3. BUILDING AND EVALUATING A WARNING SYSTEM

The future holds the potential for unimagined hazards for which warning systems may be useful, as technology advances (biotechnology is only one recent possibility), as more is learned about the natural world (poison gas at lake bottoms is only recently recognized as a significant natural threat), and as the strategies of political and social causes are stretched to new limits (urban terrorism against innocent civilians, although not a new idea, seems now to be a more frequent event). While all these hazards will continue to be varied and different, they may be more similar than dissimilar in relation to the need for warning systems. Warning systems for any low-probability catastrophic event share many organizational and human response components and building blocks. For example, detectors of a hazard must be linked to public warning disseminators, and citizens will respond to a warning on the basis of their situational risk perceptions regardless of hazard type. There are themes common to all warning systems; our common knowledge of these themes can serve as the blueprint for the construction of any warning system.

This chapter presents a common warning system blueprint, outlining the themes that are important in any effective warning system for a low-probability catastrophic event. The points we make are general, by design, and are applicable to all warning systems. The ways of adapting and implementing these general considerations for a particular hazard type are discussed in Sect. 6.

3.1 GOALS OF WARNING SYSTEMS

3.1.1 Alternative Goals and Audiences

The goal of any warning system is to alert and notify people of potential disaster to reduce death, injury, and loss of property. This obvious goal can be overlooked by persons involved in warning system preparedness. Warning systems typically cut across a variety of organizations. Membership in one organization with a limited warning role can constrain perceptions of warning system jobs. For example, hazard detecting organizations typically monitor the natural, technological, or civil environment to warn a political jurisdiction of an impending hazard. Such organizations may, therefore, view passing warning information to a governor as the end of their warning responsibility. A state bureaucracy which passes the information along to local government may view its warning role as completed when local officials are informed. The organizational and bureaucratic structures of society in the United States are such that the general goal of a warning system—to provide citizens at risk with information to maximize the odds that they will engage in some appropriate response to the risk—is too often defined as someone else's job. Moreover, in warnings, information needed by the public can be somewhat broader than that needed by organizations. Consequently, too often, actual public warnings can be inadequate while members of warning system organizations have done their jobs well.

Several specific goals might be sought to achieve the general goal of warning systems. The first is to get people at risk to listen to emergency information and to prepare them to respond with some sort of protective action. The second is to guide people to take what is considered to be the best protective action. The third is to help

people understand that their actions are part of an organized response to protect the community.

Warning systems involve a variety of organizational actors (Sect. 2) and can include, for example, scientific monitoring organizations and federal, state, and local governments. Warning systems also involve a range of alternative target audiences—for example, the public at risk, the public not at risk, and special at-risk populations. A consequence of the innate structure of warning systems is that different goals (e.g., communicating risk information only to the next bureaucratic level versus telling the public) and different audiences (e.g., the public at risk versus the state bureaucracy) exist for different actors involved in warning systems. The factor that should not be overlooked by any warning system actor is the fundamental reason for the existence of the warning system: to inform the public at risk in a timely manner with the kind of information they need.

3.1.2 Alternative Protective Actions

The public has a limited number of strategies available to use in responding to a warning. One is to go about planned normal activities. The second is to seek more information. The third is to take some form of protective action. These alternatives are not mutually exclusive. Persons frequently engage in all or some of these in response to warnings. Protective actions themselves can also be divided into three alternatives. One is to take shelter in a structure or in protective clothing. A second is to move away from the area of likely impact. A third is to block or divert the impacts, as, for example, by sandbagging a river or using a protective mask in a toxic vapor cloud.

Public response to warnings differs for different hazards and depends on the threat and situation at the time of impact. At some point a policy decision must be made regarding what sort of protective action the public will be encouraged to take. As will be discussed in Sect. 5, if guidance about appropriate responses is not provided, it should not be a surprise that different members of the public will respond in different ways. It is an inadequate warning strategy to simply pass risk information to the public without telling them what to do for their safety.

3.1.3 Myths That Confuse Goals

In designing and implementing a warning system, warning system actors and decision makers should not fall prey to myths that have historically undermined public warnings. To summarize, the fallacies of these myths are as follows.

First, the public simply does not panic in response to warnings of impending disasters. Hollywood and Tokyo screenplays are probable culprits in the propagation of the panic myth. Research documents that panic occurs only in situations in which there is closed physical space, in which there is an immediate and clear threat of death, and in which escape routes will not accommodate all those in danger in the minutes before death comes to those left behind. Thus, panic does not follow a warning except in very rare circumstances.

Second, the public rarely if ever gets too much emergency information in an official warning. It is true that people do not remember all the information contained in a warning if they hear it only once; therefore, detailed messages should be repeated in an emergency. Emergency warnings are simply not subject to the 30-s rule known to operate in Madison Avenue attempts to sell toothpaste and deodorant soap. People are

information hungry in a warning situation. They should be provided with all the information they need, and this information can be part of warning messages.

Third, the effectiveness of people's responses to warnings is not diminished by what has come to be labelled the "cry wolf" syndrome, if they have been informed of the reasons for previous "misses." Obviously, there would be a negative effect on subsequent public response if false alarms occurred frequently, if no attempt was made to explain why there were false alarms, and if the cost of response is high. Yet, false alarms, if explained, may actually enhance the public's awareness of hazard and its ability to process risk information in subsequent warning events. False alarms are better viewed as opportunities for conveying information than as problems.

Fourth, people at risk want information from a variety of sources and not from a single spokesperson. Multiple sources help people confirm the warning information and the situation, and reinforce belief in the content of the warning message. This does not mean that multiple and different warning messages from different spokespersons are desirable. The objective could be achieved in one of two ways. Different spokespersons could all deliver the same message, or a panel of spokespersons could deliver a warning a number of times.

Fifth, most people simply do not respond with protective actions to warning messages as soon as they hear their first warning. Most people seek more information about the impending risk, and appropriate responses from people they know and from other information sources. People call friends, relatives, and neighbors to find out what they plan to do. People also turn on radio and television to get more information.

Sixth, most people will not blindly follow instructions in a warning message unless the basis for the instruction is given in the message and that basis makes common sense. If instructions in an official warning do not make sense, people typically will behave according to other information sources that do supply sensible instructions.

Last, people do not remember what the sounding of various siren signal patterns means, but they may try to find out the reason for the siren if it continues to sound or is repeated. Sirens are best viewed and used as an alert for the public to seek out other emergency information, rather than as a signal that should elicit adaptive and protective actions from the public. An exception may be the frequent use of siren drills through which response becomes automatic. This use is largely inappropriate for the general public, but it may be useful in work settings or in special situations that can be supported by an intensive education program.

Fear of public panic in response to warnings, the idea that a warning must be so short as to rob the public of needed information, fear of false alarms based on the "cry wolf" syndrome, and the other myths just reviewed have often acted as constraints preventing warning systems from achieving their general goal of maximizing good public response decisions. There must be a continuing effort to convince planners to abandon these deep-seated myths.

3.2 LINKS WITH HAZARD DETECTORS

A warning system cannot function if appropriate emergency officials do not receive timely information about risk. The failure of officials to receive information in a warning sequence is a documented cause of many warning system failures (see Sect. 4). Emergency officers cannot always assume that they will receive this information reliably. A warning plan must take a proactive approach on establishing links between hazard

detectors and emergency managers. Emergency planners should first identify those who detect each relevant hazard for their jurisdiction (see Fig. 3.1). As part of this identification, planners should meet with the group detecting the hazard and learn the process by which they collect, process, and report information.

The next step is to develop the appropriate hardware link (and a backup link) to ensure that a physical means for communication exists. Nondedicated phone lines are not a reliable primary or backup link. Agreements on when the detector can communicate information to officials should be established and documented. Finally, an understanding of how the organization will maintain relationships in an emerging warning situation should be established.

Such prior arrangements will help to develop better working relationships in an emergency. They will also facilitate open and timely communication between these two parts of the warning system network.

3.3 INTERPRETING HAZARDS COMMUNICATIONS

3.3.1 Preparing for Interpreting Scientific Information

Emergency managers in a warning system must become technically and scientifically informed in order to be able to make warning decisions on the basis of received scientific and technical information. It is also part of the detector's responsibility to communicate information in ways which will make it understandable to emergency managers. Managers must gain a fundamental understanding of the risk or hazard systems with which they are dealing in the warning process. Managers do not need to become technical and scientific experts themselves; however, they must develop a knowledge base adequate for understanding when communicating with experts in a warning context. It will probably be the warning manager's responsibility to further translate technical or scientific information relayed to him by detectors into a format and language that the public can understand and to translate risk information into hazard terms and then into recommended public protection actions.

In many emergencies, this learning takes place rapidly during the first phase of the warning process. When approached in this fashion, learning has varying degrees of success. An alternative to situational learning is planning. Under planned learning, one can envision a range of alternative risk scenarios, seek to specify the circumstances in which such scenarios are possible and develop an understanding of what sort of risk exists for the public in reference to each scenario.

3.3.2 Preparing for Interpreting Nonscientific Information

Emergency managers who play a warning systems role must also be prepared to receive information from detectors about risk regarding hazards such as civil crisis. This information must be translated into public risk information that can provide a basis for recommended public protective actions. This translation will likely be less time consuming if it is facilitated by knowledge and planning.

	HAZARD		
PLANNING TASK	VOLCANO	FLOODS	WATER TREATMENT PLANT
WHO DETECTS	Volcano observatory	National Weather Service	Plant shift supervisor
COMMUNICATION LINKS FROM DETECTOR TO EMERGENCY MANAGER	Dedicated phone or radio	Teletype or commercial phone	Alarm or radio
INITIATION OF NOTIFICATION	When a prediction is made	When flash flood alert is issued	When a release is detected
MAINTENANCE OF COMMUNICATIONS IN AN EMERGENCY	Send representative to volcano to observe	Establish two-way radio contact	Set up computer link via modem

Fig. 3.1. Examples of detection-management linkages.

3.3.3 Dealing with Probability, Uncertainty, and Disagreement

The behavior of many hazardous systems (geological, climatological, technological, and national security) for which warnings are designed is based on probability. When certain conditions are present, a hazard system may pose a threat only part of the time. This poses problems for warning officials because it is difficult to use probability concepts in warnings. People tend to view risk in more absolute terms: will a hazardous event occur or not. This could be changing, in part because of recent efforts to educate the public about probabilities. For example, NWS uses probabilities in many of its warnings. Scientists couch their predictions in probabilistic terms, but warning officials need to make a yes or no decision to warn. They do not have the luxury of repeating the scientific information to the public. They have to convey with confidence the need to take protective actions in an uncertain situation.

Another problem for warning officials is dealing with conflicting information, opinions, and interpretations. It is highly likely that such disagreements will reach the public through the media, because the media tend to seek out and publicize both sides of most stories.

A reasonable philosophy for emergency managers to consider in dealing with uncertainty and conflict in risk information is one of prudence. If in doubt, one could opt for the warning strategy that will err on the side of protecting the public. Such action is perhaps most prudent if performed on the basis of information from scientists or risk detectors with formal responsibilities to gather such data. In such cases, the public can be brought to better understand uncertainty, and the basis for cautious decisions, in the public interest. The bottom line is that emergency managers must recognize that most risk situations are probabilistic. Planning should address under what circumstances warnings

should be issued to the public and when probabilities are so low as to be ignored from a public warning viewpoint.

3.4 DECIDING TO WARN

3.4.1 What the Decisions Are

Four basic decisions face emergency managers confronted with risk information from detectors as they ponder communicating warnings to the public. These are whether to warn the public, when to issue the warning, who and where to warn, and how to warn.

3.4.1.1 Whether to Warn

There are many circumstances in which there is no alternative to a public warning. Some examples are the sighting of a funnel cloud moving on a path toward a populated area or the occurrence of a certain category of accident at a nuclear power plant, in which case a public warning is required by law. Cases like these are more rare than common. In most events, the probability of actual impact is less than certain, and the legal system has not clearly determined when warnings will and will not be issued. In many of these cases emergency managers have determined that public warnings were not needed because of the low-probability of impact. They wish to avoid public "panic," the economic costs of "unwarranted" warning and public response, or the loss of credibility resulting from a false alarm. While these are recurring concerns, they rarely prove to be valid. The public would rather be safe than sorry. People tolerate false alarms if there is a valid scientific rationale for the warning and the "miss." For example, the public has been tolerant of hurricane warnings, for which there is an evacuation-warning false alarm rate of 70%. People subject to this hazard are willing to evacuate needlessly 70% of the time to ensure that they will avoid staying when evacuation is needed. The bottom line is, when in doubt, warn. The consequences of being wrong are more severe if a disaster occurs when there has been no public warning than if a disaster does not occur after warning. In addition, even if an official warning is not issued, unofficial ones are likely to be made as information about the risk becomes available to the press and the public.

We noted in the first chapter of this report that public warning systems are capable of disseminating safety as well as risk information. Risk information exists on a continuum that ranges from "background," with extremely low probabilities of risk, to risk with a 100% probability of materializing. Most of the events that precipitate the use of a warning system fall somewhere between background probability and 100%. The question of whether to warn or not is best cast not as whether the public needs to be told about risk or not, but instead as at what point should emergency managers recommend through public warnings that people act as if impact will occur and, therefore, engage in protective actions. The answer to this question is rarely simple or straightforward. The decision must be made as events occur, and it would be better as the consequence of planning rather than being influenced by unpredictable pressures operating in actual emergencies.

3.4.1.2 When to Warn

Emergency officials have sometimes delayed issuing public warnings in order to get more information and increase their confidence that they will issue a "correct" warning. There is a belief that people will not respond if the lead time to act is too long, yet the ultimate danger of delay is issuing a warning when it is too late for people to take protective action. Ideally, a warning should be issued early and its content geared to the uncertainty and likelihood of the event. The warning then can be revised to reflect the changing circumstances. Early and open disclosure will prevent officials from being "scooped" by unofficial sources such as the media or being accused of a cover-up. Failure to disclose information can undermine the credibility of those issuing information to the public through the emergency warning system.

3.4.1.3 Who and Where to Warn

The next major decision concerns which geographical area to warn given the projected impact of the disaster. This decision also includes determining which if any areas should be informed that they are not at risk, and whether different areas are at different risk and should receive different warnings. These decisions are limited by available data and knowledge about how to use the data that are available. The precision with which these decisions can be made is determined by the particular hazard, the ability to measure risk and hazard, and the analytical tools available to the decision maker. It is desirable to have established knowledge about impact before the time when public emergency warnings are being considered. Such knowledge should not be given inflexible boundaries. For example, the Chernobyl nuclear power plant accident illustrated that a planned for 10-mile risk zone did not take into account radiological hazards at 50 or 100 miles. Other events that are more geographically random, such as terrorism or transportation spills of hazardous materials, need a highly flexible warning dissemination system. The lessons gained from some historical events also illustrate that caution is also prudent. It is better to warn a large area than to have to react quickly as the impacts spread into unwarned areas.

3.4.1.4 How to Warn

The final decision to be faced is the decision about how to disseminate the warning to the public. The decision includes specifying the source of the warning, the channel of communication, the message content, the frequency with which the warning is given, and whether different audiences within the same areas require different warnings; for example, warning may be given in several languages. These topics are the subject of the latter part of this chapter.

3.4.2 Who Decides to Warn

It is important that a warning plan specify who will decide to issue a warning before a decision is needed. One problem that can occur is competition for warning authority, which can delay or prevent a good decision. Where possible, decisions should rest with people with normal day-to-day decision authority. This avoids confusion or conflict even when the decision is specified.

Either an individual or a group can have warning decision authority. If this authority rests with an individual, a back-up decision structure should be specified in case that individual is unavailable, and if decision authority rests with a group, the membership and convening mechanism should be established as well as backup procedures should the group be unable to convene. Who decides may be determined by legal mandate. In some states, only the governor can legally issue a warning; in others, the person in authority may be a county sheriff or a local mayor. In any case, planners should ensure that a prompt decision can be made if the situation calls for a rapid warning.

3.4.3 Decision-Making Processes

It is also desirable to specify in plans how the warning decision will be made in the emergency situation. This involves establishing the broad criteria on which to make a decision and indicating how those criteria should be used. Rigid decision-making frameworks should be avoided. Human judgment is still an important and necessary part of decision making even with today's advanced technology.

Analytical models and decision criteria are helpful to making good decisions, but these tools cannot make the decision. For example, one warning decision system we reviewed involved a complex model in which data were entered and the system made a yes or no warning decision. But as the final step of the process the decision maker could override the model and go ahead with the warning anyway. Decision models may be of greater use in deciding when and where to warn than in actually deciding whether to warn. The exception would be for extremely fast-moving events in which a warning must be automatically triggered to provide sufficient time for the public to take protective actions.

3.5 WRITING THE WARNING MESSAGE

One of the clearest and most consistent conclusions of social science research is that the warning message itself is one of the most important factors in determining the effectiveness of a warning system. In large part, it is the content and style of the actual warning message that shapes the extent to which an endangered public engages in protective actions.

In the following section, we review the elements of both message style and content that should be considered in writing a public warning. Before proceeding, however, let us correct the notion that public warning messages must be short or else the endangered public will become confused or lose interest in the subject. The public does have a short attention span. But major emergencies like tsunamis, dam failures, and nuclear power plant accidents are unique in terms of how willing a public is to listen to information. Emergency warnings of impending catastrophes convert an information-adverse public (you have only 30 seconds to convince me to buy your product) into a public that is information hungry (why are we at risk, do you really mean me, how long do I have, what is it you think I should do, and so on). Warning messages that "keep it short" are inappropriate in public emergencies because short messages set a diverse at-risk public on an information scavenger hunt to fill the information voids left by the short message. Such brief messages can be dangerous since they can lead people to consult friends, neighbors, relatives, superstitions, biases, and a raft of other "information providers" to fill the void. These other sources may provide inaccurate information (it never floods here, lightning never strikes in the same place twice and we had ours last year, all nuclear power accidents release radiation as happened at Chernobyl) and create rumors. Subsequently,

poor public response decisions or lack of protective actions can result. The sections which follow address the style and content of public emergency messages appropriate for inclusion in plans for warnings.

3.5.1 The Warning Content

Five topics are important to consider in assembling the content of a public warning message. These topics are hazard or risk, guidance, location, time, and source (Fig. 3.2).

3.5.1.1 Hazard

A warning message must provide the public with information about the impending hazard by describing the event that may occur and how it poses a danger to people. It is insufficient, for example, for a warning to simply state that a dam may break. This warning must also describe the height and speed of impact of the floodwaters that will ensue, and the size and location of the areas that could be affected. A warning for a nuclear power plant accident might indicate that the radiation will filter into the air like a cloud and then travel with the wind while becoming less and less concentrated.

These examples are not meant as prototype descriptions for dam failure and nuclear power plant radiation releases. They simply illustrate that warnings should be specific about the character of the hazards involved. A warning could describe "a wall of water 20 feet high moving at 40 miles per hour," "an explosion hotter than the inside of the sun covering half of the county," "or a seismic shake severe enough to bring down half the unreinforced brick buildings in the city." If a hazard is well described, people are better able to understand the logic of protective actions, (e.g., close the windows in the house because the risk is in the air; get out of brick buildings because they may fall down).

Thus, hazards should be described with sufficient detail so that all members of the public understand the character of the disaster agent from which they are to protect themselves. Informing the public about the physical characteristics of the hazard will reduce the number of people in an endangered public who misperceive the hazard and then make poor response decisions because of those misperceptions. The hazard aspect of warning message content provides the public with a rationale for subsequent behavior.

3.5.1.2 Guidance

Public warning messages must also include guidance about what people should do to maximize their safety in the face of impending disaster. It cannot be assumed that members of the public will know what constitutes an appropriate protective action. The protective action must be described. This point may seem obvious, but it is not. For example, warnings must do more than tell people that they should "get to high ground." High ground for some may be the low ground for others. High ground should be defined—for example, "ground higher than the top of City Hall," or specify areas to which people should evacuate.

MESSAGE STYLE	MESSAGE CONTENT				
	HAZARD	LOCATION	GUIDANCE	TIME	SOURCES
SPECIFICITY					
CONSISTENCY					
ACCURACY					
CERTAINTY					
CLARITY					

Fig. 3.2. The style and content of a warning message.

3.5.1.3 Location

A warning message must also describe the location of risk because of the impending hazard. The hazard factor first described and this location factor are closely linked. Detailing the location of risk is best done in ways readily understood by the public. For example, a flash flood warning could say: "The area of town that will flood will be between Second and Fifth Streets, from Elm Avenue to Magnolia Boulevard." If there is reason to be concerned that people who are safe could think that they are unsafe, then the warning should address them—for example, "People who live in other parts of the city will not experience flooding"—but the warning should then explain why they are safe. This is usually necessary because a wider audience than those at risk will hear the warning message.

3.5.1.4 Time

Public warnings must also address the "when" aspect of response. The public at risk needs information about how much time is available for them to engage in protective actions before impact, or how much time there is before they should initiate protective actions. For example, "The tsunamis would not strike before 10 p.m. this evening, and you should be on the northern side of U.S. Highway 72 by 9:45 p.m. to be on the safe side."

3.5.1.5 Source

The final important dimension of warning content is the source of the warning. The source of the warning should be identified in the message. Warnings are most believable if they come from a mixed set of persons. For example, "The mayor and the head of civil defense have just conferred with scientists from our local university and the National Weather Service as well as with the head of our local Red Cross chapter, and we now wish to warn you that. . . ."

3.5.2 The Warning Style

The five aspects of warning content can be cross-classified against the varied stylistic aspects of a warning message (Fig. 3.2). The stylistic aspects are specificity, consistency, accuracy, certainty, and clarity. A warning message could readily be evaluated by viewing the specificity of the message regarding location, guidance, hazard and time; the consistency of the message regarding these same content factors; and so on. The sections which follow describe the quality of the five stylistic aspects of the most effective public warnings.

3.5.2.1 Specificity

A good warning message is specific about the area at risk, what people should do, the character of the hazard, how much time people have to engage in protective actions, and the source of the message. There are many occasions when specificity on all these items cannot be high. Something may be unknown or known imprecisely. On these occasions, the warning message itself need not be nonspecific. For example, "We do not know nor can it be known which buildings in the city will be safe and which will not be

safe when the earthquake strikes, but we do know that most people will be safer if they go home now."

3.5.2.2 Consistency

A warning message must also be consistent, both within itself as well as across different messages. Inconsistencies exist within a message for a variety of reasons and in different ways. For example, it is inconsistent to tell a public to evacuate but that their children will be kept in neighborhood schools. In most emergencies there are numerous inconsistencies across different warnings as more is learned about the impending event and updates are issued. For example, inconsistencies can appear as new information reveals that the hazard has decreased or increased, the number of people at risk has become larger or smaller, and so on. Consistency can be rendered across messages in circumstances such as these by simply referencing and repeating what was last said, what has changed, and why.

3.5.2.3 Certainty

A message should be stated with certainty even in circumstances in which there is ambiguity associated with the hazard's impact. For example, "There is no way for us to know if there really is a bomb in the skyscraper, or that it will actually go off at 3 p.m. if there is, but we have decided to recommend that the building be evacuated now, and that we will act as if the bomb threat is a real one." Certainty in warning messages extend beyond message content to include the tone with which it is delivered to the public. The warning should be spoken by the person delivering it as if he or she believes or is certain about what is being said.

3.5.2.4 Clarity

Warnings must be worded in simple language that can be understood. For example, "a possible transient excursion of the reactor resulting in a sudden relocation of the core materials outside the containment vessel" might better be stated as "some radiation may escape from a hole in the nuclear reactor."

3.5.2.5 Accuracy

The last important stylistic attribute is accuracy. A warning message must contain timely, accurate, and complete information. If people learn or suspect that they are not receiving the whole truth, they may well not believe the message, or they may consider its sources to be noncredible. Accuracy is enhanced simply by being fully open and honest with the public regarding a hazard. In addition, accuracy is important in parts of the warning that may be viewed by officials as being trivial. For example, calling Broad Street "Board" Street by mistake may send a signal to the public that other essential information is also incorrect, even though they can correct the error on the basis of personal knowledge.

3.6 DISSEMINATING THE MESSAGE

3.6.1 Warning System Communication Channels

Warnings can be issued to the public in a variety of ways. They can be conveyed by voice, electronic signals, or printed medium. Voices can be direct or broadcast over loudspeakers, public address systems, telephone, radio, or television. Signals include sirens, alarms, whistles, signs, and lights. Leaflets or video can be used to distribute graphic information and printed messages. In this section we review briefly the technology of each warning channel and discuss the strengths and weaknesses of each.

3.6.1.1 Personal Notification

Personal notification involves using emergency personnel to go door-to-door or to groups of people to deliver a personal warning message. This type of warning mechanism can be used in sparsely populated areas, in areas with a large seasonal or diurnal population (such as recreation areas), in areas not covered by electronic warning capabilities, and in areas with adequate numbers of emergency personnel.

The chief advantage of personal contact is that people are more willing to respond to a warning delivered personally because they are more likely to believe that a danger exists. However, this method is time-consuming and may require the commitment of many vehicles and persons. To support the implementation of this method, emergency personnel should develop a plan for systematically traversing the threatened area and should issue the warning, beginning with the highest risk zone and proceeding to those of lower risk. A trial run is useful for establishing the warning time needed to notify the population at risk and for establishing a rate for different types of areas.

3.6.1.2 Loudspeakers and PA Systems

It is feasible to use existing public address (PA) systems to notify people in areas which are covered by such systems. Schools, hospitals, prisons, nursing homes, sports arenas, theaters, or shopping centers often have PA systems. In addition, portable loudspeakers can be used from vehicles to warn nearby populations; often these are used in conjunction with personal notification procedures. Existing PA systems supplement other warning system communication networks. They are useful in reaching small segments of the population in confined settings. To be effective, PA systems need a good communications link to the operators so that messages can be disseminated quickly and accurately. Portable loudspeakers increase the speed of warning populations lacking other means to receive the warning. They are particularly useful during night-time hours when many people are asleep. Their chief disadvantages are that it is often difficult for people to hear a warning broadcast from a moving vehicle, that sometimes people only hear part of the message, and that it is difficult for people to confirm the warning.

3.6.1.3 Radio

Radio is a major channel for disseminating warning information because it can quickly reach a large number of people during nonsleeping hours. Certain EBS radio stations have been designated as part of the NAWAS system. These stations usually have arrangements with local civil defense offices or other government agencies to broadcast

emergency warnings for most hazards. In most situations, other radio stations broadcast warnings as well. The use of radio as a warning channel will continue to be a major practice in emergencies. Often plans for notification and the use of standardized messages accelerate the speed at which a warning can be issued over the radio. One disadvantage of the radio is that the broad area often covered by broadcasts may include areas not at risk. Second, radio messages exclude the use of graphic materials. Third, radio reaches only a small portion of the population during late night-time hours.

3.6.1.4 Tone Alert Radio

The tone alert radio is a specialized warning device that can be remotely activated. These radios operate on a standby condition and provide a warning signal; some types can subsequently broadcast a verbal warning message. Upon receipt of a code, the radio emits a tone and broadcasts a prerecorded or read message. The code and message are broadcast from a radio transmitter which typically has a range of 40 miles. The radio receivers operate on normal electric power; some have battery back-ups.

One tone alert system is NOAA Weather Radio. This system covers a major portion of the population within the country. Its chief function is to provide continuous weather forecasts. NWS can activate radio receivers to issue warnings regarding severe weather. This system can be used to issue warnings for other hazards such as nuclear attack or nuclear power accidents by pre-arrangement with the NWS. The advantages of the tone-alert system include a quick dissemination time, the combination of an alerting signal with specialized messages, and around-the-clock availability. Disadvantages include maintenance problems, availability during power failures, limited broadcast range, and the difficulty of outdoor use. The radio receivers are relatively inexpensive, costing less than $50.

3.6.1.5 Television

Warnings are also broadcast over commercial television. This can be done by interrupting normal programming or by displaying scrolled text on the bottom of the screen. Television reaches a large number of people, particularly in the evening hours. Like radio, it is a poor channel during sleeping hours. Television is a particularly good channel for warnings about slowly developing events. It is likely to take longer to issue a warning over television stations except where prewritten scrolled messages are used. One major advantage of television is the ability to use graphic information such as maps or diagrams in the warning.

3.6.1.6 Cable Override

The existence of cable television in many areas means that local commercial stations may reach less of the public than once was the case. As a result, systems have been developed to issue scrolled or broadcast messages over all cable channels. Thus, a person in Cheyenne, Wyoming, watching a Chicago station or a movie channel could still receive a tornado warning. Usually the override systems are operated by local civil defense offices in coordination with a cable television station. This requires pre-arranged agreements on the use of such a system. The advantages and disadvantages of normal television apply.

3.6.1.7 Telephone Automatic Dialers

Switching and automatic dialing equipment that is currently available has the potential to reach a large number of people in a relatively short time frame. In most cases, current technology could allow a simultaneous call to about 20 to 30% of a local phone company's customers using the local system's resources and to a higher percentage by routing calls through distant switching stations. These systems make use of existing phone networks. Other systems can be specifically designed to issue emergency warnings. Most of the modifications and special equipment are installed at the phone company. These systems play prerecorded messages which can be updated fairly quickly to provide timely information. Advanced systems can automatically hang up phones in use or block out all incoming calls. It is also feasible to have them use a special ring that would act as an alerting function. They can also be combined with the use of telephone hotlines to provide specialized information. Automatic dialing systems are expensive and for this reason limited in their use. Further, without modifications of the system they can still serve only a fraction of local area phones at one time. Other problems exist. People are not always near a phone to receive a message, and busy phones would prevent warning if less expensive systems without the automatic hang up feature are used. Deregulation of the phone industry may constrain the use of these systems due to the segmented market. Because of these problems, automatic telephone systems are currently used chiefly for organizations but not for the public; for example, they are used to notify emergency response personnel and to warn institutional facilities such as hospitals at risk during nuclear power plant accidents.

3.6.1.8 Sirens and Alarms

The technology of siren and alarm systems is such that an audible signal could be provided to most populations at risk, although it might be expensive to implement the technology. These types of warning devices are designed to provide rapid alert to the threatened population. While a few types of sirens have public address capabilities as well, most only sound a noise. Siren systems are limited in their use by the lack of instructional messages. At best they alert people to seek further information unless there has been an intensive program of public education used to instruct people what to do when the signal sounds. This is possible only in situations when the same response would be desired every time a warning is issued.

Multiple signals, such as a wavering signal versus short blasts, are rarely differentiated by the public. Consequently, reliance on different signals is on fairly weak grounds. Other problems that constrain the use of sirens and alarms are false alarms because of technical failures, equipment failures in emergencies, maintenance problems, coverage problems (particularly in adverse weather), difficulties in propagating sounds into buildings, and sometimes public indifference to sirens in largely urban areas. Siren systems are a main component of many warning systems in use today despite all these problems.

3.6.1.9 Signs

Permanent warning signs are sometimes used to directly communicate to the public in remote hazardous areas. These signs often instruct people about how to recognize the onset of a hazard and what to do if one occurs. Signs can be used to supplement more effective warning devices if they are in good locations for viewing and if they are visible at

the time an emergency occurs. In addition, signs may serve as a valuable educational device; people who see them frequently may learn what to do in an emergency without needing a specialized warning. Problems with signs include their need for periodic maintenance and replacement and identifying their proper locations.

3.6.1.10 Aircraft

In special cases, airplanes and helicopters can be used as part of the warning process. Low-flying aircraft can carry sirens or bullhorns to provide an alert or a warning message. In addition, they could drop prepared leaflets containing a warning message. This type of warning channel is useful in reaching remote populations or populations that cannot be reached through normal communication channels. Disadvantages include access to aircraft, maintenance, cost and the risk of accident in difficult flight terrain. A further problem is obtaining sound systems that can broadcast messages audible over the noise of the aircraft itself.

3.6.2 Selecting the Channel

The choice of a channel or set of channels to be used depends on the hazard at issue, as well as the characteristics of the population at risk. The use of a matrix filled with channel types for a particular area (Fig. 3.3) provides information that could help ensure that special subpopulations are targeted with appropriate channels of communication for different hazards. Such a planning technique approach could ensure that warnings can reach all those at risk for each potential hazardous situation. Whenever feasible, the warning system should use multiple channels to ensure overlap and comprehensive coverage. Channels also need to be selected on the basis of the amount of information each is capable of conveying and the amount of information needed to describe the hazard and appropriate response.

POPULATION SUBGROUP	HAZARD		
	VOLCANO	FLOOD	CHEMICAL PLANT
PERMANENT			
Urban residential Rural residential Apartments	Media/Emergency Broadcast System	Door to door	Sirens
INSTITUTIONAL			
Hospitals Schools Nursing homes	Commercial telephone	Tone alert radio	Tone alert radio
TRANSIENT			
Highway Sports facility Parks	Signs	Barricades	Loudspeakers

Fig. 3.3. A guide for selecting warning channels.

3.6.3 Frequency of Dissemination

There is no magic formula for specifying how frequently a warning message should be repeated, but some guidelines can be established on the basis of knowledge about how the public processes warning information. In part, dissemination frequency is geared to the dynamics of the emerging risk and its severity, as well as being influenced by increased or changed knowledge about it. Frequency is best dictated by the needs of the public at risk.

The major lesson on this point, as research has shown, is that it is difficult provide people at risk with too many warnings. People want updates of information even when there is little change in the content. In protracted emergencies, however, there is a point of diminishing returns after which constant delivery of no new information may be counterproductive. The frequency of warnings should diminish after the initial warning period, but warning officials should be ready to increase the frequency of warnings if the risk changes.

There are a number of potential advantages of frequently recurring warning messages. Frequently recurring warnings (e.g., "This message will be repeated over this same station every fifteen minutes, unless new information updates are available") focus people on official warnings, reduce rumors, and increase public confidence in the validity of the warnings.

3.7 MONITORING RESPONSE

The chief reason for monitoring public response to a warning is to determine whether the warning system is guiding behavior in a manner consistent with the potential hazard and disaster risks. If people are engaging in actions that place them at greater risk, the warning may have been poor. If the warning is not effective, adjustments in the warning process may be needed. These adjustments may include changing the contents, tone and clarity of the message, the frequency of dissemination, the channel of dissemination, the source of the information, or other basic facets of the warning process.

3.7.1 Methods of Monitoring Response

There are several ways to monitor public response to disaster warnings. No one method is necessarily better than another, and a mix of methods could be used in a particular event. We briefly describe each of the methods below.

3.7.1.1 Communication Lines to the Field

One way to gain feedback about response is to communicate with emergency workers such as law enforcement officers on the periphery of the targeted warning area. This type of communication can only provide qualitative assessments of warning response. For example, if the advice is to take shelter and people are observed on the streets, it is apparent that not everyone is following the advice of the warning. One role of an emergency operations center (EOC) is to organize qualitative field observations into a general picture to determine if revised warnings are needed. In most disaster settings this type of reporting is done on an ad hoc basis. However, some situations may warrant more carefully planned feedback. In such cases, it may be desirable to establish reporting

requirements for some field personnel or a set of questions to ask while communicating with field personnel.

3.7.1.2 Systematic Observation

In some situations, it may be desirable to have personnel assigned to observe and perhaps even measure human response systematically. This can be done in several ways. For a large-scale evacuation, traffic guides might estimate the number of vehicles passing by on central routes. Shelter workers might regularly report the number of people arriving at shelters. Such observation plans can be tailored to the specific risk situation.

3.7.3.1 Unobtrusive Measures

Unobtrusive indicators of public warning response may also be feasible. One obvious indicator is a real-time traffic counter that measures vehicle flows from an area. These counters can be used to measure evacuation from risk areas provided the monitors are in the right locations. Other possibilities include monitoring utility use rates such as water or electricity consumption; this approach, however, is hypothetical and has not been tested.

3.7.2 Establishing a Monitoring System

A public monitoring system is an important part of a comprehensive warning plan even though it may not seem relevant before a disaster. A number of postdisaster audits show that if officials had known what was happening, a revised message or a different warning strategy could have produced a more effective response or, in some cases, saved lives. Yet, few emergency plans have adopted the concept of a monitoring system. Monitoring takes place informally in some emergencies, but is rarely labeled or formalized.

A first step in establishing monitoring capabilities is to review how information will be fed into the EOC during an emergency and assess whether this method is adequate to provide information on public response. If the information feedback system is adequate, planners should structure the nature of the reporting to be done and indicate by whom it will be done; they should also make sure that a back-up means of communication exists. If the existing communications are inadequate, provisions for adding personnel in the field to provide reports may be necessary.

Potential problem areas—such as a narrow bridge on a hurricane evacuation route, major freeways in an urban area, shelters in a densely populated neighborhood, or institutional facilities housing special populations—may warrant a designated and dedicated feedback mechanism.

3.8 TESTING WARNING SYSTEMS

As we have seen, warning systems are not simple systems. They cut across a variety of types of organizations— scientific organizations, government bureaucracies at all levels, private corporations, and so on—and involve people from a wide range of backgrounds (e.g., scientists, elected officials, bureaucrats, military personnel, and the public). Warning systems are composed of links and communication between all involved organizations. Some of these linkages are routinely used, while others are unique or scheduled for use only when the warning system is implemented. Obviously, warning systems do not have a

life of their own; they are artificial organizational arrangements that may be rarely used, except for warning systems for frequently occurring events. Infrequently used systems must conduct tests and exercises to discover and correct flaws that would almost certainly otherwise arise during an actual emergency.

The most apparently realistic way of testing a warning system is through the use of full-system exercises. In such exercises, all facets of the system can be drilled from initial detection up to but not including the dissemination of public warnings. Public warnings are excluded because involving the public in exercise response is not necessary for discovering and correcting flaws in the system except in the testing of the warning communication-channel hardware (e.g., a siren). However, full-system exercises limit the number of things that can be carefully evaluated. Partial-system exercises can sometimes be preferable since they can focus on the most important or questionable parts of the warning system.

3.9 POSTSCRIPT

In this section we have presented what we feel are basic planning and evaluation warning system concepts, based on social science research findings concerning the organizational and public response aspects of such systems. The outline of the section constitutes a checklist of concepts to be addressed in planning and evaluating any public warning system. We recognize that the way these concepts are implemented may vary across hazard types, or across different jurisdictions with different local political realities, but the concepts discussed here are the building blocks of an ideal warning system.