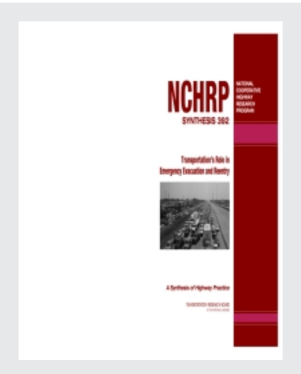

Transportation's Role in Emergency Evacuation and Reentry

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Brian Wolshon; Transportation Research Board

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NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Transportation's Role in Emergency Evacuation and Reentry

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Transportation's Role in Emergency Evacuation and Reentry

A Synthesis of Highway Practice

CONSULTANT
BRIAN WOLSHON
Louisiana State University

SUBJECT AREAS
Planning and Administration, Highway Operations, Capacity, and Traffic Control, and Security

Research Sponsored by the American Association of State Highway and Transportation Officials
in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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COVER FIGURE: Evacuation of Houston Area for Hurricane Rita, I-45.

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FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice.*

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Gail Staba
Senior Program Officer
Transportation Research Board

The goal of this study was to collect and document information on transportation's role in emergency evacuation and reentry by summarizing aspects of its planning, control, and research, as well as highlighting effective and innovative practices. The review of practice showed that transportation plays an active role in supporting and assisting in evacuations. Transportation personnel are involved before, during, and after evacuations by managing and maintaining transportation systems, including traffic control, monitoring, planning, and management. After an event they are involved in managing debris removal and signal restoration for reentry and the monitoring and inspection of critical infrastructure. Transportation professionals also bring expert knowledge and a situational awareness of transportation systems into an emergency response. In states with large rural areas and populations, departments of transportation are often one of the few agencies with manpower, equipment, and communication assets in remote areas that can be used to evacuate people to safety. Among the best defined and well developed roles of transportation in evacuations are in the areas of direction and control of highway networks. One high profile and effective recent innovation has been the development of contraflow for "all lanes out" mass evacuations. In areas with the need to evacuate more dispersed populations, the role played by transportation is to keep evacuees and decision makers informed about which routes are open and which routes should be used as alternates. Contrary to commonly held views, transportation agencies responding to the practice survey did not convey an overwhelming feeling that their resources were overcommitted or inadequate to carry out a large-scale evacuation. The majority of transportation agencies also indicated they had adequate communication capabilities to carry out their role. The survey did, however, suggest that the greatest needs were for more financial and manpower resources dedicated to plan for and manage evacuations.

A survey of evacuation policies and practices was conducted by means of a literature review and a survey of transportation and emergency management agencies.

Brian Wolshon, Louisiana State University, collected and synthesized the information and wrote the report. The members of the topic panel overseeing this project are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

TRANSPORTATION'S ROLE IN EMERGENCY EVACUATION AND REENTRY

SUMMARY

Over the past decade, interest in and awareness of the topic evacuation has grown enormously. This has led to a wealth of new information on the role of transportation in emergency evacuation practice, planning, and research. First-of-their-kind plans for transit-based evacuations, regional contraflow, and emergency traffic simulation have all come into being within the last half decade. In many areas, evacuation plans also now include modes such as rail, air, and maritime.

A recent study of evacuations by the Sandia National Laboratories showed that between 1990 and 2003, the 230 evacuations involved 1,000 or more evacuees. The most common hazard for which evacuations were necessary during this period was wildfires, followed by floods, fixed-site (i.e., nonmobile) hazardous material releases, railroad accidents, and hurricanes. Interestingly, the great majority (75%) of these events required an evacuation of 5,000 or fewer people and only 14 of the 230 (6%) involved more than 100,000 evacuees. It is these major events, however, that most often capture media attention and cause the most concern.

The goal of this study was to collect and document information on transportation's role in emergency evacuation and reentry by summarizing aspects of its planning, control, and research as well as highlighting effective and innovative practices. With a better knowledge and understanding of the characteristics and operational requirements, costs, and benefits associated with evacuations large and small, it is hoped that they can be carried out more safely and effectively in the future.

The review of practice showed that transportation plays an active role in supporting and assisting in evacuations. Transportation personnel are involved before, during, and after evacuations by managing and maintaining transportation systems, including traffic control, monitoring, planning, and management. After an evacuation, these personnel are involved in managing debris removal and signal restoration for reentry and in the monitoring and inspection of critical infrastructure. Most important, transportation professionals bring expert knowledge and a situational awareness of transportation systems into an emergency response. In states with large rural areas and populations, departments of transportation (DOTs) are often one of the few, if not only, state agencies with staff, equipment, and communication assets in remote areas that can be used to evacuate people to safety. One area in which transportation does not, however, play a role is in the declaration and timing of evacuations. These are decisions that are made by emergency management, law enforcement, and other first-responder agencies.

Among the best-defined and well-developed roles of transportation in evacuations are in the areas of direction and control of highway networks. This is not surprising because these are areas in which transportation agencies are the most knowledgeable, experienced, and best equipped to support. One high-profile and effective recent innovation has been the development of contraflow for "all lanes out" mass evacuations. In areas with the need to evacuate dispersed populations, the role played by transportation is to

keep evacuees and decision makers informed about which routes are open and which routes could be used as alternates.

Contrary to commonly held views, transportation agencies responding to the practice survey did not convey an overwhelming feeling that their resources were overcommitted or inadequate to carry out a large-scale evacuation. The majority of transportation agencies also indicated they had adequate communication capabilities to fulfill their role. The survey did, however, suggest that the greatest needs were for more financial and staff resources dedicated to plan for and manage evacuations. From a coordination perspective, the survey suggested that barriers or obstacles to coordination continue to exist across transportation agencies at various levels and jurisdictions and between transportation and other government agencies involved in the process, most notably law enforcement and emergency management. A positive finding of the survey was the extent to which transportation agencies are included in evacuation planning and preparedness exercises. All but three of the transportation agencies surveyed indicated involvement in their jurisdiction's evacuation exercises. Much of this is thought to be the direct result of changed and new philosophies since Hurricane Katrina.

Somewhat disappointing was the continued low level of planning by transportation agencies for the evacuation of dependent and special needs populations. The survey showed that only about half of the transportation agencies surveyed currently have accommodations for these populations. The literature review did show, however, that the importance of this issue has been recognized and that several reports have identified and documented the gaps in practice as well as the needs to be addressed in the coming years.

Communications during evacuations was another area of continuing improvement. Communication now appears to be looked upon within a wider context of a multi-information flow and data exchange in which details flow between agencies, evacuees, and remote data acquisition devices. The practice review showed that transportation-related communication takes place during all phases of evacuations and encompasses en-route guidance as well as public information, awareness, education, and outreach campaigns. Information is also conveyed using a wide variety of media, including television, radio, print, newspaper, Internet, regular mail, e-mail, phone (reverse 911), variable message signing, and highway advisory radio.

Among the needs and gaps in knowledge and practice is a lack of formal planning for postevent reentry of evacuees and mass repopulation of impacted areas. Currently, the role of transportation in the reentry process is oriented toward the inspection of critical infrastructure; the immediate (and longer-term) repair of damaged roads, control systems, bridges, and so on; debris removal and the reopening of roads; and, to a limited extent, the coordination and use of buses for the return of assisted evacuees to their places of origin. Another unaddressed gap is the impact of highway work zones during evacuation. Construction activities on evacuation routes have been an issue during several past evacuations and will result in future evacuation problems if not addressed.

As the final draft of this synthesis was being prepared, nearly 2 million people, including an estimated 32,000 special needs and assisted evacuees, were safely and successfully bused, flown, and railed to safety ahead of Hurricane Gustav. The planning and involvement of transportation professionals from across the Gulf Coast contributed to this achievement.

CHAPTER ONE

INTRODUCTION

Although history shows that the topic evacuation has been widely unaddressed within the transportation community throughout the years, interest and involvement from transportation professionals in the field has grown considerably in the past decade. The increased levels of awareness and concern have brought a wealth of new information on the role of transportation into emergency planning and practice. First-of-their-kind plans for transit-based evacuations, regional contraflow, and emergency traffic simulation have all come into being within the last half decade. In many areas, evacuation plans now include transportation modes other than highways, including rail, air, and maritime.

Although it is not possible to include every new concept, report, study, and plan in this summary report, the goal of this study was to collect, synthesize, and document as much of this information as possible and to condense it into a single-source format. The following chapters of this synthesis on transportation's role in emergency evacuation and reentry summarize and highlight key aspects of planning, practice, and research from a transportation-based perspective. This report includes a nationwide survey on the views and practices of transportation and emergency management agencies (EMAs) involved in evacuation planning and management as well as several case discussions covering recent evacuations of various sizes and locations. Combined, this information is expected to give readers an understanding of the role played by transportation in emergency evacuations as well as the philosophies of agencies involved in the process. For those seeking more detailed information related to specific ideas and topics, an extensive list of references and related sources, including online sources, is provided at the end of this document.

MOTIVATION AND OBJECTIVES

Even though evacuations have taken place since community members threatened by hazards have had the ability to move to safer locations, transportation planners and engineers have been only peripherally involved in the planning and management of transportation assets and resources for these events. The reasons for this limited role have been as diverse as they are numerous. One of the most common reasons was the misperception that there was little that these personnel could do. Evacuations were viewed as events that involved overwhelming surges in demand over short time periods that far exceeded the available capacity of transportation networks; a simple case of too much demand and not enough capacity that—without more roads, buses, and so on—could never be solved. Another view was that evacuations were rare events that occurred in isolated locations (near coastlines and nuclear power stations, for example) and, given the unpredictability of the occurrence of these disasters, little could be practically done to improve them. Most evacuations were seen as the concern and responsibility of EMAs that, with specialized training, experience, and authority to make decisions, were the agencies best suited and prepared to respond to such events. As such, transportation agencies have not "owned the problem" (TRB 2008c). When all of these philosophies and perspectives are viewed within the context of the existing responsibilities of transportation agencies, it is not surprising that most agencies were reluctant to allocate scarce staffing and financial resources to the issue.

The experiences of the past decade have shown that many of these previously held views are not accurate and there are new ways of looking at the evacuation problem. The change in thinking with respect to the role of transportation in evacuation has come about because of a confluence of events. Among the most important were the obvious and repeated series of poorly executed hurricane evacuations in the southeastern and Gulf Coast states and a newly recognized need to evacuate cities that were previously viewed as nonthreatened following the terrorist attacks of September 11, 2001, in New York City and on the Pentagon. Events such as these demonstrated not only the weakness in the position of transportation agencies to deal with mass evacuation scenarios, but also the level of vulnerability that is faced when societies are not prepared and able to move citizens away from hazardous conditions. It has also been recognized that evacuations are not the rare events that most people have believed. U.S. Nuclear Regulatory Commission (NRC) statistics show that a large-scale evacuation of at least 1,000 people occurs on average about every 3 weeks in the United States (FHWA 2006a).

Another motivation for undertaking this synthesis was to address the need for an increased level of understanding within the transportation community relative to evacuation and reentry. With a better knowledge of the characteristics and operational requirements, costs, and benefits associated with these scenarios, it is hoped that they can be carried out more effectively in the future.

During an emergency evacuation, local transportation resources are relied on by emergency responders. These include, but are not limited to, roadways, buses, maritime ferries, aircraft, and communication assets. Many transportation agencies throughout the United States have experience in the planning and management of emergency evacuations. However, to be helpful, this experience must be documented and shared. Despite the long history of evacuations in the United States, relatively few quantitative evaluations and research studies have been conducted on performance aspects of these events. Similarly, there is also a comparatively limited amount of published information on issues related to their planning, operation, control, and management. Much of this lack of information is because evacuations have been managed by law enforcement and EMAs and not transportation agencies. Because there are no standardized and formalized practices in the field, when transportation agencies do become involved, they must rely on experience, professional judgment, and observation of traffic conditions under routine or nonemergency conditions. Combined, these shortcomings have resulted in considerable variation within the practices, philosophies, and policies of transportation officials in evacuation management.

The low-level of involvement and lack of experience within the transportation community has meant that some of the nation's most knowledgeable and useful sources of information on the planning and utilization of transportation resources for emergency conditions have gone underutilized. As a result, society has not been able to take full advantage of the range and utility of transportation infrastructure and assets available to it. It could even be argued that this lack of involvement may have contributed to the immense delays, inefficiencies, loss of life, and the poor allocation of resources that occurred in some recent evacuations.

STUDY SCOPE

The long list of natural and man-made hazards for which evacuations may be necessary is large and growing. Across the nation, evacuations have been used as a protective action for incidents ranging from fires to toxic releases to floods to hurricanes. Most recently, terrorist attacks have also been added to this list. Today, many state and local departments of transportation (DOT) functions have been broadened to include more evacuation and reentry activities. However, not all state and local transportation personnel are familiar with emergency management processes and these personnel have not always been involved in the development of evacuation plans even though they included transportation resources.

This review of practice includes published information as well as comments, opinions, and views from a cross-section of transportation officials in DOTs, regional metropolitan planning organizations, and transit agencies, as well as emergency managers at the local, regional, and state level, each of whom has planned for or directed a recent evacuation or reentry. Among the questions addressed are the following:

- Who manages evacuations in the United States and what is their management structure?
- What are the roles of the transportation agencies within these management structures?
- Are transportation resources overcommitted in some locations?
- Do barriers or obstacles to coordination between various agencies exist?
- Which emergency evacuation scenarios do plans consider?
- Are evacuation plans exercised and, if they are, are transportation agencies included in the exercises?
- How are the needs of dependent (i.e., special needs) populations included and accommodated in evacuation activities?
- How are agency resources planned and allocated in advance and during emergencies?
- What types of transportation assets and infrastructure are available for emergency evacuation and where are the needs and gaps?
- What communications protocols are in place for sharing information and communicating evacuation traveler information to the public and what mediums are used to communicate it?

The synthesis includes six case illustrations of locations that have lead or have participated in an evacuation event. These examples document these experiences from the standpoints of the type and characteristics of the hazard requiring evacuation; size of evacuated population; types of special needs populations that were evacuated; modes of transportation used for the evacuation; lessons learned from the evacuation and reentry operation; and coordination, communication, and interjurisdictional issues.

Although the role of transportation in evacuation has been somewhat limited, the general topic of evacuation is quite large. As such, it was not practical to include all closely related topics and studies, reports, and practices from all overlapping and allied field (such as emergency and disaster sciences and management; the behavioral and social sciences; geography; and so on) within this report. For example, this report does not include a discussion of emergency sheltering. Sheltering issues are recognized to be a key component of evacuation planning because the number of people who opt to shelter-in-place reduces the number who otherwise would evacuate.

METHODOLOGY

The synthesis was developed in three parts. The first was a review of the body of existing literature. The literature review included two separate, though closely related, information categories. The first were "traditional" sources of technical information, including scientific and practitioner-oriented journals, conference compendiums, trade publications, research project reports, and nontechnical reports. The review was undertaken using various library search services, the National Transportation Library's Transportation Research Information Service (TRIS), and the DHS's Lessons Learned Information Sharing (LLIS). The second was a review of the "gray literature," including unpublished planning studies for local communities, DOT reports, law enforcement and emergency management operational manuals, and other location-specific or difficult-to-access reports and studies.

The second part of the synthesis included a survey of current practice. The survey was conducted using a questionnaire (included in Appendix C) that was developed to give an overview of current evacuation practice, including procedures, policies, plans, and jurisdictional roles and involvement in the United States. The questionnaire was used to gauge some of the general trends and philosophies within this topic.

Both the survey and the literature were key elements to the last step of the synthesis, which included field visits and discussions with practitioners in locations where evacuations have been carried out or are being planned. The interviews and site visits were a key component of the synthesis effort because they permitted a firsthand opportunity to review the plans and experiences of various agencies. They also permitted researchers to get answers to detailed questions and to obtain copies of reports and plans.

REPORT ORGANIZATION

This synthesis contains nine chapters that describe the processes and issues associated with evacuations as well as the practices employed to carry them out. Where appropriate, the information is presented in chronological order to illustrate the development of evacuation practices and associated planning and management tools and techniques over time.

Chapter two summarizes the general principles and objectives of evacuations as well as general descriptions of the types of hazards for which evacuations have been used and the agencies that are charged with planning and managing them. The chapter also includes a description of the characteristics of hazards that can precipitate evacuations and their relative scale of impact. Chapter three focuses on evacuation planning, particularly the technical and policy components used by emergency managers. Chapter four addresses the direction and control of transportation systems during an evacuation. The chapter also summarizes traffic control devices and management techniques used for evacuations, including contraflow. Chapter five covers the critical, though historically overlooked, area of assisted evacuations. Since Hurricane Katrina, the issue of special needs and transit-based evacuation has received more attention than any other topic in the field and has seen the greatest number of new reports and studies. A separate synthesis could be dedicated just to the new information generated on this topic since 2005. Also included in this chapter are descriptions of evacuee characteristics, such as their health status, mobility characteristics, and transportation needs. Chapter six synthesizes the current state of evacuation traveler information, including communication methods and public information strategies. The chapter includes a discussion of public education and outreach programs, methods, and results; spatial and temporal methods of data acquisition, processing, and information dissemination; and the spectrum of media communication methods. In chapter seven, discussion shifts to the planning, coordination, and management of postevent reentry of evacuees. Topics covered include plans, debris removal, inspection of critical infrastructure systems, credentialing, and reentry communication. Chapter eight synthesizes the current state of practice and summarizes the results of the survey. It also includes case studies of natural and man-made threats, modes, and temporal conditions, covering a geographically diverse set of locations. Chapter nine summarizes the findings of the synthesis as well as some of the lessons learned, needs, and suggested areas of future research. The report also includes references and a bibliography of sources that were reviewed for the development of this report but not specifically referenced within the text.

Four appendixes include additional information in several areas that were deemed to be too specialized for a general discussion of the topic. Appendix A includes a summary discussion of emerging knowledge in the field, including some recent research initiatives and modeling and simulation. Appendix B highlights the roles and processes of emergency management in evacuation at various federal and state levels. Appendixes C and D include the survey questionnaire study and the results that were gathered from it.

CHAPTER TWO

BACKGROUND

Although the purpose of this synthesis is to discuss the role of transportation in evacuation and reentry, it is difficult to understand and describe this role without an understanding of several domains of knowledge closely related to the processes. These include emergency management, emergency response services, law enforcement, and education and outreach. History has shown that the majority of prior evacuations have involved relatively little input from transportation agencies. Rather, they have been planned and managed by emergency management and response agencies and, in some cases, the military. Indeed, the involvement of agencies with a primary transportation focus—such as DOTs, transit agencies, and other providers of transportation services—has only recently become a part of the evacuation equation.

Although this may appear counterintuitive, the characteristics of the hazards that warrant most evacuations are often so dynamic that transportation agencies were not well suited to respond. Interviews with officials responsible for evacuations revealed that, in many cases, formal detailed evacuation plans for some well-recognized hazards do not exist—even in areas with a fairly regular need to evacuate. In southern California, for example, the conditions associated with wildfires are recognized to be so variable that population size, geographic extent of threat region, amount of warning time, available routes, and shelter destinations are never known with certainty until the onset of the fire. As a result, emergency preparedness and response agencies find it more effective to work from a general framework that permits flexibility to respond to rapidly changing conditions. Thus, the role played by transportation agencies in the planning, operation, and management of such events is often minor.

For threats such as hurricanes and nuclear power plants, the hazard and shelter locations are better defined. And although specifics will vary, the amount of warning that is available and the general direction of evacuation movement and routes out of the threat zone are much less variable. In these cases, the roles of transportation are much more detailed and formalized.

Although evacuations are most often associated with hurricanes, the need to evacuate can come from many different man-made and natural events. Worldwide, evacuations have been used as a protective action against hazards such as volcanoes, wildfires, floods, tsunami-generating earthquakes, storms, chemical spills, nuclear power plant accidents, and, most recently, terrorist attacks. Evacuations are by nature disruptive and expensive, and they can become politically sensitive issues. The costs of hurricane evacuations, for example, can exceed $1 million per mile of coastline from losses in tourism, commerce, and general productivity. Evacuation orders can be difficult to make because the movement and development of hazards can change over short periods of time. The scope and breadth of an evacuation must be proportional to the threat. An evacuation order needs to be sufficiently large to protect people. But it must not be unnecessarily large so that it needlessly disrupts the economic activity of a region; or worse, leads to a "boy who cried wolf" perception among the public.

The United States is unique among countries worldwide in that its evacuations are used as a primary protective action during disasters and emergencies. Most countries use limited, if any, highway-based evacuation for hurricanes. Unlike many other countries, however, the United States has the ability to move large numbers of people significant distances in a timely and safe manner and then shelter them at locations away from the hazard zone. Some critics of evacuation have argued that this has led to an overreliance on evacuations. These critics contend that the need to evacuate for hurricanes could be reduced by strengthening building codes and increasing the availability of local shelter facilities.

The level of interest in evacuation, as a behavioral-, geographic-, research-, planning-, and engineering-related topic has ebbed and flowed with the needs and conditions of the day, and the number and types of hazard conditions for which an evacuation could become necessary is also growing. During World War II and the subsequent Cold War era, interest in evacuations was focused on moving populations away from urban centers that could become attack targets. As satellites were developed and weather forecasting capabilities improved, hurricanes could be tracked several days out to sea. With these more reliable forecasts, planning in the 1960s and 1970s began to focus on the evacuation of coastal areas for hurricanes. Later, after the Three Mile Island incident in the late 1970s, interest in evacuations analysis and modeling grew out of concerns over nuclear power plants. Most recently, evacuation simulation and modeling has advanced significantly, particularly for hazards associated with the storage, transport, and disposal of chemical, biological, and nuclear weapons, as well as the risks associated with terrorist attacks.

Generally speaking, evacuations are used when the conditions of a hazard are such that people are not safe in their existing location and must move to a safer one. The distance of this movement might be as little as several hundred feet or as far as several hundred miles. It may involve several individuals or several million people. The source and conditions associated with hazards also vary widely. Some hazards develop or move slowly and provide days or even weeks of warning time, whereas others occur with no warning. The latter are called "no-notice evacuations."

Hazards can be classified in numerous different ways. One method distinguishes hazards in terms of origin: *natural* or *man-made*. Common natural hazards include hurricanes, floods, earthquakes, wildfires, and tornados. Man-made hazards include technological hazards such as biological, chemical, and radiological hazards, including anthrax attacks, toxic chemical spills, and nuclear power plant accidental releases as well as conditions such as explosions, fires, hazardous material spills, and so on. Man-made conditions may be subclassified in terms of *intentional* or *unintentional*. Although it is likely that the majority of man-made hazards are unintended consequences of human activity, some are initiated purposefully. Occurrences such as wars and terrorist attacks are both examples of intentionally man-made events that have required evacuations.

A recent study investigating the characteristics of recent evacuations was conducted by researchers at the Sandia National Laboratory in Albuquerque, New Mexico, as part of their work for the U.S. Nuclear Regulatory Commission (NRC). For this effort, statistics were collected on some evacuations documented in the United States between 1990 and 2003 that were estimated by authorities to have included 1,000 or more evacuees. During this 14-year period, 230 such instances were identified and categorized by date, location, size, and hazard type.

As shown in Figure 1, the most commonly occurring hazard for which evacuations were necessary was wildfires. Nearly one-quarter of all the evacuations in the sample, 56 of the 230 records, were associated with various types of wildland fire incidents. The next highest were flood events

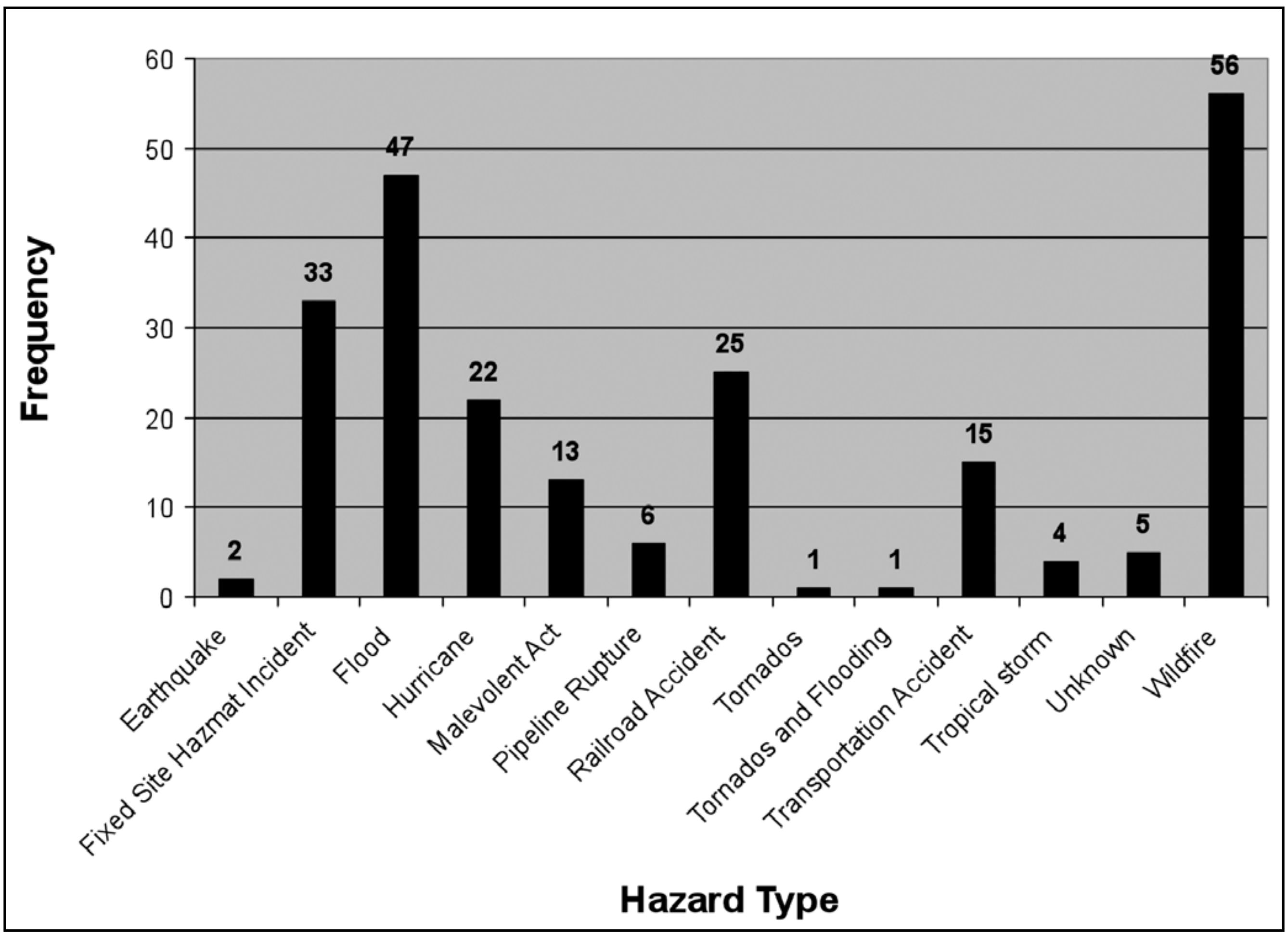


FIGURE 1 Evacuation frequency based on hazard type (1990–2003) (*Source:* F. Walton, Sandia National Laboratory).

with 47 incidents, then fixed-site (i.e., nonmobile) hazardous material releases with 33 incidents, followed by railroad accidents and hurricanes with 25 and 22 incidents. These statistics are generally consistent with the Federal Emergency Management Agency (FEMA) disaster declaration statistics, which are dominated by flood emergencies (FEMA 2008a). It is expected that a future report, currently in development, will more closely examine the relational details between the various evacuation types, sizes, frequencies, and locations in this data set.

More relevant from a transportation context are the size and notice given by a hazard. These temporal and spatial conditions are the two key factors that influence the size and urgency of an evacuation as well as the scope of the threat and the amount of warning time available to move people to safety. Size, although typically thought of in terms of geographic area, also can be based on the amount of the population that will be affected. Although a hurricane may threaten a large geographic area, it can make landfall in sparsely populated areas where its threat to people is minimal and involves a small evacuating population.

The Sandia National Laboratory statistics showed that only a small percentage of the evacuations conducted between 1990 and 2003 involved more than 5,000 people. As shown in Figure 2, about three-quarters of the total sample population were estimated to have included 5,000 or fewer evacuees. Only about 6% involved more than 100,000 evacuees.

The amount of notice given by a hazard is important in an evacuation. A long lead time permits complex evacuation traffic management measures, such as transit services; contraflow operations; movement of structures, signals, and gates; and phased evacuation plans to be implemented if needed. In a study by Wilmot (2001), the temporal and spatial relationship between warning time and impact area were presented as a continuum encompassing the scale of the threat in terms of the geographic area over which its effects can be felt and the amount of warning time the hazard may provide before the onset of dangerous conditions. The author developed a hazard scale versus evacuation warning time relationship, which is represented in Table 1.

Although the specific conditions of the hazards in the table may vary, the warning time and potential impact area generally increases from top to bottom. At one end of the continuum are hurricane evacuations. Hurricanes are the largest and one of the most catastrophic natural hazards. When compared with other threats, however, hurricanes move slowly and can be tracked for days before landfall.

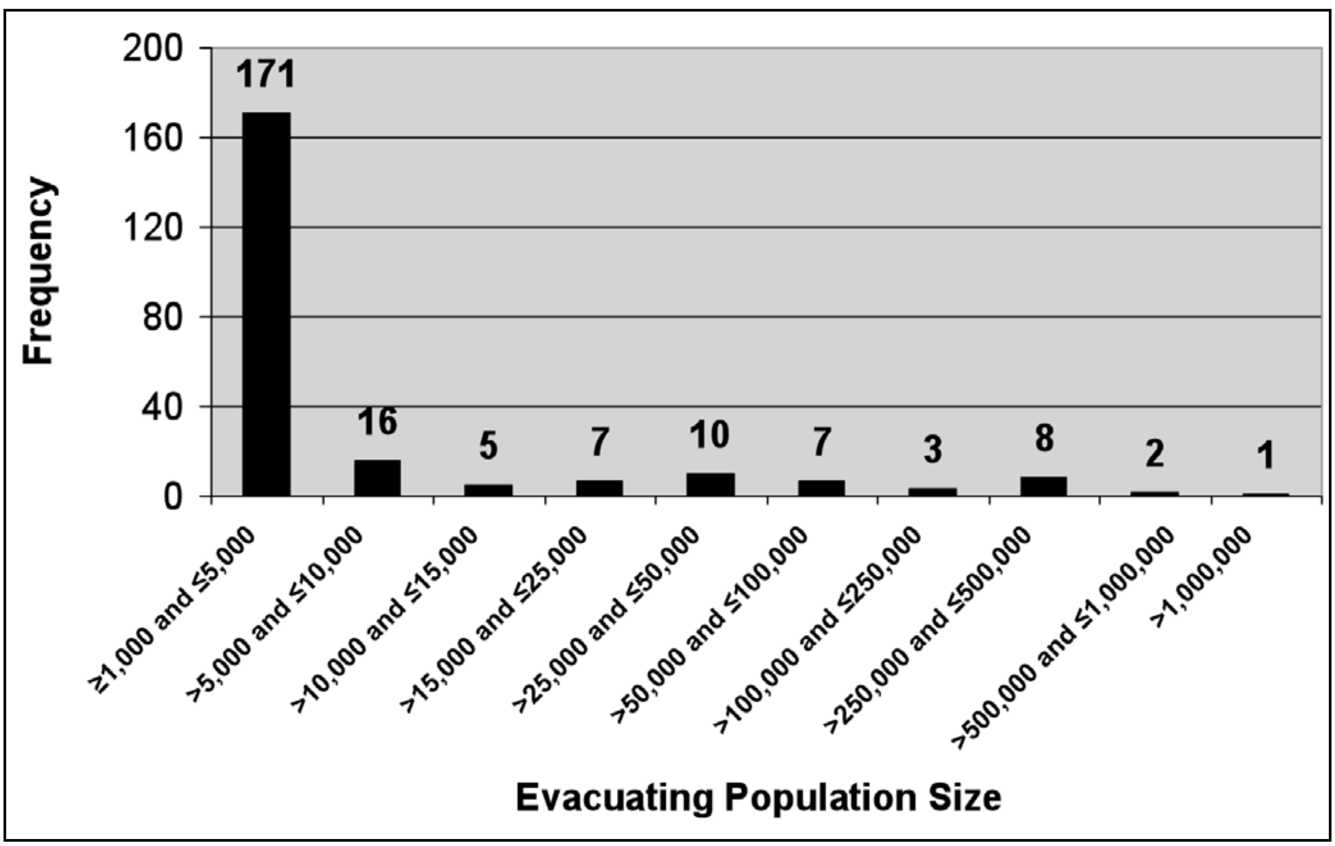


FIGURE 2 Evacuation frequency based on evacuating population size (1990–2003) (*Source:* F. Walton, Sandia National Laboratory).

TABLE 1
EVACUATION ADVANCED WARNING TIME AND IMPACT AREA OF HAZARDS

Hazards Potentially Requiring Evacuation		
Man-Made Events		**Natural Events**
Terrorist Attack	General Advanced Warning Time and Potential Impact Area Both Increase	Earthquake
Chemical Release		Volcanic Eruption
Nuclear Power Plant Accident		Tornado
Dam Failure		Tsunami
		Wildfire
		Flood
		Hurricane

(*Source:* Wilmot 2001).

With warning time, emergency managers are able to determine the extent of an area to evacuate and begin moving evacuees out well in advance of storm landfall. At the other end of the continuum are terrorist attacks. Terrorist attacks (excluding those involving weapons of mass destruction) affect a comparatively small area, on the order of a city block or several buildings. However, they give little or no warning time, rendering evacuation impossible until after the event.

Interestingly, the general geographic area affected by the disasters also tends to increase in size from top to bottom in the table, meaning that more people may be affected and longer distances be traversed to avoid the danger. Thus, not only is evacuation a more feasible means of avoiding danger in hurricanes because of the longer warning time, but travel conditions are also more critical because more people are involved over more route-miles than for evacuations for other disasters.

In reviewing the full range of man-made and natural disasters that are encountered, actions such as sheltering-in-place often serve as a better protective action than an evacuation. This often applies to events such as chemical spills, terrorist attacks, or earthquakes. Other hazards such as tornados are generally preceded by a warning, but the warning is insufficient for an evacuation to be an effective protective action to avoid the consequences of the event. For hazardous conditions that give no warning at all, evacuations are appropriate only to escape the aftermath of the disaster.

Recent work undertaken by the Maryland DOT and published by the National Academies described the temporal and spatial conditions of hazards and their impact on transportation in terms of the relationship between the scale of an emergency, its duration, and required level of response (TRB 2008c). The Maryland DOT scale-warning time continuum is depicted graphically in Figure 3. This graphic represents the spatial impact of an event in terms of local, regional, state, and national levels. At the local impact level are events such as traffic crashes that typically affect only segments of road networks. At the opposite end are major hazard events that, under some conditions, could affect even transportation networks nationwide.

The graphic also includes curves to represent the level of public preparedness for these events and the level of involvement required from state and federal level agencies. As would be expected, the level of preparedness for small-scale localized incidents is regarded to be quite high. As the scale of the event and need for state and federal involvement increases, however, the level of preparedness is believed to decrease. Even though mass-scale events are infrequent, the public needs to be capable of quickly preparing when necessary.

Even when a clearly recognized hazard exists, an evacuation may not always be the best protective action alternative. History has shown that evacuations under some circumstances can be as risky, if not more so, than the hazard itself. This can occur when travel or exposure conditions deteriorate at a rate that makes it problematic to travel, during the onset of storm conditions, or during a BRC release when shifting winds may put evacuees and responders within the area of exposure. For the elderly and infirm, the stresses of lengthy evacuations away from life-sustaining facilities can be fatal. The highly publicized bus explosion and fire during the evacuation of Houston for Hurricane Rita that resulted in the deaths of 24 people provides a tragic example of such risks (Moreno 2005). Statistics collected by the Texas Transportation Institute showed that although not a single life was lost as a result of the direct effects of Hurricane Rita, more than 100 people perished during the evacuation (Henk 2007). Although lives were likely saved because people did evacuate, these figures also show that evacuation itself is not without risk.

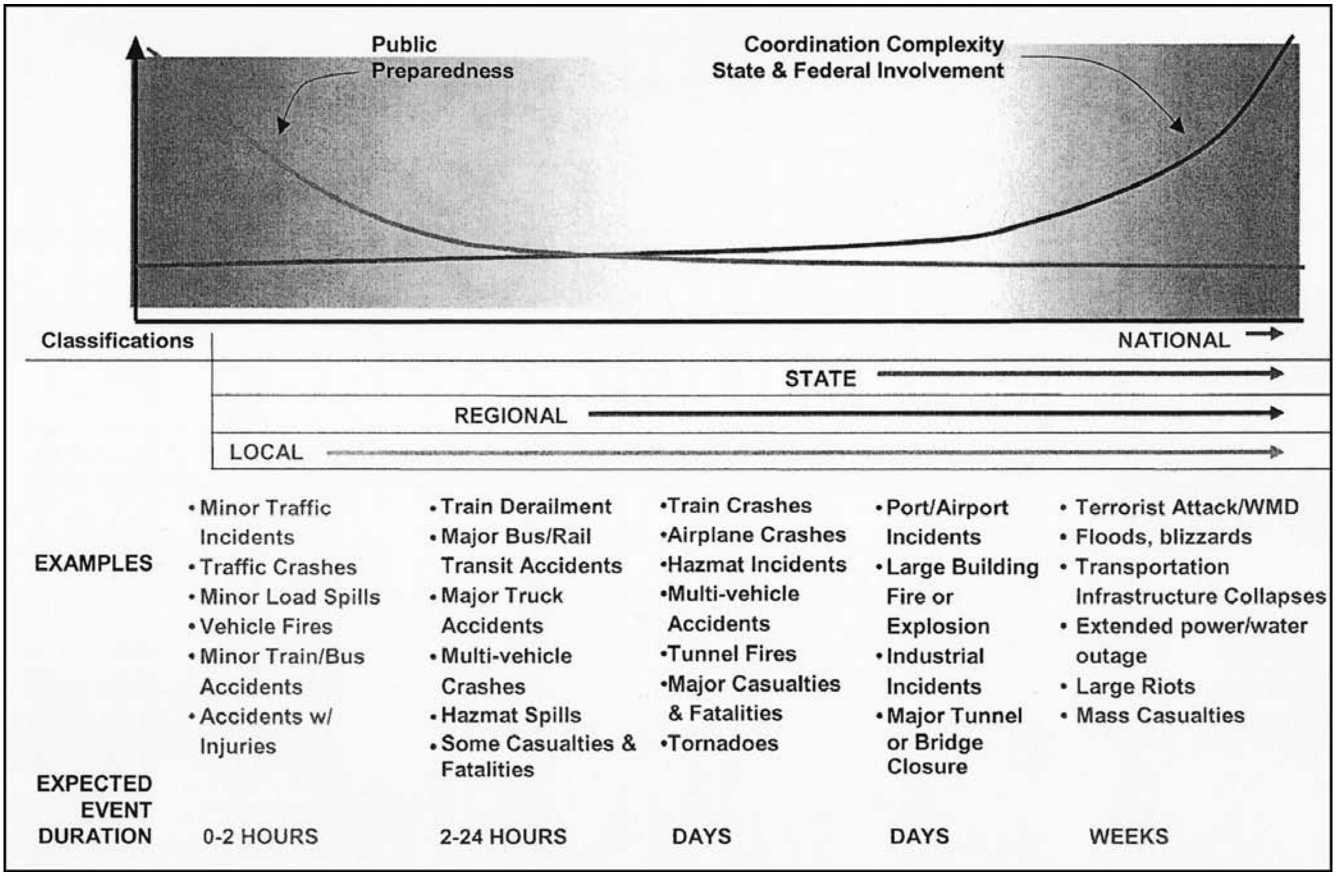


FIGURE 3 Scale of an emergency incident and appropriate level of response (*Source:* NAS 2008).

CHAPTER THREE

EVACUATION PLANNING AND PHASING

The development of many transportation-specific techniques, models, tools, and strategies now in use for evacuations have evolved over years of events, including several notable occurrences such as the Three Mile Island nuclear power plant emergency in 1979; Hurricane Floyd in 1999; the terrorist attacks of September 11, 2001; and Hurricanes Katrina and Rita in 2005. In their own way, each of these events brought about new knowledge about the threats that the nation faces as well as a recognition that the preparedness plans for mass evacuations were lacking in various areas.

The Three Mile Island accident demonstrated the need for evacuation on a mass scale for man-made hazards. This emergency spurred the development of some of the first traffic simulation models constructed specifically for evacuation analysis. Twenty years later, Hurricane Floyd showed that natural hazards such as hurricanes can have an impact on the movement of traffic on a regional scale, affecting areas over several states. Hurricane Katrina highlighted a lack of planning for evacuating people without access to personal transportation. Hurricane Rita showed the vulnerability of major cities when the number of people who seek to evacuate far exceeds the plan and, like Floyd, demonstrated the need to provide en route services such as fuel and water to evacuating travelers. The September 11 terrorist attacks showed the need to plan for no-notice evacuations, particularly within major urban areas without significant natural hazard threats.

Despite the hard-gained knowledge from each of these events, there remains a great need for even better planning, management, and utilization of transportation networks and resources. No other transportation-related activity has the potential to affect the lives and safety of more people in as short a time as an evacuation. Even with the recent history of disasters, evacuation continues to rank as a low priority in day-to-day transportation planning and engineering activities. This should not be surprising given the enormous number of transportation needs and the limited amount of monetary and labor resources available to address them. Some people have suggested the need to plan for evacuations as a matter of routine course; similar to the way in which any transportation improvement projects are routinely reviewed for environmental impact, safety benefit, congestion mitigation, and the like. Once developed, evacuation plans need to be regularly reviewed, updated, and practiced so that they can be institutionalized and implemented on a moment's notice.

EVACUATION PLANNING PROCESSES

The task of planning evacuations involves several areas of specialized expertise that generally reside in the domain of emergency management. Baker (2000) described the key technical and policy components for hurricane evacuation. However, these general processes can be applied to any scenario for which evacuation is an appropriate protective action. Baker's components, generalized here for any hazard, include the following:

- *Hazard analysis* to identify the area that would need to be evacuated for a particular hazard condition.
- *Vulnerability analysis* to ascertain the number of households and people who are susceptible to the threat condition.
- *Behavioral analysis* to project how people will respond to the threat.
- *Transportation analysis* to assess roadway capacities within the transportation network and identify conditions such as bottlenecks or links vulnerable to the hazard. The objective of the transportation analysis is to develop *clearance times* within an evacuation area. Clearance times are estimates of the time that would be required to evacuate an area.
- *Shelter analysis* to evaluate the capability of buildings to withstand the hazards conditions and their suitability to be used as refuges for evacuees.
- *Decision making* to develop procedures to assess whether a hazard presents a level threat to warrant an evacuation and, if so, when to initiate an evacuation order.
- *Development management* to regulate the growth of population and land development that could make evacuation more difficult.

Several of the aforementioned components are regularly undertaken by transportation planners and engineers. The only difference is that they are done for routine, rather than evacuation, transportation planning purposes. For example, the behavioral analysis of determining how many people will evacuate, when they will leave, where they will come from, where they will go to, and what modes they will select to make the trip are all components of planning studies and traffic impact analyses.

The transportation analysis component of evacuation planning uses the characteristic evacuation roadway network with inputs from the vulnerability and behavioral analyses to calculate the total time required to safely evacuate an area (Baker 2000). It is a valuable tool to identify transportation-related problems that may hinder an evacuation, such as the location of potential traffic bottlenecks and insufficient transport resources for assisted evacuations. Methods for conducting the analyses vary by the type of hazard and the agency undertaking the analysis. The most commonly employed approach for hurricane hazards was developed for the U.S. Army Corps of Engineers. The NRC has developed a process for nuclear power plants. The NRC is also currently developing a specific set of processes and objectives that will raise the level of consistency and uniformity of such studies (Jones and Wolshon Forthcoming). The U.S. Army Corps of Engineers approach for hurricane evacuation transportation analyses (U.S. Army Corps of Engineers 1995) and adapted from Baker (2000) is summarized here. These processes can be readily generalized to other hazard scenarios.

1. Evacuation transportation zones are defined based on storm scenarios. These zones represent subareas of the region under threat and serve as the basic units of origins and destinations in the analysis.

2. Dwelling unit data are developed for each zone based on the prior vulnerability analysis. These data include more detailed characteristics of the population, number of dwelling units, and number of vehicles. Such data are readily available from sources such as the U.S. Census Bureau.

3. The roadways that are part of the evacuation transportation network are identified, and their key characteristics such as capacities and use of contraflow are inventoried. Particular attention is paid to intersections and link segments in which reductions of outbound lanes occur. These data are also readily available within most transportation agencies and metropolitan planning organizations in the form of geographic information systems (GIS) inventories.

4. A travel demand estimate is conducted to forecast the number of expected evacuation trips. Evacuation travel demand forecasting relies on the behavioral analysis. The process is used to estimate the number of people and vehicles that will go to local public shelters; homes of local friends and relatives; local hotels, motels, churches, and other types of local destinations; and all destinations outside the local area. These trip productions are calculated for each evacuation transportation zone. A worst-case participation rate is used to determine how long the evacuation would take if everyone ordered to leave actually did. It also results in inflation of actual or even probable worst-case evacuation clearance times. Each evacuation transportation evacuation zone is assessed based on its potential to accommodate evacuees. In nuclear power plant travel analyses, a variety of day-night, weekday-weekend-holiday, summer-winter, and clear-rainy-snowy conditions are assessed.

5. Similar to trip-generation gravity model analyses, trips are then distributed among evacuation transportation zones. The result is a set of origin-destination matrices for each storm scenario. During this step, it is critical to consult with local emergency management officials to determine the extent to which local plans will constrain or otherwise influence the movements within the system.

6. The last step is to assign the evacuation trips to the road network that connects the origin and destination zones. Because of the dynamic nature and iterative nature of the assignment processes, complex models are often employed and local officials are consulted to verify their results and include any local conditions that may influence route choices.

From this process, evacuation time estimates and clearance times can be calculated for each storm scenario. Because of the complex nature of queue buildup and release conditions, computer simulation models are usually employed to conduct regionwide analyses. The clearance time for each scenario indicates the time from when the first evacuating vehicle enters the road network to the time when the last vehicle reaches an assumed point of safety.

PHASED EVACUATIONS

Based on the results of evacuation planning studies, the need for special traffic provisions such as contraflow operations, road closures, and police intersection traffic control can be identified. Another traffic demand management technique that can be identified from such studies is the need for *phased evacuations*.

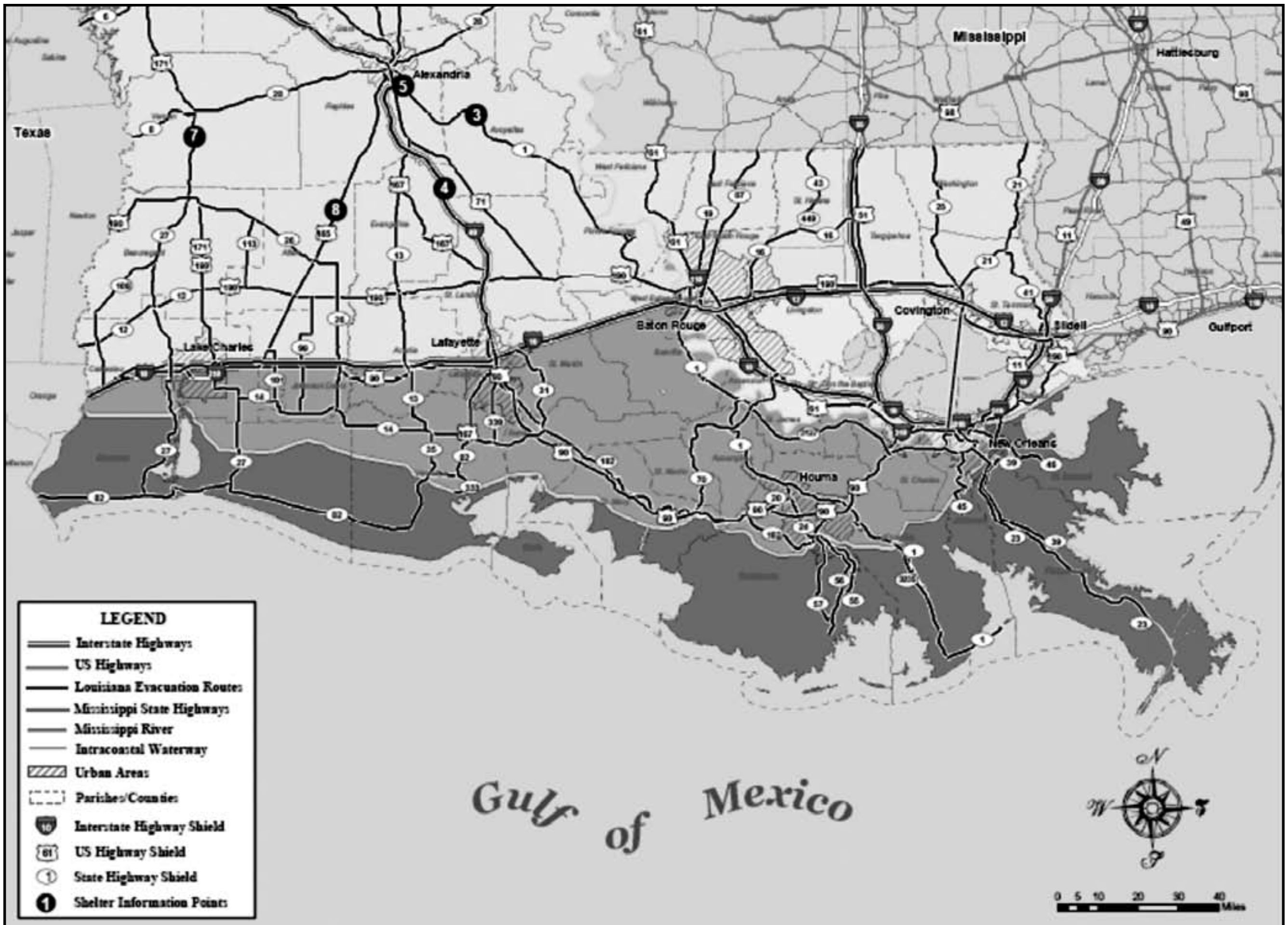
Although by definition the goal of an evacuation is to move endangered people away from a threat as quickly as possible, a single concentrated travel departure pattern can inhibit overall traffic movement, particularly at critical junctions such as intersections and freeway ramps. Because evacuations also involve movement in a single direction, evacuees closest to the hazard can experience the longest travel times. For example, the most vulnerable people in hurricane evacuations are closest to the coast and in nuclear power plant emergencies those that are closest to the release. However, as evacuees take to the roads, the downstream congestion created by traffic from areas more distant from the hazard can create upstream gridlock that extends back to the hazard source. These types of conditions can be multiplied exponentially when *shadow evacuations*, in which people not actually in danger also evacuate, occur.

Shadow evacuation-induced gridlock that impairs the movement of upstream evacuees was observed recently in Houston during the evacuation for Hurricane Rita in 2005. Vague instructions and statements from the authorities, misperceptions regarding vulnerability, (Peacock et al. 2007) and the timing only 2 weeks after Hurricane Katrina had Houstonians evacuating in numbers that far exceeded those planned for. As a result, traffic in the region came to a virtual standstill for more than a day. In addition to causing driver frustration, using up available fuel supplies, and potentially decreasing the participation rates of future evacuations, these conditions also limited the ability of coastal evacuees in the Galveston area to evacuate. It impaired the movement of infirm and special needs evacuees from hospitals and other care facilities.

To reduce the potential for similar occurrences in the future, phased evacuation plans for hurricanes have been (or are being) developed in several states. Phased evacuation planning for hurricanes is particularly useful because storms tend to give several days warning, allow for the most vulnerable areas to be clearly recognized, and often create massive numbers of evacuees. The idea of phased evacuation plans is to issue sequential evacuation orders that initiate evacuations in the most threatened areas first and permit evacuees to pass through areas of higher population before the onset of road congestion. Phased evacuations give residents and business owners in remote and higher threat areas a "head start" to secure properties before the arrival of hazardous conditions.

The phasing plan for coastal Louisiana developed jointly by the Louisiana State Police and Department of Transportation and Development (DOTD) is shown in Figure 4. Similar to plans in Houston, the strategy seeks to sequence evacuation orders starting from the coast and moving inland. One of the interesting features of the plan, shown in the bottom legend, is that it is developed specifically for evacuation traffic management purposes and not as a protective action plan. Part of the Louisiana plan is to incrementally implement increasingly restrictive traffic management plans. One of the basic philosophies of this plan is "Leave early and go where you want—Leave late and go where we tell you" in which all roads are open initially, then road closures and forced routings are implemented as a storm moves closer. Thus, the phasing plan also establishes when contraflow plans could be expected to take effect.

It is recognized that phased evacuations are not without problems of their own. Chief among these is evacuees following procedures properly. Many evacuees tend to wait for clear evacuation orders before leaving. Thus, there can be a tendency for later evacuations, even in the early phase designated areas of the plan. There is also the potential (as seen in Houston) for many more people than necessary to evacuate. Because it is effectively impossible to enforce phased evacuations, they end up as a guidance-only strategy.



Phased Evacuation

During a threat of a hurricane, a phased evacuation will be based on geographic location and time in which tropical storm winds are forecasted to reach the affected areas.

Phase I - 50 Hours before onset of tropical storm winds. Includes areas south of the Intracoastal Waterway. These areas are outside any levee protection system and are vulnerable to Category 1 and 2 storms. These areas are depicted in RED on the Evacuation Map. During Phase I there are no route restrictions.

Phase II - 40 Hours before onset of tropical storm winds. Includes areas south of the Mississippi River which are levee protected but remain vulnerable to Category 2 or higher storms. These areas are depicted in ORANGE on the Evacuation Map. During Phase II there are no route restrictions.

Phase III - 30 Hours before onset of tropical storm winds. Includes areas on the East Bank of the Mississippi River in the New Orleans Metropolitan Area which are within the levee protection system but remain vulnerable to a slow-moving Category 3 or any Category 4 or 5 storm. These areas are depicted in YELLOW on the Evacuation Map. During Phase III, certain routes will be directed and the Contraflow Plan implemented.

Phased evacuation procedures are for traffic management purposes only. Consult your local Office of Emergency Preparedness Director for further evacuation information.

FIGURE 4 Louisiana State Police hurricane evacuation phasing map (*Source:* http://www.lsp.org/pdf/Web_StateMap.pdf).

CHAPTER FOUR

DIRECTION AND CONTROL ON HIGHWAYS

Among the best-defined and well-developed roles of transportation in evacuations are in the areas of direction and control of transportation systems. This is not surprising because traffic control and traffic operations are the areas that transportation agencies are the most experienced and best equipped to support. As a result of a series of several recent high-visibility mass evacuation problems, state DOTs across the United States have begun to take much more active roles in planning regional evacuations and, in some cases, have served lead state agencies in the development of management and control strategies.

There is also a trend among DOTs to employ dedicated full-time staff members whose primary responsibility is maintaining evacuation readiness and coordination with other state agencies. These personnel have proved to be valuable in establishing and maintaining communications and coordination with neighboring states where evacuations cover multistate regions and where evacuation monitoring and control takes place from regional and statewide traffic management centers. Two illustrations for which these measures have been particularly useful are for the complex regionwide freeway management plans that are now in place for New Orleans and Houston. The DOTs in Louisiana and Texas were instrumental in development of the plans, both of which now incorporate coordinated evacuation phasing, contraflow, and assisted evacuations.

The direction and control of transportation systems should not, however, be interpreted as extending into the direction and control of evacuations, directly. Although transportation agencies play key roles in supporting and assisting in the execution of such orders, the review of practice showed that the declaration and timing of evacuations are decisions that are made by emergency mangers and law enforcement agencies and that there were no examples in which transportation agencies were involved in such decisions. Instead, transportation support activities were limited to actions such as the reconfiguration and implementation of traffic control, traffic management planning, and areawide traffic monitoring, among many others.

This chapter summarizes and highlights many current practices and recent developments in traffic control and the role that transportation agencies play in supporting plan development and decision making in emergency evacuations. A discussion of specific tools and techniques such as evacuation contraflow and traffic control devices is included.

TRAFFIC CONTROL DEVICES

To help in the control and guidance of traffic during evacuations, several transportation agencies have developed tools and strategies to convey information to travelers. The three most common are signs, pavement markings, and traffic signals. The following sections include examples of evacuation-specific techniques using these devices.

Signs

Traffic control devices and techniques for evacuation are well established for some hazards. The *Manual of Uniform Traffic Control Devices* (*MUTCD*) (MUTCD 2003) includes a section dedicated specifically to signing for emergency management. Chapter 21 in the manual includes guidance on the design, size, and placement of these devices. This chapter can also be accessed online at http://mutcd.fhwa.dot.gov/htm/2003r1/part2/part2i .htm. Signs in this section of the *MUTCD* are meant to guide, restrict, or control traffic operations and to limit access to essential emergency and aid-related vehicles. The chapter also includes suggested signs for medical, welfare, registration, and decontamination centers that may be required for various types of hurricane, radioactive fallout, chemical, and general hazards. In addition to these facility location signs, the *MUTCD* includes one sign specific to evacuation.

The EM-1 "Hurricane Evacuation Route" signs are designed for posting along designated evacuation routes (see Figure 5). The EM-1 sign may be used with legends for other types of hazards than hurricanes, and this line of text may be omitted for more general use. The sign configuration shown on the left side of Figure 5 also includes a commonly used supplemental sign with AM and FM radio station frequencies that provide emergency information.

In addition to the formally designated signs in the *MUTCD*, it is not uncommon for local transportation agencies to develop their own signs for local use in emergencies and evacuations. These include signs specifically created for use on contraflow segments to convey radio frequencies for evacuation travel

FIGURE 5 *MUTCD* hurricane evacuation guidance signs.

information and to provide general information that would be conveyed on variable message signs (VMS). Because they are not included in the *MUTCD*, no formally established standards guide their design and implementation.

Signing on contraflow segments is particularly important along the reverse flowing side of contraflow freeway lanes. When the alignments of directional freeway lanes become independent or separated by medians, drivers in contraflowing lanes may not always be aware of exit locations and services available, because they cannot see into the other lanes and the signs in their lanes face the opposite direction.

To accommodate these drivers, agencies such as the Alabama DOT (ALDOT) use “fold-down” signs adjacent to contraflow lanes. When not in use, these signs are folded upward and appear as blank sign backs as shown on the left side of Figure 6. When needed, a crew unlocks the latches permitting the bottom half of the sign to fall into the open position and secures the bottom sign half to the sign supports (see the right side of Figure 6).

To maintain readiness for the implementation of traffic control devices during the hurricane season, ALDOT, as with several other states, also maintains ready-for-use mobile transport vehicles for rapid deployment. An example of one of these vehicles, loaded to implement contraflow on I-65, is shown in Figure 7.

An example of a VMS in use during contraflow operations is shown in Figure 8. This sign, located just before a key decision point outside of New Orleans, was used to guide drivers into the appropriate lane based on their destination. At this location, the left two lanes are guided into the contraflow lanes west toward Baton Rouge, whereas the right two lanes continued in the normal flow lanes northbound toward Mississippi.

An example of a less sophisticated, though highly useful sign is shown in Figure 9. Although this sign is not used on an evacuation route, these flood-level gauges signs are common in evacuation routes in New Orleans where roadways are prone to flooding. These passive flood depth measurers give drivers an idea of the depth of water in low-lying areas near underpasses. In Figure 9, the horizontal line shows the flood depth at this underpass location sustained during the landfall of Tropical Storm Allison in 2001.

Pavement Markings

Another type of traffic control device that has come into use for evacuations is pavement markings. As with some of the previously mentioned signs, these markings are not found in the *MUTCD*, but rather they have been developed for local use. Pavement markings for evacuations are much less common than signs.

FIGURE 6 Fold-down guidance signing for contraflow lanes (Connor 2005).

FIGURE 7 ALDOT ready-for-use traffic control device vehicle (Connor 2005).

An example of pavement markings used to designate shoulders for use as an additional travel lane is shown in Figure 10. These markings have been developed by the Texas DOT (TxDOT) and have been affixed on shoulders along US-290, an evacuation route for the city of Houston west toward Hempstead. On the left side of the figure is the marking used for the inside shoulder adjacent to the normal flowing lanes. These markings are particularly important in advance of interchange ramps as the paved shoulder aligns with the off- and on-ramp auxiliary lane. The marking on the right side of the figure is used on the inside shoulder of the contraflowing lanes. The difference is the addition of a directional arrow above the hurricane symbol to indicate the intended direction of travel.

The review of practice showed that some new types of heat-applied thermoplastic pavement markings retain their retro-reflective properties even when submerged below two or three inches of water. Thus, they may be desirable on routes prone to flooding during evacuations.

FIGURE 8 Variable message sign evacuation information (I-10, New Orleans) (*Source:* Alison Caterella-Michel).

Traffic Signals

The use of traffic signals to facilitate evacuations is another area that has begun to receive more attention, particularly for evacuation of urbanized areas under no-notice conditions. The review of practice showed that, currently, there are no standardized or recommended rules of operation for traffic signal control during evacuation emergencies. Although it is recognized that the primary goal should be to facilitate the outbound movement of traffic away from the hazard zone, it is also recognized that as in nonemergency conditions cross-street turning traffic needs to be accommodated. In urbanized areas with densely spaced street grids, it is possible that primary movement may not be clearly defined. This lack of definition has been controversial.

An example of such an issue was noted in recent hurricane evacuations for the timing of signals along primary arterial highways in less densely populated areas. In several instances, evacuation traffic on the major highway passed through small towns with one or two traffic signals. In some cases, signal indications along the primary highway were set to a flashing yellow to maintain uninterrupted flow along the main route. However, this caused some areas of these small towns to become inaccessible as local travelers were unable to find adequate gaps to cross the major highway. To avoid similar conditions in later evacuations, some localities have maintained normal, nonemergency, peak-hour signal timings to service cross-street traffic. Not surprisingly, this

FIGURE 9 Passive underpass flood depth gauge (Baton Rouge, Louisiana). (*Note:* the horizontal line indicates the 8-ft flood depth during Tropical Storm Allison in 2001.)

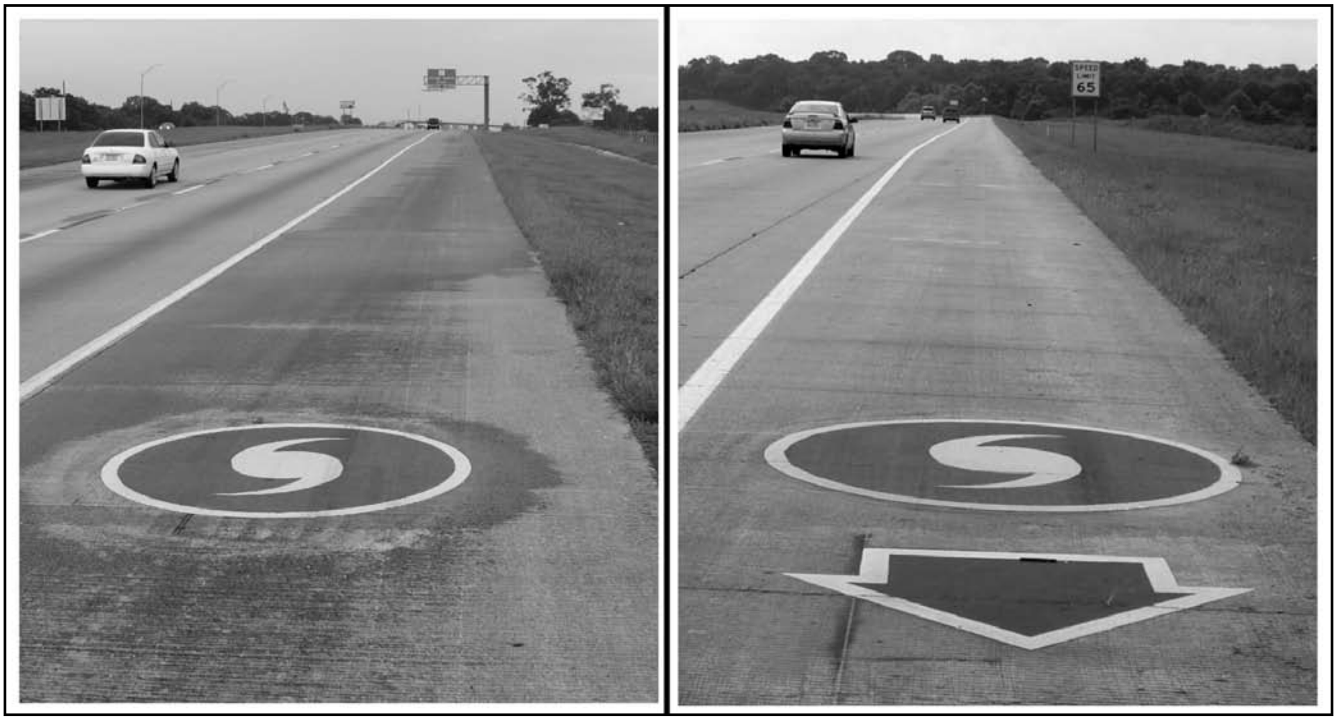


FIGURE 10 Hurricane evacuation route directional shoulder pavement markings (normal lanes at left and contraflow lanes at right), US-290, Texas. (*Note:* photos not taken under evacuation conditions.)

led to congestion, long queues, and delays as well as the potential for prohibiting full clearance of the hazard zone. To address these issues, some state agencies now plan to use flashing yellow in conjunction with police enforcement to permit cross-street traffic maneuvers.

A recent study conducted by Chen et al. (2007) used traffic simulation modeling to examine the effects of varied traffic signal timing for no-notice urban evacuation scenarios. The effort focused on plans developed by the District of Columbia DOT to evacuate Washington, D.C. under various no- and short-notice evacuation scenarios. Simulations were performed on two arterial corridors over a 10-hr period using cycle lengths of 180, 240, and 300 s as well as all-yellow and all-red flashing modes. The results quantified the trade-off between network clearance time and delays for cross-street traffic.

It was found that the "best" plan depended on what needed to be achieved. As expected, the longer green times for the outbound evacuation traffic was best for maximizing the amount of outbound evacuation traffic volume and minimizing their delay. Although the authors recommended a flashing yellow to give a virtual infinite green to the evacuation traffic, they also pointed out that, if approach volumes are closer to those of routine peak periods, the usual nonemergency timing plans could be most effective. If average delays of 15 min to cross-street traffic were deemed to be acceptable, then cycle lengths of 180 s to 240 s (depending on the amount of evacuating volume) could also be effective.

CONTRAFLOW

Since Hurricane Floyd in 1999, the use of evacuation contraflow has become one of the most notable forms of evacuation traffic management and one in which transportation agencies have played a leading role. Contraflow is a form of reversible traffic operation in which one or more travel lanes of a divided highway are used for the movement of traffic in the opposing direction. (The common definition of contraflow for evacuations has been broadened over the past several years by emergency management officials, the news media, and the public to include the reversal of flow on any roadway during an evacuation (AASHTO 2004). It is a highly effective strategy because it can both immediately and significantly increase the directional capacity of a roadway without the time or cost required to plan, design, and construct additional lanes. It is also popular with the public because it is viewed as a logical utilization of the unused lane capacity of adjacent inbound lanes as shown in Figure 11.

Since 1999, contraflow has been planned to evacuate regions of the southeastern United States when under threat from hurricanes. As a result of its recent demonstrated effectiveness during Hurricane Katrina (Wolshon 2006), it is also now looked upon as a potential preparedness measure for

FIGURE 11 Evacuation of Houston Area for Hurricane Rita, I-45.

other mass-scale hazards. Contraflow segments are most common and logical on freeways because they are the highest capacity roadways and are designed to facilitate high-speed operation. Contraflow is more practical on freeways because these routes do not incorporate at-grade intersections that interrupt flow or permit unrestricted access into the reversed segment. Freeway contraflow can be implemented and controlled with fewer staffing resources than unrestricted highways. Nearly all of the contraflow strategies currently planned on U.S. freeways have been designed for the reversal of all inbound lanes.

The configuration, shown in Inset 1d of Figure 12, is referred to as a "One-Way-Out" or "All-Lanes-Out" evacuation. This is the most common form of contraflow. Though not as popular, some contraflow plans have also included options for the reversal of only one of the inbound lanes (Inset 1b) with another option to use one or more of the outbound shoulders (Inset 1c) (Wolshon 2001). Inbound lanes in these plans are maintained for service vehicles to enter the threat area to provide assistance to evacuees in need along the contraflow segment.

Recent Contraflow History

Although evacuation-specific contraflow is a relatively recent development, its application for other types of traffic problems is not new. Indeed, various forms of reversible traffic operation have been used throughout the world for decades to address many types of directionally unbalanced traffic conditions (Wolshon and Lambert 2004). These operations have been most common around major urban centers where commuter traffic is heavy in one direction and light in the other. Reverse and contraflow operations have also been popular for managing the infrequent, but periodic and predictable, directionally imbalanced traffic patterns associated with major events such as concerts, sporting events, and other public gatherings. Reversible lanes have been cost-effective on bridges and in tunnels where additional directional capacity is needed, but where additional lanes can not be added easily.

Although the date of the first use of contraflow for an evacuation is not known with certainty, interest in its potential began to be explored after Hurricane Andrew struck Florida in 1992. By 1998, transportation and emergency management officials in both Florida and Georgia had plans in place to use contraflow on segments of interstate freeways. The watershed event for evacuation contraflow in the United States occurred with Hurricane Floyd in 1999. Since then, every coastal state threatened by hurricanes has developed and maintains plans for the use of evacuation contraflow.

Hurricane Floyd triggered the first two major implementations of contraflow, one on a segment of I-16 from Savannah to Dublin, Georgia, and the other on I-26 from Charleston to Columbia, South Carolina. The results of both of these applications were generally positive, although numerous areas for improvement were identified. The contraflow application in South Carolina was particularly interesting because it was not planned. Rather, it was implemented on an improvisational basis after a strong public outcry came from evacuees trapped for hours in congested lanes of westbound I-26 seeking ways to use the near-empty eastbound lanes.

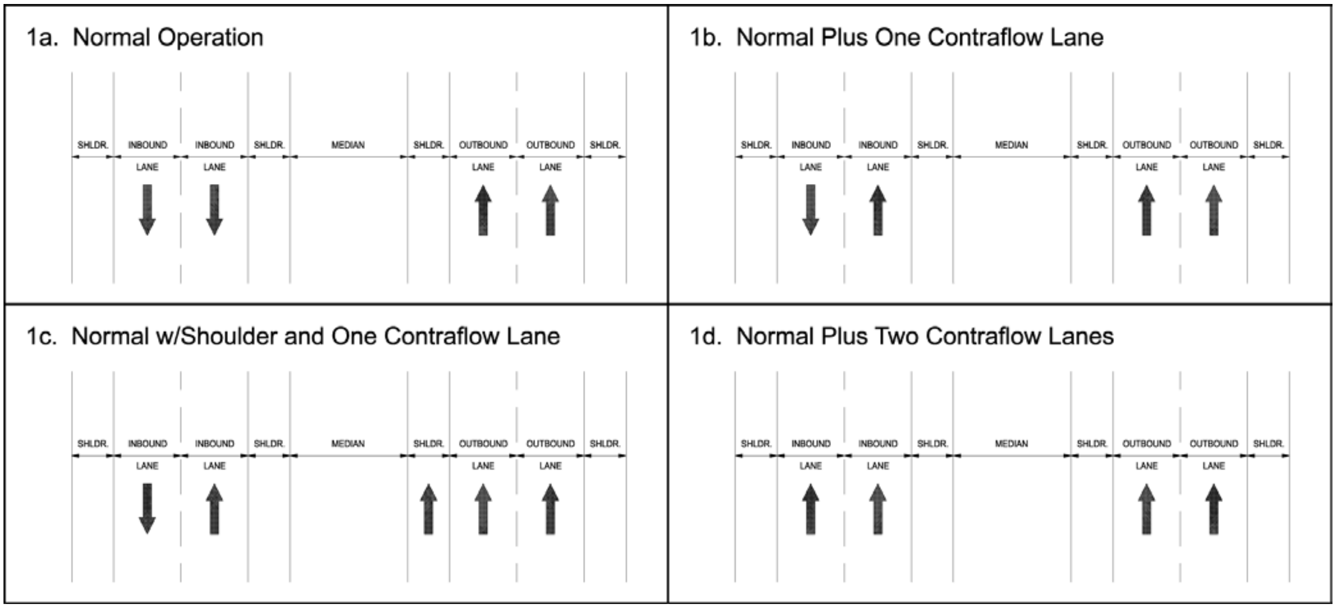


FIGURE 12 Freeway contraflow lane use configurations for evacuations (Wolshon 2001).

The first post-Floyd contraflow implementations occurred in 2004 on I-65 in Alabama for the evacuation of Mobile and on I-10 in Louisiana for the evacuation of New Orleans during Hurricane Ivan. Once again, many lessons were learned and numerous improvements were suggested in both physical and operational aspects of the plans (Wolshon et al. 2006). The timing of these events was quite fortuitous for New Orleans. Within 3 months of the major changes that were implemented to the Louisiana contraflow plan, they were put into operation for Hurricane Katrina. The changes in the Louisiana plan were the most aggressive and far-ranging of any developed until that time (Wolshon et al. 2006). They involved the closure of lengthy segments of interstate freeway, forced traffic onto alternative routes, established contraflow segments across the state boundary into Mississippi, coordinated parallel nonfreeway routes, and reconfigured several interchanges to more effectively load traffic from surface streets. The results of these changes were reflected in a clearance time for the city that was about half of the previous prediction (Wolshon and McArdle 2008).

Operational Characteristics

Although the basic concept of contraflow is simple, it can be complex to implement and operate in practice. If not carefully designed and managed, contraflow segments have the potential to be confusing to drivers. To ensure safe operation, improper access and egress movements must be prohibited at all times during its operation. Segments must be fully cleared of opposing traffic before initiating contraflow operations. These are not necessarily easy tasks to accomplish, particularly in locations where segments are in excess of 100 miles and where interchanges are frequent. For these reasons, some transportation officials regard them to be risky and only for use during daylight hours and under the most dire situations. These risks also explain why contraflow for evacuation has been planned nearly exclusively for freeways, where access and egress can be tightly controlled.

Until now, contraflow evacuations have also been used only for hurricane hazards and wildfires and no other type of natural or man-made hazard. The first reason for this is that these two hazards affect much greater geographic areas and tend to be slower moving relative to other hazards. Because of their scope, they create the need to move larger numbers of people over greater distances than other types of hazards. The second reason is that contraflow often requires considerable manpower and material resources as well as time to mobilize and implement. Experiences in Alabama and Louisiana showed that the positioning of traffic control devices and enforcement personnel takes at least 6 hrs in addition to the time to plan and acquire equipment for the event. In Florida, where needs are great and manpower resources are stretched thin, evacuation contraflow requires involvement from the Florida National Guard. For this reason (among others), Florida officials require a minimum of 49 hrs of advance mobilization time for contraflow to be implemented (Wolshon, Urbina, Levitan, and Wilmot 2005).

As the goal of an evacuation is to move as many people out of the hazard threat zone as quickly as possible, the primary goal of contraflow is to increase the rate of flow and decrease the travel time from evacuation origins and destinations. Before field measurement, it was hypothesized that the flow benefits of contraflow would be substantial, but less than that of an equivalent normally flowing lane (Theodoulou and Wolshon 2004). These opinions were based on measurements of flow on I-26 during the Hurricane Floyd evacuation and the theory that drivers would drive at slower speeds and with larger spacing in contraflow lanes.

The highest flow rates measured by the South Carolina DOT (SCDOT) during the Floyd evacuation were between 1,500 and 1,600 vehicles per hour per lane (vphpl) (PBS&J 2000a). Traffic flows measured during the evacuations for Hurricanes Ivan and Katrina on I-55 in Louisiana were somewhat less than the South Carolina rates. Flows in the normal flow lanes of I-55 averaged about 1,230 vphpl during the peak 10 hrs of the evacuation. Flow rates in the contraflow lanes during the same period averaged about 820 vphpl. These volumes compare to daily peaks of about 400 vphpl during routine periods and a theoretical capacity of 1,800 to 2,000 vphpl for this segment (Wolshon 2008b).

Figure 13 illustrates the hourly traffic flow on I-55 during the evacuations for Hurricanes Ivan (when contraflow was not used) and Katrina (when contraflow was used). During the 48-hr period of the Ivan evacuation (shown on the left side of the graph), a total of 60,721 vehicles traveled northbound through this location. During the Katrina evacuation, the total volume was 84,660 vehicles during a corresponding 48-hr period. It is also worthy to note that the duration of the peak portion of the evacuation (i.e., when the volumes were noticeably above the prior three-week average) was about the same for both storms.

The data in Figure 13 are of interest because they are consistent with prior analytical models of evacuation that have estimated maximum evacuation flow on four-lane freeways with contraflow to be about 5,000 vph. One of the difficulties in making full analyses of evacuation volume in general, and of contraflow volume specifically, has been a lack of speed data. Although the flow rates recorded during the two recent Louisiana hurricane evacuations are considerably lower than the theoretical capacity of this section of freeway, it cannot be determined with certainty whether the conditions were congested with low operating speeds and small headways or relatively free flowing at more moderate levels of demand. It is noteworthy that empirical observation of speed at a point toward the end of the segment did not appear to support the popular theory of elevated driver caution during contraflow. Traffic enforcement personnel in Mississippi measured speeds well in excess of posted speed limits as the initial group of drivers moved through the newly opened lanes.

Design and Key Elements

Reversible roadways have a number of physical and operational attributes that are common among all applications. The principle physical attributes are related to spatial characteristics of the design, including its overall length, number of lanes, and the configuration and length of the inbound and

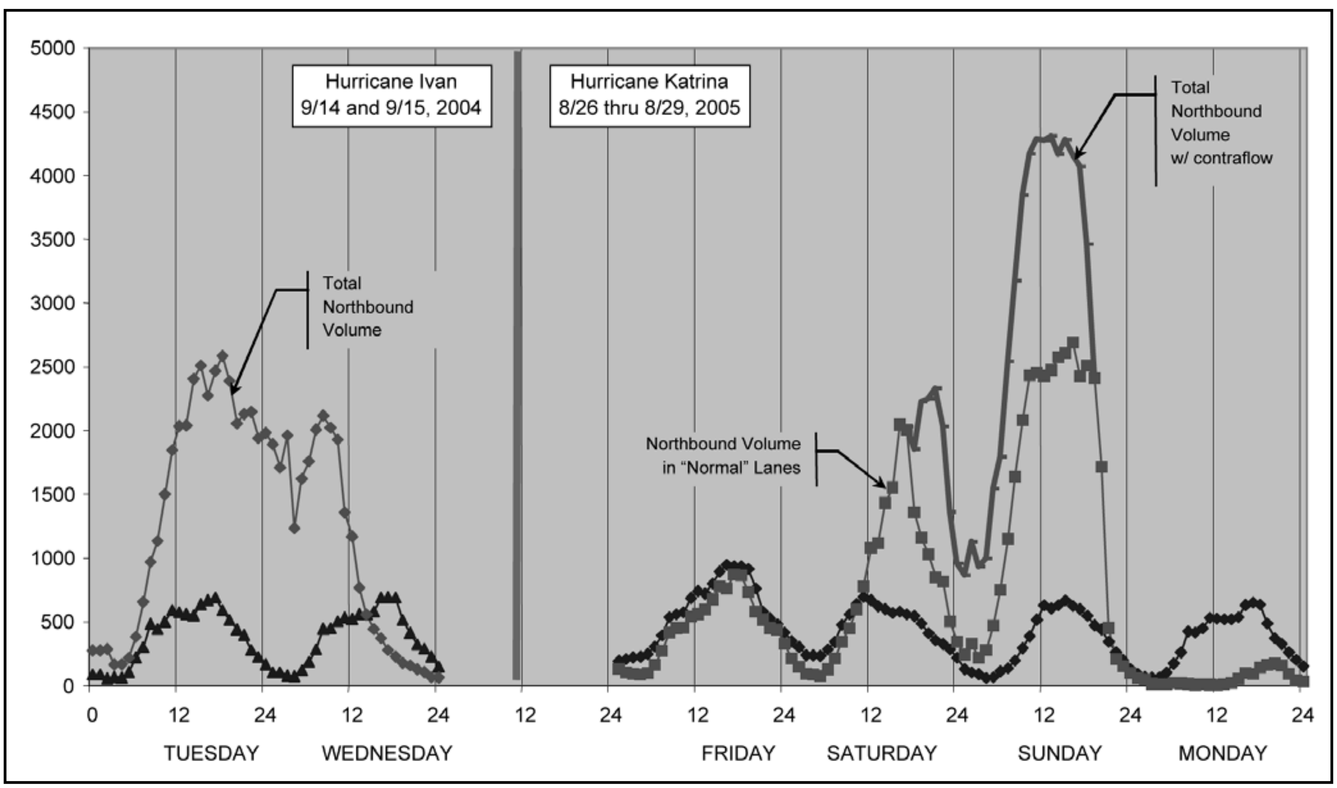


FIGURE 13 Northbound traffic volume—I-55 at Fluker Louisiana (Wolshon and McArdle 2008).

outbound transition areas. The primary operational attributes are associated with the way in which the segment will be used and include the temporal control of traffic movements. The temporal components of all reversible lane segments include the frequency and duration of a particular configuration and the time required to transition traffic from one direction to another. The duration of peak-period commuter reversible applications, for example, typically last about 2 hrs (not including setup, removal, and transition time), twice a day. Evacuation contraflow, however, may be implemented only once in several years, and its duration of operation may last several days.

Like all reversible flow roadways, contraflow lanes need to achieve and maintain full utilization to be effective. Although this statement sounds like it can be taken for granted, it can be challenging to achieve in practice. The most common reason for underutilization has been inadequate transitions into and out of the contraflow segment. Contraflow requires a transition section at the inflow and outflow ends to allow drivers to maneuver into and out of the reversible lanes from the unidirectional lanes on the approach roadways leading into it. Because these termini regulate the ingress and egress of traffic entering and exiting the segment, and they are locations of concentrated lane changing as drivers weave and merge into the desired lane of travel, they effectively dictate the capacity of the entire segment.

Through field observation and simulation studies (Theodoulou and Wolshon 2004; Williams et al. 2007), it has been shown that contraflow entry points with inadequate inflow transitions result in traffic congestion and delay before the contraflow segment and prohibit the segment from carrying capacity-level demand. This was illustrated by I-10 contraflow segment in New Orleans during the Hurricane Ivan evacuation. At that time, evacuating traffic vehicles in the left and center outbound lanes of I-10 were transitioned across the median and into the contraflow lanes using a paved crossover. However, the combination of the crossover design, temporary traffic control devices, the presence of enforcement personnel, and weaving vehicles created a flow bottleneck that restricted inflow into the contraflow lanes. This caused two problems. First, it limited the number of vehicles that could enter the contraflow lanes, limiting flow beyond the entry point significantly below its vehicle carrying capability. Second, it caused traffic queues upstream of the crossover that extended back for distances in excess of 14 miles. This plan was significantly improved before the Katrina evacuation one year later by permitting vehicles to enter the contraflow lanes at multiple points, spatially spreading the demand over a longer distance, and reducing the length and duration amount of the congested conditions (Wolshon et al. 2006).

Inadequate designs at the downstream end of contraflow segments can also greatly limit its effectiveness. Prior experience and simulation modeling have shown that an inability to move traffic from contraflow lanes back into normally flowing lanes will result in congestion backing up from the termination transition point in the contraflow lanes (Lim and Wolshon 2005). Under demand conditions associated with evacuations, queue formation can occur quite rapidly and extend upstream for many miles within hours. To limit the potential for such scenarios, configurations that require merging of the normal and contraflowing lanes are discouraged; particularly if they also incorporate lane drops. Two popular methods that are used to terminate contraflow include routing the two traffic streams at the termination on to separate routes and reducing the level of outflow demand at the termination by including an egress point along the intermediate segment. Several of the more common configurations are discussed in the following section.

The primary physical characteristics of contraflow segments are the number of lanes and the length. A 2003 study of hurricane evacuation plans revealed that 18 controlled access evacuation contraflow flow segments and three additional arterial reversible roadway segments have been planned for use in the United States (Urbina and Wolshon 2003). Currently, all of the contraflow segments are planned for a full "One-Way-Out" operation. The shortest of the contraflow freeway segments was the I-10 segment out of New Orleans at about 25 miles long. The longest were two 180-mile segments of I-10 in Florida; one eastbound from Pensacola to Tallahassee and the other westbound from Jacksonville to Tallahassee. Most of the other segments were between 85 and 120 miles.

In the earliest versions of contraflow, nearly all of the planned segments that were identified in the study were initiated by means of median crossovers. Now that single-point loading strategies have been shown to be less effective, many locations are changing to multipoint loading. The most popular of these are median crossovers, with supplemental loading achieved through nearby reversed interchange ramps.

The termination configurations for the reviewed contraflow segments were broadly classified into two groups. The first were *split designs*, in which traffic in the normal and contraflowing lanes are routed onto separate roadways at the terminus. The second were *merge designs,* in which the separate lane groups are reunited into the normal flow lanes using various geometric and control schemes. The selection of one or the other of these termination configurations at a particular location by an agency has been a function of several factors, most important, the level of traffic volume and the configuration and availability of routing options at the end of the segment.

In general, split designs offer higher levels of operational efficiency of the two designs. The obvious benefit of a split is that it reduces the potential for bottleneck congestion resulting from merging four lanes into two. Its most significant drawback is that it requires one of the two-lane groups to exit to a different route, thereby eliminating route options at the end of the segment. In some older designs, the contraflow traffic stream was routed onto an intersecting arterial roadway. This type of split design requires adequate capacity on the receiving roadway.

Merge termination designs also have pros and cons. Not surprisingly, however, the costs and benefits are almost the exact opposite of split designs in their end effect. For example, most merge designs preserve routing options for evacuees because they do not force vehicles onto adjacent roadways and exits. The negative side is that they also have a greater potential to cause congestion because they merge traffic into a lesser number of lanes. At first glance, it would appear illogical to merge two high-volume roadways into one. However, in most locations where they are planned, exit opportunities along the intermediate segment will be maintained to decrease the volumes at the end of the segment.

The list of applications for contraflow continues to grow as transportation and emergency preparedness agencies recognize its benefits. As a result, the number of locations that are contemplating contraflow for evacuations is not known. However, a comprehensive study of contraflow plans in 2003 included 21 reverse-flow and contraflow sections. The locations and distances of these locations are detailed in Table 2 (Urbina and Wolshon 2003).

As experiences with contraflow increase and its effectiveness becomes more widely recognized, it is likely that contraflow will be accepted as a standard component of emergency preparedness planning and its usage will grow. Several recent high-profile negative evacuation experiences have prompted more states to add contraflow options to their response plans. Contraflow is also being evaluated for use in some of the larger coastal cities of northeast Australia. In other locations

TABLE 2
PLANNED CONTRAFLOW/REVERSE FLOW EVACUATION ROUTES

State	Route(s)	Approx. Distance (miles)	Origin Location	Termination Location
New Jersey	NJ-47/ NJ-347*	19	Dennis Twp	Maurice River Twp
	Atlantic City Expressway	44	Atlantic City	Washington Twp
	NJ-72/ NJ-70*	29.5	Ship Bottom Boro	Southampton
	NJ-35*	3.5	Mantoloking Boro	Pt. Pleasant Beach
	NJ-138/I-195	26	Wall Twp	Upper Freehold
Maryland	MD-90	11	Ocean City	U.S. 50
Virginia*	I-64	80	Hampton Roads Bridge	Richmond
North Carolina	I-40	90	Wilmington	Benson (I-95)
South Carolina	I-26	95	Charleston	Columbia
Georgia	I-16	120	Savannah	Dublin
Florida	I-10 Westbound	180	Jacksonville	Tallahassee
	I-10 Eastbound	180	Pensacola	Tallahassee
	SR 528 (Beeline)	20	SR 520	SR 417
	I-4 Eastbound	110	Tampa	Orange County
	I-75 Northbound	85	Charlotte County	I-275
	FL Turnpike	75	Ft. Pierce	Orlando
	I-75 (Alligator Alley)	100	Coast	Coast
Alabama	I-65	135	Mobile	Montgomery
Louisiana	I-10 Westbound	25	New Orleans	I-55
	I-10/I-59 (east/north)	115*	New Orleans	Hattiesburg*
Texas	I-37	90	Corpus Christi	San Antonio

*Notes: Delaware and Virginia contraflow plans are still under development. The actual length of the New Orleans, Louisiana, to Hattiesburg, Mississippi, contraflow segment will vary based on storm conditions and traffic demand. Because they are undivided highways, operations on NJ-47/NJ-347, NJ-72/NJ-70, and NJ-35 are "reverse flow" rather than contraflow.
(*Source:* Urbina and Wolshon 2003).

where hurricanes are not a likely threat, contraflow is being studied. Some of these examples include wildfires in the western United States (Wolshon and Marchive 2007) and tsunamis and volcanoes in New Zealand. Greater emphasis on terrorism response has encouraged cities with few natural hazards to begin examining contraflow for various accidental and purposeful man-made hazards (Sorensen and Vogt 2006).

Other Issues

Although the use of contraflow is widely viewed as a significant advantage for increasing the speed and efficiency of regional evacuations, it is also not considered to be the cure for all evacuation-related problems. The benefits of contraflow come with significant costs in terms of required enforcement man-power, control strategies, convenience, and potential safety impact.

Safety

One of the primary considerations in the design and operation of any highway facility is safety. By its nature, the contraflow movement of traffic violates several of the most basic elements of highway safety. The most obvious of these is the movement of vehicles in the "wrong" direction in the lanes of roadways. This increases the potential for sideswipe and head-on accidents with vehicles traveling in the opposing direction in adjacent lanes or those that may have entered the contraflow lanes inadvertently. To address part of this problem, most states plan to reverse all inbound lanes rather than maintaining opposing traffic movements within a single roadway. This will eliminate the problem of opposing flows in adjacent lanes. To reduce the potential for inadvertent entry in to the contraflow lanes, most states will use state police or National Guard troops positioned at entrance ramps on the inbound lanes to prohibit the entrance of inbound traffic. After the entrances are blocked and before the opening of the contraflow lanes to outbound traffic, many of these same enforcement agencies plan to conduct sweeps of the contraflow segments by air and with ground patrols to ensure that there are no inbound vehicles. As a final measure, the contraflow traffic stream will be led by state police vehicles—for example, in the case of I-10 out of Jacksonville, Florida, state police vehicles were preceded at a short distance by two large DOT dump trucks.

Most guidance and safety features of highways, particularly freeways, are designed for vehicle movement in one direction. Under contraflow operation, many of these features will not be functional for the contraflow traffic stream, including guardrails, crash impact attenuators, and breakaway signs, and they could even be hazardous to vehicles driving in the opposite direction. To address this issue, some states are planning to redesign or retrofit existing safety appurtenances (Wolshon 2001). The North Carolina DOT has proposed the reconstruction of guardrails along I-40 to protect vehicles traveling in the opposite direction (NCDOT 2000). Interestingly, most states have taken the approach not to redesign such devices. This view is founded on the premise that contraflow is expected to be used infrequently, and thus such action would not be cost-effective. It is widely assumed that during contraflow operations vehicles will maintain relatively low speeds, thereby decreasing the likelihood and severity of crash impacts.

Traffic incidents on evacuation routes were identified as another concern during contraflow operations. A traffic incident refers to any nonrecurrent event that causes reduction of roadway capacity or an abnormal increase in traffic demand. When incidents occur, lanes are blocked, thereby reducing roadway capacity. During hurricane evacuations, vehicular incidents such as overheating, flat tires, vehicles running out of fuel, and accidents are anticipated. When they do occur, the vehicles need to be cleared in a safe and timely manner to restore the roadway to its full capacity. Incident clearance is a greater challenge during contraflow operations, however, because of the difficulty of service and law enforcement vehicles to gain access to the incident site. To address this issue, some states plan to place wreckers at strategic points along the contraflow route. For medical emergencies, some states also plan to use airlift resources to move injured or stricken evacuees from contraflow routes. The SCDOT will use the motorist assistance program called State Highway Emergency Program. The use of this program would assist in situations such as repairs to disabled vehicles, traffic control, and incident management. If needed, State Highway Emergency Program patrol personnel can provide first aid until emergency medical services arrive. In Texas, officials will take advantage of the state's extensive system of two-way freeway frontage roads to circulate emergency response and service vehicles.

Driver Understanding

Another issue that was considered to be important in terms of its impact on the safety and efficiency of an evacuation was the level of driver understanding of the evacuation routes, particularly for those that included contraflow. It is a generally accepted theory that driver confusion can result in diminished flow capacity and in some cases can contribute to an increased potential for traffic accidents. During an evacuation, it is expected that many drivers would be traveling on unfamiliar routes. The problem of driver knowledge and confusion is compounded on the reversed lanes of a contraflow segment, where normal roadway guidance features such as road signs and pavement markings may be different from their normal configurations or may not be visible at all.

All states currently use standard hurricane evacuation route and information signs on designated evacuation routes and provide AM and FM radio station frequencies to broadcast evacuation routes and shelter information. Few states, however, have addressed the issue of signing for contraflow lanes. As shown earlier, ALDOT has flip-down signs to designate exit numbers and locations on contraflow lanes. Most other states are planning extensive use of permanent and portable dynamic message signs (DMS) and highway advisory radio (HAR) transmitters to disseminate locations of intermediate crossovers, proximity of termination points, and other information pertinent to evacuating drivers.

To enhance general public awareness of contraflow evacuation procedures, the Georgia DOT (GDOT) produced and distributed brochures to explain its contraflow plan and its operation as well as maps showing the evacuation routes. The Virginia and Georgia DOTs present similar information on their websites. Most survey respondents believed that measures such as these could be supplementary to more traditional means of highway guidance information such as highway signing and delineation, because only a few, if any, of the evacuees will have access to the Internet in their cars. They also believed that reading these brochures during an evacuation could be a distraction for evacuating drivers.

Accessibility

Contraflow evacuations can significantly curtail accessibility to adjacent roads and properties. The most obvious limitation is for inbound traffic. Although it is not generally expected that inbound traffic demand would be significant, access for people entering the evacuation area to retrieve family members, as well as emergency and service personnel, must be provided to respond to traffic incidents and other emergencies along the evacuation routes and potentially within the evacuation zone. The most commonly proposed method of inbound access involves the use of parallel “secondary” routes. Secondary routes would include non-freeways and other routes that have not been converted for contraflow use. In isolated communities such as the Florida Keys that have only one route of access and egress, contraflow may not be appropriate unless alternate provisions for inbound access or circulation can be maintained.

Another accessibility issue involves vehicles exiting from or entering the lanes of a contraflow segment. Although one of the primary objectives of an evacuation is to keep vehicles moving, evacuees still need to have access to food, roadside restroom facilities, gas stations, and, in some cases, emergency facilities such as hospitals. The contraflow plans currently in place in most states will limit access to these facilities, particularly for evacuees traveling on the contraflow lanes. To address this issue, some states will attempt to loosen the exit restrictions of vehicles in the inbound lanes. In North Carolina, most interchange exits are planned to be opened from both the normal and contraflow lanes, although they also have to be closely monitored by police and DOT personnel. In South Carolina and Georgia, evacuees will be allowed to exit the contraflow lanes at several designated locations (typically spaced 10 to 20 miles apart) along the segment. However, they will be permitted only to reenter the normal outbound lanes. Some states are considering the construction of intermediate crossovers to facilitate the access to contraflow lanes. In Alabama, for example, four intermediate crossovers have been constructed to facilitate traffic movement back into the contraflow lanes. It is anticipated that this will help balance the traffic volume on both sides of the segment.

Enforcement

Although the benefits of contraflow are significant, they also come at a cost. One of the most significant costs is for control and enforcement manpower. The implementation and operation of contraflow operations requires the extensive use of enforcement personnel. During a storm, this becomes a particularly critical issue because enforcement agencies such as the National Guard and state police also have other critical functions.

The number of personnel required to enforce and control a contraflow evacuation segment depends on the length and complexity of the plan. Areas where law enforcement personnel are most critical are at on-ramps and some of the off-ramps that permit access to contraflow lanes, at the beginning and termination points of the operation, and in the medians to avoid the illegal crossover of vehicles to the outbound lanes. In Georgia, it has been estimated that 74 Georgia state patrol officers will be required over 120 miles of the I-16 contraflow segment. In Florida, estimates of the number of law enforcement personnel needed range from as few as 20 on the 20-mile segment of SR-528 to as many 210 on the 110-mile section of I-4 between Tampa and Orlando. Transportation agencies are looking into the use of other systems and measures to limit ramp entry into the contraflow lanes. One of these measures is a specially designed gate, similar to a railroad crossing gate, which would be used to prohibit unauthorized vehicle movements at contraflow exit or entry locations. To prohibit unauthorized median crossovers between lanes of the contraflow flow segments, the South Carolina Department of Public Safety is considering the installation of a three-strand cable guardrail similar to those in place on interstate freeway medians throughout North Carolina.

Contraflow Implementation

Timing is critical during an evacuation scenario. Long-term preparation such as the planning of routes and construction of crossover lanes may start months or years before a storm. However, the actual implementation must be accomplished in a matter of hours.

In the days before a storm, one of the critical items of business is to decide whether contraflow is warranted and, if it is, to deploy and configure traffic control and enforcement manpower and material resources as soon as possible. In general, the implementation process would begin immediately after it is determined that contraflow is needed. This decision to implement a contraflow evacuation strategy would typically be made by a state EMA (in consultation with DOT officials) based on the characteristics of a particular storm (e.g., size, intensity, and track). Today, the decision process has been streamlined by combining the key representatives of the emergency management and transportation agencies in joint emergency operations or crisis management centers.

The time required to implement contraflow includes the time necessary to clear the segment of all inbound vehicles and to set up controls prohibiting unwarranted access at all interchange ramps. Thus, the advanced notification time of storm landfall is a key factor that influences this decision. In most states, estimates for the time required to fully implement contraflow after the decision has been made range from 4 to 12 hrs depending on the length of the highway in which the operation will be implemented, and the number of interchanges, ramps, or merging points that may require control devices, and law enforcement personnel. As mentioned earlier, one of the most notable exceptions is the state of Florida, where authorities estimate they will require 49 hrs to prepare for a contraflow operation. This time includes notification by the governor, the time necessary to activate the National Guard, and 12 hrs for setup (Collins 2001). Long setup durations also affect the ability to use contraflow as an evacuation tool.

Ending Contraflow Operations

The time required to terminate contraflow operations is just as important as the time needed to implement them. Termination time is critical because it needs to be planned such that it reduces the potential for evacuees to be stranded on open stretches of highway without adequate shelter. In the survey, the two most commonly identified factors that dictated the shutdown criteria for contraflow operations for hurricane evacuations (if not the evacuation in general) were a decrease in evacuation traffic volumes and the arrival of tropical storm force winds.

Even with the common themes of traffic volume and wind speed criteria, there was no universal agreement on the times relative to these criteria from state to state. For example, Virginia plans to shut down contraflow operation about 2 hrs before the arrival of tropical force winds. By contrast, the state of North Carolina plans for a shutdown approximately 3 hrs before the same wind speed. In Florida, the publicly stated termination criterion is the arrival of nightfall. As is similar in Georgia and other states, officials would not likely end contraflow operations if conditions warranted its continued use.

Some states plan to use refuges-of-last-resort for evacuees who may become stranded on the highway. Again, the specifics and usage of these facilities vary widely among the states. In Florida, the Palm Beach County Division of Emergency Management has developed refuges-of-last-resort that include public structures that can accommodate people who cannot or do not evacuate in time to reach safe public shelters. These refuges are located within a mile after exiting the highway and have little or no food, water, utilities, or supervision. They are not guaranteed to be safe in strong hurricane situations; however, they do provide an option that is better than remaining in vehicles during strong winds.

Another option under study in some locations for people who did not or could not evacuate areas threatened by storm-surge flooding is vertical evacuation. In a vertical evacuation, people move to the upper stories of multistory buildings to avoid rising floodwaters. They are, however, still at risk from damage to these buildings caused by hurricane-force winds. Despite the name, vertical evacuation is really a type of local sheltering, not a true evacuation strategy. The basic concept of hurricane evacuation is to move residents and visitors out of the hazardous coastal zones to locations far enough inland that they will not be subjected to storm-surge flooding and hurricane-force winds. In vertical evacuation, people may move short distances to the building identified for use as a vertical refuge, but they remain in the at-risk coastal zone.

Another consideration in determining evacuation shutdown times is the removal of service personnel from the threatened area. Evacuation termination plans try to account for the time necessary to move field traffic control personnel and law enforcement officials from the evacuation routes. Texas is one of the few states that includes explicit shutdown time sequencing into its evacuation timeline. There, it is estimated that 4 hrs will be required to set up the contraflow routes and 5 hrs will be required to shut them down and then evacuate field personnel. In Florida, it is estimated that 8 hrs will be required to set up I-4 for contraflow and 6 hrs will be required to end contraflow operations.

Contraflow Criticism

As the concept of contraflow has recently been more publicized and better understood by the public and EMAs, it generally has been better received. Anecdotal evidence suggests that evacuees are satisfied that government officials are seeking to use all practical means to protect the public despite the difficulties inherent in its use and the cross-jurisdictional hurdles that need to be cleared. However, as with any decision that affects a significant number of people, some groups are opposed to contraflow evacuations and various aspects of its planned use.

Among these groups have been the agencies involved in dealing with the evacuees and the traffic on the outflow ends of the contraflow segments. The number of evacuees that are conveyed by contraflow segments can be enormous. Evacuees arriving on the downstream end of the segments will be required to shelter somewhere. Officials at these destination points are not always confident that they can accommodate all of the evacuees that contraflow can bring to them. The issues they express are primarily associated with the accommodations necessary for a sudden (and perhaps significantly increased) number of evacuees and the impact of traffic load on the local road system.

They contend that, because contraflow will make evacuation a more palatable alternative to sheltering-in-place, more people are likely to evacuate, which would significantly increase the demand for sheltering services. They also fear that the contraflow segments would tend to attract evacuees away from other routes, thereby concentrating both the traffic and numbers of people into a smaller number of areas. Finally, these critics believe that not enough attention has been paid to traffic control at the end of the segments, resulting in an outflow restriction that could bring traffic to a standstill over a substantial portion of the latter part of the route.

Another common criticism of contraflow in specific and evacuation strategies in general is that overreliance on evacuations comes at a cost of not strengthening the building codes to meet the threats posed by hurricanes. Critics believe that there will not be a call for stronger buildings if people can leave them behind in a storm. They believe that this results not only in the problems expressed earlier, but also in higher costs for insurance and more damage to buildings during storm events. In actuality, both strategies need to be pursued. Building codes and construction techniques in hurricane-prone areas need to be improved to allow the option of in-residence or local sheltering for people exposed to hurricane winds but not at risk of storm-surge flooding. This sheltering provides enhanced life safety protection for occasions when complete evacuation may not be possible, such as for hurricanes that spin up quickly near the coast or for storms that rapidly intensify, accelerate, or change course, and thus strike with limited warning. The more people who can safely shelter locally also reduces evacuation demand and clearance times for those who need to evacuate the most (i.e., people in areas threatened by storm-surge flooding). However, improvements in building codes and construction techniques do not help the existing building stock. Even if all new coastal area construction as of today were made storm-resistant, it would be a generation before the majority of buildings would meet these criteria. Therefore, contraflow and other evacuation improvement strategies must be pursued simultaneously with improving the storm-resistance of buildings.

WORK ZONES ON EVACUATION ROUTES

A final and often-overlooked issue in evacuation direction and control has been highway work zones. Construction activities on evacuation routes have been an issue during several past evacuations. All roads must be maintained, and economics dictates that these activities need to be undertaken in ways that often require the closure of travel lanes and, sometimes, entire road segments. However, the risks of diminished capacity could be weighed against the increased costs of modifying the construction season, distance, performance time, or phased sequencing of projects to retain full capacity should an evacuation be necessary.

In 1995, during the evacuation of Hurricane Opal in northwest Florida, numerous short segments of I-10 between Pensacola and Tallahassee were reduced from two lanes to one for overpass bridge reconstruction. Then, in 1998, during the evacuation for Hurricane Georges, the states of Alabama, Mississippi, and Louisiana all had construction zones on evacuation routes. In Louisiana, evacuation traffic on westbound I-10 out of New Orleans was limited to a single lane. A year later, similar problems of construction on evacuation routes were experienced in North Carolina during Hurricane Floyd. Recognition of these problems by the state DOTs have, in some cases, allowed them to request that the contractor clear construction equipment and open both lanes (even those partially constructed) for evacuating traffic. In these cases, contractors acted quickly and delays were minimized. However, this series of repeated problems in different locations suggests a lack of lessons learned.

At an absolute minimum, it has been suggested that DOTs could have procedures in place to at least inform EMAs of construction plans and schedules so that they are not caught by surprise. Some DOTs have made attempts to avoid conflicts by adding special provisions in construction contracts to accommodate evacuation traffic through work zones. The most common way to do this has been to add clauses that require a contractor to cease all construction activities once an evacuation is declared, clear all equipment, and open all lanes of traffic including those under construction. These types of contract provisions limiting lane closures in work zones are not that unusual. Most states, particularly those where traffic congestion is routine, restrict construction that reduces capacity. For example, the Maryland and New York DOTs do not allow construction to restrict traffic on any state arterial route to less than the normal number of lanes during the peak summer travel period from June to September. Although these restrictions cover most of the recognized hurricane season, they do not apply to the less active, though still potentially dangerous, months of October and November.

Other options to maintain capacity through work zones on evacuation routes have included limiting the construction season, distance, performance time, or phased sequencing of projects. However, these types of contract provisions can increase the cost and duration of projects, because they may require a contractor to work in shorter segments or use nonstandard construction practices.

The construction work zone problem is illustrative of the central issue confronting transportation engineering and planning practice as related to evacuations and emergency management, in general—that is, trying to maintain a balance between the needs of evacuations and the enormous need for limited transportation resources for routine conditions. Evacuations are comparatively rare events. Although some locations such as Southern California and the Florida Keys may have to evacuate several times per decade, areas with fewer hazards are likely to evacuate even less often. Locations along the Atlantic and Gulf coasts may have to evacuate only once every few decades. Although improving evacuation capacity could potentially save many lives, it has been argued that it may not be logical to devote significant resources toward planning, designing, and constructing transportation infrastructure for an evacuation that may occur once in a generation, if ever. More creativity and forward thinking could be used to devise ways that transportation services can serve multiple functions and competing needs of special event and routine conditions can be brought into balance.

CHAPTER FIVE

EVACUEE TRAVEL CHARACTERISTICS AND ASSISTED EVACUATION

As with nonemergency travel planning, transportation planning for evacuations requires an understanding of the population that will be traveling during the event. Included in this are spatial and temporal characteristics such as the number and location of the evacuees, when they are expected to evacuate, where they are likely to travel, and what routes they are likely to take. With the recent emphasis on assisted evacuations and the need to provide transportation services for some evacuees, it is also necessary to identify the travel needs of individuals and match them to the transport modes that will be available (or need to be provided) for the evacuation. Given the knowledge and experience of transportation agencies in these types of activities, evacuee and mode travel analyses is another key role that can be addressed by transportation agencies.

The importance of identifying and understanding the travel characteristics and requirements of evacuating populations was demonstrated during Hurricane Katrina when tens of thousands of New Orleans residents chose not to or were unable to evacuate. It has been suggested that an inadequate level of understanding of the threat posed by flooding of the city coupled with a failure to provide adequate transportation services led to the disproportionately high number of fatalities among the elderly of New Orleans. Figure 14 shows that of the 853 storm-related fatalities in Louisiana, at least 584 (nearly 70%) were over the age of 60 and 388 (nearly 45%) were over the age of 75.

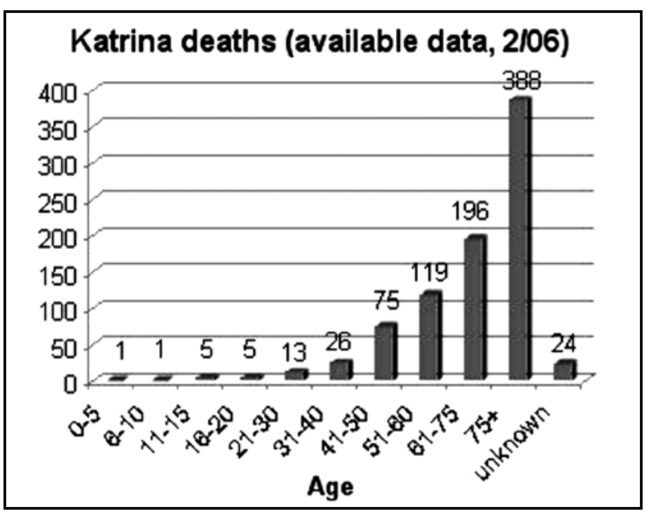


FIGURE 14 Relationship between age and mortality in New Orleans (*Source:* http://www.publichealth.hurricane.lsu.edu/PublicHealth.html).

A study released by the USDOT and DHS in 2006, "Catastrophic Hurricane Evacuation Plan Evaluation: A Report to Congress," showed that plans for evacuating people with special needs are "mostly nonexistent." In 2006, U.S. Government Accountability Office publication "Transportation—Disadvantaged Populations: Actions Needed to Clarify Responsibilities and Increase Preparedness for Evacuations" also highlighted similar needs (GAO 2006).

Although the debate over the responsibility for the movement of New Orleans nonevacuees continues and will likely carry on for many years, many government agencies have recognized the need and have taken a greater responsibility in future assisted evacuations. Even with these good intentions, it will be necessary to know how many people are in need of transportation assistance, where they are located, and what type of assistance may be needed, which greatly complicates the process. Equally challenging will be maintaining up-to-date records of this information, particularly in large urbanized areas where the potential number of people involved makes data collection and recordkeeping both practically challenging and enormously costly (TRB 2008c).

This chapter summarizes current knowledge in the identification, classification, and understanding of characteristics and needs of evacuating populations. In addition to presenting general characteristics of various self-evacuating and non-self-evacuating groups, this chapter discusses the development of recent plans to communicate with and address the transportation needs of these groups using a variety of private and public resources.

A great deal of the information in this chapter comes from two recent federal studies that were under development at the time this report was written, including a congressionally mandated panel study by TRB of the National Academies titled "Role of Transit in Emergency Evacuation" (TRB 2008c) and the FTA's "National Study on Carless and Special Needs Evacuation Planning" led by John Renne at the University of New Orleans (Renne et al. 2008a). It is expected that both of these studies will become available for public use concurrently with the publication of this synthesis or shortly thereafter. This chapter also relies heavily on many of the discussions and issues brought to light at the *2007 National Conference on Disaster Planning for the Carless Society* held in New Orleans. The enormous amount of detail and useful information contained in these reports and conference summary cannot be fully summarized in a single chapter of this report. However, interested readers are encouraged to review these documents.

EVACUEE CHARACTERIZATION

One of the first steps in planning evacuations, particularly assisted evacuations, is determining the characteristics of the evacuating population. A factor that has complicated this process is the growing number and diversity of terms used to define various evacuating groups and the variation of these definitions. One example is the term *special needs,* which is often used to describe evacuees who require some form of assistance and who may, in whole or in part, be unable to evacuate themselves.

In the past, the special needs definition was limited to groups requiring major medical support assistance. Over time, the scope of this definition has been widened to include other groups that require other forms of care, such as the elderly and mentally or physically disabled. More recently, it has been broadened further to include nearly anyone not capable of moving themselves as well as the "chemically dependent" and others who "may not necessarily be part of 'main-stream' modern American society, including those with mobility, sensory, or cognitive impairments as well as those with limited English proficiency" (Renne et al. 2008b). In one of the latest definitions, the definition has been broadened even further to include the concept of "carless evacuees." The broadly encompassing definition includes "anyone, for any reason, that does not have access to an automobile or the ability to use it for purposes of evacuation (no money for gas/lodging, fearful of operating it under stress, etc.)." It also includes the young, elderly, disabled, poor, and anyone else who does not drive.

Although the transportation-related characteristics and needs of every evacuee are different, both practitioners and researchers of evacuations have found it useful to categorize evacuee travel behaviors, needs, and characteristics into general groups to plan for and serve their needs. Characteristics ranging from the willingness and ability to evacuate to walking speeds, transit loading times, space requirements on buses, and so on can significantly affect the amount of resources that must be allocated as well as the times and locations at which they will be needed. Other important evacuee attributes include the size and distribution of special needs populations within a city as well as the means by and times at which they may be making their trips. Much of this information can be developed using demographic characteristics from the U.S. Census, including vehicle ownership, economic status, age, and other disabilities that can be used to predict evacuation travel behavior.

Evacuation Willingness and Ability

One method of categorizing evacuees is by their ability and willingness to evacuate when emergencies arise or when evacuation orders are given. To illustrate these relationships, the four-quadrant map of Figure 15 is used. In the figure, a person's or group of individual's willingness to evacuate is represented on the x-axis. Moving left to right along this axis implies the willingness of persons to evacuate. The right side of the figure describes the most cautious type of evacuees. In practice, these individuals would be among the first to evacuate—in some cases, before formal evacuation orders are even issued. At the left of the figure are people who are much less willing to evacuate. Although individuals in this area of the graph are often characterized as stubborn,

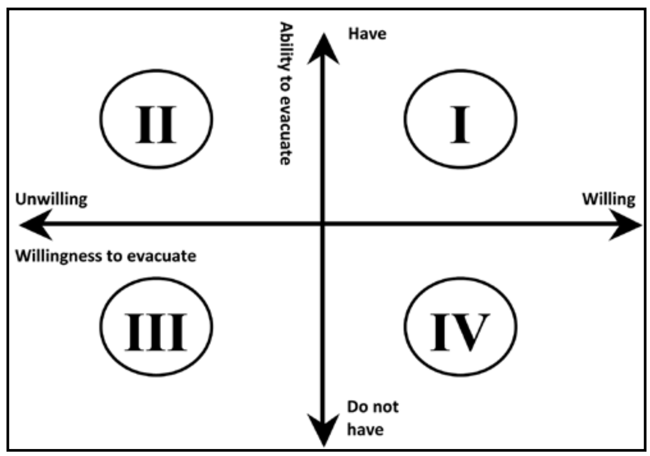


FIGURE 15 Willingness versus ability to evacuate.

poorly informed, or thrill-seeking daredevils, the reality is that many people who do not evacuate when encouraged or ordered to do so, often do not leave for quite practical and necessary reasons.

In past evacuations, people have not evacuated because they thought it was safe to stay or because they believed they needed to protect their homes and property, tend to pets, or take care of a friend or relative who (often because of age or disability) was not able to be safely evacuated. Reports developed by the American New York Academy of Medicine and the American Association of Retired Persons (AARP) suggested that low-income and minority persons, the elderly, immigrants, and people with low-education attainment are hesitant to evacuate because of a lack of trust in the government.

A person's or group of individual's ability to evacuate is represented on the y-axis of Figure 15. The majority of persons in most areas of the United States would be described by the upper half of the graph. Compared with most countries, American society tends to be highly mobile with great emphasis placed on individual transportation. This is not, however, the case in all cities. Recent studies by the FTA have shown that the percentage of the population without access to personal transportation (described earlier as "carless" populations) in cities such as New York and Boston is about 50% to 60% (Bailey et al. 2007). The lower half of the graph would encompass these individuals. People in this population can range from wealthy, able-bodied, people who choose not to own a vehicle; to the economically disadvantaged, elderly, and infirm populations; to people who are fully dependent on the assistance of others for the most basic of life-sustaining necessities.

Persons within the latter parts of this description, although comparatively fewer within the total population, are among the most vulnerable segments of society and often require the most significant allocation of resources, both economic and manpower, during an evacuation. Examples of special resources used in recent evacuations include assistance devices such as lifts and ramps on buses. In New Orleans, identification devices such as scannable hospital bracelets have been planned to track and anticipate the needs of people as they move through the state-assisted evacuation system.

The four quadrants of the figure illustrate the areas of transportation planning needed in an evacuation. The most obvious group, and the one that historically has received the most targeted planning and management efforts, is included in Quadrant I. These are the evacuees who are willing and able to evacuate on their own. They include able-bodied individuals with their own vehicles, commonly referred to as *self-evacuators*. In most areas of the United States, self-evacuators make up the vast percentage of an evacuating population, particularly in locations outside of major cities where few transit resources exist. Evacuation planning for self-evacuators has tended to focus on highway management techniques such as contraflow, phased evacuations, priority signalization, and so on. These techniques have been most desirable because they are also often the most cost-effective and least labor-intensive methods in terms of resulting evacuation clearance and travel time improvements.

Evacuees in Quadrant IV are generally characterized as those who would like to evacuate but are unable to do so without some form of assistance. The level of the assistance required for these *non-self-evacuators* or *assisted evacuees* varies widely based on individual needs. As such, they can range from able-bodied persons without a personal vehicle who may be able to do something as simple as rent a car or arrange a ride from an acquaintance, to incapacitated persons on various forms of life support who require transport by ambulance or life-flight aircraft.

To plan for and allocate transportation resources to evacuees with such diverse needs, transportation agencies must determine how many people require assistance, assess their needs, and identify their locations. Before Hurricane Katrina, this level of planning in major urban centers was not widely or effectively undertaken. In the years since, emergency agencies across the country have substantially increased their effort to plan for the evacuation of such individuals.

To identify the number and location of assisted evacuees, the city of Houston has developed an online hurricane evacuation transportation registration system. Using user-provided input, the Houston system classifies special needs evacuees into five categories based on the type, amount, and level of complexity of assistance that would be needed (City of Houston 2007). They include the following:

- Level 1—A person dependent on others or in need of others for routine care (eating, walking, toileting, etc.); child under 18 without adult supervision, etc.
- Level 2—A person who is blind, hearing impaired, deaf/blind, or has an amputation, including any of the above with a service animal.
- Level 3—A person needing assistance with medical care administration, monitoring by a nurse, dependent on equipment, assistance with medications, mental health disorders.
- Level 4—A person outside an institutional facility care setting who require extensive medical oversight (i.e., IV chemotherapy, ventilator, peritoneal dialysis, hemodialysis, life-support equipment, hospital bed and total care, or is morbidly obese).
- Level 5—A person in an institutional setting such as hospitals, long-term care/assisted living facilities, or state schools.

Discussions with experts in the area of transit-supported evacuation suggest, however, that the preregistration of special needs populations for evacuation is not working effectively. A transit manager of a major metropolitan city advises transportation agencies to shift toward information management of existing information and away from past methods of identifying and preparing for special needs evacuation and to investigate programs that involve vouchers for the elderly and disabled. It was also urged that drivers of transit vehicles receive some level of training and certification to permit them to address health incidents during transport.

Experts urge transit operators and maintenance personnel to be trained in and familiar with the National Incident Management System (see Appendix B) and be able to respond with flexibility during evacuations. They recommend that transit agencies know how to use their transit vehicles, staff, and resources for evacuation while normal service continues and until the conditions associated with a hazard require a complete system shutdown of service. In a prior emergency, buses needed to be removed from normal service and immediately unload passengers in a safe area. At that point, those passengers effectively became transportation dependent, requiring additional resources, and further complicating the overall evacuation.

Populations included in Quadrants II and III of Figure 15 remain an ongoing issue from a transportation perspective. Transportation plans are not made and do not account for individuals who do not seek to travel. Although opinions vary as to its impact, it is possible that the reasons for some people's unwillingness to evacuate may be related to transportation issues. These include conditions such as intolerable traffic congestion and delay; confusion in selecting and accessing travel routes; and perceived difficulties in accessing the necessary mode of transport. Recently, as more comprehensive evacuation transportation plans have been created, various transportation agencies have sought to better communicate route guidance and transit availability information to threatened populations in the hopes of reducing the percentage of nonevacuators.

Evacuation Travel Movements

Using the physical and behavioral characteristics of evacuee travel, it is possible to understand the movements of evacuating populations. These, in turn, can be used to develop plans and aid in the identification and allocation of transportation resources during evacuations. This information can incorporate temporal characteristics, including when evacuees will make their departures, how long it might take them to clear the hazard threat zone, and when they might be expected to arrive at their destinations. An example of how evacuee travel characteristic can be used was illustrated in a recent activity-based evacuation traffic simulation study of New Orleans in which it was necessary to model both self- and assisted-evacuee travel for the purposes of an areawide traffic analysis.

In the study, evacuees were broadly categorized into three groups based on their access to and use of personal transportation; their need to use transit buses; and their need to have transportation services provided directly to them. These three groups are summarized in Table 3 and are described in more detail in the following paragraphs.

Group 1 Evacuees

The first of the three classification groups used in the study, shown in Table 3 as Group 1, were the *self-evacuators*. Based on U.S. Census population data characteristics for the region, Group 1 households included about 70% of the modeled population. In the context of the study, Group 1 evacuees were easiest to model because there was no need for them to interface between modes of transportation. This is important under real-world conditions because modal interchanges can slow the evacuation process. Spatially, Group 1 evacuees were assumed to be uniformly distributed across the study area. In real life, however, the percentage of self-evacuators varies based on the existence of hospitals, care centers, and income demographics. The model was able to take advantage of U.S. Census statistics to evaluate vehicle ownership in various locations as well as to determine localized traffic demand.

Group 2 Evacuees

The second and third groups were defined based on their lack of access to personal transportation or other limitations that would impede the ability to self-evacuate. Although such individuals are often included in the "carless evacuee" definition, they can be quite diverse in terms of travel behavior and need. They include able-bodied individuals who use non-auto-based transportation modes such as transit, bicycle, or walking, as well as the elderly, persons with disabilities, or those under medical care. In the study, it was assumed that carless individuals would be dependant upon third-party transportation. Although such an assumption was deemed to be reasonable (and useful) for the modeling, in reality, such assumptions are not always true because many carless individuals receive rides with friends and family. For planning purposes, other sizable carless subgroups include tourists, the economically disadvantaged, and incarcerated individuals. Specific individuals can overlap more than one of these groups. For these reasons, such groups are complicated to plan for and to model. In terms of movements, Group 2 evacuees were assumed to be the predominant users of the bus transit services and also were assumed to have the ability to walk or otherwise travel to one of the transit bus evacuation boarding locations.

TABLE 3
EVACUEE MODE CHOICE

Evacuee Group	Access to Personal Transportation	Utilization of Public Transit Buses	Utilization of Private or other form of "provided" transportation
1 – Self-evacuators	Yes	No	No
2 – Able-bodied non-self-evacuators	No	Yes	No
3 – Dependent non-self-evacuators	No	No	Yes

Census statistics show that, in most major U.S. metropolitan areas, the percentage of zero-vehicle households exceeds 15% of the total population, with some major cities such as New Orleans and New York exceeding 30% (Bailey et al. 2007). Given the average household sizes of three or four people, the number of actual individuals without vehicles can include hundreds of thousands of individuals in large cities.

Group 3 Evacuees

The third group, Group 3, is also carless but made up of special needs individuals unable to move themselves even for short distances. As such, this group was classified as *dependent non-self-evacuators*. These individuals are reliant on others for their movement during an evacuation. Evacuees in this category include people who are disabled, hospitalized, and incarcerated, or in some cases, elderly evacuees who are unable to drive themselves or otherwise reach a transit pickup point. Group 3 individuals require additional transportation services, such as paratransit, privately contracted bus services, ambulatory transportation, and secured transportation.

The locations of Group 3 evacuees can be estimated using land-use information, such as hospitals and care center housing, in addition to population statistics. Transportation resources for Group 3 individuals are often arranged directly by the administrators of the facility in which they reside. Thus, they are not as reliant on public transportation assistance as Group 2 evacuees. The total number of such individuals is also smaller than the previous evacuee groups. This does not, however, imply that such individuals should not be included in evacuation transportation plans, rather their impact on and contribution to the overall traffic conditions within a network is comparatively minimal. A final note of concern with some of the non-able-bodied evacuees is that their physical conditions may make it difficult to move them or keep them in transit for substantial periods of time. In such cases, difficult decisions that weigh the pros and cons of sheltering-in-place come into consideration. Recently, some have suggested restricted-use evacuation lanes for use by special needs transport vehicles to reduce the travel time for frail evacuees.

Temporal Characteristics

From the standpoint of travel demand estimation, the temporal aspects of evacuation departure processes are less complex than those of routine travel periods. Normal daily travel patterns involve several peaks that move in various directions during the day. Evacuation travel follows a pattern in which traffic moves in a single (outbound) direction and within one or two distinct time windows. Knowledge of these temporal patterns is important for the allocation of assisted evacuation services as well as to determine when to implement and terminate evacuation traffic management and control measures.

Figure 16 shows a cumulative departure curve typical of hurricane evacuation travel process. Advance-notice evacuations tend to follow an S-shaped pattern. Initially, evacuees load the network at a slowly increasing rate until arriving at a rate that is limited by the capacity of the network (i.e., vehicles cannot load any faster). Ultimately, as the threat clears, or as nightfall arrives, evacuation demand tails off as fewer evacuees enter the system. Figure 16 is taken from traffic data collected during the Hurricane Katrina evacuation; the curve shows a double S-curve form because the evacuation took place over a two-day period. As the slope steepness of the curve is a function of the amount of traffic observed from hour to hour, the steepest curve segments reflect the peaks of the evacuation during the daylight hours of Saturday, August 27, and Sunday, August 28. Similarly, the curve is much flatter during the beginning and ending of the evacuation as well as through the overnight hours from Saturday to Sunday.

What the curve does not show are the related travel activities that were taking place within the evacuation zone. The lengthy warning times afforded by advancements in metrological forecasting makes it possible for preevacuation mobilization activities to occur over several hours or even days in advance of the storm. During this time, activities may include multiple trips between various locations and the incorporation of several activities, such as travel between places of employment, shopping, and home; retrieval of children from school; travel to the homes of friends and family; coordination of several evacuation parties; and the need to fuel of one or more vehicles. For people without access to personal transportation, the process can involve the interface of several different modes of transportation that take place at various locations, requiring various durations, at various times during the evacuation event. An additional temporal issue can arise when transit-based evacuations take place during periods of low or high nonemergency transit ridership and when connections might be necessary between multiple modes of transportation. For example, transit buses may not be available in significant numbers if a no-notice evacuation event were to occur during an off-peak time in which service providers' shifts and bus availability were at a low level.

The aggregated data of the evacuation departure curve do not capture the relationship of location and departure time. Although not always the case, evacuees closest to the threat area tend to evacuate first. In areas where phased evacuation plans are implemented, such patterns are explicitly encouraged as discussed in the preceding chapter.

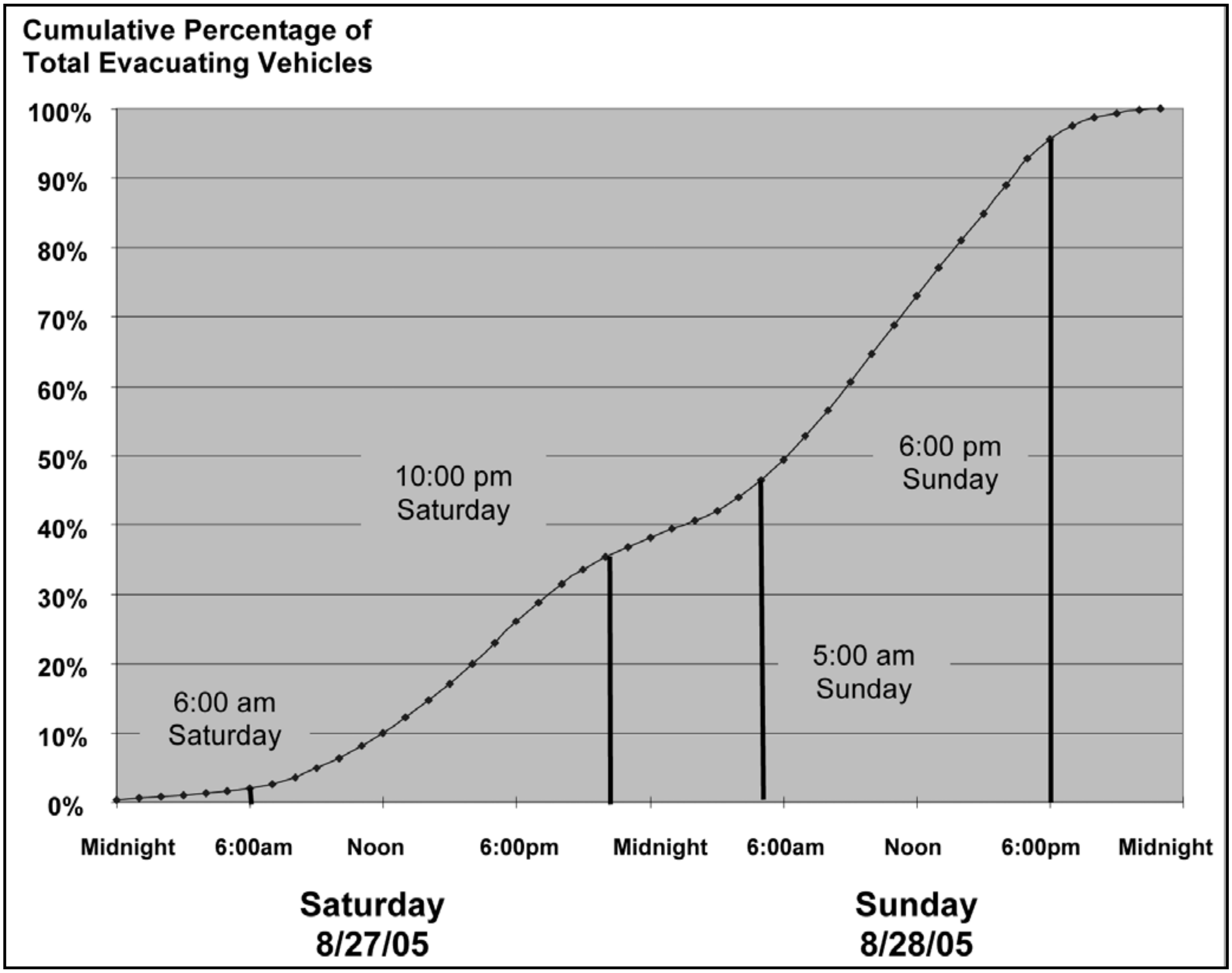


FIGURE 16 Cumulative evacuation departure curve (*Source:* Wolshon 2008).

CARLESS EVACUATION STUDY FINDINGS

To better understand the current state of practice and gauge the levels of preparedness and need for carless evacuees, the FTA sponsored a study of issues. A group of researchers led by John Renne from the University of New Orleans completed a series of reports included in the "National Study on Carless and Special Needs Evacuation Planning" (Renne et al. 2008a,b). The goal of these reports was to study the disaster vulnerability of carless populations and evacuees with special mobility needs to better understand the state of carless and special needs evacuation planning in the United States. The first report included a comprehensive literature review of information in the field and the second was a report of carless evacuation challenges, needs, issues, and practices using stakeholder focus groups. The utility and amount of information contained in these reports makes them a vital resource to any agency engaged in assisted evacuation planning. The following sections briefly include many of the major findings of these reports.

Needs and Challenges

When stakeholder focus group agencies were questioned about challenges, they stated that outreach and identification of special needs or carless persons were their two greatest issues. Low participation in disaster registries and assisted evacuations was also noted. Study participants stated that information was critical during an evacuation. It was found that the general public needs to first and foremost be aware of the risk level, evacuation routes, and other important safety information. However, participants also stated that providing such outreach for special needs and carless populations was challenging, because these populations tend to be quite diverse and have a variety of needs and demands that can be dynamic. For example, resources may need to be allocated to carless persons, seniors, disabled adults, the homeless, the socially isolated, the blind, the hearing impaired, those that do not speak English, the paraplegic, those in postoperative recovery, the illiterate, and populations with pets.

The report stated that the term “outreach” should always represent information flow in two directions. Agencies must reach out to the public with important information regarding the importance of evacuating early, the assistance available to them, and how to access it. Outreach was also framed in terms of creating *personal responsibility* for continual preparedness. Agencies suggested that this personal responsibility could emphasize knowing what to do during an emergency, including knowing how to evacuate, having “go-bags” always at the ready, and having emergency supply kits prepared in advance of a disaster. The Miami stakeholder group stated that such outreach was best achieved through a focused, consistent, and unrelenting public information campaign.

The report found that vital information also comes from the community. People with special needs or carless people need to reach out to the appropriate agencies so that their needs are accommodated during an emergency. A review of Internet resources by the research team showed that online methods to identify special needs evacuees have become an increasingly popular method of two-way communication to assist in the allocation of transportation resources to non-self-evacuators. In Houston, the city’s Office of Emergency Management has implemented an online system for the registration of special needs transportation services for hurricane evacuations (City of Houston 2007). The system allows users to register for services by entering key pieces of identifying information. The system also communicates information in both English and Spanish.

Although many cities offer these types of disaster assistance registries, their effectiveness remains somewhat suspect as participants in the FTA study noted a number of issues with current systems. In New Orleans, for example, it was found that only a fraction of the population has registered for assisted evacuation. This is not uncommon. The Miami stakeholder group noted that it would be impossible to provide service to all of its registrants within a short period of time. Registries provide crucial emergency resource planning information and a real opportunity for agencies to respond to individual needs, but the report found that more attention needed to be spent on thinking through the logistics of how registries are set up and how they will work during an emergency.

The identification of special needs or carless persons has to overcome confidentiality issues. The public’s concern over confidentiality needs to be appropriately addressed to avoid low participation. Just as an undocumented immigrant may be reluctant to register with a disaster assistance registry out of fears of deportation, a senior may be equally reluctant because of concerns about personal privacy. However, special needs can be better identified using preexisting networks. Examples have included the creation of Community Emergency Response Teams such as San Francisco’s “Community Disaster Response Hub” concept that has been shown to increase the efficiency of bringing resources into a disaster area.

The FTA reports identified reasons why some segments of carless and special needs populations often were reluctant to evacuate when ordered to do so. These reasons ranged from “attachment to place” to a basic complacency about the level of danger. Such attitudes were particularly evident in the event of hurricane evacuations. Often, planning changes are developed as a reaction to past disasters. After several years without a problem, however, levels of complacency among people tend to increase, as if they believe it will not happen again. Recently, there have been several incidents in which evacuation buses have been sent out during an emergency, but they returned with very few people. The report’s authors used the example of Miami residents who have ridden out Hurricanes Andrew and Wilma and consequently do not believe they are threatened. As a result, transportation officials have seen evacuation buses go underutilized. Another past problem can resurface when many people do not evacuate and a significant disaster occurs. In such cases, posthurricane evacuations become necessary as seen in New Orleans following Hurricane Katrina.

Planning and Coordination

The focus group participants noted that as the scope and severity of a disaster increase, the cross-jurisdictional interactions of evacuation planning also grow in number and complexity. These complications are particularly acute for the carless. Examples of difficulties associated with cross-jurisdictional interaction have been seen throughout the country. Although several of these problems have been identified in past disasters or preparedness exercises, most are not realized until the occurrence of an event. Based on the report findings, it is apparent that most of them are yet to be resolved.

In Florida, the Miami–Dade County Transit Authority supplies evacuation buses to Monroe County (i.e., the Florida Keys). Because only a single road connects the Keys to the Florida mainland, the entire evacuating population of Monroe County passes into Dade County. Thus, to some extent, all Monroe County evacuees become the responsibility of Miami–Dade County. In California, San Francisco has made substantial progress toward organizing a community-based response. However, study participants from that area agreed that intergovernmental agreements regarding transit use for assisted evacuations are not entirely formalized. In several areas, only “gentlemen’s agreements” are in place to address various needs, such as quickly arranging to have every available transit driver assigned to the nearest city vehicle in the event of a disaster. In reality, however, considerably more vehicle training is needed for drivers, which is difficult to both mandate and implement.

Participants in the study also noted that, in assisted evacuation planning, it is important to distinguish between two broad categories: *temporarily carless* and *permanently carless*. These two groups offer separate and distinct challenges. For those requiring medical assistance, for example, many issues would arise if strangers were to help them evacuate. Although regular caregivers best know the needs of their clients, they also may be evacuating. In Chicago, the Chicago Association of Retarded Citizens assists 1,500 clients with 600 staff members and a fleet of vehicles. This organization would face two major challenges in the event of evacuation: (1) loss of staff as a result of evacuation and (2) limited communications to coordinate their evacuation with the city's efforts. Chicago is an interesting case because it does not make evacuation routes and shelter locations publically known in advance because of security concerns. Because the nature of disaster planning in Chicago is focused on no-notice emergencies, it was believed that publicizing routes and shelters could compromise public security. As such, people would not know where to go during an event. The consequences of this issue are somewhat lessened, because it is widely recognized that most evacuation routes essentially would be "snow routes." Nevertheless, nongovernment involvement must rely on direction from local authorities in the event of an emergency.

In New Orleans where enormous improvements have been made in the area of assisted evacuation since Hurricane Katrina, officials continue to have difficulty identifying, locating, and communicating with carless and special needs populations. When asked, "What are the biggest challenges in meeting the evacuation needs of the carless?" the consensus of the local focus group was, "Identifying people who need assistance, communicating to them what assistance is available and how to access it, and convincing them to use that assistance to leave early." Members detailed continuing difficulties in identifying, locating, and educating vulnerable residents, along with concerns about the availability of appropriate transportation resources. Representatives perceived self-reliance as necessary, and called for increased outreach to vulnerable populations, including the elderly, disabled, homeless, non-English-speaking and immigrant groups, service providers such as law enforcement, health care providers (including mental health and addiction services), clergy, neighborhood associations, and community groups.

Although the post-Katrina elderly population of the New Orleans has decreased, the number of homeless residents and those with limited English proficiency has increased dramatically within city. Identifying, locating, and communicating with carless and special needs populations is hindered by the constant transience of these groups. Complacency as a result of past experience or perceived safety was also cited as a concern. An advocate for the elderly stated that only 1,600 to 1,700 people have registered for the 311 emergency information and assistance system.

Another issue of evacuation coordination identified in New Orleans was liability concern. In particular, legal obstacles discourage private sector involvement. It was suspected that private sector participation had been discouraged by exposure and vulnerability to lawsuits as well as the insecurity of reimbursement. This issue has been addressed in 2008 based on a legal opinion issued by the Louisiana Attorney General limiting the legal exposure of groups and individuals seeking to assist. Focus group participants believed that large-scale disasters required a state and federal response, which had been hindered by current structures of coordination and command, as well as the distribution of responsibilities and resources.

Finally, in New York City, one of the most significant planning concerns is a lack of vehicles to transport the carless. Local officials stated that even if all available fleets are taken into consideration, there still would not be an adequate supply for the city. This is because nearly 60% of New York households do not own a car. Because of these conditions, it was apparent that mass evacuation on foot was the most efficient mode of evacuation during the September 11 terrorist attacks. For the disabled populations of the carless, this could require people in wheelchairs to push their way out of the city during the next major disaster. For those using motorized mobility devices, dead batteries could seriously complicate matters, possibly leaving people stranded waiting for ambulances. The City's Disability Disaster Preparedness Committee looked at evacuation issues for special needs persons as well. They defined evacuations as their biggest challenge or the "Achilles' heel" of their planning effort. Pursuant to this realization, they have made recommendations to have buildings of more than three stories equipped with evacuation chairs. Despite all of this attention, it was recognized that special needs evacuation planning has been relatively avoided, and the city sees the need to move toward planning for better use of the transportation resources, including ramp taxis, lift-equipped municipal buses, and paratransit vehicles.

CHAPTER SIX

COMMUNICATION, DATA EXCHANGE, AND PUBLIC INFORMATION

A critical component of an effective evacuation is the exchange of timely, accurate, and useful information. Evacuees need to know whether they should evacuate, when they need to leave, and where they could go. Thus, authorities need to be able to provide this information and to suggest routes to avoid, places to find assistance, and more. Although this appears to be a simple task, communications during emergencies is challenging. This is true not only between authorities and the public, but also between and within the agencies charged with directing evacuations. In the past, it has been apparent that many agencies involved in the process were working separately. In referring to the evacuation that preceded Hurricane Floyd, a FEMA hurricane program manager stated that "each state planned and carried out its evacuation in isolation as if it were an independent republic with restricted borders. Everyone did his own thing" (Tibbets 2002). In the years since Floyd, significant strides have been made to improve inter- and intrastate communications as well as communications within and between agencies and jurisdictions, and with field personnel.

Repeated communication difficulties have arisen during several recent evacuations, including those following the September 11 terrorist attacks and Hurricane Katrina. These problems have led to improvements in interoperability and redundancy of emergency communications. Over this time, views on the exchange of data and communications also have changed. Communications during evacuations are now looked on within a wider context of data and information exchange as a two-way process in which information flows between agencies involved in the event. Communications are required to and from remote-sensing and data acquisition devices. From a temporal standpoint, the following evacuation-related information also must be communicated:

- Before an evacuation (many weeks, if not months) to help potential evacuees become aware of, prepare for, and develop strategies to ensure their personal safety
- During an evacuation to give transportation- and sheltering-related guidance
- After an evacuation to let evacuees know when they may return and areas they may not be able to access.

This chapter highlights the types of information that need to be communicated during evacuations, what it is used for, and the agencies that need to use it. It includes a review of methods and systems used by transportation agencies and emergency management to communicate information to evacuees. Some of these methods and systems include public information and awareness campaigns, such as public education and outreach programs; spatial and temporal methods of traveler data acquisition, processing, and information dissemination; and the use and development of methods to convey information to evacuating travelers, such as television, radio, print, newspaper, websites, mail, e-mail, telephone (reverse 911), Internet, VMS, and HAR. This chapter also includes a discussion on collecting information from evacuees so that plans can be developed for the use of transportation resources, when necessary.

EN-ROUTE DATA ACQUISITION AND EXCHANGE

Access to timely and accurate traffic information during evacuations is critical for the management of evacuation processes. Information about traffic flow rates and speeds, along with lane closures, hazard conditions, incidents, and the availability of alternative routes is needed to effectively guide evacuees. During many recent evacuations, access to and exchange of accurate and timely traffic information has been difficult. Comments from emergency management officials showed that they often found themselves "working blind," with little quantitative knowledge about which evacuation routes were flowing well and which were gridlocked. As a result, these officials were unable to direct traffic away from routes that were congested to nearby roads that were carrying little traffic.

One of the ways that transportation agencies have responded to the need for up-to-date evacuee traveler information is through the application of intelligent transportation system (ITS) technologies. All of the transportation agencies contacted for this review incorporated existing and developing ITS technologies into their response plans for evacuations. The most common area of ITS application is for real-time monitoring of travel conditions. Several states, most notably South Carolina, Florida, and Louisiana, use remote traffic detection systems. The most important quantitative evacuation traffic data available from detection devices are volume and speed. This information can be used to guide officials when determining when to start and end an evacuation and can be used to reroute traffic. By comparing traffic flow with historical data, officials can determine whether volumes and speeds are higher or lower than normal and evaluate this information against the capacity of the routes. Such data can yield insights into the existence of flow impeding incidents.

By federal requirement, all DOTs incorporate some type of statewide traffic data recording program into their routine planning activities to monitor and assess statewide traffic volume and speed characteristics. Although the design of individual systems vary, they typically use a remote-sensing system (i.e., pavement loops) and a basic traffic data recorder. Under routine operation, data from even the most primitive systems can be downloaded through telephone connections. Recently, minor modifications to these same systems have allowed DOT officials in some states to retrieve this information on an hourly basis or in 15-min increments during evacuations. The modifications allow data to be assembled and displayed in tables and graphs to monitor the progression of the evacuation, track volume changes, and identify routes with excess capacity. Although these systems may not provide real-time data, they can give EMA and DOT evacuation coordinators a much better idea of up-to-date travel conditions than they have received in the past (Wolshon and Levitan 2002). In Louisiana, DOT officials have integrated traffic data recorders at several key locations into the U.S. Geological Survey's Louisiana HydroWatch systems. With this integration, authorities in Louisiana are able to receive updates on both traffic and flooding conditions in the state through satellite communications.

Another common type of surveillance method is closed-circuit television cameras (CCTVs) that are capable of remotely monitoring traffic speeds and flows. CCTVs have an advantage over loop detection in that they can also provide direct visual confirmation of traffic and weather conditions at remote locations. These cameras can be used to detect incidents and verify their removal. One of the limitations of CCTV is that, unlike the count stations described earlier that can operate on solar power and transfer small volumes of data, it typically requires direct power and hardwired communication connections. This connectivity is often difficult to achieve in remote locations along evacuation routes.

A significant limitation in the application of ITS to hurricane evacuation monitoring and management is that most ITS infrastructure is concentrated in urban areas, whereas many evacuation routes, particularly for hazards such as wildfires and hurricanes, are in rural areas. To address this, several states use portable communications systems, such as HAR, DMS, and mobile traffic data recording systems (Ishak et al. 2008). These self-contained mobile data collectors can be used to provide real-time traffic flow information using wireless communication technologies deployed to any location. Another limitation of ITS is its expense. Because evacuations are infrequent and cover wide areas, it is difficult to justify the cost of these systems solely as an evacuation tool unless they can incorporate multipurpose functionality for everyday use.

EVACUEE GUIDANCE

By definition, evacuations are dynamic events. Even under scenarios with substantial advanced warning time, conditions can change such that routes of egress become closed, problematic for travel, congested, or blocked by traffic incidents. Because of this, it is helpful to have the ability to communicate to evacuees during their evacuation transit. In addition to en-route communications, both emergency management and transportation agencies have developed plans and procedures to communicate with potential evacuees long before hazard conditions arise so that they can anticipate their needs and plan accordingly and know when they may be able to return.

The review of practice showed that a wide variety of communication methods and systems have been or are planned for use. Also evident were the types of information passed to evacuees and the methods used to acquire and disseminate this information. Among the key transportation-related guidance information of need are the following:

- *Who* needs to evacuate and who does not
- *When* people need to evacuate
- *Where* they need to go
- *What* routes they need to take to get to their destination

In areas with well-recognized hazards such as nuclear power plant emergencies, wildfires, and hurricanes, public education for evacuations is routine. These locations have well-developed public education and outreach campaigns that target messages to potential evacuees. Evacuation route maps and tip sheets are disseminated in stores, newspapers, phone books, and even utility bills. Officials also commonly work with local media outlets to announce the beginning of high-threat seasons and hold public informational meetings to which local news outlets are invited.

Among the best-developed campaigns are the public information plans and procedures used for nuclear power plant evacuations. As part of their licensing requirements from the NRC, each nuclear power plant operator is required to develop detailed evacuation plans for all people within a 10-mile radius of their facility. Included in these plans are also the phone numbers, locations, and needs of populations requiring evacuation assistance. The plant operators then conduct drills in cooperation with local emergency managers, law enforcement, and other first responder agencies. It is notable that, despite the longstanding threat from other natural hazards such as floods, fires, and hurricanes, few agencies have as well-developed plans as those of the nuclear power industry.

Although evacuation mass communication is outside of the direct expertise and guidance of transportation agencies, several communication means are available to them and under their control. Two of the most highly utilized (and planned) are HAR, VMS, and DMS. To make the most effective use of the limited range of HAR (it typically has a range of about 3 to 5 miles), many states place transmitters in advance of exits and interchanges where services and alterative routes are available. Portable, trailer-mounted HAR systems can be moved to any needed location. The type of information conveyed through HAR and DMS usually includes shelter locations, alternative evacuation routes, congestion, incident information, and locations of services such as gas stations, rest areas, and lodging. As an alternative to traditional HAR, some states have acquired commercial AM and FM radio stations for use as a statewide travel information station. During nonemergency periods, these stations are used to disseminate general travel information. Relatively small states such as Delaware have the ability to use a single station to cover the entire state. In Florida, the DOT teams with the state's network of public radio stations during emergencies to broadcast travel information, simultaneously, throughout the state.

Another form of evacuation information communication that has gained favor with DOTs is the Internet. Use of the Internet can be combined with ITS to enhance its capability. Today, nearly all DOTs and EMAs maintain websites to keep people informed of evacuation routes, road conditions, and weather information. Some emergency management websites provide links to hotels within and outside of their state to facilitate booking hotel reservations. EMA websites can provide evacuees with information about evacuation routes, road conditions, and shelter availability. Several agencies have translated this information into Spanish for areas of the country with large Hispanic populations.

These Internet information systems have been targeted primarily for use before the evacuation because of the limited availability of wireless Internet along evacuation routes. However, there is little doubt that future wireless-Internet technologies will allow these sites to be used with ever-increasing frequency in the years to come.

INTERNAL INFORMATION EXCHANGE

Internet computer resources have grown as a means to communicate evacuation planning and operational evacuation information among agencies. One of the most robust and useful resources for the dissemination of plans, reports, and other emergency preparedness documents is the DHS's LLIS. Available to U.S. citizens at www.LLIS.gov the online system is

> the national network of Lessons Learned, Best Practices, innovative ideas, and preparedness information for homeland security and emergency response professionals. By facilitating the sharing of knowledge, LLIS.gov enhances the nation's ability to prepare for and respond to terrorism, natural disasters, and other incidents. LLIS.gov is not only a repository for information but also a network that enables homeland security and emergency response professionals from across the country to share their knowledge and expertise in a secure, online (DHS 2006a).

The system is designed to allow secure restricted access to information to facilitate efforts to prevent, prepare for, and respond to acts of terrorism and other incidents across all disciplines and communities throughout the United States. All lessons learned and best practices reports are peer-validated by homeland security professionals. The site also houses an extensive catalog of After Action Reports and homeland security documents from DHS, and other federal, state, and local organizations. This single-source reference is a "must-use" for any transportation agency involved in any type of emergency transportation work.

CHAPTER SEVEN

REENTRY

After the passage of hazardous conditions, evacuees often seek to return to their homes, businesses, and properties as soon as possible. The desire for a quick return is motivated by many reasons, including the need to determine the condition of and extent of damage to property; protect and secure property that may have been damaged or vulnerable to looting; tend to pets and livestock; and check on friends, family, and neighbors who did not evacuate. Although postevacuation reentries do not involve the same life-or-death urgency as evacuations, they can generate enormous amounts of demand over short durations of time that result in traffic congestion. Reentries can put returning evacuees at risk if roads and other highway infrastructure are not sufficiently cleared, repaired, and free from flooding or other dangers. Because of these risks and the need to maintain order and security in areas that may be without utility services, there may be a need to regulate and control reentries into affected areas.

Another reentry issue, and one that has received a significant amount of attention recently, is the development of plans to support the mass return of assisted evacuees to their locations of origin. In addition to the limited plans to evacuate the carless populations of New Orleans for Hurricane Katrina in 2005, there was also no plan to return these individuals after they were evacuated. Although in many cases there was little to return to, the repopulation of New Orleans has become an important issue as people have been limited in their ability to return to homes, jobs, and possessions. Some people have suspected that this process has slowed the recovery effort in this area. Although New Orleans is often held up for criticism for lacking in plans for postevent repopulation, it is apparent that few, if any, other locations across the country are any better prepared. The issue of postevent repopulation is not a direct responsibility of transportation agencies. Some have suggested, however, that there is a role that they can play.

This chapter summarizes some of the key issues involved in postevacuation reentry and the plans, policies, and procedures that have been developed for the safe and orderly return of evacuees after emergency conditions. The discussion includes examples of the roles played by transportation agencies in this process and identifies various location-and hazard-specific plans and practices for the return of evacuees.

REENTRY ISSUES

Even without the presence of an imminent life-and-death danger, the return of evacuees after an evacuation is not a routine transportation process. There are a number of areas of potential concern to transportation agencies and ones in which they can and do play key roles. At the very least, conditions that have precipitated large-scale evacuations have the potential to create inordinately high inbound directional demand that is concentrated within a short duration, in effect, a reverse evacuation. As with the evacuation that preceded it, these demand conditions can result in significant congestion, delay, and even traffic safety issues that may require the attention of transportation agencies to ensure a safe, orderly, and expeditious return of a population to its origin. For hazards that have caused physical damage to transportation infrastructure systems, expedited inspections and repairs may be necessary. Examples of major damage after recent hurricanes and floods have included storm-surge decking damage and foundation scour on bridges, washed out pavements and embankments, and the flooding of traffic signal systems. The required repair of these items can necessitate the development of alternate traffic plans, which are important before allowing evacuees back into affected areas.

In addition to the transportation system itself, reentering evacuees can be in danger from lingering conditions of the original hazard. In the event of tornados and hurricanes, structures may be unsound, and fire and explosive dangers can exist after wildfires. In technological hazard emergencies, such as biological, chemical, or radiological releases, dangerous conditions may not be immediately and directly detectable without specialized and sophisticated detection and testing equipment. Thus, experts outside of the transportation field who are adequately trained and equipped to assess conditions must be brought in before evacuees can return. In some cases, this may take several days.

Washed-out roadways and collapsed bridges are obvious hazards. However, less noticeable threats can include conditions such as leaking gas pipes, downed electrical lines, and structural and foundation failures. As a result, transportation officials are called on within hours of a disaster to conduct inspections to assess the extent of damage, determine which routes can be opened, and certify critical structures such as bridges, retaining walls, embankments, and so on. This work can occur simultaneously with utility company and other nongovernmental agency inspections for facilities such as hospitals and stores to ensure that the basic needs required to support and sustain a populace is in place and functioning.

Discussions with local officials showed that the process of postevacuation reentry has several layers of complexity. Because public safety is always paramount, reentry often becomes an effort to manage or restrict the entry of returning evacuees until their safety can be ensured. In all but a few of the most confined cases, the management of reentries is a hit-or-miss proposition. Most states permit evacuees to return after the evacuated areas are deemed to be safe by local and state officials. In practice, however, many evacuees leave shelters as soon as it appears that reentry routes are open and typically well before any "all-clear" advisories are issued. In Lafayette, Louisiana, after the Hurricane Andrew evacuation in 1992, evacuees left shelters early in the reentry process without having received an "all-clear" advisory from authorities, which delayed DOT and utility repair and restoration efforts.

By the very nature of their design, highway transportation systems are developed to provide convenient access to properties. Often, this is accomplished with multiple routes of access into populated areas. When combined with the eagerness of evacuees to return, these configurations also make it difficult to prohibit access on a large scale. Discussions with authorities in wildfire-effected states revealed that the only effectively managed large-scale reentries have been at the subdivision level, where access into the affected area can be restricted at a handful of relatively easy-to-control entry points.

A consistent opinion was that most areas have yet to devise an effective method to realistically (efficiently and safely) deal with reentry, particularly because of legal and staffing issues. In some locations, particularly those in which no formal plans exist to manage reentry, political considerations are a driving force in reentry. In one location, it was noted that some public officials liked to be viewed as the first authorities to demand that evacuees be allowed back into affected areas. As a result, it was noted that there have been virtual "races" among elected officials in various jurisdictions and levels of government to demand reentry for displaced populations.

ENTRY MANAGEMENT RESTRICTIONS

The review of practice showed that the planning and management of reentry after major events is the responsibility of emergency management and law enforcement agencies. Transportation agencies typically play limited supporting roles to these authorities, usually by leading or assisting with road inspections, traffic management, and debris removal, and by restoring traffic control systems and other road infrastructure. Some specific examples are included later in this chapter.

The predominant role of emergency management and law enforcement agencies is the enforcement of entry restrictions. Such measures are necessary to provide for the safety of returning evacuees and to maintain security for exposed properties and possessions. One way that restrictions can be maintained and enforced is achieved through credentialing and placard programs that identify entering residents and response personnel and certify the validity of their purpose. Another is achieved through the use of tiered reentry processes in which the most critically needed emergency services and personnel gain first entry. This is then followed by a gradual opening of areas to residents and less critical workers. A third way to maintain and enforce restrictions is to establish "Look and Leave" policies that permit property owners to look at their damage and, if safe, enter for limited amounts of time, but that require them to leave if utilities or other basic services are not functioning.

Discussions with local officials from various parts of California showed that much of their reentry planning started after the very active 2003 wildfire season. Because the hazard-prone areas of their counties tend to be in rural regions, the primary intention of the plans was to control the reentry of residents without letting in a flood of others, including "curious lookers," in particular those who might have malevolent intentions. In practice, however, they found that the identification verification process was problematic. In many cases, even when property owners had identification, the address on their identification did not always match the address for the effected area, because they were often vacation and second homes. Similar issues were encountered for residents who had post office box mailing addresses.

In California, officials have now begun to issue "critical worker passes" for utility workers, food and fuel provides, and other personnel. To help the situation, they have instituted a curfew policy wherein anyone caught staying behind the mandatory evacuation zones could be arrested. The curfew, however, was not easy to enforce because police personnel had to use time and resources to arrest and detainee violators while also trying to perform other critical aspects of their job. Police found that there were so many "critical workers" that it was not practical to stop and check everyone who may or may not have been a violator. As a result, the most realistic policy has been to warn people once and then arrest them on a second violation. This policy resulted in the arrest of about 80 people during the 2007 fires.

Other jurisdictions have purposely chosen not to have a formal reentry plan. Experience has shown that in many areas reentry was effectively impossible to enforce for wildfires because of the geographic extent of many disasters and the need for enforcement manpower to control access on the hundreds of entry points into effected areas. Authorities also found that other legal and political situations arise between residents and the various agencies and utilities involved in an event. For example, many agencies require that utilities be "secured but not operational" before allowing reentry. Thus, utility services may not be available for returning evacuees, and uncharged power lines and gas pipes may be exposed. Because police are not permitted to prohibit neighborhood reentry in small-scale emergencies such as downed powerline situations, they likely are not able to legally prohibit similar activities in the aftermath of fire-related blackouts.

Managed or controlled reentry within areawide jurisdictions was regarded to be effectively impossible for other practical reasons. City officials in one location pointed out that their experiences with reentry have tended to be a "tidal wave" process. Once it is started, it is nearly impossible to stop—for many of the same reasons described earlier. However, these officials did indicate that reentry has been done with some success in a few isolated neighborhood-size areas. In such instances, a local assistance center was set up at the entry point to an area. This center included many different services that were offered to "help effected people get their lives re-started." In addition to managing access, it was meant to provide security against looters, safety hazards within the area, and unscrupulous contractors. Before permitting reentry, the first step of the process was to permit time for the fire department to checks for natural gas and electrical hazards. Then, grant approvals for individuals to enter the area on a single daylight-hour workday basis. There was no nighttime access. The next day, the entire process of checking identifications and credentialing was repeated.

Traffic Management

The management of traffic for reentry is not an area of significant planning or operational activity among transportation agencies. It is also not an area in which there are a large number of formalized or documented plans. For agencies that do have plans, the activities tend to be focused on debris removal, supporting access control efforts, and returning signal systems to operable condition.

In an earlier study, it was noted that TxDOT is one transportation agency that maintains a documented procedure to govern their reentry process (Urbina 2002). It consists of two phases: (1) the initial or reentry phase, and (2) the cleanup or recovery phase. TxDOT officials believe that a two-phase reentry decreases the time needed to gain access to affected areas. The reentry phase consists of opening minimum (14-ft-wide) entry paths on roadways. This facilitates access for law enforcement, public works, utility, and relief vehicles into affected areas. During this phase, priority is given to opening routes to hospitals or emergency centers, followed by primary highway routes, including interstates, federal roads, and key state highways. During this stage, traffic is limited to official vehicles and damage to the roadway or bridges along the route is reported (Urbina 2002).

The recovery phase consists of the removal of debris and the opening of all remaining access routes. During this phase, the full width of the roadway is cleared to provide two-way access for returning evacuees. GDOT maintains a similar procedure to that in Texas in that the reentry process occurs in two phases: the initial (or basic restoration) phase and the follow-up (or full restoration) phase. In addition to decreasing the time needed to gain access to affected areas, the GDOT process also seeks to limit access into the affected areas, enhancing the ability of law enforcement officials to maintain security, control sightseers, and prevent looting.

The prior review also showed that the SCDOT has included provisions to facilitate reentry using inbound contraflow along their reversible evacuation freeway segment. The two-direction contraflow capability was developed following the Hurricane Floyd evacuation of 1999 when public demand for contraflow was so strong that unplanned contraflow operations were implemented "on-the-fly" on I-26 between Charleston and Columbia. When the SCDOT developed a formal contraflow evacuation plan, the termination point outside of Columbia was constructed with two directional crossover roadways that connected both sides of the freeway for contraflow in either direction. An aerial photograph of this configuration is shown in Figure 17.

Since its construction nearly a decade ago, contraflow operations have not been necessary in South Carolina; therefore, the configuration has never been used. During this time, officials have stated that, given the need for additional enforcement and the potential for conflicting maneuvers, it is highly unlikely that inbound contraflow for reentry would ever be used in the state.

Infrastructure Assessment and Repair

Past disasters have shown that the most active role of transportation agencies in reentry has been in the inspection and repair of damaged roadway infrastructure. The Hurricane Katrina surge and flooding of New Orleans and nearby areas provides several examples that illustrate several areas of activity, including signal system restoration, bridge damage assessment and repair, and pavement assessments.

Bridges

Within a day after the storm's passage, officials from the Louisiana DOTD conducted airborne assessments of highways bridges within the areas affected by Hurricane Katrina

FIGURE 17 Dual contraflow crossover terminus—Columbia, South Carolina (*Source:* South Carolina DOT).

(Gautreau 2007). From these inspections, it was obvious that numerous bridges had been severely damaged by the storm, others remained submerged, and many more had been rendered impassible by debris. Damage to ferry landings and other railroad bridges was also evident. Among the most critically damaged structures were the I-10 "Twin Span" bridges. These bridges connected the east side of New Orleans to the north shore of Lake Pontchartrain and the "mainland" of southern Louisiana, a length of about 10 miles. By the second day after the storm, strategy meetings were held to develop project priority lists and draft contracts to begin engineering and restoration projects. Within 2 weeks of the storm, bid documents were prepared and issued; bids were received; contracts signed; and construction started. The eastbound lanes of the bridge were reopened to two-way traffic one month later. This was 16 days ahead of schedule, despite the effects of Hurricane Rita, which occurred 2 weeks after Katrina. The southbound bridge was reopened less than 3 months later.

In a more comprehensive and scientific study, Okeil and Cai (2008) conducted a study of the storm-induced damage to short- and medium-span bridges affected by Katrina. The study included a survey sample of 12 bridge sites that included roadway and railway bridges, moveable and stationary bridges, reinforced and prestressed concrete, and steel bridges. Based on these inspections, it was concluded that storm-surge-induced forces had easily overcome the anchoring design of the bridges. This damage was the result of the concept that bridge design is mainly controlled by gravity loads, whereas the actual damage was created by lateral and uplifting forces caused by storm-surge waves and water currents. Mechanical and electrical systems for movable bridges were also found to be extremely vulnerable to flooding, which often rendered them inoperable immediately even when no structural damage took place.

Pavements

After Katrina, DOTD engineers in Louisiana were also tasked with assessing the condition of roadway pavements. Although it was initially assumed by many experts that the impact to pavements would be minimal because the roadbed soils around south Louisiana are frequently subjected to saturated conditions, a report by Gaspard et al. (2006) indicated that significant degradation did result to the long-term strength of some pavements. Among the general findings of the pavement evaluation were that thinner submerged pavements experienced more relative damage than the nonsubmerged pavements. Based on sets of before-after data from projects scheduled for rehabilitation and reconstruction, it was found that, for asphalt pavements, the damage to thinner sections would require at least another inch of asphalt. Using recent bid prices in the area, the cost to rehabilitate the 200 miles of submerged state-owned roads would be about $50 million. The study did not take into account additional damage resulting from continuous use by debris-hauling trucks. The study concluded that duration of submergence was not a factor in the level of asphalt pavement damage. Interestingly, it was also found that submerged concrete pavements demonstrated little relative loss of strength compared with similar nonsubmerged pavements.

Traffic Signals

A final example of the role of transportation in the restoration of traffic control systems for postevent reentry was illustrated in the expedited project to reestablish traffic signalization within the city of New Orleans. By contractual agreement, the city of New Orleans maintained the responsibility for the operation and preservation of both city- and state-owned traffic signals within its jurisdiction. At the time of Hurricane Katrina, there were a total of 458 signals in the New Orleans network. Of these, 286 were city owned and the remaining 172 were owned by the Louisiana DOTD. As a result of the flooding that followed the storm, most of the traffic signals in the city of New Orleans were significantly damaged. A presentation by Dykes (2006) summarized the extent of the damage and the efforts by Urban Systems Inc. of New Orleans to assess the scope of damage, prioritize and schedule the restoration projects, and redesign the most significantly damaged locations. The presentation discussed problems caused by the lack of traffic signals as well as the efforts to restore "normal" traffic flow in the affected areas.

Because of the extent of the devastation in the city, New Orleans officials did not have funds to complete the work. The Louisiana DOTD reallocated state transportation funds to help pay for the restoration projects. Ultimately, the federal government agreed to reimburse the city and state for the repairs. To qualify for the emergency funding reimbursement, however, all work was required to be completed within 180 days.

In the weeks following the storm, city personnel conducted a site-by-site inspection of all 458 traffic signals. Any signal with a flooded controller, such as the signal in Figure 18, was immediately condemned. Signals that were considered to have incurred more than 50% damage from wind or flooding were also condemned. Based on the field assessment, 185 signals required full reconstruction. All other, more moderately damaged, signals were repaired by the Louisiana DOTD signal maintenance crews.

FIGURE 18 Flooded signalized intersection in New Orleans (Dykes 2006).

The inspections showed that intersections with newer and more modern signal designs better resisted the impacts from storm winds and flooding. At most of these locations, signal heads and mast arms needed to be rotated back into proper positions, as shown in Figure 19 or had to be replaced. In addition to flooded control cabinets, pedestals were also found to have significant damage. Older signals, which tended to be pedestal based, did not withstand the storm effects nearly as well. In many cases, entire concrete foundations were uprooted as shown in Figure 20 and had to be replaced. At many locations, older signals had to be brought into compliance with current *MUTCD* standards. This work was also completed within the restoration project.

Because of the expedited performance period and the extent of the damage, there was very little time to conduct detailed field surveys. As a result, some of the restoration plans were prepared from aerial photographs. Fortunately, plans for most of the more recently constructed signals were salvaged from city and contractor archives. In total, more than 600 mast arms, 600 pedestal poles, 500 junction boxes, and 700 signal heads were included in the restoration. During

FIGURE 19 Wind and flood damage to mast arm signal location (Dykes 2006).

FIGURE 20 Foundation damage to pedestal mounted signal (Dykes 2006).

the reconstruction process, traffic at signalized intersections was controlled using all-way ground-mounted stop signs as shown in Figure 21. Because traffic was significantly lower, in some areas as little as 10 percent to 20 percent of prestorm conditions, these temporary control measures did not significantly affect traffic operations.

Soon after the project began, it was apparent that the repopulation of the effected areas would be a long and slow process. As such, it was suggested that some signals did not need to be immediately reactivated. Despite this, a strategic decision was made to fully restore the transportation system to encourage the repopulation of the city.

The planning for formally organized postevent reentry of evacuees remains a largely unexplored topic in both practice and the literature and is likely to remain a low priority. The general consensus of the sources investigated for this report was that reentry is a complicated and manpower-intensive process and is more of a "luxury" than a necessity compared with the evacuation itself. Despite these findings, the need to control access into potentially hazardous areas after an evacuation is critical. However, such control is typically managed by enforcement-oriented agencies with the authority to restrict and control the movements of the public as well as arrest and detain violators. Currently, the roles of transportation in the reentry process are oriented toward the inspection of critical infrastructure; the immediate (and longer-term) repair of damaged roads, control systems, bridges, and so on; debris removal and the reopening of roads; and, more recently, the coordination of the return of assisted evacuees to their places of origin.

FIGURE 21 Temporary four-way stop control (Dykes 2006).

CHAPTER EIGHT

CURRENT STATE OF PRACTICE

To include the most current sources of practice information, a survey of current and planned evacuation and reentry practice was undertaken. Surveys were sent to transportation and EMAs throughout the United States at various levels of government. The survey served three main purposes. Most important, it was used to gather the most current information from a sample of users across a range of hazard conditions and geographic regions. This helped to identify who is planning for or has used evacuations, how they have been carried out, and the hazard conditions that have precipitated their use. Next, the survey allowed less widely disseminated information to be gathered directly from their sources. Finally, the survey made it possible to compare and contrast the transportation policies and practices used for the development of evacuation plans.

The first part of this chapter highlights the findings of the survey of practice and includes information gathered during follow-up interviews and site visits. The discussion also notes instances in which particularly innovative practices have been used and where responses were found to be different than expected. The second part of the chapter includes summary descriptions of six recent evacuation experiences to highlight the variety in the conditions and practices in the evacuations.

SURVEY OF PRACTICE

The survey of evacuation policies and practices was conducted over a six-month period between December 2007 and May 2008. Survey questionnaires were sent to representatives of all 50 states and three U.S. territories for distribution to state highway department officials. In addition to these, a supplementary list of approximately 116 additional city- and county-level transportation agencies and state and local EMAs was also developed and distributed. From this distribution of 169 surveys, a total of 39 responses were received, for a total response rate of 23%. Of these, 19 were received from state DOTs and 11 from state EMAs. Of the remaining nine responses, three came from county and city DOTs, six from county and city EMAs. Six of the states returned surveys from both their DOT and EMA. The map in Figure 22 summarizes the distribution of the responders as well as the locations of some of the cities and counties included in the survey.

The survey questionnaire (included as Appendix C) consisted of 43 questions that, using a checkbox and fill-in-the-blank format, investigated five key areas of interest. The arrangement of the topic areas generally overlapped the chapters of this report, including the following:

- Preparedness, planning, and policy
- Direction and control
- Evacuee and mode characterization
- Communication and public information
- Reentry

The preparedness, planning, and policy questions were developed to determine many of the basic roles and involvement of the responding agencies. They included questions related to the elements and components included in the local plans, the resources that are planned for use, and any key training and evaluation issues. The direction and control questions focused primarily on the key command and control elements of the evacuation plans, including the agencies and personnel involved, contracts for support services that are planned for use, and various decision-making processes that are involved. The evacuee and mode characterization questions were used primarily to assess the level of need and planning for assisted evacuees. The questions were designed to probe the level of planning that has already been undertaken as well as the level of need for assisted evacuees within the subject jurisdiction. The questions in this section also sought to assess the methods used to identify the populations in need as well as the context and elements of the special needs plans. The communication and public information section of the survey addressed issues associated with the systems and methods used to convey information to evacuees as well as methods used to acquire, transfer, and evaluate remote travel data. Lastly, the reentry section of the survey dealt with plans and processes used to facilitate the return of evacuees to their locations of origin and, more specifically, plans related to road clearing, hazard removal, and credentialing.

The following sections highlight and summarize the responses to the questionnaire as well as some of the more unique techniques that have been applied. The specific numeric responses to each question can be found in Appendix D of this report. To preserve the anonymity of specific agencies and to illustrate potential differences in practice between DOTs versus EMAs and state-level agencies versus

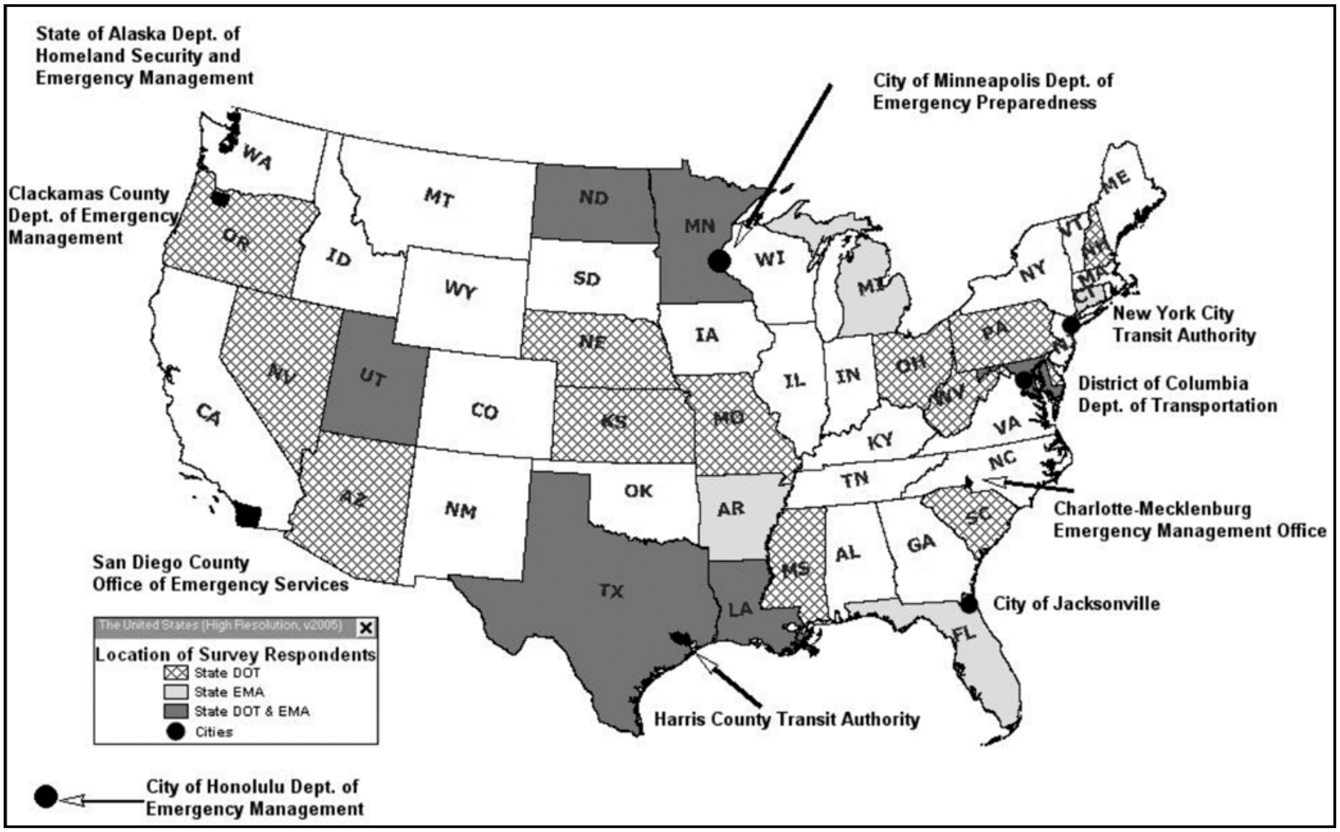


FIGURE 22 Survey of evacuation and reentry practice respondent jurisdictions (map: H. Fu).

local-level agencies, the responses are presented in aggregate form based on these four groupings.

Finally, the following analyses reflect an interpretation of the responses received. Although efforts were made to limit the potential for subjective interpretation of the survey questions, individual respondents were free to judge the intent and meaning of all questions for themselves. Respondents were permitted to not answer any question if they did not know the answer or if they were unwilling or unable to answer them for any reason. As a result, many of the question responses included considerably less than 39 total survey replies, whereas others included more than a single answer.

Preparedness, Planning, and Policy

The first set of questions was posed to gain a broad overview of the general practices of the respondents and then to evaluate specific procedures and areas of emphasis within their plans. All 33 of the agencies responding to the survey question indicated that their agency had an evacuation plan. The survey showed a relative balance between Annex and FEMA Emergency Support Function (ESF) format. This even balance also extended to DOTs and EMAs, although all of the city and county agencies used an Annex format. To assess the relative responsibilities of the agencies, a follow-up question was added to identify the roles of the emergency management, transportation, National Guard, and law enforcement agencies at each location. It was apparent that the EMAs were the *coordinating agency* in the majority of the locations. It was also evident that the transportation agency was most often the *lead agency* in ESF 1, and the National Guard and law enforcement agencies were nearly always the *supporting agencies*. This finding was consistent across the various state, local, DOT, transit authority, and EMA groups.

Based on the responses that were received, it was somewhat difficult to assess the specific types of hazards for which evacuations are currently planned. Not all locations are effected by the same type of hazards and several indicated the development of plans for “all hazards” and not for specific scenarios. For the agencies that responded to the survey, however, man-made and less location-specific hazards such as chemical and radiological releases were the most common scenarios used for evacuation planning. This is not surprising because 103 operating nuclear reactors are spread across 63 licensed reactor sites in the United States and all of them are required to develop and maintain detailed evacuation plans. Of the natural hazard categories, floods and hurricanes ranked the highest followed by wildfires. Several respondents named natural hazards such as earthquakes and tsunamis in the “other” category. Several EMAs included terrorist attacks, biological hazards, and public health emergencies and pandemics.

The survey next assessed a lingering question regarding the usage and definition of certain types of evacuation orders. Past study showed mandatory and voluntary evacuations to be the most common methods used to order evacuations. The definition of "mandatory" has been unclear, however, because nearly all agencies have stated that it is not realistic to enforce orders that compel people to evacuate. The survey showed that 69% of the responding agencies reported using the term "voluntary" to issue evacuation orders and 42% used "mandatory" evacuations. In response to the question of whether or not they could or would enforce a mandatory evacuation order, only 4 of the 33 responding agencies responded affirmatively. Most stated that they had no enforcement authority to carry out forced movement, that such decisions would be left to local law enforcement agencies, and that it was not an issue in which a transportation agency would become involved.

Evacuation Plan Elements

Following several recent evacuations, it has become increasingly apparent that people evacuate with pets and in some cases livestock, particularly horses. There has also been evidence to suggest that many pet owners are reluctant to evacuate an area if they cannot relocate to a shelter location that permits the housing of pets. As a result, many evacuation plans have been revised to permit the inclusion of animals as part of their operations. To assess the level of provisions for pets in evacuation planning, the survey included questions to determine whether they are being considered in plans and, more specifically, how sheltering plans include amenities for pets, livestock, and service companions.

The survey results showed that nearly 70% of the agencies responding to the question included considerations for pets and service companions at some level and that more than 60% included them in their sheltering plans. Although comparatively lower at 30% and 25%, respectively, planning and sheltering and provisions for livestock were both higher than expected. Interestingly, planning and sheltering provisions for pets and service companions was highest at the local level. All of the agencies with such provisions included services companions and only one of the eight respondents did not include pets.

The survey also investigated the different modes that were included within each agency's Emergency Operation Plan. As expected, the most common was the highway mode. Although it was assumed that all plans would include highways, the survey included transit authorities and other agencies that may not directly include roads in their plans. Other commonly cited modes included school buses, transit buses, and commercial coach buses. Rail and air mode were indicated by several of the respondents, and seven agencies cited waterborne plans for evacuation. Agencies in the latter group further indicated these would be carried out using ferries and fish and wildlife vessels.

Somewhat surprising in this category was the limited amount of pedestrian planning, both in terms of numbers and the agencies involved. A total of seven agencies indicated the inclusion of pedestrians in their plans. Perhaps even more interesting was that only three of the nine local- and county-level agencies included the pedestrian mode. It was assumed that pedestrian evacuation would be a more significant issue in local agency planning. However, it was also found that the percentage of bus use was generally higher at the local level and among EMAs.

Another key element of evacuation planning that has received considerable attention since the 2005 Hurricane Rita evacuation of Houston is the planning of en-route services for evacuees. These include procedures to deliver fuel, water, food, and wrecker services to evacuees during an evacuation. Such services are thought to be much more than a mere convenience because they can effect the lives and health of evacuees trapped on congested roads and can clear travel lanes blocked by broken-down and out-of-fuel vehicles.

The responses to this question were surprising in that more than half of the survey respondents indicated they would be providing one or more of these services. Overall, 25 of the 36 agencies (about 70%) indicated they have plans in place to provide en-route fuel to out-of-fuel vehicles, and 21 indicated that their agency plans to provide wrecker services to remove disabled vehicles from evacuation routes. From discussions with some of the respondents, vehicle moving would be limited to removing it from the travel lanes where it would not create a blockage.

The structure of the question also permitted a determination of the agencies in charge of providing these services. EMAs were found to most often take the lead in these activities. The relatively low numbers in the local agency category are not necessarily surprising because several of them indicated they did not have any roads under their jurisdiction and many of them stated that their component of the evacuation travel route was quite limited.

Evacuation Processes

Another key component of evacuation planning was the elements that make up the overall evacuation process. In the survey, a series of questions was included to assess the methods used to coordinate and carry out evacuations. One of these was the integration of local plans into wider regional or statewide plans. The majority of the plans were integrated on a statewide level, with only 3 of the 36 respondents indicating their plan was for a single jurisdiction. The greatest number of these plans was at the state level. The majority of agencies responding to the survey also had some level of temporal or spatial phasing of evacuation orders. These were most common at the state level where more people and wider geographic areas would be affected.

The number of agencies planning to use lane reversals, or contraflow, was much higher than expected. Over half of the agencies responding indicated plans for contraflow for an evacuation of their jurisdiction. This is a significant increase over a 2001 study (Urbina and Wolshon 2003) that showed only a handful of the most critically threatened "hurricane states" had developed plans for contraflow. One area that has changed little since 2001 is that the official in charge of ordering contraflow in the majority of jurisdictions remains the highest elected official, most often a state governor. In areas where contraflow plans are more fluid in response to varying hazard conditions such as wildfires, law enforcement agencies were most often in charge.

As the number of contraflow user agencies has increased over the past 5 years, the planned time required for its implementation has appeared to decrease. About half of the respondents indicated they would need between 4 and 8 hrs to implement their contraflow plan. One agency plans less than 4 hrs, two were between 12 and 24 hrs, and only one of the 13 agencies indicated the need for more than 24 hrs. In the 2001 study, most agencies planned to use at least a full day for contraflow implementation. The criteria used to end contraflow operations have not changed significantly. Most agencies continue to use a qualitative observation of volume decrease or the impending onset of tropical storm-force winds (39 miles per hour) as the threshold to terminate contraflow. One state, where contraflow operations are planned only for daylight use, continues to plan to terminate its lane reversals at sunset.

The final question in the area of processes was an inquiry into the perceived barriers and obstacles to effective evacuations. The most commonly named obstacle was a lack of coordination in command and operations between various agencies, jurisdictions, and levels of government. This shortcoming was particularly important to agencies needing to coordinate evacuations across multiple cities, counties, and states. Several agencies, particularly on the transportation side, also cited inadequate funding and personnel that were able to be dedicated to evacuation planning and analyses. EMAs tended to be more forthcoming in identifying and noting barriers and obstacles to planning. One agency representative expressed hope for an increased willingness of the state DOT to take on a higher degree of responsibility in command and control evacuations.

Plan Resources

One of the key areas of evacuation planning is the identification and utilization of available resources. The next set of questions was posed to assess these resources within the responding agencies. One method of organizing and managing emergency resources is to use the FEMA typing system. The typing of resources helps to standardize asset descriptions and, among other things, helps to facilitate communication by more precisely defining the sizes and capabilities of equipment and other physical resources.

The survey results showed that about half of agencies responding to the question used the FEMA typing system and about one-third actually have typed their resources. About two-thirds of the agencies reported the use of software systems to manage their resources; with the WebEOC® system being the most popular. When asked to name specific resources planned for use, variable and changeable message signs were the most common, followed closely by school and transit buses. Other commonly cited resources included traffic control devices such as barriers, barricades, arrow boards, and the like. Less common, though also cited, were systems such as HAR and traffic service and patrol crews. In the area of "most critical," several EMAs also named ambulances, boats, helicopters, and tow trucks. Two of the local-level agencies named paratransit services.

Fewer than half of the agencies thought their plans and available resources were adequate to support a large-scale evacuation within their jurisdiction. Interestingly, the DOTs tended to be more optimistic about the ability to evacuate than the EMAs. Similar to earlier responses, the EMAs were more detailed in listing areas in which additional resources and support are needed. They cited shortcomings in ambulances, manpower, funding, coordination, special needs transport, bus drivers, en-route refueling stations, and contracts with private carriers. The DOTs listed only more tow trucks and additional support from law enforcement and their emergency management counterparts as areas of need. Together, this suggests that the DOTs actually may be well prepared or, because they are not nearly as experienced in emergencies as the EMA counterparts, may be falsely confident in their ability to carry out a mass evacuation, or these needs may be tasked to another agency.

Training and Performance Measurement

Another key area of emergency preparedness is training of staff and management for potential disasters. Nearly all of the agencies reported that their agency routinely conducts evacuation exercises, and all but one state DOT indicated they were included in their state EMA training exercises. Among the expected outcomes of training is improved effectiveness in the evacuation. One of the difficulties in determining the actual effectiveness of evacuations, however, is the lack of established standards and data availability on which to base the quality of an evacuation. A recent paper by Han et al. (2007) discussed this issue as well as the factors that often add to its difficulty.

The survey sought to determine which agencies actually had criteria to determine whether or not a evacuation was "successful" and to determine what those criteria were. The results of the survey showed that fewer than half of the agencies indicated the use of such criteria. This finding was consistent across the various agency and jurisdictional classifications. Among those who did have criteria, the *total number of evacuees moved, avoidance of injuries and fatalities en-route, positive feedback from the public and news media,* and *effectiveness of communications during the evacuation* were all rated as the most-utilized criteria. Interestingly, all of the responding EMAs reported that the *total number of evacuees moved* was one of their criteria, whereas the various transportation agencies tended to look at *avoidance of en-route injuries and fatalities* and *user feedback* more often than their EMA counterparts.

Direction and Control

The next section of the survey evaluated evacuation command and management. The first several questions were targeted at determining who was making the evacuation orders and the manners in which they were made. It was inferred that evacuations are influenced by politics, particularly those that involve large groups of people. In nearly all cases, respondents indicated that a high-ranking elected official made formal evacuation declarations. However, such decisions were by no means unilateral. Typically, the official was advised (formally or informally) by a group of agency directors from law enforcement, emergency management, transportation, and in some cases, the military. In one area affected by wildfires, it was learned that the key voice in developing evacuation orders was the fire department. As in the other hazard cases, this makes sense because the fire department is the agency that is most familiar with the hazard conditions and its projected movements and development.

After an evacuation order was issued, the agency cited as responsible for carrying it out varied among the respondents. The most common were the EMAs. However, this command was commonly undertaken in conjunction with other agencies, most often law enforcement and, to a lesser extent, transportation. Although a small number of the agencies indicated that a DOT was one of the responsible agencies, the role of transportation in evacuations is primarily to provide support to these other agencies.

Additional questions were included to determine whether assistance beyond the resources of the particular agency were necessary to carry out an evacuation. About half of the respondents indicated that they maintained contracts to assist with evacuations in their jurisdiction. Of these, most were managed by a transportation agency, followed by an EMA, and one respondent was managed by some other administrative agency. Several agencies indicated that they have contracts with commercial bus companies, transit bus agencies, and school bus service providers. A handful stated that they maintained contract agreements with ambulance companies.

One method used to maintain preparedness for emergencies is the use of timelines or decision matrices to guide decision-making processes and strategies. Such frameworks can be particularly valuable for hazards such as hurricanes in which the movement of hazardous conditions can be forecast and tracked several days in advance. For hazards with no notice or with rapidly changing movements, these types of guideline can be much more difficult to use. In the survey, about 40% used timelines to commit resources and carry out evacuations. These results were consistent among the various agency groups. This was somewhat unexpected because it was thought that DOTs, particularly those with more complex strategies such as contraflow, might maintain formalized decision timelines for implementation and termination.

Another issue indentified during recent mass evacuations is the need to guide evacuees to open shelters and areas with hotel vacancies during the evacuation. This can lessen the likelihood of shelter overcrowding or underutilization as well as the need for transport assets to make multiple trips to find available space. The survey showed that about a third of the agencies indicated that their plans allow for in-vehicle communication with buses while en route to a shelter.

The final two questions of this section were posed to determine how many of the agencies within the survey have actually carried out large-scale evacuations (involving 50,000 people or more) or evacuations of isolated communities. The reason for asking the large-scale evacuation question was that, although larger-scale evacuations are relatively infrequent, data show that small-scale evacuations (those involving 1,000 people or fewer) are surprisingly common. However, events at these more modest levels typically do not involve significant involvement from transportation agencies. In the major evacuation category, three of the respondents indicated the need to conduct a large-scale evacuation over the past 2 years; eight in the past 3–4 years; and five in the past 5–6 years. These included the evacuations associated with Hurricanes Katrina and Rita, Tropical Storm Isabel, and the Southern California wildfires of 2006 and 2007.

A follow-up question was posed to assess the occurrences of isolated community evacuations, such as would be associated with coastal towns threatened by hurricanes, mountain communities threatened by wildfires, and the like. Though much less populated than more densely developed urban and suburban centers, isolated areas are commonly served by fewer roads; often only one or two outbound routes, which themselves can be made impassable by floods, fires, and other hazardous conditions. The survey suggested that these types of evacuations are much more frequent than mass-scale evacuations. Eleven agencies indicated the need to conduct an evacuation of an isolated community in the past 2 years; 14 in the past 3–4 years; and 10 in the past 5–6 years. This was about double the frequency of the large-scale evacuations.

Evacuee and Mode Characterization

The biggest evacuation issue to come out of the Katrina experience in New Orleans was the movement of special needs and other types of non-self-evacuating populations. The main emphasis of this section of questions was to gauge the level of planning in this area. The first question sought to determine how many agencies included any type of special needs evacuation in their planning. About 70% indicated they were addressing this need. As expected, the emphasis was highest at the local level where seven of the eight responding agencies indicated special needs planning as opposed to only about two-thirds at the state level. As expected, EMAs were also higher (13 of 15) than DOTs (10 of 18).

In terms of the specific types of low-mobility groups included in the plans, the most commonly cited were *frail elderly* and *persons with disabilities* with one or both indicated by about half of the responding agencies. Most of the other categories were indicated at similar levels. The primary exception was planning for *homeless populations* with only four agencies. The *tourist* category was relatively low at seven agencies. Because many of the replies came from locations with presumably low tourist populations, it is not surprising that they would not be specifically included in the evacuation plan. More unexpected were the high number of agencies that included hospitals, nursing homes, and assisted living facilities. As these typically are considered to be private entities, they usually are required to develop and maintain their own evacuation plans. In general, the EMA group was higher then the DOT group and the local agencies were higher than the state agencies in terms of this type of planning. This should not be surprising, however, because special needs populations are dealt with on the local level and their needs fall within the purview of EMAs more often than transportation agencies. As a final point of note, several EMAs also included additional special needs groups in the *other* category. These included schools, prisons, unaccompanied minors, and *protected populations* such as residents of battered women's shelters and the like.

A key part of providing services for non-self-evacuating groups is identifying their numbers and locations. To assess the sizes of these populations, another series of questions was posed. The reported percentage of the populations considered to be special needs numbers were considerably higher than was anticipated. Of the 23 agencies responding to the question, six estimated their proportion to be in excess of 20% of their total population. Such levels are thought to be significant given the complexity and amount of resources required to evacuate such individuals. Most locations assumed their special needs populations to be between 6% and 10%, although these estimates varied considerably. The data also showed that local and emergency management agencies tended to estimate higher because they "own" the problem and would be expected to estimate more conservatively.

To help locate special needs individuals, many agencies have developed systems to permit citizens requiring assistance to register for this service. The survey revealed that two-thirds of the responding agencies acknowledged the availability of registration systems in their evacuation plan. This was surprising because such services are typically handled at the local level. The type of systems indicated by these agencies included 211 and 311 telephone systems, Internet pages, public health organizations, and 911 emergency calls. Although it is important to estimate special needs populations and develop registration methods, such measures have limited value if those in need choose not to use them. As expected, the survey showed that most agencies estimated that the percentage of special needs individuals registering service was low, with half of them estimating it to be 10% or less.

Some of the details on the specific role of transportation in special needs evacuation were evident in the follow-up questions. For example, it was found that the transportation's role in special needs evacuation was limited to picking up and transporting evacuees and not registration and managing registration databases. It was also shown that only eight agencies reported having paratransit services available for evacuation assistance.

Communication and Public Information

The flow of timely, accurate, and useful information during an evacuation is key to an effective process. In addition to travel guidance provided to evacuees, evacuation communications also includes the acquisition and transfer of transportation-related data to decision makers. The questions in this section were used to assess practices in data collection and transfer as well as the resources dedicated to this purpose. The first questions investigated what type of information has been or will be collected, and determined the means by which it was or will be acquired. The most commonly collected data was the *number of people evacuated*. Next were the *origins and destinations of evacuees* and the amount of congestion and delay they experienced during the evacuation. These statistics were followed closely by travel time and then, to a slightly lesser degree, travel speed. As would be expected, routinely collected measures such as speed, volume, congestion, and travel time were most often collected by DOTs, although strategic information such as evacuee numbers and departure times were favored by the EMAs. The methods by which the aforementioned data were or would be collected also varied. Direct field observation was the most common, with 70% of responding agencies indicating its use. Routinely used systems such as vehicle detection and video surveillance systems were more commonly cited by transportation agencies.

Among the questions left unanswered by the survey was how the data cited previously was collected and used in practice. For example, one-half of all the agencies surveyed indicated that they collected the number of people who were evacuated. However, it was not clear how this was accomplished. In the wake of Hurricane Katrina in New Orleans for example, the state of Louisiana desperately sought information on how many people were able to evacuate so they could estimate how many people may have remained in the city and still were in danger from the flood waters. Using conventional traffic count data, it was possible to assemble an estimate of the number of evacuating vehicles then multiply them by historical estimates of evacuation vehicle occupancy to broadly estimate a total evacuation number. In reality, however, this method was uncertain because vehicle counts were available only from a handful of freeways and a few primary routes out of the New Orleans metropolitan area. There was also no way to assess the origin of these vehicles or the numbers of people in them.

Next, the survey questioning turned to the transfer of field information into emergency operations centers (EOCs). In addition to the extensive use of conventional land line and cellular telephones, other systems such as emergency management software and electronic communication mediums were commonly cited. Several agencies named satellite phones and amateur radio systems as methods.

In evaluating the transfer of information between agencies responsible for managing the evacuation process, the responses were similar, although there was a much lower use of hard-wire communication. The two most frequently cited were digital radio systems and cellular phones. Analog radios and electronic systems such as text messaging, e-mail, and emergency notification software were cited by 40% of the respondents. These wireless communication systems also have been credited as being helpful for communicating to transit drivers while en route.

After the information flow moves from data acquisition, it must next be interpreted and converted into guidance for public dissemination. To determine the most commonly targeted hazards for which public awareness campaigns are used, agencies were asked to identify those that applied to them. Similar to earlier findings, the results showed that public awareness campaigns for evacuations associated with radiological releases were the most commonly undertaken. This, along with the responses to earlier questions, shows the maturity of planning and management associated with nuclear power plants.

When an evacuation is ordered, it is critical to bring it to public attention as quickly and widely as possible. To accomplish this, the transportation and EMAs included in the survey used a variety of mass communication methods. As expected, traditional mass communication media such as television and radio were well utilized. Emergency alert systems (EAS), which also broadcast on television and radio, were similarly highly noted. Traditional low-tech alert systems such as loud speakers, sirens, and knocking on doors were still in wide use, with between 30% and 40% of agencies still employing these methods. In the *other* category, responding agencies indicated the use of websites, highway VMS, and hazard radio broadcasts as other means of emergency communication.

Reentry

One of the more understudied topics of evacuation has been the postevent reentry of evacuees. To assess the state of reentry policy and practice, the final five questions of the survey focused specifically on this subject. The first sought to identify the lead agency responsible for planning postevent reentry. Although several agencies indicated cooperative efforts that involved multiple agencies, EMAs were the most frequently cited followed by law enforcement and then combined approaches of transportation and law enforcement.

It was found that the role of transportation agencies in the reentry process was significant. The survey revealed that each of the five roles named in the questionnaire was indicated by more than 70% of the respondents. It was evident that many agencies used a tiered reentry system in which the return of evacuees is preceded by a sequence of response and recovery services to ensure the safety and accessibility of the roads. Such a process was indicated by nearly half of the EMAs. A lesser number of agencies indicated the use of credentialing and “Look and Leave” policies to control the flow of reentering traffic.

Survey Conclusions

The survey of current practice revealed many of the processes of evacuation and reentry and how transportation fits into the broader perspective. The responses showed that the emergency management process flows in a bottom-up fashion as intended within the National Incident Management System framework. In it, local agencies are largely in charge of their own emergencies and typically request involvement and assistance from regional, state, and federal agencies only when necessitated by the conditions of the emergency. Transportation agencies play supporting roles to various emergency response agencies that also increase as the scope of the emergency increases. For localized emergencies or those that affect a small number of people, this role is typically minor. Because DOTs and transit agencies have specialized transportation knowledge and possess critical assets such as data acquisition and communication resources, heavy equipment, and transit vehicles, they are called on when these resources are needed. As a rule, however, they are not "in charge" of evacuations, rather they respond to requests when needed. The practice review showed that some of the transportation officials would actually like a bigger role and some emergency management officials would like to see them assume a greater leadership position.

One issue that could not be fully assessed within the scope of the survey was the extent to which practices have changed since September 11 and Hurricane Katrina, particularly in terms of the evacuation of low-mobility and special needs individuals. Similar studies conducted before these two events showed that transportation agencies were only peripherally involved in emergency management processes. The involvement of transportation grew significantly as the desire to incorporate more contraflow segments into state plans increased in the late 1990s. Since 2005, transportation's role has further increased as a greater emphasis has been placed on assisted evacuations for non-self-evacuators.

It should be recognized that negative responses or non-responses in the survey should not be interpreted as inadequate planning or oversight. Not all locations included in the survey have a need for every type of resource, method, or plan element. For example, several of the states included in the survey were not threatened by any of the hazards for which mass evacuations are used. In those locations, the role of transportation in evacuation planning and management is often focused on determining and communicating which routes are open for travel and what alternative routes can be used if others are closed. Similarly, the level of detail and development of plans for certain responses such as contraflow, en-route services, and special needs planning are not as necessary because their jurisdiction may be small or sparsely populated, or the hazard conditions are such that they do not threaten populated areas near major highways.

CASE ILLUSTRATIONS

To compare and contrast evacuation practices across the United States under varying hazard types and response conditions, six case illustrations are included in the following sections. These case illustrations have been selected to represent a range of hazard-response scenarios in which evacuations of various sizes and geographic areas have been used. In addition to reviewing a cross-section of natural and man-made threat characteristics and response scales, modes, and temporal conditions, the case scenarios were selected to cover a geographically diverse data set that included all regions of the country.

In addition to the discussion of the specifics of the evacuation process, each case illustration describes the general characteristics of subject hazards for which it is used and the location in which it occurred. Where appropriate, the case illustrations include a discussion of the relevant preparedness characteristics of the locality, including a description of the state of emergency planning and training used in each as well as descriptions of the key components of the emergency response processes.

The case descriptions included here are based on a related report prepared by Jones et al. (2008) at the Sandia National Laboratory for the NRC. The NRC sought similar knowledge gained from the results of recent large-scale emergency response activities with the primary purpose to determine whether there were areas within the NRC and FEMA emergency preparedness program for nuclear power plants that could be enhanced based on recent lessons learned. Readers interested in the complete detailed findings of this work are encouraged to review the complete project report.

Case Study 1—Hurricane Katrina

Hurricane Katrina was a watershed event for both emergency management and transportation from many perspectives. It was by far the most costly natural disaster in the history of the United States and was also one of the costliest in terms of loss of life. From an evacuation perspective, it demonstrated many of the best and worst aspects of the current state of mass evacuation planning and operation.

The hurricane made landfall on the Gulf Coast near Buras, Louisiana, on August 29, 2005, as a Category 3 hurricane (NHC 2006). At one point, the storm was approximately 400 miles across, prompting the evacuation of approximately 2 million people along the Gulf Coast from Louisiana to Florida. The highway-based portion of the evacuation was generally considered to have been successful as hundreds of thousands of vehicles moved away from southeast Louisiana in less than 48 hrs. The Katrina event was also unique in that after the storm's passage, the levee system surrounding New Orleans failed, flooding 80% of the city. This meant that everyone who had remained in the city had to be evacuated. In the days following landfall, local, state, and federal government response agencies were tested to their limits.

Preparedness and Planning

State transportation officials had integrated lessons learned from Hurricane Ivan and revised the state contraflow plan, which was a key factor in the successful evacuation of Louisiana. The City of New Orleans Comprehensive Emergency Management Plan (2005) provided for the use of all available resources to evacuate threatened areas and identified that special arrangements would be made to evacuate people unable to transport themselves. The plan identified the need to evacuate approximately 100,000 citizens of New Orleans who did not have personal transportation. The state of Mississippi and local communities, such as Gulfport, Biloxi, and Pass Christian, implemented their emergency plans. Alabama transportation authorities had implemented lessons learned from Hurricanes Dennis and Ivan and had practiced to reduce the time needed to implement contraflow. Alabama officials also implemented a proactive communications strategy that was a key element in the response.

Decisions to evacuate were made by local officials and were often coordinated with neighboring parishes and the state. Although many parishes in Louisiana and counties in Mississippi and Alabama were evacuating under mandatory orders, the city of New Orleans had issued a voluntary evacuation order. The delay in ordering a mandatory evacuation was viewed by some to have contributed to the consequences as identified in the "Failure of Initiative" (Select Bipartisan Committee 2006), which states "the incomplete pre-landfall evacuation led to deaths." The law in Mississippi gave the governor the authority to order an evacuation, although longstanding practice is to give that responsibility to local authorities. When evacuation decisions are made, they are communicated to state agencies who implement evacuation elements such as traffic control and contraflow.

In St. Charles Parish, Louisiana, the parish president evacuated the public works staff to a coordinated location just outside of the hazard area. Once the hurricane had passed, the public works staff were then in place with the necessary equipment to facilitate reentry into the area. Reentry into effected areas required, among other things, clearing roadways of fallen trees and debris to allow traffic movement. The foresight to preposition public works staff and equipment expedited the reentry activities and ensured that a fully equipped and available public works staff could begin postincident assessments and repairs to the infrastructure. In Mississippi, some emergency response staff was allowed to evacuate, but after the passing of the hurricane, many were unable to return.

Evacuation Direction and Control

The Louisiana evacuation plan had been updated in 2004 after the evacuation for Hurricane Ivan. The updated plan included a staged evacuation and an improved contraflow plan, which was prepared and implemented in less time than expected (Select Bipartisan Committee 2006). It was estimated that approximately 92% of the threatened population in Louisiana had evacuated (Select Bipartisan Committee 2006). According to traffic count data collected from routes close to New Orleans, traffic flow had dropped to a "trickle" about 8 hrs before storm landfall, suggesting that everyone with the means and desire to evacuate had done so (Wolshon and McArdle 2008). In New Orleans, it was estimated that only about 80% of the population actually left, leaving close to 70,000 people still in the city.

Following the mandatory evacuation order for New Orleans on August 28, 2005, the Regional Transit Authority began running special transportation services from 12 sites across the city to take evacuees to the Superdome and later to take assisted evacuees and special needs persons to Baton Rouge (Select Bipartisan Committee 2006). In the afternoon of the following day, conditions had reached a point that all flights in and out of New Orleans airport were canceled as a result of high winds, and contraflow operations ceased. Evacuations in Mississippi were generally staged, with lower-lying areas, mobile home communities, and residences along waterways encouraged to evacuate before those in safer areas.

Communication and Public Information

At the start of each hurricane season, there are many opportunities for the residents along the Gulf Coast to receive information on the threat of hurricanes. These include local television and radio broadcasts, newspaper articles, and websites. The New Orleans Comprehensive Emergency Management Plan identifies the need for public education and includes discussion on developing media for those that do not use traditional media (City of New Orleans 2005). Brochures are routinely mailed out in many counties and parishes. The emergency awareness brochure for Plaquemines Parish had been completed and was distributed to residents only a couple of weeks before Hurricane Katrina.

The public was notified of the approach of Hurricane Katrina days in advance of landfall primarily through local and national media. The National Hurricane Center disseminated warnings and hurricane forecasts through the National Oceanic and Atmospheric Association weather radio and online, operating in conjunction with the EAS (White House 2006). Pamphlets were handed out in many areas instructing residents on the order in which they were to evacuate during staged evacuations. Residents in mobile homes, along waterways, and those in lower elevation areas were also encouraged to evacuate early.

Local news stations, radio stations, cable television, and national television stations broadcast the voluntary and mandatory evacuation orders issued by officials. The most common form of notification was through the media. All parishes and counties used media to inform the public and some had law enforcement personnel go door-to-door and drive streets in selected areas using loud speakers to notify residents of mandatory evacuation orders. St. Charles Parish has its own television station, website, and radio station that provided up-to-date information. During the evacuation, message signs were provided along the evacuation routes to inform evacuees of current traffic and storm conditions. In

New Orleans, some information was also communicated in Spanish and Vietnamese, whereas in Florida, some information was published in Spanish, French, and German.

A postevacuation survey of Hurricane Katrina evacuees (Kaiser Family Foundation 2005), reported that of those who chose not to evacuate 73% heard the evacuation notification, and 25% reported that they did not hear the message. Of the 25% who did not hear the notification, 19% said that although they did not hear the evacuation message, they were aware that an order had been given for their area. Sixty-six percent said that the evacuation notice provided was clear (Kaiser Family Foundation 2005).

Assisted Evacuation

An element of the Hurricane Katrina response that received a large amount of media coverage was the evacuation of the special needs population. In Gulfport, Mississippi, arrangements were in place to use school buses to transport the special needs population to area shelters. The system was effective in getting people to a safe location. Arrangements were also in place with an ambulance service to transport those who were nonambulatory. Before the evacuation, a special needs list had not been fully compiled through local agencies; however, the ambulance service had its own list, and the county was able to use it to identify some of the special needs individuals. There were no plans in place to evacuate individuals who were transit dependent. These individuals needed to make arrangements for transportation to shelters and in many cases called 911 to request assistance.

In Louisiana, police and fire department personnel were sent through the city asking people to go to checkpoints where buses would pick them up to take them to the Superdome. Following the mandatory evacuation order of New Orleans on August 28, 2005, approximately 20 buses were used to support this effort (Select Bipartisan Committee 2006). There were no signs posted with instructions on where to meet buses, and residents found it difficult to know where these checkpoints were located. There were no plans for individuals who could not get to a checkpoint.

Nursing home managers and owners prefer to shelter-in-place during a hurricane and, as a result, approximately 70% of nursing homes did not implement evacuation procedures (Schlenger et al. 2006). Evacuating the sick and nonambulatory is stressful to the patient and can lead to further health complications for the individual. Many times, the owner has to evaluate which scenario is more threatening for nursing home residents. Also, evacuating a nursing home is expensive, requiring special transportation arrangements for ambulances and specialized busing. This cost is not refunded to a nursing home owner if a hurricane shifts course and misses an evacuated area. Therefore, the decision to evacuate a nursing home is often made late in the event, although these decisions are better made early, because it takes much more time to evacuate special needs facilities.

Sixty to 70 nursing homes were affected by Hurricane Katrina. The Louisiana Department of Health and Hospitals had established seven special needs shelters, which quickly became overwhelmed (Schlenger et al. 2006). According to the Louisiana Nursing Home Association, licensed facilities are required to have an emergency plan. The development of individual evacuation plans resulted in facilities identifying the same local busing and ambulance resources to support an evacuation. This planning practice resulted in a lack of resources. Only 21 Louisiana nursing homes evacuated before hurricane landfall (LNHA 2006). Buses that had been contracted were not always available (Schlenger et al. 2006), and residents had to travel in borrowed vehicles that sometimes lacked air conditioning or broke down along the way. Trips took longer than expected. and food and water were sometimes rationed. Medicine, oxygen tanks, and incontinence supplies were often left behind. Thirty-six additional facilities were evacuated postlandfall, but these nursing homes and hospitals were not a priority during the rescue process (LNHA 2006). As a result of poor planning, bad decisions, and unfortunate circumstances, more than 200 nursing home patients died as a result of Hurricane Katrina.

Another group of special needs persons are those under the control of local and state correctional facilities. With the approach of Hurricane Katrina, some facilities evacuated prisoners in the days before landfall. A few facilities, most in Orleans Parish, did not evacuate before the storm. The Louisiana Department of Corrections stated that the evacuation, although a "logistical challenge," was safe and efficient (DPS 2005[This is included as the "Louisiana Department of Public Safety and Corrections" reference – am I doing this correctly?]). More than 6,000 inmates were evacuated before and after the hurricane.

Case Study 2—2007 Southern California Wildfires

Between October 20 and November 9, 2007, a series of 23 wildfires raged across a seven-county area in Southern California that encompassed Los Angeles and San Bernardino counties in the north and San Diego and Imperial counties near the U.S.–Mexican border in the south. As a direct result of these devastating fires, more than 517,267 acres were burned and 3,204 structures were consumed and destroyed (GOES 2007). The fires tragically resulted in the deaths of 10 people and were directly attributed to the injury of an additional 139 people (GOES 2007), including 61 firefighters (CNN 2007). The wildfires also precipitated the largest evacuation in California's history, with some estimates suggesting the emergency relocation of nearly a million people ("Scale of the Fire's Disruption" 2007).

Preparedness and Planning

Although the 2007 wildfires were spread over two Mutual Aid Regions and seven counties, the decision to evacuate was made at the local level. The California Department of Forestry and Fire Protection provided overall command and developed mitigation strategies to fight and ultimately contain the wildfires. They employed several area commands, usually at the county level, which provided coordination and prioritized resources. In addition, the Incident Command System, which incorporated a local unified command, was established with local fire departments taking the lead in fighting fires within their areas. Typically, the decision to evacuate was the responsibility of the local incident commander or, in some cases, local authorities.

Wildfires present unique challenges to emergency officials with regard to conducting evacuations. Although many coastal communities have detailed plans with specific timelines to initiate emergency evacuation procedures for hurricanes, wildfires tend to be unpredictable and are event driven. Wildfires generally have the capability to spread at a rate of 1–5 mph, but have the potential to move faster than a person can run and, based on wind speeds, can actually move up to 60–70 mph. This high rate of speed is achieved when embers from the flame tops are blown to new locations where new flames are ignited. Based on the unpredictability of a wildfire there are no formally written evacuation plans, although a basic template of action does exist. Emergency officials attempt to establish trigger points in which fires pass a certain location and the decision to initiate an evacuation for a specific area is implemented. Predetermined evacuation routes do not exist and areas to evacuate are determined based on the nature of the wildfire.

The decision to evacuate and the determination of when evacuations could begin consistently came from the fire departments, which are provided by the incident commander at the local level. The fire departments developed "evacuation boxes" based on highly recognizable and understandable physical boundaries such as highways and waterways, and relayed that information to law enforcement and the city or county EOC. With the decision made to evacuate, law enforcement and transportation officials were responsible for developing the mechanisms to initiate the evacuation and carry out the evacuation order. Meetings with local officials showed that fire department officials designated where and when to evacuate based on knowledge and experience of weather conditions, fuel source availability, and threats to population. However, it was clear that their job was to fight fires and not evacuate people. The actual evacuation process was managed and controlled by law enforcement agencies. Local DOT and Department of Public Works agencies played a minor role overall in the evacuation by providing barricades, variable information signs, and closing roads as directed by law enforcement officials.

The California DOT (Caltrans) also had representation in the local EOCs, in addition to establishing their District Command Centers, which included key management and staff. Caltrans assisted with the coordination of emergency response, evacuations, and route closures with assistance from the California Highway Patrol. Caltrans mobilized maintenance and construction crews to assist in Route Closures, Traffic Control, and Field Damage Assessments.

As typical of most large-scale evacuations, the exact number of residents who evacuated, when they left, and where they went was not known for certain. However, it is generally accepted that more than 900,000 people evacuated as a result of the wildfires, with some sources saying that the number actually approached 1 million people. Regardless of the total number of individuals who evacuated, it is accepted that this was the largest evacuation in California history.

Reports and interviews showed that evacuation orders were issued as both "mandatory" and "voluntary" during the event. The type of evacuation and when the orders were issued were a function of the speed and direction of the fires. Although first responders in San Diego County noted that they do not have the capability to force citizens to evacuate under a mandatory evacuation, they did believe that under existing laws for child endangerment they had the legal authority to forcibly remove children from a house, and if they threatened the parents with this, they estimated that people actually end up evacuating "99.9 percent" of the time.

During the 2007 wildfire evacuations, there was no implementation of proactive traffic management techniques such as contraflow or priority signalization. In general, such actions appeared to be viewed somewhat negatively because of the additional control manpower they would likely require. Despite this, contraflow operations were seriously discussed for Ramona (north of San Diego) by local officials but, ultimately, they were never implemented. One method of traffic control used by the San Diego mayor was to request that people stay home and stay off the roads to free capacity for evacuee traffic, responders, and the basic safety of all. Although the impact of the request cannot be measured, it demonstrates a proactive message and effective utilization of the media to convey to citizens how they can facilitate emergency actions.

Evacuation Direction and Control

As a result of the wildfires, up to 15 major highways were closed during the fires because of dangerous fire conditions; however, these closures did not appear to have affected the evacuation. Most notably, all of the most heavily traveled highways of Interstates 5, 8, and 15 were closed at different times. To compensate for these closures, local officials worked with their federal counterparts at the Camp Pendleton Marine Corps Base to permit public use of on-base roadways for evacuation traffic to access northbound of I-5 in lieu of I-15.

One of the ways in which Caltrans assisted with road closures was through the release of the "Caltrans Commuter Alert," which provided location and details about road closures throughout the seven county areas. These road closures were illustrated through geographic information systems by providing detailed maps that depicted the road closures as well as the perimeters of the wildfires. Both San Diego and Caltrans provided mapping services to assist responders and the citizenry during this period.

Assisted Evacuation

In addition to the threatened population, 14 nursing homes evacuated nearly 1,200 residents in San Diego County. An additional 85 assisted-living facilities evacuated 2,189 seniors. The fires also resulted in two acute care hospitals and a psychiatric hospital being temporarily shut down. During the emergency, it was found that some elderly and infirm groups experienced some difficulties in evacuating. Of the 3,300 nursing home residents and elderly residents who evacuated, six were reported to have died ("Scale of the Fire's Disruption" 2007). In San Diego, the Office of Emergency Services estimated that more than 1,000 seniors were moved through transit buses and EMS assets. This was the only noted use of transit assets in San Diego County for this evacuation.

Because of San Diego's location near the Mexican border, the county is home to a large migrant worker population. During the 2007 wildfires, it was reported that there were several challenges to meeting the needs of this diverse group. Several factors contributed to the difficulties in evacuating this group, including the following:

- A lack of English-speaking proficiency, which may have resulted in inadequate communication, confusion, and misunderstanding of evacuation and sheltering orders
- A lack of trust of public officials because of possible illegal immigration status of prior negative encounters with law enforcement and immigration agencies
- Limited financial resources to cover nonworking periods

Because of these issues, some migrant workers in California were reported to have remained in agricultural fields even if they were under a mandatory evacuation, and some were denied entry at shelters because they did not possess adequate identification (NPR 2007). Although city officials pointed out that no one was killed or injured as a result of not evacuating because of language barriers, the city's After Action Report did document a "chronic lack of translators, which hindered the ability to evacuate and/or provide other emergency services" (City of San Diego 2007).

Communication and Public Information

Until the 2007 wildfires, the 2003 wildfires that struck San Diego County had been the most destructive fires in California history. One of the major shortfalls identified during the 2003 wildfires was a lack of interoperable communications equipment among the first responder agencies. San Diego County has since worked aggressively to address this shortfall, and it is generally acknowledged that communications among first responders was considered a major success during the 2007 wildfires. The overwhelming opinion was that communications were handled quite effectively from within and between the various responding agencies. San Diego County uses two different 800 MHz trunked systems, a regional system for San Diego and Imperial counties, and a dedicated system to for the city of San Diego. In 2007, the DHS ranked the San Diego Tactical Interoperable Communications Plan as one of the four highest scored out of the 73 evaluated cities. Overall, the system performed very well; however, there were a few denoted deficiencies, including a shortage of 800 MHz radios among firefighting crews, that may have, at times, slowed the deployment of firefighters and equipment at various times and locations. Another identified shortfall was the lack of tactical channels for unit-to-unit communications. This limitation led to overcrowding on the available channels and the delay of information exchange at times when the bands were filled.

Another example of an effective tool in San Diego County were the web-based emergency management communication tools such as WebEOC® software, which made it possible for up to 500 agency representatives to have complete, instantaneous, and full situational awareness. The primary function of the WebEOC® platform is for local government to process resource requests through a single system as well as to provide situational awareness reports that allow all those logged into the system to see what is going on throughout the disaster event. Because it is web-based, all local and state agencies, including Caltrans, were able to maintain situational awareness and respond to resource requests throughout the duration of the wildfires.

To educate the public, issue evacuation orders, and provide up-to-the minute information on the wildfires, the city of San Diego employed a full range of communication assets to ensure that the necessary information reached its citizenry. The city of San Diego reported using the following methods to communicate with the public:

- Door-to-door knocking by first responders
- Police and fire rescue vehicle sirens
- Police and fire rescue vehicle and helicopter lights
- Constant monitoring and information flow to media outlets for dissemination to the public
- EAS through television media
- AlertSanDiego mass notification system

- Community access phone system
- 211 information line
- Individual and community preparedness

One of the key areas identified for improvement following the 2003 wildfires was the ability to directly alert the public of emergency information during periods of disasters. To mitigate this area, San Diego has invested in the AlertSanDiego system, a citizen call ring down system. The AlertSanDiego system was populated with listed and unlisted phone numbers provided by the counties 911 database. Although the system is only designed to alert citizens through land lines, citizens are able to register their mobile devices and sign up for text messaging at the counties website, ReadySanDiego.org. One of the significant enhancements of the system is the ability to designate areas through the creation of polygons on a county map to ring down just the area that has been selected on the map. This is an ideal system for conducting evacuations in this type of environment, because once the fire departments identified an “evacuation box,” AlertSanDiego was able to notify just those individuals who were physically located within the area being evacuated. This allowed for only the necessary number of phone calls to be made and avoided calling out an entire zip code or area code. Through this system, San Diego reported that they were able to issue approximately 12,000 calls an hour.

Another new enhancement that the county was able to use was the 211 call system to relay nonemergency information to the public. The 211 prefix was set aside by the Federal Communications Commission for the public to obtain non-emergency-related information. During the 2007 wildfire, 211 received more than 120,000 calls and was staffed with more than 1,200 volunteers. By utilizing the 211 service, citizens in San Diego County were able to receive up-to-the-minute information about evacuations, shelters, road closures, and volunteer and recovery information and services (San Diego 211 2005). More important to emergency officials, the system was useful most notably to relay non-emergency-related agency contact numbers, allowing the general population to contact these offices directly instead of using emergency dispatchers to give out the number or transfer calls to others.

Reentry

San Diego County, as with many counties, did not have a formalized plan for reentry following the containment of the wildfires. Officials noted that a managed and controlled reentry for the San Diego area is considered to be practically impossible. Although formal plans have not been developed for reentry, guidelines for allowing reentry into certain areas were followed. The primary concern for reentry focused on public safety and ensuring that areas were safe to reoccupy. Utility companies focused on ensuring that utilities were secured; however, this did not equate to utilities being restored. In addition, Caltrans Damage Assessment Teams certified the safety of state and federal roadways. The Caltrans Damage Assessment Teams also addressed immediate safety needs for reopening route segments. Caltrans’ immediate priorities focused on slope stabilization, erosion control, guardrails, signage, culverts/drainage, and electrical requirements for call boxes, lighting, and so on. Owing to Caltrans’ efforts, all route segments were reopened within 2 weeks.

Although a controlled reentry was not possible for the entire San Diego County, there were examples of isolated neighborhood-size areas in which a controlled reentry was established. In these instances, a local assistance center was set up at the entry point to an area. This center included many different services to “help effected people get their lives re-started.” In addition to managing access, it was meant to provide security against looters, safety hazards within the area, and unscrupulous contractors. Before permitting reentry into an area, the fire department conducted assessments to check for natural gas, electrical, and other potential hazards. Once individuals obtained the necessary credentials, they were required to check in and then they were granted access only during daylight hours. This process was repeated daily until authorities allowed for a full reentry. San Diego officials also maximized the use of the reentry assistance centers by co-locating grief counselor’s to assist those who experienced difficult emotional issues as a result of the wildfires.

Case Study 3—2005 Chemical Plant Fire

On the evening of August 9, 2005, a chemical recovery plant in Romulus, Michigan, caught fire when a hazardous waste tank exploded. Workers heard noises and smelled a solvent, and then evacuated the site according to the site evacuation plan. Local and neighboring fire officials and hazmat teams immediately responded to the incident. After assessing the fire, response teams decided to let the fire continue to burn. After the fire abated substantially, it was extinguished by the firefighters.

A voluntary evacuation was ordered for households within a 0.5-mile radius of the chemical plant. This evacuation order encompassed approximately 3,000 people or 1,200 households. Many of those who were evacuated were not aware of the proximity of the plant to their homes (Ecocenter 2005). Unlike the previous two examples, transportation agencies within the effected area did not have a major role during the event.

Evacuation Direction and Control

The decision to evacuate was made by local emergency response authorities. The command and control process was implemented in accordance with the formal emergency response plan for the area. According to the plan, the local fire chief was in charge of the incident command team. Police and fire personnel drove through some neighborhoods to verify that residents had evacuated. Traffic control points were established and manned during the entirety of the event. Barricades were put up to keep people out of the area, but it was reported that a few individuals went around the barricades and returned to their homes.

Communication and Public Information

Emergency planning information is available through the city of Romulus website and through the Local Emergency Planning Committee. No recent evacuations had occurred in this area so residents had little experience with alerting methods. This lack of familiarity did not appear to affect the success of the evacuation, however.

Senior officials were notified of the incident after the emergency call was received by 911 operators. To support the response, a mobile command post was brought in, and all decisions were coordinated from this location. No problems were encountered with the notification of senior officials or emergency responders. Communications between field emergency responders and the EOC were conducted primarily over radios and cell phones. Typically, cell phones were used to communicate to officials and department heads who were located off site, and radios were used in the field.

The fire department only issued an order to evacuate a 0.8-km (0.5-mile) radius; however, the media broadcast a 1.6-km (1-mile) radius for the evacuation area. Because the area was larger and the additional evacuees were not affecting the response, the fire department did not attempt to correct the error. In the days following the explosion, officials communicated event status, hazards, and reentry information to the public predominantly through media outlets, including television and radio broadcasts and newspaper articles. Only a few residents outside the evacuation area were reported to have evacuated.

Assisted Evacuation

There were no special needs facilities in the area covered by the evacuation order. Ambulances were used to evacuate some special needs individuals out of the area. There were also plans in place to use school buses to evacuate people who did not have transportation, but there were no reports of these being implemented. The city of Romulus website provides instructions for residents who lack transportation out of an area to ask a neighbor for assistance. If a neighbor was not available, instructions were to listen to the emergency broadcast station for further information.

Case Study 4—2006 Hawaiian Earthquake

On October 15, 2006, two earthquakes occurred within a few minutes of each other in the general vicinity of the Hawaiian cities of Hawi and Kiholo Bay. Hawi is a small town on the island of Hawaii. Tremors resulting from the earthquakes were felt throughout all of the islands. Extensive though primarily nonstructural damage occurred as well as landslides, power outages, and waterline breaks, which were reported to some degree throughout west side of the Island of Hawaii. Around 70% of the island was without power for varying periods of time.

Approximately 3,000 people were evacuated from Kona and South Kona, many of whom were from damaged hotels (Harris 2006). Kona Community Hospital was also evacuated because of damage. Most of the evacuees stayed on the island and moved to temporary shelters. Evacuees from the Kona Community Hospital were taken to the Keauhou Sheraton Conference Center (Chock et al. 2006), and a few acute-care patients were flown to Hilo Medical Center. About 50 residents were moved from a long-term care facility in Honokaa, and 60 residents were evacuated from the Paniolo Club condominiums.

Preparedness and Planning

Although it was determined there was no threat of a tsunami, police implemented tsunami plans to keep traffic moving on the roadways. Residents and tourists who did not have to drive were encouraged to stay off the roadways, and police reported people were cooperative with emergency response. The earthquakes occurred early on a Sunday morning when people were just awakening and traffic on the roadways was light.

Evacuation Traffic Direction and Control

Road transportation was disrupted in some places because of landslides and damage to bridges. Because there are a limited number roadways within Hawaii, when roads are closed, areas can be cut off from access by emergency response vehicles. The area of North Kohala, including Hawi, was cut off from the rest of the island for hours as a result of road closures. Kawaihea Port, which handles approximately 60% of the imports coming to Hawaii, was also closed following the earthquake.

The evacuation of the hotels and hospital was conducted relatively quickly. The number evacuated from each facility was small, and the distance needed to move people to safety was not far. Hapuna Beach Prince Hotel staff stated that it only took a few minutes to evacuate the hotel. Police did staff traffic control points after the earthquake, and evacuees were given specific instructions about where they were supposed to go. Traffic lights were nonfunctional because of the loss of power.

Communication and Public Information

The community is aware of the local hazards and evacuation procedures. However, the majority of those evacuated following the earthquake were tourists and hospital patients. As a result, it is expected that the awareness with evacuation procedures for those who were actually evacuated was low. The community was also aware of how to obtain information concerning necessary actions in the event of an earthquake. Most residents relied on television or radio sources to obtain information concerning the earthquake, but a power outage made information difficult to obtain in the first few hours.

Guests staying in hotels were notified to evacuate by means of the facility public address systems and staff going door to door. No problems with communication were reported and guests cooperated with directions. The community had previous experience with the alerting mechanism used, including EAS messages broadcast by radio and television stations. The island does have emergency sirens, but these are used only in the event of an approaching tsunami. Because a tsunami threat was not a concern with this emergency, the sirens were not used.

Assisted Evacuation

The evacuation was unique because special facilities primarily were evacuated. Hospital facility administrators decided to evacuate patients from Kona Community Hospital and the long-term care facility in Honokaa. Kona Hospital patients were assisted and cared for by hospital staff until they could be transferred to other facilities. There were no reports of injuries to patients caused by the evacuation efforts.

Case Study 5—Toxic Release/Train Derailment

On the evening of October 5, 2006, a fire started at a hazardous waste management and transportation facility in Apex, North Carolina. Responders who arrived at the site described a haze in the air near the storage facility and observed smoke coming from the building. The Apex fire chief immediately ordered the team to back off and directed that water not be used on the fire. The fire chief contacted Wake County Emergency Management and requested notification calls to residential and business telephones within 0.5 mile of the facility. A message instructed the public to "stay inside, close windows and doors and listen to the radio or television for further information." At 10:00 p.m., an evacuation order was issued for the same area. The evacuation order was then expanded to a 1-mile radius from the facility about 90 min later. The Apex response included implementation of shelter-in-place, a large-scale evacuation, evacuation of a nursing home, and evacuation of transit-dependent individuals. Each of the response elements was successfully implemented and the protective action response activities were complete within about 6 hrs.

Some law enforcement personnel reported being overcome by fumes as they conducted house-to-house evacuation notifications. This resulted in the evacuation zone being expanded to about 4 miles downwind of the facility. Evacuations continued through the night with the final evacuation zone established around 4:00 a.m. on October 6, 2006. Approximately 17,000 residents were estimated to have evacuated (National Response Center 2006b), and a shadow evacuation of up to 33,000 people was also reported.

Preparedness and Planning

The Apex fire chief was the incident commander and made the decision to evacuate. The decision-making process was clear, and decisions were made and executed in a timely manner. The level of cooperation among local, state, and federal agencies before, during, and after the incident was considered to be outstanding. The town of Apex fire, emergency medical service, and law enforcement agencies have had "mutual aid" agreements in place with the surrounding communities on a continuing basis. Success of the incident response was attributed to the cooperation among local, county, and state personnel. Federal responders brought expertise and cooperated well with local responders.

Evacuation Direction and Control

The evacuation began at around 10:00 p.m. on October 5, 2006, and within about 6 hrs 17,000 residents (approximately 50% of Apex, North Carolina) were evacuated. Emergency responders estimated that up to 33,000 additional residents left during a shadow evacuation. The evacuation was staged with clear geographic demarcation areas conveyed to the public. The success of the evacuation was attributed to the professionalism of the fire department and law enforcement personnel.

Initial protective action instructions to shelter-in-place were provided by emergency responders through the media. It was observed that most people were willing to comply with those instructions. Some people evacuated spontaneously before being told to do so, and a small number of people chose not to evacuate the area.

An early issue in the response was whether enough emergency responders were available to assist in road closures, evacuations, and traffic direction out of the area. However, extra personnel were obtained after the North Carolina State University football game ended and state troopers, county sheriffs, and city police became available to help with traffic (White 2007). Traffic control points were staffed until the evacuation order was lifted. Raleigh city buses were mobilized ad hoc to transport any people who required public transportation out of the area. However, few people used the bus transportation. No traffic problems were encountered during the evacuation, and only a few minor accidents were reported.

Communication and Public Information

The Communicator System, similar to a reverse 911 system, was used to notify residents of the evacuation. The public was also notified through EAS messages, National Oceanic and Atmospheric Association weather radio, radio and television broadcasts, and in some cases, door-to-door notification from law enforcement personnel. There were no problems with notifying emergency personnel.

Special Needs

There were no reported incidents of residents not being able to evacuate. The city medical branch assisted in the evacuation of 103 nursing home patients from a single nursing home. Seventeen ambulances, wheelchair vans, and two transit buses were used to evacuate the facility (White 2007). The evacuation of the nursing home was completed without incident in about 3.5 hrs.

Case Study 6—2007 New England Flooding

From May 11 to May 23, 2006, record amounts of rainfall fell over Massachusetts, New Hampshire, and parts of southern Maine. The flooding that occurred as a result of the heavy rainfall was regarded as the worst since the New England Hurricane of 1938. More than 7,000 people were evacuated under mandatory and voluntary evacuation orders as flood levels rose. Homes were evacuated on an as-needed basis depending on where they were located in the flood plain and according to projected forecasts. Frequently, homes in lower-lying areas of communities were the only ones evacuated. Dams within the region were at capacity with some breaches further contributing to the flooding ("Evacuations Enacted in Newmarket" 2006). One death was reported of an individual found in a submerged vehicle located on a road that had been barricaded as a result of flooding (Associated Press 2006).

Preparedness and Planning

Emergency preparedness activities are conducted extensively at state and local levels. These activities include preparing plans, conducting training exercises and drills, and educating the public about local emergency hazards. The communities are aware of the alerting mechanisms used for this type of disaster. The public is often informed of hazardous situations through EAS messages announced over local radio and television stations, through local law enforcement, and reverse 911 systems.

Evacuation Direction and Control

Affected counties within New Hampshire and Massachusetts used their emergency plans in response to the flooding. Local officials ordered evacuations, and there were no major problems reported with the decision-making process or with the time spent on decision making. Local and state EMAs, along with police and fire departments, aided in the evacuation effort. As a result of the localized areas of flooding, evacuations were typically conducted on a small scale, although there were some instances of entire communities needing to evacuate. Evacuees were informed of shelters in the area, but they were not provided specific directions to their location. In these small communities, residents generally know the locations of the schools and community centers and directions are not needed. Often, families were simply instructed to move to higher ground and were able to return to their homes within a few hours. There were cases of families evacuating before they were ordered to do so, but this was not a problem.

More than 600 roads were closed in New Hampshire ("Portions of New England Submerged" 2006) at various times owing to flooding. The Army National Guard assisted in manning road blocks, and the DOT was involved in repairing roads damaged by the flooding. Residents were cooperative and usually left early enough to avoid problems in reaching their desired destinations. Some of the evacuated areas included residents dependent on public transportation. No plan was in place to evacuate these individuals, and they were able to evacuate either with the aid of family and friends or by using the regular public transportation system. Police aided in directing traffic and manning road blocks. One traffic fatality did occur during the evacuation. Considering all aspects of the evacuations, state officials said that the evacuations as a whole went very well, and no major problems were identified.

Communications with Emergency Responders

The means by which the public was notified of weather conditions and evacuation status was dependent on the community. Methods of notification included EAS messages on local television and radio stations, route alerting with public address systems, reverse 911 calls, and door-to-door communication. As a result of the nature of the flooding, evacuations did not occur simultaneously.

As conditions gradually worsened in the days before evacuations, officials and the public were notified of the conditions by means of extensive television and radio coverage. There were no problems with the notification and no reports of language problems during the evacuation.

Assisted Evacuations

Several special needs facilities were evacuated as a result of the flooding, including several nursing homes and a half-way house with 40 female inmates (Associated Press 2006). It took approximately 10 hours to evacuate one nursing home, when a hoist was required to be constructed to safely move a nonambulatory patient from a sublevel floor. In Lawrence, Massachusetts, a large nursing home with approximately 243 residents was evacuated in 8 hours. Because of the fast-rising flood, evacuees had to be floated out of the facility in oversized laundry bins ("Flooding Forces Mary Immaculate Evacuation" 2006).

In New Hampshire several special needs individuals were evacuated to shelters ("Evacuations Enacted in Newmarket" 2006). The States of Massachusetts and New Hampshire both recognize the concern of evacuating special needs residents, and both agree that there is definite room for improvement on how this evacuation could be completed effectively. Although it is encouraged at the state level for special needs plans to be created, ultimately it is up to local jurisdictions to create such plans and registries to identify this population. Also, because of privacy issues, which are cited as primary reasons for not registering in other states, often it is left up to the individual to register themselves as a special needs person.

CHAPTER NINE

CONCLUSIONS AND FUTURE NEEDS

The review of transportation's role in emergency evacuation and reentry demonstrates the importance of and contributions made by transportation agencies in emergency planning and management. Over the past several decades, the role of transportation in evacuation has significantly expanded and will continue to grow as both the number and complexity of threat scenarios grow. The assessment shows that the role played by transportation agencies has increased in association with a several high-profile disasters and unsuccessful evacuations. Currently, state DOTs (particularly in the Atlantic and Gulf coastal states) are directly involved in evacuation route planning and management, in some cases extending across state boundaries. Transportation's role is also expanding to reflect the increasing number of threats for which evacuations are a desirable protective action. As recently as a decade ago, few transportation and emergency planners realized the threat posed to the United States by tsunamis and terrorist attacks.

The most well-developed direct role of transportation in evacuations is in the direction and control of transportation systems: the areas in which transportation agencies are the most experienced and best equipped to support. Numerous examples of evacuation-specific traffic control strategies can now be found across the country. These include newly created or adapted traffic signs and pavement markings as well as traffic management techniques such as phased evacuations and contraflow operations. In areas without the hazards or population distribution to warrant mass evacuations, transportation functions focus more on support activities such as providing information on open and closed roadways and detours; committing manpower and material resources for roadway closures; performing inspections, repairs, and debris removal on affected roadways; and using Intelligent Transportation Systems to provide en route communications and traffic flow monitoring.

The review also shows that transportation agencies are involved in communications at many levels, including between various authorities as well as the public and within and across the agencies charged with directing evacuations. Significant improvements have been made in the interoperability and redundancy of emergency communications systems and new methods have been developed for data exchange from remote data acquisition devices. Transportation-related communication takes place during all phases of evacuations, from en-route guidance during an event to public information, awareness, education, and outreach campaigns throughout the year. Information is conveyed to evacuees using a wide variety of media, including television, radio, print, newspaper, websites, mail, e-mail, telephone (511 systems and reverse 911), Internet, variable message signing, and highway advisory radio. This information will enable travelers during evacuations to be aware of routes, shelter availability, timetables for their return, and locations that may be inaccessible.

Another general finding was that, despite the extent to which transportation agencies support evacuations, a limited number of readily available sources of information include guidelines, suggested practices, and standards that can be used in the planning, analysis, utilization, and design of transportation facilities for evacuations. The information collected for this report suggests that the development of current evacuation techniques among transportation agencies has been adapted largely from conventional practice; for example, the use of contraflow for increasing directional roadway capacity. This lack of information and guidance has led to a tendency to develop localized emergency transportation practices using trial-and-error techniques. Evacuations are anything but conventional—they are a matter of life and death with a ticking clock. Transportation agencies need to be better informed and find creative and innovative solutions to the problems they face. Novel and effective ideas and practices need to be adapted from other locations. Instead of avoiding involvement in evacuations, transportation agencies must take leading roles in transportation-related activities of evacuations and take a greater ownership of the problem. In many locations this has already happened. A new emphasis has been placed on evacuations by the FHWA and FTA through the dissemination of guidance documents to lessen the information gap among transportation agencies involved in evacuation.

Separate from the level of involvement or roles taken by transportation agencies was the fundamental finding that effective evacuations are founded on the concept of individual responsibility and decision making. Officials from across the country echoed the assertion that no matter what amount of planning and resource expenditure are allocated, the primary responsibility for personal evacuations lies with individual evacuees. People who are dependent on another person, entity, or agency (whether public or private), are at greater risk. The reality, however, is that not everyone is able to be completely independent during an evacuation. In many large cities, transportation dependence exceeds a quarter of the population. As such, evacuation planning will need to include dependent non-self-evacuating groups. Based on the current level of preparedness, it is likely to be many more years before the needs of assisted evacuation planning are fully accommodated in evacuation planning. It is a problem that is just beginning to be addressed in most locations. Unfortunately, a major catastrophe is usually required before these deficiencies are recognized.

In terms of reentry, transportation's role is currently oriented toward response and recovery roles, including the inspection of critical infrastructure; the immediate (and longer-term) repair of damaged roads, control systems, bridges, and so on; debris removal and the reopening of roads; and, more recently, the coordination of the return of assisted evacuees to their places of origin. This review shows that reentry processes are primarily managed by enforcement-oriented agencies with the authority to restrict and control the movements of the public as well as arrest and detain violators. The general consensus of the sources investigated for this report showed that reentries are often complicated and manpower-intensive processes and are likely to remain a low priority. From a transportation-perspective, the formal planning of postevent reentry of evacuees remains a largely unexplored topic, both in practice and the literature.

A shortage of information was found on the topic of small-scale and low-population evacuations as well as no-notice evacuations of tourist and transient populations. These topics were raised by numerous agencies during the development of this report. Small-scale and tourist evacuations are matters of significant interest in locations not threatened by more visible and widely publicized hazards. A no-notice evacuation of Las Vegas was cited as an example of such a location. Small-scale and low-population evacuations warrant future attention.

Evacuation is a complex topic that can be influenced by an enormous number of interacting factors. Individual agencies have developed plans and response mechanisms to deal realistically with the threat conditions that exist within their jurisdiction. For example, states such as Arizona and New Mexico do not have plans to deal with hurricane evacuations, states such as North Dakota with low population density and low levels of dependent populations do not have a great need for assisted evacuation planning. As such, it is difficult to identify gaps in practice, "best" practices, or even "effective" practice because the types, scales, and characteristics of the hazards, populations, and transportation networks and resources are so variable across the country. No single type of practice or even group of practices is necessarily appropriate in all locations. A best practice might include the need to maintain flexibility and open-mindedness to solve problems on the fly in response planning. However, effective planning and management of transportation resources can significantly increase the chances for "luck" in future emergencies. It is hoped that readers of this synthesis have been able to gain a broader appreciation and understanding of the current roles played by transportation in evacuation and reentry and to gain awareness of emerging ideas and technologies that are being developed to improve the state of this field.

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APPENDIX A

EMERGING KNOWLEDGE AND TECHNOLOGIES

In addition to the recent development of new and effective field practices, the role of transportation in evacuation also extends to the development and application of new knowledge from research into emerging technologies and ideas. This appendix includes a discussion of emerging knowledge and technological tools in the field, some of which have already been used and others that are in development, under study, or are currently being discussed.

Modeling and Simulation

An emerging area that has seen significant and rapid improvements in both theory and practice has been in modeling and simulation of evacuation traffic. Recent advances in both the affordability and power of personal computers have resulted in notable advances in the development and application of computer-based evacuation modeling, simulation, and visualization. Over the last decade the creation, adaptation, and utilization of simulation for evacuation traffic analysis has increased rapidly. More than a dozen different general-purpose and specific-use simulation programs are available to evaluate and forecast the impacts of and conditions associated with mass evacuation scenarios.

While both the number of programs that are being used and the amount of people using them has been a positive development for evacuation planning, the selection of any particular system for a specific location and hazard can be difficult. Each system comes with varying levels of development effort, computational speed, output fidelity, and so on. They also vary by purpose. Some traffic analysts have preferred to use general-purpose traffic simulation models and adapt them to evacuation conditions, while others have tended toward special-purpose simulation packages developed specifically for emergency evacuation traffic flow modeling. Some of the more notable special-purpose evacuation systems include: MASS eVACuation (MASSVAC), NETwork emergency eVACuation (NETVAC), the Oak Ridge Evacuation Modeling System (OREMS), DYNamic network EVacuation (DYNEV), and the Evacuation Traffic Information System (ETIS). Additional detailed discussion of the capabilities and requirements of these models and others can also be found online in "Appendix F: Hurricane Evacuation Models and Tools" of the recent U.S.DOT "Report to Congress on Catastrophic Hurricane Evacuation Plan Evaluation" (U.S.DOT 2006).

A recent effort by Hardy and Wunderlich (2008) compared 30 of the most commonly used simulation systems for evacuation modeling. Among the significant contributions of this work was a characterization of the trade-offs between the scope of the scenario and complexity of the system. The study also included a description of three general classes of modeling scales (*macro, meso,* and *micro*) and how each system could be or has been used for modeling evacuation events. The inventory review concluded with an analysis of the ability of each to model varying scopes and complexities as well as the tradeoff between capturing appropriate system detail, developmental effort, and computational speed. The authors used the graphical representation shown in Figure A1 to comparatively illustrate the different scales at which these three modeling scales operate.

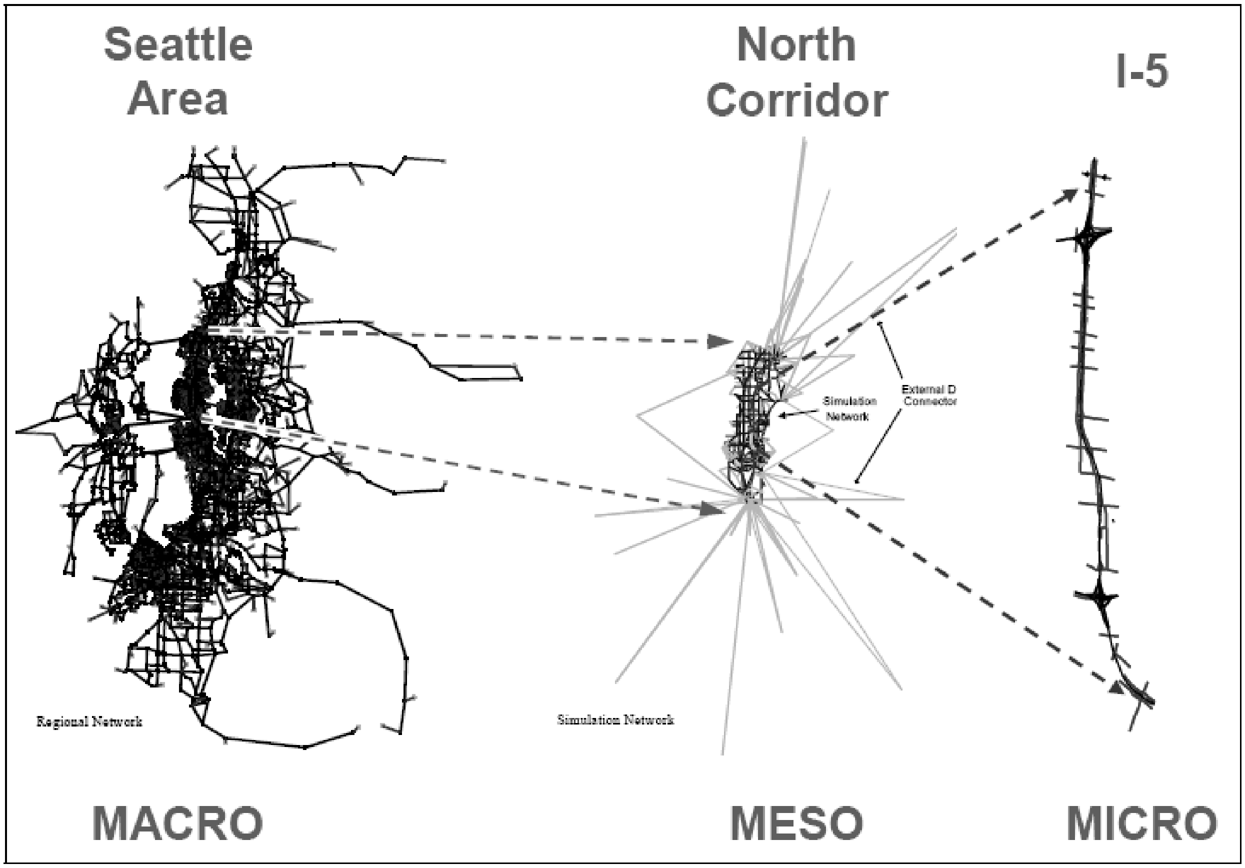

FIGURE A1 Comparisons of traffic simulation scale and detail (Hardy and Wunderlich 2008).

Macroscale Systems

At the left of Figure A1, the road network of Seattle metropolitan area is represented at a macroscale level. The representation of traffic flow within macroscale models is often compared to fluid flow through a pipe. At this level of abstraction, roads only down to the functional level of collector-distributor are included and characteristics and movements of individual vehicles and people are aggregated to group averages. Some recent macro-level models have been developed for use in real-time decision support. These tools have been favored by high level decision-makers because they can provide broad view information about how certain transportation system management techniques are likely to impact the movement of evacuees.

The diversity and functionality of macroscale evacuation transportation simulation systems are highlighted below using examples of the MASSVAC, OREMS, and ETIS models. These three systems, though all considered macroscopic, require different development effort and yield quite different levels of output. The summary descriptions provided below have been excerpted from the appendix of the 2006 U.S.DOT *Report to Congress* (U.S.DOT 2006).

The precursor to MASSVAC was NETVAC. NETVAC was developed 1982 in response to the Three-Mile Island nuclear reactor incident three years prior. While useful for evacuation with single Point-A-to-Point-B traffic movements, it was found to be limited in applicability to hurricane evacuation, which more often includes multiple origins and destinations. Transportation and emergency managers have used the model to analyze route selection, intersection controls, and lane management. MASSVAC was released in 1985, as a more robust and flexible simulation model designed for “the analysis and evaluation of evacuation plans for urban areas threatened by natural disasters,” including floods, hurricanes, tsunamis, and other related events. It is capable of simulating flow on highway networks and identifying the available efficient routes from a hazard area to the nearest shelters and calculating the evacuation time for the network.

In the mid-1990s, the Department of Energy’s Oak Ridge National Laboratories Center for Transportation Analysis developed the OREMS, “to simulate traffic flow during various defense-oriented emergency evacuations.” The system was based on the U.S.DOT FREEFLO platform which gave it instant familiarity to traffic modelers who were acquainted with the data input and modeling processes of the CORSIM system. It is a probabilistic model that uses network characteristics that, with local knowledge, can be produced with baseline data inputs. Like NETVAC, OREMS shows how a solution for one homeland security problem (terrorist incident) can be cross-applied to another (hurricanes). However, it has not been empirically validated by the developers for hurricane evacuations. As described in its online documentation (ORNL 2005), some uses of OREMS include:

- modeling of large transportation networks (covering emergency planning zones that cover thousands of square miles),
- determining the feasibility of evacuation without detailed route planning,
- identifying best evacuation routes,
- identifying bottlenecks that would constrain the flow of traffic,
- assessing the effectiveness of alternative traffic control strategies,
- assessing the effectiveness of different evacuation strategies,

- estimating traffic speed and other measures of effectiveness on specific roads or potions of the network, and
- estimating clearance times for the network or potions of the network.

Some of the advantages of OREMS include:

- easy data entry through a user-friendly interface,
- extensive context-sensitive help,
- ability to create evacuation zones through a rubberbanding tool,
- ability to zoom in and out of the network,
- ability to model evacuee response rates,
- ability to easily modify the network to simulate accidents or other impediments,
- ability to modify the network to assess traffic control strategies such as lane reversal, and
- ability to graphically display the results of the simulation statically and dynamically.

The ETIS system was created under the support and direction of the U.S.DOT as a direct response to significant cross-state regional traffic problems that were encountered during the evacuation for Hurricane Floyd in 1999. The ETIS program operates on a model that combines behavioral studies, data from past occurrences, and real-time data from ongoing incidents, including weather information, evacuation percentages, and tourist occupancy rates in affected areas. Originally favored by emergency management agencies, it is a web-based GIS tool that assists with collection and dissemination of transportation information during an evacuation. During an emergency transportation officials in each threatened state are responsible for entering information for coastal counties on evacuation status, tourist occupancy, evacuation participation rates, and traffic count information. With this information, ETIS provides a platform for States and the FEMA Regional Operations Center to monitor the overall evacuation process. Among its most useful features was its ability to forecast the amount total cross-state traffic and the likely destinations of the evacuees.

Mesoscale Systems

In the middle of Figure A1 is a representation of the group of tools classified as mesoscopic models. These systems are typically used to represent larger geographic areas than micro models while permitting the computation of more disaggregate results than macro models. Various models within the mesoscale category can have more or fewer characteristics of the micro and macro categories. One way mesoscale results are produced is by subdividing a corridor into sub-segments where the movement of vehicles is aggregated to represent “average” flow rates and speeds. The cell transmission technique is one example of such an approach.

Recently, the U.S.DOT has supported developmental work to investigate adaptability of the mesoscale TRansportation ANalysis and SIMulation System (TRANSIMS) for the purposes of evacuation traffic analysis. TRANSIMS is a set of activity-based travel modeling procedures that give detailed output on travel, congestion, and emissions in highway networks. Because TRANSIMS has the capability to evaluate highly congested scenarios and operational changes on highways and transit systems, it has been thought to be ideally suited to the analysis of multimodal mass evacuation scenarios. Originally developed by researchers at the Los Alamos National Laboratory and commercially available free of charge through the FHWA Transportation Model Improvement Program (TMIP) website, TRANSIMS incorporates four primary modules, including a population synthesizer, an activity generator, a route planner, and a traffic microsimulator. Using these four components, the system can estimate activities for individuals and households, plans trips satisfying those activities, assigns trips to routes, and creates a microsimulation of all vehicles, transportation systems, and resulting traffic in a given study area (web source: http://tmip.tamu.edu/transims/).

Preliminary data from an in-progress FHWA TRANSIMS study of New Orleans illustrates the potential applicability of the system for evacuation traffic analysis. Among it strengths are its ability to:
simulate networks over enormous geographic areas that may encompass thousands of square miles, as shown in

- model intermodal evacuations that include pedestrian, passenger vehicle, and transit modes;
- track and collect detailed statistics on millions of separate vehicles over several days; and
- produce output that can be displayed over high resolution aerial photography using animations as shown in Figure A3 and graphically as shown in Figure A4.

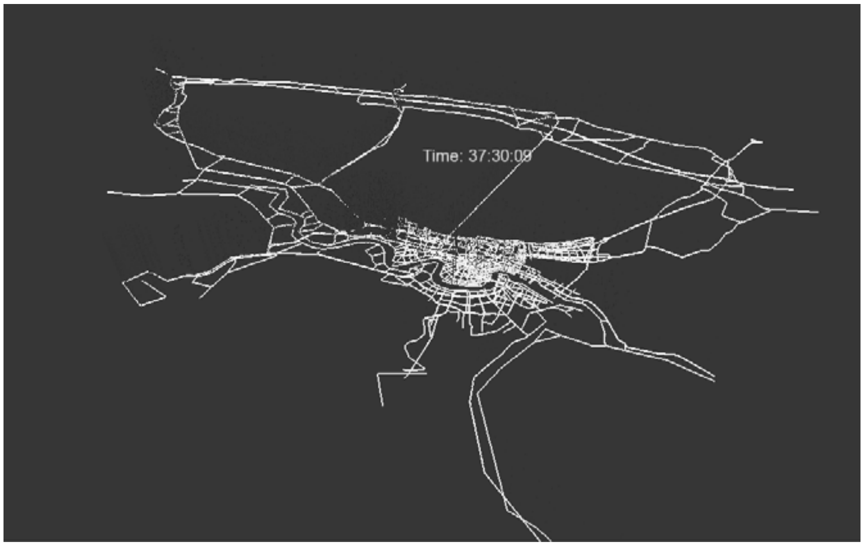

FIGURE A2 New Orleans evacuation simulation TRANSIMS regional road network.

FIGURE A3 New Orleans evacuation simulation animation.

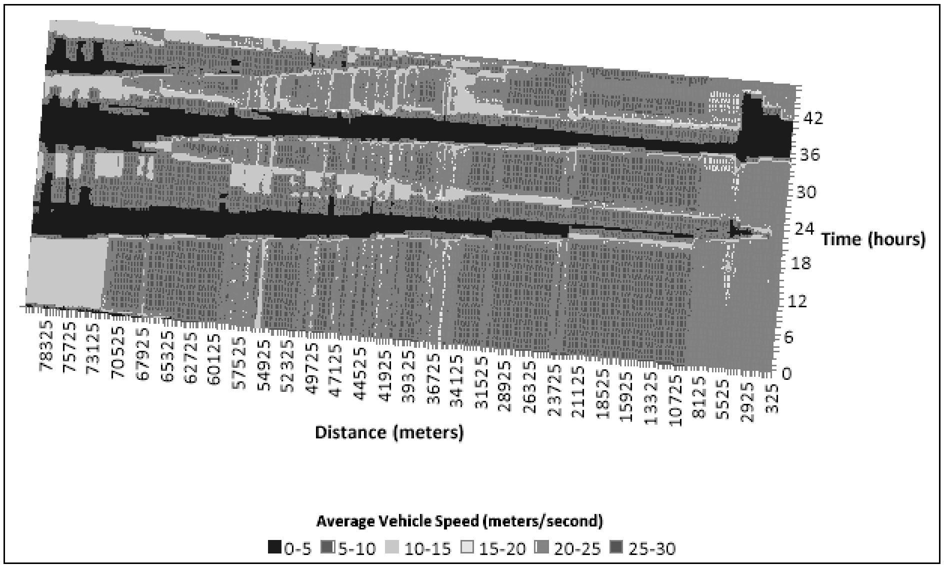

FIGURE A4 Evacuation travel speed space-time diagram.

Although the TRANSIMS system appears to be a promising avenue for mass evacuation simulations, it is not without some limitations. Among the most significant of these drawbacks is the significant level of effort required to code, calibrate, and validate the model. Calibration is particularly difficult for evacuations because few comparative evacuation traffic data sets exist. Another is the limited level of user-friendliness of the system. Currently, the program does not incorporate any type of graphical user interface. The U.S.DOT has recently redeveloped TRASNIMS to operate in a PC environment and is currently working toward simplifying its coding and model development processes.

Microscale Systems

Microlevel simulation systems afford the highest level of fidelity of the three platform types. Detailed performance measures can be produced for individual vehicles and specific locations, even down to specific intersection approach lanes. However, this additional detail comes with a price. Two major drawbacks to microscale modeling are the coding effort required to represent the network as well as limited area and time durations that can be represented. These issues have limited the applicability of microlevel modeling for the simulation of large-scale evacuation scenarios.

In the past, microscale models have been used to represent only portions of road segments because of the input data and coding challenges. Prior micro models have been used to focus on critical interchanges and contraflow termini. In these cases, however, they were immensely useful to analyze specific operating and performance characteristics in these vicinities. Another limiting factor for micro models can be computational time. Because of the required level of their detail, micro models can take many hours to process. This can result in lengthy delays when multiple iterations are required for alternative scenario analyses.

Some examples of prior microcale modeling applications include the use of the CORSIM system for the planning of the I-10 contraflow segment out of the New Orleans metropolitan area (Wolshon et al. 2006) and for the assessment of subdivision-level evacuation for wildfire emergencies (Wolshon and Marchive 2007). In the New Orleans application, micro-modeling was used to assess the performance of the contraflow segment by focusing on the initiation and termination points since these have been recognized to effectively regulate the capacity of reversible flow segments (Lambert and Wolshon 2008). The models were used to predict the operating conditions associated with the segment as well as identifying methods to enhance the flow characteristics around them (Lim and Wolshon 2005, Theodoulou and Wolshon 2004). A similar study conducted in North Carolina proved to be instrumental in the development of enhancements in the loading configuration of the I-40 contraflow segment starting in Wilmington (Williams et al 2007).

Other Research and Development Initiatives

Several other areas of research exploration and knowledge development have been occurring across a variety of related areas of specialization. Among those receiving the most significant recent interest are:

- needs for assisted evacuation,
- human behavioral aspects of evacuation process,
- evacuation transportation planning and demand forecasting,
- traffic control and management during emergencies, and
- transportation resource planning and allocation.

Although much of the recent work has been geared toward evacuations in urbanized areas and hurricane hazards, efforts have also been ongoing for other types of hazards including terrorist events and other scenarios with limited advanced notice.

Among the most active agencies in evacuation information dissemination has been the U.S.DOT through the FHWA and the FTA. Over the past several years, the U.S.DOT has published (or is planning to publish) a series of more than 20 reports aimed at improving transportation operations and mobility during emergencies. The document titles along with their FHWA document numbers are listed in Table A1. All of them are also available on the FHWA Emergency Transportation Operations electronic document library website at: *http://ops.fhwa.dot.gov/publications/publications.htm*.

TABLE A1
FHWA EMERGENCY TRANSPORTATION OPERATIONS ELECTRONIC DOCUMENTS

Publication Title	FHWA Document No.
Best of Public Safety and Emergency Transportation Operations CD	FHWA-JPO-08-037
Using Highways For No-Notice Evacuations - Routes to Effective Evacuation Planning Primer Series	FHWA-HOP-08-003
Common Issues in Emergency Transportation Operations Preparedness and Response: Results of the FHWA Workshop Series	FHWA-HOP-07-090
Best Practices in Emergency Transportation Operations Preparedness and Response: Results of the FHWA Workshop Series	FHWA-HOP-07-076
Communicating With the Public Using ATIS During Disasters: A Guide for Practitioners	FHWA-HOP-07-068
Managing Pedestrians During Evacuation of Metropolitan Areas	FHWA-HOP-07-066
Routes to Effective Evacuation Planning Primer Series: Using Highways During Evacuation Operations for Events with Advance Notice	FHWA-HOP-06-109
Transportation Evacuation Planning and Operations Workshop	FHWA-HOP-06-076
Coordinating Military Deployments on Roads and Highways: A Guide for State and Local Agencies	FHWA-HOP-05-029
Emergency Transportation Response Overview	FHWA-OP-04-048
Public Safety & Security Program: Keep America Moving Through Emergencies & National Security Events	FHWA-OP-03-108
What Have We Learned About Intelligent Transportation Systems? Chapter 2: What Have We Learned About Freeway, Incident and Emergency Management and Electronic Toll Collection?	FHWA-OP-01-006
Intelligent Transportation Systems Field Operational Test Cross-Cutting Study: Emergency Notification and Response	FHWA-JPO-99-033
Faster Response Time, Effective Use of Resources – Integrating Transportation and Emergency Management Systems	FHWA-JPO-99-004
Speeding Response, Saving Lives – Automatic Vehicle Location Capabilities for Emergency Vehicles	FHWA-JPO-99-003
Enhancing Public Safety, Saving Lives – Emergency Vehicle Preemption	FHWA-JPO-99-002
Effects of Catastrophic Events on Transportation Systems Management and Operations: Howard Street Tunnel Fire Baltimore City	Web publication only
Effects of Catastrophic Events on Transportation Systems Management and Operations: Northridge Earthquake January 17, 1994	Web publication only
Effects of Catastrophic Events on Transportation Systems Management and Operations: Cross-Cutting Study	Web publication only
Emergency Transportation Operations Planning Documents	Not yet published
Additional Emergency Transportation Operations - Prevention	Not yet published
Additional Emergency Transportation Operations - Preparedness	Not yet published

Additional Emergency Transportation Operations - Response	Not yet published
Additional Emergency Transportation Operations - Recovery	Not yet published
Additional Emergency Transportation Operations - Additional Resources	Not yet published

(*Source*: http://ops.fhwa.dot.gov/publications/publications.htm.)

The FTA has also been active in developing new information related to the use of transit for assisted and public transportation evacuations. One of the most significant is the currently ongoing *National Study on Carless and Special Needs Evacuation Planning* (Renne et al. 2008). Much of the information in this report compliments a closely related and congressionally mandated study by the Transportation Research Board of the National Academies on *The Role of Transit in Emergency Evacuation* (NAS 2008). It is expected that both of these studies will become available for use concurrently with the publication of this synthesis or shortly there after.

Recently, the U.S.DOT has also funded the creation of a University Transportation Center (UTC) focused on evacuation-related transportation issues. The Gulf Coast Research Center for Evacuation and Transportation Resiliency, a jointly administered effort between Louisiana State University and the University of New Orleans, will engaged efforts to forward research, education, technology transfer activities in the areas of evacuation traffic planning, modeling, and engineering; the use of mass transportation resources for evacuation; and transportation infrastructure systems to support evacuations among other tasks.

Several of the national laboratories are also engaged in evacuation-related work. In addition to their long history of evacuation work for the NRC, the Sandia National Laboratories in collaboration with the Los Alamos National Laboratory, houses the National Infrastructure Simulation and Analysis Center (NISAC) in Albuquerque, New Mexico (internet webpage: *http://www.sandia.gov/nisac/index.html*). As one of it many activities, NISAC conducts simulation studies of hazard impacts on various infrastructure systems, including highway evacuations. The Oak Ridge National Laboratory, through its National Transportation Research Center, has developed its own modeling tool for evacuation traffic analysis (discussed earlier in this chapter) and has also done work in truck evacuations. The Argonne National Laboratory is currently engaged in large-scale evacuation traffic analyses for the city of Chicago and is developing various high-powered computer capabilities and visualization systems for evacuation.

Other organizations such as the National Science Foundation, the Department of Homeland Security, and the National Academies of Science and Engineering through TRB, and the National Cooperative

Highway and Transit Research Programs have all also sponsored numerous evacuation-related projects of the past decade. The numbers and specifics of these projects are too numerous to include in this single report. However, descriptions and points of contact for these studies are widely available through their internet web pages.

Finally, the Transportation Research Board has also supported a committee dedicated to the purpose of developing, coordinating, and disseminating evacuation-related transportation research information. Initiated in 2000, the TRB Subcommittee on Emergency Evacuation (TRB Committee ANB10-3), was founded to serve as the national focal point for evacuation-related transportation research activities. The membership of the subcommittee is not limited in number and encompasses a diverse group of transportation professionals in the private and public sectors involved or interested in the design, planning, management, operation, enforcement, and research of transportation resources for evacuation.

APPENDIX B

EMERGENCY MANAGEMENT ROLES AND PROCESSES IN EVACUATION

This appendix summarizes and describes evacuation planning and management practices and the roles of processes used by emergency management agencies during an evacuation. It includes an example illustration of one state-level emergency management agency's process in preparing for the issuance of a mass evacuation order. Although the information presented here focuses on hurricane-related mass evacuations, the hazard for which the greatest amount of information on mass evacuation planning and management is currently available, other hazards are also discussed.

EMERGENCY MANAGEMENT PROCESSES AND SYSTEMS

Although the evacuations that receive the most attention are those that involve hundreds of thousands or millions of people, the reality is that the vast majority of evacuations are much smaller local events that involve less than 5,000 people. As such, evacuations are typically ordered and managed by local officials with relatively little involvement from transportation agencies. Even million-person mass evacuations for wildfires and hurricanes start as local events in which evacuations of threatened areas can begin on neighborhood-by-neighborhood bases. When an evacuation grows to include mass amounts of people over multiple counties (or states), agencies at the state-level become much more involved in the process. Although federal agencies like FEMA have been involved in some aspects of prior evacuations, the federal role is typically limited to providing assistance to state and local officials as the conditions of the emergency surpass local resources and capabilities. Historically, FEMA has not planned or managed evacuations. Since Hurricanes Katrina and Rita, however, FEMA has taken a more active role in pre-evacuation planning. In some hurricane-threatened locations, state emergency management agencies even have pre-scripted missions for FEMA and FEMA maintains operational elements within state and local emergency management offices.

The following sections highlight several of the key components of emergency management processes and systems. The discussion is generally presented in a top-down order, beginning with the National Incident Management System (NIMS) which has established a national management framework to plan for and respond to emergency incidents. Also included are summaries of the FEMA emergency management planning and response processes.

National Incident Management System

Following the terrorist attacks of 2001 and the creation of the US Department of Homeland Security (DHS), the federal government initiated the development of a standardized, structured framework to coordinate emergency preparedness and incident management planning and operations for governmental and nongovermental agencies across federal, state, and local levels. The framework, known as NIMS, was released by DHS March 1, 2004 (FEMA 2006). By presidential directive, all federal agencies are now required to adopt NIMS and to use it in their domestic incident management and emergency prevention, preparedness, response, recovery and mitigation programs and activities. The directive also required Federal departments to make adoption of NIMS by state, tribal, and local organizations a condition for Federal preparedness assistance beginning in 2005. In addition, all state, tribal, and local emergency personnel with a direct role in emergency preparedness, incident management or response were required to certify themselves as NIMS-compliant by October 2006.

The NIMS system was developed to provide a consistent nationwide template to enable federal, state, local, and tribal governments and private-sector and nongovernmental organizations to work together effectively and efficiently to prepare for, prevent, respond to, and recover from domestic incidents, regardless of cause, size, or complexity, including acts of catastrophic terrorism. The NIMS report (FEMA 2006) establishes its basic elements and provides mechanisms for the further development and refinement of supporting national standards, guidelines, protocols, systems, and technologies. It integrates best practices that have proven effective over the years into a comprehensive framework for use by incident management organizations in an all-hazards context (terrorist attacks, natural disasters, and other emergencies) nationwide. It also establishes the mechanisms necessary to leverage new technologies and adopt new approaches that will enable continuous refinement of NIMS over time. It was also developed through a collaborative, intergovernmental partnership with significant input from the incident management functional disciplines, the private sector, and nongovernmental organizations.

The NIMS standardized incident command and management structures are based on three key organizational systems, including (FEMA 2006):

- The Incident Command System
- Multi-agency Coordination (MAC) System
- Public Information Systems

Within NIMS, preparedness is operationally focused on establishing guidelines, protocols, and standards for planning, training and exercises, personnel qualification and certification, equipment certification, and publication management. NIMS requires incident management organizations to ensure that effective interoperable communications and information management processes, procedures and systems exist to support a wide variety of incident management activities across agencies and jurisdictions (FEMA 2006).

Emergency Management Planning Process

In preparing transportation systems for emergencies it is helpful to understand the emergency management planning process. This process is typically reflected within the five areas of *prevention*, *mitigation*, *preparedness*, *response*, and *recovery*. Although the role of transportation has tended to be concentrated within the preparedness and response stages of the process, its role has grown within both mitigation and recovery.

Mitigation

The mitigation step of the emergency planning process involves activities that are undertaken to develop systems and measures that seek to eliminate or reduce the likelihood of damage or impacts in the event of a hazard. Although the structures and systems within the built environment are purposefully designed and constructed to withstand various levels of destructive threat, the real-world includes numerous conditions that can exceed these expectations. Such was the case with the construction of the levees in New Orleans and structural design of the World Trade Center buildings. It is for these reasons that evacuation is necessary.

In some areas of the world evacuation is not an option because there is no adequately safe location from wind or flooding and/or no means by which to move there. In these areas buildings are often designed and built stronger to resist wind or built higher above the ground to resist flooding. Such techniques are certainly common in the US as well. In some locations "vertical evacuation" can be used as a protective action in which people seek shelter in the upper floors of building designed specifically for such purposes. Although such techniques are simple and reduce the need for highway evacuations, they can add significant costs to construction. Often, property owners in the US find it more cost effective to build to a lower threat standard (for hurricane hazards a Category 3 level storm, for example), then purchase insurance to cover losses in the less likely situation that a worse event (like a Category 4 or 5 storm) impacts a structure.

Preparedness

Preparedness activities involve the development of emergency plans (like those for evacuation) and set frameworks for decision-making; designate agency roles and responsibilities, implement communication systems and protocols; and develop emergency training and drills to maintain readiness; and revise and update plans. In terms of the role of transportation in preparedness, this is an area in which agencies like DOTs and DPWs have significant involvement. One illustration of this has taken place in Louisiana where a working group involving members of Louisiana's Department of Transportation & Development

(LaDOTD), the Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP), and the State Police (LSP) worked to identify State emergency evacuation routes that could be used by each of these departments and the general public for disaster situations, including chemical spills, ice storms, floods, nuclear leaks, hurricanes, etc (LaDOTD 2008a and Wolshon et al. 2006). One of the outcomes of the process was the development of the southeast Louisiana regional evacuation plan that utilizes contraflow, road closures, and the phasing of evacuation orders (LaDOTD 2008b). When used for the first time for Hurricane Katrina in 2005, the plan showed a significant improvement over prior evacuations (Wolshon and McArdle 2008). Transportation preparedness activities have also included the development and distribution of evacuation route maps and the identification and planning of transit services for assisted evacuees.

Response

Activities in the response step of the process include the mobilization and implementation of first responders and emergency support staff; the allocation of resources at the disaster locations; the issuance of evacuation orders; and carrying out its implementation. In recent past evacuations transportation agencies have supported these types of response activities by supplying barricades and other control devices and support staff necessary to implement road closures and contraflow operations.

Recovery activities seek to return evacuees to areas affected by the emergency and return conditions to normal operations. Transportation agencies have played key recovery roles in several recent emergencies. In Louisiana, for example, the LaDOTD was heavily involved in the immediate response to the flooding of New Orleans because it was the agency responsible for the maintenance of the state levee system and it had equipment, personnel, and emergency contracting mechanisms in place to respond immediately to the situation and make initial closures to the damaged levees. In several recent instances transportation agencies have also played key roles in disaster recovery by repairing damaged roads and bridges to permit the inflow of relief supplies.

Emergency Response Process

The federal government, through FEMA, requires all states to have a comprehensive emergency operations plan. These plans guide emergency operations for all types of hazards, from natural to manmade and technological. While the general evacuation issues faced by coastal states are similar, different strategies and plans have been developed to deal with variations in population, geography, and transportation system characteristics. States also differ in the way that they delegate authority, allocate people and resources, and enforce evacuations. A typical goal is to maximize the efficiency of emergency operation plans within these many constraints.

Most states take a two-tiered approach to emergency planning and response. For the most part, evacuation planning, response, and recovery activities are developed at the local level. State-level emergency management agencies serve to coordinate cross-jurisdictional emergency management planning and the participation of state-level law enforcement, transportation and other relevant agencies. An example of this approach is illustrated by practices in the State of Texas where potential threats differ widely in the various regions of the state. The Texas State Emergency Management Plan (TDEM 2001) has a general multi-hazard evacuation plan; however, specific hurricane evacuation planning is left up to local coastal jurisdictions. Inland jurisdictions in Texas are concerned more with sheltering and mass care issues rather than the movement of evacuees. In Florida, where the entire state is vulnerable to hurricanes, the state attempts to coordinate the development of evacuation plans. The FEMA/USACE Hurricane Evacuation Study program has also yielded significant benefits in Florida (and other states). It has been suggested that it is the primary reason that most coastal communities now develop hurricane evacuation clearance times and trip assignments. Due in part to the problems encountered during Hurricane Floyd, the North Carolina Department of Transportation (NCDOT) has developed an Emergency Response Procedures Manual (NCDOT 2001). The manual includes plans and procedures for dealing with a variety of emergencies including snowstorms, wildfires, floods tornadoes, and hurricanes. It also includes information on various emergency response and recovery procedures for such issues as debris removal, personnel requirements, and equipment needs.

In addition to the planning process, emergency management agencies in the US follow a generally standardized response process. This process is used to declare emergencies then coordinate response and relief resources and efforts. The following summarizes FEMA official response process that first involves preliminary damage assessments which then leads to the declaration of an emergency. It also includes the primary considerations that influence the declaration (FEMA 2008).

A governor can declare a state of emergency within his/her jurisdiction and thereby invoke the state's emergency plan to augment municipal and county resources as required. In addition, a governor may also determine that the recovery appears to be beyond the combined resources of both the state and local governments and that federal assistance may be needed. The request for federal assistance must follow the legal process detailed in the Robert T. Stafford Disaster Relief and Emergency Assistance Act, 42 U.S.C. §§ 5121-5206 (Stafford Act) and implementing regulations, 44 CFR Part 206.

A preliminary damage assessment involves a review of damage and any emergency costs that have been incurred and the impact to critical facilities like public utilities, hospitals, schools, and fire and police departments. The assessment reviews the affect of the emergency on "individuals and businesses, including the number damaged, the number of people displaced, and the threat to health and safety caused by the storm event." As part of the assessment process, estimates of the expenses and damages are also made. Ultimately this information is used to show that the costs of response efforts, such as emergency personnel overtime, other emergency services, and damage to citizens, is beyond state and local recovery capabilities exceeding available state and local resources.

Based on the results of the assessment, a governor submits a written request to the President through a FEMA regional office. Based on a FEMA review of the request and the findings of the preliminary damage assessment, FEMA recommends a course of action to the President. When developing a recommendation to the President, FEMA guidelines require a number of factors to determine the severity, magnitude, and impact of a disaster event including (FEMA 2008):

- Amount and type of damage (number of homes destroyed or with major damage);
- Impact on the infrastructure of affected areas or critical facilities;
- Imminent threats to public health and safety;
- Impacts to essential government services and functions;
- Unique capability of federal government;
- Dispersion or concentration of damage;
- Level of insurance coverage in place for homeowners and public facilities;
- Assistance available from other sources (federal, state, local, voluntary organizations);
- State and local resource commitments from previous, undeclared events; and
- Frequency of disaster events over recent time period.

Recently, FEMA has also made it possible for a state to request an emergency declaration in an advance of the impact of a disaster (FEMA 2007). If granted a pre-disaster declaration facilitates pre-positioning of direct federal assistance, equipment, and supplies to meet emergency requirements before a catastrophic hazard, like a hurricane, makes landfall.

Authority and Command Structure

The emergency response command structure differs in every state. By law, governors in most states have the ultimate authority to order evacuations. However, some governors delegate this authority to local-level officials, such as mayors, city councils, county sheriffs, county judges, or county presidents. This is primarily because these officials have a better knowledge of local characteristics and are better informed on current local conditions. Discussions with emergency management officials suggest this may also be in part because mass evacuations, particularly for hurricanes, can be unpopular and politically sensitive issues since they are so costly and disruptive and (in hindsight) the orders can turn out to be unneeded, too large, or in the worst case, too small.

Temporal Processes

A critical issue in hurricane evacuations is timing. While some hazards, like hurricanes, typically give many hours if not several days of advanced notice, many give no advanced notice at all. Under these varying conditions, the manner in which evacuations are carried out is equally varied. The earlier the evacuation order is issued, the more time people will have time to evacuate. However, the earlier it is issued the greater the possibility that the hazard conditions could change, rendering parts of the evacuation unnecessary or potentially putting more people at risk during the evacuation.

The primary criteria used to make decisions of how soon and how large of an area to evacuate for hurricanes are the storm forecasts and Hurricane Watches and Warnings issued by the National Hurricane Center (NHC). The NHC generally issues advisories on current and predicted storm track, forward speed, and intensity every six hours. As a storm nears landfall or if conditions change significantly from what was forecast, the NHC will issue intermediate advisories every two hours. Although they use the latest storm monitoring and computer modeling techniques to develop their forecasts, the current state-of-the-art is such that these forecasts contain uncertainty in the time frame of one to three days out, when evacuation decisions need to be made.

The NHC has made slow but steady improvement in track forecasts over the past few decades, but not as much in intensity forecasts. The NHC average official forecast track errors (for the period of 1989–1998, Atlantic Basin) for 24, 48, and 72 hr were 102, 186, and 278 statute miles, respectively. During the same time period, the average official intensity (wind speed) forecast errors were 12.7, 18.4, and 23.0 miles per hour, respectively. It is apparent that most agencies feel that NHC predictions for hurricanes are not timely or accurate enough since even medium-sized coastal cities need on the order of 12 hr to initiate and complete evacuations before arrival of tropical storm-force winds (39 miles per hour), the most common evacuation termination criteria.

The time required to evacuate is estimated from a combination of clearance times and the hazard time. Clearance time for a with-advance-notice hazard typically includes the time required to configure all traffic control elements on the evacuation routes, initiate the evacuation, and any additional time to clear the routes of vehicles once degrading conditions warrant its end. The hazard time for a scenario like a hurricane includes the pre-landfall hazard time during which hazardous conditions can exist prior to the actual hurricane landfall. This occurs as the outer bands of the storm begin to impact the coast, bringing combinations of tropical storm-force winds and potential roadway flooding from torrential rains and storm surge. Clearance times are often estimated using evacuation traffic models, which are themselves dependant on data such as the population anticipated to evacuate, the number of lanes available for evacuation, and other travel impacts that will affect the evacuation, including road closures and blocked lanes. The amount of time required for clearance can also be significantly lengthened by en route congestion and the setup time required for complex control features, such as those required for contraflow.

With all of the factors that need to be considered, it is not surprising that pre-planned evacuation times vary widely by location. Many areas will also include additional time for larger hazards that encompass larger evacuation zones in which a greater population is affected. In Louisiana, home to the city of New Orleans, with 1.3 million residents and limited outbound route capacities, an advanced notice of 72 hr before landfall is desired to issue an evacuation order for a hurricane. However, this much advanced notice is difficult given the limitations of current storm track and intensity forecasting. In North Carolina, clearance times for hurricanes can vary from 9 hr in some areas of the state to 24 hr in others. In New Jersey the maximum clearance time is 36 hr for their most southern county, Cape May. In the state of Texas, planned hurricane evacuation clearance times range from 2 to 29 hr. As a safety factor, officials in Texas generally add in 3 hr to advise the public and get the evacuation underway. Thus, depending on the size of the storm and its location along the coast, more densely populated jurisdictions may need as many as 32 hr ahead of storm landfall to make the evacuation decision. Evacuation orders for less populated Texas coastal areas may, however, require much less time.

Evacuation Process

The most visible part of any evacuation is when people take to the road to flee an impending or existing danger. However, this action is typically only the last step in a process that may have begun hours, days, or even a week prior depending on the type of hazard. The sequence of activities that precedes a hurricane evacuation order, for example, is typically led and coordinated by state-level emergency management officials, incorporating a progression of weather observations, readiness actions, and response activities. The level of urgency at which these activities are undertaken is based on the development and movement of the storm. Thus, while emergency management agencies follow established procedures, the sequence and timing of which may vary widely based on the characteristics of any particular hurricane.

In the following sections, the sequence used by the State of Louisiana emergency management officials for a hurricane evacuation is described (Wolshon et al. 2001). This sequence has evolved over time as more experience and knowledge has been gained and is not necessarily representative of every location and for every hazard. However, most states generally follow a similar process in response to hurricane threats.

In Louisiana, the Louisiana Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP) is responsible for developing emergency procedures and coordinating preparedness, response, and recovery functions for hurricanes. GOHSEP uses a four-step "activation" process that transitions their staff from routine operation through the various stages of readiness and response ultimately leading to recovery after the storm (LA OEP 2001). While these procedures are presented relative to the landfall time of an approaching storm, it should be noted that in preparing for hurricane there is no such thing as a "normal" storm. Hurricane behavior is notoriously unpredictable tropical storms can develop into strong hurricanes within hours. Therefore, pre-landfall time references can vary significantly and activations can jump more than one level at a time.

Levels V and IV Activation

Under routine operation GOHSEP functions at a Level V Activation status. At this level, normal staffing is maintained and no special duties are undertaken. Anytime a tropical weather system forms in the Gulf of Mexico or in the Atlantic Ocean with a track that might take it into the Gulf, GOHSEP moves to Level IV Activation. Level IV represents a very preliminary activation and operations within the management center are still relatively routine. At Level IV, a Crisis Action Team (CAT) is activated to monitor the storm (using National Hurricane Center forecasts) and prepare a situation report for key government officials, including the Governor and FEMA. Communications with local emergency management offices and other involved state agencies such as the Departments of Transportation, Environmental Quality, Health and Hospitals, etc., are also initiated. Based on weather conditions, Level IV Activation could take place up to a week prior to storm landfall.

Level III Activation

When forecasts show that a hurricane poses a threat to coastal Louisiana, GOHSEP moves to a Level III Activation in which GOHSEP staff moves to an increased state of readiness. At this point a storm strike could be as close as three days away. GOHSEP staff begins to coordinate with the LaDOTD to clear evacuation routes of all obstructions and to collect traffic volume data on key routes on an eight-hour basis. The Louisiana National Guard also determined the need to activate National Guard liaison officers to facilitate the allocation of resources required by local emergency management officials, such as the use of military vehicles for evacuation transportation. The Louisiana State Police may also send liaison officers to the Parishes. At this stage GOHSEP officials also begin to coordinate their activities with bordering states (Texas, Arkansas, and Mississippi), particularly in the area of traffic control measures, as evacuees may need to move across state lines.

Level II Activation

If a storm continues on a track that threatens the state, Louisiana emergency officials shift to a Level II activation giving them a higher state of readiness. Transition to this level would normally occur two to three days prior to predicted storm landfall. In Level II status, emergency management officials begin to disseminate evacuation and shelter information to the public via various media outlets. GOHSEP also meets with both LaDOTD and State Police officials to determine the status of evacuation routes. At this time the emergency management officials would seek a Declaration of Emergency from the Governor of Louisiana.

Level I Activation

When a storm strike is imminent, GOHSEP reaches its highest state of readiness. Activities within the Emergency Operations Center (EOC) shift to action-oriented tasks, including making recommendations to evacuate. In Louisiana, evacuation orders can only be issued by local authorities, such as a mayors or parish presidents (the highest county-level officials). Evacuations orders are typically issued at one of two levels "recommended" or "mandatory." The evacuation order level is critical since it affects several aspects of the evacuation, including the number of people who are likely to evacuate and the implementation of reverse flow operations. The geographic extent and urgency level of an evacuation order are determined after the area at risk has been defined and discussions are held with local-level officials in the risk zones. During a Level I Activation, GOHSEP monitors the status of low-mobility populations such as those from nursing homes, hospitals, and prisons. If problems arise, GOHSEP assists in coordinating resources to transport people out of these facilities.

At three hours prior to the onset of tropical storm force winds on the Louisiana coast, GOHSEP issues an order to close all evacuation routes. Evacuation traffic enforcement personnel, members of the news media, and other people who could not or did not evacuate are directed to available shelters. During the storm, GOHSEP remains at Level I Activation and develops post-storm response and recovery strategies. Activities also include assessments of casualties, damage to personal property and critical infrastructure, resource availability, planning for re-entry of the population into evacuated areas, and the coordination of services for the post-storm recovery effort.

The process followed by most states includes discussions and consultation with many other state agencies including health and hospitals, commerce, tourism, and natural resources among many others. They also coordinate activities with federal agencies such as FEMA. More recently, states have also begun to coordinate evacuation activities through the FHWA through their developing Evacuation Liaison Team (ELT), which is a cooperative effort between FEMA and FHWA.

Evacuation Type

Once an evacuation is deemed necessary, the extent and type of evacuation must be determined. The type and urgency is dependent on the characteristics of the hazard and clearance times described earlier. Nationwide, evacuations are most often classified as *recommended* or *mandatory*. Recommended evacuations are typically used to warn people in areas in which a threat to life and property exists or will likely exist in the immediate future. Although people who receive such warnings are not required to evacuate, it is to their advantage to do so. In hurricane scenarios, recommended evacuation orders are targeted toward people most vulnerable to hurricane storm surge and extreme winds, including offshore workers, persons on coastal islands, and other special populations having particularly long lead-time requirements. From a traffic perspective, recommended equations are also used as a way to motivate the most threatened people to move first and clear more heavily populated areas before later, more urgent, evacuation orders have the potential to cause congestion and delays along the travel routes. No special traffic control or transportation measures are usually taken during recommended evacuations and people may remain if they so choose.

Mandatory evacuations are more serious. During a mandatory evacuation, authorities put maximum emphasis on encouraging evacuation and limiting ingress into threatened areas. These orders are also when most evacuation transportation plans go into effect. Although people are “required” to leave under mandatory evacuation orders, such orders are difficult to enforce and most government agencies lack both the resources and the legal authority to compel threatened individuals to leave. In the past, many people have resisted orders to leave their homes and property by government officials. Under such conditions emergency management officials acknowledge that if a person wants to stay, the state will not physically remove them even if it is absolutely certain that they would be harmed. In discussions with county law enforcement officials in California, it was found that some deputies were able to encourage mandatory evacuations by compelling parents to release minor children to authorities under child endangerment laws. Once children were taken into protective custody, parents would make decisions to leave as well.

Other, more ambiguous, evacuation terminology was also found across the country. Words like *voluntary* and *precautionary* are also used in some locations. It was also learned that the terms "recommended" and "precautionary" are often used interchangeably and are not necessarily as clearly defined as the previous two. One agency described their precautionary evacuations as "pre-voluntary" and thought of them as a way to get people or entities in need of long preparation times or those in recognized at-risk areas to move toward action. Again, decisions of whether or not to leave are left to individuals and few special transportation arrangements are made.

The definition and terminology of evacuation declarations are important because they impact peoples' decision of whether or not to leave. Prior research has shown that people who said they heard mandatory evacuation orders are the most likely to evacuate; while recommended evacuation orders are met with less urgency (PBS&J 2000). The type of evacuation order and how it is communicated is also critical to avoid spontaneous evacuation, also referred to as *shadow evacuations*. Shadow evacuations occur when people who believe they are at risk evacuate even though they have not been officially advised or recommended to do so (Gunter 2001). Shadow evacuees most often leave because of concern about safety but could also leave for other reasons. Authorities in Florida and Texas feel that the one of the reasons for the extreme number of evacuees during Hurricane Floyd then later in Rita was the result of shadow evacuations. However, it has been suggested that the over evacuation problem in Houston also resulted from vague and inconsistent instructions provided by the authorities.

APPENDIX C

SURVEY QUESTIONNAIRE

TRANSPORTATION RESEARCH BOARD (TRB)
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Project 20-5, Topic 39-05
Transportation's Role in Emergency Evacuation and Re-entry

Name of Respondent: ____________________

Agency: ____________________

Title: ____________________

Address: ____________________

Telephone No: ____________________ Best time to call: ____________________

FAX: ____________________

E-mail address: ____________________

Overview and Instructions

The information collected will be used to develop a National Cooperative Highway Research Program (NCHRP) synthesis on "Transportation's Role in Emergency Evacuation and Re-entry." If you or your agency have used, studied, considered, or have an opinion on evacuation and/or re-entry, please review and respond to this survey.

During an emergency evacuation, State and local transportation resources are critical and relied upon by emergency responders. Many transportation organizations have experiences and plans relating to emergency evacuation, from which other transportation organizations can learn. However, current practices and lessons learned involving transportation's role in emergency evacuations and reentry have yet to be documented.

The main purpose of this survey is to develop a report on current practices and suggestions for improving future practice. The results may also be used to help in the development of plans and simulation models for the evacuation of major urban areas.

This questionnaire should be completed by that person(s) with knowledge of your organization's activities related to emergency evacuations and re-entry plans. Please answer as many of the following questions as possible, attaching additional sheets if necessary. Send copies of any related material and your completed questionnaire by April 30th, 2008 to:

Brian Wolshon
Dept. of Civil & Environmental Engineering
Louisiana State University
Baton Rouge, LA 70803
Fax: (225) 578-4945

If you have any questions, do not hesitate to contact Brian Wolshon (225) 578-5247 or e-mail: brian@rsip.lsu.edu.

WE APPRECIATE YOUR RESPONSE—THANK YOU

TRANSPORTATION RESEARCH BOARD (TRB)
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Project 20-5, Topic 39-05
Transportation's role in Emergency Evacuation and Re-entry

Preparedness, Planning and Policy

1. Please select all that apply to your agency:

   ☐ State ☐ Regional ☐ City ☐ Emergency Management ☐ Transportation Agency

2. Does your agency have an Emergency Operation Plan?

   ☐ Yes ☐ No

   If yes, is your plan written in the Annex Format or the Emergency Support Function Format?

   ☐ Annex ☐ Emergency Support Function Other: ________________________

3. In your Emergency Operations Plan please identify the roles of the following agencies for Emergency Support Function 1 – Evacuation and Transportation: (Select all that apply)

	Coordinating Agency	Lead Agency	Supporting Agency	N/A
Emergency Management	☐	☐	☐	☐
Transportation Agency	☐	☐	☐	☐
National Guard	☐	☐	☐	☐
Law Enforcement	☐	☐	☐	☐

4. What type of evacuation scenarios currently are included in your agency's Emergency Operations Plan: (Select all that apply)

   ☐ Hurricanes ☐ Tornadoes ☐ Wildfire ☐ Flood ☐ Fire

   ☐ Chemical ☐ Radiological Release ☐ Dam/Levee Failure

   Other: ____________________

5. If someone refuses to evacuate during a mandatory evacuation, would you remove them forcibly?

   ☐ Yes ☐ No

   If yes, does your transportation agency have a role in the plan?

   ☐ Yes ☐ No

   If yes, please explain their role: ____

6. What are the levels of evacuation in your jurisdiction?

   ☐ Mandatory ☐ Voluntary Other: ____________________

7. Does your Emergency Operations Plan include considerations for evacuating people with animals? (Select all that apply)

	Yes	No
Pets	☐	☐
Service Companion	☐	☐
Livestock	☐	☐

   Other: ____________________

8. Does your Emergency Operations Plan include considerations for sheltering people with animals?

	Yes	No
Pets	☐	☐
Service Companion	☐	☐
Livestock	☐	☐

   Other: ____________________

9. What transportation modes are utilized in your Emergency Operations Plan: (Select all that apply)

   ☐ Road Networks ☐ Rail ☐ Air ☐ Water ☐ Pedestrian

   ☐ School Buses ☐ Military Buses ☐ Military Vehicles ☐ Commercial Buses

   ☐ Transit Buses Other: ____________________

10. Does your plan address providing en route services during an evacuation once an order is given?

	Emergency Management	Transportation Agency	Agriculture Agency	City Government
Mobile Fuel	☐	☐	☐	☐
Wrecker	☐	☐	☐	☐
Water	☐	☐	☐	☐
Food	☐	☐	☐	☐

   Other: ____________________

11. Is your agency's plan part of a broader regional or statewide evacuation plan?

   ☐ Regional ☐ Statewide ☐ Single Jurisdiction

12. Does your plan include a Phased Evacuation?

   ☐ Yes ☐ No

13. Does your plan call for contraflow operations?

☐ Yes ☐ No

If yes, who makes the decision to implement and terminate contra-flow?

☐ Lead Elected Official ☐ Director of Emergency Management Agency

☐ Lead Transportation Official ☐ Lead Law Enforcement Official ☐ Adjutant General

Other: ______________________________

How much preparation time is required to implement contraflow from the time the decision is made until it is ready to be executed?

☐ 1–4 hours ☐ 4–8 hours ☐ 8–12 hours ☐ 12–24 hours ☐ 24+ hours

What are your jurisdictions criteria for the termination of contraflow?

____

____

14. What barriers/obstacles to coordination and planning has your agency encountered?

____

____

15. Has your jurisdiction identified all resources using the FEMA Typed Resource Definitions?

☐ Yes ☐ No

Has your transportation agency typed all of your available resources?

☐ Yes ☐ No

16. Is your jurisdiction using a software system to manage your resources?

☐ Yes ☐ No

If yes, which software system:

☐ IRIS ☐ WebEOC ☐ E-Team ☐ RIMS Other: ____________________

17. Please identify what types of transportation resources are currently available for emergency evacuation (Examples are transit buses, school buses, barricades, electronic road signs):

1. ____________________ 4. ____________________
2. ____________________ 5. ____________________
3. ____________________ 6. ____________________

What resources used for evacuations are most critical? ____________________

Do you think your plan and available resources for evacuations are adequate to support a large scale evacuation of your jurisdiction?

☐ Yes ☐ No

If no, what are additional resources or support is required? ____________________

____

Please describe the process your agency uses to prepare resources in advance? ________

____

____

18. Does your jurisdiction conduct exercises on evacuations?

☐ Yes ☐ No

If yes, is your transportation agency included in the exercises?

☐ Yes ☐ No

Do your exercises follow the Homeland Security Exercise and Evaluation Program?

☐ Yes ☐ No

Are transportation agencies reimbursed for expenses incurred from participating in the exercise?

☐ Yes ☐ No

19. Does your agency have criteria for defining a "successful" evacuation of your jurisdiction?

☐ Yes ☐ No

If yes, what is the criterion/criteria: (Select all that apply)

☐ Total number of evacuees moved ☐ Reduced travel times ☐ High travel speeds

☐ Avoidance of injury/fatalities ☐ Positive public feedback/media reports

☐ Effective communications network Other: ____________________

Direction and Control

20. Who is responsible for making the decision that a large scale evacuation order will be given for your Jurisdiction?

☐ Chief Elected/Governing Official ☐ Unified Command ☐ Single Agency

Please explain: (For example, in some states a unified command consisting of agency heads makes a recommendation to the governor, who ultimately makes the final decision.)

____

____

Once an Evacuation Order has been issued, who is responsible for overall execution of the order?

☐ Emergency Management ☐ Transportation Agency ☐ Law Enforcement

☐ National Guard Other: ____

21. What is the role of the transportation agency in your Emergency Operations Plan?

	Yes	No
Official and included in the plan:	☐	☐
Ad hoc or unofficial:	☐	☐

22. Are contracts currently in place to assist with evacuations?

☐ Yes ☐ No

If yes, who is responsible for managing the contract?

☐ Transportation Agency ☐ Emergency Management

☐ Administrative Agency Other: ______________________________

If yes, what types of contracts are currently in place? (Select all that apply)

☐ Transit Buses ☐ School Buses ☐ Commercial Buses ☐ Ambulances

Other: ____

23. Does your jurisdiction have a timeline/decision matrix for committing resources and calling for evacuations?

	Yes	No
Committing Resources:	☐	☐
Calling for Evacuations:	☐	☐

If yes, can we contact your agency to get a copy of your evacuation timeline?

☐ Yes ☐ No

If yes, can you please explain what factors are considered in which timelines/decision points are made to commit resources or order evacuations (Examples would be Resources, Contracts, Hazard Location)? ____

24. One of the complex problems facing emergency management agencies is the fluid activity of sheltering and changing sheltering capacity. Does your plan allow for in vehicle communications with buses moving transportation dependent citizens once they are en route to a shelter?

☐ Yes ☐ No

If yes, can you please explain who is responsible for communicating to the vehicles and how is it accomplished? ____

____

25. Has your jurisdiction conducted a large scale evacuation (50,000 or more citizens) within the last: (Select all that apply)

	Yes	No
1–2 Years	☐	☐
3–4 Years	☐	☐
5–6 Years	☐	☐

If yes, when did the evacuation occur and what hazard resulted in an evacuation being initiated?

____

26. Has your jurisdiction conducted an evacuation of an isolated community within the last two years: (Select all that apply)

	Yes	No
1–2 Years	☐	☐
3–4 Years	☐	☐
5–6 Years	☐	☐

Evacuation and Mode Characterization

27. Does your plan address evacuating citizens with Special Needs?

☐ Yes ☐ No

If yes, please identify which groups your plan addresses: (Select all that apply)

☐ Frail Elderly ☐ Nursing Homes ☐ Citizens using Home Health ☐ Hospitals

☐ Tourists ☐ Citizens without Transportation ☐ Homeless

☐ Persons with Disabilities ☐ Assist Living Facilities

Other: ____

What % of your jurisdiction's population would you estimate to be considered Special Needs?

☐ 1%–5% ☐ 6%–10% ☐ 11%–15% ☐ 16%–20% ☐ Greater than 20%

28. Does your plan allow citizens with Special Needs to register for assistance prior to an evacuation being ordered?

☐ Yes ☐ No

If yes, what mechanism is in place that allows them to register with your agency (3-1-1 for example or a dedicated phone number): ______________________________

____

If yes, what percentage of the total special needs population in your jurisdiction, do you estimate registers?

☐ 1%–10% ☐ 11%–20% ☐ 21%–30% ☐ 31%–40% ☐ Greater than 41%

What role does your transportation agency have with evacuating individuals with Special Needs?

☐ Picking Up and Transporting ☐ Registration ☐ Managing the Special Needs List

Other: ____

Does your transportation agency have a paratransit division to assist with evacuating individuals with Special Needs?

☐ Yes ☐ No

29. Does your plan have a City Assisted Evacuation Component (citizens without transportation)?

☐ Yes ☐ No

If yes, does your plan call for multiple pick up points for citizens to report to that do not have the necessary means to evacuate themselves?

☐ Yes ☐ No

If yes to either question, does your plan utilize a central location that serves as an evacuation center to manage your City Assisted Evacuation Component?

☐ Yes ☐ No

What role does your transportation agency play in your City Assisted Evacuation Plan?

____

____

Communications and Public Information

30. What information and data is collected from the evacuation event?

☐ Travel Time ☐ Origin–Destination ☐ Time of Departure/Arrival

☐ Speed ☐ Volume ☐ Congestion/Delays ☐ Number of People Evacuated

31. What systems / methods does your agency use to collect data and or monitor evacuation processes? (Select all that apply)

☐ Video Surveillance Systems (CCTV) ☐ Vehicle Detection (loops, ATMS, etc)

☐ Automated Vehicle Locations (AVLs) ☐ Personal Observation

Other: ______________________________

32. How is information communicated from the evacuation location to the State Emergency Operations Center? Select all that apply:

☐ Analog Radio System ☐ Digital Radio System ☐ Telephone (land line)

☐ Reports submitted electronically ☐ Text Messaging ☐ Video Streaming

☐ P25 Compliant Radio System ☐ E-mail (Black Berry) ☐ Cellular Telephone

☐ Emergency Management Software (WebEOC, E-Team) Other: ____________

33. Does your jurisdiction have redundant communication systems in place to ensure multiple modes of communications are in place?

☐ Yes ☐ No

34. How are local communications being maintained with multiple agencies that are responsible for executing the evacuation process?

☐ Analog Radio System ☐ Digital Radio System ☐ Cellular Phone Service

☐ Reports submitted electronically ☐ Text Messaging ☐ E-mail (Blackberry)

☐ Emergency Notification Software Other: ____________

35. Does your transportation agency have adequate communications to communicate directly with law enforcement, emergency management, and National Guard personnel?

☐ Yes ☐ No

36. Does you jurisdiction have a public awareness campaign in which evacuation information is published and distributed to the citizenry?

	Yes	No
Hurricanes	☐	☐
Tornados	☐	☐
Wildfires	☐	☐
Flood	☐	☐
Fire	☐	☐
Chemical	☐	☐
Radiological release	☐	☐
Dam / Levee Failures	☐	☐

Other: ______________________________________

If yes, please briefly describe your jurisdictions public awareness efforts? ____________

____

____

37. How are evacuation warnings and evacuation related public information provided to the public and special facilities?

☐ Media–TV ☐ Media–Radio ☐ Media–Print

☐ Emergency Alert System ☐ Text Messaging ☐ Government Owned Radio

☐ Reverse 9-1-1 ☐ Loud Speakers ☐ Sirens

☐ Knocking on Doors Other: ____________________

38. What public information and communication structures does your agency currently have in place to notify the public?

☐ Emergency Alert System ☐ Text Messaging ☐ Government Owned Radio

☐ Reverse 9-1-1 ☐ Sirens Other: ____________________

Reentry

39. Who is the lead agency in planning for reentry?

☐ Emergency Management ☐ Transportation Agency ☐ Law Enforcement

☐ National Guard Other: ____

40. Who is the lead agency in executing the reentry plan once the hazard has passed?

☐ Emergency Management ☐ Transportation Agency ☐ Law Enforcement

☐ National Guard Other: ____

41. What is your Transportation Agency's role in preparing for reentry?

☐ Road Inspections/Assessments prior to Reentry ☐ Traffic Management

☐ Debris Removal ☐ Restoration of Traffic Control ☐ Restoration of Road Infrastructure

Other: ____

42. If your transportation agency is not responsible for validating the safety of roads, who is:

____

43. Does your reentry plan include considerations for the following for re-entry?

☐ Credentialing/Placards ☐ Tiered Reentry (Emergency Services, Response Support, etc.)

☐ Look and Leave (policy to allow citizens to look at their damage and then leave due to lack of services)

APPENDIX D

SURVEY RESULTS

Note: The totals and subtotals of the various responses do not always sum to the number of responses received (n) for all questions. The reasons for this are that not all agencies responded to all parts of a question and others indicated more than one response to a single question.

Section 1: Preparedness, Planning and Policy

Question 1: Please select all that apply to your agency

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
State	29	0	29	18	11	29
Regional	0	4	4	1	3	4
City	0	6	6	2	4	3
Emergency Management	14	7	21	0	18	18
Transportation Agency	18	3	21	21	0	21

n = 39

Question 2: Does your agency have an Emergency Operation Plan?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	28	9	37	20	17	37
No	0	0	0	0	0	0
Total	28	9	37	20	17	37

n = 37

Question 2a: If yes, is your plan written in the Annex or the Emergency Support Function Format?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Annex	14	7	21	10	11	21
ESF	13	0	13	9	4	13
Total	27	7	34	19	15	34

n = 34

Question 3: In your Emergency Operations Plan please identify the roles of the following agencies for Emergency Support Function 1 – Evacuation and Transportation: (Select all that apply):

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Emergency Management Agency						
Coordinating Agency	16	7	23	12	11	23
Lead Agency	7	2	9	3	6	9
Support Agency	9	1	10	7	3	10
Transportation Agency						
Coordinating Agency	2	0	2	2	0	2
Lead Agency	21	5	26	18	8	26
Support Agency	6	4	10	2	8	10
National Guard						
Coordinating Agency	0	0	0	0	0	0
Lead Agency	1	0	1	1	0	1
Support Agency	25	4	29	16	13	29
Law Enforcement						
Coordinating Agency	0	1	1	0	1	1
Lead Agency	4	2	6	3	3	6
Support Agency	22	6	28	16	12	28

Question 4: What type of evacuation scenarios currently are included in your agency's Emergency Operations Plan: (Select all that apply)

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Hurricanes	11	6	17	10	7	17
Tornadoes	10	4	14	8	5	13
Wildfire	11	5	16	9	7	16
Flood	14	6	20	8	11	19
Fire	8	5	13	8	5	13
Chemical	18	7	25	12	13	25
Radiological Release	22	7	29	16	13	29
Dam / Levee Failure	12	5	17	8	9	17

Others: Earthquake, public health emergency, terrorist scenario, tsunami, volcanic ash fallout, energy shortage

Question 5: If someone refuses to evacuate during a mandatory evacuation, would you remove them forcibly?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	3	1	4	1	3	4
No	25	8	33	19	14	33
Total	28	9	37	20	17	37

n = 37

Question 5a: If yes, does your transportation agency have a role in the plan?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	3	2	5	1	4	5
No	10	3	13	9	4	13
Total	13	5	18	10	8	18

n = 18

Question 6: What are the levels of evacuation in your jurisdiction?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Mandatory	13	5	18	7	11	18
Voluntary	22	6	28	16	12	28
Total	35	11	46	23	23	46

n = 35

Others: Recommended, shelter in place, advisory (also described as equivalent to "pre-voluntary")

Question 7: Does your Emergency Operations Plan include considerations for evacuating people with animals? (Select all that apply)

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Pets	19	8	27	13	14	27
Service Companion	20	9	29	13	16	29
Livestock	10	3	13	7	6	13
Total	49	20	69	33	36	69

n = 32

Others: Sled dogs

Question 8: Does your Emergency Operations Plan include considerations for sheltering people with animals?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Pets	19	5	24	11	13	24
Service Companion	19	6	25	10	15	25
Livestock	9	1	10	7	3	10
Total	37	12	59	28	31	59

n = 34

Question 9: What type of evacuation scenarios currently are included in your agency's Emergency Operations Plan: (Select all that apply)

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Road Networks	27	6	33	18	15	33
Rail	12	3	15	8	7	15
Air	15	1	16	9	7	16
Water	8	2	10	4	6	10
Pedestrian	4	4	8	3	5	8
School Bus	20	3	23	11	12	23
Military Bus	4	0	4	0	4	4
Military Vehicles	11	0	11	7	4	11
Commercial Bus	17	4	21	9	12	21
Transit Bus	15	6	21	10	11	21

Others: Government vehicle fleet, various aircraft

Question 10: Does your plan address providing en route services during an evacuation once an order is given?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Mobile Fuel						
Emergency Management	8	4	12	6	6	12
Transportation Agency	8	3	11	6	4	11
Agricultural Agency	2	0	2	1	1	2
City Government	1	3	4	3	1	4
Wrecker						
Emergency Management	6	3	9	3	5	8
Transportation Agency	10	2	12	8	4	12
Agricultural Agency	0	0	0	0	0	0
City Government	0	4	4	2	2	4
Water						
Emergency Management	13	3	16	8	7	15
Transportation Agency	2	1	3	3	0	3
Agricultural Agency	0	0	0	0	0	0
City Government	1	2	3	2	1	3
Food						
Emergency Management	13	3	16	8	7	15
Transportation Agency	0	1	1	1	0	1
Agricultural Agency	1	0	1	1	0	1
City Government	1	2	3	2	1	3

Other: Medical response; food and water provided by the Red Cross

Question 11: Is your agency's plan part of a broader regional or statewide evacuation plan?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Regional	11	5	16	8	8	16
Statewide	22	3	25	14	11	25
Single Jurisdiction	2	1	3	1	2	3
Total	35	9	44	23	21	44

n = 39

Question 12: Does your plan include a Phased Evacuation?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	18	7	25	14	11	25
No	11	2	13	7	6	13
Total	29	9	38	21	17	38

n = 38

Question 13: Does your plan include contraflow operations?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Lead Elected Official	7	3	10	5	5	10
EMA Director	4	0	4	3	1	4
Lead DOT Official	3	3	6	4	2	6
Lead Law Enforcement Official	3	2	5	2	3	5
Adjutant General	0	0	0	0	0	0
Total	17	8	25	14	11	25

n = 25

Others: Unified Commander, incident commander

Question 13a: How much time is required to implement contraflow from the time the decision is made until it is ready to be executed?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
1-4 hours	2	2	4	2	2	4
4-8 hours	7	1	8	3	5	8
8-12 hours	0	1	1	0	1	1
12-24 hours	1	1	2	2	0	2
24+ hours	1	0	1	1	0	1
Total	11	5	16	8	8	16

n = 16

Question 13b: What are your jurisdiction's criteria for the termination of contraflow?
Observation of diminished traffic volume; terminated by neighboring state since contraflow traffic enters from that state; onset of tropical storm force winds, and onset of darkness after sunset.

Question 14: What barriers/obstacles to coordination and planning has your agency encountered?

Coordination with various other state agencies, including the Governor's Office, county governments; the lack of a joint operations command capability; staff availability; lack of local evacuation planning; lack of funding to develop detailed plans; need to coordinate multiple law enforcement and transportation jurisdictions and districts; transportation assets for special needs and medical patients; evacuee apathy; lack of integrated state/local plans, lack of experience; lack of leadership from lead evacuation agency (DOT); and no guidelines/standards.

Question 15: Has your jurisdiction identified all resources using the FEMA Typed Resource Definitions?

Response Options	**State-level Agencies**	**Local-level Agencies**	**Total**	**Transportation Agencies**	**Emergency Management Agencies**	**Total**
Yes	13	4	17	9	8	17
No	14	5	19	11	8	19
Total	27	9	36	20	16	36

n = 36

Question 15a: Has your transportation agency Typed all of your available resources?

Response Options	**State-level Agencies**	**Local-level Agencies**	**Total**	**Transportation Agencies**	**Emergency Management Agencies**	**Total**
Yes	12	2	14	9	5	14
No	15	6	21	11	10	21
Total	27	8	35	20	15	35

n = 35

Question 16: Is your jurisdiction using a software system to manage your resources?

Response Options	**State-level Agencies**	**Local-level Agencies**	**Total**	**Transportation Agencies**	**Emergency Management Agencies**	**Total**
Yes	23	6	29	14	15	29
No	6	3	9	8	1	9
Total	29	9	38	22	16	38

n = 38

Question 16a: If yes, which software system?

Response Options	**State-level Agencies**	**Local-level Agencies**	**Total**	**Transportation Agencies**	**Emergency Management Agencies**	**Total**
IRIS	1	0	1	1	0	1
WebEOC	11	3	14	5	9	14
E-Team	4	3	7	2	5	7
RIMS	2	0	2	2	0	2
Total	18	6	24	10	14	24

n = 24

Other: SAP, MMS, in-development, custom system, DLAN, Maximo, and PeopleSoft

Question 17: Please identify what types of transportation resources are currently available for emergency evacuation (Example are transit buses, school buses, barricades, electronic road signs):

Response Options	**State-level Agencies**	**Local-level Agencies**	**Total**	**Transportation Agencies**	**Emergency Management Agencies**	**Total**
VMS/CMS	23	5	28	18	10	28
Arrow Boards	2	0	2	2	0	2
Barricades	18	2	20	11	9	20
Moveable Barriers	4	1	5	5	0	5
Agency Vehicles Fleet	7	2	9	6	3	9
School Buses	15	5	20	10	10	20
Transit Buses	15	9	24	12	12	24
SART vehicles	1	0	1	1	0	1
HAR	7	0	7	6	1	7
Route patrol crews	5	1	6	4	2	6
511	3	0	3	2	1	3
Traffic control crews	1	0	1	1	0	1

Most critical: Buses; CMS; all; traffic control crews; communication, corridor coalitions; signage; 511; busses; ambulance, airplanes/helicopters; trains; boats; manpower; military vehicles; tow trucks; subway; paratransit, TMC; Reverse 911; light rail

Question 17a: Do you think your plan and available resources for evacuations are adequate to support a large scale evacuation of your jurisdiction?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	12	4	16	10	6	16
No	14	5	19	8	11	19
Total	26	9	35	18	17	35

n = 35

If no, what other additional resources or support is required?

Tow trucks; law enforcement and EMA support; ambulances and litter equipped; busses; manpower and funding; regional coordination; public education/awareness; a reentry plan; special needs; additional drivers; refueling stations; MOU's w/private contractors; more trained people; and better cooperation across various levels of government

Question 18: Does your jurisdiction conduct exercises on evacuations?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	26	7	33	19	14	33
No	4	0	4	3	1	4
Total	30	7	37	22	15	37

n = 37

Question 18a: Is your transportation agency included in the exercises?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	24	9	33	17	16	33
No	1	0	1	1	0	1
Total	25	9	34	18	16	34

n = 34

Question 18b: Do your exercises follow the Homeland Security Exercise and Evaluation Program?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	26	6	32	17	15	32
No	1	2	3	2	1	3
Total	27	8	35	19	16	35

n = 35

Question 18c: Are transportation agencies reimbursed for expenses incurred from participating in the exercise?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	15	4	19	7	12	19
No	20	5	25	13	12	25
Total	35	9	44	20	24	44

n = 44

Question 19: Does your agency have criteria for defining a "successful" evacuation of your jurisdiction?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	10	4	14	8	6	14
No	18	4	22	11	11	22
Total	28	8	36	19	17	36

n = 36

Question 19a: If yes, what is the criterion/criteria: (Select all that apply)

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Total # of Evacuees	7	2	9	3	6	9
No Fatalities or Injuries	6	2	8	6	2	8
Reduced Travel Times	5	1	6	3	3	6
High Travel Speeds	1	0	1	1	0	1
Positive Public/Media Feedback	5	3	8	6	2	8
Effective Communications	6	4	10	6	4	10

Other: Deployment time for C/F

Section 2: Direction and Control

Question 20: Who is responsible for making the decision that a large scale evacuation order will be given for your jurisdiction?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Chief Elected Official (usually local)	17	4	21	13	8	21
Unified Command	4	4	8	3	5	8
DOT Director Single Agency	0	0	0	0	0	0
Unified Command Advises Governor.	7	1	8	5	3	8
Total	28	9	37	21	16	37

n = 37

Question 20a: Once an Evacuation Order has been issued, who is responsible for overall execution of the order?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Emergency Management Agency	18	3	21	14	7	21
Transportation Agency	6	0	6	5	1	6
Law Enforcement	11	4	15	7	8	15
National Guard	4	0	4	3	1	4
Unified Command	4	2	6	2	4	6
Total	43	9	52	31	21	52

Question 21: What is the role of the transportation agency in your Emergency Operations Plan?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Official & in plan	26	8	34	20	14	34
Ad hoc / Unofficial	1	1	2	0	2	2
Total	27	9	36	20	16	36

n = 36

Question 22: Are contracts currently in place to assist with evacuations?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	12	4	16	9	7	16
No	16	4	20	11	9	20
Total	28	8	36	20	16	36

n = 36

Question 22a: If yes, who is responsible for managing the contract?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Transportation Agency	7	2	9	5	4	9
Emergency Management Agency	0	1	1	1	0	1
Other Administrative Agency	3	2	5	2	3	5
Total	10	5	15	8	7	15

n = 15

Other: Transit Authority

Question 23: Does your jurisdiction have a timeline / decision matrix for committing resources and calling for evacuations?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Committing Resources	9	4	13	7	6	13
Calling for Evacuations	9	4	13	7	6	13
Total	18	8	26	14	12	26

n = 31

Question 24: One of the complex problems facing emergency management agencies is the fluid activity of sheltering and changing sheltering capacity. Does your plan allow for in vehicle communications with buses moving transportation dependent citizens once they are en route to a shelter?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	8	5	13	6	7	13
No	17	3	20	12	8	20
Total	25	8	33	18	15	33

n = 33

Question 25: Has your jurisdiction conducted a large scale evacuation (50,000 or more citizens) within the last: (Select all that apply)

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
1-2 Years	2	2	4	0	4	4
3-4 Years	7	2	9	4	5	9
5-6 Years	6	0	6	2	4	6
Total	15	4	19	6	13	19

Hazard: Tropical Storm Isabel, Hurricane Katrina, Hurricane Rita, and wildfires in 2006 and 2007

Question 26: Has your jurisdiction conducted a large scale evacuation (50,000 or more citizens) within the last: (Select all that apply)

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
1-2 Years	9	2	11	8	3	11
3-4 Years	13	3	16	9	7	16
5-6 Years	10	1	11	8	3	11
Total	32	6	38	25	13	38

Section 3: Evacuee and Mode Characterization

Question 27: Does your plan address evacuating citizens with Special Needs?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	18	8	26	11	15	26
No	9	1	10	8	2	10
Total	27	9	36	19	17	36

n = 36

Question 27a: If yes, please identify which groups your plan addresses: (Select all that apply)

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Frail Elderly	16	7	23	10	13	23
Nursing Homes	13	7	20	9	11	20
Citizens using Home Health	13	6	19	10	9	19
Hospitals	13	5	18	8	10	18
Tourists	7	4	11	4	7	11
Citizens without transportation	13	8	21	8	13	21
Homeless	3	4	7	3	4	7
Persons with Disabilities	15	8	23	9	14	13
Assisted Living Facilities	11	7	18	7	11	18

Other: Schools, prisoners, unaccompanied minors, protected populations, other disabled persons

Question 27b: What % of your jurisdiction's population would you estimate to be considered Special Needs?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
1% - 5%	2	0	2	2	1	3
6% - 10%	8	0	8	7	2	9
11% - 15%	3	2	5	1	3	4
16% - 20%	2	1	3	0	3	3
Greater than 20%	4	4	8	2	6	8
Total	19	7	26	12	14	26

Question 28: Does your plan allow citizens with Special Needs to register for assistance prior to an evacuation being ordered?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	13	5	18	6	12	18
No	9	3	12	9	3	12
Total	22	8	30	15	15	30

n = 36

Method: Public health agency registries, self-registration system, local registration; 211, 311, and 911 systems; nuclear plant registration; webpage; phone/mail-in; Internet, fire department

Question 28a: If yes, what percentage of the total special needs population in your jurisdiction, do you estimate registers?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
1% - 10%	8	1	9	3	6	9
11% - 20%	1	2	3	0	3	3
21% - 30%	1	1	2	1	1	2
31% - 40%	1	0	1	0	1	1
Greater than 41%	1	0	1	0	1	1
Total	12	4	16	4	12	16

n=16

Question 28b: What role does your transportation agency have with evacuating individuals with Special Needs?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Picking up and Transportation	4	5	9	4	5	9
Registration	0	1	1	0	1	1
Managing Special Needs	0	2	2	0	2	2
Total	4	8	12	4	8	12

n=12

Other: Driving busses

Question 28c: Does your plan allow citizens with Special Needs to register for assistance prior to an evacuation being ordered?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	5	6	11	3	8	11
No	16	1	17	10	7	17
Total	21	7	28	13	15	28

n = 28

Question 29: Does your plan have a City Assisted Evacuation Component (citizens without transportation)?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	6	6	12	8	4	12
No	14	3	17	6	11	17
Total	20	9	29	14	15	29

n = 29

Question 29a: If yes, does your plan call for multiple pick up points for citizens to report to that do not have the necessary means to evacuate themselves?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	7	6	13	8	5	13
No	5	1	6	1	5	6
Total	12	7	19	9	10	19

n = 19

Question 29b: If yes to either question, does your plan utilize a central location that serves as an evacuation center to manage your City Assisted Evacuation Component?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	4	3	7	3	4	7
No	6	5	11	5	6	11
Total	10	8	18	8	10	18

n = 18

Section 4: Communications and Public Information

Question 30: What information and data is collected from the evacuation event?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Travel Time	12	2	14	9	5	14
Origin-Destination Data	11	5	16	7	9	16
Time of Departure/Arrival	8	2	10	8	2	10
Speed	10	1	11	8	3	11
Volume	12	1	13	9	4	13
Congestion/Delay	12	3	15	11	4	15
Number of People Evacuated	15	5	20	8	12	20

Other: None

Question 31: What systems / methods does your agency use to collect data and or monitor evacuation processes? (Select all that apply)

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Video Surveillance	17	5	22	14	8	22
Vehicle Detection	12	0	12	10	2	12
Automatic Vehicle Locating	4	2	6	3	3	6
Field Observation	21	8	29	15	14	29

Other: None

Question 32: How is information communicated from the evacuation location to the State Emergency Operations Center? Select all that apply:

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Analog Radio	14	4	18	10	8	18
Digital Radio	18	4	22	13	9	22
Land Telephone	23	8	31	16	15	31
Electronic Reports	18	8	26	13	13	26
Text Messaging	9	4	13	8	5	13
Video Streaming	8	2	10	6	4	10
P25 Radio System	9	1	10	6	4	10
Email (Blackberry)	18	6	24	13	11	24
Cell Phone	24	6	30	18	12	30
EOC Software	20	5	25	14	11	25

Other: Satellite phone/radio; Chart workstation; amateur radio

Question 33: Does your jurisdiction have redundant communication systems in place to ensure multiple modes of communications are in place?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	28	9	37	20	17	37
No	1	0	1	1	0	2
Total	29	9	38	21	17	38

n = 38

Question 34: How are local communications being maintained with multiple agencies that are responsible for executing the evacuation process?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Analog Radio	17	3	20	11	9	20
Digital Radio	22	6	28	14	14	28
Land Telephone	3	1	4	4	0	4
Electronic Reports	14	3	17	9	7	17
Text Messaging	11	2	13	9	5	13
Video Streaming	3	1	4	4	0	4
Email (Blackberry)	10	4	14	8	6	14
Cell Phone	21	6	27	15	11	27
EOC Software	14	3	17	12	5	17

Other: Website, conference calls

Question 35: Does your transportation agency have adequate communications to communicate directly with law enforcement, emergency management and National Guard personnel?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Yes	20	6	26	14	12	26
No	8	1	9	6	3	9
Total	28	7	35	20	15	35

n = 35

Question 36: Does you jurisdiction have a public awareness campaign in which evacuation information is published and distributed to the citizenry?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Hurricanes	8	6	14	7	7	14
Tornados	7	4	11	6	5	11
Wildfires	5	5	10	4	6	10
Floods	11	6	17	7	10	17
Fires	7	5	12	6	6	12
Chemical	10	6	16	7	9	16
Radiological Release	14	5	19	9	10	19
Dam/Levee Failure	8	6	14	7	7	14
Tsunami	2	2	4	3	1	4
Hurricanes	8	6	14	7	7	14

Other: Earthquake, winter storm, heat wave, tsunami, shelter in place is preferred for all hazards
Public awareness efforts: Brochures ; public information campaigns; news releases, website, citizen corps, 511, public radio; local presentations

Question 37: How are evacuation warnings and evacuation related public information provided to the public and special facilities?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Media/TV	23	9	32	16	16	32
Media/Radio	24	8	32	17	15	32
Media/Print	15	4	19	10	9	19
Emergency Alert System	22	9	31	14	17	31
Text Messaging	7	3	10	6	4	10
Government Radio (including HAR)	6	3	9	6	3	9
Reverse 911	10	7	17	7	10	17
Loud Speakers	9	4	13	5	8	13
Sirens	11	5	16	6	10	16
Knocking on Doors	10	7	17	8	9	17

Other: All hazard radio, website, VMS

Question 38: What public information and communication structures does your agency currently have in place to notify the public?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Emergency Alert System	18	8	26	9	17	26
Text Messaging	7	4	11	6	5	11
Government Radio (including HAR)	11	2	13	9	4	13
Reverse 911	7	5	12	2	10	12
Sirens	7	3	10	3	7	10

Other: All hazard radio, website, 511 system, DMS/CMS, media releases

Section 5: Reentry

Question 39: Who is the lead agency in planning for re-entry?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Emergency Management Agency	18	4	22	16	6	22
Transportation Agency	2	0	2	1	1	2
Law Enforcement	5	4	9	3	6	9
National Guard	1	0	1	1	0	1
Other – Unified Command	2	2	4	2	2	4
Total	28	10	38	23	15	38

n=38

Question 40: Who is the lead agency in executing the re-entry plan once the hazard has passed?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Emergency Management Agency	19	1	20	15	5	20
Transportation Agency	0	1	1	1	0	1
Law Enforcement	4	5	9	2	7	9
National Guard	1	0	1	1	0	1
Total	24	7	31	19	12	31

n=31

Question 41: What is your transportation agency's role in preparing for reentry?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Road Inspections/Assessments	29	5	34	19	15	34
Traffic Management	22	6	28	19	9	28
Debris Removal	27	4	31	18	13	31
Restoration of Traffic Control	22	6	28	18	10	28

Question 42: If your transportation agency is not responsible for validating the safety of roads, who is?

Law Enforcement, Department of Health, private contractors

Question 43: Does your re-entry plan include considerations for the following for re-entry?

Response Options	State-level Agencies	Local-level Agencies	Total	Transportation Agencies	Emergency Management Agencies	Total
Credentialing/Placards	4	2	6	2	4	6
Tiered Reentry	8	4	12	3	9	12
"Look and Leave"	3	1	4	1	3	4
Total	15	7	22	6	16	22