SELF ORGANIZATION IN DISASTER RESPONSE:

The Great Hanshin, Japan Earthquake of January 17, 1995

Louise K. Comfort
Graduate School of Public and International Affairs
University of Pittsburgh
Pittsburgh, PA 15260
E-mail: lkc+@pitt.edu

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Louise K. Comfort
Graduate School of Public and International Affairs
University of Pittsburgh

Introduction

This report presents findings from a Quick Response Study of the response system that evolved following the Great Hanshin, Japan Earthquake on January 17, 1995. The study was initially designed to examine the processes of self organization specifically in the medical response to this earthquake. However, in making plans for the study, it became clear that the medical response was inseparable from the larger disaster response system, given the interdependent characteristics of local and intergovernmental disaster management in Japan. Consequently, this study addresses the process of self organization in the broader disaster response system for this earthquake, with particular attention to emergency medical services.

Building a community capacity for rapid transition in event of disaster is fundamental to effective disaster response. In every disaster environment, evidence exists of spontaneous reallocation of resources and reorganization of action to meet urgent human needs. However, such systems vary significantly in timing, efficiency, effectiveness, and reliability in practice, with associated costs in lives and property. This study explores the characteristics of self organization in order to characterize more accurately the dynamics of this process in a complex, interdependent, densely populated, metropolitan environment.

The conditions of self organization require a sociotechnical system that combines sufficient structure to facilitate exchange of information among its multiple components with sufficient flexibility to adapt action to the demands of a dynamic environment. Self organization depends upon ready access to timely, accurate information through an information infrastructure that supports systematic monitoring of critical conditions, feedback to responsible participants, and revision of actions taken in the light of new information.

Inquiry into actual processes of self organization in disaster environments requires appropriate measurement. While we can devise theoretic measures of assessment, most require sophisticated computer technology that has not yet been incorporated into practicing disaster operations centers. Building upon the concepts outlined by Stuart Kauffman (1993:174,208-227) in his discussion of the interaction among actors in a complex, dynamic system, I outline a preliminary methodology that reveals the major characteristics of rapidly evolving disaster response systems and their inherent processes of self organization.

The study was initially designed to address four basic questions regarding emergency medical services following the Hanshin Earthquake of January 17, 1995. They were:

1. Who provided emergency medical care and how was the medical response organized in the critical hours immediately following the Hanshin Earthquake of January 17, 1995?

2. What consequences did this pattern of organization and delivery of emergency medical services have for the survival rate of patients injured or affected by the earth-

quake?

3. To what extent did patterns of self organization evolve in the affected communities in response to the urgent medical and public health needs generated by the earthquake?

4. What lessons can be learned from this experience for the organization and delivery of emergency medical services in other metropolitan areas vulnerable to seismic risk?

These questions were rephrased to identify the wider emergency response system that evolved following the disaster, its patterns of organization and communication, the consequences of these patterns for the delivery of services to the earthquake-affected communities, and the lessons learned from this event.[1]

This study focuses on the emergence of a disaster response system in a technically advanced, densely populated, metropolitan region. The size, shape, and timing with which the system evolved are critical to defining not only the losses endured in the given event, but also the scope of interorganizational action required for reconstruction and recovery. Specifically, I examine the process of self organization in the Hanshin-Awaji, Japan Earthquake on January 17, 1995. In societies vulnerable to seismic risk, severe earthquakes represent the civilian equivalent of war, a massive shock to the entire technical, organizational, economic, political, and social system. How a complex, sociotechnical system responds to this shock provides valuable insight into its likely evolution to the next phase in its performance, and its likely actions to prevent recurrence.

This study is significant for at least four reasons. First, it explores means of facilitating the emergence of self organization in disaster environments in order to reduce losses in lives and property in disaster-afflicted communities. Second, it presents a preliminary methodology for assessing rapidly evolving response systems following disaster. Third, it offers suggestions for continuing research on complex, adaptive systems (CAS) in disaster environments. Finally, the findings contribute to our theoretical understanding of the dynamics of CAS and institutional change.

Methods and Measurement in Nonlinear Systems

Methods needed to assess self organizing processes in disaster environments differ from those used in assessing linear systems. Disaster environments are fundamentally nonlinear, and require a mode of measurement and modeling that can capture the continuously evolving relationships among the interdependent components of the system. Linear models are singularly inappropriate for these nonlinear, dynamic conditions.[2] In disaster environments, there are too many agents involved in performing too many different functions simultaneously under radically altered conditions to attribute direct, linear causality to any one agent or condition.

The capacity to make 'transitions' between different states, an essential feature of complex behavior (Nicolis and Prigogine, 1987:36), distinguishes nonlinear from linear social systems. With linear models of policy analysis, econometrics, or trend analysis, we are able to chart the performance of established systems within prescribed parameters over time (McKibbin and Sachs, 1991). However, these models do not allow us to anticipate future states in dynamic systems or to predict with any degree of certainty what outcomes would follow from which alternative courses of action. Linear models assume that existing conditions are likely to remain stable over time, and that conditions operating in the future will function very much as they did in the past. In the rapidly changing, complex environments of disaster, such models are often invalid or misleading.

In nonlinear systems, differences in initial conditions precipitate variations in performance that increase markedly in processes iterated over time (Prigogine and Stengers, 1984; Ruelle, 1991; Nicolis and Prigogine, 1987). Nonlinear systems also exhibit primary characteristics of stochasticity and irreversibility in time (Prigogine, 1987; Gell-Mann, 1994). That is, random events set in motion sequences of reasoning and action that differ from previous behavior in the system, generate different dynamics of selection and evolution in performance (Kauffman, 1993), and create different memories and interpretations of that experience. Disaster events, therefore, produce unique combinations of choices, actions, and reasoning that could not be predicted. Once generated and instantiated in experience and practice, however, these reasoning and action processes cannot be reversed. We need a set of nonlinear measures and supporting concepts to capture this dynamic exchange of information, attention, and action both within the system and between the evolving system and its environment.

Borrowing from biology, the concept of an N-K system (Kauffman, 1993: 175-209) permits identification of basic characteristics of self organizing systems that reallocate their energy and action to serve changing system needs. In Kauffman's original model, N equals the number of actors in the system, K equals the number of interactions among these actors, and P equals the 'bias for choice' among the actors, or the goal of the system that drives action. These three measures allow the identification of a fourth measure -- the boundaries of the system -- operating in response to specific events, times, conditions, and locations in the wider environment. Defining the boundaries helps to identify the relationships between types of complex systems and especially to distinguish sub-systems within larger systems.

The measure, D, represents the duration of the interactions among actors in the system, acknowledging that some interactions may be intense but brief, while others may continue at lower levels of effort over longer periods of time. A final measure, T, denotes the types of transactions that are carried out by organizations operating as participants in the system. Other characteristics regarding the sources of support and conditions of the environment may be identified and mapped, but this set of measures provides an initial assessment of the operating characteristics of a complex, adaptive system.

This set of characteristics may be summarized as follows (Comfort, 1994:306-307):

1) N = number of organizations participating in disaster response
2) K = estimated number of interactions among participating organizations
3) P = shared goal of organizations, or 'bias for choice' in actions

4) B = boundaries of the system
5) D = duration of interactions among organizations
6) T = types of transactions performed by organizations

These six measures allow us to track the dynamic characteristics of system performance, but they also exceed the capacity of individual managers to monitor their operating systems, using ordinary methods of data collection, analysis, and static representation. Advanced information technology permits the design of monitoring and mapping techniques that allow managers to track characteristics of dynamic system performance over time and to incorporate this information into their management processes. These methods can be very effective in providing decision support in rapidly changing environments (Comfort and Chang, 1995).

Until such technology is fully incorporated into disaster management operations, cruder measures may be used to distinguish evolving systems in a complex society. We can identify sets of interacting organizations which, in turn, contain subsystems that perform separate functions in related contexts. Such measures document patterns of interaction within and between interdependent organizational systems in a first step toward charting the dynamics of transition in disaster response. They also identify gaps in the exchange of information among these interdependent systems that inhibit acceptance of alternative strategies, reinforcing static behavior and resistance to change. These methods use standard data collection methods as interim procedures, but follow the logic of nonlinear reasoning.

I used the N-K model to guide data collection and analysis in the field study of the disaster response system that evolved following the 1995 Hanshin, Japan earthquake. Computerized information systems were not fully in place to provide measures of exchange of information among participating organizations in this case of disaster operations, although partial records of some activity were available. I present data from the field research, following the logic of the N-K model and noting gaps and inadequacies in this preliminary application.

Three types of data were used in the conduct of this field study: 1) semistructured interviews with responsible management personnel at the municipal, prefectural, and national levels; 2) operations records and reports prepared by the participating agencies as well as professional reports prepared by external organizations; and 3) content analyses of newspaper reports of disaster response operations in local and national newspapers following the earthquake. Interviews were conducted in the field with the assistance of local translators. A detailed description of the sample design and questionnaire used for the survey of practicing managers and procedures for conducting the organizational analyses is presented in the Appendix.

Hanshin, Japan: An N-K System of Disaster Response

A severe earthquake struck the Hanshin region of Japan at 5:46 a.m. on January 17, 1995, registering 7.2 on the Richter scale of magnitude. The epicenter was located on northern Awaji Island, just off shore from Kobe, a city of 1.5 million population, and the rupture registered strong ground motion directly through downtown

Kobe and northward to the neighboring cities of Nishinomiya, Ashiya, Itami City, Amagasaki, Takarazuka, and other towns in Southern Hyogo Prefecture. A disaster response system evolved following this event, revealing significant aspects of the process of self organization in dynamic, uncertain environments.

Initial Conditions: Southern Hyogo Prefecture

The initial conditions prevailing in the Southern Hyogo Prefecture of Japan in January, 1995 shaped the response system that evolved following this disaster in significant ways. The technical, organizational, and social conditions of this metropolitan region were those of an advanced industrial society. Kobe, the principal city in the Hanshin region, is located roughly in the center of Honshu, the main island of Japan. Geographically, the city stretches 30 kilometers east to west along Osaka Bay, with the Rokko Mountains rising steeply to the north. Kobe is a modern city, with interdependent systems of transportation, industry, trade, banking, education, and medical care linking the city to others in the region. The transportation system, for example, is an advanced mix of highspeed rail transport, local railways, city bus lines, and expressways, connected to international transport via a major new regional airport and a busy international shipping port, the sixth largest in the world. Extensive networks of telecommunications, electrical, gas, and sewer lines provide efficient, modern service to this metropolitan region of over 10 million people. Building structures represent a mix of types, with sophisticated seismic engineering in high-rise buildings interspersed with old style wooden houses with heavy tile roofs. The technical profile of the region is generally strong and, prior to the earthquake, was a matter of pride for residents of the region.

Organizationally, however, the area was not well prepared for seismic risk. Although the islands of Japan are located at the juncture of three tectonic plates and seismic risk is well known in the nation, residents generally believed the Hanshin region, which had last experienced a moderate earthquake (6.1 Richter scale) in 1916, was relatively stable in contrast to the Tokyo Region, which had suffered a major earthquake with heavy losses in 1923. Consequently, relatively little investment had been made in earthquake preparedness, either by public organizations or residents. While cities in the region had emergency plans, their preparation had primarily been oriented toward small, local disasters of fires and floods.

Private utility companies, such as Kansai Electric Co. and Osaka Gas Co., demonstrated substantial investment in seismic mitigation efforts to protect their interests, but were not directly linked to the public agencies. Socially, there existed little tradition of voluntary organizations or community self help associations. Most people focused their lives on their work associations and their families.

Although the initial technical systems were strong, there was little interorganizational capacity to reallocate resources and action in timely response when these interdependent systems failed under the severe shock of the unanticipated earthquake.

Impact of the Earthquake and Assessment of Need

In the densely populated, complex urban environment of the Hanshin region, the Magnitude 7.2 earthquake at 5:46 a.m. on January 17, 1995 set off a cascading effect in the area's network of interdependent systems. Failure in one system triggered failure in another which triggered further failure in a third, each failure compounding the damage and leading to full-scale disaster, affecting approximately 4 million people in the metropolitan region.

The damage was extensive. The death toll has climbed past 6,000 in recent reports, although the National Land Agency reported the following official statistics, as of April 23, 1995:[3]

Number of Casualties

Total dead:	5,502
Missing:	2
Injured:	
Seriously wounded	1,961
Lightly wounded	25,008
Under observation	14,679
Total injured:	41,648
Housing:	
Destroyed:	101,233
Half-destroyed:	107,269
Partially destroyed:	182,190
Total losses:	390,692
Public buildings:	549
Commercial bldgs:	3,120
Total buildings	3,669
Number of fires:	294

The dynamics of the destruction were sobering. The strong vertical ground motion ruptured underground gas and water mains, causing leaks and disrupting service throughout the region. An estimated 4,500 km. of gas lines were heavily damaged, and 1,200,000 houses were left without water. Electrical facilities were also damaged, cutting off sources of electrical power to 850,000 city departments, businesses, and households. The total cost of the disaster is estimated at US$200 billion.

As the gas mains ruptured, fires broke out. With no water available for fire suppression, the fires raged largely unchecked through seriously damaged sections of the city. In Kobe, 60 fires broke out before 6:00 a.m. on January 17, 1995, and burned simultaneously. Before 9:00 a.m., the number of fires burning simultaneously had increased to 85, with a total of 109 fires reported for the city of Kobe and a total of 294 fires for the entire earthquake-affected area. The major cause of fire was broken gas mains. Debris from collapsed buildings blocked the streets, preventing fire trucks from getting through. Over 9,403 blockages in roads were reported for the area.

Under these conditions, communications capability was critical. The Kobe Fire Department had just installed a advanced computerized dispatch system with video monitors in December, 1994. However, it was not yet operational and was not used in disaster operations. Telephone lines were out of order during the first day in a large areas of the region, while others were overloaded. Over 1800 emergency calls made on 118 emergency circuits were recorded on the 119 dispatch logs on January 17, 1995, at roughly 100 calls per hour or 1.7 calls per minute.[4] Further, these were only the calls that could get through. Fire departments had their own radio systems, but could not communicate with other departments. Communications capability proved very limited in the first critical hours following the earthquake.

These conditions proved overwhelming for the Kobe Fire Department which had primary responsibility for emergency response, but only a total of 11 fire stations, 176 engines, and 305 personnel on duty when the earthquake occurred. Three of the 11 stations were damaged in the earthquake, and even with emergency call-out procedures, only 663 personnel were able to report for duty within the first two hours.[5] The actual destruction was beyond any training scenario for municipal emergency response.

Evolution of the Disaster Response and Recovery System

In this densely populated, urban region, a disaster response system did evolve, seriously affected by the initial conditions of organizations operating within a context of already great complexity and a limited model for massive disaster. Consequently, emergency response preparations designed to ensure careful response in smaller scale disasters inhibited the rapid transition needed for an event of this magnitude.

For example, the Fire Department operates on a "doctor-car" system for emergency medical services. When a citizen calls the emergency number, 119, the Fire Department responds by dispatching a team of paramedics that can administer first aid. If an injury is involved, the Fire Department also calls the local hospital, which dispatches a physician trained in emergency medicine. The firemen, even though they may be "first on scene," are legally prevented from administering any emergency medical procedure unless it is supervised by a licensed physician. While this procedure works well for traffic accidents or small fires, it hinders delivery of emergency medical services in large-scale disasters.[6] While the toll in lives of this practice cannot be calculated by any exact measure, informed paramedics and physicians were sobered by its consequences and concur that it must be changed.[7]

In this urgent context, the operations logs of the Kobe Fire Department document actions taken during the first critical hours following the earthquake. These records correspond with reports from governmental agencies at the prefectural and national levels.[8] The record of operations for the three levels of government during the first hours of response on January 17, 1995 are listed in Table 1, Appendix.

The record reveals the gaps in information that seriously affect the coordination within and between jurisdictions. For more than four hours, neither the Hyogo Prefectural Government nor the National Fire Defense Agency in Tokyo had a clear picture of the degree of destruction and damage in Kobe. Constrained from action by the existing law until a request for assistance had been received from the City of Kobe, these governmental agencies did not enter the response system until more than four hours after the initial shock. In further irony, existing law kept the dogs from the French Search and Rescue team in quarantine, not allowing them to enter response operations until the fourth day after the earthquake when they extricated dead bodies, instead of performing live rescues.[9] These conditions indicate the ironic effects of law, intended to protect citizens, in restricting the capacity of public managers to carry out their mission under dynamic conditions (Smart and Vertinsky, 1977).

More damaging was the lack of communication between the public agencies and the private utility companies. Osaka Gas Company, a private company and owner of the ruptured gas lines that were fueling the fires, was apparently not in communication with the city departments. Only after reviewing the data from their own seismic monitoring devices at approximately 11:00 a.m. on January 17, 1995, did the Company's Policy Group decide to close off five of the fifty-five blocks of their 50,000 km. distribution system. The Company began to shut off the gas in critically damaged areas at 11:30 a.m., and completed the task about 11:50 a.m., six hours after the earthquake.[10]

The gap in information and communication regarding emergency medical services was even more severe. For the first 12 hours following the earthquake on January 17, 1995, the Emergency Medical Division, Ministry of Health in Tokyo had little or no information regarding the conditions and need for medical services in the disaster area. On January 23, 1995, six days after the earthquake, an Emergency Operations Center was established in Kobe with the assistance of the national Ministry of Health.[11]

As the immediate shock of the earthquake gave way to action and as information about the damage became clearer, a disaster response system began to evolve across organizational and jurisdictional lines that eventually engaged assistance from 43 of Japan's 47 prefectures, 44 nations and regional organizations, and the United Nations. The supporting data for the disaster response system are presented in tables and figures in the Appendix. Figure 1 presents a profile of this response system, ordered by first mention, funding source, and day for the first five days of disaster response, January 18 - 22, 1995. First mention indicates the organization's entry into the disaster response system as reported in the Japan Times. On the first three days following the earthquake, public organizations received the largest proportion of first mentions, with a small number of first mentions for private organizations and no mention of nonprofit organizations until Saturday, January 21, 1995, four days after the earthquake. By Sunday, January 22, 1995, nonprofit organizations received the largest number of first mentions.

Figure 2 presents the breakdown for public organizations by first mention, day and jurisdictional level. Figure 3 presents the profile of the response system by type of funding source and week for the first month following the earthquake, identifying 330 organizations as participants in disaster operations from news reported in the Japan Times.

Figure 4 presents the profile of organizations engaged in disaster response by frequency of mention, funding source, and day for the first five days. This profile shows the clear predominance of public organizations in reported response operations for the first four days, limited mention of private organizations during this time, and no mention of nonprofit organizations until Day 4, with an increasing number of mentions for nonprofit organizations on Day 5.

From these profiles, it is clear that different types of organizations entered the response process at different times and engaged in disaster and relief operations for different periods of time. Participation of both private and nonprofit organizations peaked in the third week of operations, as reported in the Japan Times. Interesting also is the active role of the yamaguchigumi, the Japanese mafia, in the organization and distribution of disaster relief, in apparent cooperation with local governmental officials. Table 2 presents the list of organizations that are identified for the interorganizational response system. Other data show the extraordinary mobilization of a national response through fire departments, medical volunteers, and water teams from 43 of Japan's 47 prefectures. These activities all required communication and coordination, central to cooperative action.

The active N-K system, in Kaufmann's terms, is the product of interactions among the identified actors in the system. Table 3 presents the number of interactions among types of organizations reported in news articles on disaster response in the Japan Times in the first month following the earthquake, January 18 - February 17, 1995. These data represent only one source of public documentation for interactions among organizations participating in the response system, but they do indicate some important characteristics of the response. The largest number of interactions, 59.1%, occurred among governmental organizations, with private organizations ranking a distant second place at 14.8%. Nonprofit/charitable organizations ranked third, with 12.5% of the reported interactions. Figure 5 shows these data graphically.

Table 4 presents the number of transactions performed in disaster response operations that were reported in news articles in the Japan Times during the first month following the earthquake. These data indicate that the largest number of reported transactions, 22.54%, involved recovery/reconstruction activities, while the second largest number, 16.9%, represented disaster relief activities, and the third largest number, 15.5%, were activities related to medical/health care to the injured. Communication and coordination activities, central to dynamically evolving response systems, ranked fourth at 12.7% of the reported transactions. Since each transaction included multiple actors, the number of actors is also reported by type of transaction. Figure 6 shows the frequency distribution of transactions performed in disaster response operations, with the associated number of actors involved in the transactions, by type of organization.

The shape of the response system in the Hanshin Earthquake differed significantly from those observed in other disasters.[12] It appeared overwhelmed and tenuous at first, giving way to confidence and strength as participants gained in knowledge and commitment to response operations. The manner in which the response system evolved, however, had a critical effect on the search and rescue operations and the number of lives saved from collapsed buildings. Table 5 presents a brief profile of the number of persons rescued from collapsed buildings who lived, by day of rescue. The figures reveal a startling drop in the proportion of persons who lived after being rescued from collapsed buildings and underscore the critical issue of timeliness in emergency response. This same

Table 5

Number of Persons Rescued

Date	Jan. 17	Jan. 18	Jan. 19	Jan. 20	Jan. 21
Total rescued	604	452	408	238	121
Total who lived	486	129	89	14	7
Percent rescued who lived	80.5	28.5	21.8	5.9	5.8

Source: Kobe Fire Department, "The Great Hanshin-Awaji Earthquake [Kobe City Area]: Record of Fire Fighting in Kobe. 1995:12.

pattern of steep decline by day of rescue has been confirmed in studies of other disaster response operations (Pretto et al., 1992). The cost in timeliness, measured in loss of lives, is sobering, and appears directly related to the functioning of the information infrastructure that undergirds interorganizational decision making and action. The issue of timeliness is also illustrated by the high number of people living in shelters months after the disaster.[13]

Discussion

Distinctive characteristics can be identified for the Japanese disaster response system on four critical issues that are instructive in terms of seeking means to reduce risk to natural disaster on a global scale. These characteristics are summarized briefly on the issues of timing, balance between structure and flexibility, self organization, and sustainability.

1. Timing in the evolution of the response system

Interdependent emergency response organizations were unable to make rapid transition to an emergency response system vital to saving lives in the first hours following the earthquake. Critical factors inhibited this transition:

a. Basic information infrastructure needed to support the search for, and exchange of, information in the dynamic disaster environment was either not available or not functioning
b. Japan had adopted a technical strategy for seismic mitigation and had assumed that high investment in engineered buildings and transportation facilities would prevent collapse
c. Misjudgment in technical strategy was compounded by underinvestment in public sector capacity at the local level, given actual exposure to seismic risk
d. Existing organizational structure for emergency response was inadequate for a major metropolitan disaster with regional impact
e. Citizenry had relatively little experience with voluntary organizations prior to the disaster; a strong contingent of volunteers did emerge to assist in disaster response, many of whom were students or young people who were volunteering for community service for the first time
f. Interaction among the above factors resulted in a high number of people who experienced intense trauma over a longer period of time
h. Relatively high incidence of reported traumatic stress is attributed to longer exposure to uncertain, stressful conditions

2. Balance between structure and flexibility in disaster environment

The business sector had invested in information technology, and performed well within its specific range, but it did not have clear, effective communication linkages with public sector agencies responsible for life and property. Public sector investments in information technology either were not fully operational, e.g. Kobe Fire Department's GIS and computerized dispatch system, or failed, e.g. Hyogo Prefecture's satellite communication system, to support decision making in disaster operations

3. Self Organization in Disaster Response

Self organization did occur, but later and more sporadically in the response period. Volunteer groups were organized, many for the first time, to function in this disaster and entered the response period only on the fourth day. The challenge is to build upon this spontaneous base of interest and experience to foster a continuing exchange of information, knowledge, and skills in the mitigation of seismic risk in Japan and other nations.

4. Sustainability of the response system into recovery

Japan's initial conditions of a strong economy and good organizational skills became evident as the system turned from response to recovery. For example, the recovery system mobilized resources from 43 out of 47 prefectures in the nation to provide water to the areas in which the distribution system had been damaged. This system operated efficiently for about 2.5 months.

This analysis confirms important characteristics of a nonlinear model of disaster response. First, disaster creates a "symmetry-shattering event" that both disrupts established patterns of thought and action and creates the opportunity to redesign an emergency response system that 'fits' the environment more effectively.

Second, the critical function of aggregating units from different levels of intergovernmental operations easily into a wider system of disaster response underscores both the difficulty of this task under linear models of organization and the interdependence of these units in a massive, large-scale disaster. This function and its capacity to mobilize resources -- personnel, equipment, supplies, skills, and knowledge -- requires a mechanism of information exchange to achieve a shared system-wide goal: protection of life and property. This function appears to be performed more effectively in rapidly changing disaster environments by a nonlinear, dynamic system that is able to coordinate diverse resources, materials, and personnel across previously established organizational and jurisdictional boundaries through means of information exchange guided by a clear 'internal model' or goal for action and prompt feedback. Such a system uses processes of self organization in which informed participants initiate action, but adjust that action to that of others operating toward the same goal to achieve a timely, efficient response. It is essentially an organizational system operating in parallel, supported by a strong, distributed information system.

Third, the goal of the disaster response system serves as an 'internal model' or 'mental compass' for self organizing processes. This goal allows participants from diverse perspectives, experience, and resources to adjust their actions and contributions to that of other participants in the system. Finally, an 'epistemic community' (Haas, 1990) of knowledgeable people from diverse backgrounds, experience, and organizations that focuses on the shared problem is vital to the articulation of a common goal for reduction of risk and formulation of strategies for action that can be communicated to a wider set of responsible actors. This step is essential to the development of 'resonance' or willingness to support shared action when necessary to sustain the goal of a humane society. There are some indications that the formation of such a community is already taking place in Japan, for example, through the Pan Pacific Forum in Kobe that is meeting regularly to form policy recommendations for the reconstruction process. The group includes about 40 responsible community leaders from education, business, medical care, publishing, and voluntary organizations.[14]

Recommendations

In conclusion, the Hanshin disaster response system indicates that processes of self organization in disaster response are dependent upon a sociotechnical infrastructure that supports the timely, accurate exchange of information in a rapidly changing environment. The N-K model offers a means of assessing disaster response systems in different contexts in the effort to gain insight into the dynamics of the rapidly evolving process of disaster response and recovery. This approach offers a significant opportunity to design information strategies for disaster environments that would facilitate the constructive emergence of self organizing systems guided by the system-wide goal of protection of life and property. Toward this objective, I offer the following recommendations:

1. The model of a rapidly evolving disaster response system and the methodology for assessing such systems in practice need more rigorous evaluation in the context of actual organizations. This could be done through a simulated operations exercise using a computerized information system that would allow the monitoring of messages sent and received, actions taken based upon this information exchange, and feedback among organizations and jurisdictions participating in the exercise.

2. Such an exercise could be initiated as a collaborative project among a set of key actors and designed as a vehicle for research, education, and training of professional personnel in the study of rapidly-evolving disaster re-

sponse systems.

3. Such activities for global problems such as seismic risk are most effectively carried out under the auspices of international organizations such as the UN; for example, there is a current UN initiative under way to establish an interregional network for seismic policy involving Mexico, Ecuador, Indonesia, The Philippines, and China.

4. Such studies, further, contribute to our broader theoretical understanding of complex, adaptive systems and how they facilitate or fail to support proposed actions in the international arena.

NOTES

1. The shift in the focus of the study was based upon information offered by Japanese researchers familiar with disaster response operations prior to our field study in Japan in May, 1995. It was apparent that more complete information and greater access to operations personnel was available for the general disaster response system, which in fact encompassed the medical response. The study's primary criterion was to gather the most accurate and complete profile of the disaster response system possible.

2. For example, Peter May (1993:651-652) uses a standard linear regression analysis to explain the effects of state agency regulatory style upon implementation efforts in his analysis of legal mandates as an instrument of policy change in communities vulnerable to seismic risk. May's analysis assumes that the legal mandates and their designed styles of regulation are the principal factors causing change in agency behavior, and employs a linear model to assess the strength of this influence. In contrast, the dynamics of rapidly evolving disaster response systems would not permit the application of such a model.

3. Summary of Reports from Ministries regarding Status of Hanshin-Awaji Disaster Operations, National Land Agency, Tokyo, Japan, April 23, 1995.

4. The Great Hanshin-Awaji Earthquake [Kobe City Area]: Record of Fire Fighting in Kobe. Kobe Fire Department, Kobe, Japan, 1995.

5. Source: "Hanshin - Awaji Daishinsai (Kobe Shiiki) ni okeru Shobokatsudo no Kiroku". Kobe City Fire Department, Kobe, Japan, March, 1995.

6. Interview, Assistant Professor, Division of Emergency & Critical Care Medicine, Hyogo College of Medicine, Nishinomiya, Japan, May 9, 1995.

7. Interviews: Assistant Director, Emergency Division, Nishinomiya Fire Department, May 10, 1995; Assistant Professor, Division of Emergency & Critical Care Medicine, Hyogo College of Medicine, May 9, 1995; Chief, Emergency Division, Kobe University Hospital, May 15, 1995.

8. The Disaster Countermeasures Basic Act of 1961 outlines an intergovernmental response capacity that operates only at the request of the subordinate governments. The municipal government must request assistance from the prefectural government; the prefectural government, in turn, must request assistance from the national government. According to this law, assistance is not given to municipal governments by national or prefectural governments unless requested.

9. Japan Times, January 21, 1995.

10. Interview, General Manager, Corporate Planning Department, Osaka Gas Co., Ltd., Osaka, Japan, May 15, 1995.

11. Interview, Manager of Emergency Medical Services, Hospital Guidance Division, Health Policy Bureau, Ministry of Health & Welfare, Tokyo, Japan, May 16, 1995.

12. See, for example, the response systems that evolved following the Maharashtra, India Earthquake of September 30, 1993 and the Northridge, California Earthquake of January 17, 1994. L.K. Comfort, "Self Organization in Disaster Response: Global Strategies to Support Local Action." Paper presented at the Workshop on "The United Nations, Multilateralism, and Catastrophes," Institute of International Studies, University of California, Berkeley, November 9-10. 1995; L.K. Comfort, "Self Organization in Disaster Response: The Northridge Earthquake of January 17, 1994." Report submitted to the Earthquake Hazard Mitigation Program, National Science Foundation, Washington, D.C. in fulfillment of requirements for a Small Grant for Exploratory Research, National Science Foundation, #BCS 94-10896, February 8, 1995.

13. On May 16, 1995, five months after the earthquake, 40,000 people were still in shelters. Report, Disaster Management Bureau, National Land Agency, Tokyo, Japan.

14. Interview, Dean, Graduate School of International Cooperation Studies, Kobe University, Kobe, Japan, May 14, 1995. Other fora also serve this capacity, such as the Pan Pacific Conference being planned by a Canadian Disaster Management group as its contribution to the United Nations International Decade for Natural Hazard Reduction in Vancouver, Canada in July, 1996.

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