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DECISION-MAKING UNCERTAINTIES IN EMERGENCY WARNING SYSTEM ORGANIZATIONS*,**

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The record of organizational decision making in warning systems is systematically reviewed. A descriptive model of organizational decision-making points and linkages is proposed. The review of 39 historical accounts included in this work led to the identification of four broad classes, comprised of 19 specific categories, of uncertainties in organizational decision making in organizations with warning system tasks. The major decision-making uncertainty classes identified in this review were: (1) ability to interpret the impending event; (2) communications; (3) perceived impacts of the warning and (4) exogenous influences. Primary problems have been recognition of the hazardous event and physical ability to communicate information with others in the chain of warning dissemination. It is concluded that decision-making uncertainty, at all levels and stages of warning systems, has been a major constraint to warning effectiveness and would well be a prime object to be mitigated by future warning system preparedness activities.

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INTRODUCTION

Disasters due to hazards like hurricanes, floods, tornadoes, earthquakes, volcanoes, industrial accidents and the like have led to the development of organized warning structures designed to detect impending disasters and inform the public about appropriate protective actions. An extensive research literature exists on how individuals and families interpret and respond to such warnings when they are received (Mileti 1975; Mileti and Sorensen, in press; Perry et al. 1981). A large body of research also exists on how organizations respond to a disaster during its impact and in recovery (Kreps 1978; Dynes 1970; Quarantelli and Dynes 1977). In comparison to these two research areas, little analytical knowledge has accumulated about how warning system organizations actually function in the warning period, that is, from the time an impending disaster has been detected until the time their mission of getting warning to the public is completed (Sorensen et al. 1985; Leik et al. 1981). Less than a dozen or so empirical and/or analytical studies have been conducted on organizational networks and/or organizations participating in warning systems. These few studies have primarily sought to identify the factors that contribute to organizational effectiveness in warning systems, and their specific findings are reviewed elsewhere (Mileti and Sorensen 1986).

At the same time, the written record is filled with journalistic and/or historical accounts of the functioning of organizations in warning system roles. Accounts exist, for example, of the behavior of organizations as part of warning systems in reference to recent (cf. Chiu et al. 1983; Graham and Brown 1983; Louisiana Department of Public Safety 1984) as well as older (cf. Clifford 1956; Diggory 1956; Kutak 1938; National Weather Service 1960; Wallace 1956) warning events. Additionally, these available accounts cut across a wide mix of hazard types, and include for example climatological (cf. Drabek 1969; Perry et al. 1982a), geological (cf. Anderson 1970; Green et al. 1981; Sorensen and Gersmehl 1980) and technological emergencies (cf. Quarantelli 1983; Gray 1981; Erikson 1976; Dynes 1979).

It is the purpose of this research to address the question of organizational behavior in warning system activities.

We seek to develop a model of organizational and interorganizational tasks, processes and linkages in warning systems. Additionally, and perhaps more importantly, we seek to analytically explore the dozens of existing cases to be found in the written record about organizational decision making in their warning systems activities and review those cases as a qualitative data set for insights into decision-making uncertainties confronting organizations as they seek to perform their tasks in warnings systems. Specifically, we seek to first define the structure of decision making among emergency organizations participating in warning systems, and then to identify the uncertainties in decision making that face organizations involved in such roles. It is hoped this work will help clarify the ways in which uncertainty can act as a major constraint to organizations providing timely public warnings in emergencies, and also that it will contribute to sparsely researched areas in disaster research: analytical comparative research on the behavior of organizations as part of emergency warning systems.

METHODS

Existing reports and accounts of emergencies in the United States were reviewed for cases documenting the behavior of organizations with warning system roles in specific emergencies. This review produced information on 39 emergencies and/or disasters, and these events are listed with their associated reference in Table 1. The criteria used for deciding whether or not to include an account in the data base were: (1) the organizational behavior described in the account had to be specific to a warning system rather than disaster response role, and (2) the account had to address specific organizational behavior and/or problems in performing a warning system role. When both of these criterion were met, the case was included in the qualitative data base. Each of the 39 included cases were then reviewed for three types of data. We sought data on (1) the role(s) ascribed or assumed by the organization in the warning system, (2) the actual behavior of the organization as it sought to perform that role(s), and (3) constraints in terms of decision-making uncertainties to role performance.

Table 1: Warning System Case Studies Included in the Data Set

Hazard	Location	Event Reference
Dam failure	Baldwin Hill, CA	Anderson 1964
Flood	Rio Grande River	Clifford 1956
Dam failure	Port Jarvis, NY	Danzig et al. 1958
Flood	Denver, Co	Drabek 1969; Drabek and Stephenson 1971
Dam Failure	Buffalo Creek, WV	Erikson 1976
Dam failure	Lawn Lake, CO	Graham and Brown 1983
Flood	Big Thompson Canyon, CO	Gruntfest 1977; 1978
Flood	Louisville, KY	Kutak 1938
Flood	Washington State	Perry et al. 1981; Perry et al. 1982a;
Flood	Tucson, AZ	National Academy of Sciences 1982
Flood	Johnstown, PA	National Weather Service 1978
Tornado	Topeka, KS	National Weather Service 1978
Tornado	Worcester, MA	Wallace 1956
Tornado	Red River, AR	National Weather Service 1960
Volcano	Mt. St. Helens, WA	Green et al. 1981; Perry and Green 1983; Perry et al. 1982b; Sorensen 1981
Volcano	Kilauea, HI	Sorensen and Gersmehl 1980
Tsunami	Crescent City, CA	Anderson 1970
Tsunami	Hilo, HI	Bonk et al. 1960
Nuclear accident	Three Mile Island, PA	Dynes 1979
Hurricane (Iwa)	Oahu, HI	Chiu et al. 1983
Hurricane (Carla)	Gulf Coast	Moore et al. 1963; Moore et al. 1964
Hurricane (Alicia)	Texas	Savage et al. 1984
Hurricane/flood	Gulf Coast and Eastern US	National Weather Service 1973b
Chemical Spill	Mississauga, Canada	Burton 1981; Gray 1981; Liverman and Wilson 1981; Scanlon et al. 1980
Chemical Spill	Not available	Gray 1981
Chemical Fire	Taft, LA	Quarantelli 1983
Mud slide	Port Alice, Canada	Scanlon et al. 1976
Firework explosion	Houston, TX	Killian 1956

- MORE TABLE 1 -

Table 1, continued

Hazard	Location	Event Reference
Tsunami	Alaska	Haas and Trainer 1973
Hurricane	Gulf Coast, Eastern US	Baker 1979
Tsunami	Crescent City, CA	Yutzy 1964
Hurricane	Gulf Coast	Louisiana Department of Public Safety 1984
Nuclear accident	Three Mile Island, PA	Dynes et al. 1979
Hurricane	Coastal US	Wendell 1980
Flood	Rapid City, SD	National Weather Service 1973a; Mileti and Beck 1975
Hurricane	Coastal US	Wendell 1980
Hurricane	Texas	Urbanik 1978
Various	Not specific	Quarantelli 1980
Hurricane	Gulf	Windham et al. 1977
Hurricane	Gulf	Wilkerson and Ross 1970
Air Raid	Four U.S. cities	Mack and Baker 1961

Problems exist in the data assembled for this research. First, as is the case with any research which seeks to use secondary data originally gathered for other purposes, not all authors recorded information on all factors of interest to our research. For example, most of the included studies and reports did not systematically record organizational behavior or constraints to that behavior. Obviously, the problem this presented for our study was that the inclusion of a behavior or constraint from a case may not have meant that it did not exist, it could have merely indicated that it was not included as part of the historical record. Second, what was recorded in the historical cases included in this study cannot be used to infer what is common or rare, but rather it may only indicate what was more easily observed and recorded. Despite these problems with our data set, this study can well document, in an analytical way, what was reported in the 39 cases included. It does remain, however, for future research using primary data to subject our conclusions to scientific test.

ORGANIZATIONAL DECISION POINTS AND LINKAGES

The general model presented in Figure 1 was developed as a device to illustrate the key organizational decision points in a warning system in which uncertainties could occur. Key decision points are represented by the boxes in Figure 1 and linkages between decisions are indicated by arrows. The particular organizations involved with each decision, of course, varied according to the specific case under review. In this section, it is our purpose to define this model. Unlike other attempts to model the system components of warning systems (for example, Perry and Mushkatel 1984; Perry et al. 1981, p. 130; Mileti 1975; Williams 1964, p. 82; and Moore et al. 1963, p. 15), the model here proposed has sought to represent key decision-making points in the system rather than basic processes.

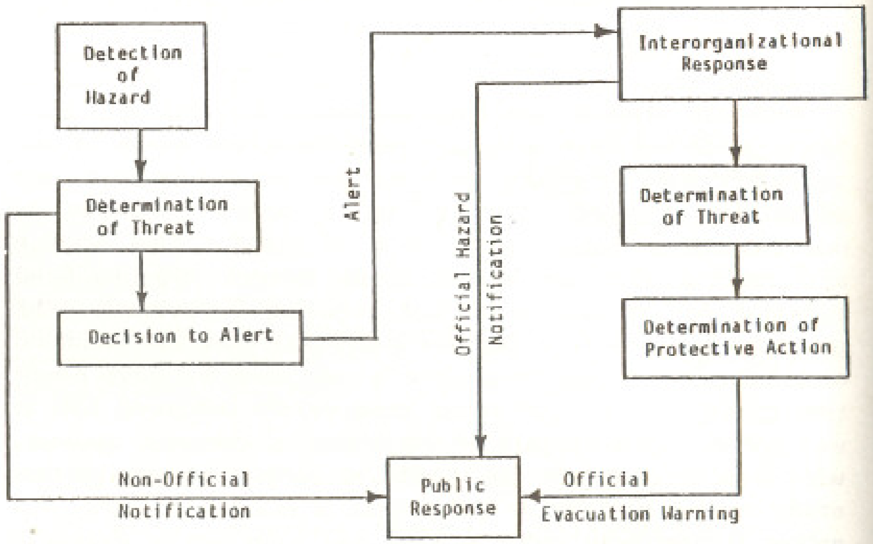

Figure 1. A Model of Organizational Decision Making Points in Warning Systems

The initial stage of any public warning is the *detection of the hazard*, that is, recognition that a particular event or situation constitutes a hazard. In a flood, for example,

event recognition may be rain and rising river levels. At a nuclear power plant, it may be a combination of instrument readings and alarms. For an earthquake, it may be unusual animal behavior or swarms of small precursory seismic events. Regardless of the type of hazard, some signs must be read and interpreted to mean that a hazard exists before a warning system can be activated. Hazard detection may be made by a member of the public (as in the case of a hazardous chemical spill from a truck) or by a complex organization set up to look for and detect hazards. For example, the National Weather Service (1973a,b) detects severe storms and tracks hurricanes; the United States Geological Service (USGS) monitors volcanoes for signs of impending eruptions; some state governments have programs to detect potential landslide hazards; and chemical companies often have monitors at storage facilities to detect releases of hazardous materials.

Once a hazard is detected the second key decision in the general process is *determination of* whether or not it poses a *threat* to human health and safety. In a flood, this may be defined as waters exceeding flood stage elevations. At a nuclear power plant, it may be defined as some off-site release. In an earthquake, threat may be indicated by an expected Richter magnitude of energy release and associated shaking intensities in populated areas. Often the determination of threat is done by the same person or organization detecting the hazard; at other times, different actors and organizations may be involved. A private citizen or company of any level of government may determine that a threat exists. The U.S. Geological Survey is, for example, formally charged with issuing hazard watches and must detect and assess threats from geologic hazards. The State of California determines whether or not an earthquake prediction is valid and constitutes a threat to the public. Local governments often must determine whether a derailed train carries hazardous materials. Public and private utilities must determine dose projections in the event of a nuclear power plant accident. Threat determination is judging that an event is or is not hazardous to the public.

Once a threat is judged to be a significant one, the hazard detector or threat assessor must *decide* whether or not *to alert* others of the risk and potential damages. Part of this decision includes determining who should receive the alert. In an earthquake, a scientist would need to decide whether or not to make an announcement to the governor or keep silent. For nuclear power plant accidents, guidelines and requirements usually spell out when and who should be alerted. Clearly, for some threats the alert decision is spelled out in plans while for others it remains discretionary.

Following an alert, that person or organization receiving the alert must decide which other parties will be involved in the decision to evacuate or implement other types of protective actions. This decision is more important than it may appear on the surface because the number and type of actors involved will affect the timing and outcome of the decision, particularly if a distinct or clear-cut threatening situation is not present. The actors involved will depend on the hazard, the location and existing emergency plans. In some cases, *interorganizational notification* is fixed and automatic; in others, it is largely ad hoc and may depend on who is available at the moment. Often participation emerges during the onset of the hazard with both the formal and informal involvement of actors and organizations in the process.

An official decision must next be reached as to whether or not the event poses a hazard to the public. The decision includes *determining* the magnitude and characteristic *of* the *threat*, the locations that would be impacted, and the nature of human exposure to the threat. This decision may be made by a single organization or may be made by a group that forms following the inter-organizational notification. Once a hazard is judged to be a significant threat to the public, a decision must be reached to *determine* whether *public protective actions* are necessary, and what protective action to recommend or implement. This will be determined, in part, by the severity of the threat and the amount of time to its impact. Other factors may also play a role which may not relate to the threat per se. As in the case of threat-assessment, a variety of groups or persons can be involved in this determination.

Following the detection of a hazard, information is usually passed on to an agency with emergency powers or responsibilities. This alert link between hazard detectors to

emergency manager officials may be a phone call to a police dispatcher, an automatic ring-down to a civil defense director, activation of a tone-alert radio in the mayor's home, and so forth. Information about the threat may also go directly to the public from detectors via a *non-official notification link* either simultaneously, before, or after the officials are alerted. The NWS may flash a severe storm warning on television. A person discovering a chemical spill may run door-to-door notifying neighbors. An *inter-organizational alert link* ties together those that will be involved in the official public protective action decision. It may be a series of telephone calls to people on a list in an emergency plan, a siren or whistle in an industrial plant, or informal word-of-mouth communication between people. Additionally, an *official to public notification link* can see, prior to a protective action decision, the public alerted by officials about an approaching or impending hazard. This alert may be through a media report, activation of an emergency broadcasting system, the sounding of a siren, or interpersonal communications. Finally, the last link in the model presented in Figure 1 is the *officials to public warning link* which, if protective action is recommended, officials use to inform the public to take that action and supply them with the details about the recommended protection action. This may be done over electronic media, route notification, with bull horns, or by door-to-door contact.

The model presented in Figure 1, therefore, formalizes the range of decision-making points, and links between them, for organizational decision making in warning systems. The catalogue of decision-making points and linkages suggested by this model served as a way to focus our review of the cases in the qualitative data set; that is, we sought to discover decision-making uncertainties regarding any or all of these points and links while reviewing the case files of events in our data set.

FINDINGS

Decision-making uncertainties confronted by organizations involved in emergency warning systems were found in cases reviewed for all types of organizations involved in warning systems, that is, federal, state, and local government organizations as well as organizations in the private sector. Also, uncertainties in decision making were found for each decision point and linkage between decision points in the warning system model presented in Figure 1. The uncertainties document in the case study review, categorized by decision point and linkage as well as by organizational type are presented in Table 2.

Table 2: Uncertainty Observations by Organizational Type and Decision Stage

	Organizational Level			
Stage of decision model	Federal	State	Local	Private
Detection of hazard	7	0	4	7
Determination of Threat	10	0	9	7
Decision to alert	3	0	0	2
Non-official notification	0	0	1	0
Alert	6	1	6	5
Interorganization notification	0	0	6	1
Official notification	1	0	11	1
Determination of threat	4	2	12	0
Decision to evacuate	1	2	54	5
Official evacuation	3	1	23	1

A review of each of these case uncertainties, approximately 200 or so uncertainties were revealed in the review, suggested that four general categories of uncertainty constraints have operated to plague organizational decision making in warning systems. These are listed, along with the specific uncertainties that comprise a general category, in Table 3. The first general uncertainty in the decision-making category observed was in reference to how people and organizations interpret threatening situations and their roles in the warning decision-making process. Specifically, uncertaintieshave surfaced to constrain sound decision making because of interpretation of the hazard, hazard information obtained directly or through others, and in reference to who is to do what as part of the decision-making

process. Second, constraints in reference to communications have been numerous in the record of past warnings.

Table 3: Uncertainties Types in Organizational Decision Making in Warning Systems

Uncertainty type	Number of times uncertainties documented
Interpretation	
Recognition of event	21
Recognition of hazard	16
Definition of magnitude	12
Self-definition of role	3
Recognition of relevant information	4
Definition of authority	13
Communications	
Who to notify	2
Ability to describe hazard	12
Physical ability to communicate	35
Conflicting information	10
Perceived impacts of decision	
Causing adverse responses	10
Personal consequences	4
Cost of evacuation	5
Liability perception	4
Exogenous influences	
Time availability	9
Feasibility of evacuation	4
Prior experience	9
Planning	5
Outside pressures/expectations	7

Protective action decision making includes a multitude of different actors and organizations at varied governmental levels. Uncertainties have prevailed in a number of warnings over whom to communicate with, as well as when and how that communication might occur. Third, decision makers have, on occasion, been a source of uncertainties themselves; concern over the impacts of their decisions--whether these concerns are warranted or are unfounded--have constrained sound warning decision making and been a source of uncertainty in the decision process. For example, concerns have included fear of public panic, the costs of an unnecessary evacuation and so on. Finally, a set of factors exogenous to the warning decision-making process has surfaced to inject uncertainty into decision making; for example, the state-of-the-art in the sciences which are used to predict the impact of a disaster. These four uncertainty categories--interpretation, communication, perceived impacts, and exogenous influences--subsumed 19 specific uncertainty categories in decision-making types discovered by the case study review (see Table 3). A summary of these findings follows.

Interpretation

The degree to which information about an impending hazardous event successfully works its way through from event detection to a prudent public protective action decision is subject to the range of interpretations that the people who process that information make as they receive the information, interpret it, and pass it along to others. These interpretations, which are relevant to more than just how hazard information is interpreted, can facilitate the evacuation process if they are made soundly; or they can raise uncertainties in the system and give rise to bad decisions.

Recognition of event. The ability to recognize the presence of an impending hazardous event is determined by the degree to which people can observe an indicator associated with a potential threat and conclude from it that a threat exists. For example, observation of a particular cloud formation may mean rain for some, tornado threat to a few, and merely indicate a cloudy day to others. Variation exists in the ability of people to recognize a potential

threat, and this variation exists among those who are "trained observers" as well as among general members of the public as well. Variation in the ability of people to recognize an impending hazardous event has constrained some evacuations in the past by consuming time thereby reducing the time available to the public in which to respond.

For example, in several recent dam failures, the private company and public agencies responsible for managing the reservoir failed to understand that the dams were unsafe. Furthermore, when the dams were about to fail after periods of heavy flooding, the inability to link runoff conditions with dam failure precluded an early warning. This was characteristic of the Baldwin Hills dam failure (Anderson 1964), the Buffalo Creek dam failure (Erikson 1976) and the Lawn Lake Dam disaster (Graham and Brown 1983). Problems in event recognition have surfaced in other floods as well (Drabek 1969; Gruntfest 1977; National Academy of Sciences 1983), tsunami (Anderson 1970), hurricanes (Chiu et al. 1983; Moore et al. 1963; Baker 1979), and hazardous material accidents (Scanlon and Padgham 1980; Quarantelli 1983).

Recognization of hazard. Variation in the ability to define the level of threat, once the event has been recognized, is a second uncertainty which has constrained effective and timely hazard recognition. Once the physical properties of an impending event are recognized--for example, that a flood will occur or a hurricane will strike--uncertainties can exist in reference to what that event will mean for the people that will be affected. For example, an impending flood could affect a large part of town or only a small segment of town; or a hurricane could produce hazardous winds for 30 miles inland or only 3 miles. Uncertainty in the ability of people to recognize the extent of a public hazard associated with a recognized impending hazardous event has been the cause of over- and underestimating the seriousness of impending emergencies. This uncertainty has led, in some cases, to less effective and poorly timed warning decisions.

Although the evacuation of 225,000 people in Mississauga, Canada, following a train derailment was effective, it was initially hampered by the inability to define the potentially hazardous materials on the train. At first, the manifest could not be located by local officials and when it was, it was unclear whether or not it was accurate (Burton 1981). Recognition of hazard is typically a problem in flood warning systems and has been extensively documented (Clifford 1956; Erikson 1976; Graham and Brown 1983; Gruntfest 1977; Kutak 1938; National Academy of Sciences 1983).

Definition of magnitude. It is often difficult to forecast accurately the precise magnitude of hazard of an impending threatening event. For example, the precise windspeed of hurricanes when landfall occurs is difficult to foretell. Consequently, the low levels of precision involved in magnitude predictions create uncertainty, on occasion, in terms of the advisability of evacuation. There are magnitudes of event for which warning is advisable, and others for which it is not.

Instances in which the magnitude of an impending event does not clearly indicate a need for action create uncertainty and can lead to what appears to be wrong evacuation decisions in hindsight after the hazard impacts the area at risk. At the same time, this problem can also delay evacuations. The Rapid City flood, for example, is a case in point (Mileti and Beck 1975). Heavy rains and rising water levels in the creek were both detected. However, the magnitude of the flood event was not accurately foreseen: the significant losses were associated with the breaking of a natural canyon dam not known to those estimating magnitude. This was not unique to Rapid City having been observed in other floods (Gruntfest 1977; Perry et al. 1982a; National Academy of Sciences 1983). This was also a problem at Mt. St. Helens, regarding the magnitude of the eruptions (Sorensen 1981). Estimates of magnitude also pose problems in hurricanes (Baker 1979; Moore et al. 1963; Savage et al. 1984) and chemical spills (Gray 1981; Quarantelli 1983).

Self-definition of role. People have sometimes experienced uncertainty in understanding, knowing, and effectively assuming the roles and obligations of participating in the communication process. This uncertainty has affected both those who initiate communication and those who receive it. People uncertain about their communication role do not

always perform it. Consequently, role uncertainty by those who play key parts in the chain of communication in a warning system has slowed the warning by not conveying risk in a timely manner.

For example, the mining company responsible for creating the slag-heap reservoir on Buffalo Creek did not define their role as one of emergency responder. As a result, when the dam failed, no timely alert was given to public officials who could issue evacuation orders (Erikson 1976). Role definition has not been extensively observed as a constraint to warning but it has surfaced in other situations (Perry et al. 1981; Wallace 1956).

Recognition of relevant information. Sorting of relevant information occurs when there is either too much or irrelevant information facing the decision maker. It is then necessary to determine which pieces of information should be used to make a decision, and which should be ignored. For example, a local sheriff who must decide whether to activate an alarm system in the vicinity of a nuclear power plant might be given recommendations from three different organizations, and in addition he is given meteorological data, information on plant conditions, source terms, projected dose rates, etc. The sheriff may well be overwhelmed by the information. Some information may be excluded and the decision made on the basis of only part of the information. Another possibility is that the information is ignored and the decision is made on the basis of some exogenous factor. This uncertainty in how information is sorted may be reflected in the quality of the decision.

For example, when Mt. St. Helens became active, emergency response organizations were given "raw" data on seismicity and plume activity. In the course of trying to understand and use this data, they tended to neglect some responsibilities such as providing warnings to the public (Sorensen 1981). This problem of information sorting has been documented for several flood warnings (Drabek 1969; Danzig 1958) and at Mississauga (Scanlon and Padgham 1980).

Definition of authority. Definition of authority is how various actors perceive the responsibility and power of other actors to make decisions. These definitions create uncertainties in several ways. First, if more than one person or agency assumes a leadership role, conflicts could occur. Second, if definitions of authority are wrongly perceived, information may not reach the right people. Third, if no one takes charge because they perceive it as someone else's responsibility, decisions could be delayed or overlooked.

This was problematic among agencies and with private corporations preceding the large eruption at Mt. St. Helens (Sorensen 1981). In this situation, disagreement over authority arose between the U.S. Forest Service and a lumbering company. The Forest Service wanted to evacuate lands that were being harvested. The conflict led to a series of revisions in evacuation policies with compromises on both sides. Fortunately the eruption occurred on a Sunday when no logging was taking place. Other warning studies also show definition of authority issues as constraints to effective warning (Danzig 1958; Drabek 1969; Graham and Brown 1983; Moore et al. 1963; Quarantelli 1983; Haas and Trainer 1973; Dynes 1979).

Communication Problems

Public advisements are usually the result of long chains of communication between different people, with varied jobs and roles, in different organizations. Consequently, a key to understanding the warning decision-making process is to view it as a series of communications between both people and organizations. This process of communication, involving people and organizations and ultimately the public, has been a general category of uncertainties that have surfaced in past evacuations to constrain the evacuation process. These uncertainties fall into four categories, and a description of each follows.

Who to notify. Uncertainty over whom to communicate hazard information, either in reference to other organizations or the identification of particular persons in other organizations, has constrained the communication process in some past warnings and, subsequently, delayed public evacuations. Sound hazard recognition and accurate determination of threat can be less than fully useful when that information is not communicated to all those who could carry that information through to other organizations and then the public. Dissemination of threat information to communities

about to experience a potential disaster can be constrained if those who possess the threat information do not know what local agencies and which people within them to notify about the threat. For example, at Mt. St. Helens, the dissemination of a warning concerning ashfall levels and consequences has been attributed to the lack of pre-disaster inter actions between state and local emergency organizations and the knowledge of whom to tell when the volcano erupted (Saarinen and Sell 1985). Quarantelli (1980) notes that this is a pervasive problem in some situations, particularly those without adequate preplanning.

Ability to describe hazard. Those engaged in the provision of hazard information to others have created uncertainties because of how threat descriptions were worded. Non-scientists, for example, rarely share a common understanding of probabilities; vagueness in the specification of the area-at-risk can lead to increased uncertainties for those confused over which people to warn; and technical descriptions of physical processes associated with a hazard may mean little to those interested in only simple definitions. The inability of some scientists and technicians to describe hazard in clear and simple ways has, sometimes, created uncertainties for those who must use that information to make decisions about public response and give public warnings. It has also created uncertainties in the sequential process of communication leading up to evacuation advisements.

For example at an explosion at a chemical plant in Taft, Louisiana, the evacuation of the surrounding population was delayed by an inability to communicate information about the explosion and potential consequences (Quarantelli 1983). Company officials did not explain the accident in terms that local officials could readily use in making their decisions. Even when they recommended a five-mile evacuation, local officials did not understand why it should be that distance.

Ability to describe hazard is a problem for rare events such as volcanoes (Sorensen 1981) or tsunami (Haas and Trainer 1973); and ones which have uncertain impacts such as flash floods (National Academy of Sciences 1983) or tornadoes (National Weather Service 1980).

Physical ability to communicate. The physical ability to communicate notifications, alerts and warnings has been a source of uncertainty in some prior evacuations. Loss of the technical capacity to communicate can retard communications to both the public and to other organizations. Some reasons include, for example, the non-match of radio frequencies, lack of dedicated phone lines when regular lines are overloaded, and lack of back-up communications systems when planned or routine systems fail. A good example of a physical communication failure is provided by the 1977 Johnstown flood. Loss of the phone system hampered efforts of the Corps of Engineers weather observer to determine rainfall and also for the NWS to subsequently alert local officials (National Weather Service 1978). The physical ability to communicate has been extensively documented in a range of settings and incidents too numerous to cite.

Conflicting information. Conflicting information is the presence of either data or recommendations which lead to different conclusions about whether to evacuate. In this situation, the decision maker must decide which information is valid. For example, if a local official in charge of evacuation receives information from one source that a dam has overtopped and from another that it is sound, a decision to evacuate may be confused or delayed. If the erroneous information is acted upon, a bad decision may result.

This type of situation was encountered in the 1983 Hurricane Alicia. Local officials relied on official forecast information from the National Hurricane Center (NHC) and Galveston National Weather Service Office. The local weather service was warning officials the hurricane could take a northerly turn and hit Galveston. The NHC was concentrating on warning of a more southerly landfall. Galveston officials played down the potential of being affected and when the storm turned, it was too late to evacuate (Savage et al. 1984). Conflicting information has posed problems in technological emergencies (Dynes 1979; Quarantelli 1983; Gray 1981) and other natural events (Anderson 1970; Yutzy 1964; Drabek 1969; Danzig 1958).

Perceived Impacts of Decisions

Uncertainties also exist in the warning process because of a range of perceptions that people in decision-making roles hold regarding the potential negative impacts of making wrong decisions. Some of these perceived impacts

have no basis in reality and are part of a general myth-structure about public emergency response. Other perceived negative impacts are potentially real. Four types of impact perceptions were identified, and these follow.

Causing adverse responses. Warning decisions can be influenced by a decision-maker's perception of adverse public consequences of ordering an evacuation. Typical concerns may be that people will panic and be hurt or killed, or that homes will be looted while residents are away. While these situations may arise in some very rare circumstances, such beliefs are largely unfounded given previous experiences. Despite elaborate research evidence to the contrary, these beliefs still persist. In addition, decision makers may also believe that a false warning may hinder future evacuation needs (cry-wolf syndrome). There is, again, little research evidence that this is the case.

For example in Hurricane Carla, it was documented that the state government decided against a general evacuation order for fear of panic and unnecessary movement. Instead they let local governments make decisions (Moore et al. 1963). In Hurricane Alicia several local governments, having evacuated unnecessarily for Hurricane Allen, decided not to evacuate for fear of being wrong again (Savage et al. 1984). Fear of panic has also been documented in chemical emergencies (Gray 1981; Scanlon and Padgham 1980) and for tsunamis (Yutzy 1964; Anderson 1970).

Personal consequences. Uncertainty has led to apprehensiveness in communicating and notifying other organizations and the public about an impending threat; often this results in downplaying the potential threat when it is communicated. Persons have feared personal negative consequences of transmitting risk information that may befall themselves with the non-occurrence of the hazard. Concern over personal consequences has centered on loss of reputation or image, loss of votes in a future election, and the like. For example, in a 1965 tsunami threat situation in Cresent City, California, local officials feared public sanctions if they called for another evacuation and no tsunami occurred (Anderson 1970).

Cost of evacuation. Warning system decision makers can be influenced by their perceptions of the dollars costs or losses that may stem from a protective action such as a precautionary evacuation. Cost may include transportation and sheltering of the public, as well as costs borne for emergency personnel. Losses can include revenues lost from employment or sales, or damages incurred from injury during evacuation, or the shutdown of productive sectors in an economy. A city, for example, which has exhausted its emergency funds for police overtime, may be reluctant to order an evacuation for which it cannot easily pay. For example, perceived economic losses played a significant role in determining evacuation zones at Mt. St. Helens. Evacuation boundaries were shifted in order to split cost of manning roadblocks between two counties and to allow access to economic enterprises in the area (Sorensen 1981).

Liability perception. How agencies or actors within them define liability questions can also influence warning decisions. This can occur in several ways. First, and most likely, liability for public safety is a frequently raised issue for public agencies. The major concern is over responsibility for damages if a hazard occurs and actions are not taken to protect the public. This perception tends to cause officials to err on the side of caution in some situations. On the other hand, decision makers may perceive liability for ordering an unneeded evacuation which leads to unnecessary costs and possible evacuation-associated damages.

Although the issue of liability as an influence on decision making is noted theoretically and is discussed in pre-emergency planning, it does not appear to be a major influence on actual decision making based on the data reviewed in this investigation.

Exogenous Influences

Other uncertainties have surfaced to constrain good evacuation decisions and outcomes that are somewhat outside the domain of the evacuation decision-making process. These sources of uncertainty, here labeled as exogenous influences, are discussed in the sections which follow.

Time availability. Time availability refers to the length of time between the detection of a hazard and the manifestation of impacts or effects. Judgments that a lengthy time exists may delay decisions. Judgments of short time may rush decisions. Furthermore, short response times may influence decisions to not warn for fear of people being

exposed to damage while they are engaged in evacuating. Concern over adequate lead time to conduct an evacuation may lead to decisions to evacuate before sufficient information about the hazard may be collected. An example is a decision to evacuate a beach community or barrier island before the path or magnitude of a hurricane is known.

Such was the case in 1980 when Hurricane Allen threatened the Texas shoreline. Decisions to evacuate had to be made while the path was still subject to a wide prediction error. As a result, the NWS advised the evacuation of Galveston, only to have the storm veer to the south (Savage et al. 1984). Timing is a significant constraint in fast onset events such as flash floods caused by dam failures (Graham and Brown 1983; Gruntfest 1978; Perry et al. 1981; 1982a; Anderson 1964; Drabek 1969) or tsunamis (Anderson 1970; Haas and Trainer 1973).

Feasibility of evacuation. The feasibility of evacuation refers to the perceived success of an evacuation in protecting the public. Feasibility perceptions can be influenced by factors such as the severity of the hazard, geography, safety of evacuation routes and so forth. Misperceptions of feasibility could lead to poor decisions concerning evacuation or influence the timing of evacuation decisions. For example, the fear of a radioactive release during a fast-moving accident at a nuclear plant, in conjunction with poor weather, could lead to an evacuation decision prior to development of plant conditions that would normally suggest that an evacuation is in order. At Taft, Louisiana, officials were concerned that evacuation may increase exposure to risk (Quarantelli 1983).

Experience. Prior experiences with other evacuations and emergencies can influence decision-maker judgments and raise uncertainties in the warning decision-making process. Occasionally, people can imagine that an impending hazardous event will materialize in a way much like those which have already been experienced, even though this image may be inconsistent with current information about the impending event. On the other hand, the lack of experience with a particular hazard can, for some, raise uncertainty in imagining what an impending event may be like. Experience, and the uncertainties it can raise, can lead to either premature or tardy communications and evacuations.

This accident situation was experienced at Cresent City, California, during 1964. The warning of a potential tsunami which proved to be a false alarm played a role in delaying law enforcement officers' decisions to evacuate people in a subsequent warning situation (Anderson 1970). Prior experience may also impact the way hurricane warnings are handled (Savage et al. 1984; Baker 1979; Chiu et al. 1983).

Planning. The presence, absence or extent of in-place emergency plans can greatly influence warning decisions. Experience shows that the lack of a plan can delay or confuse decisions to warn. Theoretically, possession of a plan could increase the likelihood of having a warning merely because it has been planned for. Additionally, emergency plans which are too rigid and too inflexible can themselves frustrate timely emergency response and, subsequently, warnings.

An example of the former is the TMI accident. The lack of a plan definitely contributed to confusion over the contents of warnings (Dynes 1979). Likewise, absence of plans for special facilities like hospitals in the vicinity of TMI may have contributed to decisions to allow hospital employees to leave without consideration of the consequences. Lack of planning was also cited as a problem with issuing warnings at Mt. St. Helens (Sorensen 1981) during the Cresent City tsunami (Anderson 1970), and in several floods (Perry et al., 1981; Graham and Brown 1983).

Outside expectations. Warning decisions can be influenced by expectation or demands of persons outside the warning-decision environment. For example, a public official may perceive that, given a certain situation, an evacuation notice is expected by the public. In addition, a decision maker may feel pressure from another level of government or some other agency when deciding whether or not to warn. At times the pressure may be counter productive when the responsible official overacts to the pressure and follows the opposite course of action.

At TMI, the Governor's decision to recommend a selective evacuation was, in part, a response to outside demands and pressures to demonstrate control and leadership (Dynes 1979).

During the approach of Hurricane Alicia, communication from the Governor to the Mayor of Galveston regarding

evacuation may have played a role in the decision to not evacuate (Savage et al. 1984). In this case, the Mayor may have reacted negatively against the state's position rather than make a decision independent of the state. Other examples include volcanic eruptions (Sorensen and Gersmehl 1980; Greene et al. 1981) and chemical accidents (Gray 1981).

CONCLUSIONS

A prime conclusion from this work is that decision-making uncertainties can and have affected all levels of government organizations at virtually every organizational decision point in the decision-making process in warning systems. This conclusion is not true for each specific situation; rather it is the case for warning experiences overall. Specific uncertainties for any given agency or level of government likely depend on both the hazard type and the evacuation context. Nevertheless, it appears that no agency at any level of government is immune from experiencing uncertainties in warning system decision making.

Second, it is also the case that the private sector is subject to uncertainties at a variety of decision points, although they appear to be more restricted than for public agencies. The private sector, as evidenced by the historical record, seems more prone to uncertainties in detection and alert decision points than elsewhere.

Third, local and state governments frequently encounter or contribute to uncertainties in warning decisions. The structure and delegation of emergency powers in the federal, state and local governments will likely continue to bear the burden of responsibility for warning decisions.

Fourth, there are numerous examples in the historical record where potential grounds for liability were present due to organizational uncertainties in warning decision making. If disaster losses occurred in these cases, it might have been possible to document the factors that could have contributed to those damages in the context of poor warning decisions. Obviously, whether or not legal action, if pursued, would have been successful is unknown.

Finally, some of the constraints that have been identified in this research could be addressed through planning; and they are somewhat likely, if addressed effectively, to be mitigated. For example, good emergency planning can define clearly who has what role in the warning decision-making process thereby reducing the potential for this as a source of uncertainty in a future evacuation. Other identified uncertainties likely cannot be readily mitigated; for example, hazard recognition is somewhat limited by the state-of-the-art in the sciences which allow the hazard to be monitored and detected. Uncertainty reduction on this front, therefore, must wait for future scientific discoveries relevant to upgrading event recognition. At the same time, most uncertainties likely fall somewhere in between these two polar extremes. Planning can, therefore, play some role in reducing uncertainties; although some uncertainties may always operate in the warning decision-making process.

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