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LEARNING FROM RISK: ORGANIZATIONAL INTERACTION

FOLLOWING THE ARMENIAN EARTHQUAKES

by

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DISASTER REANIMATOLOGY STUDY GROUP (Page 1A)**

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Learning from Risk: Organizational Interaction following the Armenian Earthquakes

by

Louise K. Comfort and the Disaster Reanimatology Study Group

Designing Policy for Environments of Seismic Risk

Catastrophic earthquakes pose one of the most difficult tests of policy design and implementation for public organizations. Policy makers are confronted with at least five conditions that challenge their capacity to assess the risk accurately and to design appropriate alternatives for response, should an event occur. First, there is the sharp contrast in the concept of time between the brief institutional memory of modern public organizations and the long span of years between geological events. Major earthquakes occur, within ranges of 90 - 150 years in zones of known seismic risk.[1] Governmental agencies, operating on year-to-year budgets, often discount the risk of events that occur with such infrequency. Lessons learned from past events are easily forgotten, as decades pass without recurrence. The trauma generated when earthquakes do occur reflects, in part, the decision not to act in preference to other needs, perceived as more immediate.

Second, it is the interaction between earthquakes and human settlements that generate disaster (Turner, 1978; Shrivastava, 1987). As populations move increasingly into seismic zones, with accompanying infrastructure and unplanned patterns of settlement,

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[1]. David Boutacoff, "Real World Lessons in Seismic Safety" in EPRI Journal, June 1989: 23-29.

the risk to human life and property increases. Paradoxically, populations in seismic environments, unaware of the risk and consequences of earthquakes, may escalate that risk with inappropriate construction, uninformed actions or inadequate coping skills.

Third, designing policy for preparedness and response to earthquakes is necessarily an interdisciplinary and interorganizational task (Comfort, 1985, 1986, 1989a, 1989b). No single discipline, no given organization commands all of the information or resources needed for appropriate preparedness or response. The effective delivery of medical services to assist injured victims, for example, depends upon timeliness of extrication, availability of appropriate life-saving first aid, access to needed extrication and medical equipment, adequacy of transportation, functioning communications, water and power facilities (Klain et al., 1989.) It is the rapid integration of multiple skills, services and organizations into a coherent response process that facilitates the protection of life and property in a disaster. Yet, in routine operations, the personnel and organizations required for such a response are unlikely to work together. Effective response to disaster requires individuals and organizations to shift to a higher level of abstraction in understanding their roles in relation to the overall goal of humanitarian assistance and in coordinating their actions with others in an integrated community effort. Such shifts are difficult to accomplish without preparedness and practice, which, in turn, are unlikely without awareness of the risk -- Catch 22.

Fourth, disaster response is necessarily interjurisdictional. In a catastrophic earthquake, the capacity of the local jurisdiction to respond to the needs of its population is, by definition, overwhelmed.[2] Appropriate response, therefore, involves multiple levels of government, local, regional, national and international. The problems of communication and coordination within and between jurisdictions escalate with the scope of the disaster and the levels of jurisdictional participation.

Fifth, managing the information involved in preparedness and response for such complex, uncertain, dynamic events rapidly overloads human and organizational information processing capacity (Simon, 1969, 1981). The coordination of multiple individuals and organizations in effective disaster response actions depends upon timely, accurate accessible information. In disaster operations, response personnel are working both in real time and against time (Zancanato, 1988) in their efforts to save lives and protect property. Accurate, accessible information is integral to the capacity to mobilize action under the urgent constraints of time and distance in appropriate disaster response. Information serves as the "nerves" of governmental operation, to recall that memorable image of Karl Deutsch (1963, 1966). This role for information is underscored in the complex,

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2. U.S. Federal Emergency Management Agency (FEMA). 1980. An Assessment of the Consequences and Preparations for a Catastrophic California Earthquake: Findings and Actions Taken. Washington, D.C.

dynamic environment of risk and disaster management.

Given these five conditions, the task of designing policy for environments of seismic risk creates an extraordinary challenge for human reasoning capacity. The set of conditions exceeds the boundaries of manipulative reason or even wisdom. Remaining is the category of "perceptive reason" or openness to new ideas, insights and learning from external sources (Deutsch, 1963, 1966: xv). How to create such a learning environment is, inherently, a problem of design.

The Operational Context of Disaster

The Armenian earthquakes of December 7, 1988 vividly illustrate these challenges to policy design and implementation. The first earthquake occurred, without warning, at 11:41 a.m. on that sunny Wednesday morning. Measuring 6.9 on the Richter scale with an epicenter near Spitak, the earthquake had devastating effects on four cities in northern Armenia -- Spitak, Leninakan, Kirovakan, Stepanavan -- and 58 villages in the area. Four minutes later, an aftershock of magnitude 5.8 on the Richter scale damaged further buildings already weakened in the first temblor. In minutes, buildings had collapsed, water, electricity and communications were destroyed, tens of thousands of people were killed and injured, and hundreds of thousands were rendered homeless. Nearly one-third of Armenia's population of 3.5 million were affected to some degree by the earthquakes. Public organizations, unprepared for such devastation, struggled to devise appropriate responses to the immensity of human needs generated by the seismic events. Catastrophe, in this context, was an understatement.

Three conditions make the Armenian earthquakes distinctive in terms of demands for public policy response. First, the earthquakes were extraordinary in the scope of damage and destruction generated for the human settlements in the area. Table 1 cites data reported by the Civil Defense, Armenia SSR regarding the consequences of the earthquakes upon population centers, industrial facilities, cultural buildings, residences, agricultural facilities and livestock of the affected area. Table 2 shows the steep decline in live extrications of victims from the rubble after Day 4, dropping still further by Day 5 to virtually none after Day 12. These data provide grim evidence of the struggle against time in life-saving efforts.

Table 3 reports the type and day of receipt of equipment for rescue work, increasing in number with time for mobilization but decreasing in utility for life-saving operations. Table 4 shows the number and types of personnel and equipment utilized in rescue operations by location. Civil defense units, with legal responsibility for response in disaster operations, were available only for the two major population areas affected -- Leninakan and Spitak. The other areas were left with only civilian personnel to carry out rescue operations. Table 5 shows the response to the earthquake consequences by area. Particularly telling is the finding that in the rural areas, left largely without trained personnel for rescue operations, 98% of the

TABLE 1

EARTHQUAKE CONSEQUENCES

CITIES AND REGIONS	POPULATION LOCATIONS		INDUSTRIAL FACILITIES		CULTURAL BUILDINGS		RESIDENCES		AGRICULTURAL FACILITIES		DOMESTIC ANIMALS	
	INITIAL	% DESTROYED	INITIAL	DESTROYED	INITIAL	DESTROYED	INITIAL	DESTROYED	INITIAL	DESTROYED	INITIAL	DESTROYED
LENINAKAN	1	75%	40	40	669	323	12450	11250	-	-	-	-
KIROVAKAN	1	25%	34	6	456		7162	2333	-	-	-	-
SPITAK	1	100%	9	6	28	24	433	433	-	-	-	-
STEPANAVAN	1	67%	9	1	134	12	2134	1430	-	-	-	-
RURAL AREAS	169	34%	39	34	581	186	29533	20094	1365	1259	34300*	76500*
TOTAL	173	60%	131	87	1868	545	51712	35540	1365	1259	34300*	76500*

Source: Civil Defense, Armenia SSR

*These data appear to have been interchanged.

The data presented in Tables 1 - 5 were obtained from General Leo Melkomov, Director, Civil Defense, Armenia SSR, in a briefing for members of the Disaster Reanimatology Study Group in Yerevan, Armenia SSR, March 21, 1989. These data were first presented in a paper by Joel Abrams et. al.,"Detection-Extrication in the Resuscitation Response to the Armenian Earthquake, December 7, 1988" to the Earthquake Injury Epidemiology Workshop, Johns Hopkins University, July 10-12, 1989. Dr. Abrams discusses the data from the perspective of search and rescue operations.

TABLE 2

RESCUE AND EVACUATION OF INJURED POPULATION

CLASSIFICATION \ DATE	7.12	8.12	9.12	10.12	11.12	12-18.12	19-25.12	TOTAL
TOTAL EXTRICATED	4328	9634	8243	6437	4419	8187	418	39795
EXTRICATED ALIVE	1382	1660	4825	5682	1757	150	1	15254
TOTAL EVACUATED	-	2470	130	1700	4081	59638	36418	119318
EVACUATED TO OTHER REPUBLICS	-	-	-	-	1300	34980	29235	79750

Source: Civil Defense, Armenia SSR

TABLE 3
EQUIPMENT RECEIVED FOR RESCUE WORK

SOURCE OF EQUIPMENT	DAYS OF RECEIPT AND TYPE OF EQUIPMENT				
	TOTAL	CRANES	BULLDOZERS	EXCAVATORS	MOTOR VEHICLES
	7 DECEMBER				
ARMENIA SSR	1530	287	190	183	870
OTHER REPUBLICS	380	32	15	19	314
TOTAL	1910	319	205	202	1184
	8 DECEMBER				
ARMENIA SSR	1980	332	247	201	1200
OTHER REPUBLICS	508	75	27	25	381
TOTAL	2488	407	274	226	1581
	9 DECEMBER				
ARMENIA SSR	2097	354	261	250	1232
OTHER REPUBLICS	1062	267	68	67	660
TOTAL	3159	621	329	317	1892
	10 DECEMBER				
ARMENIA SSR	2203	372	273	256	1302
OTHER REPUBLICS	1261	382	87	89	703
TOTAL	4064	754	360	345	2005
	11 DECEMBER				
ARMENIA SSR	2426	383	287	256	1500
OTHER REPUBLICS	2424	444	220	107	1653
TOTAL	4850	827	507	363	3153
	18 DECEMBER				
ARMENIA SSR	2531	421	291	262	1557
OTHER REPUBLICS	3631	784	451	296	2100
TOTAL	6162	1205	742	558	3657
	31 DECEMBER				
ARMENIA SSR	3036	656	291	268	1821
OTHER REPUBLICS	5922	1335	697	391	3500
TOTAL	8959	1991	988	659	5321

TABLE 4

RESOURCES UTILIZED FOR RESCUE AND TREATMENT

CITIES AND REGIONS	PERSONNEL (in thousands)			EQUIPMENT (units)			
	TOTAL	CONSISTING OF					
		CIVILIAN	CD UNITS	CRANES	BULLDOZERS	EXCAVATORS	MOTOR VEHICLES
LENINAKAN	39.3	30.5	8.8	974	301	167	2389
KIROVAKAN	3.5	3.5	-	178	124	65	474
SPITAK	7.3	6.0	1.3	415	187	103	897
STEPANAVAN	1.65	1.65	-	91	77	29	170
RURAL AREAS	9.6	9.6	-	333	299	275	1391
TOTAL	61.35	51.25	10.1	1991	988	639	5321

Source: Civil Defense, Armenia SSR

TABLE 5

RESPONSE TO EARTHQUAKE CONSEQUENCES

CITIES AND REGIONS	POPULATION					HUMANITARIAN AID					
						PRODUCTS (in tons)			HABITATION		
							INCLUDING				
	INITIAL POPULATION	PERSONS EXTRICATED	PERSONS DEAD	TOTAL PERSONS EVACUATED	PERSONS EVACUATED TO OTHER REPUBLICS	TOTAL	BREAD	MEAT	TENTS	PREFAB HOUSES	HEATERS
LENINAKAN	232.0	16959	9974	58642	39486	1688.5	1404	213.0	2924	1280	3173
KIROVAKAN	171.0	4317	420	34720	23188	1120.6	945	126.7	8280	50	560
SPITAK	18.5	13990	9733	8091	5377	982.0	835	109.0	11086	4774	2303
STEPANAVAN	21.0	108	63	-	-	857.0	747	82.0	5976	250	877
RURAL AREAS	146.5	4421	4352	17865	11699	4752.6	4316	322.0	26431	7363	8320
TOTAL	589.0	39795	24542	119318	79750	9400.9	8247	852.7	54697	14167	15233

Source: Civil Defense, Armenia SSR

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Source: Civil Defense, Armenia SSR

victims extricated from the rubble were dead. The reported cost of the disaster totaled $16 billion.

Second, the earthquakes generated an equally extraordinary response in terms of disaster assistance to the victims. Within Armenia, there was an immensely strong empathy and identification with victims and their families. Almost every Armenian was affected in some way by the disaster -- either by enduring the loss of family, friends, or colleagues or by being involved in some significant way with relief activities. Within the USSR, the Armenian earthquakes represented an historic instance in which the Central Government publicly accepted responsibility for a local disaster. News of the disaster was carried on national television. National political figures visited the devastated area. Students, physicians, rescue workers came from Karabakh, Kiev, Moscow, Leningrad and other parts of the country to assist their stricken countrymen.[3]

Within the Armenian Diaspora, the response was equally swift and generous. Armenian communities in the United States, France, Germany, Italy, Great Britain and Austria sent money, physicians, supplies and equipment, strengthening cultural and religious ties with their homeland. Within the international community, some 50 nations sent aid and solidarity payments. At least 267 physi-

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[3]. The extraordinarily generous response to the needs of the Armenian population from within the USSR is amply documented in both the US and Soviet press. See, for example, the New York Times issues for December 8 - 31, 1988. These accounts were verified by reports from our Soviet colleagues during formal and informal discussions, March 13 - 26, 1989.

cians from 14 nations volunteered their time and services in medical care for the victims.[4] Table 5 also cites humanitarian aid received in Armenia to meet basic needs of food and shelter for the victims. By December 31, 1988, Armenia had received $108,818,759 in disaster assistance from the international community.[5] The events in Armenia had created new networks of communication, assistance and support, crossing local, regional, national and international boundaries.

Third, the most distinctive characteristic of the Armenian earthquakes was the startling deadliness of their effects, despite the extraordinary efforts made in response. This deadliness is shown by two measures. The usual ratio of injured to dead, calculated from records of previous seismic events, is 3:1.[6] In the Armenian earthquakes, this ratio was reversed. Approximately three persons were found dead for every live victim extricated, as shown by the data reported in Table 5. Additionally, the gravity of injuries reported to hospitals in this disaster was exceptionally high. Of the 9,976 patients hospitalized immediately after the earthquake, 5,012 or 50.2% were

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4. Data provided by the Ministry of Health, Armenia SSR, March 24, 1989.

5. Data provided by the German Red Cross. Interview, Counselor, Embassy of the Federal Republic of Germany, Moscow, USSR, March 16, 1989.

6. This ratio has been estimated by the Pan American Health Organization, based upon cumulative data on the number of injuries/number of dead reported for recent earthquakes in the Americas. This ratio is cited in a documentary film, "International Disaster Assistance," prepared by PAHO for distribution in 1987.

classified as being in very grave or grave condition.[7] Many of these patients had multiple injuries that compounded their effects to reduce the victim's overall physical state.

The severity of consequences from the Armenian earthquakes contrasts with the damage reported from earthquakes in other regions within a comparable range on the Richter scale. For example, the 1971 San Fernando Earthquake in California registered 6.6 on the Richter scale, but less than 100 victims were killed.[8] The Mexico City Earthquake of 1985 registered 8.0 on the Richter scale, with approximately 10,000 known dead.[9] In the Chilean earthquake of March, 1985, magnitude 7.0 on the Richter scale, the bulk of injuries reported consisted of simple fractures, cuts and bruises.[10]

The extraordinary cost in lives and dollars reported in these findings compel us to ask why the Armenian earthquakes were so deadly and to re-examine the performance of the social, organizational and cultural systems critical to disaster preparedness and essential to the mobilization of disaster response. The capacity of these systems to recognize and respond appro-

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7. These data were reported by Robert A. Charchoghlian and R.V. Sekoyan in a paper presented by Dr. Charchoghlian at a conference on Earthquake Injury Epidemiology held at Johns Hopkins University in Baltimore, MD on July 10 - 12, 1989.

8. US Geological Survey Reports, San Fernando Earthquake, 1971.

9. U.S. Office of Foreign Disaster Assistance, Final Disaster Report: The Mexico City Earthquake, Washington, D.C.: January, 1986.

10. Pan American Health Organization, Medical Report, The Chilean Earthquake, March, 1985.

priately to the known threat of seismic risk, antecedent to the construction of the physical buildings that failed in Armenia, is central to our understanding of the problem of designing policy for environments at risk.

Unresolved Problems in Environments of Seismic Risk: Lessons from Armenia

Reviewing the set of events and the ensuing consequences of disaster operations from the Armenian earthquakes, three problems stand out as integrally related to the failure of human and physical systems in this environment of seismic risk. These problems are recognizable in similar environments elsewhere in the world, and, without appropriate design for public policy, are likely to recur with the next major earthquake, whenever and wherever that may be. These problems, recognized by Soviet and US observers alike, include: 1) the interdependence of events that lead to disaster, created by the interaction between seismic events and the physical and social systems established by human communities in seismic zones; 2) the organization of coordinated response among multiple organizations and jurisdictions with emergency responsibilities; and 3) the efficiency of response operations, that is, allocating scarce resources for maximum benefit to minimize losses for the affected population. Each problem will be discussed briefly in turn.

The Problem of Interdependence

The Armenian earthquakes illustrated again the fact that earthquakes trigger not only the collapse of buildings and the consequent injury and death of victims, but also the collapse of the infrastructure of communication and coordination that enable local communities to respond to the demands generated by disaster. This infrastructure includes the systems of communications, transportation, and organizational capacity to mobilize resources and personnel. For example, in Spitak, the central telephone office was totally destroyed in the earthquake, leaving the town with no civilian telephone communications. In the other cities of Armenia, the situation was the same. The military telephone system was operating, but it was not available to civilian personnel and could not be used to call civilian organizations or personnel.[11]

This condition was further complicated in the multicultural context of Armenia, where the language of coordination used by government agencies, Russian, differs from the language of the people who need services, Armenian.[12] This complexity increased with the entry of international search and rescue teams, and additional languages, into disaster operations. Cultural differences posed a formidable barrier to cognitive processes in human interaction, already under stress by the trauma of the event.[13] Coordination requires an infrastructure of communica-

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11. Briefing, Civil Defense Headquarters, Armenia SSR, Yerevan, Armenia, March 21, 1989.

12. Briefing, Civil Defense Headquarters, Armenia SSR, Yerevan, Armenia, March 21, 1989.

13. See the discussion of the selective identification of risk in Mary Douglas and Aaron Wildavsky, Risk and Culture, (Berkeley: University of California Press, 1982.) See also the

tion and common understanding that facilitates collaborative problem solving and action (Simon, 1969, 1981).

In the complex, uncertain environment of disaster, failure in one system triggers failure in other, related systems. Like dominoes falling in sequence, the earthquakes in Armenia initiated a series of events that caused systemic failure in the affected communities. For example, the schools collapsed, seriously injuring children and teachers trapped inside. Simultaneously, the communications facilities needed to call for assistance were destroyed, as were the hospital facilities needed to provide prompt medical care to the injured victims, had transport been available to get them there. Tragically, victims who survived the earthquake died from the damaged community's inability to respond to their needs in time.[14]

The problems in Armenian disaster operations were inherently interdisciplinary, requiring the combined knowledge and skills from multiple disciplines to mobilize appropriate response under the urgent time constraints of disaster. The complexity of disaster is such that no single discipline can unravel the problem. Each, in turn, contributes substantively to solving the problem. Yet, it requires continual adjustment to maintain the focus of attention on the shared problem of saving lives in order

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argument presented by Judith Bradbury, "The Policy Implications of Differing Concepts of Culture" in Science, Technology and Human Values, Vol. 14, no. 4, 1989, in press.

14. Interviews, Lay witnesses, Spitak, Leninakan, Armenia SSR, March 22, 1989.

to bring relevant information from the disciplines of geophysics, engineering, medicine, organization and management to bear on the succession of dynamically evolving events in disaster operations. Without focus, efforts to take action may lapse into stalemate or wander off track in ineffective uses of resources and time.

The Problem of Organization

The problem of organization follows directly from the interdependence of human systems in communal environments. Without communication, there can be no coordination. Without coordination, there can be no organization. Both Soviet and international observers noted an initial lack of organization in the search and rescue operations.[15] Coordination of action means knowing what to do, how to do it, when to do it, who will do it and what to do it with. This knowledge depends upon a shared understanding of the requirements of action among the participants (Simon, 1969, 1981) involved in disaster operations.

Without organization, large numbers of individuals, though well-intended, may actually slow down the search and rescue process, or hamper it in other ways. For example, when students at Yerevan State University learned of the earthquakes in northern Armenia about 5:00 p.m. on December 7, 1988, they arranged buses for transportation and left for Leninakan. However, they had no previous experience in disaster operations and arrived in Leninakan, eager to work but unprepared for the

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[15]. Briefing, Chief of Medicine, USSR Civil Defense, Moscow, March 18, 1989. See also newspaper accounts of response to the disaster, <u>New York Times</u>, December 8 - 31, 1989.

extent of devastation they found. They had no tools, no lights, no tents, no first aid training, no gloves for working outdoors in subfreezing temperatures. For too many, the experience was fruitless and their energies were expended unproductively. Disappointed, they returned to Yerevan and tried to regroup.[16]

To achieve organization in disaster environments requires clear definition of the classic functions of disaster operations, so that multiple participants may be integrated into an overall response effort to meet the vast array of demands generated by the disaster. This definition of tasks is a product of conscious policy design, best done prior to the event. Time taken for organization after the event subtracts precious minutes, hours or days from the critical period during which life-saving operations are most productive.[17]

The Problem of Efficiency

Difficulties generated by the interdependence of events and, sequentially, in the organization of response lead to the problem of efficiency in disaster operations. In the Armenian disaster, this problem was underscored by the high expenditure of effort and money in disaster response in comparison to the low rate of return in terms of lives saved and the heavy losses reported in damages. The sobering losses in the Armenian earthquakes--

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16. Interview, student participants in disaster operations, Yerevan State University, Yerevan, Armenia, March 20, 1989.

17. See Table 2 above; see also P. Safar, E. Pretto and N. Bircher, "Disaster Resuscitology Including Management of Severe Trauma" in P. Baskett and R. Weller (eds.), Medicine for Disasters (London: Wright-Butterworth Publ., 1988): 36-86.

25,000 reported dead and $16 billion in damages -- compel us to re-examine our understanding of the processes of disaster management and to reconsider our present procedures for response.

Efficiency in disaster operations requires a different measure, when the goal is to save lives placed at risk. The data show that if victims are extricated within the first 72 - 96 hours, their chances of survival are higher. The rate of live recoveries drops sharply after Day 4 and precipitously after Day 5. The measure of efficiency in disaster operations is necessarily time, not money, which runs counter to the measure used in routine operations by most government agencies.

The efficiency of the international search and rescue teams in the Armenian disaster operations illustrates this problem. The French rescue team, first of the international teams, arrived 79 hours after the event. The team helped 1,000 people who were injured, but they rescued only 15 live victims from the rubble.[18] Other teams arrived still later and rescued still fewer live victims.[19] Disaster management necessarily involves the period before the event as well as after in order to address the problem of efficiency.

Can losses incurred in disaster be reduced? We cannot stop

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18. Interview, Attache and Coordinator, French Contribution to Armenian Disaster Assistance, Embassy of France, Moscow, USSR, March 17, 1989.

19. Interviews with officials responsible for coordinating their respective nation's contribution to Armenian disaster assistance in the Embassies of the United States, Great Britain, West Germany and Italy, Moscow, USSR, March 15 - 18, 1989.

the earthquakes, but are there actions that can be taken prior to such events to reduce the risk to human populations and to lessen the damage to built environments in zones of known seismicity? In terms of efficiency, expenditures projected over a 100-year period to strengthen construction codes or to prepare populations to respond to known threats may be calculated against the known costs of disaster where these actions have not been taken. To initiate such a policy, however, requires that the responsible organizations take the "long term view" (Naisbitt, 1983), a shift in perspective that does not come easily in human organizations vying for immediate support in complex policy environments (Deutsch, 1963, 1965). Such a policy shift is not likely to be achieved without design.

Disaster managers are working against time in seeking to increase the efficiency of response operations (Zancanato, 1988; Safar, 1976, 1986.) Actions taken or not taken in one phase of the classic cycle of disaster management may facilitate or hamper operations in the next (Comfort, 1985.) Clarifying functions within disciplines and within time phases allows managers to see more directly the relationships between immediate problems and the resources available for solution, thereby increasing efficiency in disaster operations.

Cumulatively, these three problems -- interdependency, organization and efficiency -- interact to diminish human problem-solving capacity in disaster environments. Repeatedly, we observe that human judgment falters in complex environments, and performance drops (Simon, 1969, 1981; Comfort, 1985, 1986, 1987, 1988). This drop in performance is related directly to the "load" (Deutsch, 1963, 1966; Cohen, March and Olsen, 1972), or burden of demands, placed upon human cognitive capacity. It results not from perverse intent or timidity, but from our limited ability to process information in short-term memory (Newell and Simon, 1972.) According to cognitive theorists Newell and Simon, human decision-makers solve immediate problems using short-term memory capacity, but since this capacity is limited to remembering only seven items at a time, plus or minus two, it is easily overwhelmed in complex environments (Newell and Simon, 1972; Simon, 1969, 1981). In disaster environments, with the tremendous flux of information, the cognitive processes of human decision-makers quickly become overloaded. Unable to process the information quickly or accurately, human decision-makers ignore much of it...and err in judgment, or worse, are unable to act. Repeatedly observed in disaster environments (Comfort, 1985, 1986, 1988, 1989), this situation was acknowledged by Soviet officials in Armenia, and prompted a sobering re-examination of the disaster management process within the USSR and among other national agencies involved in disaster assistance and response.[20]

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[20]. Interview, Chief, Civil Defense, Armenia SSR, Yerevan, Armenia, March 21, 1989. Other organizations, national and international, also re-examined their roles in the Armenian disaster operations in an effort to prepare more effectively for participation in future disasters. For example, an international conference of leaders of search and rescue teams was sponsored by the US Office of Foreign Disaster Assistance in Washington, D.C.,

The interaction of the conditions of disaster environments and characteristics of human problem solving capacity creates a condition in which the most promising alternative for amelioration lies in increasing individual and organizational capacity for performance (Deutsch, 1963, 1966; Argyris, 1984, 1985). This task, difficult by any measure, is conceivable with the appropriate linkage of current information technology to individual and organizational decision-making processes in disaster management (Comfort, 1988, 1989.) It is, however, quintessentially a problem of design.

Increasing Capacity for Problem-Solving in Uncertain Environments

The capacity of individuals, organizations and jurisdictions to respond appropriately to the complex range of demands generated by a catastrophic earthquake depends directly upon access to timely, accurate information and modes of processing information relevant to action. In the complex, uncertain, dynamic environments of disaster, decision-makers are limited not only by the technical failures of communications facilities, but also by their own cognitive capacity, as stated above (Newell and Simon, 1972; Simon, 1969, 1981). Barry Turner, British sociologist, views the occurrence of disaster as a manifestation of gaps in information in societal decision-making processes, and our consequent ability to respond rationally to unanticipated problems from the environment. Turner (1978:134) writes:

May 8-9, 1989 to explore means of improving performance in search and rescue operations in future disasters.

> ...The limits on rationality are essentially the limits of information-gathering in a world where information-gathering has costs; the limits of the number of possible alternative solutions which can reasonably be considered and evaluated ...and the limits of a lack of knowledge of future events where rational behavior depends upon the formulation and successful execution of plans which promise attainments in the future.

Consequently, the occurrence of disaster signals the need for re-examination of the information processes upon which decisions within and between organizations, within and between jurisdictions are based in environments. Within the complex, dynamic net of organizational interaction characterizing a given community, particularly one vulnerable to seismic risk, gaps in information, reasoning or communication may have triggered unintended consequences, initiating a sequence of events that lead to disaster. The decisions leading to the construction (since 1979) of high-rise apartment buildings in Leninakan that failed seriously in the December, 1988 earthquakes tragically illustrate such gaps in information in the social decision-making process.[21]

Returning to Deutsch's (1963, 1966) concept of perceptive reason, the most promising alternative for increasing human rationality in the complex environment of disaster is to open existing decision processes to insights, modes of information processing and assistance external to present actors and procedures. Current information technology allows us to extend our

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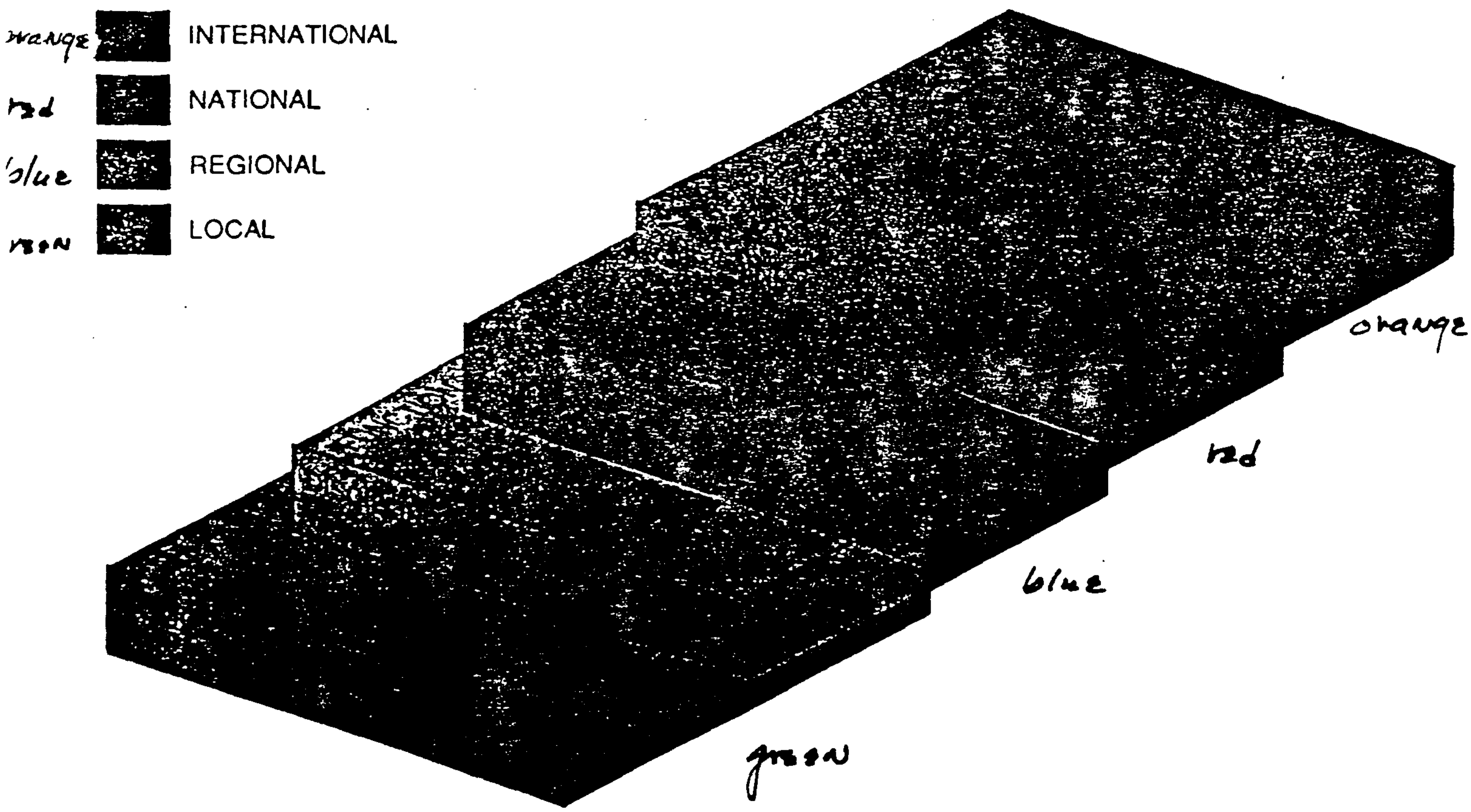
21. Briefing, US Reconnaissance Team, Earthquake Engineering Research Institute/National Research Council on the Armenian Earthquakes, San Francisco, CA, February 9, 1989: 4:00 - 7:00 p.m..

human problem-solving capacity with the aid of carefully designed computerized knowledge bases, heuristic reasoning processes and spatial representation of complex information, accessible over long distances through telecommunications and satellite linkages (Nii, 1987; Hayes-Roth, Waterman and Lenat, 1983; Dodhiawala, Jagannathan, Baum and Skillman, 1989; McCann, Taylor and Tuori, 1988; Comfort, 1986, 1989). Yet, these systems need to be designed to support human decision processes in the complex, dynamic environments of disaster (Comfort, 1988, 1989).

<u>Integrating Information Processes to Support Problem Solving in Environments at Risk</u>

The three initial problems identified in the Armenian disaster operations -- interdependence, organization and efficiency -- suggest three basic dimensions that characterize decision processes in disaster management at each jurisdictional level. These dimensions are time, function and discipline, and can be represented in a layered knowledge base, as shown in Figure 1. Within each jurisdiction, these dimensions may be further specified into sub-types that order information needed by disaster managers with differing responsibilities. The dimension of discipline, for example, addresses the problem of interdependence. If information critical to decisions involving the differing perspectives of disaster management -- technical, organizational, medical, political and cultural -- are organized by discipline and are accessible to all managers operating at each jurisdictional level, the result will be a shared knowledge

FIGURE 1 A Model of Multi-jurisdictional Response in Disaster Management



base for interdisciplinary problem solving that would otherwise not be available to any single manager. This specification of dimensions is shown for a local jurisdiction in Figure 2.

The dimension of time is critical, not only as a measure of efficiency in disaster management, but in the clear specification of tasks that show the sequence of evolving phases in disaster management. Tasks not performed in one phase are likely to carry over and increase the load of organizational demands requiring response in succeeding phases. The classic sequence of time phases in disaster management (McLoughlin, 1985), shown in Figure 2, allows the specification of primary tasks during each phase for disaster managers at the respective jurisdictional levels.

The dimension of function is central to the integration of information from the differing organizational actors within each jurisdiction and within the set of four jurisdictions. Also shown in Figure 2 are five basic functions performed by managers at each jurisdictional level: notification of the event, assessment of needs, mobilization of resources, performance of tasks, evaluation of performance and redesign of new actions.

In further specification of tasks, the information essential for each discipline may be specified by time and function in disaster management. Figure 3 illustrates this specification for the medical discipline by the subdisciplines of basic life support, advanced life support and prolonged life support (Safar, 1976, 1986; Klain et al., 1989)

In summary, it is possible to design a knowledge base that orders information by the dimensions of time, function and discipline that are essential to decision-making in environments at risk. Such a knowledge base would both increase access to shared information for participating disaster managers and reduce the complexity of information processing required of managers in disaster operations, thereby substantively extending their problem-solving capacity. Combined with the interactive capacity of satellite and telecommunications facilities and intelligent reasoning routines in the utilization of the knowledge base, it is possible to create an interactive network of information search, processing and dissemination for disaster management that may increase performance in the difficult, complex, dynamic environments of disaster (McCann, Taylor and Tuori, 1988.) A demonstration model for an interactive, intelligent, spatial information system (IISIS) for local public, private and non-profit organizations is currently under development for the Pittsburgh Metropolitan Region (Comfort, Woods & Nesbitt, 1989.)

Critical to improving performance in disaster environments is the accurate interpretation and appropriate utilization of the information available to multiple decision-makers operating at multiple levels in disaster management. Computers can also help human decision makers shift levels of analysis more easily in interpreting the vast flux of information that characterizes disaster environments. The problem-solving process in disaster management shifts through at least six levels of aggregation and inference (Argyris, 1980:147) in the translation of information into action, as shown in Figure 4. These shifts in levels of aggregation and inference are not easy for managers with emergency responsibilities, as each shift requires that we rethink the problems in the context of expanded data and broader categories of possible interaction (Argyris, 1984.) Under the urgent stress and pressure of time in actual disaster operations, this cognitive task is particularly difficult, if not impossible for human decision-makers.

Most managers shift easily from the individual to the sub-disciplinary to the disciplinary levels, but find it increasingly difficult to move to multidisciplinary, interdisciplinary and societal levels of aggregation of information and inference to action. Yet, it is precisely the capacity to design actions at these higher levels of aggregation and inference that are central to increasing the effectiveness of performance of our organizational and social infrastructure in catastrophic disaster.

To respond effectively to disaster, or to cope with the risks presented by environments vulnerable to disaster, we need to create flexible organizations (Meltsner and Bellavita, 1984) that will expand rapidly to meet the sudden demands of disaster and contract easily when the threat has passed and operations return to routine conditions. Current information technology allows us to develop this capacity by design, and recent developments in disaster management are moving steadily in this direction. Figure 5 shows a set of existing information systems that may serve this need, if extended and linked in a network of

FIGURE 4 Levels of Aggregation and Inference in Disaster Research

Level of Inference	Unit of Aggregation	Research Task
6	Societal	Definition of Goal: To Protect Life and Reduce Loss
5	Interdisciplinary	Definition of Problem
4	Multidisciplinary	Data Collection and Measurement
3	Disciplinary	Data Analysis and Interpretation of Findings
2	Sub-disciplinary	Design of Alternative Strategies for Action
1	Individual	Direct Observation, Reflection and Redesign

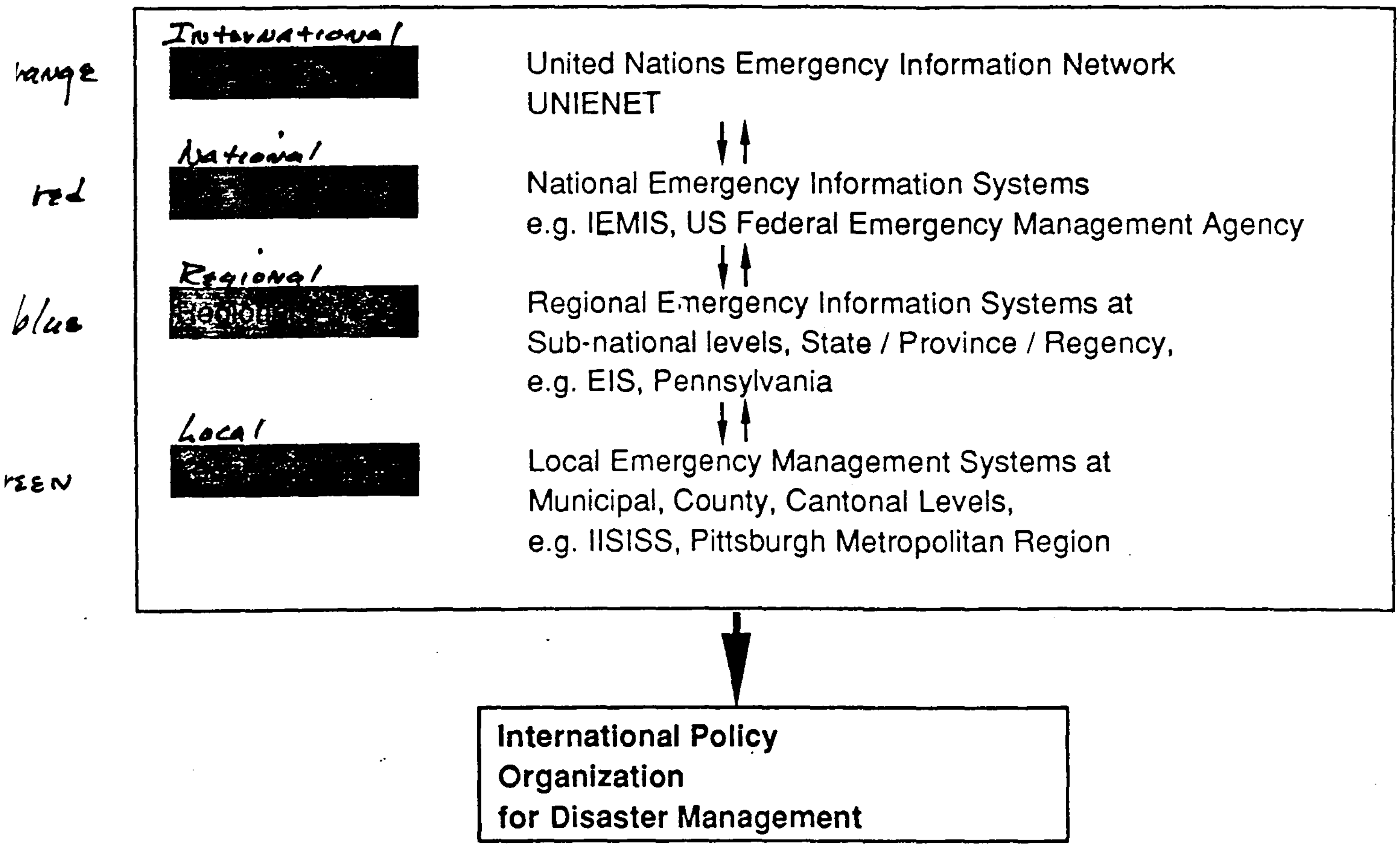
Unit of Observation: Individual

Unit of Analysis: Organization

Measure of Performance: Efficiency in Time

Outcome Variable: Lives Saved / Lives Lost

FIGURE 5 Interactive International Disaster Information Network



international information systems to support decision processes for disaster response and risk reduction.

Developed and used effectively, such a set of information networks may be used to support "policy organizations," that is, full time organizations of personnel with part-time responsibilities (Meltsner and Bellavita, 1984) for disaster management. Most managers with emergency responsibilities in public and/or private organizations have other responsibilities and other jobs. They come together only in the context of disaster to carry out a common policy of coordinated response. These policy organizations could operate at jurisdictional levels to meet particular demands or, linked together, respond promptly and appropriately to meet the demands of a catastrophic disaster. Communication and coordination processes are crucial, however, for the effective utilization of skills and knowledge of the respective participants. To the extent that these organizations are designed and used effectively, they are likely to reduce the dimensions of catastrophe in environments at risk. Such utilization may be facilitated through an interactive, intelligent, spatial information system.

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