National Review of Hurricane Evacuation Plans and Policies

Brian Wolshon
Elba Urbina
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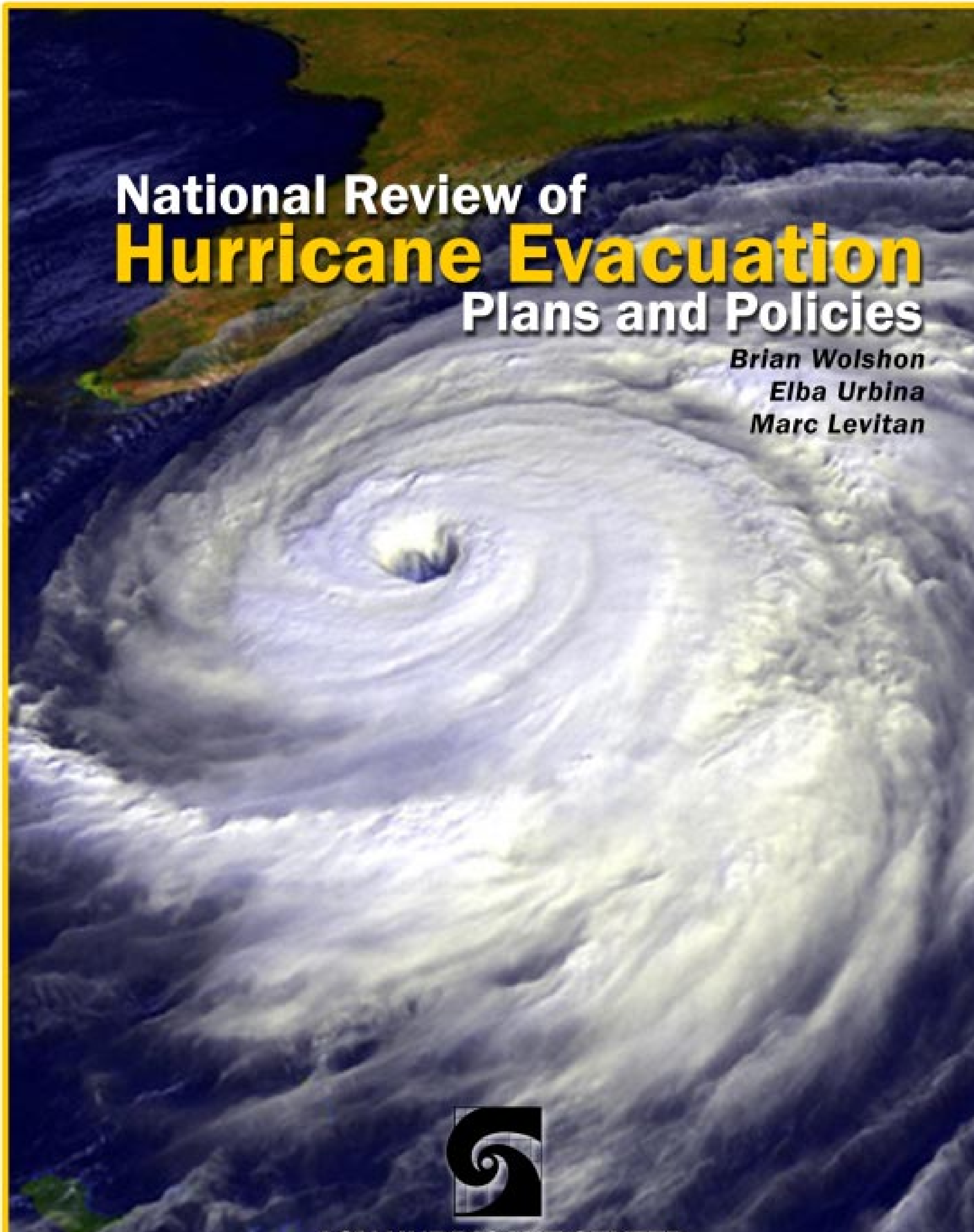

LSU HURRICANE CENTER

National Review of Hurricane Evacuation Plans and Policies

***Brian Wolshon*[1]**
***Elba Urbina*[2]**
***Marc Levitan*[3]**

The mission of the LSU Hurricane Center is to advance the state-of-knowledge of hurricanes and their impacts on the natural, built, and human environments; to stimulate interdisciplinary and collaborative research activities; to transfer this knowledge to students and professionals in concerned disciplines; and to assist the nation and the world in reducing vulnerability to these powerful and often devastating storms.

[1] Assistant Professor, LSU Hurricane Center and Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA 70803; (225) 578-5247; FAX (225) 578-5263; email: brian@rsip.lsu.edu

[2] Engineer, Chiang, Patel & Yerby, Inc., 1820 Regal Row, Suite 200, Dallas, TX 75235; (214) 638-0500; FAX (214) 638-3723; email: eurbina@cpyi.com

[3] Director, LSU Hurricane Center, and Charles P. Siess, Jr. Associate Professor of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA 70803; (225) 578-4445; FAX (225) 578-8652; email: levitan@hurricane.lsu.edu

An electronic version of this report is available on the web at www.hurricane.lsu.edu. Additional copies may be obtained from LSU Hurricane Center; Suite 3513 CEBA Building; Louisiana State University; Baton Rouge, LA 70803; Phone:(225) 578-4813; Fax: (225) 578-8652 email:info@hurricane.lsu.edu

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Executive Summary

The events of recent hurricane seasons have made evacuation one of the leading emergency management issues. Hurricanes Georges in 1998 and Floyd in 1999 precipitated the two largest evacuations in the history of the United States (US) and perhaps, its two largest traffic jams. Opinions as to why these problems occurred are numerous and varied. Some explanations that have been offered have included the well-publicized (some have argued over-publicized) threat of these storms, an over-reaction for the need to evacuate, insufficient planning, and limited coordination between the various agencies responsible for evacuations. Whatever the causes, it is obvious that evacuations have become a topic of significant concern in states threatened by hurricanes.

One of the ways that emergency management officials have responded to these events has been to increase the level of coordination between and involvement of agencies that have traditionally been only peripherally involved in evacuation. One of the most notable of these groups are Departments' of Transportation (DOTs). Since Hurricane Floyd, transportation agencies at the federal, state, and local levels have begun to take a more active role in the planning, management, and operation of hurricane evacuations. This is somewhat of a departure from prior practice, when these tasks were planned and directed nearly exclusively by emergency management officials.

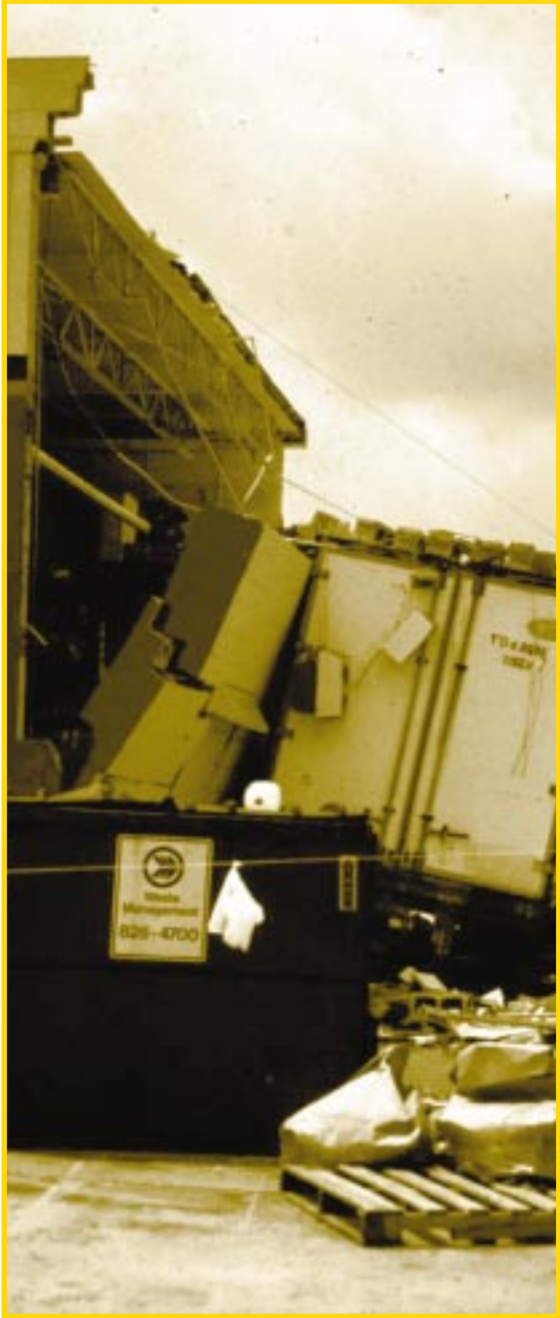
Since the involvement of transportation professionals in evacuation has been a fairly recent development, it is not surprising that the level of understanding of evacuation issues and terminology in the transportation community is somewhat limited. It has meant that many of the newly developed plans and policies have never been put into actual practice. It has also meant that many aspects of these plans and policies vary significantly from state to state and remain largely unknown to the wider professional transportation community.

To determine what the latest policies and strategies are, how they differ from one location to another, and to increase the level of knowledge and awareness of these new evacuation practices, a national review of evacuation plans and practices was recently undertaken by researchers from Louisiana State University (LSU) in cooperation with the LSU Hurricane Center. The study was carried out from a transportation (rather than an emergency management) perspective. It included both a review of transportation literature and a survey of DOT and emergency management officials in coastal states threatened by hurricanes. This report summarizes the findings of the survey while also providing some background on development evacuation practices and research in the US.

This report includes information on the application of evacuation strategies and technologies, such as the use of reverse flow operations and intelligent transportation systems (ITS). It also summarizes current evacuation management policies, methods of information exchange, and decision-making criteria. The intent of this report is to provide a broad perspective on the current state of evacuation practices, while also presenting similarities and differences in individual state practices. Particular attention is paid to unique, innovative, and potentially useful practices used in individual states that could be more widely applied.

The results of the LSU survey bring to light many of the current needs and important issues in the field and the ways in which emergency management and transportation agencies are working to address them. Key issues and problems identified by the survey include:

- limited involvement from and awareness within the professional transportation community in the field of evacuation;
- limited interagency coordination for regional and cross-state evacuations;
- limited consistency between states in the both the authority structure and planning/ design processes for hurricane evacuation;
- limited planning (at the DOT level) for the evacuation of low-mobility groups;
- less than adequate use of the available transportation infrastructure during evacuations; and
- a need to better coordinate construction work zone activities on hurricane evacuation routes.



The survey also showed that transportation agencies have recognized many of these issues and are working to overcome them. This was demonstrated in the survey by DOT efforts to:

- increase their level of involvement in evacuation transportation issues both at the state and regional level;
- enhance their ability to communicate vital traffic flow and route condition information to emergency managers and the public;
- develop contraflow evacuation plans; and
- seek ways to apply intelligent transportation systems to improve the safety, efficiency, and speed of evacuations.

Introduction

Recent trends have increased the vulnerability of the US to hurricanes. The combination of growing population and development in coastal zones, rising ocean levels, coastal erosion, and changing climatic trends have increased the potential for loss of life and property in coastal regions of the country. A recent example of such an event was Hurricane Andrew. This powerful storm struck both Florida and Louisiana in 1992, causing an estimated $25 billion in damage and economic loss (USGS, 1998). While more stringent building codes have been enacted to reduce damage from winds and flooding, not all coastal populations can be protected in their homes or shelters. To counter this threat, states in the Atlantic and Gulf coast regions of the US have plans to evacuate people from vulnerable areas in advance of threatening storms.

Historically, hurricane evacuation planning in the US has been the responsibility of emergency management and law enforcement agencies. While some state transportation agencies have contributed to the evacuation planning and management process, their activities could usually be characterized as peripheral support. In the two most recent large-scale evacuations, Hurricanes Georges in 1998 and Floyd in 1999, colossal traffic jams occurred revealing the fact that emergency response agencies may not have been as prepared for such scenarios as previously assumed. In the aftermath of these events, emergency management and state transportation officials recognized the need for an increased level of involvement from the professional transportation community.

The Georges and Floyd experiences clearly demonstrated the need for increased evacuation route capacity; development of systems for better, faster, more reliable exchange of traffic flow and traveler information; and better planning and coordination of regional and cross-state evacuations. To their credit, DOTs in every state threatened by hurricanes are now actively working at varying levels to better manage evacuations. In recent meetings and conferences organized for purpose of discussing plans and practices for evacuation, however, it was apparent that many DOT officials were not aware of the current state of practice nor the way in which new technologies and methods could be used to better address evacuation-related problems. This lack of awareness was not surprising given that most of them had never been involved in the evacuation planning and management process and there was little information available to them in the transportation literature.

To meet this need for more information, a national review of evacuation plans and practices was undertaken by researchers at LSU. The study was carried out from a transportation perspective and included a review of literature from traditional transportation-oriented sources and a direct survey of DOT and emergency management officials. The information presented here focuses on the survey portion of the study and includes a general discussion of current practice; the use of reverse flow operations, intelligent transportation systems (ITS), and public transportation during evacuations; methods of information exchange; and emergency management

policies and decision-making criteria. This report uses the survey responses to compare and contrast various state practices, with particular attention given to unique, innovative, and potentially useful practices.

Background

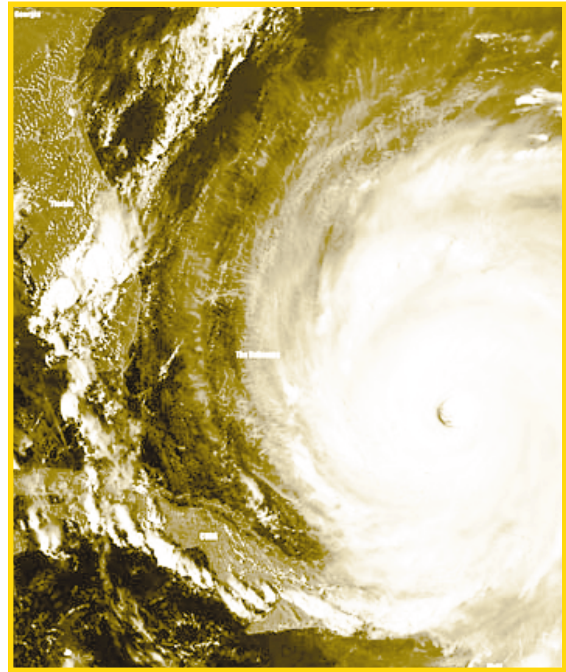


Photo Credit: FEMA

Hurricanes develop throughout the tropical ocean regions of the world, at an annual frequency of about 85 per year. While hurricanes cannot be controlled, our vulnerability to their effects can be reduced through effective planning and preparedness, including the use of evacuation. Despite the threat that hurricanes pose to life and limb, the US is among a small number of countries worldwide that effectively use mass evacuation as a means of protecting its coastal populations. Unlike many other areas, the geography of the US mainland generally makes it possible to shelter people away from coastal hazard zones and, perhaps more importantly, evacuees have ready access to transportation to take them to these locations.

Historical Perspective

The nature of evacuations in the US has been changing. Where in prior years evacuations were look upon as localized events, they have tended to become more regional in nature. One of the primary reasons for this has been the explosion in population growth along the Atlantic and Gulf coasts over the past 40 years (Culliton et al., 1990). From Maine to Texas, the population of coastal counties alone exceeds 45 million (Jerrell et al., 1992). Despite this growth, the number of evacuation routes has remained relatively unchanged over the past few decades.

The nature of hurricane preparedness and response has also been changing. Two of the most important needs for effective evacuations are advanced warning time and access to transportation. Until the middle of the 20th Century, US coastal populations had little of either. In the era prior to World War II, the only information on advancing storms came from islands and ships in the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea. Similarly, the number of roads that were available as evacuation routes and alternative modes of transportation were quite limited.

The event that brought national awareness to the danger of tropical cyclones was the Galveston Hurricane of 1900. Residents of this barrier island in Southeast Texas did not evacuate due to inadequate warning. Storm surge completely inundated the island resulting in over 8,000 deaths. This remains the single largest natural disaster (in terms of lives lost) in American history. As tragic and unfortunate as this storm was, it brought attention to the need for improved of hurricane warning and response systems and use of evacuations to protect the lives of people in coastal zones. Beginning in 1909, the advent of maritime radios allowed the US Weather Bureau to begin receiving hurricane reports from ships at sea. These sources of information were later augmented by use of weather reconnaissance aircraft, which began in 1944. Advances in both the technology and science of meteorology in the period immediately after World War II led to an improved ability to forecast the both storm strength and path (RPI, 1997).

The post war period through the 1950's also marked an era of increased storm activity. During this period more 60 hurricanes struck the US mainland, with over 20 of them categorized as major hurricanes. In the mid-50's, several strong hurricanes hit the Atlantic coast, precipitating a federal effort to collect information about how, why, where, and when people evacuated.

During the 1960's and 70's, an era of significantly improved hurricane forecasting and evacuation preparedness was ushered in with the development and deployment of weather satellites and construction of the interstate highway system. These two developments more than any other, dramatically improved the ability to both anticipate the arrival of storm and move people away from threatened areas. One of the major events of this era was Hurricane Camille, one of only two Category 5 hurricanes to make landfall on the mainland US in the 20th Century. The storm struck along the Mississippi and Louisiana coastline causing significant damage and loss of life. The storm surge from Camille sent a wall of water over 25 feet high crashing many miles inland. Most of the 256 fatalities were people who did not evacuate despite the warnings.

From the 1970's through the early 90's hurricane activity was moderate compared to the previous few decades. Probably not coincidentally, this period also saw the most significant increases in coastal population and land development. 1995 marked the beginning of a new cycle of significantly higher levels of hurricane activity in the Atlantic basin. If tropical climate patters observed over the past century hold, it is likely that this heightened activity level will continue for another two decades. This most recent time period has also seen significant improvements in our ability to identify, track, and estimate the strength of hurricanes. With the more widespread use of computers it has also been the period in which the greatest effort to model evacuations has occurred.

Source: NOAA

KILLER STORMS			
HURRICANE	**YEAR**	**CATEGORY**	**DEATHS**
TX (Galveston)	1900	4	8,000+
FL (Lake Okeechobee)	1928	4	1,836
NEW ENGLAND	1938	3	600
FL (Keys)	1935	5	408
AUDREY (SW LAN/ N TX)	1957	4	390
LA (Grand Isle)	1909	4	350
LA (New Orleans)	1915	4	275
TX (Galveston)	1915	4	275
CAMILLE (MS/LA)	1969	5	256

Background

Evacuation Modeling

One of the means of planning and preparing for evacuations involves the use of computer modeling. Since the 1970's modeling techniques have improved significantly, mainly as a result of faster and less expensive computers and access to more and better evacuation behavioral data. Today, simulation programs are used to model weather, flooding, traffic flow, and evacuation travel behavior among others.

The data that feeds many of these programs has come from the inventory of hurricane evacuation studies (HES). HES were initiated in the 1980's by the Federal Emergency Management Agency (FEMA) to integrate key aspects of hurricane evacuation planning and to assist in disaster preparedness. A HES typically consists of a storm hazard and vulnerability analysis, an evacuee behavioral analysis, a sheltering analysis, and a transportation analysis. The hazard analysis identifies the areas that would need to be evacuated based on various storm tracks and intensities. The vulnerability analysis identifies the number of people and households occupying the threatened area and the structures that need to be evacuated. The behavioral analysis is used to project how the public will respond to the hurricane threat. The shelter analysis is used to evaluate structures for safely housing the evacuees. The transportation analysis component assesses street and road capacities and identifies critical links in the evacuation network.

The most widely applied flooding model for evacuation analysis is the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model. Developed by the National Weather Service to predict hurricane storm surge for a given set of conditions, it is also used to plan evacuation routes and locate emergency shelters based on estimates of which geographic could be flooded in certain storm scenarios.

Several models have been developed for hurricane evacuation traffic flow analysis. It is interesting to note that many of the early models were initially developed to plan for other civil defense emergencies such as nuclear missile attacks and nuclear power plant accidents. One of these programs, MASS eVACuation (MASSVAC), is a macro-level model originally developed for the purpose of modeling nuclear power plant evacuations. More recently it was applied to test operational strategies for hurricane evacuations in Virginia (Hobieka et al., 1985). Another model of this type is the Hurricane and Evacuation (HURREVAC) program. HURREVAC uses geographic information system (GIS) information to correlate demographic data with shelter locations and their proximity to evacuation routes to estimate the effect of strategic-level evacuation decisions.

One of the most robust evacuation analysis tools is the Oak Ridge Evacuation Modeling System (OREMS). Developed by the Center for Transportation Analysis at the Oak Ridge National Laboratory (ORNL) using the CORridor SIMulation (CORSIM) platform, OREMS was developed to simulate traffic flow during various defense-oriented emergency evacuations. The model can be used to estimate clearance times, identify operational traffic characteristics, and other information such as evacuation routes and times necessary to develop evacuation plans. It also allows users to experiment with alternate routes, destinations, traffic control and management strategies, and evacuees response rates (ORNL, 1995).

More recently, researchers from ORNL have identified the need for a decision tool capable of modeling hurricane evacuation activities in more timely and accurate ways. An effort is underway to develop a computer-based incident management decision aid system (IMDAS) (Franzese and Han, 2001). When completed, the system will be used to identify areas that are at greatest risk from potential threats and develop alternative evacuation plans, using various operational traffic strategies such as the use of shoulder lanes and contraflow operations.

Another recent macro-level evacuation modeling and analysis system is Evacuation Travel Demand Forecasting System (PBS&J, 2000a). This system was developed in the aftermath of Hurricane Floyd, driven by the need for a capability to forecast and anticipate large cross-state traffic volumes. At the heart of the model is a web-based travel demand forecast system that anticipates evacuation traffic congestion and cross-state travel flows for North Carolina, South Carolina, Georgia, and Florida. The Evacuation Travel Demand Forecasting System model was designed so emergency management officials can access the model on-line and input category of hurricane, expected evacuation participation rate, tourist occupancy, and destination percentages for effected counties. The output of the model includes the level of congestion on major highways and tables of vehicle volumes expected to cross state lines by direction.

Other Recent Developments

Since 1998 there have been several developments to improve evacuation traffic flow and route capacity. These changes can be directly attributed to the involvement of highway and transportation agencies. The most notable of these are the use of contraflow operations to increase the capacity of evacuation routes and the application of intelligent transportation systems (ITS) systems to collect and communicate up-to-date traffic information (PBS&J, 2000c). ITS involves the use of information technologies, including hardware, software, communications, controls, and electronics, in an integrated manner to increase the safety and efficiency of the transportation system. The most widely planned use of ITS will be for the acquisition and processing of traffic flow data in real time. This information will be used to help control and reroute traffic, decision support (such as when to terminate the evacuation), and inform the evacuees and the media of current conditions. A more thorough discussion of the planned use of both contraflow and ITS usage is included later in this report.

The Evacuation Process

The most visible part of the evacuation process is when people take to the road to flee an approaching storm. However, this action is only the last step in a process often begins more than a week before. The sequence of activities that leads up to an evacuation order is typically led and coordinated by state-level emergency management officials, incorporating a progression of weather observation, readiness, 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 use established procedures, the sequence and timing of response activities can vary widely based on the characteristics of any particular storm.

The first phase of the evacuation process typically starts with routine monitoring of tropical weather patterns that have the potential to impact the coastal US. Depending on storm location and genesis, this routine monitoring phase may last from a few hours to more than a week. When it appears that a storm may pose a threat, initial preparatory steps are taken to insure readiness should a call to evacuate be issued. Once it appears that a storm strike is likely, a more active phase of the process is initiated. This phase involves specific actions, again, taken at various levels of urgency based on the storm characteristics. These actions could include the configuration of routes for evacuee movement and recommendations to evacuate. This chapter describes procedures used by the State of Louisiana as an example to illustrate the general process of evacuation decision making and implementation. Later sections of this report will present more specific information related to authority structures and the procedural aspects of evacuation management once an order is given.

Emergency management terminology and preparedness activities vary significantly from state-to-state. However, most states generally follow a similar process in their response to hurricane threats. In Louisiana, the Office of Emergency Preparedness (LOEP) is responsible for developing emergency procedures and coordinating preparedness, response, and recovery functions for hurricanes. The development of an evacuation order, while a critical part of the response process, is one of many tasks that need to be carried out during this process. The LOEP uses a five-step “activation” process that transitions their staff from routine operation through the various stages of readiness, response, and recovery after the storm (LOEP, 1999). The LOEP activation process is used to highlight the key milestones and activities of the pre-evacuation development process. 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 can be notoriously unpredictable and, as such, these pre-landfall time references can vary significantly and the activations can often jump several levels at once.

Levels V and IV Activation

Under routine operation LOEP functions at a Level V Activation status. At this level, normal staffing is maintained and no special duties are undertaken. Anytime a tropical system forms in the Gulf of Mexico or Atlantic Ocean with a track that might take it into the Gulf, LOEP 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 Activation 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.

Photo Credit: NOAA

Level III Activation

When forecasts show that a hurricane poses a threat to coastal Louisiana, LOEP moves to a Level III Activation. At Level III LOEP staff move to an increased state of readiness. At this point a storm strike could be as close as three days away. LOEP staff begin to coordinate with the Louisiana Department of Transportation and Development (DOTD) to clear evacuation routes of all obstructions and to collect traffic volume data on key routes on an eight-hour basis. The LOEP also requests the activation of National Guard liaison officers to coordinate the needs of local emergency management officials, such as the use of military vehicles for evacuation transportation. At this stage LOEP 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.

The Evacuation Process

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 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. The LOEP also meets with both DOTD 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. This declaration gives LOEP officials the authority over state services that would typically be under the sole control of the Governor.

Level I Activation

When a storm strike is imminent the LOEP reaches its highest state of readiness. Activities within the emergency operations center (EOC) shift to action-oriented tasks, including the 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 may also be issued at any one of three levels, “precautionary,” “recommended,” or “mandatory.” A discussion of the meaning and intent of these evacuation types will be introduced later. The evacuation order level is critical since it effects several aspects of the evacuation, including the number of people who likely evacuate and the implementation of reverse flow operations. Evacuation orders can also be politically sensitive and controversial decisions, thus they are used under only likely threat situations. The geographic extent and urgency level of an evacuation order is made after the extent of the area at risk has been defined and discussions are held with local-level officials in the risk zones. During a Level I Activation, the LOEP monitors the status of institutional housing and low-mobility groups such as nursing homes, hospitals, and prisons. If problems arise, LOEP helps make arrangements to transport people out of these facilities.

At two hours prior to expected storm landfall, the LOEP issues an order to close all evacuation routes and evacuates traffic enforcement and news media personnel to last resort refuges. During the storm LOEP 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, and the coordination of services for the post-storm recovery effort.

Survey

Although there is a moderately-sized body of literature on evacuations in general and hurricane evacuations in specific, most of the published material is in the domain of the social and behavioral sciences. The limited amount of transportation-oriented material that does exist lies primarily in “gray” literature, consisting of unpublished planning studies for local communities; DOT reports; law enforcement and emergency management operational manuals; and other location-specific difficult-to-access reports and studies. Thus impediments to the involvement of transportation professional in the evacuation planning and management process include: lack of familiarity with the subject; limited sources of information; and difficulty in accessing the minimal literature that does exist. To address these problems and gain access to the most up-to-date sources of information, researchers from LSU undertook a direct survey of DOT and emergency management agencies.

The survey was designed to gather information about the general practices for evacuation in each state and to examine the use of newer techniques such as reverse flow and ITS. Areas of emphasis included the authority and command structure, the advanced warning times required to implement evacuations, the policies that governed the enforcement and management of evacuations, and the communication strategies used for the exchange of data and information. The survey also posed questions that allowed the researchers to learn how transportation departments in each state viewed and dealt with construction work zones on evacuation routes and moving people without access to personal transportation. A total of 28 survey questions were presented to each survey participant.

Surveys were sent to every at-risk coastal state in the continental US. These are the 14 states on the Atlantic coast from Maine to Florida and the four states from Florida and Texas that border the Gulf of Mexico. A total of 40 surveys were mailed, faxed, or emailed to emergency management, DOT, and law enforcement officials in each of the 18 states. At least one response was received from every state in the survey, for a total of 29 responses. Of these responses, 15 were from EM officials, 10 were from state DOT officials, and three were from law enforcement officials. Additional information was also gathered from officials at the Federal Highway Administration (FHWA), FEMA, private engineering firms, and researchers. The following sections of this report highlight the major findings of the survey. Additional details on the survey findings are available in the full project report (Urbina, 2001).

Evacuation Plans and Policies

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. They seek to maximize the efficiency of their 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 (e.g. county or city) level. State-level emergency management agencies typically serve to coordinate local emergency management activities and 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 possible threats differ widely in the various regions of the state. The Texas State Emergency Management Plan has a general 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 emergency management agency takes a greater managerial role in developing evacuation plans.

State plans also differ on the level of detail in their plans. The North Carolina Department of Transportation (NCDOT) is currently developing an Emergency Operations and Procedures Manual for the Division of Highways (DOH). When finished, the plan will include information on various emergency response and recovery issues covering details down to debris removal, personnel and equipment needs.

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. It may also be in part because evacuations can often 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 worse, too small.

Table 1 shows, by state, which officials and agencies have the authority to order hurricane evacuations. Governors maintain their authority in fourteen of sixteen responding states. In New York and Texas, authority has been delegated exclusively to local authorities. The stated reason was that relatively small areas of these states are vulnerable to hurricanes. In South Carolina, the opposite is true. The Governor has sole authority to order a hurricane evacuation.

Table 1. Authority to Order Hurricane Evacuations

STATE	STATE AGENCIES			LOCAL AGENCIES					
	Governor	State Emergency Management Office	Department of Public Safety State Police	Local Emergency Management Office	Mayor	Hgihest Local Elected Official	County or City Law Enforcement	County Judge	County President
NEW HAMPSHIRE	X								
MASSACHUSETTS	X					X			
RHODE ISLAND	X				X	X			
CONNETICUT	X		X		X		X		
NEW YORK						X			
NEW JERSEY	X	X	X	X	X		X		
DELAWARE	X								
MARYLAND	X				X	X			
VIRGINIA	X			X					
NORTH CAROLINA	X								X
SOUTH CAROLINA	X								
GEORGIA	X				X				X
FLORIDA	X								X
MISSISSIPPI	X				X				X
LOUISIANA	X								X
TEXAS					X			X	

Evacuation Plans and Policies

Implementation Time

A critical issue in hurricane evacuations is timing. The earlier the evacuation order is issued, the more time residents and tourists will have to evacuate. Unfortunately, the earlier it is issued the greater the possibility the hurricane could change course before landfall, rendering the evacuation unnecessary or leading evacuees to more dangerous locations. Evacuations that turn out to be unnecessary can also lead to a "Cry Wolf" syndrome in which some people are less likely to evacuate during future threats.

The primary criteria used to make decisions of how soon and how large an area to evacuate are the storm forecasts issued by the National Hurricane Center (NHC). The NHC provides information on storm track, forward speed, and intensity to state and local authorities about every six hours. Currently, the average error in NHC storm track forecasts about 100 miles for a 24 hour forecast. However, most of the surveyed agencies felt that NHC predictions were neither timely nor accurate enough since even medium-sized coastal cities need 12 hours to initiate and complete evacuations before arrival of tropical storm-force winds (39 miles per hour), the most common evacuation termination criteria.

Time requirements for issuing evacuation orders are estimated from a combination of clearance time and the pre-landfall hazard time. Clearance time is the time required to configure all traffic control elements on the evacuation routes, initiate the evacuation, and clear the routes of vehicles once deteriorating conditions warrant its end. Pre-landfall hazards time is the time during which hazardous conditions exist prior to actual hurricane landfall. This occurs as outer bands of the storm begin to impact the coast, bringing tropical storm-force winds and possible roadway inundation due to storm surge flooding. Clearance times are estimated using evacuation traffic models, which are dependant on data such as the population anticipated to evacuate, the number of lanes available for evacuation and impacts from other areas that will affect the evacuation. Clearance time can be significantly lengthened by en route congestion and the setup time required for complex control features (e.g. contraflow)

With all of the factors listed above that need to be considered, it is not surprising that pre-planned evacuation times vary widely by location. These variables effect the preferred advance times that states use to issue an evacuation order, as shown in Table 2. Most of these times were around 24 hours. However, the survey also showed that many states required additional time for stronger storms. One of the stated reasons is that they assume that more people will heed warnings to evacuate. While not stated directly, it was assumed that during more powerful storms more people will be at risk both along the coast and further inland; states will need additional time to configure and initiate contraflow operations. Louisiana, home to the City of New Orleans, with its 1.3 million residents and limited outbound route capacities, prefers 72 hours of advanced notification time to issue an evacuation order for Category 5 storm. Obviously, this much advanced notice is difficult given the limitations of current storm forecasting.

Table 2. Preferred Minimum Evacuation Order Advanced Notification Time (in hours)

STATE	HURRICANE CATEGORY				
	1	2	3	4	5
MASSACHUSETTS	9	9	12	12	12
RHODE ISLAND	12-24	12-24	12-24	12-24	12-24
MARYLAND	20	20	20	20	20
VIRGINIA	12	18	24	27	27
SOUTH CAROLINA	24	24	32	32	32
GEORGIA	24-36	24-36	24-36	24-36	24-36
MISSISSIPPI	12	24	24	48	48
LOUISIANA	24	48	72	72	72

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 storm and clearance times. Typically, evacuations are classified as one of three types: "voluntary," "recommended," and "mandatory." "Voluntary" evacuations 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. No special traffic control or transportation measures are usually taken during voluntary evacuations and people may remain if they so choose. "Recommended" evacuation are issued when a storm has a high probability of causing a threat to people living in at-risk areas. Again, decisions of whether or not to leave are left to individuals and few special transportation arrangements are made. "Mandatory" evacuations are the most serious. During a "mandatory" evacuation, authorities put maximum emphasis on encouraging evacuation and limiting ingress to coastal areas. These events are also when evacuation transportation plans go into effect.

One of the problems of mandatory evacuations is that they are difficult to enforce. Many people resist being ordered to leave their homes and property by government officials. Although the State of Mississippi has mandatory evacuations, current law does not allow State officials to enforce them. New Jersey emergency management officials also acknowledge that if a person wants to stay, the State will not physically remove them unless it is absolutely certain that they would be harmed.

There are also variations in the specific definitions and use of evacuation terminology between states. Virginia classifies all evacua-

Evacuation Plans and Policies

tions as either “voluntary” or “recommended,” none are “mandatory.” In South Carolina, all evacuations are either “voluntary” or “mandatory.” All evacuations in Texas are regarded to be “recommended.” In areas of Georgia susceptible to storm surge evacuations may be “partial voluntary,” when only a portion of a county is asked to evacuate. Georgia also uses the terms “full voluntary,” “partial mandatory,” and “full mandatory” evacuation. In Jefferson Parish Louisiana, “voluntary” evacuations are referred to as “precautionary.”

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, 2000b). The type of evacuation order and how it is communicated is also critical to avoid unnecessary evacuations, also referred to as “shadow evacuations.” Shadow evacuations occur when people near threatened areas evacuate their homes even though they are not necessarily in danger. Authorities in Florida feel that the one of the reasons for the extreme number of evacuees during Hurricane Floyd was shadow evacuation.

Low Mobility Groups and Use of Public Transit

Transportation infrastructure in the US has developed to serve vehicular traffic. While reliance on personal transportation works reasonably well under routine conditions, it can cause significant challenges for emergency management officials. The number of people without access to transportation in New Orleans, has been estimated as high as 25 to 30 percent of the population. In addition to people without vehicles, potential evacuees include the indigent, elderly, prisoners, the infirm, and tourists. Evacuation of these low mobility and special needs groups is an area that while included in most state emergency operation plans, has been largely unaddressed by DOTs.

In practice, the responsibility for the evacuation of low mobility groups in facilities like prisons, hospitals, and schools is given to facility administrators. Often, however, these administrators are neither familiar with nor trained in emergency management or mass transportation. Recognizing this situation, some state emergency management agencies have attempted to make special arrangements for these groups.

Busing is the most common mode of transportation for low mobility groups. To transport people in busses, emergency management agencies have in the past contracted with local transit authorities, school districts, and tour operators, with varying levels of success. Many heavily populated cities do not have an adequate supply of busses to move all low-mobility evacuees. For example, about 250,000 residents of New Orleans (not including tourists or "special needs" populations) have no means of private transportation. The total number of busses in all of New Orleans would provide only a fraction of the capacity needed to transport all of these people. Thus, Louisiana emergency management officials plan to use any available alternative means of transportation, including National Guard vehicles. They also plan to open local shelters and "refuges of last resort" for those not able to evacuate. Emergency management officials in Florida have also used air transport to evacuate critically ill people from threat areas if necessary. None of the survey respondents indicated plans for the use of other forms of public transportation, such as rail, for evacuations.

New Practices

Hurricanes Georges and Floyd exposed weaknesses of evacuation planning and management practices in the US. Although some argue that the problems encountered during these two evacuations were extreme and not likely to occur on a frequent basis, others feel that evacuations of similar magnitudes are likely to occur more frequently. The latter is supported by climate forecasts that predict an increased frequency of major tropical storms and long-term population trends that forecast substantial population growth in the coastal regions of the southeast. As a result, the need for more effective transportation practices and technologies in evacuation is apparent and the expertise for them will have to come from the transportation community. The following sections describe some of the ways that DOTs are working with emergency management agencies to improve future evacuations through the application of contraflow operations and ITS systems.

Photo Credit: NOAA

Contraflow

Contraflow, or reverse laning as it is also commonly known, involves the reversal of traffic flow in one or more of the inbound lanes (or shoulders) for use in the outbound direction with the goal of increasing capacity. In 1998 only the Florida and Georgia DOTs had plans in place to reverse the flow on their interstate freeways to expedite evacuations. Today, eleven of the 18 mainland coastal states threatened by hurricanes plan to use some type of contraflow evacuation strategy. Contraflow types and associated benefits, costs, and inherent difficulties are discussed in recent several reports (FEMA, 2000; PBS&J, 2000c; and Wolshon, 2001).

While contraflow is widely viewed as the best way to increase outbound flow during evacuations, it is not a cure all. In fact, the true costs and benefits of contraflow in terms of its capacity improvements, safety, and manpower requirements remain largely unknown. Contraflow was implemented for the first time in Georgia during Hurricane Floyd in 1999 with mixed, though overall positive, results. Contraflow was also improvised in South Carolina during Floyd, after a strong public outcry came from evacuees trapped in congestion on I-26 from Charleston to Columbia.

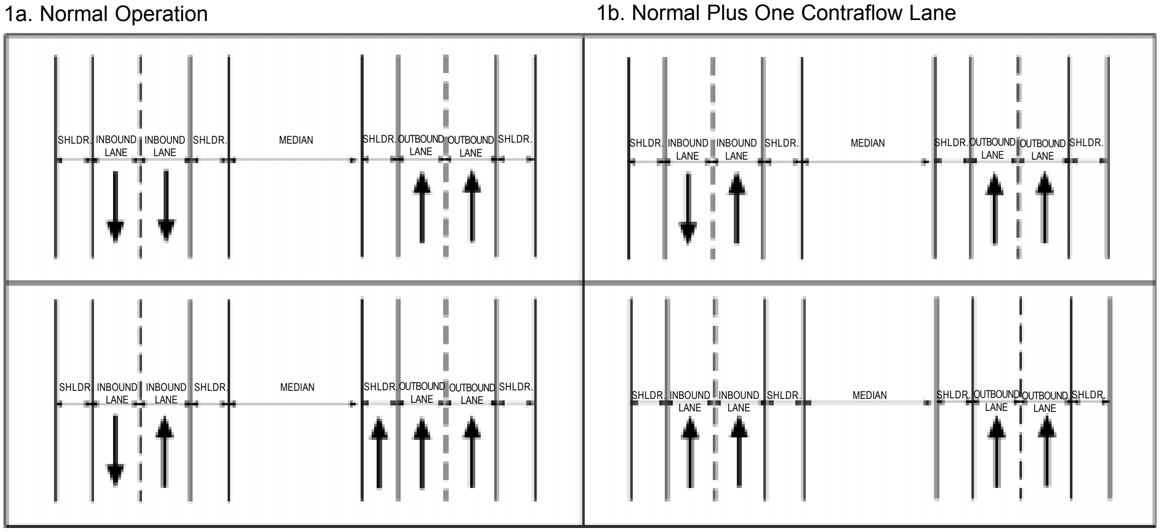
Four different variants of contraflow are currently planned for use. They include: all lanes reversed; one lane reversed and one lane with inbound flow for emergency/service vehicle entry only; one lane reversed and one lane with normal flow for inbound traffic entry; and one lane reversed with the use of the left shoulder of the outbound lanes. These configurations are shown schematically in Figure 1. The locations where they are planned for use are shown in Table 3.

Because it offers the largest increase in capacity, the most common contraflow strategy is to reverse all inbound lanes to the outbound direction. One study estimated that a full reversal would provide a near 70 percent

FIgure 1. Freeway Contraflow Lane Use Configurations

1a. Normal Operation

1b. Normal Plus One Contraflow Lane



1c. Normal w/Shoulder and One Contraflow Lane

1d. Normal Plus Two Contraflow Lanes

Contraflow

Table 3. Evacuation Contraflow Use Strategies

STRATEGY \ STATE	NEW JERSEY	MARYLAND	VIRGINIA	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	LOUISIANA	TEXAS
All lanes outbound		•	•	•	•	•	•	•	•	•
One lane reversed, one lane inbound for emergency/ service vehicle entry only	•								•	
One lane reversed, one lane inbound for traffic entry	•				•					
One lane reversed and use of outbound left shoulder lane									•	

Notes: EM and DOT officials in the State of Delaware plan to use contraflow, although the specific configuration type has not yet been determined. Officials from the State of Mississippi are in discussions with their counterparts from Louisiana to extend the northbound I-55 contraflow out of New Orleans into their state.

increase in capacity over conventional two outbound lane configurations (FEMA, 2000).

Though not as widely planned, single-lane contraflow strategies are also proposed. Single inbound lane reversals are thought to increase outbound road capacity by about 30 percent. The main advantage of this strategy is its ability to maintain a lane for inbound law enforcement personnel and emergency service vehicles, critical for clearing incidents. It can also permit access for people that want to move against the evacuation traffic. One of the major drawbacks of single-lane reversals is that it raises the potential for head-on accidents.

Another strategy to improve capacity is to use the outbound left shoulder as an additional outbound lane. This has been estimated to increase capacity by only about eight percent (FEMA, 2000). The capacity increase depends on the width and condition of the shoulder, since flow rates are decreased and drivers tend to reduce speeds when they are laterally constrained. Two additional concerns associated with the use of shoulders are pavement suitability and bridge widths. Shoulders are typically designed with a thinner pavement cross-section and greater cross-slope. They may not be able to withstand prolonged traffic loading and thus provide an inadequate riding surface. Cross-section width can be a problem on bridges. Many freeway bridges, particularly older ones, have been constructed with narrow shoulders, or as shown is Figure 2, with without shoulders. If shoulders were used as outbound lanes, these locations would create bottlenecks causing additional congestion as vehicles merge back into the through lanes.

Figure 2. Interstate Freeway Shoulder Drop at Bridge

Contraflow Design

Currently, there are no recognized standards or guidelines for the design, operation, and location of contraflow segments. Most contraflow designs have been adapted from standard design practice and past evacuation experiences. Results of the survey demonstrated that while some of their geometric design and traffic control elements were similar, there were also many obvious differences.

Contraflow sections typically start with a median cross-over or traffic control configuration that redirects or splits a portion of the outbound traffic stream into the inbound lanes. These designs vary by location. However, the most common method to affect the traffic split is through the use of a median crossover. The specific location of these crossover points is usually a function of roadway geometry, the approximate beginning of congestion during prior evacuations, and the proximity of the location to other evacuation routes. A typical at-grade crossover configuration is shown in Figure 3. This particular design in Kenner Louisiana, will divert traffic from the two left lanes of westbound I-10 into the eastbound lanes as evacuees depart New Orleans toward Baton Rouge. A water-filled segmented barrier is used to prevent vehicles from crossing the median during normal operations.

Crossover designs at the interchange of two freeways can be more complex. An example of an is shown in Figure 4. A connecting roadway has been constructed between the loop ramp from I-526 to I-26 to divert traffic into the contraflow lanes of I-26 as it departs Charleston South Carolina. An additional connecting road is used to divert evacuation traffic from eastbound I-526 into the contraflow lanes of I-26 heading toward Columbia.

Contraflow section termini designs also vary by location. One of the controlling criteria for the location of a termination point is the prevention of merging congestion. This can be accomplished in several different ways. The method that is most common, particularly for shorter segments, is to permanently split the traffic flows. In this type of design one of the streams of traffic is diverted onto a separate roadway, while the other continues travel on the original route. In New Orleans, vehicles traveling in the normal outbound lanes of I-10 will all be diverted northbound onto I-55 near the City of LaPlace (some 25 miles outside of

Figure 3. Typical At-Grade Crossover

Contraflow

Figure 4. Interchange Crossover

Source: South Carolina Department of Transportation

the City). After the I-55 diversion, the traffic in the contraflow lanes of I-10 will cross the median back into the normal outbound lanes (LSP, 2000). A similar design will also be used to terminate contraflow operations in South Carolina. At the end of the I-26 contraflow section in Columbia, all evacuation traffic in the normal outbound (westbound) lanes will be diverted on to northbound I-77, while the I-26 contraflow traffic will be diverted back into the normal westbound lanes after the I-26/I-77 interchange.

The other common type of contraflow termini design is the attrition-merge. These designs are favored in states having long contraflow segments such as Georgia and Texas. In this design, traffic in the normal and reverse flow lanes is reduced by allowing vehicles to exit to secondary routes at points along the contraflow segment. Through a process of exit attrition, it is assumed that traffic would be reduced to a level at the end of the segment that would allow a merging of the traffic streams without causing bottleneck congestion (Ford et al., 2000).

Specific lengths of contraflow segments are a function of the evacuation area geography and the road infrastructure. Planned segments range in lengths from 3½ to 180 miles. Short sections are typically used to gain maximum capacity on routes that connect other traffic arteries. Longer segments will be used to evacuate coastal cities to inland cities such as those from Corpus Christi to San Antonio, Charleston to Columbia, and Mobile to Montgomery, or for connecting to distant major evacuation highways.

Table 4 summarizes the planned routes and lengths for evacuation contraflow routes. Florida and New Jersey plan the most extensive use of contraflow operations, with seven and five segments, respectively (it should be noted the New Jersey segments are shorter those in Florida). Both states are also analyz-

Table 4. Planned Contraflow Evacuation Routes

State	Route(s)	Approx. Lengths (miles)	Origin Location	Termination Location
New Jersey	47/347 Atlantic City Expressway 72/70 35 138/I-195	19 44 29.5 3.5 26	Dennis Twp Atlantic City Ship Bottom Boro Mantoloking Boro Wall Twp	Maurice River Twp Washington Twp Southhampton Pt. Pleasant Beach Upper Freehold
Maryland	MD-90	11	Ocean City	U.S. 50
Virginia	I-64	80	Hampton Road 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 1-10 Eastbound SR 528 (Beeline) I-4 Eastbound I-75 Northbound FL Turnpike I -75 (Alligator Alley)	180 180 20 110 85 75 100	Jacksonville Pensacola SR 520 Tampa Charlotte County Ft. Pierce Coast	Tallahassee Tallahassee SR 417 Orange County I-275 Orlando Coast
Alabama	I-65	135	Mobile	Montgomery
Louisiana	I-10 Westbound I-10/I-59 (east/north)	25 115	New Orleans New Orleans	I-55 Hattiesburg, MS
Texas	I-37	90	Corpus Christi	San Antonio

Note: Delaware,Virginia and the New Orleans, LA to Hattiesburg, MS contraflow plans are still under development.

ing the feasibility of adding more contraflow routes, including I-75 from Wildwood to I-275 in Florida and the Garden State Parkway, New Jersey Turnpike, I-78 and I-80 in New Jersey (Trammell, 2001 and Augustiniak, 2001).

States also differed in the amount of detail considered during contraflow planning. These variations appeared to be related to the agency that prepared the plan. In Alabama and North Carolina, where the plans were developed by their DOTs, contraflow design plans included a considerable level of detail in the geometric design and traffic control aspects of the cross-over location. The North Carolina plans, for example, emphasized the placement and location of traffic control devices in the vicinity of the crossover and the use of highway advisory radio (HAR) and dynamic message signs (DMS) to guide evacuees. The Louisiana plan, developed primarily by the State Police, paid considerably more attention to enforce-ment requirements in the contraflow area. These plans detailed specific numbers and locations of police vehicles at the beginning and termination points of the segment, includ-ing the number of troopers and vehicles needed at each exit ramp.

Contraflow

Managing Contraflow Operations

In addition to the variation in designs, states also have significantly differing philosophies on how they plan to utilize and manage contraflow operations on their highways. South Carolina, for example, is the only state that plans to use contraflow for post storm re-entry. Differences were also apparent in the way states viewed the somewhat conflicting needs of having a rapid and orderly evacuation using contraflow versus the need to maintain acceptable levels of safety on the road. Despite the advantages that contraflow operations can bring to an evacuation, its disadvantages also need to be considered. Highway agencies agree that reverse flow operations will likely be inconvenient and confusing for drivers. They also expect contraflow to be labor intensive to initiate, difficult to enforce, and potentially dangerous for drivers. Survey questions were posed to determine managerial strategies such as who will decide when to use contraflow; under what conditions it will be started and ended; how long it will last; and how will issues associated with safety, accessibility, convenience, enforcement, and cost be addressed.

In most states the authority to start and end of contraflow operations resides with the Governor, although that responsibility falls on enforcement and/or transportation officials in a few states. Table 5 shows the agency or official having the authority to initiate and terminate contraflow operations in the states where they are planned. Consistent with their philosophy of local-level evacuation authority, Texas has given operational control to local law enforcement officials at the beginning and ending of the contraflow segment. The only state where DOT officials have full authority to

Table 5. Authority to Start and End Contraflow Operations

State	Start	End
New Jersey	Governor	Governor
Delaware	Governor	Governor
Maryland	Local emergency management with State Police and Maryland DOT	Local emergency management with State Police and Maryland DOT
Virginia	Governor	Governor
North Carolina	Governor	Governor
South Carolina	Governor	Department of Public Safety
Georgia	Governor	Georgia DOT
Florida	Governor	Highway Patrol
Alabama	Alabama DOT	Alabama DOT
Louisiana	Governor	Governor
Texas	Highway Patrol Captain in Corpus Christi	Highway Patrol Captain in San Antonio

initiate and terminate contraflow operations is Alabama. It should be noted that in states where the authority rests with the Governor, the decision of when to initiate and terminate contraflow is made in close consultation with DOT, law enforcement, and emergency management officials.

Several criteria were identified as affecting decisions on if and when to initiate contraflow operations, including: storm characteristics (size, intensity, track) and potential risks; traffic volume; set up time; and time of day. In cases where the storm was not forecast to make imminent landfall or was of modest strength, most states indicated they would resist the use of contraflow. The other criteria controlling the implementation of contraflow was traffic volume.

Because of the inherent difficulties of its use, the majority of states felt that reverse flow lanes should not be implemented until traffic volumes warranted their use. Officials in these states stated their intention to wait until volumes were at, or rapidly approaching, capacity levels before using contraflow. These opinions were not, however, shared by all states. Officials in South Carolina and Louisiana plan to initiate contraflow operations as soon as the call for an evacuation is made. It was their opinion that attempts to initiate contraflow operations after the normal outbound lanes are near or at capacity will result in the loss of valuable evacuation time.

To initiate contraflow, traffic control devices and barricades must be erected, inbound lanes must be cleared of vehicles over their length, and law enforcement and DOT field personnel must be positioned at their assigned locations. Most states anticipate this process will take from four to 12 hours. Set up time depends on the length of the segment, the number of interchanges involved, and the number ramps and merge points that may require control. In a few states, the process could take considerably longer. Authorities in Florida estimate that 49 hours will be needed to prepare for a contraflow operation. The time is so much longer than other states because Florida needs to activate National Guard forces to set up and patrol their segments (Collins, 2001).

Most states are reluctant to implement contraflow after nightfall, because of the previously mentioned implementation difficulties. Florida officials stated that they will neither initiate nor operate any lane reversals at night. Georgia officials will also resist beginning contraflow operations after nightfall. However, they also recognized that some situations may dictate the need and they want to maintain flexibility in their response. In contrast, New Jersey and Maryland officials plan to implement contraflow as needed, regardless of the time of day.

Photo Credit: NOAA

Contraflow

Ending Contraflow

The two most commonly reported factors for determining when to shutdown an evacuation (contraflow or otherwise) were the arrival of tropical storm force winds and a decrease in evacuation traffic volumes. Most states also plan for contraflow routes to remain open as long as weather conditions were favorable. Virginia plans to shutdown contraflow operations about two hours prior to the forecast arrival of tropical force winds. This additional lead-time allows them to evacuate DOT and law enforcement personnel. North Carolina plans for a shutdown approximately three hours before the same conditions. In Florida, the contraflow termination shutdown will be based solely on the arrival of nightfall. Georgia is the only state planning to maintain the contraflow operations continuously, until the storm threat has passed.

While termination criteria may differ, all states agree that the most important consideration in any evacuation is to keep evacuees from being stranded on the highway should this worst case situation arise. Palm Beach County (Florida) Division of Emergency Management has plans in place to deal with it. “Refuges of Last Resort” have been designated along certain evacuation routes in the county. These buildings, located within one mile of evacuation routes, are for extreme circumstances only and may not necessarily have food, water, utilities, or supervision. They are not even guaranteed to be safe in strong hurricanes. However, they will provide evacuees a better option than remaining on the road during the storm.

Intelligent Transportation Systems

Access to timely and accurate traffic information during evacuations is critical to the evacuation process. Information about traffic flow rates and speeds, along with lane closures, weather conditions, incidents, and the availability of alternative routes is needed to effectively guide evacuees. During the Georges and Floyd evacuations, access to and exchange of accurate and timely traffic information was often difficult. Emergency management officials were often "working blind," with little quantitative knowledge of which evacuation routes were flowing well and which were in gridlock. As a result, they were unable to redirect traffic from routes that were over capacity to nearby roads that were carrying little traffic.

One of the ways that DOT officials are responding to the need for information is through the application of ITS technologies. Currently, all of the states surveyed have plans to enhance existing and develop new ITS systems for use in hurricane evacuations. The most common area of ITS application is for real-time monitoring of travel conditions. Several states, including South Carolina, Florida, and Louisiana, are either using or planning to use remote traffic detection systems.

All DOTs have some type of statewide traffic data recording system, used for planning purposes to monitor and assess statewide traffic volume and speed characteristics. While 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, most DOTs download data from the recorders via telephone connections on a monthly basis. Recently, minor modifications to these same systems have allowed South Carolina and Florida DOT officials to retrieve this information on hourly or 15-minute basis 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. While these systems may not provide true real-time data, they will give EM and DOT evacuation coordinators a much better idea of up-to-date travel conditions than they have had in the past.

Cameras are another type of surveillance system capable of monitoring speed and flows that can be used for evacuation management. One commonly used system is closed circuit television (CCTV). CCTV cameras have an advantage over loop detection in that they can provide direct visual confirmation of traffic and weather conditions at remote locations. They can also be used for detecting incidents and verifying their removal. One of the limitations of CCTV is that it typically requires direct power and communication connections. This is often difficult in remote locations along evacuation routes.

ITS systems are also planned to disseminate travel information to evacuees. Two of the systems planned for use are highway advisory radio (HAR) and dynamic message signs (DMS). In contrast to traffic counter and CCTV systems that bring data in, HAR and DMS systems get information out. To make the make most effective use of these tools (HAR has a limited range of about 3 to 5 miles), states are planning to use them in advance of

Intelligent Transportation Systems

exits and interchanges where services and alterative routes are available. The type of information conveyed through HAR and DMS will include shelter locations, alternative evacuation routes, congestion and incident information, and services such as gas station, rest area locations, lodging availability. As an alternative to traditional HAR, the Delaware DOT is currently in the process of acquiring a commercial FM radio station for use as a statewide travel information station. The station will convey general travel information during non-evacuation periods and evacuation information in advance of hurricanes. The relatively small area of Delaware makes it possible for a single station to cover the (NHC), Virginia Department of Emergency Services, and the Red Cross. The Florida Division of Emergency Management website provides links to hotels in Florida, Alabama, and Georgia that allow evacuees to make online hotel reservations. The Florida DOT's website to provides access to its statewide network of real-time traffic volume and speed data recorders. While all of these internet systems are targeted for use prior to the evacuation, there is little doubt that future wireless-Internet technologies will allow them to be used en route.

There are also limitations in the application of ITS to hurricane evacuation. One of the most significant is that many ITS systems are located in urban areas, while the majority of evacuation route mileage is in rural areas. To address this, several states plan to use portable systems, particularly HAR and DMS. Researchers in Louisiana are also currently working on the development of a mobile traffic data recording system. When completed, these self-contained mobile data collectors will be used to provide real-time traffic flow information using wireless communication technologies. Another advantage to mobile systems is that they can be deployed to any location in response to varying hurricane scenarios. Another limitation of ITS is its expense. Since evacuations are rare events that cover such wide areas, it is difficult to justify their cost unless they can incorporate multipurpose functionality.

Work Zones

A historically overlooked issue in evacuation planning and preparedness has been highway work zones. 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. Early recognition of this problem by the DOT allowed them to request the contractor clear construction equipment and open both of the partially constructed lanes to outbound traffic. Fortunately the contractor acted quickly and delay was minimized. However, things could have been worse had the storm not changed to a more easterly course. A year later, similar problems of construction on evacuation routes were also experienced in North Carolina during Hurricane Floyd.

Since the need for maintenance and construction during the hurricane season is unavoidable, 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. While these restrictions cover most of the hurricane season they do not apply to the less active, though still potentially dangerous, months of October and November. The Houston District of the Texas DOT uses contract language that requires contractors to maintain the same number of lanes for evacuation as were originally available. According to one official, this provision is understood but not necessarily written into contracts in other Texas DOT districts.

Other options to maintain capacity through work zones on evacuation routes have included limiting the construction season, distance, performance time, and/or phase sequencing of projects. These types of contraction provisions can potentially increase the cost and/or duration of projects, since they may require a contractor to work in shorter segments or use non-standard construction practices.

Photo Credit: NOAA

Conclusion

The results of this study showed encouraging signs for the improvement of hurricane evacuations in the US. It was apparent that highway and transportation professionals have become more involved in the development of evacuation plans since 1998. This is a significant step and represents a needed change from prior practice. The involvement of transportation planners and engineers has also brought expertise and experience in dealing with transportation-related issues, including forecasting evacuation travel demand; evacuation traffic analysis and modeling; and the application of ITS technologies.

Although progress has been made in the past few years, many needs still exist. One of the most obvious is the need for education and greater exchange of information. The Federal Highway Administration has recognized this need and initiated a series of evacuation-related workshops. FHWA working with FEMA, has also established an Evacuation Liaison Team that will improve coordination and communications among states during hurricane events. A Transportation Research Board subcommittee (A3B01(4) – Subcommittee on Emergency Evacuation) has also been formed to disseminate new research findings to the practicing community.

At a more basic level, additional research and development of standards and best practices guidelines are also needed. While it is recognized that evacuation plans need to allow room for flexibility, checklists and basic guidelines could benefit state and local level DOT and EM officials in the development of specific plans. They would also ensure a basic level of practice uniformity from location to location, an issue that has gained importance as evacuations become regionalized. There is also a need to address specific transportation-related evacuations issues, including those associated with the movement of low-mobility groups, accommodating evacuation traffic through work zones, and determining the costs and benefits of contraflow operations.

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