economic, political, and institutional obstacles that stand in the way of adopting and implementing risk reduction policy. Researchers studied hospitals both as critical physical systems and as organizations. A multidisciplinary group consisting of engineers, policy experts, and decision scientists developed decision-support tools designed to help facility owners make informed choices about alternative seismic risk reduction measures.

In the late 1990s, another team of researchers from various fields began a series of projects focused on the conceptualization and measurement of earthquake (and general disaster) resilience. Recognizing that resilience itself is a multidisciplinary and even a transdisciplinary concept, researchers surveyed a wide range of studies in fields ranging from ecology to psychology, identified common concepts and indicators, and developed one of the first frameworks that applied the resilience concept to natural hazards. One early product resulting from that collaboration was the article "A Framework to Quantitatively Assess and Enhance the Seismic Resilience of

Communities" (Bruneau et al. 2003). Authors of that paper represented the fields of civil, geotechnical, and structural engineering, operations research, economic geography, decision science, and sociology.

These successful collaborations were the result of several factors. Research activities were problem focused, and the researchers involved recognized that the earthquake problem is multidimensional. Methodological tools such as geographic information systems were useful in bringing about integration across disciplines. The longevity of NCEER and MCEER was also important; long-term funding made it possible for investigators to engage with one another over prolonged periods. This also meant that over time, researchers came to better understand and appreciate the approaches and methods employed by their counterparts in other disciplines. Additionally, the intent of the funding source was a significant influence; NSF made it clear that it was looking for research that was capable of overcoming disciplinary silos.

A major example of integrated research at MCEER was the first New Madrid (Earthquake Zone) electricity lifeline case study (Shinozuka et al. 1998), which focused on the site of the largest earthquake to strike North America in its recorded history. The study team was composed of engineers, geographic information scientists, economists, regional scientists, planners, and sociologists. They addressed the complexity of the interaction of various systems in the Memphis Tennessee Metropolitan Area. This included the vulnerability of the lifeline network, business response to physical damage and production disruption, estimation of direct and indirect losses in the region and throughout the USA, and policy analysis and implementation. At the core of the research were models of economic, social, and spatial interdependence, such as input–output analysis, multisector mathematical programming, and social accounting matrices (all precursors of the now state-of-the-art approach of computable general equilibrium analysis). This research was performed around the same time as the development of FEMA's loss estimation software tool HAZUS (FEMA 1997, 2016), which was another example of an integrated assessment model (see also Whitman et al. 1997). The capabilities included in HAZUS had to be simplified in order to be incorporated into a decision-support system that could be used by a wide spectrum of emergency managers and analysts on a desktop PC. In contrast, the MCEER research was intended to advance the state of the art in improving the scope and accuracy of hazard loss estimation. As such, it proved valuable in future extensions and upgrades of HAZUS and informed other research and public and private decision-making. One of its major points was the prioritization of electricity service restoration according to various societal objectives such as minimizing lost production and employment. As one of the study authors noted: "Not taking advantage of such opportunities results in an outcome as devastating as if the earthquake actually toppled the buildings in which the lost production would've originated" (p. xvii).

MCEER was directed by Masanobu Shinozuka, George Lee and Michel Bruneau. Researchers who contributed to the integration of various disciplines under its umbrella, in addition to the directors, included Barclay Jones, Kathleen Tierney, Tom O'Rourke, Bill Petak, Charles Scawthorn, Detlof von Winterfeldt, Stephanie Chang, Ron Eguchi, and Adam Rose. Two sister centers of MCEER were established with NSF Funding in the mid-1990s: the Pacific Earthquake Engineering Center (PEER), headquartered at the University of California, Berkeley, with a focus on performance-based engineering; and the Mid-American Earthquake Center (MAE), headquartered at the University of Illinois, Urbana, with a focus on a multi-hazard approach to engineering.

Natural Hazards Center

The Natural Hazards Research and Applications Information Center at the University of Colorado Boulder—now called the Natural Hazards Center (NHC)—was founded in 1976 by Gilbert F. White, a geographer, and J. Eugene Haas, a sociologist. Center activities were built upon the foundation that White and his collaborators from many disciplines had already established, as outlined in the books *Natural Hazards: Local, National, and Global* (White 1976) and *Assessment of Research on Natural Hazards* (White and Haas 1975). In the *Assessment*, White and Haas argued that efforts to prevent and reduce disaster losses relied far too much on technological approaches, without taking into account research in the social sciences. Their position was that such research could offer important insights into societal responses to hazards and disasters while also shedding light on whether technological approaches aimed at reducing losses were likely to produce their intended outcomes. Early research assessments focused on "adjustments" to hazards that communities and societies can adopt either singly or in combination: relief and rehabilitation, insurance, warning systems, technological adjustments such as protective works, and land-use management. In the view of the founders, a key task for researchers was to better understand the conditions under which particular adjustments would be adopted and their subsequent impact on disaster losses. Early in its history, the NHC produced its own series of books, monographs, and special reports, many of which focused on findings from US National Science Foundation-sponsored research carried out by investigators in the social, economic, and policy sciences. That practice was discontinued as specialized journals began to proliferate and an increasing number of academic and commercial publishers began to show an interest in publishing research monographs and textbooks in the disaster field.

From its inception, the NHC has had a dual mission. First, it serves as a clearinghouse and information provider for social science research on hazard mitigation, preparedness, response, and recovery, again with an emphasis on alternative adjustments to hazards. The idea of an information clearinghouse arose out of recognition of the difficulties associated with getting research applied in real-world settings. Clearinghouse activities include the production and distribution of the NHC newsletter, the *Natural Hazards Observer,* library and information services, and the annual NHC workshop, which has grown over the years. From the beginning, the annual workshop was designed to bridge communication gaps among researchers and graduate students from a variety of physical, social science, and engineering disciplines, government decision-makers, and emergency management practitio-