2. DEFINITION OF A WARNING SYSTEM

A warning system is a means of getting information about an impending emergency, communicating that information to those who need it, and facilitating good decisions and timely response by people in danger. This definition is simple but accurate. Contemporary warning systems are not simple systems, however. They are complex in both organizational structure and work process. They tie together work in a variety of specialties within and across many different organizations. For example, they can link science, technology, levels of government, and the public.

It is possible to reduce the organizational and functional complexities of warning systems to a set of relatively simple concepts and relationships. It is the purpose of this section to describe these and comment on how they work in practice. First, we describe the general structure of a warning system and its subsystems. Second, we examine the components of each subsystem, with attention to process, major issues, dilemmas, and problems. In addition, we consider informal warnings. Finally, we discuss divergent views on warning systems. We suggest that these divergent views must be merged to achieve integrated warning systems.

2.1 SYSTEM STRUCTURE

The structure of warning systems has been researched and discussed for several decades (Moore et al. 1963; Williams 1964; McLuckie 1970; Mileti 1975; Perry, Lindell, and Greene 1981; Lehto and Miller 1986; Rogers and Nehnevajsa 1986). There is a large degree of consensus among researchers about the structure of a warning system and how variation in a system's structure can alter its effectiveness. The most effective structure for a warning system is that of an integrated system. An integrated system has two qualities that make it unique. First, to ensure preparedness, the warning system is composed of three relatively separate subsystems, the detection, management, and response subsystems. Second, integration requires that sound relationships among these subsystems be developed and maintained.

2.1.1 The Detection Subsystem

The detection subsystem focuses on the relatively routine monitoring of the natural, technological, and civil environments that could induce an emergency. It collects, collates, assesses, and analyzes information about those environments and, when warranted, makes a prediction about the potential occurrence of an emergency. The prediction is then communicated from the detection subsystem to the management subsystem. This typically means that scientists inform emergency management officials about impending natural emergencies. Military, police, or intelligence organizations typically inform civilian officials about civil emergencies.

The detection subsystem is largely the domain of scientific organizations for natural hazards. For example, NWS performs this function for hurricanes and USGS does it for volcanoes. Scientists also perform this function for most technological hazards. For example, radiation health physicists and others would assist in estimating off-site risk in a nuclear power plant accident. For civil hazards the detection subsystem involves other groups. For example, the military perform the detection function for nuclear attack. It is also possible that members of the public can play a role in the detection subsystem, for example, by sensing and interpreting environmental cues about a hazard and then informing others.

The hazard type does not alter the basic functions of the detection subsystem, which are to detect the presence of a potential emergency and then inform those wno must manage the event. In an integrated warning system the detection subsystem has specific structural characteristics. First, the environment-detection linkage is clear and routine. Second, the link between detection and the management subsystem is clear and familiar.

2.1.2 The Management Subsystem

The second subsystem is focused on integrating the risk information received from the detection subsystem and warning the public when warranted. This subsystem is composed largely of local emergency management officials. After receiving information from the detection subsystem, these managers must interpret that information in terms of potential losses (e.g., loss of life and property) and then decide if the risk warrants a public warning. In making such decisions, managers use specified or ad hoc criteria. Official public warnings are made following a positive decision. One part of this subsystem often overlooked is the monitoring of public response once warnings are issued so that subsequent warnings can be refined or changed if people are not responding in a way that would minimize their exposure to risk.

The management subsystem of a warning system is typically the domain of local government. For example, a mayor or county executive is usually responsible for issuing evacuation advisements for floods. Occasionally warning the public is the responsibility of a governor as, for example, in the case of nuclear power plant accidents in some states.

Ascription of management responsibility across type of government and variation in hazard type has little if any effect on the major objectives of this subsystem, which are always to interpret risk information and then inform the public. The management subsystem has particular structural characteristics in an integrated warning system. First, the linkage between the detection and management subsystems is clear and familiar. Second, because managers may need assistance in interpreting risk information, there is communication between detection and management subsystem personnel. Third, the link to the public through actual warnings and monitoring of response is comprehensive and informed, not ad hoc. Finally, the ability of the environment to bypass the detection subsystem and directly influence managers is recognized and incorporated into plans. For example, it can be difficult to issue flood warnings on a sunny day when there are no environmental cues. This constraint can be overcome through planning.

2.1.3 The Response Subsystem

Public response constitutes the third warning subsystem. People respond to warnings received from the management subsystem on the basis of their own interpretations of those warnings, and public interpretation can differ from that of detectors or managers. Moreover, the public response subsystem contains an additional warning element, in that people generate unofficial warnings for others. Unofficial warnings can come from members of the management subsystem, for example individual fire and policemen who choose to go house-to-house or from members of the warned public who inform others. People also confirm and alter warnings according to their own perception of events and their own social realities. This facet of a warning system can be overlooked in preparedness.

The ideal response subsystem has particular structural characteristics in an integrated warning system. First, comprehensive and multiple channels of communication to the public have been prepared. Second, warning messages are comprehensive and provide the public with all that it needs to know. Third, public response is monitored as it occurs and fed back into the management subsystem so that adjustments in warnings can be made as needed. Fourth, the ability of the environment to bypass the detection and management subsystems and directly influence public response is taken into account in planning. For example, warnings can explain that the potential for emergency exists despite a lack of obvious environmental cues. Finally, the possibility that detection-system personnel may informally give to the public direct information, which supports or contradicts official warnings, is recognized and managed.

2.1.4 An Integrated Warning System

The model proposed in Fig. 2.1 recognizes multiple warning subsystems and formal as well as informal linkages between them. Two of the greatest constraints to effective emergency warnings are a lack of integration among warning subsystems or a lack of recognition of all subsystem linkages.

2.2 SUBSYSTEM COMPONENTS AND PROCESSES

Each subsystem in a warning system has its own processes to accomplish work and achieve special objectives. These processes have associated issues, dilemmas, and problems. It is the purpose of this section to describe these subsystem processes and components.

2.2.1 The Detection Subsystem

The processes related to detecting an impending emergency largely involve the use of technology and/or science. Scientists and technicians have increasingly played roles in hazard detection as the amount and sophistication level of detection technology has advanced. Members of the public still play a role in hazard detection through sensory observations reported to others. Here, we review the general role of the detection subsystem and some of the problems that can arise when it is used.

2.2.1.1 Monitoring and Detection

The first function of the detection subsystem of a warning system is to collect data about the presence of hazards. This is done both systematically and serendipitously. The systematic approach involves regular observation, measurement, and recording of information about factors that could indicate an impending emergency. The serendipitous approach involves nonsystematic observation of factors which may occur by chance for nonhazard assessment purposes, or by hunch and intuition. Serendipitous observations can be made by members of monitoring organizations and by the public. Both approaches produce data that can be used to predict emergencies.

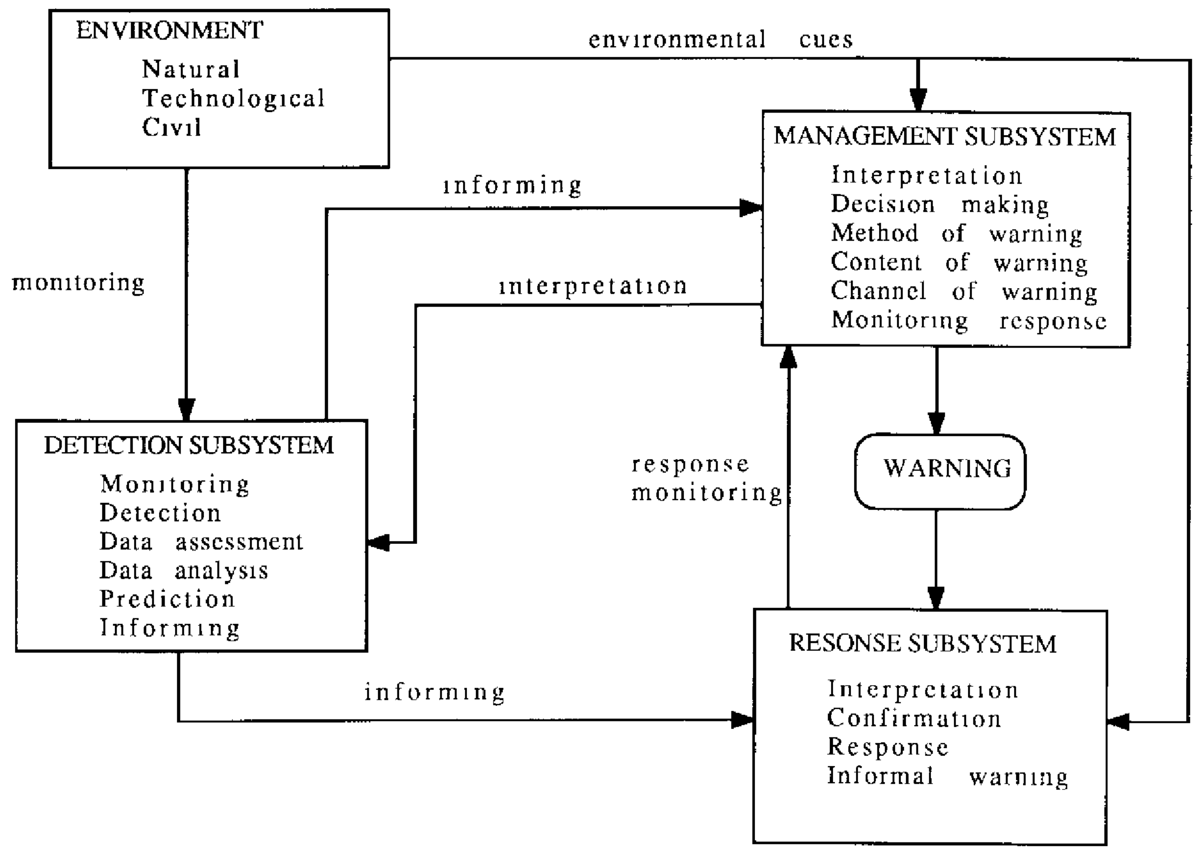

Fig. 2.1. The general components of an integrated warning system.

It is most common for official warnings to originate from the systematic monitoring and data collection approach. For example, instrumentation is in place in some parts of California to collect data for earthquake prediction and warning, rainfall gages are used locally to estimate runoff volumes in flood forecasting, an extensive array of instrumentation is used to detect transient events in nuclear power plants, and tactical and strategic intelligence data are gathered to detect nuclear attack. Sometimes impending emergencies are detected serendipitously. For example, warnings for mudflows along coastal areas frequently are made only after an initial event has occurred and others are likely.

The major issue surrounding monitoring and detection is how much information is needed to detect an impending emergency. The answer to this question hinges on a number of factors including the complexity of the hazard system being monitored, the adequacy of scientific theory or intelligence to predict an emergency, the type of data assessment that must be performed, the level of confidence desired in that analysis, and the resources available to support detection and warning. These needs vary among hazard types and locations.

Monitoring and detection are based on the recognition of some indicators of an impending emergency. For example, in a flood, recognition may be based on observing rainfall and rising river levels. At a nuclear power plant, it may be a combination of instrument reading and alarms. For an earthquake, it may be a swarm of small, precursory seismic events. Regardless of hazard type some signs must be read and interpreted before the first steps toward public warning are implemented. Detection may be made by a member of the public, as in the case of a hazardous chemical spill from a truck, or it may be performed by a specialized monitoring organization, such as NWS or NORAD, through the use of sophisticated technological equipment.

2.2.1.2 Data Assessment and Analysis

The second stage in the detection subsystem of warning systems is data assessment and analysis. Its purpose is to use data to understand the behavior of the hazard system being monitored. This can be done with a fixed set of ideas or theory about that system, or through a screening process that indicates anomalies.

The methods of data assessment range from simple computations to complex modeling efforts. Data inputs range from single variable indicators to complex sets of multiple variable indicators. For example, the assessment of local-tsunami potential is determined by the single variable of earthquake magnitude. At the other extreme, complex multiple variables are used to analyze some flood flows, and nuclear power plant accidents are simulated in complex ways. Nuclear attack could be assessed from single indicators or complicated computer assessments.

Data analysis in warning systems is limited by the factors that bound inquiry. First, limits are imposed by the adequacy of available data. For example, the analysis of hurricanes near Hawaii is complicated by the lack of local weather radar information. Second, data analysis is limited by the level of development in relevant theory. For example, earthquake prediction is currently constrained by the absence of a universally accepted theory of strain release along faults. Third, data analysis can be limited by experience. Insufficient historical records may inhibit understanding of the system being analyzed. The experience of personnel may limit the choice of the type of analysis performed. Fourth, analysis of data is limited by resources. For example, it is impossible to analyze seismological data for every active volcano; it is impossible to simulate the movement of carcinogens into groundwater supplies from every known hazardous waste site.

Several issues complicate data analysis for warnings. First, there is the issue of the legitimacy of the analysis. The scientific basis of the analysis is often not well demonstrated. The experience with earthquake predictions illustrates this problem. A recent prediction for Peru could not be scientifically validated or disproved. Second, there is the issue of multiple analyses and the need for concurrence in conclusions. Both of these issues demonstrate the need for peer consultation, review, and endorsement by a respected scientific reference group.

Once a hazard is detected, the next decision in the warning process is whether or not it poses a threat to human health and safety. In a nuclear attack this threshold may come before actual missile launches are detected. In a flood this threshold may be defined as waters exceeding flood-stage elevations. It may be defined as an off-site release at a nuclear power plant. In an earthquake prediction it may be indicated by an expected Richter magnitude of energy release and associated shaking intensities in populated areas. The determination of threat is often done by the same person or organization performing the detection. Different actors and organizations may also be involved, including private citizens, companies, or any level of government. For example, USGS is 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. Police departments assess the level of public threat in civil disorders. Threat determination is judging that an event is or is not hazardous to the public.

The collation and evaluation of information concerning the hazard are usually performed by a formal organization for which such tasks are part of its normal operations. Such organizations usually convey threat information to emergency management groups within the endangered community. They, in turn, disseminate warnings to the public.

2.2.1.3 Prediction

The purpose of the prediction function in a warning system is to forecast the behavior of the hazard system in a way useful for providing a warning of impending disaster. Predictions for use in warning systems are best if they include information on five factors: (1) lead time, or when the disaster will occur; (2) location, or the area to be impacted; (3) magnitude, or how large (measured in physical variables of the system); (4) probability, or the likelihood it will take place; and (5) consequences, or physical effects.

A variety of formal and informal methods are used in prediction. Prediction is limited by many of the same factors which limit data analysis. These includes data, theory, experience, resources, and expertise. In addition, prediction is complicated by the issues of confidence and uniqueness. Predictions contain varying uncertainties even when stated in probabilistic terms. The basic problem is deciding when uncertainties are small enough to be confident that the prediction is accurate. Prediction may be confounded by the uniqueness of the event when compared to the universe of events of its type.

2.2.1.4 Informing

If predictions are to become part of the warning system, they must go beyond those who detect a hazard and be communicated to emergency management officials. This communication was labelled as informing in Fig. 2.1.

Informing can rely on formally established procedures, which provide guidelines on when, how, who, and what to inform. For example, NWS may have formal arrangements with local media for issuing tornado warnings. Information can also be an informal process for which the responsibility rests on the personnel formulating the prediction. The communication of an imminent landslide may come only at the judgment and disposition of the earth scientist. In either case, responsibility is at the heart of the informing function. Responsibility is sometimes legislatively mandated. This is the case for the U.S. Geological Hazards Program and for nuclear power plant emergencies. In other situations, it is the result of contractual or prearranged agreements. Sometimes the burden lies on informal, ad hoc arrangement, which can, on occasion, create problems for all involved.

The effective transmition of predictions from detectors to emergency managers has not always occurred in past emergencies. The process of informing emergency managers has often been constrained due to several factors. One factor has been concern by detectors of being wrong, for example that the disaster will not occur. This sort of concern has resulted in delays in informing emergency managers about risk. A second factor that has constrained informing is communication focused. For example, detectors inform emergency mangers in technical or scientific terms which are less than clearly understood; it is not obvious to the detector to whom in the emergency management community the communication is best addressed; or communication hardware is inadequate, unavailable, or broken. These factors have also resulted in communication delays in informing emergency managers.

Once a threat is judged to be a significant one, the detector must decide whether or not to alert others about the risk and potential damages. Part of this decision includes determining who should be informed. Clearly, for some hazards—for example, nuclear power plant accident—the alert decision is spelled out in plans. The decision remains discretionary for other hazards. In most warning systems information is usually passed on to an agency with emergency powers or responsibilities through, for example, a phone call to a police dispatcher, an automatic ring-down to a civil defense director, or an activation of a tone-alert radio in the mayor's home. These same communications often occur in an ad hoc manner when not part of formal preparedness.

2.2.2 The Management Subsystem

Official emergency managers typically take the lead in issuing warnings to the public. Public warnings can also be issued by people and organizations without official warning roles. Research has demonstrated that officials who provide the public with warnings come from both formally recognized disaster response organizations and from groups whose warning roles emerge during the emergency. For example, when Mount St. Helens erupted, both the USGS (which had mandated responsibilities to provide warnings) and the Forest Service (which assumed that responsibility) were part of the emergency management component of the warning system.

2.2.2.1 Interpretation

Scientific data, analyses, and predictions are of varying use to an emergency management official who seeks to perform a warning system role. This variability occurs because some of the information provided by detectors cannot be used to make decisions about warning the public, some cannot be incorporated into the warning content, and some cannot be understood at all. The burden of converting risk information into relevant facts often falls on the emergency managers and frequently involves communication and negotiation with scientists or technicians. Negotiation is used because often the detector does not express predictions in the terms a public official wants or can use. For example, earth scientists monitoring an erupting volcano may provide officials with projections of the movement of molten lava based on harmonic tremors. What the official might want to know is where that lava will flow, the length of time it will take to get there, and what the effects will be. The emergency management component of a warning system typically demands different information than the detector is able to provide or is confident in providing.

At times emergency mangers can have a difficult time understanding hazard predictions particularly if they are offered by scientists. For example, local sheriffs responsible for sounding a siren in the event of a hazardous chemical release may not be able to decide on the basis of projected population or individual level doses. Indeed, a sheriff may not know the difference between the two measures. More interpretive information is usually necessary because uncertainty and confusion produced by misunderstood information can lead to inappropriate decisions.

2.2.2.2 Decision to Warn

The critical question facing emergency managers once apprised of a threat is, does the public need to know? Surprisingly, the decision to warn the public is one of the least understood aspects of warning systems. One major issue concerns specifying who makes the decision to warn the public. The decision may be made by a single individual or by a group of individuals. It may be carried out in interpersonal settings or in more rigid institutional environments. It may not be clearly specified who makes the decision in some cases, while in others it may be highly formalized. Previous experience with warning decisions does not clearly illustrate which type of arrangement works best; it does make clear that the person or group making the decision should be identified and recognized before the decision is needed.

A second issue is how to decide. If a single person makes the decision, should he or she do so with consultation? In a group, is consensus, a majority, or even a minority-held belief needed for a warning to be issued? What criteria should be used? Is a recommendation by a scientist necessary? Do predetermined conditions trigger the warning? How much certainty is needed in predictions? Is the decision influenced by the potential magnitude of the impending emergency? Is it sensitive to political concerns? Past experience indicates that answers to questions like these are important parts of the decision process.

The fear of being wrong often surrounds the decision to issue a public warning. This can stem from several factors, such as the fears of being embarrassed, causing public panic, and effecting unnecessary social and economic disruption. Fear can affect the timing of warnings. There are some valid reasons for delaying the issuance of a warning to the public. During a delay, more information can be gathered to validate the need for a public warning. Also, there may be concern that people will not heed the warning if the threat is not immediate. These concerns must be traded off against a growing concern about the consequences of not warning. There are both legal and moral facets to this concern. Can officials be held responsible for withholding information? Is it ethical to withhold the warning? Obviously, public death and injury can result if withheld warnings are followed by disaster.

2.3.2.3 Method and Content of Warning

The aim of a public warning is to alert the public to the likelihood, nature, and consequences of an impending disaster and outline appropriate protective actions. People not at risk as well as those at risk need to be informed, for it is important to know that one is safe from an impending threat.

The method and content of warning consists of the warning message itself, the source of that message, the channels by which it is communicated, and the frequency with which it is repeated. Messages are sometimes written before hand and read when needed. At the other extreme, messages are delivered extemporaneously with little forethought.

Past experience has shown some types of messages to be more effective than others. Good messages contain consistent, accurate, and clear information; guidance on what to do; risk locations, and confidence or certainty in tone. In general, messages must come from sources that the public view as credible. Because different people have different views of credibility, it is usually desirable for messages to come from multiple channels and sources. These include channels such as sirens, the media, emergency broadcast stations, personal contact, or such special systems as automatic telephone ring-downs and tone-alert radios. Multiple sources would include scientists, engineers, public officials, volunteer disaster organizations, or community opinion leaders. Another dimension of warning is the frequency of message dissemination. A single warning is not sufficient to get people to believe and respond.

2.2.2.4 Monitoring Response

One of the most neglected aspects of the emergency management component of warning systems is the monitoring of public response to warnings issued. It is important that those issuing public warnings have some notion of what effects the warnings are having, how the public is interpreting the information, and what additional information is being generated outside the official warning channels. The results of monitoring can be used to adjust the warning method or content on the basis of what the public is and is not doing and to dispel inaccurate warning information.

Rarely does a warning system formalize this mechanism beyond passive rumor control headquarters that the public can call to confirm or disprove rumors. On the other hand, a good system would actively monitor people and the media to correct problems before they become widespread or rumors become rampant.

2.2.3 The Response System

It is often easy for detectors, particularly if they are technicians, scientists, and emergency managers to lose sight of the "big picture" when a warning system is activated. Warning systems are not scientific experiments in which theories, hypotheses, and probabilities about occurrence are scientifically tested, but often scientists involved in warning systems view them in this way. Warning systems are also not exercises in carrying out bureaucratic procedures to honor mandated responsibilities and not exceed the limits of particular political roles and jurisdictions. Emergency managers can see them in this way. Warning systems are the means to serve the larger goal of protecting public health and safety in times of impending emergencies. As such, warning systems exist to help an endangered public take protective actions before a disaster strikes and to convey reassurance to other people not at risk.

Several factors need to be understood and used in warning system preparedness to help elicit a sound public response. Among these are, first, knowledge about how people interpret warning information, and, second, the process through which people come to respond to warning information.

2.2.3.1 Interpretation

Objective reality is not "reality" for people. What is "reality" for people is what they believe or perceive to be real. Consequently, perceptions of reality by people need not match objective reality. In an emergency, this means that even though everyone may be listening to the same warning information message, different people can reach different conclusion about what they hear. These different perceived "realities" about the emergency lead to differing public responses to the same warning message. Some responses can enhance protection while others may not. This problem can be avoided by constructing public warnings so as to help all members of an endangered public perceive reality in the same way; those perceptions can approximate objective knowledge about the impending risk.

The process whereby people act on the basis of their interpretations of emergency warning information can be described in the following way: people must hear the message that is given, it must be understood, it must be believed, and it must be personalized. People must then decide to do something, and, finally, people must carry out their response decisions. Of course, there are exceptions to this process.

Portions of a public can exit from the process at any of these stages. For example, some may understand what is being said in a warning, but they may not believe what they hear. Some may believe what they hear but not personalize the risk—that is, they may not think that they themselves are among those at risk. In addition, some may decide to respond but not be able to actually do so because they lack a means for carrying out their decision. Constraints to effective public response exist at each step in the response process. Indeed, the goals of any public warning system are (1) to have everyone who should hear a warning message hear it, (2) to have all members of the public understand what is being said, (3) to have the public believe what is being said, (4) to have people at risk personalize the warning information and those not at risk not do so, (5) to have people come to make good decisions about what they should and should not do, and (6) to have people act or respond on the basis of those decisions in a timely fashion.

2.2.3.2 Response

What people do in response to emergency warnings varies. They might evacuate, bring lawn furniture inside, close windows, or seek more information about the impending emergency. People can and often do engage in multiple responses to warnings.

Unfortunately, it is not always clear what are the best steps to take in response to emergency warnings. Judgments about response can be different in hindsight. For example, sheltering in-place might seem to be a good response to hurricane warnings, but may be a wrong decision in hindsight if the shelter is damaged or destroyed. The adequacy of responses might be measured in several ways, for example, the extent to which people react in ways consistent with the emergency information that they were provided or the number of deaths and injuries avoided.

2.2.3.3 Informal Warnings

There is an informal dimension to emergency public warnings. People who are the targets of formal warnings also participate in warning others. These informal warnings can serve a useful purpose. For example, people often contact relatives, friends, and other intimates to warn them or make sure that they have been warned. Informal warnings can also be accidental or result from behavior not intended to share warnings with others. For example, an initial first-warning response is to seek more information and confirm the initial warning, and people often contact others in this seek and confirm process. Some of these contacts spread warnings to persons not yet aware of the emergency. The result of either type of informal warnings is that people in the public help to warn others.

Sometimes informal warnings are correct and help to reinforce official warnings. Other times informal warnings can be incorrect. This is more likely when there are strong pre-emergency misperceptions about the hazard, as, for example, that nuclear power plants can explode like bombs, that lightning never strikes in the same place twice, or that it never floods on the south side of town. Informal warnings can contribute to confusion in these cases, particularly if formal warnings are weak in substance or form.

Some empirical warning studies have provided data on the incidence of informal notification in historical emergencies (Table 2.1). While no study has explicitly focused upon the phenomenon, the available data suggest several conclusions.

First, informal notification does occur in emergencies. It is likely that most members of the public engage in some behavior after being warned that could result in spreading warnings to others. Data in Table 2.1 suggest that a median of 38% of those warned received their first warnings by informal notification. Attempts to estimate public alert rates are likely to underestimate notification times if they do not take informal notification into account. The role of informal notification in providing first warnings would probably decrease dramatically as the speed of the formal alert and notification system increases. Informal notification also appears to increase as the urgency of the situation increases. Finally, almost 90% of those warned received informal notification in historical emergencies.

2.3 MERGING DIVERGENT VIEWPOINTS FOR INTEGRATED WARNING SYSTEMS

Many different people and organizations perform roles in a warning system. These people may be members of organizations with formal warning duties, members of organizations whose warning roles emerge during the emergency, and members of the general public. Organizational membership and professional specializations can cause people to view the general warning system differently. Different views of the same system by different actors can constrain system effectiveness.

Three different viewpoints on warning are those of the detector, the manager, and the public.

The detector viewpoint is focused on the detection component of a warning system (monitoring, detection, data assessment and analysis, and prediction) and downplays other

Table 2.1. Reported rates of informal notification

Event	Informal notification: Received as first warning	Informal notification: Received as any warning	Informal notification: Gave to others	Time of first warning	Lead time	Hazard type	Reference
Hilo Tsunami	-	17%	-	Evening	Short	Tsunami	Lachman et al 1961, p 11
Denver Flood	28%	40%	-	Afternoon	Short	Flood	Drabek and Stephenson 1971, Drabek 1969
Canadian Explosion	62%	-	-	-	Short	Explosion	Scanlon and Frizzell 1972, p 316
Hurricane Camille	-	81%	-	Morning	Long	Hurricane	Wilkinson and Ross 1970
Abilene Flood	25%	-	87%	-	Medium	Flood	Perry and Mushkatel 1986
Mt. Vernon Hazard Material	44%	-	68%	Morning	Short	Haz Material	Perry and Mushkatel 1986, p 32
Denver Hazard Material	58%	-	27%	Evening	Short	Haz Material	Perry and Mushkatel 1986, p. 32
Alaska Tsunami	14%	-	-	Afternoon	Short	Tsunami	Haas and Trainer 1973, p. 32
Mount St. Helens, Toutle	41%	-	-	Morning	Short	Volcano	Perry and Greene 1983, p 51
Mount St. Helens, Woodland	59%	-	-	Morning	Short	Volcano	Perry and Greene 1983
Hurricane Eloise	-	65%	-	-	Long	Hurricane	Windham et al 1977, p 38
Pittsburgh Hazard Material	18%	-	30%	Afternoon	Short	Haz Material	Rogers and Sorensen 1989
Confluence Hazard Material	18%	-	32%	Night	Short	Haz Material	Rogers and Sorensen 1989
Los Angeles Earthquake Prediction	-	83%	73%	-	Long	Earthquake Prediction	Turner et al. 1986, pp 66, 70-71
Mount St Helens Ashfall	52%	-	15%	Day	Long	Ashfall	Dillman, Schwabe, and Short 1983
Mount St. Helens	38%	-	-	Morning	Long	Volcano	Perry 1985, p 92
Fillmore Flood	39%	-	-	Morning	Short	Flood	Perry, Lindell, and Greene 1981
Three Mile Island	24%	-	-	-	Long	Nuclear Power Plant	Perry 1985, p 41
Worchester Tornado	-	-	40%	Afternoon	Short	Tornado	Wallace 1956, p 39
Valley Flood	38%	-	-	Evening	Short	Flood	Perry, Lindell, and Greene 1981
Snowquaimie Flood	43%	-	-	Night	Short	Flood	Perry, Lindell, and Greene 1981
Sumner Flood	89%	-	-	Morning	Short	Flood	Perry, Lindell, and Greene 1981
Eagle Pass Flood	32%	-	-	Morning	Long	Flood	Clifford 1956, p. 114
Piedras Negras Flood	15%	-	-	Morning	Long	Flood	Clifford 1956, p 114
Nanticoke Hazard Material	38%	58%	-	Night	Short	Haz Material	Duclos, Binder, and Reister 1989
Hurricane Carla	6%	-	-	-	Long	Hurricane	Moore et al. 1963
Air Raid	-	-	4%	Night	Short	Air Raid	Mack and Baker 1961, p 13
Mississauga Derailment	24%	-	-	Morning	Short	Haz Material	Burton et al 1981, p. 5-46
Mobile Hurricane	-	-	19%	-	Long	Hurricane	Leik et al 1981, p 189
Miami Hurricane	-	-	21%	-	Long	Hurricane	Leik et al 1981, p 189
New Orleans Hurricane	-	-	15%	-	Long	Hurricane	Leik et al 1981, p 189
Atlanta Flood	-	-	4%	-	-	Flood	Leik et al 1981, p. 189
Boise Flood	-	-	23%	-	-	Flood	Leik et al. 1981, p 189

Table 2.1. (continued)

Event	Informal notification: Received as first warning	Informal notification: Received as any warning	Gave to others	Time of first warning	Lead time	Hazard type	Reference
Wheeling Flood	-	-	12%	-	-	Flood	Leik et al 1981, p. 189
Rochester Flood	-	-	13%	Night	Short	Flood	Leik et al 1981, p. 189
Clarksburg Flood	-	-	21%	-	-	Flood	Leik et al 1981, p. 189
Minneapolis Tornado	-	-	5%	-	Short	Tornado	Leik et al. 1981, p 189

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warning system components. It leads to a limited perception of a warning system: do good detection work, detect an impending emergency, and then tell people about it. It has acted in historical emergencies as a constraint on providing emergency managers with the kind of warning information they need. Emergency managers and the public need more than simply being informed about a hazard. Additional specific information is necessary, and it should be conveyed in appropriate ways. Joint planning between detectors and emergency managers has helped reduce this problem recently, but it is by no means solved.

The management viewpoint is that most likely to be held by emergency mangers. This viewpoint is focused on the duties of emergency managers in a warning system (interpreting what those who have detected the hazard say, deciding to warn the public, determining the method and content of warnings, and monitoring public response). It leads to the following warning system focus: hear about the possible emergency from detectors, inform local emergency organizations, and then have them warn their public in whatever way they deem appropriate. This viewpoint has acted in historical emergencies to constrain providing the public with the type of warnings known to help people make good response decisions. The viewpoint is focused on getting the warning job done, and this facilitates warning the public. However, the manager viewpoint almost guarantees that different warning messages are presented to the public by different local leaders. It also can mean that warnings vary in sophistication about the possibilities for public response. This problem has been recently reduced for some hazards because of joint planning efforts between local, state, and federal emergency managers that include sharing knowledge about public response. Some of the problems posed by this viewpoint are not fully solved.

The third viewpoint about warning systems is the public view. This viewpoint reflects the public response component of warning systems. It leads to the following goals: define what is needed for good public response decisions; plan the system to achieve this objective; attempt to broaden the scientific and management viewpoints and remove the constraints they pose for warning system effectiveness; seek to hear, understand, believe, personalize, decide what to do; and then respond to warnings. Meeting these goals requires clear and information-rich warnings. This viewpoint demands more of the emergency management subsystem of a warning system than is typically provided. Some of the needs reflected in the public response viewpoint have begun to be incorporated into warning system preparedness for a few hazards, for example, at several nuclear power plants.

These three viewpoints exist in all warning systems because all systems involve detectors, managers, and members of the public. These perspectives must be broadened through interdisciplinary warning system preparedness. Only a few involved professionals have been able to broaden their warning system viewpoint beyond the one imposed by their organizational membership. Consequently, integrated warning systems remain the exception rather than the rule. All three warning system components must be recognized and integrated to create an effective system.

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