Introduction

Almost every day people evacuate from their homes, businesses or other sites, even ships, in response to actual or predicted threats or hazards. Evacuation is the primary protective action utilized in disasters such as hurricanes, floods, landslides, tsunamis, volcanic eruptions, releases of hazardous or nuclear materials, and high-rise building fires and explosions. Although often precautionary, protecting human lives by withdrawing populations during times of threat remains a major emergency management strategy. There have been some instances where removal or property and livestock to safer places has been a major evacuation activity for some businesses such as automobile or boat dealers or specialty farm managers, but these evacuation activities lack systematic validation by researchers and are only briefly discussed. The purpose of this workbook is to provide emergency planners with an overview of knowledge and good practices related to emergency evacuations. This is not a fill-in-the-blank document that will lead to a fairly useless plan that will sit on the shelf, however it does contain some specialized templates and sample plans that can be adapted in a plan. This document is interactive. Whenever the user encounters blue text, there is a hyper-link to more information. This may be a web site, a photograph, a figure, a table or PDF document. Clicking on the blue text will take one to the additional materials. It is a knowledge-based resource intended to provide basic information that is useful in developing and revising an evacuation plan.

As an alternative to evacuation, people take protective shelter inside structures to prevent harm during severe weather that includes lightning, tornados, and hail, as well as for harmful substances in the air or to quarantine during an infectious outbreak. “Vertical evacuation” in hurricanes in which people move to the upper floor of a modern high-rise building is also a form of sheltering. In some incidents officials have advised both protective actions either simultaneously for selected groups or sequentially. In comparison to evacuation, sheltering behavior is less understood with only a few social science studies having been conducted in the past 25 years including Three Mile Island (Cutter and Barnes, 1982) and a hazardous material release from an explosion in Arkansas (Vogt and Sorensen, 1999).

Evacuations can range in geographic scope from a subdivision threatened by a landslide to multiple states threatened by a hurricane. It is estimated that over 3 million people evacuated in both Hurricanes Floyd and Rita. Floyd caused evacuations in Florida, South Carolina and North Carolina while Rita impacted Texas and Louisiana. Evacuation plans are developed for areas as small as subdivisions (subdivision evacuation map), but more generally are developed at the community or state level. Planning at the regional level is not well developed as was demonstrated by the experiences in Hurricane Katrina.

In the last two decades there has been a greater focus on the varieties of sub-groups that require special attention, such as assisted care individuals or high-rise building occupants, and on the timing of warnings to alert and notify residents of the potential threat. The attention to occupant evacuation behavior after the 2001 World Trade Center (WTC) disaster has been the most crucial in changing the evacuation and engineering paradigms for high-rise buildings that are likely to be felt worldwide as the findings are disseminated (Natural Hazard Research and Applications Information Center, 2003). These trends have led to better typologies and planning models and more critical attention to factors affecting protective actions in planning and response. Real-time transportation models developed over the past decade also allow transportation engineers to better direct egress routes but the models require more sophisticated computer modeling that many communities, especially the more rural or those with a number of absentee owners, may not have resources to incorporate into their emergency plans.

Although evacuation behavior has been closely associated with officials issuing warnings, people often spontaneously evacuate (evacuate without an official order) or refuse to comply with an evacuation order for a variety of reasons (Lindell and Perry, 2004). Evacuations work best if a community plans, organizes, develops, installs, and

maintains a warning system (Mileti and Sorensen, 1990, Lindell and Perry, 1992). Developing the warning system is both an engineering and an organizational process. Warning systems are more than technology in that they involve human communications, management systems and decision-making. As was solidly demonstrated by the experiences on September 11, 2001, disaster in the WTC, warning systems also extend far beyond “official systems” as most of the evacuees in WTC 2, the second building to be hit, initiated their evacuation before they were warned to evacuate by the building's public address system (which occurred 1 minute prior to impact) (Averill et al., 2005).

In this workbook we will first briefly discuss the social construct of evacuation and the changing social and technological context of evacuation. Next we examine the extent of systematic studies conducted by disaster researchers on warnings that lead to protective actions. Four major themes are then examined:

- Warning and warning response,
- Societal characteristics,
- Organizational response, and
- Behavior in evacuations.

Finally, we examine information on evacuation control and management strategies, including evacuation modeling.

Evacuation as a Community Process

In this text we use the term "evacuation" to describe the withdrawal actions of persons from a specific area because of a real or anticipated threat or hazard. The time period for the span of withdrawal is elastic in that the evacuation may last for any amount of time, may occur more than once, or sequentially should there be secondary hazards or a reoccurrence or escalation of the original threat. Thus we include events when a return to the original site is not feasible or forbidden, as when the federal government buys out or relocates communities prone to recurring floods or a state quarantines a contaminated area. In this sense we deviate from some other researchers, such as Quarantelli (1980), who have argued that evacuation should be considered a round-trip event. Given such events as Hurricane Andrew, Chernobyl, drought and civil wars in southern Africa, and sites made uninhabitable by persistent chemical hazards, the decision to include long-term resettlement or relocation as part of the evacuation continuum appears appropriate. Long-term relocation or extended evacuation periods may signal another trend affecting evacuation research issues.

Although evacuations occur daily in the United States, it is difficult to typify a generic model because evacuations lack both definition and consensus on specific parameters. Occurring across various time periods and affecting various numbers of people or groups, evacuations can also impose significant psychological and physical impacts on those involved or who are close to victims. Evidence from the 2004 hurricanes in Florida suggest that those impacts may be delayed or occur significant distances from the hazard source. For example, after the 2004 hurricanes many low-income elderly evacuees found it impossible to rebuild their damaged residences and as a result were forced to move to other states to live with family members. Public outcry over congested highways used for evacuation routes for Hurricane Floyd also forced states to consider coordinating with other state's departments of transportation (Wolshon et al., 2005). Evacuees from Floyd traveled to destinations across several counties and even into other states seeking refuge (Hazards Management Group, no date)

Evacuation is rarely an individual process. Even in single person households, the first response to the initial evacuation warning is to seek further information on the validity of the threat or consult with a friend, co-worker, neighbor, family member or relative. Evacuations usually take place in a group context (Drabek and Stephenson, 1971). Families will try to reunite, if possible, to evacuate as a group, but not necessarily in a single vehicle if two or more vehicles are owned. In business settings, co-workers typically evacuate in groups (Aguirre et al., 1998).

Events that necessitate evacuation vary widely from natural or technological disasters to deliberate terrorist events. Aside from the fundamental issue of intent in terrorist induced disasters, there are some commonalties in evacuations from deliberate and non-deliberate disasters, particularly relating to response and recovery. For example, response parallels exist between wildfires and arson, accidental explosions and bombs, airplane accidents and aviation terrorism, floods and dam sabotage, chemical releases and chemical attacks, and epidemics and biological terrorism (Demuth, 2002).

The Changing Technological and Social Context of Warnings

Warning processes have traditionally been linear communication systems. In a linear process, governmental organizations identify the presence of a hazard through validated monitoring and detection systems. The data is then assessed and analyzed and could lead to the prediction of an extreme event. Such predictions typically included a forecast of the estimated lead time until impact, general location to be affected, estimated magnitude of the event, the probability of occurrence, and the likely consequences for residents. The organizations making these predictions communicate the information to public emergency officials, who in turn interpret the information, decide whether to warn, determine the content of the warning, decide the method to disseminate the message, and then issue the warning to citizens. Again, such a system is linear, going from one actor to the next. The warning that eventually gets to citizens at risk is official. People at risk are expected to respond to these official warnings. This warning process has served our nation for over a half a century, and may still be of use in rural areas with widely dispersed population and few resources.

Significant changes in American society have occurred since this linear warning process was developed. Both cultural and technological shifts in the last decade have altered our view of the public warning process and require a different approach to planning and issuing warnings. These changes include:

- new warning technologies (cell phones, internet, pagers, palm pilots)
- private warning subscription providers,
- nationalization of news coverage,
- increased availability of visual images and information, and
- increased use of GPS for alert and notification.
- In addition to technological changes, societal changes have impacted the warning process.
- The public does not rely on a single official source of warning information and has access to multiple sources of information, some of which may be unreliable or not supported by valid models or detection systems.
- Increasing ethnic diversity has created more barriers to communication with minority groups at the same time that the number of such groups has grown tremendously.
- Increases in single-person, single-parent, and elderly households have affected people's ability to respond to warnings, or even to respond at all.

- Increasing communications compete for an individual's attention that can be a considerable problem especially for fast-moving events with no environmental cues.
- Increasing news coverage of high consequence/low-probability events compete for attention with more common risks that occur more frequently and for which warnings generally protect people.
- Increasing residential and institutional development in vulnerable areas (especially coastal surge zones) has led to greater populations at risk. Placing nursing homes and assisted living facilities on vulnerable barrier islands further saps scarce resources for communities that must also deal with large seasonal tourist influxes that may also be at risk.

The Research Record

The empirical study of public evacuation and response to emergency warnings has proceeded for more than 40 years (Lachman et al., 1961, Drabek and Stephenson, 1971, Perry and Mushkatel, 1986; 1984; Leik et al., 1981; Quarantelli, 1980; Baker, 1979; Mileti and Beck, 1975). These studies, when viewed collectively, have compiled an impressive record about how and why public behavior occurs in the presence of impending disaster or threat. For example, it is well documented that emergency warnings are most effective at eliciting public protective actions like evacuation when those warnings are frequently repeated (Mileti and Beck, 1975), confirmatory in character (Drabek and Stephenson, 1971) and perceived by the public as credible (Perry et al., 1981). Excellent summaries of this research currently exist (Lindell and Perry, 2004, Tierney, et al., 2001, Drabek, 1986; Mileti and Sorensen, 1990). Studies and summaries like these have done much to further social scientific understanding of how people process and respond to risk communications in emergencies; it has also served to inform practical emergency preparedness efforts in this nation and abroad.

The empirical research record on public behavior in evacuations is listed in Table 1. These studies represent major post-disaster surveys of the public that resided in areas for which a warning of an impending disaster was issued. The warning or warnings that were officially issued for these events included an order or advisory for the public to evacuate. Each study represents the following common characteristics:

- a discrete event took place,
- a clear threat to the population was present,
- an official warning was issued, and
- a more or less random sample of the population at risk served as the basis for the survey on which the researcher (s) compiled data on public evacuation behavior.

Disaster researchers have also studied evacuation behavior for discrete populations or in specific settings. Drabek (1996) studied tourist and transient behavior in Hurricanes Bob, Andrew, and Iniki and in the Big Bear Lake and Northridge earthquakes. Vogt (1990, 1991) examined evacuation of institutionalized facilities including hospitals, nursing homes and schools. Drabek (1999) studied the evacuation behavior of employees in 118 businesses in seven disaster events around the country. Aguirre and colleagues (1998) and Fahy (1995) examined evacuation behavior of building occupants following the 1993 bombing at the WTC. More recently an extensive study about evacuation of the WTC on September 11 was conducted (Averill, et al., 2005). Heath (2001a, 2001b) studied the evacuation of families with pets in a hazardous material accident and in a flood.

Major Research Findings

The major categories of warning and evacuation topics that have been addressed in disaster research include:

• *Warning and warning response*. These research questions focus on the information dissemination process, the quality of the information, and the timing of the message delivery and compliance with the warnings. Hurricanes and riverine floods typically have long warning periods during which information both on the physical characteristics of the event and recommendations on protective actions are widely distributed, often over national media outlets. Other incidents have a very short time span between detection and impact and require rapid warnings. For a radiological emergency at a nuclear power plant or a chemical release, emergency personnel may elect to shelter-in-place populations at potential risk instead of recommending evacuation. Some communities, with many large industrial facilities, recommend that residents initially shelter-in-place when sirens sound and then listen for further instructions to evacuate or not (Sorensen et al., 2004). Some research (Three Mile Island, the West Helena explosion) indicates that residents will often defy official recommendations and evacuate even when told to shelter or advised that no protective action is needed. Among the important topics that disaster researchers have studied with respect to warning and response are:

- community adoption of warning systems,
- the timing of warning receipt and warning diffusion, and
- factors influencing household decisions to respond to warnings
- *Societal characteristics.* This research centers on the pre-emergency population attributes, including psychological, demographic, and social characteristics of those a risk. How a threat or potential risk is perceived and how (or if) people respond, especially in a rapid onset event, are often determined by existing conditions, including individual vulnerability. Some researchers have found that existing problems among population groups, such as domestic violence, escalates during disasters, especially if they include evacuation to a shelter or loss of residence (Enarson, 1998). Among the topics that disaster researchers have studied with respect to social issues are:
- how experience affects evacuation decisions,
- depersonalization and denial of risk,
- panic
- impact of preparedness effort on evacuation, and
- the relationship between culture, ethnicity, race and evacuation.

• *Organizational Response.* Typically this research has focused on the behavior of emergency preparedness and response organizations and their capacity to scale up to their response and resources if the event expands or secondary hazards occur. Among the topics that disaster researchers have studied with respect to organization are:

- the relationship between planning and response effectiveness,
- improving behavioral assumptions in planning, and
- reentry into evacuated areas, especially if decontamination effectiveness is
- problematical.

• *Behavior in Evacuations.* This category of research focuses on actual behavior in evacuations (and sheltering-in-place). Among the major research topics are:

- evacuation compliance,
- evacuation of special populations,
- evacuation of pets, and
- evacuation destinations.

• *Evacuation Planning and Management.* This research arena focuses on the processes that go into developing plans to facilitate evacuation, evacuation management strategies, development of traffic control strategies, and the use of models in planning. Among the major research topics are:

- Evacuation strategies
- Reverse lane/contra-flow, and
- Evacuation modeling

• *Public Education and Information to Support Evacuation.* This arena focuses on how to deliver effective information to communities in support of protective action programs. Major topics include:

- Developing a educational program, and
- Delivering effective messages

Warnings and Warning Response

Adoption of warning systems

Only a few researchers have investigated the community adoption of warning systems at the community level. Most research concerning adoption has focused on mitigation at either at the community (Berke et al., 1989) or household (Lindell, 1997) level. A study reviewing community emergency evacuations (Hushon, Kelly, and Rubin, 1989) found the methods most often used for notification and warning were door-to-door warnings coupled with emergency vehicle public address systems and TV and radio announcements. A survey of 18 early warning systems in the United States developed to protect communities against flash floods and dam failures revealed problems of unanticipated maintenance and malfunction costs of the warning systems' components, varying levels of local commitment to maintenance, and an under-emphasis on response capacity (Gruntfest and Huber, 1989).

One of the few national studies of community preparedness for chemical hazards conducted by EPA looked at the types of warning systems used by communities with hazardous materials industries (Sorensen and Rogers, 1988). Warning systems were classified into three basic types: enhanced systems, siren based systems, and ad hoc systems. Enhanced systems use sirens and some form of specialized alerting such as tone alerts. Siren-based systems rely on sirens for alert with use of media-based notification (if the siren has no voice capability to broadcast a warning message). Ad hoc systems generally rely on media reports, an Emergency Alert System (EAS), and on door-to-door or route alert. The study found that the predominant means to warn people in close proximity of the chemical facilities was usually by an ad hoc method (45%). Sixteen percent relied on route alert or door-to-door notification. Another 29% relied on EAS or media warnings. Siren-based systems were utilized in 33% of the communities. Only 12% had access to an advanced system involving both sirens and tone-alert radios for notification.

Timing of warning receipt

Overall we have good insight into timing of warning dissemination. Much of this knowledge has been derived by contentions over warning systems for nuclear power plants, primarily due to Atomic Safety Licensing Board (ASLB) rulings. The most significant debate on what constitutes a state-of-the-art alert/notification system came in an ASLB proceeding on the Shearon Harris Nuclear Power Plant in which disaster researchers served as expert witnesses. In their final decision the ASLB defined what constitutes "essentially 100% notification within 15 minutes in the first 5 miles of the Harris Emergency Planning Zone (EPZ)" (NRC, 1986). In this matter the board required the utility to prove that over 95% of the people within 5 miles of the facility would receive a warning in 15 minutes in summer nighttime conditions, one of the most difficult warning times. The utility could not do so by relying solely on a siren system. In order to exceed

the 95% requirement, commercial tone alert radios were proposed for all households within the 5 mile radius. The ASLB accepted this plan as exceeding 95% notification.

Researchers have modeled the timing of warning dissemination for specific events with multiple sources (Lindell and Perry, 2004) or for different warning technologies (Rogers and Sorensen 1988). Often warning time is broken down into the decision time (time for officials to reach a decision to issue a warning) and dissemination time (the time it takes for the message to reach the public) (Rogers 1994, Lindell and Perry, 1992).

Survey data collected on the Nanticoke, PA, evacuation due to a metal processing plant fire enabled the construction of empirically-derived diffusion curves for different warning technologies (Sorensen, 1992). The curves show the cumulative percent of the population receiving the first warning over time by the four major methods of warning. These are shown in Figure 1. The timing of the diffusion is very similar for sirens, route and informal alerting. Some of the early reporting of sirens and route alerts were likely made by people who heard emergency vehicles responding to the fire. The curves show a steep increase in notification when the official warning activity ensued. By 15 minutes into the official warning, data indicate that about 65% of the public had been notified. About 22% of the public had received a siren warning at this point. The remainder had received an informal warning, from route alert or from media.

Little research has been conducted on explaining individual variations he timing of response (Sorensen, 1992). For example, what differentiates early or rapid responders from those who delay their response? In events requiring rapid evacuation the strongest predictor of when people leave is the time that they receive a warning. In longer lead time events the timing of departure is influenced by the time people are normally mobile such as going to work or school or after work or school.

Factors influencing household decision to evacuate

A robust understanding of factors influencing evacuation compliance has been developed by social science researchers. The focus of the research has been on whether or not people evacuate when advised to do so (see Lachman et al., 1961; Withey, 1962; Williams, 1964; Anderson, 1969, Drabek, 1969, 1983; Drabek and Boggs, 1968; Drabek and Stephenson, 1971; Mileti, 1975; Baker, 1979; Quarantelli, 1980, 1984; Perry, et al 1981, 1982; Perry, 1979; Leik et al., 1981; Cutter and Barnes, 1982; Perry and Greene, 1982, 1983; Stallings 1984; Perry and Mushkatel, 1984; 1986; Mileti and Sorensen 1988, Dow and Cutter, 1998, Lindell and Perry, 2004).

Warning response involves a sequence of cognitive and behavioral steps. Perry and Lindell (1992, 2004) characterize warning response as a four stage process:

- Risk identification: Does the threat exist?
- Risk assessment: Is protection needed?
- Risk reduction: Is protection feasible? and, finally
- Protective response: What action to take?

Mileti and Sorensen (1988) characterize the process as sequential process:

- Hearing the warning;
- Understanding the contents of the warning message;
- Believing the warning is credible and accurate;
- Personalizing the warning to oneself;
- Confirming that the warning is true and others are taking heed; and,
- Responding by taking a protective action.

Social scientists have identified both general and specific factors that affect the warning response process which include sender and receiver factors, situational factors, and social contact. The specific factors are summarized in Table 2 (Sorensen, 2000). Only a few of these factors can be manipulated as part of the warning process. The chief way warning response can be affected by the emergency planner is in the design of the warning system including the channel of communication, public education and specific wording of the emergency message. In addition, incentives can be offered to increase response, including information hotlines, transportation assistance, mass care facilities, and security and property protection for evacuated areas (Lindell and Perry, 1992).

One frequent response to a warning is to confirm the original message received (Drabek 1969). Confirmation increases with longer lead-time to impacts (Perry et al., 1981), for warnings received from the media (Dillman et al, 1983; Sorensen, 1992), and for alerts received by sirens (Sorensen, 1992). Confirmation levels decrease with the specificity of information in the first warning received (Cutter and Barnes, 1982) and when the initial warning is heard from police and fire personnel going door-to-door or using loudspeakers (Sorensen, 1992).

One myth regarding disaster response is that people panic when warned or confronted by an emergency event. These beliefs are at odds with actual experiences during emergencies including fires and terrorist events. People are not frightened into a state of paralysis. People do not panic. People do not engage in widespread anti-social behavior. Even massively destructive events such as the attacks on the World Trade Center (WTC) confirm these findings about human behavior in disasters. The evacuation in 1993 was calm and orderly (Aguirre et al., 1998). As Tierney (No Date) concludes regarding the 9/11 attacks in New York:

"The rapid, orderly, and effective evacuation of the immediate impact area - a response that was initiated and managed largely by evacuees themselves, with a virtual absence of panic - saved numerous lives." Overall statistics confirm the success of the evacuation. Of the estimated 17, 400 person in WTC 1 and 2, 87% safely evacuated and 99% below the impact zone safely exited the building (Averill et al., 2005). (see table on evacuation of the WTC).

Panic can occur under very specific circumstance such as in a fire in a crowded and confined building with inadequate exit routes and when it is clear that not everyone will exit before their lives are in grave danger, but panic has never occurred in a community evacuation.

Societal Characteristics

How experience affects evacuation decisions

Experiencing a disaster or a close call with an event often shapes people's response to future events; however, it does not do so in a predictable or systematic way. Direct hazard experience does not effect interpretation of warning information, decision processes, behavior, or information seeking (Lindell and Perry, 2004). Hurricane Kate led to an evacuation of the Tampa Bay area about 4 months after Hurricane Elena had prompted an unnecessary evacuation of the same area. Baker (1987) found that evacuation rates in the Tampa Bay area for Hurricane Kate were similar to that for Elena, despite the earlier false alarm. Others have suggested that long-term residents of coastal areas, who experienced minor hurricanes without severe damages, become complacent, and are less likely to evacuate in subsequent events (Windham et al., 1977). Others have suggested previous experience has had a mixed effect on warning response (Sorensen, 2000). In some cases it deters response and in others it increases response.

Personality, depersonalization and denial of risk

There has been a fairly widespread belief that personality factors such as locus of control (it is in the hands of others) or fatalism (what will happen will happen regardless of what I do) effect evacuation behavior. This is mainly

supported by anecdotal information or newspaper coverage of people who refuse to evacuate and not by extensive empirical research. Good anecdotal examples are Harry Truman who refused to leave his cabin near Mt. St. Helens volcano when warned because he felt his fate was in the hands of a higher authority (he died during the eruption) or people having hurricane parties. Several studies have concluded fatalism diminishes warning response for earthquakes (Turner et al, 1981) and for tornados (Sims and Baumann, 1972). When faced with a warning to evacuate people often are initially in disbelief – it's not really happening to me (Drabek, 1999). Usually such perceptions are rapidly replaced by the reality of the situation.

Impact of preparedness efforts on evacuation

There is no conclusive evidence regarding whether or not preparedness programs, public education or information program actually makes a significant difference in increasing human response to warnings. The most reasonable interpretation of the evidence, when considering the empirical, anecdotal and practical is that a good pre-emergency information program will increase response although the amount cannot be estimated (Sorensen and Mileti, 1991). Conversely a poor program will not likely make a great overall difference. In addition, while providing information may lead to increased knowledge and preparedness, the effects drop off over time (Waterstone, 1978).

The relationship between ethnicity, culture and evacuation

Some researchers argue that membership in a minority group typically isolates a person from information and decreases the likelihood of responding to a warning (Perry et al., 1981, Gladwin and Peacock, 1997). Other studies demonstrate that ethnicity has no significant effect on evacuation when perceived risk has the greatest influence (Perry and Lindell, 1991). Language - the inability to understand the warning message - may also be a factor explaining why culturally isolated groups fail to understand a warning. The high number of deaths of Hispanics in the Saragosa, TX tornado, was attributed to a failure to provide a good translation of the warning into Spanish (Aquirre et al., 1991).

Perry (1987) suggests from his research that some minority group members perceive authority figures--particularly uniformed 'government' representatives differently from majority group members. Perry (1987) also offers evidence that suggests that there appears that no ethnic differentials exist with regard to the relationships between warning belief and personal risk and warning compliance; i.e., higher levels of warning belief and personal risk are correlated with higher levels of warning compliance. The higher the credibility of the warning source, the more likely the development of high levels of warning belief and assesses personal risk, and consequently the more likely the recipient will engage in a protective action. Thus the accomplishment of emergency management tasks depends upon knowing the degree of ethnic composition of any given community of interest.

Organizational Response

The relationship between planning and response effectiveness

Evacuation warnings given without forethought or planning and without input from partners can be disastrous to both sender and receiver. It is important to plan for warning credibility, the warning message, the method of dissemination, rumor control, protective action recommendations, and incentives to response (Mileti and Sorensen, 1990; Lindell and Perry 2004). Moreover, a warning may not be heeded by the public when the information is in direct contrast to what is being observed. To be most effective, a warning message should be planned with the concerted efforts to tell people where, when, how and why the hazard has occurred (or is predicted to occur) and what people can do to avoid harm (Lindell and Perry, 2004). Plans should include the lead partner who will issue warnings for specific events.

Flexibility is also an essential element in planning and disseminating warnings (Mileti and Sorensen, 1990). A particular issue is how the hazard is defined and therefore, who is in charge. If an event is considered a potential crime scene, the emergency agencies responding may not be the ones who issue follow-up messages about the hazard. The key is to develop procedures to avoid conflicts in information in warning messages, recognizing that partnerships will fluctuate as the event unfolds.

At the family level it has been found that households with an emergency plan are more lively to comply with an evacuation warning than those without a plan. (Lindell and Perry, 2004). (See FEMA Family Planning Brochure)

Improving behavioral assumptions in planning

Many emergency planning processes now involve the use of simulation models. All models concerning disaster management contain assumptions about human beings, be it an engineers' mental model of an equipment failure mode or a psychologist's model of how people respond to a stimuli. Few efforts have been made to identify and document behavioral assumption in models developed for and used in disaster management. It is essential that critical assumptions used in models be validated. For example, Lindell and Perry (1992) noted that the assumptions about warning and preparation times used in evacuation time estimates are based on engineering assumptions and not on behavioral data.

More work is need to develop robust models of human behavior in emergencies, including models of decision-making, communication, interaction, warning systems, and protective action behaviors. For example, some dose assessment models assume people are passive receptors of an agent or are located in the same place during daytime as well as nighttime hours. Models based on these assumptions might not apply when people are fleeing or taking precautions in place. Santos and Aguirre (2004) argue that simulation models for emergency planning and intervention need to be linked to fieldwork and empirical investigations of emergency evacuations in order to provide modelers with the appropriate parameters for human behavior.

Reentry into evacuated areas

Planning for reentry remains an issue that is often not addressed in plans. What is known on reentry procedures is not always implemented in practice. We know residents want to return as soon as possible to evacuated homes, that they don't travel far from home, and that considerable antagonism results if they are forced to remain away from their homes (Dash and Morrow, 2001). Research from Hurricane Elena evacuees indicated that approximately 75% of evacuees sought refuge in their home counties and reentry to designated evacuated areas became a significant issue (Nelson et al., 1989).

Guidelines for reentry into an area following a chemical release are practically non-existent as are protocols and equipment for environmental monitoring in areas evacuated (Vogt and Sorensen, 2002). In the Miamisburg, Ohio, white phosphorous accident, citizens returned to their homes after being evacuated only to be forced to evacuate again as the situation worsened (Menker and Floren, 1986). Stallings (1991) suggests that reentry will be more problematic in emergencies involving hazardous materials than in natural hazard events. People who left pets in the evacuation zone frequently attempt to reenter the area to rescue the animals prior to a official order to allow reentry (Heath et al., 2001a).

Managing traffic during reentry can be more problematic than during the evacuation. Witzig and Shillenn (1987) study of traffic accidents in over 300 evacuations traffic jams were more likely during reentry rather than in the movement out.

Behavior In Evacuations

Compliance with evacuation recommendations

Disaster researchers have studied issues associated with compliance with official orders to evacuate or not to evacuate. Such issues concern “shadow” evacuation, defined as people evacuating from outside the official evacuation zone, “early” or "spontaneous” evacuation, defined as people evacuating before an official warning is issued, evacuation rates in different risk zones, and "cry-wolf" effects. "Cry wolf" effects are defined as the non-compliance with warnings behavior that might be expected from residents who have responded to too many "false alarm" warning messages. "Warning fatigue" and the design of warning messages for special populations with limited sight or hearing have also been discussed in the literature but not with the depth as the subjects previously mentioned (Mayhorn, 2004).

"Shadow evacuation" was well documented for Hurricane Floyd. The Hazards Management Group of Tallahassee, FL, (No Date) studied the public's response to Hurricane Floyd in 1999 through 6900 structured telephone interviews with North Carolina, South Carolina, Georgia and Florida residents in surge and non-surge areas, as well as residents in non-coastal areas. Results revealed some of the highest participation rates ever experienced in an evacuation in the high risk surge zone. Most evacuees cited evacuating because of notices from public officials and what they heard on the Weather Channel and local weather stations. A large percentage of respondents sought refuge out-of-county and out-of-state, with very few seeking refuge in official shelters. The data indicate that "shadow evacuation" in low risk areas not told by officials to evacuate was high in almost every location. For example, evacuation rates in non-coastal counties, the lowest risk zone, ranged from 12% to 49% with an average of 26%. In a recent study of a chorine release caused by a train derailment the shadow evacuation in an area 1 to 2 miles from the release was 59% (Mitchell et al., 2005)

The concept of "spontaneous" evacuation grew out of analyses of the evacuation at Three Mile Island, when many more people evacuated than were advised to leave (Cutter and Barnes, 1985). In fact spontaneous evacuation occurs in most evacuation events. People leave coastal areas when a hurricane seems eminent before officials order or recommend evacuation. In hazardous material accidents plant workers or first responders contact friends and relatives thought to be at potential risk before an official evacuation order (Vogt and Sorensen, 1999).

In most evacuations, not everyone at risk or in areas in which evacuations are ordered or recommended, participate in the evacuation. Reasons for non-compliance include not having access to transportation, being mobility impaired, not being able to afford to evacuate, needing to work, needing to provide care, thinking one’s location is safe. Evacuation rates vary for different hazard types, for different events, and for different level of risk (as defined geographically). Evacuation rates are very high for most hazardous material accidents, where compliance may be in the high 90% range. Evacuation rates are typically low for slow onset events such as riverine floods. Evacuation rates vary in hurricanes depending on the strength of the storm and location. In high-hazard storm surge area evacuation rates may be as high as 90% in major storms. Evacuation rates are much lower for smaller hurricanes and in lower risk zones.

The effectiveness of people's responses to warnings is not always diminished by what has been labeled the "cry-wolf" syndrome. Two issues regarding false alarms are significant. The first concerns a false alarm that leads to public taking a protective action such as evacuating. In this case, if the basis for the warning and reasons for the "miss" are told to the public in question and understood by them, the integrity of the warning system will be preserved. Data from hurricane evacuation studies indicate that false alarms do not prevent people from evacuating in the future if they know the basis for the uncertainty and the false alarm (Baker, 1987).

The second issue related to the "cry wolf" syndrome concerns repeated activation of the alert mechanisms. If such false alarms occur and no attempt is made to explain why they were false alarms, there could be a negative effect on subsequent public response to warning of a subsequent event (Breznitz, 1984). This is particularly true of inadvertent

sounding of sirens if such malfunctions are frequent and not explained. It may also occur in populations around industrial facilities that use sirens to signal work-shift changes.

Animals in evacuations

Most disaster relief shelters or commercial lodging facilities do not allow people to bring in pets or other animals. FEMA, however, recommends people evacuate with pets. An issue receiving increasing attention is what evacuees do with pets or other animals such as livestock when they leave their homes and whether having pets or animals impacts their decision to evacuate. In Hurricane Elena, Nelson et al. (1989) found 25% of evacuees left their pets at home while they were gone. Most evacuees either took their pets to a friend or relative. The 11 % of evacuees who took their pets to shelters left the animals in vehicles for the duration of the stay. In a flood evacuation, Heath (2001b) found that half of the pet owners evacuated with their pets and the other half did not.

For a protracted evacuation or one in which toxic fumes were involved, leaving pets behind could be a significant problem as premature reentry by evacuees could further place residents at risk. Cann (1990) found that during the 10 day Haggersfield evacuation from an area where burning tires created toxic fumes, residents routinely returned to their homes to care for livestock. In a chemical accident (Heath, 2001a) found that 60 % of the evacuees had dogs and cats. Of those, 49% evacuated with their pets, 41% initially left them home but latter attempted to rescue them, and only 10% left them home without a rescue attempt. Buck (1987) notes that in certain situations evacuating livestock may be the only measure offering protection to animals. How that is best accomplished under various time frames remains problematic. Nelson et al. (1989) found that in Hurricane Elena people who had pets at time of hurricane were less likely to evacuate. Similar results were found in a study of evacuation behavior in Hurricane Bonnie (Whitehead et al., 2000).

Many evacuation plans develop specific strategies to deal with evacuated pets or larger animals including co-locating animal housing facilities at mass care shelters, or using facilities such as fairgrounds to house evacuated animals. (See: EMI Independent Study Courses - Livestock: http://training.fema.gov/EMIWeb/IS/is111.asp

Animals: http://training.fema.gov/EMIWeb/IS/is10.asp, and http://training.fema.gov/EMIWeb/IS/is11.asp

The Humane Society of the United States has developed preparedness brochures for pets horses and livestock - (http://www.hsus.org/hsus_field/hsus_disaster_center/disaster_preparedness_brochures.html) and the American Veterinary Medical Association also have brochures on their web (http://www.avma.org/products/disaster/default.asp).

Evacuation of special populations

Special populations are those groups of people who because of their special situations or needs require different planning strategies from those of general evacuation planning (Vogt 1990, 1991). The term "special population" is somewhat misleading in that populations of institutions or special facilities are frequently considered homogeneous when in reality they exhibit many characteristics that differ by physical or geographical constraints (Lindell et al., 1985). While some populations may be concentrated in institutions such as schools, prisons or hospitals, other will be widely dispersed. Among the dispersed individuals that make up such groups are the hearing or visually impaired, the foreign speaking, transients such as motorists passing through the area, tourists or other temporary visitors such as day workers, and the non-ambulatory confined to residences either temporarily or permanently. See Preparing for Disaster for People with Disabilities and other Special Needs - FEMA 476 and N.O.D. Guide On The Special Needs Of People With Disabilities.

Access information developed by the Department of Justice - Making Community Emergency Preparedness and Response Programs Accessible to People with Disabilities at http://www.usdoj.gov/crt/ada/emergencyprep.htm.

The reasons why these groups may fail to respond to warnings to take protective actions is that they may require special transportation while others require different types of warnings or technologies to receive a warning. Some groups must rely on care-givers (such as schools and day-care centers) to hear the warning and respond. Populations of nursing homes or assisted-care facilities may combine various aspects related to mobility and mental competence that makes evacuation the last resort in protective action planning. The state of New York has developed a useful checklist for developing a nursing home emergency plan. Lack of mobility may not be voluntary as in the case of prisons where continued constraints must be imposed during the evacuation process. The National Institute of Corrections has published a guide for developing prison emergency plans.

Most schools have plans to evacuate children in event of a community emergency. Two planning strategies most frequently used by schools include:

• Early dismissal, in which children are returned to their homes. Children who cannot return are sheltered at the school.

• Relocation of the school populations to a pre-designated shelter by bus.

In emergencies where the time to impact is fairly long, some parents will likely attempt to pick up students at school. This rarely interferes with the evacuation process. In rapid-moving events children are evacuated before parents have the opportunity to pick up children. Exercises suggest that schools can evacuate in 10 to 20 minutes following the decision to move students out of harms way. Several resources are available to help develop school plans including a model plan workbook developed by the state of Missouri and a guide developed by the Department of Education. In addition a guide developed by UCLA to develop emergency plans for HEADSTART programs offers useful advice for day care facilities.

Drabek (1994) studied evacuation planning in the tourism industry and found that most establishments did not have a written emergency plan for evacuating their clientel. Pinellas County, FL, noted for their planning for special populations, has developed a generic evacuation plan for hotel/motel operators.

Timing of Evacuations

Once the warning is given, a mobilization time or preparation time (referring to the time taken to prepare to implement the protective action) is modeled. Implementation (or departure times) time is defined as when the evacuation is undertaken. Mobilization times are highly variable and seem to depend on the time to impact and the level of urgency to respond (Lindell and Perry, 1992). For rapid onset events the curse are fairly steep. In one hazardous material emergency it was estimated that close to 90% departed within 30 minutes (See example mobilization curves). In slower events, such as a hurricane, departure times are more spread out, but can vary by location. In Hurricane Floyd there was a relatively steep departure curve in the Charleston area. Further north in Myrtle Beach, the departure rate was more spread out (Floyd Departure Curves).

Clearance time is the sum of the time a warning is received, mobilization time, and trip travel time, which is the time from evacuation trip departure to reaching the destination. This is illustrated using data from the study of an evacuation in Nanticoke, PA caused by a fire at a chemical facility (See Clearance Curves). In this event the clearance curve reflects the fact that evacuees did not travel very far to reach safety. Clearance time can be much longer for other event such as hurricanes, particularly in populated areas. In Hurricane Floyd it took evacuees an average of about 9 hours to reach their final destinations.

Destinations of evacuees

Despite efforts by public officials to provide public shelters to house evacuees, most people evacuate to relatives, friends, or hotels. The use of public shelters in evacuations is variable and has ranged from less than 1% for the TMI evacuation to over 40% in the Nanticoke hazardous materials evacuation. On average, shelter use is about 13% of the evacuating public. It appears to be higher when the evacuating population is of low income and older and lower when the population is more affluent and young (Mileti et al. 1992, Table 3). Among transient populations the homeless and migrants are much more likely to use public shelters during an evacuation than more affluent transients such as business travelers or vacationers (Drabek, 1996).

Vehicle Use in Evacuations

Most data on vehicle use in evacuation comes from hurricane events. Vehicle use is fairly constant from event to event and averages 65-75% of the vehicles in an area that evacuates. Expressed in another way the average number of vehicles per household is 1.3. In the hurricane Floyd evacuation in South Carolina the vehicle use rate ranged between 1.18 and 1.48 vehicles per evacuating household. The vehicle use is usually somewhat higher in high-risk zones and lower in low- risk zones.

Some people require assistance in evacuating because they do not own a vehicle or cannot drive. In hurricane Floyd in South Carolina the percent of evacuees needing assistance ranged from 3 to 11%, depending on the location. Most of these received assistance from family or friends. In several locations 1-2% required assistance from officials.

Evacuation Planning and Management

A variety of strategies have been developed to increase the speed of evacuation in large urban areas. Often this involves the use of evacuation simulation models. Traffic control strategies include altering signaling, use of traffic control guides, using roadblocks and barriers, lane reversal and lane expansions. Evacuation management strategies include sector evacuation, keyhole evacuation, selective evacuation and phased evacuation.

Evacuation modeling

Early efforts to develop evacuation simulations were primarily driven by crisis relocation planning (Brand, 1984). Such early efforts were largely based on road capacities and evacuation times were calculated by comparing estimated traffic demand to capacity. Similar techniques were used in some of the early evacuation planning for hurricanes. Requirements to conduct evacuation time estimates around nuclear power plants led to the development of more sophisticated models (Urbanik, 1981, Sheffi et al., 1982). Such models track the flow of vehicles over a network and reconcile traffic loading and discharging at key intersections.

Since those early efforts there is a growing research literature on community evacuation modeling. This included re on evacuation time estimates (Urbanik, 2000, Southworth, 1991), optimizing evacuation behavior (Yamada, 1996, Church a Cova, 2000), and the effectiveness of traffic control strategies such as reverse lanes or traffic guides (Hobeika and Kim, 199 and Johnson, 2003, Wolshon et al., 2005).

Basically, the problem of determining optimal evacuation paths out of an area at risk can be modeled as a network flow problem. The objective of the network flow evacuation problem is to route a given amount of people from a set of source nodes —representing urban neighborhoods, rural areas, schools and businesses to a set of exit nodes — to an area outside the risk zone—in the least amount of time, without violating the capacity constraints of the system. These nodes are connected by directional links (representing the transportation system including streets and highways) that indicate the allowed direction of flow of people or vehicles during the emergency evacuation. Those links have attributes

such as capacity (i.e., maximum flow that can traverse the link), geometric characteristics, and travel time (which depends on the flow and geometric characteristics of the link in question).

The process of conducting an evacuation time estimate involves the establishing the following data (Southworth, 1992, Urbanik 2000, NRC, 2005:

1. Identifying the population to be evacuated and their spatial location (See LandScan Example);

2. Estimating the number of vehicles evacuating, the rate they load onto the network, and where they load (Examples of Loading Curves); and

3. Estimating the capacity of the transportation network and the characteristics of lanes and traffic controls.

Alternative scenarios can be modeled such as daytime versus nighttime evacuations, good weather versus bad weather, special events, traffic obstructions, or various traffic controls.

Research and planning tools, however, are not typically available to the practicing emergency planning community. Among the question that evacuation modeling can help emergency planners address are:

- Can an area at risk be evacuated with free-flowing traffic?
- How long will it take to evacuate the population at risk (expressed as various percentages)?
- If congestion occurs where are the problematic areas on the network?
- What are the best routes out of an area?
- If an event occurs before the evacuation ends, what is the residual population at risk?
- What are the best traffic control and management strategies?
- What is the impact of traffic impediments on evacuation times?
- How will road maintenance and construction effect traffic flow?

The Oak Ridge Evacuation Modeling System (OREMS) {http://emc.ornl.gov/CSEPPweb/data/html/software.html} is an example of a state of the art simulation tool for evacuation planning that was developed for FEMA for use in the Chemical Stockpile Emergency Preparedness Program (CSEPP). OREMS is called a modeling system because it consists of several traffic models/algorithms that are integrated together with an advanced graphical user interface. It has a pre-processor for entering information into a database used in evacuation modeling, a simulation model, and a post-processor linked to GIS for displaying the results of the simulation. OREMS can be used to estimate clearance times for evacuating an area, for predicting traffic bottlenecks, and to evaluate traffic control strategies. OREMS uses current state-of-the-art network codes derived from US Department of Transportation models. Furthermore it is the only model of its kind endorsed for use by DOT in regional evacuation planning. OREMS was developed to replace out-of-date technology found in other evacuation simulation solutions. Although OREMS was developed to model evacuation from a city, its principles and algorithms are applicable to other network problems such as evacuation from a complex building. The current release is version 2.6.

Development of a dynamic evacuation model

Historically evacuation models, including OREMS, used static traffic assignment (or static allocation of flows to different paths) that assume that the conditions of the network at the beginning of the simulation prevail throughout the evacuation. A better representation of the problem of determining the optimal a priori evacuation paths would be a dynamic network flow model. In dynamic networks, the state of the system changes over time. That is, as vehicles move through the network over time, the traversal times determine how long each unit of flow spends traversing any given link while the capacities restrict the rate of flow on that link. Capacities along the link are recaptured as the flow moves out of

the link. Dynamic traffic assignment also provides a better linkage between the traffic assignment and simulation models so the dynamics of traffic flow, or the route selection process, is more accurately modeled than in models that rely on static assignments.

Dynamic network flow problems may also be considered in a purely static environment, i.e. the attributes of the network, including link traversal times, link capacities, and supply, are time-invariant and are known with certainty. Although better than static assignments, for evacuation problems, such representation is still inadequate. In order to develop a real time evacuation model it is necessary to link a dynamic traffic assignment models to real time data. For example, Barett et al. (2000) described a decision support system with an embedded dynamic traffic assignment procedure for modeling the movement of traffic in evacuating a geographic region. This procedure, however, was not simulation-based. As Urbanik (2000) points out, one cannot use a generalized traffic congestion simulation code to handle an evacuation problem. The main challenge is to develop code to use the real time data to readjust the network flow at regular intervals and recalculate the simulation to produced updated values.

A prototype dynamic assignment model was developed at ORNL prior to the development of real time traffic monitoring (Southworth et al., 1992) for vehicular networks. An experimental application to use traffic data was also developed (Janson and Southworth, 1992). This code has been recently integrated with OREMS simulation code ESIM to produce a dynamic evacuation code called DSIM. In each time period of the simulation new traffic assignments are calculated that are based on the distribution of traffic in the previous time period. Predictions of future traffic behavior are based on current traffic patterns, which are continuously updated at discrete time periods.

The DSIM code more closely simulates driver behavior in congested traffic than a static model. If people encounter stalled traffic they will take an alternative route based on their knowledge of the area, maps, or traffic guides. Seeking alternative routes that represent underutilized capacity decreases the time needed to evacuate. Initial tests of DSIM show that evacuation times are predicted to be shorter than when modeled with a static assignment (Franzese and Sorensen, 2004).

The dynamic assignment makes it feasible to use real time traffic sensor data to drive the model. The real-time data would be supplied by sensors that assess travel times and flows along the different links on the network as well as queues at chocking points (Gwynne, et al, 1999, Kastrinaki,et al., 2003). Some techniques derived from the application of remote sensing to vehicular emergency evacuations (Franzese and Xiong, 2001) can also be used to collect this real-time information.

Traffic Control Strategies

Signaling

Traffic lights can be set to facilitate the flow of traffic during an evacuation. In Washington, DC, this strategy was tested in 2005 for the July 4 fireworks display. Starting 15 minutes after the fireworks show ends, police officers directed tens of thousands of pedestrians and motorists leaving the Mall to seven evacuation routes (See DC Evacuation Map) in which green and red traffic signals were extended to four minutes. The test lasted 45 minutes. Extending the length of signals increases traffic flow because it reduces start up times. Four minutes is the maximum length of time to set traffic signals because at longer times people perceive that signals are not working and attempt to merge by violating the signal, which can increase the risk of accidents.

Traffic Control Guides

Deploying traffic control personnel to problem intersections to manually direct traffic in place of existing traffic lights can facilitate the flow of traffic because the guide can help keep traffic moving in the primary evacuation direction. Some major cities such as Washington, DC regularly use traffic control guides at problem spots during the afternoon rush hour. Most statues governing traffic control during emergencies are established at the state and local level. Chapter 6 of DOT's Manual on Uniform Traffic Control Devices { Ch6A-E.pdf, Ch6F.pdf, Ch6G.pdf, Ch6H.pdf, Ch6I.pdf} addresses Temporary Traffic Control, which sets national standards for traffic control practices.

Roadblocks and barricades

A variety of methods are used to stop or divert traffic. Roadblocks and barriers include a number of different technologies:

- Tape barriers
- Portable signs
- Cones
- Barrels
- DOT Type II rail barricades: must be at least 3 feet high with two rails 2 feet in length.
- DOT Type III rail barricades: must be at least 5 feet high and have three rails that are at least 3 feet long.
- Concrete or water-filled barricades (manual)
- Automated vehicle barricades
- Manual swinging gate barricades

These devices can be set in place without staffing or staffed by traffic guides or law enforcement personnel (traffic control). In general, un-staffed and removable barricades are not very effective as drivers can circumvent them rather easily. For example, during a flash flood in Cheyenne, WY, several people died by driving into a flooded stream after removing the tape barricade placed by police to keep motorists from driving into the flooded creek. Prior to the major eruption of Mt. St. Helens people used logging roads to get around the un-staffed barricades set up on highways to restrict access to high risk areas to get close to the eruption site. Solid or staffed barricades are much more effective than portable devices.

Permanent Signage

Often evacuation routes are marked with permanent signs that help people to find the best evacuation route of an area. These are particularly useful is areas with large transient or tourist populations. The state of Florida has developed a section of their Traffic Engineering Manual on evacuation signage for hurricanes. This has been popular in most hurricane areas (See North Carolina Sign) Recently the state of Oregon has developed a signage program for Tsunamis (See Oregon Sign Manual).

Electronic Signage

Electronic signage networks are LED (light emitting diodes), LCD (liquid crystal displays), or plasma screen-based display solutions that are utilized in airports, borders, ports, highways, and other public areas to inform people during emergency or disaster events. Such signs can be permanent or portable. They have been incorporated into Amber alert systems in many locations. In 2003 the Salt Lake City Police issued an alert after a 3-year-old boy was taken by some acquaintances of his mother and authorities received information that the child was in danger. A man was driving to a meeting that same morning and saw "CHILD ABDUCTION ALERT" flashing on the electronic highway signs. He spotted the suspects one hour later as they were walking into the YWCA. He called the police and the baby was recovered less than five hours after the alert went out. Electronic signs are used during evacuations to advise motorists that an evacuation is in progress and the routes to take. (See Electronic Highway Sign) They also can be used to advise motorist to take alternative routes or alert them to traffic problems. (See warning sign)

Lane Expansion

Lane expansion involves using road shoulders to increase the vehicle capacity of evacuation routes. It is only feasible when unobstructed shoulders are available and the shoulders are not needed for emergency vehicles. If remerging due to a bridge or shoulder constriction is necessary, lane expansion is not a good option because the remerging will further slow the evacuation. Furthermore, options for moving stalled vehicles out of the shoulder need to be available.

Contraflow

Contraflow or lane reversal involves directing traffic to use lanes coming toward the source of a hazard to move people away from the hazard. Such a strategy can be used to eliminate bottlenecks in communities with road geometries that prevent efficient evacuations or to facilitate the flow of traffic out of major urban areas. Such strategies are commonly used in larger urban areas to accommodate rush hour traffic. Wolshon (2001) points out however that there are significant differences in routine daily contraflow, where operations are well controlled and familiar to drivers and emergency contraflow, where operations are non-routine. Among the considerations in planning emergency contraflow are traffic control, access management, merging, exiting, access to fuel and and supplies, safety concerns, labor requirements, and cost.

Contraflow configurations need to be carefully planned based on a number of factors such as the location of the potential hazard, the geometry of the road structure, origin of evacuees, the destination of the evacuees, and ingress and egress points. Making a two lane state highway into a 2 lane outbound route involves as much planning as making a multiple lane freeway into a one-way exit. (See Sample plans for South Carolina: US-21 and I-26) {US21.pdf, I-26.pdf. Planning is very critical for successful contraflow operations. In advance of Hurricane Katrina, New Orleans successfully utilized a contraflow plan to evacuate the city in a rapid manner. (See plan) . In contrast, for Hurricane Rita, no contraflow plan existed for Houston. When they implemented the strategy on an ad-hoc fashion, many problems occurred including massive congestion and vehicles running out of gas. One major lesson learned from these events is that terminating the contraflow needs to be carefully planned to avoid creating choke points. Some contrflow plans go into great detail regarding operational planning. (See Alabama Contraflow Planning) {ALDOT-rl, ALDOT} and Mississippi Contraflow Planning). It is also important to develop a public education program about contraflow. (See MS Brochure).

Evacuation Management Strategies

Sector and zonal evacuation

At times maps of an area that may be potentially evacuated are divided into sectors or zones for cases where not all zones need to evacuate or phased evacuation is used (see below). Criteria for defining the zones are usually risk or hazard based or based on geographical features. In other cases they are based on geometry such as concentric circles and lines extended from the center of the circles. For hurricanes, evacuations zones are established based on damage potential associated with different categories of hurricane intensity. In Texas, three zones have been established: Zone A for categories 1 and 2, Zone B for category 3 storms and Zone C for category 4 and 5 storms. (see Example for Galveston area) In South Carolina there are 4 evacuation zones. (See Charleston map)

Some emergency planning zones for hazards such as fixed site nuclear power plants or chemical facilities divide their planning zones into sub-zones. Typically these areas are divided using major highways and streets as well as geographical areas such rivers or streams. An example for Westchester County, NY which is part of the emergency planning zone for Indian Point Nuclear facilities is provided. (see map) Typically a 30 degree wedge is over-laid on a map based on wind direction and all zones touching the wedge are evacuated.

Yet another approach is to divide an area into geometric zones such as quadrants or concentric circles. The evacuation maps for downtown Cleveland, OH (see map) {downtownevacplan-23Sept021.pdf, evacuationplan1pagesummary.pdf } and Charlotte, NC see map) provide examples for a quadrant-based evacuation. This approach for evacuating an urban area is largely untested. One problem is that people will likely try to evacuate toward their destination, which may not conform to the proposed single direction flows out of a downtown area.

Keyhole evacuation

Keyhole evacuation is similar to the wedge sector evacuation but an area upwind of the facility is evacuated as well. In general all people within a specified radius of the incident (usually 2 miles in the case of a nuclear power plant) are evacuated. People living downwind from the projected path of plume travel and bordering sectors are also evacuated. This area, the downwind sector and two adjacent sectors, affords protection from potential wind shifts and plume meander. This is known as a "keyhole" because of its appearance. (See diagram)

Selective evacuation

Selective evacuation involves advising a subset of the population to evacuate based on selective criteria. Such criteria could be demographic such as age, health status such as respiratory problems, or other conditions such as pregnant women or mobility impaired. In the Three Mile Island nuclear power plant accident the Governor advised that pregnant women and children under 5 years of age within 5 miles of the plant evacuate.

Phased evacuation

Phased evacuation stages the evacuation in a sequential manner. The timing in which different geographical locations or zones are warned to evacuate depends on the nature of the evacuation problem that the phasing is attempting to eliminate. In hurricane prone areas plans have been developed to evacuate coastal areas prior to inland areas. (See examples from LA and VA) {VDOT Travel Center- Virginia Hurricane Evacuation Routes}. Other strategies can involve a combination of sheltering and evacuation such as sheltering people nearest to the hazard and evacuating people more distant or, the reverse, evacuating people closest to the hazard and sheltering more distant populations.

Public Education and Information

Public Educational Programs

People's responses to an evacuation notice depend most strongly upon the information provided by emergency managers at the time of the impending event. Perceptions of risk will be impacted by pre-conceived notions of the hazard and will vary by population group. Because of the varied nature of hazard interpretations, knowledge about protective actions, and understanding of the warning processes, it is important to provide public information and education about hazards before they occur in order to prepare residents for future events and minimize surprises during a hazard warning. Pre-event public education should be though of as a part of larger emergency management education efforts and is best accomplished in coordination with multiple partners.

Being alert to hazards is not second nature to all everyone. While people living in areas that have frequent tornadoes may be familiar with weather radio alerts, sirens, physical environmental cues, or have folk-knowledge about how to protect themselves, there are many people who are not aware of hazards that can affect them, warning systems processes, or the appropriate protective actions that should be taken. Public education about existing hazards, the types of warning that they will receive, and the appropriate response to the warning should take place before an emergency situation occurs. The information should be consistent throughout the media used and should describe both mitigation and

response measures people can take to protect themselves. Ideally, such education will open a dialogue between the population groups affected and emergency officials that will create a more effective response to a warning from the public when an event occurs.

Public educational material should describe the warning systems used for alert and notification of hazards. Alerts for hazards that have a quick onset require different response actions from those events with longer detection periods that have greater amount of time for people to evacuate. Priming the public to respond appropriately to different types of hazards will involve introducing them to the types of technologies that will be used to notify people of impending danger and what they should expect to see or hear at the time of warning.

Education about hazard alerts must also include education about how to interpret certain types of warnings. For instance, passive avalanche warnings posted in mountainous areas require some personal ability to interpret the level of danger that is posted and what should be done to avoid or protect oneself from this danger. Signs telling people to move to high ground should indicate the location of high ground (e.g., up the slope of the cliff, at least 300 feet away from the shoreline, past the colored post upriver from the bridge).

Knowing where the information about the hazard and its dangers comes from will help reduce confusion and surprise when a warning is given as well as increase confidence in the need to respond with protective actions. Education campaigns should include explanations about who will provide the warning to the public and how officials will determine a warning is necessary. The affected population groups should be made aware that official warnings are based upon detection systems ground in science and are made public through governmental and non-governmental agencies. This may reduce the impact of non-official predictions that are not based on scientific research or dependable detection technologies. Those types of predictions are difficult to counter, especially when media outlets focus on them as newsworthy events.

An effective public education and information campaign is an essential ingredient of an effective emergency management program. Pre-emergency public education program raises public awareness of the community hazards and advises citizens of actions they can take, both before and during an emergency, to reduce risks to themselves and their property. A public warnings education campaign will identify the information that will be communicated to the public in the event of an impending hazard and the strategies that will be used for disseminating this information rapidly. Public education campaigns for warnings will focus on two important outcomes:

- familiarity with alert and notification systems, and
- knowledge of protective actions to take in response to these notifications.

While emergency managers are responsible for developing public awareness of local hazards and hazard responses, the effort to provide community-wide education must come from multiple sources. Not only is the task of providing community-wide education daunting to most emergency management agencies, but also communities are not homogenous and will require different strategies to reach different sectors. It is important to develop partnerships between governmental and non-governmental organizations including local businesses, community groups, non-profit organizations, and schools in order to disseminate information that will effectively reach targeted audiences. For instance, persons in the community who are non-English speakers may be better reached by leaders within their own population who are connected with local management.

Using multiple information sources increases the chances that people will receive education information about hazard warnings and appropriate protective actions. Relevant information must come from various sources including state and local authorities, technical experts and scientists and engineers (if applicable), and form people familiar to locals.

Multiple sources can author the same communication and/or the same communication can come from multiple sources or, better yet, from both. Examples of ways to provide multiple information products are provided in the insert.

The information provided to the public should be consistent and changes form past messages should be explained. Moreover, messages should be repeated frequently through many different media and disseminated through varied networks such as neighborhood networks, community association or the news media. This means that some will hear or see the message multiple times, increasing the possibility that warning receivers will integrate information and knowledge about hazard responses.

Public education about community hazards, risks, and warning systems is an ongoing need that can be addressed through multiple channels. Educational campaigns may include written documentation in the form of brochures and fact-sheets that are distributed at community centers, and local meetings or forums. Supplemental information such as brochures or coloring books can be positioned throughout the local community or distributed through facilities serving children, seniors, or special needs populations. Additional multi-media presentations can be developed that use slide shows or film strips to educate people about what they can expected at the time of a hazard warning.

Dissemination of information can be appropriately timed to reach people at opportune moments, such as during the time frame immediately following a high-visibility event or during the recovery process. When people are more aware of the possibility of future danger, their awareness will be heightened and they may pay greater attention to future preparedness measures. Also, false alarms or near misses are opportunities for public education because public attention has already been stimulated and persons are likely to be interested in learning about protective measures. Events that occur in other places but gain local awareness are good educational opportunities. For instance, severe weather that occurs in another part of the state and to which your local community is vulnerable creates an opportunity to educate the public about available resources and protective measures they can take prior to an extreme event. This is also a good time to remind local residents about alert systems that will be in operation should severe weather impact their part of the state.

(See Methods to Distribute Information to the Public About Emergency Preparedness)

Warning the Evacuating Public

It is incorrect to think that public warnings must be short because it is difficult to hold people's attention. During major disasters members of the public become information hungry, and many different sources of warning information emerge. Official warning information should more closely resemble an ongoing dialogue with the public who need to be warned. People need a lot of warning information, and they need to have it communicated to them often. Fifteen minute intervals are not too short a time for repeated warnings in fast paced events.

During a warning situation, members of public form ideas about what's about to happen, then take or don't take steps to protect themselves based on these ideas. No single factor impacts what the public thinks and does in response to a warning more than what one says in the warning message. Elaborate research of the last half century provides a strong basis for knowing what works and does not work in a warning message.

People at risk who receive warnings that contain recommended protective actions won't automatically follow those recommendation no matter how important the job title, e.g., mayor, governor, or President of the United States. This is because warning response follows a fundamental social process and does not conform to a military-like command and control structure. Additionally, there will always be a few people who choose not to take any protective action regardless of the pending risk.

Writing a Warning Message

1. Content of Warning Messages

Research over the last half-century has provided clear evidence that public warnings work best to protect the health and safety of the public if those warnings contain information on certain topics. Warnings that do not contain this information do not work as well. And some topics are more important to have in a warning than others. These topics that are important include:

- guidance
- location
- time
- hazard characteristics, and
- source.

Guidance: Recommending Protective Actions

The single most important information to have in a warning is guidance that tells people at risk what to do. This may sound obvious, but it is not an easy task to communicate what people should do. It can never be assumed that people will know what constitutes an appropriate protective action when words such as “shelter” or “evacuate” are used in a warning. Resist the temptation to deliver a technical description of why protective actions are important.

Officials must decide what protective action(s) that they want people to take before a warning is issued and then put that recommendation into the warning. The recommended protective action(s) must be fully described in the warning. For example, warnings must do more than tell people to “get to high ground;” high ground for some may be low ground to others. High ground should be defined, for example, “ground higher than the top of City Hall.” A warning to evacuate should describe what specific areas are at risk and where safe areas are located. For example, residents that evacuate should “be on the other side of the county line, which is Interstate 25 on the west, Interstate†70 on the east, the baseball park on the north, and the Hudson River on the south.”

Location: Who should respond to warning

Who should respond and who shouldn’t must be clearly specified in every warning message. Consequently, warnings should clearly describe in language everyone can understand the geographical region that is targeted for the warning. Remember that the people that are targets of the warning will likely include the community locals, visitors to the area, people who are and are not familiar with the locale, and so on. The more simply the area(s) at risk can be described the better since it will be more likely understood by more people. There are a variety of ways that this can be accomplished, and how to do it may vary from place to place depending on prominent local geographical features. This is particularly important since most warnings communicate to more people not at risk than they communicate to people who are at risk.

Additionally, some warnings may elicit protective actions by people outside the area at risk for which protective action recommendations are being made. A well-documented account of this is “shadow evacuation.” This phenomenon describes people in an area not being advised to evacuate leaving the area anyway. The degree to which people who are safe take actions to enhance their safety depends on a variety of factors.

These factors may include:

- the time of the day the warning is issued,
- the level of details about risk location contained in the warning message,

- the degree to which the warning message contains adequate information about why people who are safe are thought to be safe, and
- other factors (age, gender, children present, etc.).

Time: How much time people have to accomplish protective action(s)

A third important topic to communicate to people in a warning is how much time they have in which to successfully complete the protective action that is being recommended. Also tell them how much time they have before they should begin taking actions. For example, a warning might say, “The tsunami will not strike before 10 p.m. this evening, and you should evacuate to the northern side of U.S. Highway 72 no later than by 9:45 to be on the safe side. This means that you should begin evacuating now, not 10 min. from now, but now.”

Hazard: Describe the risk

A warning 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.

If this is not done, people will think differently about the hazard they are facing depending on their individual imaginations. For example, it is insufficient for a warning to simply state that a dam may break. The 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 illustrate how warnings can be made specific about the character of the hazards involved. A warning could describe “a wall of water 20 ft high moving at 40 miles an hours with the impact of a giant bulldozer,” or “a seismic shake severe enough to bring down all of the bricks off all of the buildings in the city.” If a hazard is described in a warning, 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 outside their building or why they should go outside and stay away from brick buildings because bricks might fall down on them.

Thus hazards that people should seek to protect them selves from should be described in the warning in enough detail so that all members of the diverse public understand the character of the disaster agent from which they seek to protect themselves. This will reduce the number of people who make poor response decisions based on misperceptions about the hazard they face.

Source: Who issues the warning

The final important topic to cover in a public warning is who is issuing the warning. Warning source is important because it has an impact on whether people believe the warning (other factors also impact believability of a warning and can even override the negative impact of having a not credible source issue a warning). Put simply, there is no one single credible source for all members of a diverse public. Pre-warning planning with partners should be conducted that would enable a warning to come from a mixed set of people or a warning panel. For example, “The mayor and the head of emergency planning for the city and county have just conferred with scientists from our local university, the NWS, and the head of our local chapter of the American Red Cross. They have all decided to warn you that you should evacuated immediately.”

2. Style of Warning Message

In the last section, we reviewed the topics that should be included in a public warning message: guidance, location, time, hazard, and source. In this section we cover the style and demeanor to use when delivering a warning message. How one speaks when issuing a warning is almost as important in influencing what people do in response to a warning as what is actually being said. There are, five aspects to the style of a warning that past research shows influence public response. If these five aspects of warning style are seriously considered when one gives a public warning, public health and safety will be maximized. These five style aspects are

- Specificity,
- Certainty,
- Clarity,
- Accuracy, and
- Consistency.

Specificity: Leave nothing up to their imaginations

The most effective warning messages are those that contain very specific information about the five topics contained in the warning. However, most of the time there is insufficient information about what is going to happen to be very specific about the approaching disaster. For example, it is not really possible to know exactly where a terrorist will strike (and if that information were known and put into a warning, the terrorist might well target a different location). It is rare that science can really predict the precise location of a hurricane landfall; tornadoes can change direction at almost any time; a gaseous chemical plume can change direction as easily as the wind changes, and so on. This lack of confidence in precisely predicting the future, however, need not mean that a warning message not be specific. If the information contained in a warning is left un-specific, people at risk will invent their own meanings. This will create a wide range of public responses, some of which may be counterproductive to public health and safety.

Specificity can be rendered into warning messages which acknowledges that there is uncertainty in what may happen, but one is specific about what is the most appropriate course of action for people to take given the ambiguity. For example, in the case of a short-term earthquake prediction: “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.”

Certainty: One has to decide what may happen even if you’re not sure

A warning message must be stated with certainly even if there is ambiguity regarding the hazard’s impact. For example, “There is no way for us to know for sure if there really is a bomb in the skyscraper, or that it will actually go off at 3 p.m. But we’ve 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 a warning message also extends beyond the content of the message itself to include the tone in the voice of the person delivering it to the public. The warning should be spoken (if it is delivered by voice) as if the person speaking the words believes and is certain about what he/she is saying.

Clarity: Use simple language to convey information

It may seem obvious, but a warning message must be worded in simple language that can be understood by most people who listen to it. For example, “a possible transient excursion in the reactor resulting in a sudden relocation of the core materials outside of the containment vessel” might better be stated as “some radiation may escape from a hole in the nuclear reactor.”

Accuracy: Tell the truth and own up to mistakes

All major events that involve the health and safety of the public in our nation will be fully investigated. If something goes wrong, eventually, someone will find out all about it. A warning message must contain timely, accurate, and complete information. If people learn or suspect that they are not receiving the whole truth, your credibility and believability is lost and it may never be regained. Accuracy is enhanced by being fully open and honest with the public regardless of the hazard. In addition, accuracy is important in parts of a warning message that one may consider trivial. For example, calling Broad Street "Board Street" by mistake may send a signal to the public that other essential information is also incorrect. Use subsequent warning messages to correct errors in previous messages, tell the truth, and own up to uncertainly when it exists.

Consistency: Describe the events consistently

If people are given inconsistent information many will pick the information that they "prefer" believing were true. Yet one of the most important elements of the style of warning information to enhance the odds that people at risk take actions to protect themselves is that information be consistent, both within a single warning message as well as across different warnings.

Inconsistencies can exist within a single warning message for a variety of reasons and in different ways. For example, it is inconsistent to tell people to evacuate but that their children will be kept in local schools, and it is inconsistent to tell people that a terrorist may poison the local water supply, but "not to worry" when there is obvious cause for worry and concern.

Inconsistencies can also exist across different warning messages. This is especially true since, as emergencies evolve, more is often learned about impact and the new information may reveal that the hazard has increased or decreased and the number of people at risk has decreased or increased. Consistency can be rendered across messages simply by referring and repeating what was last said, what has changed, and by telling people why.

Don't Mislead People

A warning message is not intended to reassure and to calm people. First of all, people do not need to be calmed down; the opposite is true -people need to be rallied into action. Do not say "there is no cause for concern." If there is no cause for concern, do not issue a warning. Do not say "stay calm," because it may be prudent for people to take sudden action to save their lives. One way this mistaken urge to reassure has often materialized is in warnings that suggest that people who take the recommended protective action will escape risk and not experience harm. It is not appropriate to say things such as "Get under a heavy table of desk so nothing falls on you." Instead say "getting under a solid desk as it will minimize the chance of being injured." The truth is that there is no such thing as zero risk.

The warnings that officials issue will be far from the only warnings that the people will receive. Warning information will also be available from a multitude of other non-local sources. This requires that one listen to these other sources of warning information, take what they are saying into account, and address what they are telling the people one is accountable for warning in the subsequent warning information that is issued. In some cases, one might need to correct mis-information that they are disseminating.

Use Graphics and Visuals

We live in an information-rich society where citizens are used to being presented with information in graphically and visually illustrated formats and media. Additionally, warning graphics and visuals can do a great deal in assisting people understand what is trying to be communicated in a warning.

Where and how the graphics one selects for use in a warning are presented will depend on how much attention is given to creating graphics during warning preparedness for some future warning event. The use of graphics and visuals will also be impacted by how much time is available between the initial detection of a hazard and the beginning of its impact on people. Television and newspapers are two key places that the public will turn for information about a warning. Television is more frequently used for warning information by the public for longer lead time hazards than those that are warned for in a rapid moving event. Particularly when the warning information is covered in the evening.

Graphics and visuals are excellent devices for communicating levels of risk and areas that can be impacted. For example, graphical hurricane landfall probability forecasts on television, (see storm track map) for example, have greatly aided the public in understanding the pending risk of hurricanes and the likelihood that evacuation orders will be issued.

Conclusions

This guidebook has intended to give a brief overview of research on emergency evacuations and provide a set of resources that may be useful to planners developing evacuation plans for the hazards that their communities are at risk from. Weekly people in some part of the U.S. successfully evacuate from harm. Successful evacuations are facilitated by careful planning and by learning from past experiences. It is hoped that this guidebook promotes better planning.

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