Title
Integrating information technology into international disaster policy and practice

Author
Comfort, Louise K.

Publication Date
1992

INTEGRATING INFORMATION TECHNOLOGY INTO INTERNATIONAL DISASTER POLICY AND PRACTICE

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

Working Paper 92-3

IGS
INSTITUTE OF
GOVERNMENTAL
STUDIES

UNIVERSITY OF CALIFORNIA AT BERKELEY

INTEGRATING INFORMATION TECHNOLOGY INTO INTERNATIONAL DISASTER POLICY AND PRACTICE

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

Working Paper 92-3

INTEGRATING INFORMATION TECHNOLOGY INTO INTERNATIONAL DISASTER POLICY AND PRACTICE

Louise K. Comfort

Graduate School of Public and International Affairs
University of Pittsburgh

Prepared for presentation at the International Conference, "The Impact of Natural Disasters", University of California, Los Angeles, July 10-12, 1991.

Revised: December 27, 1991

ACKNOWLEDGMENTS

The author acknowledges, with thanks and appreciation, the Institute of Governmental Studies, University of California, Berkeley for providing a stimulating and supportive environment for scholarly work. Also acknowledged are the many practicing managers engaged in disaster operations in local, state, provincial, national, and international jurisdictions who have provided candid assessments and access to field observation of disaster operations. For reasons of professional confidentiality, they are not named in this study, but the work could not have been done without their willing and substantive cooperation. Nathaniel Comfort provided editorial assistance.

ABSTRACT

Decision processes in disaster environments pose a special challenge to rational problem solving. The urgency, complexity and uncertainty of disaster environments test the limits of human capacity for seeking, processing, and disseminating information to support coordinated action. Current information technology offers a means of extending human problem solving capacity through an interactive, intelligent, spatial information system, if it is supported by a parallel organizational system designed to facilitate coordinated action.

A preliminary model of organizational problem solving is proposed, focusing on the global problem of seismic risk. The model relies on the function of information technology to reduce uncertainty by increasing the timeliness and accuracy of information to disaster managers, thereby improving coordination in organizational performance. The model links information technology to organizational structure in ways that create feedback channels, improve organizational learning, and increase capacity to correct organizational mistakes. The model is presented in terms of structuring technical and organizational conditions to support improved capacity for organizational problem solving in communities vulnerable to seismic risk. Illustrative data from a series of seven earthquake disasters demonstrate an evolving receptiveness to the integration of information technology into international disaster policy and practice.

INTEGRATING INFORMATION TECHNOLOGY INTO INTERNATIONAL DISASTER POLICY AND PRACTICE

Complexity, Decision Processes and Information Technology in Disaster Environments

The rate and efficacy of organizational and interorganizational problem solving in complex, uncertain environments may be increased through structured information processes and appropriate uses of current information technology. This increased capacity for interorganizational problem solving may then be incorporated into policy and practice to increase the efficiency of international disaster assistance. The present analysis will, first, review briefly the major theoretical perspectives on organizational decision processes in uncertain environments and propose a rationale for continuing inquiry. Second, it will assess the characteristics, strengths and limitations of current information technology as a means of facilitating decision processes for practicing managers engaged in interorganizational disaster operations. Finally, it will examine the potential benefits, liabilities and requirements for integrating information technology into international disaster policy and practice.

In the urgent context of disaster, actions are taken without calculating cost until the critical phase of life-threatening danger is past. But in the aftermath, questions of effectiveness, efficiency, and timeliness in disaster operations are asked again. Disaster managers, searching for ways to improve their effectiveness, are hindered by a critical lack of information and/or means of communicating it in timely manner to the relevant parties to coordinate appropriate response. Problems of efficiency in organizational action directly affect the capacity of the community to respond in disaster.

Decision processes in disaster environments defy ordinary rules of rational analysis and organizational performance (March and Weissinger-Baylon, 1986; Comfort, 1986, 1988). The context of action is too uncertain and the elements of planning are too ambiguous for the development of detailed, specific strategies to guide action effectively in crisis. The critical task is to identify the factors that increase the capacity of organizations to solve problems under stress, the factors that inhibit this process in actual disaster events and the points of interaction between the two sets.

To address this task, we need to examine both the modes of analysis and the design of organizational decision processes in disaster environments. This paper will examine three aspects of the problem: 1) the means of inquiry to support decision making in disaster environments; 2) the interaction between the disaster environment and decision processes in actual operations; and 3) the potential of information technology to facilitate decision processes in the environment of disaster.

Organizational Decision Processes Under Conditions of Uncertainty

Four major perspectives on organizational performance under conditions of uncertainty have emerged from practice and research. These are command and control, organizational anarchy, evolutionary learning, and organizational problem solving. Each will be reviewed briefly to present the research traditions that have informed this analysis.

Command and Control

Military training and tradition exemplifies most aptly the concept of 'command and control' (Train, 1988; Weissinger-Baylon, 1988; Crecine, 1988), but it is also reflected in the hierarchical design of authority structures and highly specified tasks of "tightly coupled systems" in the administrative science literature (Taylor, 1911, 1967; Gilbreth, 1917, 1973; Perrow, 1972). The principle of 'command and control' is clear specification of the authority relationships among subunits in order to increase control over performance of the whole organization. It is largely a deterministic model, and seeks to reduce uncertainty in organizational performance through detailed plans and training.[1] While this organizational design has proven functional and robust in well-structured, routine conditions, it is weakest in uncertain, dynamic conditions. In these complex environments, it is vulnerable to "lock out," (Cohen and Levinthal, 1990:136) or the exclusion of relevant information from the decision process. In disaster management, organizations with legal responsibilities for first response -- police, fire, emergency medical services -- operate primarily with a command and control orientation in training and field action. Field commanders have recognized the weaknesses of this orientation in the complex, dynamic conditions of disaster. Extensive efforts have been made to adapt the strengths of command and control principles to disaster environments, where common training and skills enable multiple units to work readily in coordinated action, but flexibility is needed for rapid response. For example, the US Forest Service developed the "Incident Command System," a widely used adaptation that is accepted by emergency response services across the US.[2]

Organized Anarchy

A second major perspective views organizational decision making largely as "organized anarchy" (Cohen, March and Olsen, 1972). Under conditions of uncertainty and ambiguity, the authors assert that organizational decision making is not a rational process determined by careful planning, but rather one that is strongly influenced by the limitations of human capacity for attention, timing and the continual flux generated by a dynamic environment. The model reverses the assumption of organizations operating in static, well-structured environments and acknowledges demands placed upon organizational decision processes by conditions of "problematic preferences, unclear technology and fluid participation" (Cohen, March and Olsen, 1972:1-2). In such environments, agreement on either goals or means is difficult to achieve. Without consensus on goals, acknowledgment of authority becomes largely irrelevant and means of action are unrelated to specific objectives. Consequently, organizational decisions, when they occur, are largely accidents of timing and spontaneous recognition of an appropriate 'fit' between problem, solution and participants.

Organizational problem solving requires participants to focus attention on external demands and resources from the environment in an intelligent, timely manner (March, 1988; Cohen, 1988). Cohen (1988:65-66) further proposes the criterion of "flexibility" in adapting to the demands and opportunities generated by the environment as a measure of organizational effectiveness. This flexibility allows participants to recognize novel solutions emerging from dynamic conditions that may fall outside the previously defined rules of "command and control."

Recognizing that organizational decision processes may not be fully nor consistently anarchical, several researchers have used the garbage can model to examine decision processes in more structured settings (Weiner, 1976; Crecine, 1988; Train, 1988). Train's (1988) characterization of the stages of organizational decision in battle, acknowledging the constraints of heavy load and deadlines upon military commanders, offers a useful analogy to decision making in disaster environments.[3] Disaster managers operate under similar constraints of heavy load and deadlines, but frequently without the common skills and orientation of military training.

In comparing the performance characteristics of tightly coupled systems, such as those in command and control organizations, to those of loosely coupled systems, such as those characterterized by organizational anarchy, Crecine (1988: 82-88) notes that both types of systems confront conflicting goals among participants, cope with uncertainty in the parameters of action, search for solutions to problems, and engage in organizational learning. However, the two types of systems cope with uncertainty in fundamentally different ways, and this difference shapes their performance on other primary relationships. Tightly coupled systems seek to establish greater control over their participants and operating conditions in response to unexpected or ambiguous demands from the environment, restricting organizational attention to specific problems and solutions. In contrast, loosely coupled systems acknowledge that previously defined problems may be inaccurate or their associated rules inappropriate under changing or ambiguous conditions. These systems relax structural controls on attention and allow the spontaneous matching of problems, solutions and participants in creative response to perceived opportunities or needs. Neither type of organization, however, manages to achieve fully consistent, efficient performance in uncertain conditions. The difference between the two models lies in their assumptions about how organizations learn.

Evolutionary Learning

A third major perspective on decision processes in uncertain conditions emphasizes patterns of evolutionary learning in organizational behavior (Holland, 1975; Piaget, 1980; Axelrod, 1884; Comfort, 1986; Haas, 1990). This perspective draws on the theory of adaptation from evolutionary biology (Holland, 1975), and observes that organizations consistently assess the consequences of their actions upon their immediate environment and, over time, will choose alternatives for action that strengthen their chances of survival. However, time is required for adaptation and the feedback process driving organizational learning is indirect. Organizations may learn inappropriate lessons from limited experience and seek to apply those lessons in a similar context, but obtain very different results.

While the evolutionary learning perspective offers insight for understanding adaptation in organizational behavior over the long term, it does not meet the needs of disaster managers who cope with sudden onset events requiring immediate response. Organizations appear to engage in two types of learning. First, they assimilate information from experience and the external environment and store it in their repertoire of possible responses to apply in similar situations (Newell and Simon, 1972; Argyris, 1982; Piaget, 1980). Second, more directly related to problem solving, they create knowledge to fit novel situations (Simon, 1985). Disaster managers urgently need this type of creative problem solving in the complex, time-dependent context of disaster, but it is also difficult to achieve at the organizational level.

Organizational Problem Solving

A fourth perspective, organizational problem solving, addresses the problem of decision making under conditions of uncertainty through the design (or redesign) of systemic patterns of communication, information and action (Deutsch, 1963; Churchman, 1971; Lindblom, 1979; Meltsner and Bellavita, 1983). This perspective acknowledges information as the driving force of organizational action (Deutsch, 1963), and considers skills in search, processing and utilization of information central to the design of structures for action (Churchman, 1971; Habermas, 1976; Burt, 1982).

The goal of the system becomes the organizing framework for collective action, and the organizational components of the system adjust their actions to one another and to the environment in terms of their respective understanding of the systemic goal and its requirements. The organizational system, in turn, becomes the vehicle for common discovery and transmission of information from the environment to its constituent parts and back again, enabling the members to reach a collective goal.

An inquiring system is fundamentally a means of organizing information and communications processes in order to solve problems for a specific group. It is goal-seeking, open-ended, enabling and fosters cooperation among the participating members (Churchman, 1971: 200). This perspective allows organizations to draw from a wider array of knowledge and resources than is possible for individuals acting alone, enabling them to address larger, more difficult and more complex problems.

The difficulty in designing an inquiring system intended to solve a particular set of problems lies in keeping that system sufficiently open for continuing, broad information search and processing, but sufficiently focused to carry out specific action. The system needs to operate simultaneously at macro and micro levels in the search for, processing and transmission of, information. At the macro level, decision makers need to view the entire organization's operation to maintain their focus on the basic goal. At the micro level, managers need detailed information to plan specific actions that, cumulatively, achieve the goal for the whole system. Information about specific units at the micro level is aggregated to inform macro level policies for the entire organization, while macro level monitoring of the environment, in turn, provides resources and sets limits on micro level action. The interaction between the two processes of inquiry is continuous.

This perspective quickly encounters the limits of human information processing capacity in addressing large, complex problems. Although the basic ideas have been present in the literature for nearly thirty years, researchers have not linked information processes with structural designs for action in consistently successful ways. Shifting the focus on problem solving from the individual to the organizational level presents problems of communication and coordination that are significantly more complex and interactive (Argyris and Schon, 1974, 1978). Descriptive accounts of organizational networks (Meltsner and Bellavita, 1983) document successful organizational efforts to achieve specific goals, but these networks become vulnerable to changes in inputs of individual energy and commitment over time (Bardach, 1977). Current information technology extends human problem solving capacity through the use of computers and telecommunications in the design of an inquiring system, resulting in a problem solving approach that is strong both technically and organizationally. While the technical capacity is available to meet the information processing requirements for large, complex problems, the organizational designs to establish and utilize these systems productively are not yet defined or developed.

In summary, information processes drive the decision function in all four theoretical perspectives, yet the result of these processes differs in interaction with the structure of the organization. Improving the technology of information processes in disaster management alters one of the basic parameters of the "organized anarchy" model, and links information to action in ways that reduce uncertainty in the disaster environment. The resulting shift in organizational design, however, requires technical assistance for the organizational participants to acquire new skills in the search for, and utilization of, information. Introducing this technology also creates opportunities to restructure the organization (Goodman, Sproull and Associates, 1990) and to re-examine the allocation of authority, attention and resources in disaster operations on the basis of more timely, accurate and comprehensive information. Such proposed changes are likely to encounter resistance in established organizations reluctant to yield accustomed practice, even if unproductive, to unfamiliar technologies (Argyris, 1990; Goodman, Sproull and Associates, 1990). A clear portrayal of the function of information technology in relation to organizational decision making in uncertain environments is central to its appropriate use.

The Function of Information Technology in Uncertain Environments

Information technology provides three ways of overcoming some limitations in human information processing that have long stymied organizational action in complex environments. First, it allows the creation of an interactive network for disaster managers (Comfort, Woods and Nesbitt, 1990), facilitating communication and focusing attention on the same problem at the same time. Second, information technology allows the representation of information in graphic form, thus simplifying complex data and increasing the speed and accuracy of communication (Deutsch, 1963; Simon, 1969, 1982). Third, information technology allows the development of an 'extended memory' or knowledge base for a given community, which stores relevant knowledge about the community and its population and assists managers in quickly formulating alternative courses of action during a disaster. Each of these functions has been discussed in detail elsewhere (Comfort, Woods and Nesbitt, 1990).

The three computerized information functions -- interactive communications, graphic representation and logical inference -- operating together for a given organization, create a fourth, and vital, capacity to correct organizational mistakes in a timely manner. This capacity shifts the time perspective of organizations forward, and encourages participants to review their performance in order to improve strategies for future action. This capacity for adaptive response to incoming information, reflected in Cohen's (1990) concept of 'flexibility,' is greatly facilitated by the ease of storage, retrieval and review of information through a carefully designed knowledge system. It acknowledges the useful role of error, or deviation from established rules, in maintaining the effective functioning of the system. Professional monitoring of errors in a complex, dynamic system provides valuable clues to possible weaknesses in the system or changes in the environment that allow necessary adjustment before more serious failure occurs. Like tuning an orchestra, such monitoring is not construed as a penalizing measure, but rather as adjusting the 'fit' of the units of the organization to one another and to the environment improving the performance of the whole. The value of error hinges on the interpretation of consequences for the whole organization and its continuing action in the wider environment.

Technology alone does not ensure an increase in an organization's problem solving capacity. Rather, it provides a means for re-examining the ways in which organizations seek to solve problems (Goodman, Sproull and Associates, 1990), thereby enabling conscious efforts to improve the process. Weick's (1990) concept of parallel information structures, one within the machine and one within the manager's mind, offers an apt analogy to the appropriate use of information technology in creative problem solving. To Weick, the effectiveness of information technology in solving problems increases to the extent that the manager understands the functions that are performed by the machine. This condition is especially true for a complex, interorganizational system engaged in international disaster operations.

The converse is also true: problem solving processes will be useful only to the extent that they are designed to reflect the desired model of problem solving within the organization (Hayes-Roth, Waterman and Lenat, 1983). This point is critical for the design of the knowledge system within the computer. Logical inferencing techniques, carefully designed, support the creation of knowledge by practicing managers, whereas search, storage and retrieval systems provide systematic, reliable confirmation of existing knowledge. In disaster operations, both techniques are needed, but the inferencing techniques become increasingly important as urgency and uncertainty rise.

At the community level, parallel technical and organizational information systems could be created to support collective problem solving to mitigate disaster. The relevant characteristics of a community and a community-wide organizational system would be stored electronically, with a matching mental model of problem solving tasks, skills and goals stored in the minds of the responsible managers in that community. The result is a process of 'structuration' (Weick, 1990; Scott, 1990; Barley et al., 1990) or interaction between the organization and its environment, where thoughts and actions of members of the community become part of the 'technology' shaping the organization and its overall capability to solve problems for the community.

The implementation of such a community-wide information system, therefore, presents both technical and organizational requirements. The organizational requirements include a willingness on the part of the participants to learn the conceptual and technical skills essential to participate effectively in the information system. The rate at which such a system may be implemented successfully depends in part upon the community's "absorptive capacity," (Cohen and Levinthal, 1990) or ability to absorb new information and translate it into working knowledge and skills. To implement a community information system effectively, disaster managers need to adjust the levels of information and skills needed to operate the technical system to fit the users' mental skills and knowledge, while encouraging the development of the users.

The concept of parallel technical and organizational information systems operating at the community level supports the development of community capacity to respond effectively to disasters. It suggests a rational ecology of interacting human, natural and technical systems that may be designed as a global inquiring system to support international disaster assistance.

A Model for a Global Inquiring System Directed Toward Reducing Seismic Risk

Seismic risk to human systems can be substantially reduced with the appropriate design and implementation of information technology. Earthquakes occur, without warning, in inhabited areas where infrastructure is not built to withstand the severe shaking. Without adequate preparation for earthquakes, failure in one technical system triggers failure in others, as buildings fall, transportation routes collapse, communications jam, and power lines, water systems and other basic services are disrupted. As the technical systems fail, they trigger disruptions in organizational, social and economic systems, producing disaster. Seismic events pose a special challenge to rational planning, for while earthquakes occur with known regularity, they occur at great distances around the globe and outside the timeframe of human memory and organizational planning cycles in specific locations. For example, moderate earthquakes occur in a given seismic region every 40 - 60 years; major earthquakes occur every 90 - 150 years (Boutacoff, 1989). Time and distance dull the residents' awareness to the silent danger of seismic risk. Without planning, communities remain vulnerable to disaster over the long term.

Building on the concept of community information systems, we may link a set of such systems designed for communities vulnerable to seismic risk into a global inquiring system (Churchman, 1971; Comfort, 1990) directed toward reducing losses in life and property associated with seismic events. The potential of such a system is shown through professional observation of disaster operations in a series of seven major earthquakes since 1985[4]. The set of disasters serves as an example of the destructive interaction between human and natural systems that may be altered through design.

In each disaster, the source of failure was primarily the lack of adequate information regarding the interaction between the natural system of earthquake faults and tectonic plates and the human systems of infrastructure in these inhabited areas. In each case, the earthquake occurred in a region of known seismicity, with recorded instances of previous events. The seven disasters document dramatically a set of ecological relationships gone awry.

Advances in information technology within the last ten years make it possible to address seismic risk through rational design. While there is still much work to do, and organizational changes may prove more resistant than the technical redesign, we can now conceive of a world where developments in information technology will allow human systems to live in rational balance with the natural seismicity of the earth, without devastating losses of life and property. The following model proposes a design for a global inquiring system to address the problem of risk from the natural seismicity of the earth to the human systems of community infrastructure and social organization.

Assertions

Three basic assertions link information technology to organizational learning, problem solving and action. They reflect the technical capacity of information systems to reduce ambiguity and uncertainty in information available to organizations operating in changing conditions. They also relate organizational learning of the participants to increased clarity in the portrayal of informed alternatives for choice. These assertions are:

1. Information technology allows multiple participants in a collective process to focus attention on a common set of problems, creating timely access to shared information

2. Ready access to shared information and means of communication increases the likelihood that participants will choose a common solution against a perceived threat and cooperate in achieving a common goal[5]

3. Information technology facilitates decision processes in interorganizational networks by mapping choice opportunities onto the respective organizational decision structures as well as mapping problems onto their respective choice opportunities[6]

These assertions are stated in general terms, but underly the design of a global inquiring system to address the problem of seismic risk. The model makes the following specific assumptions:

1. Information processes and skills serve as the primary means of system design (Burt, 1982); information technology includes both electronic and mental processes.

2. An inquiring system operates in parallel technical and organizational structures on at least two jurisdictional levels, allowing access of the lower level(s) to wider ranges of resources, knowledge and personnel.

3. Coordination operates on at least three levels:
   a) self-adjustment at particular sites on the basis of feedback from the immediate range of observation, service area and performance
   b) global adjustment that integrates information from all affected sites, areas of operation, and sources
   c) intermediate levels of coordination as needed, with units of aggregation formed to reduce complexity in the global system.

4. The knowledge base for the system is cumulative, accessible to responsible participants, and organized by three dimensions: function, discipline, time.[7]

5. The critical measure of performance is time, in response to seismic threat locally and in reduction of seismic losses globally.

Actors:

The actors in the inquiring system are organizations. The actors are grouped generically into the following four types by level of administrative jurisdiction:

1. Community Organizations: Households, private businesses, nonprofit community organizations, public agencies with legal responsibility for emergency response

2. State/Provincial Organizations: Public agencies with legal responsibilities for disaster operations; charitable organizations with state/provincial service networks; institutions with state/provincial constituencies

3. National Organizations: Public organizations with legal responsibility for coordinating disaster response or delivering specified public services; charitable organizations with national networks and constituencies; national institutions with specialized skills, knowledge and resources

4. International Organizations: Public and charitable organizations with international service missions; international professional associations and institutions with specialized skills, knowledge and resources

Organizations participating in the inquiring system may differ from site to site, but the functions performed at each site are likely to be similar. Specific organizational participants need to be identified by administrative level, with their respective functions in disaster operations indicated both in relation to their immediate administrative level and to the whole system.[8]

Operating Premises:

Since the inquiring system operates at different administrative levels simultaneously, the model requires a set of operating premises that allows interaction of the separate levels, and the organizational units within them, with a minimum of error. These premises are:

1. Organizational participants at all jurisdictional levels of operation -- local,state/provincial, national, international -- share the goal of reducing seismic risk

2. The inquiring system is designed to support informed action to reduce seismic hazards and to respond to disasters within and between jurisdictional levels, drawing upon available knowledge, resources and skills

3. Participants at all jurisdictional levels know and accept the basic terminology and concepts of system operation

4. Participants at all levels of administration master basic training in essential system operating skills

5. Authority relationships between organizations and administrative levels of jurisdiction are identified, discussed, and agreed upon prior to actual operations

6. Operations responsibility is allocated in at least three ways to minimize error:
   a. by specialized knowledge, as required at particular sites for specific disciplines
   b. by holistic perspective, as required to manage the entire operation
   c. by degree of complexity in operations, allowing the allocation of operating responsibilities accordingly

7. Mutual adjustment and/or correction of error occurs through feedback within and between organizations, administrative levels, and throughout the whole system

8. Operation of the whole system is subject to periodic professional review, with summary reports to participating clientele

The set of eight premises is intended to focus attention and minimize operating error both within and between components of the whole system. Since information processes drive the inquiring system, the quality of performance depends upon the accuracy, timeliness and comprehensiveness of information produced by each component and aggregated, in graduated stages, to the global system.

Anticipated Outcomes:

Anticipated outcomes from an operating inquiring system, both within local communities and the global system, include:

1. Greater awareness of seismic risk and informed alternatives for action
2. Greater likelihood of timely, organized action to reduce seismic risk
3. Greater flexibility in organized response to seismic events
4. Greater efficiency in disaster operations
5. Reduced losses in lives and property in seismic zones

Assessment of the Model in Terms of Field Observations

The technical capability for a global inquiring system has been demonstrated in a number of advanced projects, initiated by both scientific and governmental organizations.[9] A more difficult task is the design of a parallel organizational model that would span four jurisdictional levels of operation and, facilitated by information technology, produce significant improvement in organizational problem solving capacity across the levels.

Treating seven recent earthquake disasters as a longitudinal set of case studies on disaster operations,[10] it is possible to examine organizational problem solving performance on four jurisdictional levels over a six-year period. While a detailed analysis of the full set of disaster operations is outside the scope of this paper, incidents of organizations adapting information technology to support problem solving activities are found in each case. Further, adaptations made in organizational performance indicate increasing awareness of the potential of information technology to support organizational decision processes at all four jurisdictional levels. A set of representative adaptations from the sequence of disaster operations is presented briefly below.

Mexico City, September 19, 1985 (M = 8.1)[11]

The impact of information technology on organizational action was dramatically illustrated during the Mexico City Earthquake by the timely transmission of news reports of the disaster to international audiences via satellite communications. The earthquake occurred at 7:19 a.m., and CBS News telecast reports of the event that evening on the 6:00 p.m. news.[12] Transmitted to world capitals and family living rooms via international satellite, news of the disaster quickly generated response from governments, business organizations, international charitable organizations, and religious and volunteer groups.[13] While the volume of international disaster assistance demonstrated great empathy and international good will toward the afflicted nation, it also created additional burdens on organizational attention, resources and time in seeking to manage the unsolicted contributions to disaster operations. The incident illustrates the power of nearly instantaneous transmission of news via current communications technology in eliciting worldwide support for disaster-stricken communities, but it also indicates the larger problem of organizing information, skills and resources to direct this support efficiently to those in need.

San Salvador, October 10, 1986 (M = 5.4)

During the San Salvador Earthquake operations, two incidents illustrate the growing importance of information technology in disaster operations and organizational initiatives to adapt this technology to support decision processes. The first incident notes the absence of relevant data from previous seismic events in the policy process. Records show that the Reuben Dario building, which collapsed in downtown San Salvador killing nearly 300 persons, had been seriously weakened during an earlier earthquake in 1969.[14] Although data were available, they were not easily accessible to public managers. Under conditions of civil war, there was no mechanism for translating known information about seismic risk into preventive action for the protection of the community. The organizational capacity to solve a documented engineering problem had not been developed, nor were information processes established to support organized action to protect the public from risk. The collapse of the Reuben Dario building stimulated inquiry into the problem of organizational memory in a city vulnerable to seismic risk,[15] and raised questions regarding seismic policy for the community in future years.

A second incident documents the adaptive use of information technology to assist decision processes by a major voluntary organization. The earthquake left an estimated 100,000 persons homeless. The Salvadorean Red Cross, responsible for shelter and welfare during disaster, had to determine how many people needed what type of assistance, and to establish a reliable delivery system to provide timely service. Through the League of Red Cross Societies, the Salvadorean Red Cross requested and received international assistance. The Red Cross organizations initiated, for the first time in international disaster operations, a house-to-house survey of families in the damaged neighborhoods, seeking accurate information for the design of their service delivery system. A staff member from the American Red Cross organized and conducted the survey in San Salvador, using a personal computer to create an organized knowledge base for the Red Cross project. Additional computers and staff were requested to manage the database for this operation.[16]

Both incidents illustrate the interaction between technical and organizational capacity in collective problem solving. The first led informed professionals to propose the design of a continuing record of structural damage to major buildings following earthquakes to support decision making in seismic policy.[17] In the second, Red Cross organizations turned to information technology as a means of improving capacity to cope with the demand for timely, accurate information in interjurisdictional service delivery, using resources from several administrative levels to increase the efficacy of its problem solving processes.

Ecuador, March 5, 1987 (M = 6.1, 6.9)

Different types of organizational skills were demonstrated in the two Ecuadorian earthquakes that occurred, respectively, at 8:54 p.m. and 11:10 p.m., local time.[18] Two instances of critical transmission of information illustrate important consequences for organizational action in disaster operations. The earthquake caused the collapse of a 40-kilometer section of the Ecuadorian pipeline that transported oil from the eastern oilfields in Lago Agrio to western coastal ports for export abroad. The collapse of the pipeline disrupted the export of oil, which provided at least 50% of the national income, and severely affected the economy.[19] The pipeline problem was massive, interdisciplinary, and interorganizational. Working with an array of technical facilities, information processing skills and expertise, Ecuadorian and international policy makers agreed on a technical design for rebuilding the pipeline and a plan for international monetary assistance to finance the project within a period of weeks.[20] For the Ecuadorian Government, this agreement was facilitated by expertise in information processing made available to the Department of Commerce by the Information Computing Center at the Universidad Catolica de Quito.[21]

The second incident illustrates the adaptation of communications technology and the timely use of information to link four administrative levels of voluntary organizations in an effective program of international disaster assistance. Much of the damage from the 6.9-Richter-scale earthquake occurred in small to moderate-sized towns and villages in the Andean Highlands. In the province of Cayambe, north of Quito, few lives were lost, but tens of thousands of people lost their homes and belongings. Already living on marginal incomes, most of these people had few or no reserves with which to rebuild their lives. Although official requests had been submitted, the welfare of the citizens of Cayambe received little national attention, as the Government was intensely preoccupied with the pipeline issue. The mayor of the town of Cayambe, an engineering graduate from Stanford University familiar with the role of communication in focusing attention on problems requiring public action, called the principal newspapers in Quito and invited them to come to the town, interview the residents and take pictures of the damage. A day later, the major Quito newspapers carried full-page photo spreads on the condition of quake-damaged Cayambe, and international as well as national correspondents arrived to investigate the impact of the earthquake on this provincial town. Four months later, in July, 1987, Cayambe was heralded as an example of international cooperation in disaster assistance, as seven international organizations had arranged to fund and build housing in joint projects with the residents.[22]

Both incidents illustrate adaptive behavior by organizations to the sudden, adverse consequences of disaster. They indicate intelligent initiative in terms of searching for available alternatives, and a willingness to use the most current and accessible information technologies to produce constructive action.

<u>California</u>: <u>Whittier Narrows</u>, <u>October 1, 1987</u> (M = 6.1); <u>Loma Prieta</u>, <u>October 17, 1989</u> (M = 7.1)

The advantages of training and technology were evident in the disaster response operations for the two California earthquakes, Whittier Narrows and Loma Prieta. Organizational response for the two earthquakes demonstrates the strongest evidence among the seven cases of information technology contributing to improved organizational performance. A moderate earthquake, the Whittier Narrows event proved a sober exercise in disaster operations. For the City of Los Angeles, disaster operations were largely over in four hours, after the City Emergency Operations Center exercised its full emergency assessment plan to determine the extent of damage to infrastructure, City operations and residential areas.

The assessment plan included helicopter overflight, radio communications and computer-aided dispatch facilities for the City's Police and Fire Departments. The Public Works Department had its own departmental radio communications network that linked field crews, departmental offices, and the City Emergency Operations Center. The City directed its emergency response activities by using appropriate communications and information technology, facilitating rapid action by a large, complex set of response organizations.

In eastern Los Angeles County, smaller cities closer to the epicenter suffered more serious damage and continued to operate their Emergency Operations Centers for two to three days. The City of Whittier introduced an innovation that contributed substantially to integrating public, private, nonprofit organizations and households in informed, responsible disaster operations. The City opened a telephone "hot line" with direct access to an information center at City Hall that provided current information from city departments on the status of earthquake damage, the availability of means of assistance, and the necessary steps to initiate damage assessment, structural repair or to obtain assistance. Again, the City structured a responsible pattern of interaction among community organizations that contributed significantly to the community's capacity for recovery and reconstruction by using available information and communications technology.[23]

Two years later, evidence of organizational learning from the Whittier Narrows event was noted in the response of Northern California organizations to the Loma Prieta Earthquake. At 7.1 Richter scale, this earthquake was ten times stronger than the Whittier Narrows event, and it left 63 dead and property losses estimated at $7.1 billion.[24] Disaster operations for this earthquake were managed largely through local response; a surprising result for an earthquake of this magnitude, but evidence of the increased capacity of organizations in the San Francisco Bay Area to work together cooperatively against a common threat. While some of the technology designed for emergency communications failed -- for example, the computer went down for the Alameda County emergency information system, radio channels were jammed, and telephone lines were overloaded -- new technologies were adapted to meet the increased need for communication between emergency response organizations. Pacific Bell, the regional telephone company, made cellular telephones available to emergency response personnel, enabling them to continue their work without technical interruption. The Region II Office of the California Office of Emergency Services in Pleasant Hill, California, created an informal electronic mail network to communicate directly with participating emergency response organizations over dedicated telephone lines. Regional administrators used the Loma Prieta event to document the need for additional computers and submitted requests to the State Office for more advanced hardware and software to meet emergency demands.

Organizational response to the two earthquakes in California demonstrated a familiarity with information technology and timely action to extend its use in organizational policy and practice.

Northern Armenia, December 7, 1988 (M = 6.9)

More than 25,000 people died following the Northern Armenia Earthquake, creating an overwhelmingly difficult environment for disaster operations. The scale of this disaster generated broad international assistance, and responding organizations initiated a vivid illustration of the potential for a global inquiring system. US and Armenian physicians, supported by satellite telecommunications capacity contributed by the US National Aeronautics and Space Administration, designed and implemented a medical consultation service that operated for four months to aid medical treatment of injured survivors (Ausseresses, 1990).[25] The service was continued to assist with treatment of burn victims from the train disaster at Ufa in June, 1989. The US-USSR Space Bridge, as the operation was named, demonstrates the technical capacity to support the development of an inquiring system directed toward reducing seismic risk. Equally important, the cooperation engendered between US and Armenian physicians in the implementation of this program has created a base of experience, commitment to continued cooperation and international service that will inform the next stages of international inquiry in reducing seismic risk.

Costa Rica, April 22, 1991 (M = 7.4)

The potential for information technology to support decision processes to minimize seismic risk is shown most recently following the Costa Rica Earthquake. The earthquake left 58 dead in seismic activity that crossed the border into Panama.[26] The epicenter of the earthquake struck in a largely uninhabited area, but the force of ground movement caused severe damage in the port city of Limon, some 40 kilometers to the northeast, and to villages and towns in the province. The Comision Nacional de Emergencia (CNE -- National Emergency Commission) of Costa Rica had already initiated plans to develop an advanced Geographic Information System (GIS) for the entire nation, but when the earthquake occurred, the GIS was not sufficiently advanced to support disaster operations. Without the GIS in place, it was difficult to gather accurate information on the affected area, its population and infrastructure to determine the extent of the damage. Staff at the CNE quickly turned the disaster into an opportunity to record basic information concerning the earthquake, entering data from the event into the knowledge base for the GIS and creating the opportunity for feedback of information gathered from actual disaster operations into future organizational learning and performance.

These seven incidents indicate continuing inquiry into problems of seismic risk at local, state/provincial, national and international levels. While they represent only a trend, these incidents demonstrate the potential of information technology to extend organizational problem solving capacity in uncertain environments, and together point to an organizational readiness to support its incorporation into disaster policy and practice.

Conclusions and Recommendations

In summary, the basic requirements for linking information technology to structured organizational problem solving processes appear sufficiently established to support the development of a prototype inquiring system for the reduction of seismic risk. Such a prototype would build a set of parallel technical and organizational systems designed to enhance community capacity for solving problems related to seismic risk. Appropriate uses of information technology can sharply reduce the incidence of death and injury from earthquakes by facilitating a rational ecology of human systems living in balanced, informed relationship with the natural seismicity of the earth. Information, widely distributed and appropriately aggregated with timely feedback processes, enables organizations to develop the context, goals and capacity for timely action to reduce seismic risk.

NOTES

1. For example, missions performed by the US Army in disaster operations require that all mission commanders prepare and submit a 'plan of operations' before action is taken. Such a plan includes five basic elements:

1. Problem
2. Mission
3. Resources
4. Administration and Logistics
5. Command and Control

Specifying the content of these elements for all men involved in the mission clarifies the conditions of the operation, establishes the parameters for action and reduces the uncertainty associated with the mission. Operating in disaster environments, military commanders apply their previous training and experience to increase the success of their missions. The trade-off, however, is the time required for planning in life-threatening events. Ambiguity returns when other organizations interpret the problem or mission differently, or resources, communication and coordination with external organizations that are part of the larger disaster response operations fail. Interview, US Military Commander, San Jose, Costa Rica, April 29, 1991.

2. For example, the California Office of Emergency Services has accepted the Incident Command System as its primary mode of training and operations in disaster response. This system was effectively used in disaster operations at the Cypress Structure collapse following the Loma Prieta Earthquake of October 17, 1989. Cite Cal OES manual, Interview, Chief, Oakland Search and Rescue Team, Cypress Structure Command Post, Oakland, CA, October 21, 1989.

3. Train (1988: 299-307) identified a set of phases in a recurring decision cycle that characterizes military organizations in battle. These phases are instructive for disaster managers, as they often face similar constraints. These phases are: a) problem recognition; b) crisis avoidance; c) crisis denial; d) problem definition; e) allocation of resources: time, attention, material; f) transition from preparedness to response operations; g) relation between field and command during operations; h) recognizing crisis termination; i) accountability and authority. The sequence of these phases is altered for disaster managers in sudden onset events, when crisis avoidance and denial are eliminated by the obvious manifestations of the event.

4. The seven seismic events, listed in chronological order, are:

1985: September 19, Mexico City, 8.1 Richter scale, more than 10,000 dead

1986: October 10, San Salvador, 5.4 Richter scale, more than 1,000 dead
1987: March 5, Napa Province, Ecuador, 6.1 Richter scale, approximately 1,000 dead
1987: October 1, Whittier Narrows, California, 6.1 Richter scale, 8 dead;
1988: December 7, Northern Armenia, 6.9 Richter scale, more than 25,000 dead
1989: October 17, Loma Prieta, Northern California, 7.1 Richter scale, 63 dead
1991: April 22, Limon Province, Costa Rica, 7.4 Richter scale, 58 dead

In the summer of 1990 there were two major earthquakes: Northern Iran, June 21, 1990 and Baguio, The Philippines, July 16, 1990. They are not included in this list because the author did not conduct field research on site.

5. See the argument presented on this issue by Karl Deutsch in <u>The Nerves of Government</u> 1963. New York: The Free Press.

6. These assumptions demonstrate means by which the information technology clarifies the conditions of uncertainty and ambiguity described by Cohen, March and Olsen (1972: 1-25) in their theory of organized anarchy.

7. These dimensions have been described in detail in an earlier paper, "Learning from Risk: Organizational Interaction following the Armenian Earthquake", Working Paper 89-23, Institute of Governmental Studies, University of California, Berkeley.

8. An example of this specification of organizational participants in disaster response is given in Louise K. Comfort, "Organizational Interaction in Response and Recovery" in Robert L. Schuster, ed., <u>The March 5, 1987 Ecuadorian Earthquakes</u>, (Washington, D.C.: National Research Council, Committee on International Disasters, Post-Disaster Research Report, 1991: 122-163).

9. The International Decade for Natural Hazard Reduction, supported by the United Nations with contributions from scientific and professional associations, has initiated planning for a global database of scientific information about seismic risk. The US Geological Survey, supported by the US Department of Interior, operates a computerized databank that provides historical data on seismic events around the world. Other research projects supported by the US National Science Foundation, US Geological Survey and the Federal Emergency Management Agency are exploring innovative uses of information technology to the problems of design, seismic monitoring and damage assessment in zones of seismic risk.

10. See David Collier's discussion of research using a small number of cases, "The Comparative Method: Two Decades of Change" in Dankwart A. Rustow and Kenneth Paul Erickson, eds., Comparative Political Dynamics: Global Research Perspectives. New York: Harper Collins, 1991.

11. The magnitude of the earthquakes is reported on the Richter scale.

12. TELMEX, the Mexican state-owned and operated television station, was severely damaged during the earthquake and rendered inoperable. However, George Natanson, CBS News correspondent in Mexico City, shot roles of video tape of the disaster, hired a Lear Jet and flew to Laredo, Texas, where he reported the first live coverage of the disaster on the regular network news show. Interview, George Natanson, Mexico City, September 27, 1985. See also L.K. Comfort, "International Disaster Assistance in the Mexico City Earthquake," New World, Vol. 1, No. 2, Fall 1986: 12-43.

13. L.K. Comfort, "International Disaster Assistance in the Mexico City Earthquake" in New World, Vol. 1, no. 2: p. 34, Table 1.

14. L.K. Comfort, "The San Salvador Earthquake" in Uriel Rosenthal, Michael T. Charles, and Paul t'Hart, eds., Coping with Crisis: The Management of Disasters, Riots and Terrorism (Springfield,IL., Charles C. Thomas, 1989): 323-339.

15. L.K. Comfort. 1989. "The San Salvador Earthquake" in U. Rosenthal, M. Charles, P. t'Hart, eds. Coping with Crises: The Management of Disaster, Riots and Teroorism. Springfield, IL: Charles C. Thomas, Publisher: 323-339.

16. Interview, Manager, Red Cross Survey; San Salvador, October 19, 1986. Interview, Regional Manager, Red Cross Organizations, San Salvador, October 25, 1986. See also L.K. Comfort, "The San Salvador Earthquake" in U. Rosenthal, M. Charles and P. t'Hart, eds. 1989. Coping with Crises: The Management of Disasters, Riots and Terrorism. Springfield, IL: Charles C. Thomas, Publisher: 323-339.

17. Engineering professionals have proposed the analysis of buildings damaged during earthquakes to determine their structural weaknesses and the types of injuries sustained by their collapse. Please see the summary of research issues identified at the interdisciplinary workshop on earthquake epidemiology, held at Johns Hopkins University, Baltimore, MD, July 10-12, 1989. The workshop was organized by N.P. Jones, F. Krimgold, E.K. Noji, and G.S. Smith, who have summarized the workshop findings in "Considerations in the Epidemiology of Earthquake Injuries," Earthquake Spectra, Vol. 6, No. 3, 1990: 507-528.

18. R.L. Schuster, Introduction, The March 5, 1987 Ecuador Earthquakes: Mass Wasting and Socioeconomic Effects (Washington, DC: National Academy Press, 1991): 11.

19. Robert Schuster, ed. "The March 5, 1987 Ecuadorian Earthquakes: Mass Wasting and Socioeconomic Effects". Washington, DC: National Research Council, in press, 1991.

20. Interview, Managing Executive, CEPE (Consortium Ecuatoriana de Petroleo), Quito, Ecuador, July 11, 1987.

21. Interview, Managing Executive, CEPE (Consortium Ecuatoriana de Petroleo), Quito, Ecuador, July 11, 1987.

22. Interview, President, Municipal Council, Town of Cayambe, Province of Cayambe, Ecuador, July 2, 1987. See also L. K. Comfort, "Interorganizational Interaction in Response and Recovery" in The March 5, 1987 Ecuadorian Earthquakes: Mass Wasting and Socioeconomic Effects, Washington, DC: National Research Council, 1991: 122-163.

23. Survey, managers of public, private and nonprofit organizations engaged in disaster operations following the Whittier Narrows Earthquake in eight cities in Eastern Los Angeles County, June, 1988. Research funded under "Interorganizational Coordination in Disaster Management: A Model for an Interactive Information System," National Science Foundation Grant #CES 88-04285, 1989.

24. "Loma Prieta Earthquake Reconnaissance Report," Chapter 11, 'Socioeconomic Impacts and Emergency Response' Earthquake Spectra, Supplement to Vol. 6 (May 1990): 393-451.

25. This project is a remarkable example of interorganizational problem solving among governmental institutions, hospitals, health ministries and professional associations in both the US and Armenia. Please see discussion in L.K. Comfort, "Designing and Interactive, Intelligent, Spatial Information System for International Disaster Assistance," International Journal of Mass Emergencies and Disasters, November, 1991, Vol. 9, No. 3: 339-353.

26. L. K. Comfort, "Field Report: The Costa Rica Earthquake, April 22, 1991." University of Pittsburgh, Pittsburgh, PA. May 31, 1991.

REFERENCES

Ausseresses, A. D.
1990 Telemedicine: Technology in Practice. Paper presented to an International Symposium, "Medical Aspects of Earthquake Consequences in Armenia," Yerevan, Armenia SSR, October 9-11, 1990.

Argyris, Chris
1990 Overcoming Organizational Defenses. Boston: Allyn & Bacon.

Argyris, Chris
1982 Reasoning, Learning and Action. San Francisco: Jossey-Bass.

Argyris, Chris
1964, 1990 Integrating the Individual into the Organization. New Brunswick: Transaction Press.

Argyris, Chris and Donald A. Schon
1974 Theory in Practice: Increasing Professional Effectiveness. San Francisco: Jossey-Bass Publishers.

Argyris, Chris and Donald A. Schon
1978 Organizational Learning: A Theory of Action Perspective. Reading, MA: Addison-Wesley Publishing Co.

Axelrod, Robert M.
1984 The Evolution of Cooperation. New York: Basic Books.

Bardach, Eugene
1977 The Implementation Game: What Happens After a Bill Becomes a Law. Cambridge, MA: The MIT Press.

Barley, Stephen R., Gordon W. Meyer and Debra C. Gash
1988 "Cultures of Culture: Academics, Practioners and the Pragmatics of Normative Control." Administrative Science Quarterly, 33: 24-60.

Boutacoff, David
1989 "Real World Lessons in Seismic Safety." EPRI Journal, June:23.

Burt, Ronald S.
1982 Toward a Structural Theory of Action: Networks of Social Structure, Perception and Action. New York: Academic Press.

Carley, Kathleen
1988 "Efficiency in a Garbage Can: Implications for Crisis Management" in J.G. March and R. Weissinger-Baylon, Ambiguity and Command. Marshfield, MA: Pitman Publishing Inc.

Churchman, C. West
1971 The Design of Inquiring Systems: Basic Concepts of Systems and Organizations. New York: Basic Books.

Cohen, Michael D.
1981 "The Power of Parallel Thinking". Journal of Economic Behavior and Organization, 2: 285-306.

Cohen, Michael D.
1988 "Artificial Intelligence and the Dynamic Performance of Organizational Designs" in J.G. March and R. Weissinger-Baylon, Ambiguity and Command.

Cohen, Michael D. and James G. March
1974 Leadership and Ambiguity: The American College President. New York: McGraw Hill.

Cohen, Michael D., James G. March and Johan P. Olsen
1972 "A Garbage Can Model of Organizational Choice." Administrative Science Quarterly, 17:1-25.

Cohen, Wesley M. and David A. Levinthal
1990 "Absorptive Capacity: A New Perspective on Learning and Innovation". Administrative Science Quarterly, 35: 128-152.

Comfort, Louise K.
1986 "International Disaster Assistance in the Mexico City Earthquake," New World, Vol. 1, No. 2, (Fall): 12-43.

Comfort, Louise K.
1988 "The Logic of Uncertainty: Interorganizational Coordination in International Disaster Assistance." Institute of Governmental Studies, University of California, Berkeley, Working Paper 88-22.

Comfort, Louise K.
1991. "Field Report: The Costa Rica Earthquake, April 22, 1991." University of Pittsburgh, Pittsburgh, PA.

Comfort, Louise K. and Anthony G. Cahill
1988 "Increasing Problem Solving Capacity between Organizations: The Role of Information in Managing the 31 May 1985 Tornado Disaster in Western Pennsylvania" in L. K. Comfort, ed. 1988. Managing Disaster: Strategies and Policy Perspectives. Durham, NC: Duke University Press: 280-314.

Comfort, Louise K.,Theresa M. Woods and James E. Nesbitt
1990 "Designing an Emergency Information System: The Pittsburgh Experience" in Advances in Telecommunications Management, Vol. 3, Information Technology and Crisis Management. Greenwich, CT: JAI Press:13-33.

Crecine, John P.
1988 "Defense Resource Allocation: Garbage Can Analysis of C3 Procurement" in J.G. March and R. Weissinger-Baylon, eds. 1988. Ambiguity and Command. Marshfield, MA: Pitman.

Deutsch, Karl W.
1963 The Nerves of Government. New York: The Free Press.

Haas, Ernst B.
1990 When Knowledge is Power: Three Models of Change in International Organizations. Berkeley: University of California Press.

Dryzek, John
1987 Rational Ecology: Environment and Political Economy. Oxford: Basil Blackwell Ltd.

Habermas, Jurgen
1979 Communication and the Evolution of Society. Boston: Beacon Press.

Hayes-Roth, Frederick, Donald A. Waterman and Douglas F. Lenat
1983 Building Expert Systems. Reading, MA: Addison-Wesley Publishing Co., Inc.

Holland, John
1975 Adaptation in Natural and Artificial Systems. Ann Arbor, MI: University of Michigan Press.

Goodman, Paul, Lee S. Sproull and Associates
1990 Technology and Organizations. San Francisco: Jossey-Bass Publishers.

Gilbreth, Frank B.
1917, 1973. Applied Motion Study. Easton, PA: Hive Publishing Co.

Lindblom, Charles E. and David K. Cohen
1979 Usable Knowledge: Social Science and Social Problem Solving. New Haven, CT: Yale University Press.

Mackenzie, Kenneth D.
1986 Organizational Design: The Organizational Audit and Analysis Technology. Norwood, NJ: Ablex Publishing Corporation.

March, James G. and Johan P. Olsen, eds.
1976 Ambiguity and Choice in Organizations. Bergen, Norway: Universitetsforlaget.

March, James G. and Roger Weissinger-Baylon, eds.
1986 Ambiguity and Command: Organizational Perspectives on Military Decision Making. Marshfield, MA: Pitman Publishing Inc.

Meltsner, Arnold and Christopher Bellavita
1984 The Policy Organization. Beverly Hills: Sage Publications.

Piaget, Jean
1980 Adaptation and Intelligence. Chicago: University of Chicago Press.

Perrow, Charles
1972 Complex Organizations. Glenview, IL: Scott, Foresman.

Smart, Carolyn and Ian S. Vertinsky
1977 "Designs for Crisis Decision Units." Administrative Science Quarterly 22, no. 4 (December): 640-57.

Scott, W. Richard
1990 "Technology and Structure: An Organizational Level Perspective" in P. Goodman, L. Sproull and Associates, Technology and Organizations. San Francisco: Jossey-Bass Publishers.

Simon, Herbert A.
1969, 1981 The Sciences of the Artificial. Cambridge, MA: The MIT Press.

Taylor, Frederick W.
1911, 1967. The Principles of Scientific Management. New York: W.W. Norton.

Train, Harry D.,II
1988 "Decision Making and Managing Ambiguity in Politico-Military Crisis" in J. G. March and R. Weissinger-Baylon. Ambiguity and Command. Marshfield, MA: Pitman.

Weick, Karl E.
1990 "Technology as Equivoque: Sensemaking in New Technologies" in Paul Goodman, Lee Sproull and Associates. Technology and Organizations.

Weiner, S. S.
1976. "Participation, Deadlines and Choice" in J.G. March and J. P. Olsen, eds. Ambiguity and Choice in Organizations. Bergen, Norway: Universitetsforlaget.