Use of Rural Transportation Infrastructure in Evacuation Operation for the North Gulf Coastal Region

Technical Memorandum 1: Literature Review

by

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1. INTRODUCTION

The Northern Gulf Region's coastal communities are in constant threat of hurricanes each fall, witnessing deadly hurricanes Katrina, Rita, Ivan, and others in the last five years that required mass evacuations and other major emergency transportation services. Residents of these communities experienced fuel shortages, traffic congestion, significant delays receiving civil supplies, frustration, and risk during evacuations in the wake of hurricanes Katrina and Rita. These events led all systems including emergency management, law enforcement, and transportation to miserably and indiscriminately fail, particularly affecting the young, elderly, poor, and disabled. Seniors living independently but unable to drive were victims of the flooding to a disproportionate degree.

When evacuations take place, planning and coordination among emergency management, law enforcement and transportation agencies lead to an effective system allowing anyone with a car to evacuate from urban areas. But rural coastal communities remain at high risk and are difficult to evacuate in a timely manner due to larger geographical areas, low density, and limited resources. To date, emergency planning efforts have focused primarily on addressing urban versus rural needs. Furthermore, urban evacuees' travel behavior may impact rural areas. In a common evacuation scenario, urban evacuees travel to rural communities in close proximity to urban areas. A lone rural evacuation study, "Urban to Rural Evacuation: Planning for Rural Population Surge" by the Rural Health Research and Policy Centers, finds the following:

- Significant population surges are likely to occur in rural communities following an urban disaster.
- Fifty-five percent of evacuees would likely travel to nearby rural communities.
- There is lack of coordination between urban and rural evacuation planning efforts.
- Rural communities do not consider an urban-to-rural population surge in emergency planning efforts.
- Urban and rural evacuees are likely to drive on rural roads.
- Traffic jams and blockages are likely to happen on rural roads due to unexpected and spontaneous evacuation on two-lane rural roads.
- Evacuees may consume fuel, food, water, and sanitation resources while traveling through rural areas.
- Limited health care and public health infrastructure are critical weaknesses in rural communities.

As described above, the resources of the receiving rural communities adjacent to urban areas can be overwhelmed by the population increase. In smaller rural communities even small numbers of evacuees can represent sizeable increases in population, and can jeopardize the integrity of resources and disproportionately impact rural law enforcement agencies, health care facilities, and transportation agencies, which often have limited fiscal resources. But behind all issues and concerns, the transportation network is the key component as all amenities and resources are placed along the transportation network. An efficient and effective evacuation and emergency management plan relies on the performance of the transportation network. Thus, it is necessary

to understand the dynamics of rural transportation networks to understand rural evacuation issues. Important features of this network include the following:

- According to the Federal Highway Administration (FHWA) rural roads comprise 80 percent of national road miles (3.1 million rural road miles).
- Rural areas are facing a phenomenal period of growth and development, accompanied by large increases in travel within and through these areas. For example, after the 2005 hurricanes, rural communities within 100 miles of the coastline of the North Gulf Coastal Region experienced rapid growth that impacted already limited infrastructures. In this time period, almost 5,000 new dwelling units have been built in rural areas bordering the coastal counties in Mississippi.
- Nearly 40 percent of the country's transit-dependent population, primarily senior citizens, persons with disabilities, and low-income individuals, live in rural areas.
- Due to a lack of travel services, rural populations are more automobile dependent than their urban counterparts. Rural households travel 38 percent more miles than urban households, even though they make 5 percent fewer trips.
- Ninety percent of rural roads are two-lane.

The rural transportation network is a major component of a larger, multimodal system that is critical for moving people, goods and services. When evacuations occur, the recommended safe distance is 150 miles from the immediate coastline. Evacuees, then, may drive 150 miles or more, largely through rural areas, giving rural roads a larger role in evacuations than may be currently recognized. Further, rural roads may substitute for interstates and other major highways in the event they become functionally impaired (e.g., congested or damaged).

With an increased focus nationally on safe evacuation and dealing with natural disasters, the rural transportation network across and throughout every region of the country must be effective and efficient during emergencies. Therefore, national evacuation policy must address evacuation and transportation as whole—not just isolated urban hotspots where the evacuation process is highly visible—but also focus on the large rural areas that hold the country together. It is critical to begin identifying and addressing the gaps in evacuation planning and operations relative to critical rural transportation issues.

The literature review related to rural transportation and evacuation issues is presented in this technical memorandum.

2. LITERATURE REVIEW

This chapter reviews and summarizes the state of the art and practice pertinent to emergency evacuations, with a focus on rural areas. Specially, information related to the following topics was reviewed:

- Classification of evacuation community versus evacuee-receiving community with respect to community resources, and historical and infrastructure context;
- Stakeholders involved in evacuation events;
- Use of rural transportation infrastructure;
- Tools for the dissemination of traveler information; and
- Lessons learned from previous evacuation events.

2.1 Classification of Evacuation Communities

When evacuations take place, people move or are moved from dangerous or potentially dangerous areas to safe areas. Dangerous and safe areas can be classified as evacuee or impacted communities. A community where evacuees would like to move to or is designated as a safe area that provides resources such as personal services, shelters, health care, law and order, education, animal care and so on is called an evacuee-receiving community or destination community. Both the communities' resources are impacted either through disasters or evacuation operations. For example, during the 2005 hurricane season, around 300,000 evacuees from New Orleans passed through or were sheltered in the city of Fort Worth, Texas, and other surrounding areas, and 900 families were provided shelters for long-terms (Williams, 2006).

Based on urban and rural area classifications, evacuations can be divided into four categories:

1) Urban to urban evacuation;
2) Urban to rural evacuation;
3) Rural to urban evacuation; and
4) Rural to rural evacuation.

Evacuees traveling to urban areas might not have the same impact they would have when moving to rural areas because of the ample infrastructure available in urban settings. Based on an analysis of interviews with 17 preparedness experts and planners at the national and local levels, the Walsh Center for Rural Health Analysis found that urban evacuees are likely to travel to and through rural areas (Meit et al., 2008). Traffic flow into rural areas may exceed existing roadway capacity and result in unexpected traffic jams and blockages. People evacuated to rural areas would consume fuel and food and use roadside amenities. Researchers recommend two important areas to be studied: 1) estimates and information about urban to rural evacuees, and 2) identification of sites in rural areas where evacuees can be sheltered and provided resources (Meit et al., 2008).

2.2 Evacuation Stakeholders

The objective of evacuations is to move people out of affected areas to safe places as quickly as possible. Needless to say, evacuees are the most important stakeholders in evacuations. In addition, a variety of agencies are involved during the evacuation process. An emergency evacuation should be carried out through interagency coordination due to its extensive impact on people and property in affected areas. Among the partners, governors and/or mayors are the decision makers that usually have the ultimate authority to order evacuations. A survey of 18 states revealed that governors and mayors from 17 states had the authority to order evacuations (Wolshon et al., 2005a). In addition, the decision makers are responsible for requesting assistance from neighboring state and federal governments through mutual aid agreements or other prescribed methods (Houston, 2006).

Emergency evacuations are usually coordinated through state emergency management agencies (EMAs) or local (e.g., county or city) emergency operations centers (EOCs). In most states, emergency evacuation preparedness, response, recovery, and mitigation are developed and coordinated at local EOCs. The EOC is staffed with employees from different partners. For example, the EOC in St. John the Baptist Parish, Louisiana, is staffed with employees from the parish's Department of Public Safety (DPS), Civil Defense, Office of Fire and Rescue Service, and the E-9-1-1 communications center (http://www.sjbparish.com/eoc.asp). In some other states, such as Florida, the state EMA takes a greater managerial role than local emergency management offices because the entire state is exposed to hurricanes (Wolshon et al., 2005b). During evacuation operations, emergency managers from state EMAs or local EOCs are responsible for gathering key players in the evacuation, collecting and analyzing information, recommending actions, and ordering and providing resources for emergency operations (Houston, 2006).

Over the past decade, transportation has been playing a more and more active role in emergency evacuations. Many transportation agencies such as state and local departments of transportation (DOTs), transit agencies, public works, highway contractors, and the towing industry are involved before, during, and after evacuations to maintain transportation systems. The potential roles of transportation in emergency evacuation are summarized in the following table (Houston, 2006; Wolshon, 2009). One of the important roles of transportation during evacuations is the direction and control of highway networks. Transportation agencies have developed tools and strategies to convey information to travelers and help control and guide traffic during evacuations. The most common tools and strategies are signs, pavement markings, traffic signals, and contraflow (Wolshon et al., 2009). It should be noted that while transportation plays active roles in evacuations, transportation personnel do not get involved in the declaration and timing of evacuation. The study (Wolshon et al., 2009) also found that barriers or obstacles to coordination in command and operation exist between transportation and other government agencies (e.g., law enforcement, emergency management agencies).

Table 1: Transportation's Roles in Evacuation

Phase of Evacuation	Transportation's Role
Before (Readiness and Activation)	1) Provide road inspections/assessments 2) Develop management and control strategies 3) Provide evacuation routes
During (Operations)	1) Order and provide traffic operations resources 2) Direct and control highway networks 3) Collect, analyze, and report traffic information 4) Conduct traffic incident management with first responders and local law enforcement 5) Provide information to EOC 6) Provide information to FHWA (Federal Highway Administration) and other impacted state DOTs as necessary
After (Reentry)	1) Remove debris 2) Restore traffic

First responders and volunteers also play an important role during evacuation operations as they provide on-scene services to evacuees. First responders consist of people from different departments such as police, fire, and emergency medical services (Houston, 2006). They can provide needed resources and equipment to facilitate safe evacuation, especially for those with special needs. Volunteers from various organizations provide support to relieve evacuees along highways, open and staff shelters, coordinate with first responders and transportation personnel, etc.

Coordination between partners involved in evacuations is necessary and important. Before evacuation, emergency managers and transportation personnel should work together to determine evacuation routes, as transportation personnel have specialized transportation knowledge and possess assets that are useful for evacuations. Highway contractors, law enforcement, public works officials, and other stakeholders need to be involved to make sure that those routes are clear before evacuation. Interagency coordination is also needed between jurisdictions since in many cases evacuees need to cross jurisdictional and state boundaries. Some examples of coordinated efforts are presented by Plowman (2001):

- Florida has developed formal procedures to coordinate multi-county evacuations. These procedures include the designation of inland "host counties" that will open shelters for evacuees from coastal counties.
- Delaware, Maryland, and Virginia have formed the Delmarva Emergency Task Force to improve evacuation traffic flow between the states on that vulnerable peninsula.

- The Georgia Emergency Management Agency has created an interstate coordinator position to facilitate communications with neighboring states.

2.3 Rural Transportation Infrastructure

The most important rural transportation infrastructure is the existing road system, especially those routes planned for use in evacuations. The rural road system is largely managed and maintained by local governments. In Kansas, the maintenance of rural transportation infrastructure is mainly the responsibility of local governments. Ninety percent of roads and 80 percent of bridges are their direct responsibility (Hossain et al., 2003). In addition, local government agencies (e.g., EOCs, EMAs) are responsible for evacuation planning. Evacuation route maps, evacuation guidance, emergency contacts, and other information are usually available on local agencies' web sites. In Louisiana, the parish emergency management web site (http://www.ohsep.louisiana.gov/linkpages/parishpa.htm) provides links to each parish's Office of Homeland Security and Emergency Preparedness, from which evacuation routes and other emergency evacuation information can be easily accessed. Such information is also available in other Northern Gulf Coast states (Mississippi, Alabama, and Florida). The vast majority of evacuation routes in rural areas are interstate highways, U.S. highways, and state highways; lower-level roads are usually not used for evacuation due to their limited capacities and other restrictions.

The use of contraflow or reverse lanes was given little attention until after Hurricane Floyd in 1999 (Tibbetts, 2002). Since then, contraflow has been one of the most important traffic management strategies for evacuation operations. Transportation officials are responsible for contraflow operations as they have the best knowledge about existing road systems and traffic operations. Contraflow is effective as it increases the directional capacity of an evacuation route without further highway design or construction efforts. Nevertheless, setting up contraflow operations requires a certain amount of time: South Carolina requires two hours to place barricades and two hours to flush traffic (Harrelson, 2004); Alabama DOT requires approximately one hour to implement reverse-laning operations (Conner, 2006); and the state of North Carolina requires three to four hours (PBS&J, 2000). As of 2003, approximately 10 states have implemented contraflow or reverse-laning operations, with a focus on interstate highways (Urbina and Wolshon, 2009). The length of contraflow or reverse-laning operations varied from a few miles to nearly 200 miles.

Successes have been achieved through the implementation of contraflow or reverse lanes. Data from the Interstate 55 (I-55) contraflow segment showed a 40 percent increase in the 48-hour outbound volume between hurricanes Ivan (without contraflow operations) and Katrina (with contraflow operations) (Wolshon and McArdle, 2009). However, data from an I-10 contraflow segment in Louisiana showed that the maximum recorded traffic flows were somewhat lower than what would have been assumed (Wolshon and McArdle, 2009). In addition, without proper implementation of contraflow, the strategy will not have a positive impact on evacuations. The state of Louisiana used contraflow operations during Hurricane Ivan on a 12-mile segment of I-10 (Laska, 2004). The distance of the segment was limited due to state police concerns about the need for staff to close the exits. As a result, evacuees felt that "the short distance merely shifted the location of the major jams" and "it took residents up to 11 hours to go the distance usually traveled in less than 1.5."

Highway construction work zones may affect emergency evacuations by reducing traffic capacities. Highway work zones are an often-overlooked issue in evacuation planning and preparedness (Urbina and Wolshon, 2001). It was reported that during the evacuation for Hurricane Georges in 1998, the states of Alabama, Mississippi, and Louisiana all had construction work zones on evacuation routes. Only one lane was open to the evacuation traffic on westbound I-10 out of New Orleans. Fortunately, state DOT requested the construction contractor to clear equipment and open both of the partially constructed lanes to outbound traffic and the contractor acted quickly to minimize traffic delay. To reduce the impact of work zones on evacuation operations, it has been suggested that DOTs could have procedures in place to inform EMAs of construction plans and schedules (Wolshon, 2009). Based on the experience gained from Hurricane Floyd, some DOTs have been adding special provisions in construction contracts to accommodate evacuation traffic through work zones; clauses have been added to require a contractor to stop construction activities, clear equipment, and open all lanes once an evacuation is declared (Urbina and Wolshon, 2001).

Public transportation is potentially another useful element in rural transportation infrastructure for evacuations. Rural transit systems have facilities, personnel, and equipment to evacuate people with special needs. Transit agencies have the potential to play a role in each phase of emergency planning, including mitigation, preparedness, response, and recovery. The role of transit in an emergency evacuation is affected by many factors, including the characteristics of an emergency incident, the predisposition of the public, available resources, the characteristics of the transit system itself, etc. (TRB, 2008).

The Texas Disaster Act of 1975 and the Texas Emergency Management Plan include public transit systems that can be called into service during disasters. However, many local jurisdictions do not have a detailed plan for transit's role in emergency evacuations (Higgins et al., 2000). A study by the Federal Transit Administration (FTA) provided recommendations to assist in transit and emergency response organization personnel to evaluate their emergency response plans (Hathaway and Markos, 1991). The study also provided recommendations for the use of urban, rural, and specialized transit systems by the general public, elderly disabled persons, clients of human service agencies and so on.

In addition to the above infrastructure, implementation of regional evacuations requires a lot of other resources, both in rural and urban areas. In a Florida study, a variety of resources are listed to support evacuations (State of Florida, 2002):

- programmable electronic public information signs/displays;
- local/small area radio broadcast stations;
- wreckers, tow trucks, and other heavy equipment for clearing roadways;
- gasoline tankers for replenishing fuel supplies at gas stations on regional routes;
- shelters and supplies.

2.4 Traveler Information

Dissemination of evacuation-related information to the public is key to an effective evacuation. Emergency evacuations are unplanned events so evacuation-related information should be provided to the public as timely and accurately as possible. Before an evacuation, the public

needs to be notified and potential evacuees need to prepare for the event; during an evacuation, the evacuees need information about transportation, shelter, lodging, etc.; after an evacuation, evacuees need to know when safe reentry is possible (Wolshon, 2009).

Traveler information is important for providing guidance to evacuees. There are numerous tools that can be used to facilitate communication and information exchange. The following table shows tools that can be used for evacuations and they are divided into three categories: communication, traffic control, and weather and condition assessment tools. Different tools can be used depending upon the characteristics of the evacuation itself. Some of the tools are discussed in this subsection.

Table 2: Evacuation Information Exchange Tools

Communication	Traffic Control	Weather and Condition Assessment
Dial 511 Dial (reverse) 911 Loud Speakers Siren System Highway Advisory Radio Roadside Information Locations Dynamic Message Signs Newspapers Flyers Television\ Public Address Mailing List and Emails Cell phones	Portable Traffic Signal Ramp Meters Ramp Gates Traffic Signs Channelization Devices Temporary Pavement Markings Dynamic Message Signs Traffic Management Centers	National Weather Service *Clarus* Initiative (Established by the FHWA Road Weaher Management Program) Evacuation Traffic Information System (Developed by FHWA) Evacuation Travel Demand Forecoasting System Hazard U.S.-Multihazard (HAZUS-MH MR2) (Developed by FEMA)

During evacuations, Intelligent Transportation Systems (ITS) have been widely deployed to monitor roadways and disseminate real-time traveler information. The most commonly used systems include Dynamic Message Sign (DMS), Highway Advisory Radio (HAR), traffic sensors (to detect traffic volume and speed), traffic surveillance cameras, and traffic signal systems. Due to lack of utilities (or other supporting infrastructure) in rural areas, portable (or temporary) systems equipped with solar panels are usually utilized and placed at designated locations (Ishak et al., 2008). Although ITS systems could help make evacuations safer and more efficient, their usage is limited by expense (Wolshen, 2009). Studies have been conducted to develop low-cost ITS systems for evacuations. For example, a FHWA study was done to develop a low-cost surveillance system model that can be used to monitor rural evacuation routes, on which surveillance systems are not typically available due to low traffic volumes (Maxon Hill, 2005). Transportation system managers can better manage the road network and provide evacuees with better real-time information with such a low-cost system in place.

A variety of evacuation-related information can be obtained through the Internet. Evacuees may use the Internet to find information about evacuation routes, weather, lodging, etc. As noted by Wolshen (2009), nearly all DOTs and EMAs maintain websites to keep people informed of evacuation routes, road conditions, shelter availability, and weather information; some emergency management websites also provide links to hotels within and outside of their state to facilitate lodging reservations.

The 511 (America's traveler information number) service can provide information to the traveling public during emergency evacuations (Wilson-Goure, Houston and Easton, 2006). 511 is the single FCC (Federal Communications Commission) designated telephone number for use by states and local jurisdictions. This traveler information system has been widely used across the nation. As of July 2009, over 30 states have deployed 511 and more than 10 other states have received Federal assistance funding under the 511 Planning Assistance Program (http://www.fhwa.dot.gov/trafficinfo/511.htm). The 511 service provides weather information that ranges from a regional alert (e.g., hurricane) to a route-specific observation or alert (e.g., pavement conditions, low visibility). During emergency evacuation, 511 can be used together with other traveler information system (e.g., DMS) to increase its usage (call volumes) (Wilson-Goure, Houston and Easton, 2006).

In practice, different traveler information system technologies are used together to facilitate evacuations. The state of Alabama uses a combination of technologies including reversed direction signage, DMS, HAR, and the Alabama DOT web site for hurricane evacuations (Conner, 2006). The combination of technologies provides different ways of information dissemination to the public and facilitates evacuation operations in a safer and more efficient way.

2.5 Lessons Learned

Various lessons have been learned from previous evacuation events (e.g., wildfires, hurricanes, blackouts, terrorist attacks, and floods). Based on the project scope, this part of the review mainly included those lessons that are more related to the rural environment and evacuation events (e.g., hurricanes, floods) and that are more of concern in the North Gulf Coastal Region. Those lessons are summarized in the following table. The lessons learned from previous evacuation events could be useful for better planning for and responding to future events.

Table 3: Lessons Learned

Discussed Topics	Lessons (Reference)
Evacuation Planning	1) Coordinate evacuation plans that cross state lines (SAIC, 2003); 2) Use historic evacuation data for developing future evacuation plans (PBS&J, 2000); 3) Plan for the evacuation of those with special needs (Sill, 2003); and 4) Consider the emergency needs (e.g., drinking water, food, and gas) of both people and equipment (DeBlasio et al., 2004).
Training and Education	1) Conduct exercises and test evacuation plans (MIPT, 2002; Hulett, 1999); 2) Include public transit in the training exercises (MTI, 2002); 3) Educate the public on evacuation routes (Moller, 2004); 4) Provide better education to the public regarding their vulnerability (Dumont, 2000);
Coordination and Cooperation	1) Coordinate evacuation routes across jurisdictional boundaries (Sill, 2003; SAIC, 2003); 2) Develop better coordination between various agencies (PBS&J, 2000); 3) Develop mutual-aid agreements (Hulett, 1999); and 4) Develop strong interpersonal relationships with other agencies/entities (Buck et al., 2004);
Shelters	1) Locate shelter hubs appropriately (Carpender et al., 2006); and 2) Consider strategies to reduce demand for shelters near evacuation origins (Sill, 2003).
Work Zones	1) Coordinate current work zone activities (Sill, 2003); and 2) Plan for how to deal with construction along evacuation routes (Hulett, 1999).
Transit	1) Plan for the use of public transit to support evacuations (Jenkins, 2003); 2) Use public transit equipment for the response (Jenkins, 2003); and 3) Consider use of a bus system to provide transportation for special needs members of the community (Hulett, 1999).

Discussed Topics	Lessons (Reference)
Evacuation Management	1) Improve the efficiency of detecting, responding to, and clearing incidents on evacuation routes (Sill, 2003); 2) Develop the capacity of evacuation routes (PBS&J, 2000); 3) Efficiently utilize the available capacity to reduce the potential for operational failures during evacuation (Sill, 2003); 4) Improve management of the local streets that provide access to and from evacuation routes (Sill, 2003); 5) Identify conflicting needs and impediments (SAIC, 2003); 6) Modify evacuation routes as necessary (Sill, 2003); 7) Consider tow truck usage at key bottleneck locations along evacuation routes (Hulett, 1999); 8) Station tow trucks at strategic points so that accidents and broken-down vehicles can be quickly cleared (Moller, 2004); and 9) Ensure the efficient, safe, and secure reentry of the evacuees to their counties (Sill, 2003).
ITS Technologies	1) Consider ITS functionality that could be particularly useful during an emergency (DeBlasio, 2004); and 2) Use ITS technologies to provide information and assist in decision making (DeBlasio, 2004).
Communication	1) Develop convenient communication tools (PBS&J, 2000); 2) Ensure the ability to communicate (Carpender, 2006; Buck et al., 2004); 3) Ensure clear and accurate communication (Brown, 2004); 4) Provide lodging information (Morrow, 2002); and 5) Use multiple communications technologies and types (DeBlasio, 2004).
Public Health	(UMN, 2004): 1) Identify state and local public health (PH) capacities in rural areas; 2) Identify the expanded rural PH system for PH response; 3) Identify necessary competencies in rural PH response; 4) Model practices in rural PH response; and 5) Increase human and financial resources to build necessary infrastructure.

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