STRUCTURE AND PROCESS IN THE STUDY OF DISASTER RESILIENCE

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ABSTRACT :

While the concept of disaster resilience has become increasingly prominent in disaster loss-reduction research and practice, the concept remains undertheorized. This paper, which employs insights from a variety of social science fields, expands upon the 4-R/TOSE framework developed by investigators from the Multidisciplinary Center for Earthquake Engineering Research, focusing on structural factors and on processes, activities and practices that promote resilience. Diversity, decentralization, network forms of organization, and social capital constitute structural contributors to resilience. Reduction of production pressures, collective sensemaking and distributed cognition, and improvisation, are processes-related factors that enhance resilience.

KEYWORDS:

disaster resilience, resilience measures, disaster response, disaster recovery

1. INTRODUCTION

While almost never used in the study of disasters ten or even five years ago, the concept of resilience is now very widely discussed and studied. Enhancing resilience is considered the key to preparing for, responding to, and recovering from disasters. Researchers seek to define and measure resilience, many books and articles have been written on the topic, and new government programs center on strategies for resilience development. Synthesizing material from a range of sources, this paper presents a multidisciplinary perspective on the concept of resilience, with a special emphasis on contributions from basic and applied social science research. The overarching framework guiding this discussion was developed by a collaborative group that was funded by the Multidisciplinary Center for Earthquake Engineering Research (MCEER), a U. S. National Science Foundation-funded research consortium headed by the State University of New York at Buffalo, USA (Bruneau et al. 2003; Rose 2004; 2006; Tierney 2006; Tierney and Bruneau 2007). Insights from the fields of sociology, community psychology, organizational behavior, and social network analysis expand this framework, shedding light on social structural and process-related antecedents of resilience. No effort is made to develop a general theory of resilience. Instead, the paper shows how different research traditions serve both heuristic and explanatory functions in the study of resilience..

2. RESILIENCE AS A CONCEPT AND GOAL

2.1. *The Emergence of the Concept*

The concept of disaster resilience has gained great currency in the U. S. in only a few short years. While used previously in other disciplines until recently the term resilience seldom appeared in disaster-related publications. The term was not employed during the International Decade for Natural Disaster Reduction in the 1990s, nor did it appear in significant policy documents such as the 1994 *Yokohama Strategy for a Safer World*. The concept is mentioned in the influential U. S. volume *Disasters by Design* (Mileti 1999), but the author places far more emphasis on the concept of sustainability and its connection to disaster loss reduction.

In the U. S., disaster resilience appears to have emerged as a research and policy priority in the aftermath of the terrorist attacks of September 11, 2001. Since that time, numerous publications have focused on the concept

(Pelling, 2003; Vale and Campanella 2005; Chernick 2005; Paton and Johnson 2006; Flynn 2007). In its report on "grand challenges" for disaster reduction, the U. S. Subcommittee on Disaster Reduction (2005) emphasized the need for developing methods for assessing and enhancing community resilience. Interest in the concept expanded further following Hurricane Katrina. Community resilience is also set out as a major goal in policy documents such as Homeland Security Presidential Directive 21, which seeks to enhance medical and public health preparedness. Following the Hyogo World Conference on Disaster Reduction in January, 2005, the *Hyogo Framework for Action* (United Nations 2005) highlighted community resilience as a major goal for disaster loss reduction efforts.

2.2. *Defining Resilience and Specifying Its Dimensions*

Resilience has been defined in a variety of ways in a broad range of disciplines. Norris et al. (2007) list 21 different definitions, which have been applied at the level of the individual, community, and social, ecological, and physical systems. In a recent formulation, Cutter et al (forthcoming) state that

> [r]esilience is the ability of a social system to respond and recover from disasters and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-event, adaptive processes that facilitate the ability of the social system to reorganize, change, and learn in response to a threat.

Research on the concept of disaster resilience began at MCEER in the late 1990s. At that time, MCEER investigators recognized that the fields of earthquake engineering and disaster loss reduction lacked a means of defining and measuring the concept. Seismic resilience was initially defined by the MCEER research team as "the ability of social units (e.g., organizations, communities) to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways that minimize social disruption and mitigate the effects of future earthquakes" (Bruneau et al 2003: 735).The MCEER resilience framework (now known as the "4-R" approach) characterized resilience as encompassing four attributes—robustness, redundancy, resourcefulness, and rapidity—each of which can be applied to different units of analysis (engineered systems, organizations, communities). *Robustness* refers to the ability to resist disruption and failure and continue functioning effectively in the face of environmental shocks. The lack of robustness of the levee system was one reason for the high mortality rate in the 2005 Hurricane Katrina disaster in the U. S. *Redundancy* refers to the extent to which other alternative systems can continue to provide functionality and services when primary systems fail or are disrupted. In the 1989 Loma Prieta earthquake in the U. S., water main damage made it impossible to use water to fight fires in San Francisco, and the backup water system for firefighting also failed. However, an additional portable back up system made did enable responders to fight fires. *Resourcefulness* refers to the ability to mobilize resources in a timely manner to address disaster-related problems. As used here, resources may be material, financial, informational, or human. *Rapidity*, or timely resolution of disaster-related challenges, is the end product of the other three attributes of resilience (for more discussions on the MCEER perspective, see Bruneau et al. 2003; Tierney and Bruneau, 2007).

Further elaboration of the 4-R framework involved the specification of domains to which the concept applies. Four domains were identified: technical, organizational, social, and economic (later labeled the TOSE framework). This elaboration made explicit MCEER's implicit assumption that the 4-R framework has applicability not only to engineered (technical) systems, but also to organizational and societal domains. Also made explicit is that each TOSE domain represents an independent set of units of analysis for resilience characterization and measurement. Indeed-resilience can sometimes vary dramatically across domains. For example, in the World Trade Center disaster in New York City in 2001, the building housing the city's emergency operations center failed catastrophically on the day of the terrorist attacks, and no back up facility existed. This was a clear example of a lack of technical (physical) robustness and redundancy. However, the Office of Emergency Management—that is, the organization charged with managing the disaster response—was able to perform in a resilient fashion despite losing its facility, owing primarily to its ability to remain coherent as an organization (robustness) and to its resourcefulness.

2.3. *Additional Insights*

2.3.1. Inherent and Adaptive Resilience

Economist Adam Rose, a member of the MCEER team that initially developed measures of resilience, emphasized the importance of distinguishing between *inherent* and *adaptive* resilience (Rose 2004;2006) Inherent resilience, which resembles robustness in the MCEER framework, refers to characteristics of different economic units (households, businesses, communities, local economies) that serve as sources of strength when disasters occur. For households, for example, inherent resilience may be based on household income, savings, and other sources of wealth and can also encompass activities such as the development of household disaster plans. For businesses, inherent resilience may be rooted in attributes and actions such as large corporate assets, market diversification, and the development of business continuity plans and mutual aid agreements. Adaptive resilience, which is manifested when a disaster event occurs, refers to the capacity of social units to overcome crisis-related problems through effort and ingenuity. Following the MCEER framework, the elements of overall resilience most closely associated with adaptive resilience are redundancy and resourcefulness. Communities facing disasters must find substitutes for resources that are destroyed or are no longer available, identify and mobilize personnel, material, and financial resources, and exercise creativity in areas in which plans fall short.

2.3.2. Performance Standards and Resilience: Relative Resilience Expectations

The notion of resilience is inextricably tied to the notion of time. Regardless of discipline, the literature concurs that more resilient systems are those that are able to return to pre-disaster levels of functioning or to an accepted "new normal" in a timely fashion. However, like the concept of acceptable risk, acceptable disruption, or what constitutes timeliness in restoration and recovery processes, is essentially a matter of social definition. Indeed, recognition of the social dimension of resilience expectations has been a key factor in the rise of performance-based earthquake engineering. Judgments concerning what constitutes acceptable disruption (or acceptable levels of resilience) can and have been measured (see, for example, Tierney and Dahlhamer 1998 on business owners' ratings of acceptable levels of electrical power disruption). Resilience expectations also reflect social values and are often institutionalized in legislation and regulations. The willingness of California and other states to set high seismic resistance standards for hospitals, schools, and other critical facilities is indicative of consensus-based resilience expectations. Cost considerations clearly play a role in determining standards for resilience. For example, efforts to retrofit water and power systems involve taking into account the costs of system retrofits, the potential social and economic costs of water and power system disruptions, and improvements in resilience that may be achieved through retrofit measures (see Chang and Shinozuka 2004).

3. STRUCTURE AND PROCESS IN THE PRODUCTION OF RESILIENCE

Despite its widespread use and despite an explosion of interest in resilience measurement, the concept itself remains undertheorized. Recent empirical work clearly demonstrates the usefulness of the concept (see Rose and Lim 2003; Chang et al. 2008), but relatively few studies focus on how and why resilience itself develops. What accounts for observed differences in resilience across communities, societies, and disaster events? What types of societal interventions promote resilience? The sections that follow extract insights from the extensive social scientific literature on hazards, disasters, and risk with the goal of identifying factors that contribute to the development of resilience. Discussions center first on structural features of units of analysis that lead to higher levels of resilience and next on process-related variables.

3.1. Does Richer Mean Safer? A Less Nuanced View on Resilience

It is evident that some societies, communities, organizations, and engineered systems are more resilient than others but it is less clear why this is the case. One facile explanation is that wealth and investment at the societal, organizational, and household level are key factors that impart resilience (Wildavsky 1988). To the extent that it translates into wise infrastructure investments, well-designed and constructed buildings, the ability to amass disaster response resources, and the capacity to exercise multiple options when disaster strikes, wealth does make an important contribution to resilience. However, not all wealthy societies invest equally in risk management and other resilience-enhancing activities. Moreover, as perhaps best indicated by post-September 11 U. S. expenditures on homeland security measures in the aftermath of the terrorist attacks of 2001, it is often quite difficult to determine the extent to which investments actually translate into higher levels of resilience. Moreover, the mere capacity to make large investments in infrastructure means little if those making the investments place no priority on disaster resilience. Major and even catastrophic disasters do occur in wealthy societies, further undermining the "richer is safer" argument (see Clarke 1989).

3.2 More Robust Findings on Sources of Resilience: Structure and Process

Several theoretical and research traditions provide useful insights on factors that contribute to resilience as outlined in the MCEER model and other formulations. There is no one-to-one correspondence between these areas of research and specific dimensions and domains of resilience, nor would such a correspondence be expected. Rather, themes emerge from diverse literatures that when analyzed and synthesized help identify important causal contributors to resilience. The discussions that follow are organized (somewhat arbitrarily) into structural and process features of resilient systems.

3.2.1. Structural Correlates of Resilience

For purposes of this discussion, structural contributors to resilience are defined as (more or less) stable attributes of systems, components, and/or social and economic units. Examples of structures include modes of social and economic organization, connections among social actors, and relationships of sub-system elements both to one another and to the larger system. The concept of structure also encompasses attributes such as size, complexity, and other features of analytic units within the four TOSE domains..

Diversity in its many forms is a system attribute that is associated with robustness, redundancy, and resourcefulness. Ecological research demonstrates how diversity helps buffer systems from disaster impacts and also promotes recovery. Applying ecological insights to economic activities, Rose observes that (2006: 233):

> [e]cology provides lessons for the economic system, especially the concept of *diversity.* This applies to both economic structure (economies composed of several industries are more likely to withstand shocks than are monocultures) and to tools to cope with shocks (including the number of resilience responses that may be operative in a given crisis.) Diversification has long been appreciated as a major strategy to mitigate risk, but its usefulness in cases of decisions regarding economic resilience has not.

Examples abound of the ways in which diversity enhances resilience. Businesses that rely solely on local markets for their goods may find demand reduced following disasters. Again relying on insights from both ecology and disaster research, diversity rather than uniformity among emergency management, public safety, and other crisis-relevant organizations helps ensure that such organizations are well-adapted to the distinctive features of the communities they serve.

Decentralization constitutes a second significant structural contributor to resilience, and here again the term is used in several different ways across resilience dimensions and domains. In a recent book, *The Next Catastrophe* (2006) organizational theorist Charles Perrow argues that "concentrations"—more specifically, concentrations of dangerous substances and technologies, populations, and economic and political power—are major sources of disaster vulnerability, and that such concentrations make systems vulnerable to catastrophic failure. Using one example, that of population concentration, the primate city phenomenon and rapid urbanization have fueled the growth of megacities in highly hazardous regions worldwide. In the U. S., migration to coastal areas, resulting in more concentrated development, is a key contributor to escalating disaster losses.

Decentralization is a source of resilience in several respects. As noted by Perrow (2006), *locational or geographic decentralization* serves to "shrink targets," resulting in less serious impacts from disasters and terrorist attacks. For economic enterprises, locational decentralization can add needed redundancy under disaster conditions. *Decentralization of decision making* during crises is closely associated with both redundancy and resourcefulness. Overly centralized decision making systems are also less robust during disasters because it takes more time for information to move up and down through hierarchical structures, because information can be distorted in that process, and also because centralization can create overreliance on the decisions of a few central actors. Decentralized decision making contributes to resourcefulness, in that those who are closest to and most familiar with disaster-generated problems are more likely to understand the types of resources that are needed for an effective response.

More than two decades ago, Perrow (1984) also called attention to the lack of resilience inherent in complex, linear, tightly coupled systems. The fact that an electrical power system is inherently less resilient to external shocks than the internet is due in large measure to differences in the structural features of these systems. Grids are linear and tightly coupled; in contrast, the internet is a prime example of the *network form of organization*, which is also inherently less centralized than linear and hierarchical forms. Technological networks are resilient to disruption, and social networks have this same property. Hierarchies are centralized and tightly coupled, while networks are decentralized and loosely coupled, in the sense that networks are robust to the loss of nodes and even regions within the network configuration. Network forms of organization also tend to be high in redundancy, in that information and processes can find multiple paths along which to travel. Although disaster plans attempt to specify a priori the organizational entities that will participate in responding to disasters, new multi-organizational networks inevitably emerge when disasters strike. These emergent multi-organizational networks (EMONs) contribute in significant ways to resilience, particularly along the dimensions of redundancy and resourcefulness (see Tierney and Trainor, 2005 on the World Trade Center disaster EMON for further discussion.)

With respect to the social domain of resilience, for individuals and social groups the concept of *social capital* (Bourdieu 1985; Portes 1998) is frequently used to describe the benefits that result from network embeddedness. Social capital indicators include attributes such as membership in organizations, informal groups and professional and social support networks, along with other types of "connectedness," such as community participation. The ways in which social capital functions include increasing opportunities for the acquisition of information and financial and material resources, enhancing individual and group potential for collective action and access to centers of power, and providing emotional support. Research emphasizes the importance of social capital in disaster resilience (National Research Council, 2006; Norris et al. 2008). Social capital contributes to resilience for individuals and groups by enhancing robustness, redundancy, and resourcefulness.

3.2.2. Resilience-Enhancing Processes

As discussed here, processes include activities, procedures, and practices that characterize activities and interactions among social actors, where actors are understood as individuals, organizations, and groups. Processes associated with a lack of resilience in the face of disasters and with catastrophic systems failures have been studied extensively by social scientists (Roberts 1989; Roberts and Rousseau 1989; Sagan, 1995; Vaughan 1996; 1999). Like the foregoing review of structural features of resilient systems, the discussion below relates back to resilience as conceptualized in the 4R/TOSE framework. The areas in which these process insights apply include engineered systems, organizations that manage such systems, loss-reduction professions and practices, various social units, markets, and economies.

Reduction of production pressures is a key process ensuring greater resilience—particularly the robustness of systems. Many disastrous events and system failures can be traced to production pressures. Under time pressure and faced with the need to make profits or meet other goals, organizations and systems begin to deviate—often gradually and imperceptibly—from safety procedures and best practices. Small deviations accumulate, and systems that were originally designed to ensure safety are compromised. Production pressures played a role in many disastrous events, including the Exxon Valdez oil spill (1989), the space shuttle Challenger accident (1986), and the Tokaimura nuclear power accident (1999). Production pressures in the construction industry can result in shoddy (or nonexistent) inspections, use of substandard materials, and other deviations from appropriate practices. The extensive damage that occurred in newer housing developments in South Florida as a consequence of Hurricane Andrew (1992) was attributable in part to pressures within the homebuilding industry and poor inspection practices, and Andrew is far from an isolated case. Although not the sole source of failure, production pressures played a significant role in the mortgage crisis that continues to plague the U. S. economic system.

Effective crisis responses require processes that enable *collective sensemaking* and *distributed cognition.* The structural advantages of decentralization in crises were discussed earlier, but structural decentralization is further enhanced when participants in disaster response and management networks possess sufficient agency that they are free to share information and contribute to problem-solving efforts. Sensemaking and distributed cognition are critical with respect to the resourcefulness dimension of resilience, since they both ensure the mobilization of information resources and make it possible to identify what types of resources are needed during specific disaster events.

All true disasters contain elements of surprise—otherwise they would not warrant that classification. Both surprise and the drastic changes that occur in operational environments during disasters require extensive and collective "searching" for situationally appropriate (and usable) shared social constructs such as situation assessments, problem diagnoses, and ideas about resource requirements. Such searching takes place in different organizational and group contexts (including, importantly, in informal and emergent social groupings) and at different scales, including very local ones, but the critical point here is that the information that is found must be collectively shared within crisis management networks (for further discussions, see Weick 1993; Weick, Sutcliffe and Obstfeld 2005; Weick and Sutcliffe 2007). To elaborate further, it is also clear that lack of transparency and barriers to information sharing limit the capacity for collective sensemaking.

A third resilience-enhancing process, *improvisation*, takes place when social units of analysis (individuals, groups, organizations, institutions) depart from conventional norms, rules, and procedures—and also, importantly, from disaster plans—and display creativity in response to disaster-generated challenges. Improvisation is a key contributor to all dimensions of resilience and can also be observed across four TOSE domains (see Mendonca and Wallace 2004 and Wachtendorf 2004 for examples). Improvisation becomes necessary under a variety of conditions, including situations in which new problems present themselves that were not anticipated in plans, the types of resources required for response are either not operational or unavailable, or disaster-related demands on response systems greatly exceed capabilities. One advantage of improvisational activities is that they are well adapted to the often unique demands of particular disaster events.

4. CONCLUSIONS

Formulations emphasizing the significance of resilience for disaster loss reduction are not entirely unproblematic. Expansion in the use of the term has resulted in a good deal of conceptual blurring, such that resilience is now used as a synonym for sustainability, mitigation, adaptation, loss reduction, disaster resistance, and other related terms. Concepts that become vague and general lose their heuristic and explanatory usefulness. At the same time, there is lack of agreement on what constitutes resilience. Some formulations (Cutter et al. 2008, the MCEER framework and this paper) include resistance and robustness as attributes of resilience, while others restrict the use of the term to adaptive activities that enhance the ability to rebound when disasters strike.

This paper has attempted to address another problematic aspect of the use of the resilience concept in the study of extreme events: the emphasis on measurement, as opposed to theoretical explanation. The ideas presented here complement new and useful theoretical work, such as the comprehensive resilience framework proposed by Norris et al. (2008) and recent contributions by Cutter et al. (forthcoming) and MCEER-affiliated investigators. The overarching argument is that resilience remains a construct that requires explanation and that a potentially productive approach to causal modeling is to identify both structural and process-related factors that contribute both independently and interactively to observed levels of disaster resilience.

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