7. PROBLEMS, LIMITS, AND IMPROVEMENTS

The purpose of Sect. 7 is to review a variety of issues that constrain an ideal warning system. Some of these issues are practical issues, while others are ethical; some are based on the research record while others are not. In addition, the section recommends more research with high potential payoff in knowledge and applications. Section 7 concludes with reminder of recurring themes that have emerged from this review; these are presented as a philosophy of warning.

7.1 TECHNOLOGICAL ISSUES

7.1.1 Monitoring and Detection

The ability of a system to provide timely public warnings begins with monitoring the environment so as to detect hazards. Table 7.1 summarizes the current state of development and applications of monitoring and detection technology in the United States.

Detection technology is readily available for some hazards and in a state of development for others. Technological capabilities also vary with respect to the amount of lead time provided and the "noise" in the detection signal. Monitoring technologies are of equal importance. Whereas detection refers to the recognition of an hazardous event, monitors provide ongoing data about the physical system. Coverage of monitoring technology is fairly good for some hazards and poor for others, such as hazardous materials accidents. Complete coverage of the entire U.S. land mass, or even of all areas where people live, has not been perfectly achieved for any hazard. The best coverages are for a massive nuclear strike and for earthquake aftershocks.

7.1.2 Communication Hardware and Use

Despite advances in technology, many warning systems are constrained by communications equipment problems. Recent problems (Sects. 2 and 4) have included lack of equipment, equipment failure, lack of back-up equipment, and human error in the use of equipment. Problems with communications hardware surface at two levels: in communications between organizations and in the public notification process. These problems are only partially caused by lack of technology. Nevertheless, technological advancements (e.g., microwave relays or fiber optics communication lines) are still likely to improve future warning systems over today's systems. A greater problem is the lack of dissemination and adoption of technology among warning systems throughout the country. There is a reluctance by some to use innovative warning technology. Another problem is maintaining equipment so that it functions properly in an actual emergency. The warning systems that could benefit the most from adopting state-of-the-art communications hardware are those for which the technology could mean getting warning information to a larger number of people with greater reliability in a shorter amount of time at reduced per capita costs.

Table 7.1. Status of monitoring and detection technology and application coverage for warning systems

Hazard	Monitoring technology	Detection technology	Application coverage
Hurricane	Well developed	Well developed	Good
Flash flood	Well developed	Well developed	Partial
Riverine flood	Well developed	Well developed	Good
Tornado	Developed	Difficult	Good
Avalanche	Developed	Difficult	Poor
Earthquake	Developing	Difficult	Poor
Tsunami	Developed	Problems	Good
Landslide	Developed	Problems	Poor
Volcano	Developed	Problems	Poor
Dam failure	Developing	Problems	Poor
Transported hazardous materials	Poor	Difficult	Good
Fixed-site hazardous materials	Developing	Poor/Good	Poor/Good
Nuclear power	Developed	Developed	Complete
Terrorism	Developed	Problems	Good/Poor
Nuclear attack	Developed	Developed	Good

7.2 ORGANIZATIONAL ISSUES

7.2.1 Domain Conflicts

Conflicts among organizations over roles and responsibilities in warning systems are still problematic in some situations (see Sect. 4). The problem of organizational conflict goes beyond the realm of emergency management. It is symptomatic of organizational systems in general and may never be totally eliminated. However, there is evidence that the emergency planning experience may facilitate cohesion among warning system participants and that improved planning could help to minimize conflicts. Emergency planning for warning systems should address organizational domain negotiation as part of the planning process.

7.2.2 Decision Making

Normative decision tools are gradually being developed to aid officials in making warning decisions. These tools range from simple classifications schemes to complex computer simulation models. As these tools become more sophisticated and widespread, it will be important to monitor how they are used and to determine if they lead to better warning decisions. Complex or conflict-ridden decisions delay the issuance of public warnings (see Sect. 4). This is of little consequence in precautionary situations or protracted emergencies. In fast-moving events, however, decision-making problems may lead to ineffective warning or to delays. Ways of achieving more automated decisions in the case of fast-moving events and hazards need to be explored and tested; these include computer recognition of tornadoes in Doppler radar data, expert systems for chemical plant accidents and automated public warning systems for earthquake events seconds away on other fault segments.

7.2.3 Maintaining a Warning System

Warning systems, except perhaps for those in place for nuclear power plant accidents, are infrequently put to a real or even a practice test. This problem of nonuse diminishes as the size of the area and the number of hazards served by the system increases, because such systems are more frequently used. It is difficult to garner support and finances for a warning system with low probability of being activated in any given year. Additionally, it is difficult to maintain an effective warning capability when a warning system is not used or tested. People who are a part of the warning process lose interest and shift their attention to more pressing day-to-day responsibilities.

Most warning plans are not reviewed or updated. Communications among participating organizations may wane with time. Personnel with time dedicated to the warning function may grow bored. We know of one warning plan, for example, which calls for meteorological experts to work on a 24-h basis to predict a potential downwind chemical release from a plant that has an estimated 1 in 1000 probability of a release with public health consequences. All of these characteristics diminish the potential effectiveness of the warning system when implemented.

It seems apparent that warning systems must be exercised often to guarantee their effectiveness (Sect. 4). Frequent exercises occur for some hazards, for example for nuclear attack, but not for others. An alternative could be to build warning systems on top of existing communication systems that function routinely for other reasons. This could be difficult because many of the organizational and individual actors in most warning systems are brought together in unique configurations relevant only for the warning system. A good approach may be to construct warning systems on top of whatever routine communication patterns do exist and to exercise those systems often.

7.2.4 Recommending Protective Actions

The success of any warning system is dependent on recommending appropriate protective actions to the public and on the public's acting on those recommendations. Ambiguity in warnings about what the public should do has often resulted in needless loss of life in emergencies (Sect. 5). Death and injury still occur in circumstances in which people thought they were doing the correct thing but were behaving inappropriately. This issue poses a major warning dilemma because not every emergency situation has a best protective action strategy. Many situations will have multiple protective actions that are appropriate for differing public circumstances; variations in protective response are difficult to communicate through warning messages.

A major factor that hampers providing good recommendations for protective actions is a poor understanding for some hazardous events of the effectiveness of each feasible protective action, and under what circumstances that effectiveness may be hampered or enhanced. For example, some uncertainties exist about sheltering versus evacuation. In hurricanes should people seek shelter or evacuate? In nuclear attack, is relocation more effective than sheltering from fallout and blast? In earthquake aftershocks should people run outdoors in clear fields or seek shelter in an available structure? Emergency officials would benefit from clearer guidelines on protective action decisions for the range of hazards. The same is also true for the range of subpopulations at risk to whom they must issue guidance.

7.3 SOCIETAL ISSUES

7.3.1 Ethics and Warning Systems

Warning systems are meant to serve the public good by saving lives, property and reducing injuries. To do so warning systems must intervene into human lives and influence and guide public behavior. On the one hand warning systems should not interfere with civil liberties. On the other hand, they cannot help but do so to some degree.

Debates on ethical issues have surfaced from time to time regarding various aspects of warning systems. For example, in the early 1970s an effective alert device called DIDS (Disaster Information Dissemination System) was viewed as a warning breakthrough. This system externally activated radios and broadcast warning information. The system was not adopted because it was viewed by many as a breach of privacy. Today, however, tone-alert radios are in place in many areas for selected hazards.

Another frequently occurring ethical issue has been whether warnings should advise the public regarding protective actions or order those actions. Contemporary consensus is that warnings in the U.S. provide advice and recommendations. Sometimes this has meant standing by in the face of almost certain disaster as some decide not to evacuate and face almost certain death. For example, officials at Mount St. Helens knew that some residents refused to leave. Sometimes it has meant the opposite. For example, a week after the Rapid City flood, the mayor ordered another public evacuation, even though he lacked legal authority to do so. Ethical questions continue to surface on both sides of this matter. Such issues are not readily resolved, and resolutions are likely to vary across time and place.

7.3.2 Costs and Benefits of Warning Systems

Some hazards do not appear to warrant a large investment of money in warning preparedness since sufficient benefits in saved lives, reduced injuries and reduction in property loss would not justify warning system investment.

Two different approaches have been used in estimating the costs and benefits of warning systems. First, analysis can be performed on average annual losses. For example, this approach would compare the average annual costs for warning preparedness to the average number of lives saved by the system. In such an analysis the benefits reaped can appear low for disasters that occur infrequently. Second, analysis can ignore average annual estimates and instead focus on the potential for the infrequent catastrophe. For example, this approach would compare the cost of warning preparedness to the benefits of the system when the maximum credible disaster does occur. Most analyses of the costs and benefits of warning systems contain both of these approaches. Results can vary widely across hazards as well as for the same hazard in different communities.

Some decisions about warning system adoption and preparedness do rest on rational analysis of costs and benefits. Many times, however, preparedness decisions ignore this approach or minimize its input to preparedness and systems are adopted even though they do not meet cost-benefit criteria. Warning systems often emerge because of policy decisions based on public sentiment after a particular emergency regardless of the outcome of cost-benefit analysis. Cost-benefit analysis versus political responsiveness after major emergencies are not necessarily compatible in the conclusions they might reach regarding the need for warning system preparedness. This does not diminish the need for including analysis of costs and benefits in making warning preparedness decisions.

7.3.3 Withholding Warnings

The control and timing of public warnings will continue to be thorny issues in emergency preparedness and response. There are several reasons why detectors and emergency managers withhold information.

First, there is an unfounded but widespread belief that the public will become unnecessarily alarmed if warned about a low-probability but high-consequence event. This belief has resulted in reluctance to tell the public about a hazard until it is absolutely necessary, and even then some warnings are delayed, muddled, or suppressed. This reluctance to inform has affected both hazard detectors and emergency managers. Examples concerning both natural hazards and technological can be found.

Second, warnings are sometimes withheld because of concern over negative social and economic effects on the hazard manager and on society in general. Only a partial disclosure of information may occur in such cases. This can seriously undermine warning effectiveness from the viewpoint of public protection. In such cases additional information may well become public through nonofficial sources, creating credibility problems for warning officials. Interestingly, withholding information in a warning situation can actually be the cause of the problem that it was originally designed to avoid.

The "to warn or not to warn" dilemma will continue to surface regarding the release of information about hazards to the public. Consider, for example, the dilemma facing a scientist with information that a whole town is likely to be destroyed from a volcanic eruption sometime during the next 20 years. To which vested interest does the geologist bow: those who think that the public has the right to know; those in the public who would probably not do anything differently if they did know; the shareholders of a property development corporation, the owners of the local tourist industry, who may not want to know; or the state emergency planning bureaucracy, which wants to know in order to do planning? The geologist would probably tell everyone. The dilemma of vested interests is likely to be strong in the future. Effective long-term warnings could well elicit the wrath of vested interest groups not served by the release of believable hazard information.

The "to warn or not to warn" dilemma also persists for short-term warnings and is not likely ever to be fully removed from warning systems. Most disasters cannot be predicted with total certainty. Officials must make decisions about whether or not to issue warnings on the basis of probabilities. For example, is a public warning issued if the probability of an earthquake is raised from 1% on any given day to 5% for tomorrow? If not, what percentage increase in probability must occur before a warning is issued, given that certainty, or 100% probability, will never be attainable? The dilemma is clouded even after a policy decision is made that a predetermined probability will trigger information flow to the public. At what probability of impact will the information being passed to the public cease to be hazard information and become an actual public warning including recommended public protective actions? The forecasting of disasters before they happen is imprecise, and elaborate public warnings are needed to elicit good protective response.

The dilemma of deciding at what level in the former is needed to activate the latter is not easily or readily resolved.

7.3.4 Liability

Liability can create problems in several ways. First, officials may fail to issue warnings to the public, and the event occurs. Second, they may warn the public, but the event does not occur. Third, they may provide a warning that contains wrong or inadequate information. Fourth, officials may withhold some relevant warning information from the public about an event that occurs. The consequences of each of these situations could be litigation involving the officials, the organization for which they work, or both.

We have been able to discover only a few documented cases in which fear of litigation actually constrained the issuance of public warnings. This lack of cases may be caused by the infrequency with which the topic has been studied. Nevertheless, there are two ways in which fear over liability can be minimized as a constraint to warning issuance. First, decision makers can be made free of liability for what they do or do not do in a warning situation. This has been accomplished through legislation for the governor of the state of California in reference to earthquake predictions. Second, warning decision makers can have their decision making formalized and subject to postevent audits; this is the case, for example, for parts of warning systems for accidents at nuclear power plants.

7.3.5 Public Response

Much is known about the process that shapes public response to emergency warnings (Sect. 5). However, some problems still remain in fully understanding public response.

First, we do not fully understand how response can be enhanced by pre-emergency public information and education. It makes intuitive sense to educate people about hazards and possible future emergencies and warnings. However, the most cost-effective and salient form of pre-emergency warning education is not known.

Second, the factors which influence public warning response as described in Sect. 5 may well differ in quantity as they occur in different emergencies. Nevertheless, these same factors are likely to operate in all emergencies to impact public response in the same theoretical way. Yet we do not fully understand with full mathematical precision the relative effect of all factors on warning response. Sorting out these differences, if they exist, would enhance our ability to develop generic multihazard and cross-hazard warning systems.

7.4 TOWARD IMPROVED WARNING SYSTEMS

7.4.1 Application of Existing Knowledge

A comparison of existing warning systems (Sect. 1) with existing knowledge about preparedness leads to the conclusion that no contemporary system uses all that is known. Warning systems for nuclear power plant accidents are perhaps the most intensive users of preparedness knowledge. All warning systems could be improved in varying degrees through review and adoption of existing knowledge. In Sect. 3, we attempted to outline a framework for building better systems based on that knowledge.

Two key areas promise the most benefits in improving warning systems. These are building more effective organizational arrangements and improving the content and type of actual public messages. The former could remove some of the constraints that limit the dissemination of warnings in a timely fashion. The latter action could help increase the odds that the public will take appropriate and timely protective actions in response to warnings.

Some warning systems are relatively well designed; other systems can be greatly improved. Most fall somewhere between these extremes. We conclude that building generic systems and differentiating them on the mix of hazard types (as discussed in Sect. 6) is a more effective way to upgrade warning systems than continuing with separate systems for each hazard. The generic warning process is similar for all hazards. However, the implementation of warnings can differ across hazards. These differences should be planned for when particular hazard and site characteristics are taken into account.

7.4.2 Needed Research

7.4.2.1 Differences and Commonalities in Warning Response

Warning response research has been varied in method and approach. Each piece of research has focused largely upon only one or some few of the many factors that affect response (see Sect. 5). Consequently, research is needed which takes advantage of the knowledge already accumulated but which goes several methodological, theoretical, and practical steps further. An integrated warnings systems research effort is needed to (1) use state-of-the-art knowledge to study warning system structure and factors that influence human response; (2) measure those factors in the same or functionally equivalent way across a range of geological, technological, climatological, and national security emergencies to provide for sound cross-hazard comparability; (3) determine common themes applicable in all warning systems as well as hazard-specific lessons; and (4) allow research to be performed almost immediately after an emergency before warning response data become less reliable.

The specific purposes of cross-hazard comparisons should be (1) to determine common warning system elements for all hazards—for example, hardware and technologies, emergency organization, and warning messages; (2) to catalog what common warning system elements can be used to reduce duplication of warning systems in the United States and to integrate cross-hazard warning systems; (3) to suggest what common warning system preparedness elements are likely to hold in emergencies for hazards not yet experienced; (4) to reveal hazard-specific elements of warning systems needed for use in preparedness for the full range of potential hazards; and (5) to systematically test and refine a theory of public warning response. Something is already known about each of these issues, but knowledge is far from complete, and some of it is based only on anecdotal evidence which remains to be analytically demonstrated.

7.4.2.2 Adoption Constraints and Incentives

The state of knowledge regarding effective warning systems is good relative to other human interventions (land use, engineered solutions, insurance, etc.) to reduce losses from disaster. However, this knowledge is not fully used.

A research effort is warranted to determine the major incentives and constraints to adoption of warning system knowledge. This research should include all hazards for which warning systems could be useful. The research should also address the full range of entities that could be involved in adopting findings; these include local, state, and federal agencies as well as some private sector organizations that maintain warning systems. This research could do much to reveal why the high potential for setting up effective warning systems for most hazards is being ignored or is under used. It could also produce insights on how planners could be encouraged to use existing knowledge.

Finally, this research should include an assessment and cost-benefit analysis of existing warning systems to determine fruitful paths for cross-hazard integration of warning systems design and technology.

7.4.2.3 The Role of Public Education

It is unclear how and to what extent pre-emergency public education affects the behavior of people in response to future warnings. It is intuitive to presume that public education has a positive impact on public warning response. Moreover, it is not clear what type of public education is the most effective. At present, we can only hypothesize about the topics which pre-emergency public education should address, as well as about the form a public education campaign should take. For example, it would be appropriate to now hypothesize that the most effective form of public eduction is education that is a continuing process, specific in content regarding the actions which people should take, and varied in approaches used to deliver the information.

Research is needed to determine the relative effectiveness of alternative types of public information and education on warning response. This research should include the range of education avenues (i.e., brochures, school curriculum, telephone-book pages, and public signs, to name but a few), and seek to determine when and why the provision of information actually does result in learning. Research should also study the range of topics that could be addressed in public education, including, for example, the hazard, appropriate protective responses, and emergency warning types and sources. The effort should discover whether differences exist on the basis of hazard types, experience, location, and so on. It is likely that the intensity of the public education effort would affect subsequent warning response. Consequently, this factor should be made to vary in the research design; this would probably require field experiments.

7.4.2.4 Quantitative Decision Research

Warning system organizations (Sects. 2 and 4) involve a complex sequential system of tasks, roles, and decisions and cut across a variety of organizational subdivisions, different organizations, varied political boundaries, and sometimes the public and private sectors. There is historical evidence that dilemmas and uncertainties at each level in these interorganizational systems have caused warning system failures. The research record on the organizational aspects of warning systems is not elaborate, particularly when compared to the rich literature on public response to warnings. Most existing organizational studies are focused on disaster response and not predisaster warnings. Most such studies are largely case histories of a single event and were not drafted in analytical ways.

Uncertainties have affected and continue to affect all system decisions that lead up to public warnings. Two research efforts are needed to produce knowledge that could help minimize the effects of uncertainties on timely warning system decision making. The first should investigate how uncertainties detract from sound decision making. The second should investigate aids that would assist in making decisions.

We also need several analytical case studies of natural, technological, and national security events, focusing on inter- and intra-organizational decision making leading up to public protective-action advisement decisions. Such studies should seek to document how uncertainties affect decision making at each point in the warning system, from the detection of a hazard through actual evacuation decisions. The research should also address why uncertainties arose and what could have helped reduce the negative effects of those uncertainties on decision making. A quick response would be needed to make this research sound. Investigations should begin as soon as possible after an emergency has occurred, if not during the emergency.

In addition, the role of decision-making aids such as expert decision-making systems should be investigated. Several studies appear promising. First, a set of laboratory studies should be conducted to determine how under similar scenarios different available decision-making models and aids might lead to different or similar warning system decisions. The results of this research should enable the fine-tuning of good models and aids, as well as the abandonment of the less useful ones.

Second, the adoption of the models and aids should be investigated across localities engaged in warning system decision making. An adoption-diffusion/transfer study could do much to enhance the use of good models and aids. Such a study would be particularly useful, for example, on hurricane decision making, since good new models have recently become available.

Finally, work should be performed to discover what kind of information, aids, and models could assist decision makers in making warning decisions. This research should be from the decision-maker or "user" viewpoint. For example, it should determine whether evacuation decision makers with recent experience feel that "real-time" traffic data would assist in decision making, and if so, how that system could best be designed for their use. Such a survey would be performed on decision makers for a variety of hazards with recent public warning experience.

7.4.2.5 Warnings for Fast-Moving Events

Fast-moving events pose unique public warning and response questions. We know too little about the unique needs for public warnings for such events to offer conclusions with confidence. No warning response study has been conducted on an event with less than 30-min response time. It has long been known that most members of the public seek confirmation of warnings before taking an action such as evacuation. Yet some emergencies are so fast-moving that seeking confirmation leads to increased losses. We also need to focus on the social psychology present during fast-moving events. This research should produce findings that would enable endangered publics to make quicker protective action decisions in response to fast-moving events. The existing empirical research record does not include many such events, for these have been historically infrequent (Sects. 4 and 5).

Research into fast-moving events should be cross-hazard, including events like flash floods and chemical spills during train derailments and should seek to generate generic cross-hazard principles as well as unique hazard-specific findings. Particular attention should be paid to how pre-emergency education and disaster warnings could help the public perform alternative protective actions to evacuation. For example, some chemical emergencies would not cost lives if people covered their noses and mouths with wet cloths and stayed indoors.

Effective public response to fast-moving events requires that the hazard be quickly detected and that the public be informed rapidly. Constraints may inhibit this process, and each should be researched. One of these constraints deals with the hardware of public alert. Research should address alternative schemes for alerting endangered publics: sirens, telephone systems, and the like. Second, in fast-moving events the processing of hazard information in the detection and management components of warning systems must be streamlined. Retrospective studies of recent events and studies of events as they occur could help uncover procedures that would help reduce the time needed to process risk information prior to the issuance of public warnings to the bare minimum. Third, technical research is needed for some hazards to determine what the risks of public exposure are. For example, it may not be clear what are the risk scenarios nor range or efficacy of alternative protective public actions regarding the immediate release of nerve agent or other chemicals. This information can assist planning. Finally, research on the efficacy of pre-emergency public eduction for special fast moving events could help reduce the time needed for public response. For example, the application of research findings in this arena could possibly reduce the time the public would ordinarily spend seeking confirmation of warning received.

7.4.2.6 Warnings for Concurrent Hazardous Events

A three-pronged research effort is needed to fill gaps in knowledge regarding warning system planning for concurrent hazardous events. We were unable to find any warning studies that addressed this type of warning (Sects. 4 and 5).

First, physical science and statistical studies should be directed toward cross-hazard assessments to typologize probable concurrent hazards for linked hazards (one causes another) and for independent hazards (both coincidentally occur at the same time). This ranking would provide an informed basis on which to judge which concurrent events should be planned for and which are best ignored. This effort need not be elaborate, but a systematic assessment by an interdisciplinary team of experts is needed in order to inform planning for concurrent hazardous events.

Second, planning and response experts should share judgments to produce a systematic catalog of warning planning needs for concurrent hazards. This assessment should detail generic and unique issues specific to unique hazards or sets of concurrent hazards.

Finally, prototype plans should be developed in some localities that can be transferred to others. This "action research" component has already been shown to be effective with earthquake and earthquake prediction planning, among others. This three-step research process (based on physical science, planning and social science, and plan development) is sequential, is predicated on existing knowledge, and promises payoff.

7.4.2.7 Media Role in Warnings

In emergencies, key media actors often intervene between those who have accurate information and the public. The media are the gatekeepers of most public risk information and warnings. The use of an Emergency News Center helps standardize information and fully inform the media in emergencies. Despite the important role of the media in warning systems, however, few studies have ever been performed on the media. We have done too little to bring the media into the warning system preparedness effort.

Currently, one research effort concerning the media in disasters is under way at the Disaster Research Center at the University of Delaware.

It is appropriate to proceed with at least two studies of the media in reference to warning systems. First, it would be useful to gather data on how the media presents emergency information to the public during warnings. This study should assess media public information output from the viewpoint of factors demonstrated to have an impact on public response (i.e., frequency, clarity, consistency; see Sect. 5). Such a study would provide information regarding the final communication link in warning systems between the media and the public. Second, it would be useful to explore the most effective way to inform the media of the factors important to keep in mind when performing a role in a warning system.

7.4.2.8 Improving Communications

Warning systems are communication systems linking a variety of organizational actors to each other and then to the public. Therefore they involve communication devices and systems. Some of these are technological, such as dedicated phone lines, sirens, radios, and tone-alert radios. Others are behavioral, such as informal notification. The effectiveness of a warning system is dependent on systems such as these that constitute the "hardware" of a warning system.

Few planning efforts for warning systems have taken stock of the full array of communication systems on which a warning system depends, considered back-up means of communication, or addressed updating communications technology (Sect. 1). It would be appropriate to assess the alternative efficiency and effectiveness of available means of communicating and explore how adoption constraints could be removed.

7.4.3 Multihazard Warning Systems

The classification scheme developed in Sect. 6 is a first step toward resolving the question of whether the nation should pursue a single cross-hazard warning system or multiple hazard-specific warning systems. A single cross-hazard warning system would imply one warning system in place to warning of any hazard. Multiple hazard-specific warning systems imply separate systems for each and every hazard that could impact a particular place. This analysis suggests that a single-system design will not work for all different hazards warning situations but that some events with similar characteristics may fit the same warning implementation strategy. In any case, hazard-specific knowledge must be incorporated into any general warning system. It may be that a tiered warning scheme, which is a warning system with some shared components across hazards but also some unique hazard-specific elements (Fig. 7.1), is the best approach to warning system development. Any warning plan would address warning system organizational principles (Sects. 2 and 4) and the basic public response process (Sect. 5). This plan would then be specified or tiered into unique implementation procedures for each of the different hazard types that a community may need warnings for as grouped in Sect. 6 (see Fig. 6.1). Finally, unique hazard-specific information and site-specific conditions would be annexed onto the plan.

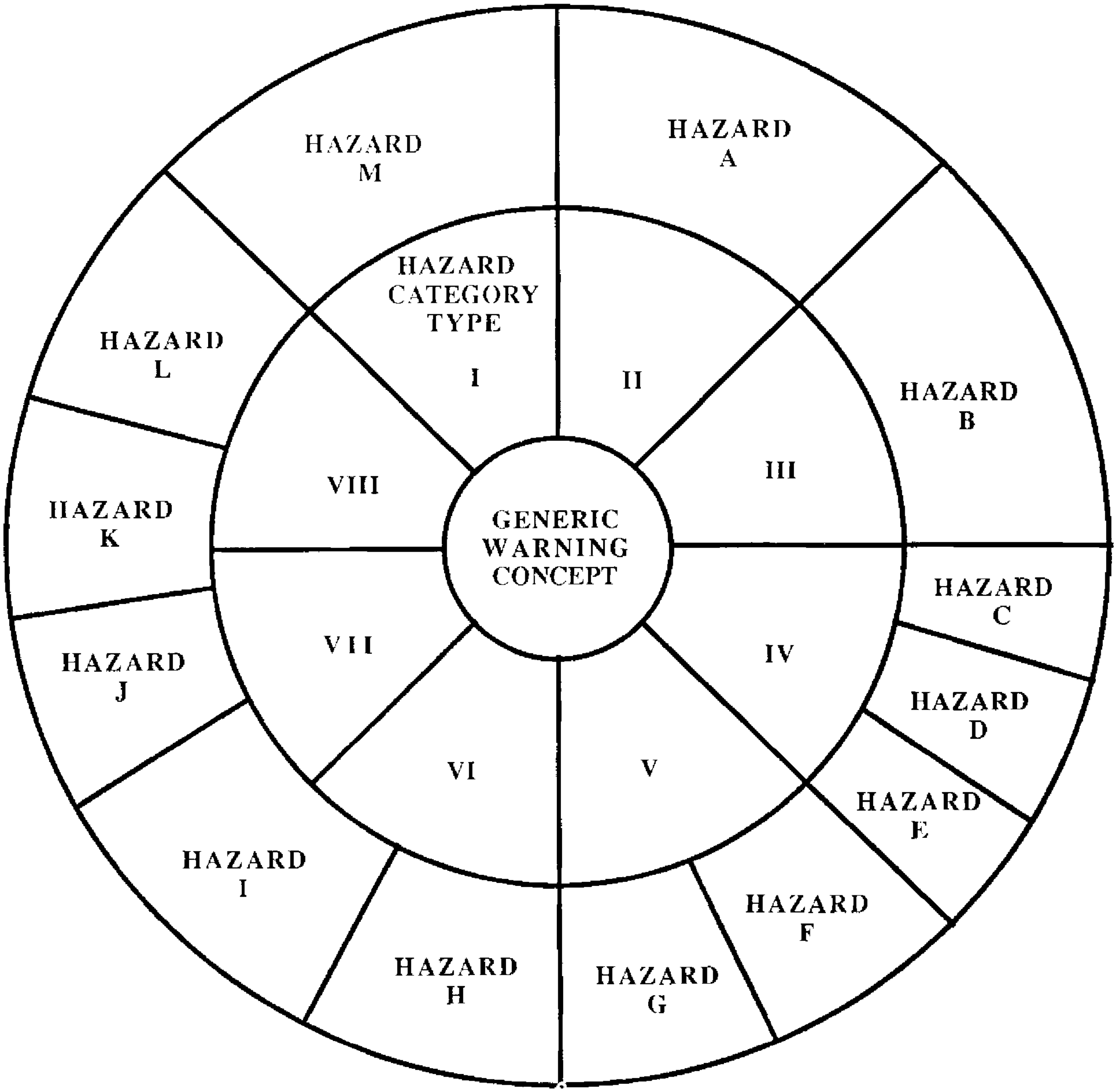

Fig. 7.1. A proposed cross-hazard tiered warning system scheme.

7.5 A PHILOSOPHY OF WARNING

Several recurring themes emerged from the review of warning systems research. These themes help frame some general principles for building warning systems.

7.5.1 The Role of Planning

History contains many examples of warnings that have been a success, but it also illustrates failures. Some of each type have not been prefaced by warning system planning. Interestingly then, emergency planning is not essential for an effective warning system in all cases. There are two reasons for this.

First, warnings are not rare events for some hazards in some parts of the country. For example, tornado warnings in some midwestern communities and flood warnings along the Mississippi are not uncommon. Repeated experience with warning events can teach those responsible for warning activities what does and what does not work. Plans are not essential for activities that people already know how to do well. But warning system personnel retire, and unfamiliar hazards can occur.

Second, some warning events are protracted enough that protective public action—for example, evacuation—can be elicited without plans. However, the nation cannot count on having enough lead time to accomplish effective warning in the absence of planning.

In fact, poor warnings are almost always a result of poor planning. Thus, while planning is not always necessary, it can help facilitate effective warnings. Planning for warning probably increases in importance as the frequency of experience with a particular hazard decreases. This suggests that planning for warning of events not yet experienced—for example, nuclear attack or a great urban earthquake—may be more fruitful than planning for events often experienced. Most of the hazards addressed in this work occur infrequently enough in a particular locale to make planning essential for them all.

7.5.2 Knowing the Public

The American public is diverse, and the relevance of that diversity for warning preparedness has already been reviewed (Sect. 5). It is inappropriate to cast the public in the role of potential evacuees waiting for a short warning message from the county executive before beginning to engage in protective actions that must take place within a few minutes. This assumption of instant public response appears often enough to suggest that many warning systems are based on an inaccurate model of public behavior. Public warnings must speak to a diverse and heterogeneous public. The presumption of a simple stimulus-response model of public warning response is invalid and must be laid to rest.

7.5.3 Warning System Failures

There is no foolproof warning system. Every warning system has the potential for failure, or at least for functioning less effectively than originally intended. Consequently, disaster losses in terms of lives lost and injuries can never be reduced to zero. Warning systems are the final line of defense against disaster. When other strategies (control works, structural resistance, land use, safety systems, diplomacy, and so on) fail and disaster is imminent, warning systems can serve to minimize the number of people in harm's way.