Emergency Communications for Evacuation (EVAC) in New Orleans Impact Assessment Report

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15. Supplementary Notes

Linda Dodge, Government Task Manager

16. Abstract

This document constitutes the Impact Assessment Report for Emergency Communications for Evacuation (EVAC) in New Orleans. Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) is a bundle of applications that targets the improvement of traffic safety and mobility during crashes and other emergencies that affect the highway network. A key R.E.S.C.U.M.E. focus is on traffic incident management and responder safety. Another is emergency communications for evacuation.

The R.E.S.C.U.M.E. bundle includes the following three applications:

1. Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)
2. Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
3. Emergency Communications for Evacuation (EVAC).

Areas of interest within the EVAC application include information on traffic and road conditions, location of available lodging, and location of fuel, food, water, cash machines, and other necessities for evacuees using their own mode of transportation and those for whom transportation services were provided. The EVAC application bundle employs mobile communications technologies. This document assesses the potential impacts of EVAC through simulation that uses a model of the Greater New Orleans region.

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Executive Summary

Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) is a bundle of applications that targets the improvement of traffic safety and mobility during crashes and other emergencies that affect the highway network. A key R.E.S.C.U.M.E. focus is on traffic incident management and responder safety. Another is emergency communications for evacuation.

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Areas of interest within the EVAC application include information on traffic and road conditions; the location of available lodging; and the location of fuel, food, water, cash machines, and other necessities for evacuees using their own mode of transportation and those for whom transportation services were provided, including tourists, carless residents, and persons with medical and other functional needs. The EVAC application employs mobile communications technologies to provide travelers with the information they need to make decisions that provide benefits to themselves and the system as a whole.

This document assesses the potential impacts of EVAC through the application of a simulation model of the Greater New Orleans region that represents the traffic processes that occurred during Hurricane Katrina in August 2005. This model was originally developed as part of a U.S. Department of Transportation (USDOT) project between years 2007 and 2009 (Wolshon et al., 2009). Later, as part of continuing research, the model was enhanced to include the region's Citizen Assisted Evacuation Plan (CAEP) that was developed and refined in the months and years following the Katrina event. As part of the R.E.S.C.U.M.E. assessment effort, the goal was to integrate the R.E.S.C.U.M.E. functionality into the TRansportation ANalysis and SIMulation System (TRANSIMS) to model and analyze the emergency transportation plan for the New Orleans metropolitan region, as if key aspects of this connected vehicle system had existed under the Katrina evacuation scenario.

The analysis performed for the current assessment of EVAC encompasses seven simulation scenarios including one baseline scenario and six strategy scenarios in which an EVAC functionality or a combination of functionalities were modeled. The strategy scenarios were compared to the baseline scenario to determine the benefit of the applied EVAC functionality. Each scenario was evaluated with three levels of EVAC penetration and compliance rates. This set of simulation runs provides a range of potential benefits to evaluate the overall effectiveness of the technology.

Based on the results of the modeling efforts, the EVAC functionalities that were evaluated showed positive impacts for several key aspects of hurricane evacuation.

[1] INC-ZONE and RESP-STG were assessed separately, using the US 101 San Mateo model. Those two applications were not part of this *Impact Assessment Report* and were addressed in a different document.

First, EVAC's capability to provide route guidance under normal and incident conditions had positive impacts on alleviating congestion. EVAC's information helped to reduce congestion by encouraging evacuees to use underutilized arterial routes, which alleviated the congestion on major freeway corridors.

Second, EVAC's functionality to provide pickup time and location options for special needs evacuees (i.e., transit services) demonstrated significant benefits related to improving mobility for transit-based evacuees. It significantly reduced the wait time (by over 90 percent for EVAC-equipped evacuees) for transit services, thus expediting the transit-based evacuation process. In the case of Hurricane Katrina, evacuees with additional mobility needs such as hospital patients were evacuated from the region prior to the two-day modeling horizon developed by previous efforts. As a result, these evacuees were not considered in this study.

Third, EVAC's functionality to assist evacuees in locating resources like fuel and lodging proved to have positive impacts. EVAC showed potential to reduce fuel-related breakdowns. In addition, EVAC's capability to provide lodging information and make reservations could significantly reduce lodging-seeking evacuees' travel time by relocating them to closer destinations.

In summary, EVAC functionalities such as route guidance, communications about transit services, and lodging and fueling assistance could be beneficial to evacuees in terms of reducing travel time and overall network congestion.

Chapter 1. Introduction and Background

1.1. Introduction

Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) is a bundle of applications that targets the improvement of traffic safety and mobility during crashes and other emergencies that affect the highway network. A key R.E.S.C.U.M.E. focus is on traffic incident management and responder safety. Another is emergency communications for evacuation.

The R.E.S.C.U.M.E. bundle includes the following three applications:

1. Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)
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Areas of interest within the EVAC application include information on traffic and road conditions; location of available lodging; and location of fuel, food, water, cash machines, and other necessities for evacuees using their own mode of transportation and those for whom transportation services were provided. The EVAC application employs mobile communications technologies to provide travelers with the information they need to make decisions that provide benefits to themselves and the system as a whole.

This document assesses the potential impacts of EVAC through the application of a simulation model of the Greater New Orleans region that represents the traffic processes that occurred during Hurricane Katrina in August 2005. This model was originally developed as part of the U.S. Department of Transportation (USDOT) Project No. FHWA BAA - DTFH61-06-R-00042 *Application of TRANSIMS for the Multimodal Microscale Simulation of the New Orleans Emergency Evacuation Plan*, completed between years 2007 and 2009 (Wolshon et al., 2009). Later, as part of continuing research, the model was enhanced to include the region's Citizen Assisted Evacuation Plan (CAEP) that was developed and refined in the months and years following the Katrina event. As part of the R.E.S.C.U.M.E. assessment effort, the goal was to integrate the R.E.S.C.U.M.E. functionality into the TRansportation ANalysis and SIMulation System (TRANSIMS) to model and analyze the emergency transportation plan for the New Orleans metropolitan region as if key aspects of this connected vehicle system had existed under the Katrina evacuation scenario.

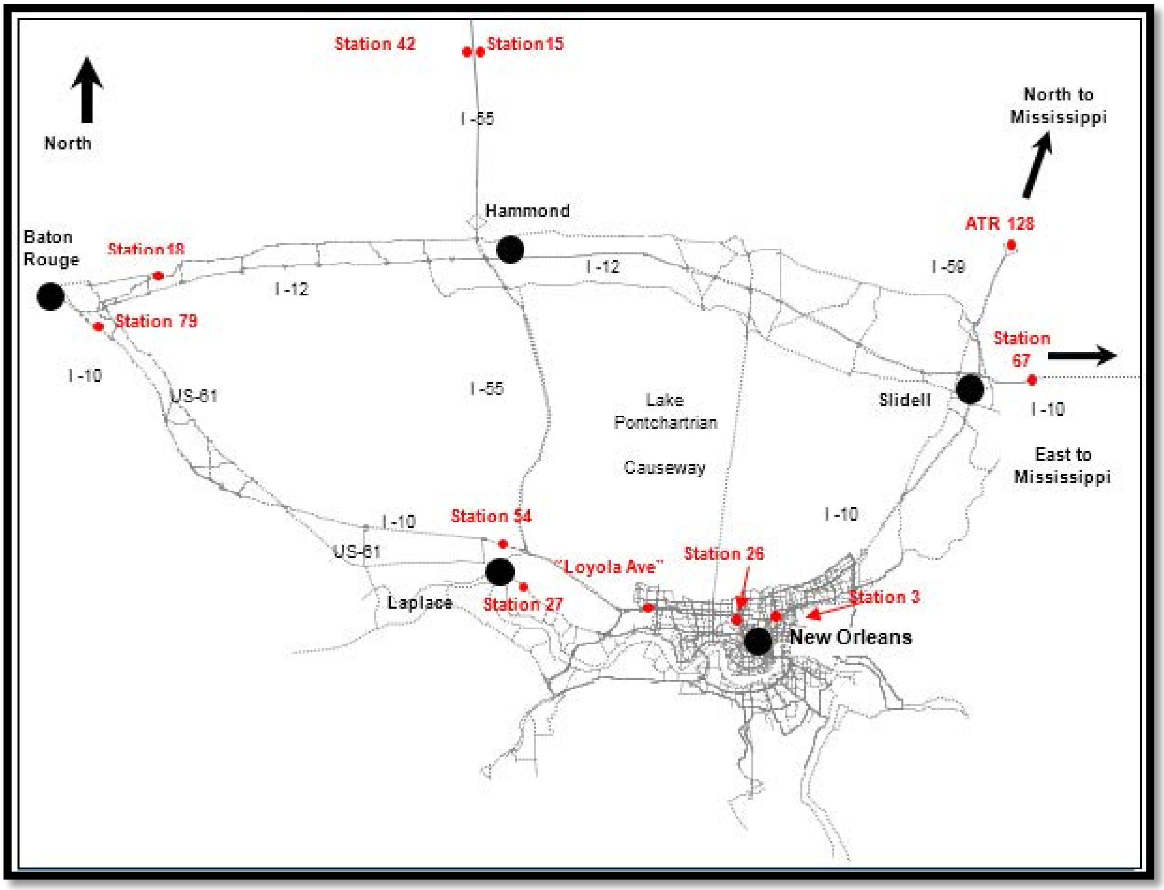
The original simulation of the New Orleans metropolitan area included several coastal parishes to the east and south of the city and sought to replicate the travel processes of the Katrina evacuation of

[2] INC-ZONE and RESP-STG were assessed separately, using the US 101 San Mateo model. Those two applications were not part of this *Impact Assessment Report* and are addressed in a different document.

August 2005. Most importantly, this “base model” was able to be validated against actual traffic counts collected during the Katrina evacuation (Dixit et al., 2011). This is the first and likely the only mass regional evacuation model to have been so validated. The base model included the area road network, population data from the 2000 Census, evacuation decision orders, and routing option hierarchy (including contraflow[3] and closures) that were in place during Hurricane Katrina.

Figure 1-1 shows the extent of the New Orleans regional analysis area as well as the approximate locations of the Louisiana Department of Transportation and Development traffic data collection stations from which actual traffic data was used to validate the model results. Although the map is not shown at a specific scale, the east-west distance is about 100 miles and the north-south distance is about 80 miles.

[3] Contraflow is a traffic management technique used in New Orleans (and planned for use in evacuations in many locations throughout the United States) in which flow in the inbound lanes is reversed to move traffic in the outbound direction, effectively creating an all-lanes, one-way-out operation (Wolshon 2001). This type of reversible traffic operation is widely regarded as a quick and highly cost-effective method to increase the directional capacity of an existing roadway because the under-used capacity in the minor-flow direction lanes can be used to serve traffic in the major-flow direction without the need to construct additional lanes (Wolshon and Lambert 2004).



Source: Wolshon et al., 2009

Figure 1-1. New Orleans Analysis Area and LA DOTD Traffic Data Collection Stations

This assessment addresses the potential impacts of EVAC on mobility and safety. In addition to a description of the assessment approach (Chapter 2), this document incorporates details about the analysis scenarios and the corresponding results (Chapter 3), the key findings and an assessment of the computed impacts of the EVAC functionalities (Chapter 4), and the references used as part of the study (Chapter 5).

1.2. The New Orleans Model

The assessment of the impacts of EVAC was carried out using the TRANSIMS software. TRANSIMS was initially developed at the Los Alamos National Laboratory (LANL) as part of the Federal Highway Administration (FHWA) Travel Model Improvement Program (TMIP) to replace traditional macroscopic transportation planning models with microscopic, activity-based, disaggregated demand models that are capable of modeling the complex stochastic and dynamic nature of transportation in a fine resolution. The software can generate a variety of detailed outputs such as vehicle trajectory and travel time and delay, in addition to conventional outputs such as speed, density, and volume. These outputs can be readily visualized in geospatial packages such as ArcGIS.

TRANSIMS is currently an open-source package maintained by David Roden of AECOM. With such capabilities, TRANSIMS has been demonstrated to be ideally suited for the purpose of wide-scale multimodal evacuation modeling (Naghawi, 2010) as demonstrated by the Chicago evacuation study (TRACC, 2011), and the Greater New Orleans evacuation study (Wolshon et al., 2009), the prototype basis for the current assessment.

The Greater New Orleans TRANSIMS model evolved out of early developmental efforts to assess the effects of contraflow from the New Orleans region, and progressed to answer questions related to clearance time, congestion locations and durations, and travel time during mass evacuations of the city. The model is unique because it is one of a few, if not the only, regional evacuation traffic model that has been validated and calibrated using actual mass evacuation traffic counts (Dixit et al., 2011). In later versions of the model, more detailed aspects of the area's evolving plan, such as the multimodal CAEP, and regional route closures were incorporated for study. The following are key features of the Greater New Orleans TRANSIMS model that were of relevance and importance to the R.E.S.C.U.M.E. assessment project:

- The model includes an auto-based evacuation.
- The model incorporates an assisted transit evacuation (CAEP).
- Evacuee departures were modeled based on observed traffic volumes from the Katrina evacuation.

Although the precise numbers have been debated, the commonly accepted population of the New Orleans metropolitan area at the time of the Katrina evacuation was 1.3 million people, with about 400,000 of that population living within the city limits. From census data, it has also been generally accepted that about 27 percent of the New Orleans population lacked access to personal transportation (Naghawi and Wolshon, 2010).

Based on these numbers, the CAEP estimated that 20,000 people would use public transportation services during an evacuation. Seventy percent of this total (i.e., 14,000 people) were expected to evacuate through the New Orleans Arena (NOA) on buses provided by the State of Louisiana. The remaining 6,000 evacuees were assumed to be senior citizens who would be evacuated by Amtrak trains through the Union Passenger Terminal (UPT) (Naghawi and Wolshon, 2010). These numbers were generally consistent with the level of utilization that was observed during the first, and only, operational implementation of the CAEP in advance of Hurricane Gustav in 2008.

1.3. Target Population Groups

The EVAC application addresses the differing information needs of individuals able to evacuate themselves and those requiring a certain level of assistance to facilitate a safe and efficient evacuation, as well as the emergency responders who must coordinate evacuation efforts.

For those able to use their own means of transportation, this application focuses on providing evacuees with a range of en-route information (current traffic and road conditions; location of available lodging; and location of fuel, food, water, cash machines, and other necessities) to assist in helping them evacuate as safely and efficiently as possible. The incorporation of en-route guidance has been suggested to be particularly useful during regional emergency evacuations because observation has shown that evacuees tend to favor (and over crowd) more-familiar and direct routes to shelter destinations, while virtually neglecting other adjacent high-capacity parallel routes. The importance of provisions for en-route vehicle services (such as fuel, repair, or towing) and personal care necessities (such as food, medical care, personal hygiene) also extend beyond convenience because they were recognized to contribute to the maintenance of stable and efficient traffic flow.

For those who need assistance, this application focuses on integrating information from existing databases to identify and locate people who were more likely to require guidance and evacuation assistance (e.g., people with special health care requirements), provide information to identify existing service providers and other available resources, and guide both of them more safely and efficiently through the network and changes of mode from their origins to their destinations.

The New Orleans CAEP provides a useful case study basis of analysis because it involves multiple modal changes between walking and buses, and involves carless residents, the elderly, infirm, and tourists. Specifics of the CAEP as well as descriptions of how it was originally modeled and how these models were used to make quantitative assessments of its operation are available in several publications (Naghawi and Wolshon, 2010; Naghawi, 2010; and Naghawi and Wolshon, 2015).

1.4. EVAC Functionalities

This section provides an overview of the planned functionalities for EVAC.[4]

1.4.1. Communications

The Communications function of the EVAC application receives provider-supplied data (i.e., input data) and then transmits the generated output data to its intended data consumer(s) quickly and securely, possibly via smartphone applications, websites, and roadside communication devices. This includes the processes required to exchange messages with the emergency operations centers (EOCs), traffic management centers (TMCs), functional needs evacuees, and non-functional needs evacuees. Such processes include data receipt, data transmission and termination, data de-confliction to mitigate repeat requests, error detection, and authentication and data validation. The EVAC Communications function should be able to integrate with existing mass warning and notification system data (either registered users and/or reverse 9-1-1-type information[5]) to maximize the number of users the EVAC system can reach within a jurisdiction.

1.4.2. Mobility Needs Assessment and Staging

The Mobility Needs Assessment and Staging function of the EVAC application provides information that can be used to determine the segments of the population that require assistance to evacuate themselves. This includes both persons with functional needs as well as persons without functional

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[4] Functionalities were extracted from the *R.E.S.C.U.M.E. EVAC Information Broker Framework Analysis Final Report*; Battelle; March 2015.

[5] Reverse 9-1-1 allows telephone notifications to be sent to residents and businesses within an area impacted or threatened by an emergency. The system uses 9-1-1 telephone databases and is therefore able to contact listed and unlisted landline telephones. http://www.sandiego.gov/ohs/emergencynotification/ Accessed 5 September 2014.

needs, but for whom there is an urgent mobility need as a result of the evacuation or subsequent incidents.

1.4.3. Shelter Matching

The Shelter Matching function provides an evacuee with a recommendation for which kind of shelter or shelters would best suit their needs, such as a standard shelter, a functional needs shelter, or a shelter that accepts pets. This information may also suggest hotels or motels as potential sheltering options. The evacuee goes to a website or uses a smart phone application to provide information, including name, current location, and number of people in their “group.” The website or application then prompts the evacuee to provide critical information such as whether they are evacuating with a pet, whether someone requires medical support, and the mode of transportation. Based upon this information as well as the prevailing travel conditions and predicted shelter loads, the evacuee is matched with a shelter and receives route and traffic information.

1.4.4. Dispatch and Routing

One purpose of the Dispatch and Routing function is to match assistance and transportation requests with the appropriate resource, dispatch the appropriate resource, and provide the resource with the most effective route to its destination given current road and traffic conditions.

1.4.5. Roadside Resource Identification

The Roadside Resource Identification function provides evacuees with information on resource locations and availability (as reported by other users; not necessarily validated information) including fuel, financial services (e.g., ATMs), food, and lodging along their evacuation route. Although the model does not assume that evacuees are accessing their smartphone while driving, the model assumes evacuees have access to the information regarding roadside resources through a smartphone application or another device that has an Internet connection. In addition, the assessment model only considers the results of having the information, but not the information transmission.

1.4.6. Evacuee Return Support

Recovering from an evacuation and returning the evacuees to a jurisdiction can be just as complex as the initial evacuation, depending on the extent of the damage. This function provides evacuees with information regarding when they can return to their area of the jurisdiction and recommended routes taking into consideration road conditions (e.g., roadway infrastructure and traffic lights).

While the descriptions of the EVAC functionalities, as detailed in the *EVAC Information Broker Analysis* document, can be implemented in real-world scenarios with some investment in technology and infrastructure, there are limitations with respect to the functionalities that could be modeled within a simulation environment. The next chapter details the scope of the EVAC assessment approach used in this study.

Chapter 2. EVAC Assessment Approach

This chapter summarizes the EVAC assessment approach and provides details on each of the seven modeling analysis scenarios. The chapter also describes the performance measures produced by the simulation model and how they were used to assess the impact of the EVAC functionalities.

2.1. Modeling Scenarios and Methods

Table 2-1 summarizes the EVAC functionalities and the combination of selected functionalities that were evaluated as part of the impact assessment plan (IAP), based on stakeholder input and the analysis scope. Since the information communications and the behaviors of evacuees upon receipt of information were outside the scope of this study, only the effectiveness of accepting recommendations from EVAC were modeled. This document refers to the combination of market penetration and compliance as the level of EVAC market penetration. In addition, the EVAC market penetration may be considered as the net effect of the EVAC information allowing potential communication failures.

In total, seven simulation scenarios were developed in this evaluation study. These included one base scenario and six additional strategy scenarios in which EVAC functionality or a combination of functionalities were modeled. The strategy scenarios were compared to the base scenario to determine the benefit of the applied EVAC functionality. Using this comparative design, it could be assumed that changes observed between the base scenario and any of the six test cases could be attributed to the addition of the EVAC functionality in combination with its market penetration. The sensitivity of the potential benefit of the EVAC functionality was examined by simulating it under three levels of EVAC market penetration, including 15 percent, 25 percent, and 50 percent. To eliminate the random noise in selecting EVAC-equipped evacuees, the EVAC-equipped evacuees in the 15-percent and 25-percent penetration scenarios were selected by sub-setting those in the 50-percent penetration scenario.

Table 2-1. Model Scenarios and Methods

Scenario Number	EVAC Functionality	Modeling Method
1	None	The baseline evacuation conditions used for quantifying the benefits of EVAC strategies. The baseline reflected the observed conditions during the Katrina evacuation.
2	Route information and guidance	TRANSIMS modeled traffic conditions associated with temporally and spatially staged evacuation orders and regional contraflow operations. The evacuees with EVAC had access to information about traffic conditions and were allowed to divert to a potentially under-utilized route. System performance was compared to the base scenario at pre-determined market penetration rates, which define the percentage of the evacuees that acted on the EVAC information.

Scenario Number	EVAC Functionality	Modeling Method
3	Route guidance with incidents and road closures	This scenario added an incident on I-10 that blocked a travel lane for one hour. Evacuees with EVAC were informed of the incident and location and allowed to re-route to minimize the impact of the incident-induced congestion to their evacuation trips. To quantify the full impact of this scenario, the baseline evacuation condition was re-run with the incident included. This provides an estimate of the impact of the incident on the overall system performance both with and without EVAC.
4	Location of available lodging and shelters	TRANSIMS modeled shelter and lodging facilities as a destination capacity constraint. Evacuees with EVAC were assumed to have access to information about available lodging and shelter before they departed or en route, and could reserve lodging and change their destination based on this information. Those evacuees without EVAC proceeded to their original destination. If unable to secure lodging at that location, they proceeded to the next destination along their evacuation route. They may have traveled extra distance during their evacuation trips due to failed attempt(s) to secure lodging or shelter and increased their travel time by stopping at each destination option to determine if space was available. EVAC effectiveness was measured as lodging and shelter demand and capacity ratio and average travel time.
5	Location of fuel, food, water, cash machines, and other necessities	TRANSIMS modeled fuel consumption for each vehicle and the fuel supply at gas stations along the evacuation routes. This EVAC strategy recommended a specific fueling location including commercial fueling stations and the government-designated fueling facilities along evacuation routes based on the vehicle’s location when the gas tank was one-quarter full. The fuel consumption of the evacuating vehicles were modeled based on elapsed travel duration and traffic conditions. Those evacuees without EVAC would stop at each fueling location along their route after gas tanks reach a quarter full until they found a location with available fuel or ran out of gas.
6	Provide pickup time and location options	The TRANSIMS model included feeder bus routes to centralized collection points that provide intercity coach service to external evacuation sites. Travelers minimize their walking, waiting, and in-vehicle travel time to the final destination given a pre-determined departure time from their home. The EVAC strategy provides travelers with a recommended departure time that will minimize their total travel time and reserves a seat on each bus along their route. Travelers without EVAC may need to wait for several bus runs to get an available seat.
7	Route information, lodging availability, fuel locations, and transit assistance strategies	TRANSIMS modeled all of the strategies at the same time to estimate any synergistic effect of these functionalities.

2.2. Performance Measures

Seven performance measures were developed as ways to quantify the objectives of the EVAC application—to decrease congestion, shorten the evacuation clearance time, and improve mobility. This section describes each of the performance measures in more detail.

The link performance and turning delay data for each 15-minute period during the 60-hour simulation served as the primary input to calculating changes in the performance measures attributable to a given scenario. The performance measures were generally produced by post-processing the input link performance and turning delay files.

2.2.1. Measures of Roadway Congestion and Travel Time Benefit

The link performance file generated by the TRANSIMS assignment included the number of vehicles (in passenger car equivalents) that occupied a link during each 15-minute period. This included vehicles that entered and exited within 15 minutes and those that traveled on some portion of the link during the 15-minute period of analysis. It also recorded the total vehicle kilometers traveled (VKT) and vehicle hours traveled (VHT) on the link during the period. These measures were used to describe the overall network conditions during the simulation period.

Several measures were employed to quantify the congestion level. The ratio of vehicle miles to vehicle hours determined the average speed on the link. Link length divided by average speed determined the loaded travel time. The travel time ratio was the loaded travel time divided by the free-flow travel time. In this study, “congested travel” was defined as a link-based travel time ratio of 2.0 or greater for a period of 15 minutes. Congested vehicle hours traveled were calculated based on the same definition. Similarly, congested vehicle kilometers were the VKT under congested condition. The difference between the loaded travel time and free-flow travel time was considered to be the delay. The vehicle hours of delay (VHD) summed the delay experienced by all the vehicles present on a link within a given 15-minute time period. The temporal extent of the congestion was measured by the percentage of hours during which each lane-mile of roadway experienced congested conditions. The measure was calculated by dividing the number of 15-minute periods of the simulation period when a given link in the network had a travel time ratio of 2.0 or greater by the total duration across the entire network during the entire simulation period. The potential congestion reduction benefit brought by EVAC deployment was shown in the decreased values of these measures in the EVAC scenario compared to those in the base scenario. As discussed in the next chapter, regular evacuees (those without EVAC) stayed on paths identical to those in the baseline scenario. Only EVAC-equipped evacuees traveled to different destinations. In some EVAC scenarios, evacuees did not change evacuation destinations. Therefore, these congestion-related performance measures describe the difference between the base scenario and the EVAC-enabled strategy scenario. If evacuees changed destinations due to EVAC information, these measures also served to quantify EVAC’s impact on congestion alleviation.

In addition to the congestion-related performance measures, the travel time differences between the base scenario and strategy scenario were computed for each evacuee and then aggregated by different evacuee group depending on EVAC availability.

2.2.2. Scenario-Specific Measures

Some additional measures were provided for four scenarios—the lodging scenario (Scenario 4), fuel scenario (Scenario 5), transit option scenario (Scenario 6), and multiple functionalities modeled (Scenario 7). A more direct measure was employed for the lodging scenario. This measure was the travel time to lodging facilities for lodging-seeking evacuees to replace the general travel time difference. In Scenario 5, the unfulfilled fueling demand was used to demonstrate EVAC's potential to reduce fuel-related breakdowns. Average wait time was added in Scenario 6 to provide a direct measure of mobility of transit-based evacuees. Table 2-2 summarizes the measures, their definitions, and the scenarios in which they were used.

Table 2-2. Summary of Performance Measures

Measure	Definition	Scenario
Vehicle Kilometers Traveled	Total distance in kilometers traveled by all vehicles	1, 2, 3, 4, 5, 6, 7
Vehicle Hours Traveled	Total travel time in hours traveled by all vehicles	1, 2, 3, 4, 5, 6, 7
Vehicle Hours of Delay	Total accumulated delay (difference between free-flow travel time and loaded travel time) for all vehicles	1, 2, 3, 4, 5, 6, 7
Congested Vehicle Kilometers	Total distance in kilometers traveled by all vehicles under congested conditions	1, 2, 3, 4, 5, 6, 7
Congested Vehicle Hours	Total time in hours traveled by all vehicles under congested conditions*	1, 2, 3, 4, 5, 6, 7
Percentage of Time Congested	The percentage of lane miles under congested conditions	1, 2, 3, 4, 5, 6, 7
Travel Time Differences	The difference of travel time between the base scenario and the strategy scenario	1, 2, 3, 5, 6, 7
Travel Time to Lodging Facilities	Travel time to lodging facility by a vehicle	4, 7
Unfulfilled Fueling Demand	Number of trips that fail to secure fuel	5, 7
Average wait time	Average wait time for transit vehicles for all transit-based evacuees	6, 7

** Congested travel was defined as a link-based travel time ratio of 2.0 or greater for a period of 15 minutes.*

2.3. Description of the Simulation Configurations for Each Scenario

2.3.1. Scenario 1: Baseline Scenario

The baseline scenario was constructed based on the New Orleans TRANSIMS model. The evacuation, resembling the one for Hurricane Katrina, was assumed to take place over a two-day period. Other important simulation configurations include the evacuee demographics, evacuation mode, evacuation departure time distribution, evacuation destination, and transit operations, which are described below.

2.3.1.1. Evacuee Demographics

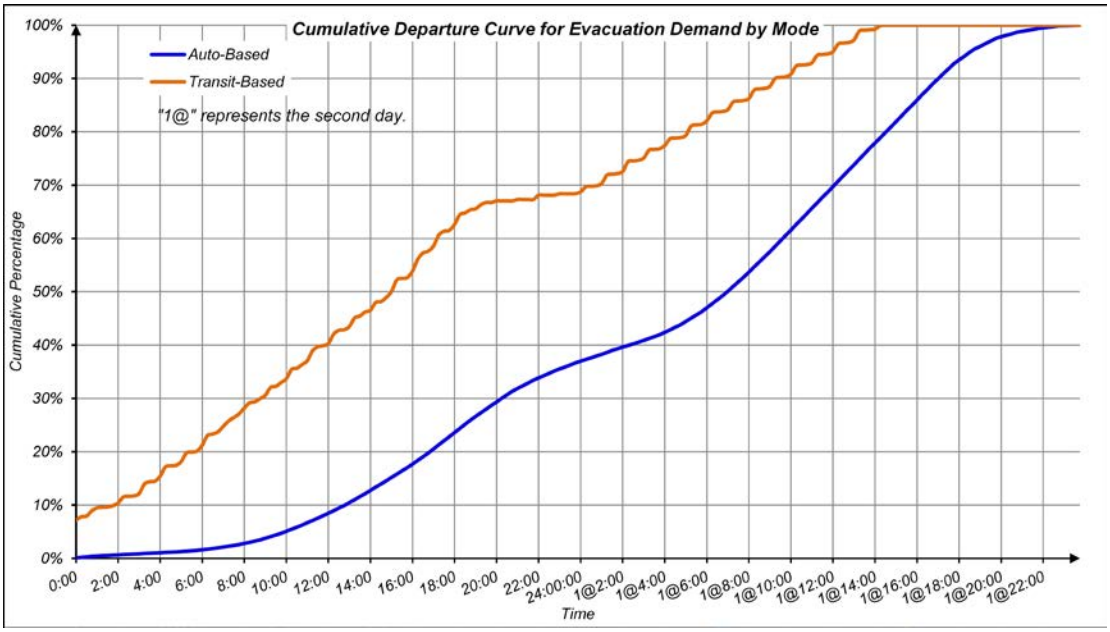
A total evacuating population of 997,813 persons living in 425,598 separate households was generated within the study region. Each household was assumed to use only one vehicle for evacuation if they rely upon their personal vehicles for evacuation. Although a100-percent evacuation participation is unlikely and has never been observed in prior events, such a rate was assumed in this project to account for a shadow evacuation in which voluntary evacuations occur outside of the designated evacuation zone and to assess conditions that could occur under the worst-case scenario event (Wolshon et al., 2009). In addition, 10,000 tourists were included in the evacuation demand. Hospital patients and persons living in various care facilities were not considered by the simulation model because their numbers and locations vary and an exact number of these individuals or the vehicles required to serve them could not be determined with reliable precision (Wolshon et al., 2009).

2.3.1.2. Evacuation Mode

Based on the evacuees' level of mobility, it was assumed that 96.1 percent of the evacuees would use their personal vehicles or ride with family and/or friends, which contributed to the auto-based evacuation demand. This translated into a total of 375,223 auto-based evacuation trips (Wolshon et al., 2009). Note that these evacuees also included those who did not own any vehicles and evacuated with their friends or family members. The picking-up trips were not modeled. The carless population and senior citizens, about 3.9 percent of the evacuees, were assumed to use transit services for evacuation. In particular, 6,000 senior citizens were assumed to evacuate the study area by AMTRAK trains from the UPT. A total of 10,000 tourists were also assumed to travel from the French Quarter area (a major tourist area) to the New Orleans airport and leave the region by plane. Other carless evacuees were assumed to use the pickup bus service to reach the processing centers and then board the external buses to leave the region. In total, there were 53,901 local evacuees who were assumed to use local bus services for evacuation in addition to the tourists. This group of evacuees was the main beneficiary of the pickup time and location information provided by EVAC. This service was modeled in Scenario 5.

2.3.1.3. Evacuation Departure Time Distribution

A double S-shaped departure curve, as shown in Figure 2-1, was used to assign departure times to both auto-based and transit-based evacuees (Wolshon et al., 2009). Similar to the method used by Wolshon et al. (2009) in prior modeling, evacuation destinations were assigned based on observed traffic data during the Hurricane Katrina evacuation.



Source: AECOM

Figure 2-1. Temporal Distribution of the Evacuation Demand

2.3.1.4. Evacuation Destination

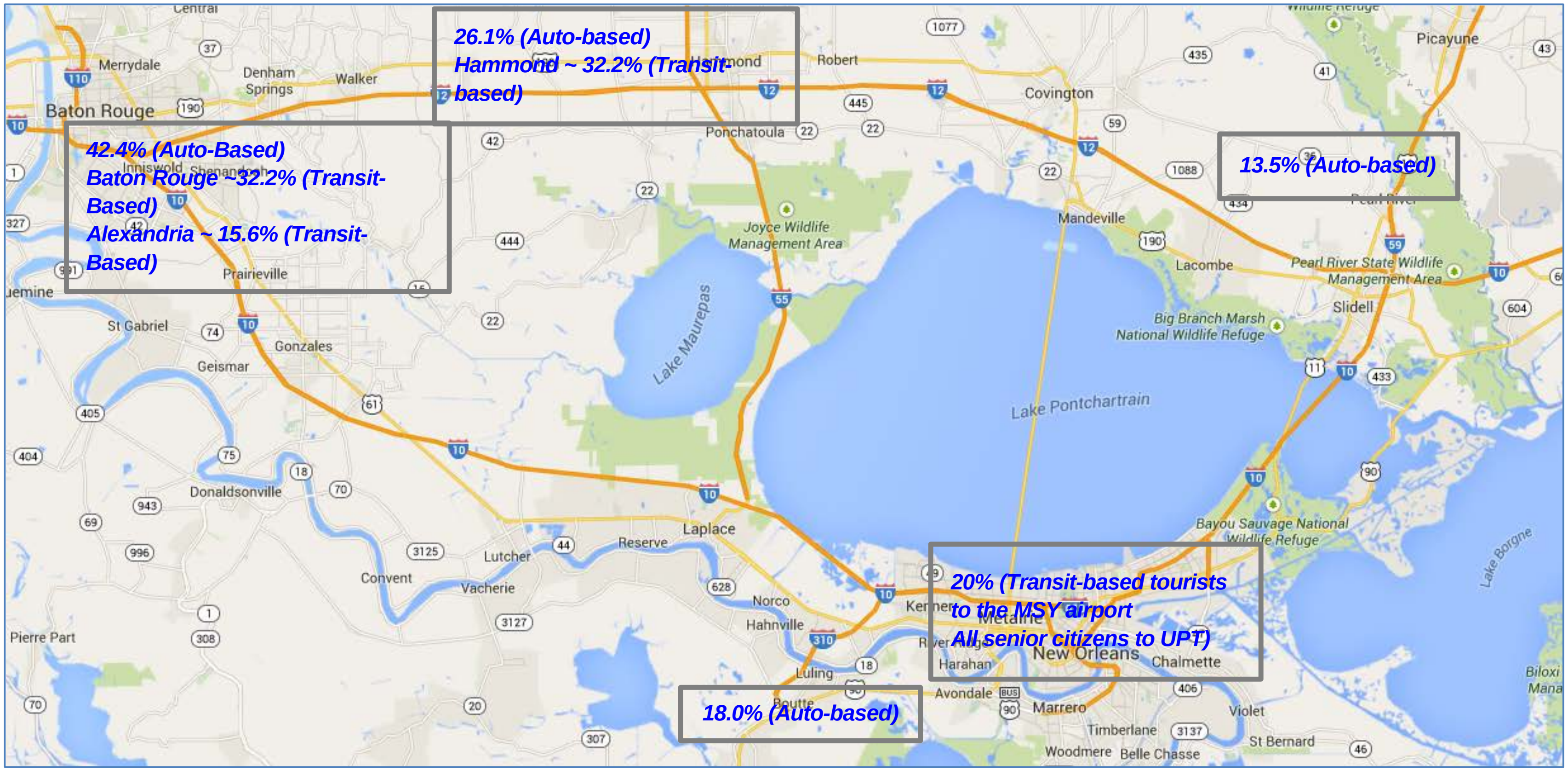
Figure 2-2 depicts the travel directions, estimated based on observed traffic data during Hurricane Katrina evacuation, by evacuation mode.

2.3.1.5. Transit Operations

The simulated transit operations represented the New Orleans 2007 CAEP and the Jefferson Parish Publicly Assisted Evacuation Plan, shown in Figure 2-3. The transit-based evacuees were assumed to walk to the 17 designated pickup locations in the City of New Orleans and 6 locations within the Jefferson Parish. Buses were assumed to operate between these pickup locations and the two processing centers for the City of New Orleans and two for the Jefferson Parish. Evacuees were then taken to their respective destinations by external transit routes that ran from the processing centers to the evacuation destinations. The headway for the external routes was 30 minutes and for the internal pickup routes ranged from 20 to 60 minutes. The following assumptions were made for the transit operations for simulation purposes (Wolshon et al. 2009):

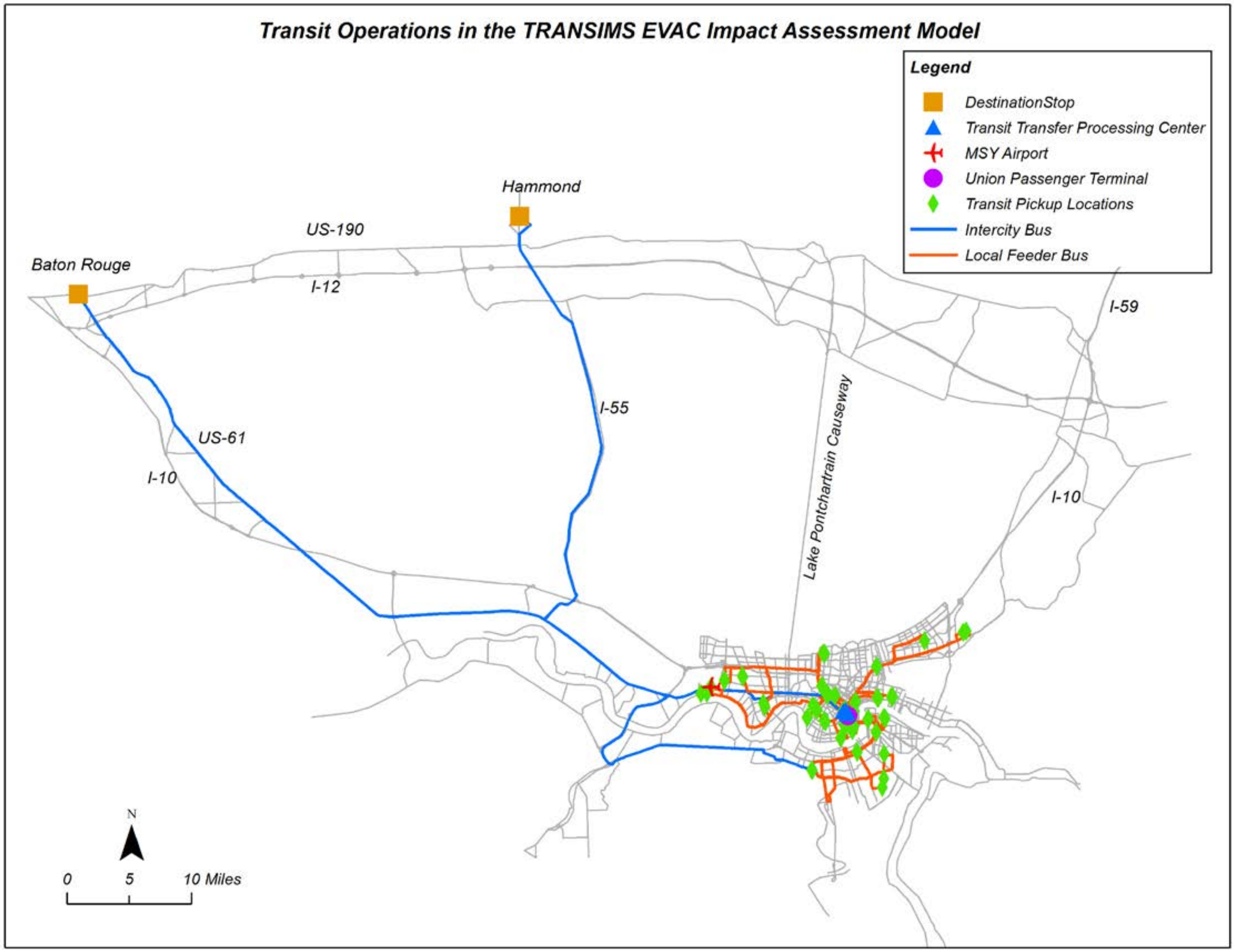
- Routes followed the shortest path.
- The bus routes would only stop at two locations, which were the pickup locations and the processing centers.
- No other Regional Transit Authority regular buses were assumed to operate. The train route was not considered because it would not affect the traffic conditions during evacuation.
- There was no specific evacuation bus lane.
- The maximum loading and unloading times were assumed to be 20 minutes.
- It was assumed that the external bus routes (intercity routes), operated by charter buses, would use US-61 (Wolshon et al., 2009).

The simulation of the baseline scenario assigned a path between the origin and the ultimate destination for each evacuee. This path served as the habitual evacuation path from which the evacuee might deviate due to receiving EVAC information.



Source: AECOM

Figure 2-2. Evacuee Travel Direction by Evacuation Mode



Source: AECOM

Figure 2-3. Simulated Transit Operations

2.3.1.6. *Modeling Lodging and Shelter in Baseline*

To model lodging and shelter, it was essential to know or assume the number of evacuees choosing hotels and shelters as their accommodation. Since the lodging and shelters were located outside of the model network, empirical data about their locations in terms of the distance from the external stations and capacity of the lodging and shelter facilities were obtained from publicly available economic census data. The baseline simulation can estimate the lodging demand and capacity ratio and average travel time to lodging, which were used as measures of effectiveness for comparison against strategy scenario simulation results to determine the benefit of EVAC.

2.3.1.7. *Modeling Vehicle Re-Fueling in Baseline*

A random distribution was used to assume the initial fuel quantity when evacuees embark on their evacuation trips. TRANSIMS was capable of estimating fuel consumption based on vehicle characteristics (car, truck, bus) and traffic conditions. Evacuees were assumed to begin seeking fuel when their tanks were one-quarter full. Fueling stations were designated at certain locations within the model network, and their supply level was monitored by TRANSIMS. If an evacuee stopped at a station that did not have any fuel, he/she would need to continue traveling and try the next stop. A 10-minute penalty was applied for the unsuccessful attempt to find fuel. The average time spent to obtain fuel was used to compare the baseline to the EVAC strategy scenario.

2.3.1.8. *Traffic Assignment Scheme*

Since evacuees only have limited knowledge of potential traffic patterns, possibly from past experience, the traffic pattern can never reach user equilibrium. As suggested by Wolshon (2009), evacuees tend to use familiar routes like major freeways and arterials. Therefore, 10 iterations of a dynamic user equilibrium (DUE) algorithm were executed to approximate these conditions. This assignment scheme allowed the major evacuation routes to carry the majority of the demand, while other possible parallel routes to evacuees were often underutilized. This assignment scheme was also used for the auto-based demand in all other strategy scenarios.

When EVAC information was available, the EVAC-equipped evacuees were allowed to change their behavior based on the received information in the strategy scenario. The regular evacuees continued to follow the paths generated in the corresponding baseline scenario.

2.3.2. Scenario 2: Baseline Travel Conditions with EVAC Route Information and Guidance

Table 2-3 summarizes the simulation configuration for Scenario 2. Scenario 2 inherited the network and demand configuration from the baseline scenario. EVAC-equipped evacuees were provided route guidance information that considered current and future travel conditions throughout the network to select a path that minimized the total travel time to their destination. This behavior was modeled by executing 10 additional DUE iterations for the subset of travelers that accept EVAC guidance. All non-EVAC travelers continue to follow the path identified in the baseline simulation.

In reality, this type of guidance information would be offered to them as a network congestion map or travel advisories. Because the routing of drivers on shortest-time path routes would not be compulsory under actual live conditions, their likelihood to follow the guidance is expected to vary. As a result, in addition to varying the rate of penetration of EVAC guidance within the driver population, the amount of evacuating drivers who would also heed the guidance and follow the optimized routing strategies was also varied. As described earlier, the combination of the overall EVAC penetration rate within the driver population multiplied by the percentage of evacuating drivers who would follow the guidance was established as the market penetration rate. This varied from 15 percent, 25 percent, and 50 percent in the various scenario trials.

Table 2-3. Simulation Configurations for Scenario 2

Simulation Configuration	Description
Network	Identical to the baseline network
Evacuation Demand	Mode, departure time distribution, destination, and transit operations were all identical to the baseline scenario
EVAC Market Penetration	15 percent, 25 percent, 50 percent
EVAC Equipment Assignment	Randomly assigned to evacuees based on market penetration rate
EVAC Information	Congestion level of all routes and suggestion of a faster route
EVAC Evacuee Behavior	Allowed to make route choice by switching away from congested routes
Non-EVAC Evacuee Behavior	Follow habitual paths
Additional Inputs	None
Additional Assumptions	Evacuees do not need to re-fuel their vehicles before they leave the model network to isolate the effect of this EVAC functionality
	Evacuees do not change their destinations by using EVAC's hotels and shelter information
Measures of Effectiveness	Vehicle distance traveled Vehicle hours of travel Vehicle hours of delay Congested vehicle distance Congested vehicle hours Percentage of time congested Travel time differences

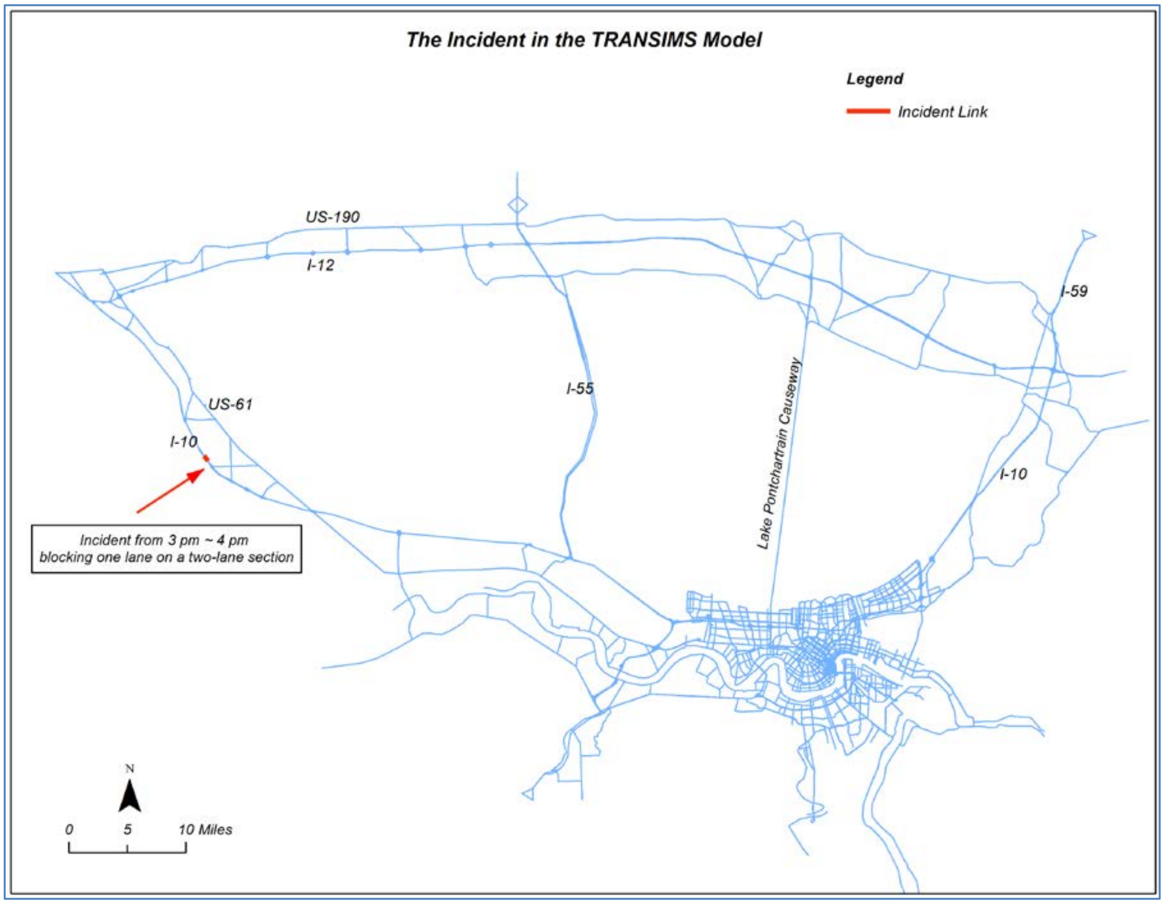
2.3.3. Scenario 3: Incidents and Road Closures Were Added to the Baseline Travel Conditions

Table 2-4 summarizes the simulation configuration for Scenario 3. Scenario 3 was identical to Scenario 2 in terms of the behavior of EVAC-equipped evacuees, but an incident was added to the network. This scenario assumed a traffic accident that blocks one lane on a two-lane section of westbound I-10 near State Route 30 between 3:00 pm to 5:00 pm on the first day of the evacuation. This location was on I-10, which is the most heavily used corridor and had an underutilized parallel route that EVAC could utilize.

Figure 2-4 shows the incident location that was modeled in TRANSIMS to represent a lane-use restriction. To gauge the full impact of the EVAC implementation, the baseline condition was re-run with the incident as well to compute the difference between the two scenarios.

Table 2-4. Simulation Configurations for Scenario 3

Simulation Configuration	Description
Network	Identical to the baseline network
Evacuation Demand	Mode, departure time distribution, destination and transit operations were all identical to baseline scenario
EVAC Market Penetration	15 percent, 25 percent, 50 percent
EVAC Equipped Travelers	Randomly assigned to evacuees based on market penetration rate
EVAC Information	Congestion level of all routes, incident location and severity, and suggestion of a faster route
EVAC Evacuee Behavior	Allowed to make en-route route choice by switching away from congested routes and/or the incident location
Non-EVAC Evacuee Behavior	Follow habitual paths
Additional Inputs	Incident location, duration, and severity
Additional Assumption	Evacuees do not need to re-fuel their vehicles before they leave the model network to isolate the effect of this EVAC functionality
	Evacuees do not change their destinations by using EVAC's hotels and shelter information
Measures of Effectiveness	Vehicle distance traveled Vehicle hours of travel Vehicle hours of delay Congested vehicle distance Congested vehicle hours Percentage of time congested Travel time differences



Source: AECOM

Figure 2-4. Location of the Simulated Incident

2.3.4. Scenario 4: Provide Lodging and Shelter Options

Scenario 4 was developed to evaluate the impact of using the EVAC system to provide support to evacuees in their attempt to find an accommodation location. In prior evacuations, it was observed that many evacuees had to make multiple stops at successive hotels and motels along freeway routes to find a vacancy. While the choice of a hotel or motel as a destination is not the most utilized accommodation option, when an evacuation involves a half million to one million evacuation trips, even 10 percent to 15 percent using such accommodations can significantly impact the characteristics of an evacuation process. Since only a small fraction of evacuees would use public shelters, they were not considered during the current phase of the impact assessment.

From a transportation and travel perspective, the impacts from having to stop and restart the evacuation journey to find hotel or motel accommodations include having to make multiple unneeded exits and entrance maneuvers from and to evacuation routes, which also adds travel time to the evacuation journey. From an evacuee perspective, these unnecessary starts and stops cause additional frustration and confusion among affected evacuees and can impact their safety both from the added amount of driving activities and, potentially, from exposure to the hurricane wind, rain, and surge hazards. It is envisioned that a system like EVAC can be used to provide accommodation availability and location information to evacuees while en route. This would save travel time, decrease frustration and fuel consumption, and increase safety by getting evacuees off the road and to a safe destination as quickly as possible.

Table 2-5 summarizes the primary assumptions used in the Scenario 4 trials, including the availability and location of accommodations.

Table 2-5. Simulation Configurations for Scenario 4

Simulation Configuration	Description
Network	The baseline network expanded with lodging locations in cities and towns along major freeways
Evacuation Demand	Mode, departure time distribution, and transit operations were all identical to the baseline scenario
EVAC Market Penetration	15 percent, 25 percent, 50 percent
EVAC Equipped Travelers	Randomly assigned to evacuees based on market penetration rate
EVAC Information	Locations of available lodging and shelter dynamically updated throughout the evacuation period
EVAC Evacuee Behavior	Select hotel based on shortest travel distance and reserve hotel rooms according to EVAC-provided lodging availability before departure
Non-EVAC Evacuee Behavior	Travel to evacuation direction identical to baseline. Make stop at each possible lodging location along the route
Additional Inputs	Percentage of evacuees going to shelter and hotel locations
	Approximate shelter and hotel capacity by distance
Additional Assumptions	Evacuees do not need to re-fuel their vehicles before they leave the model network to isolate the effect of this EVAC functionality
	The capacity of the hotels and shelters were dynamically updated
Measures of Effectiveness	Vehicle distance traveled Vehicle hours of travel Vehicle hours of delay Congested vehicle distance Congested vehicle hours Percentage of time congested Differences in travel time to lodging facilities

2.3.4.1. Network Expansion and Lodging Demand Generation

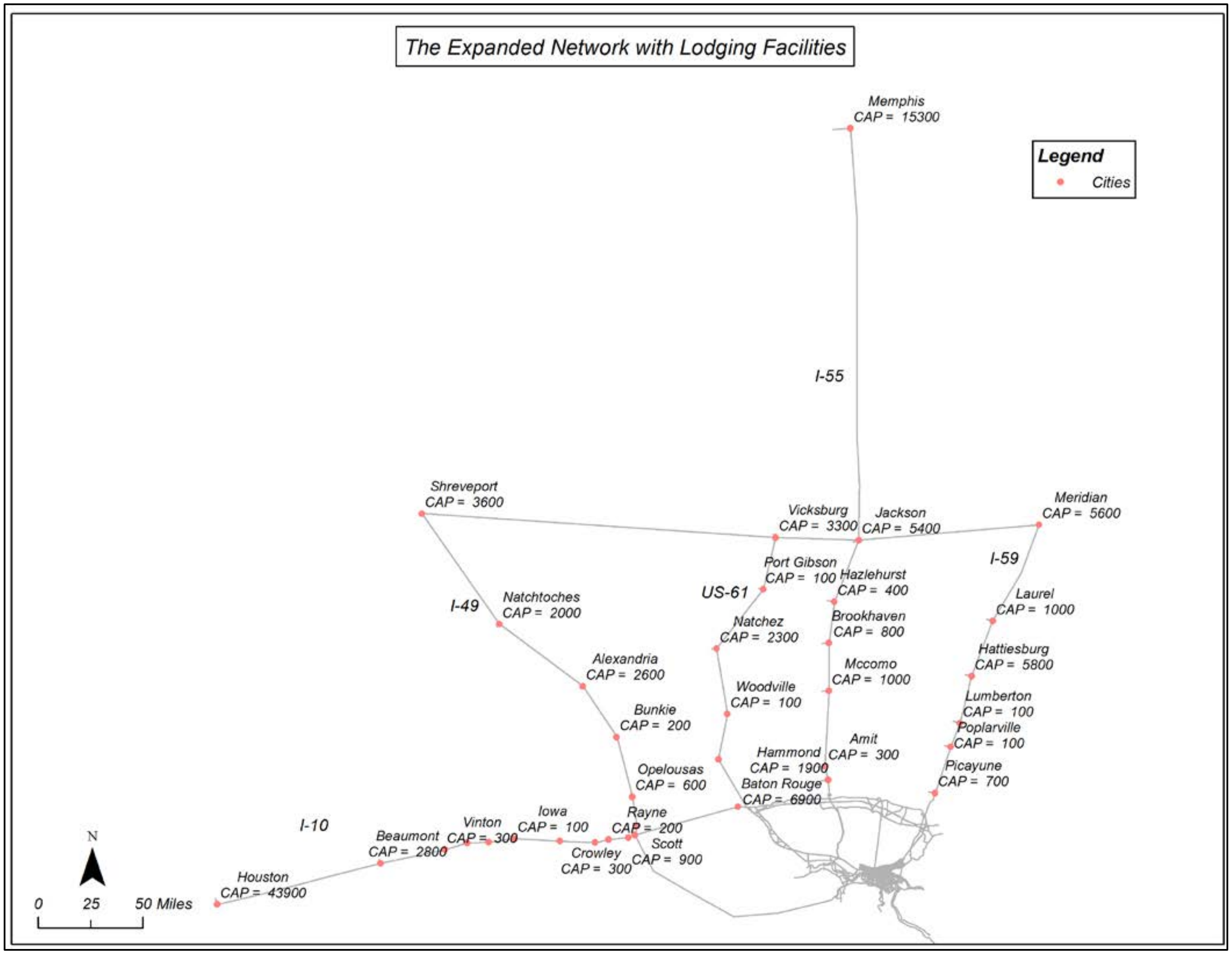
Since evacuees were assumed to clear the New Orleans study area before they sought lodging, the base study area network was expanded by about 400 miles to include the cities and towns with potential lodging destinations along the major freeway routes. Figure 2-5 shows the expanded network, incorporating cities and towns along freeways such as I-10, I-49, US-61, I-55, and I-59. In total, the expanded network reached Memphis, Tennessee, to the north and Houston, Texas, to the west.

The lodging capacity of each city was estimated based on publicly available data. First, the number of accommodation establishments including both hotels and motels within a jurisdiction was obtained from the Economic Census 2007. The average number of rooms per establishment was obtained from the American Hotel and Lodging Association. The hotel occupancy rates for June and July were obtained from the Louisiana Department of Culture Recreation and Tourism. The lodging capacity was then estimated as the product of these three metrics as shown in the following equation:

$$\text{Lodging Capacity} = \text{Number of Establishments} \times \text{Number of Rooms per Establishment} \times \text{Occupancy Rate}$$

EVAC-equipped evacuees were assumed to receive information about available lodging and were able to make reservations. The regular evacuees must find lodging by stopping at each city along their route and checking availability. If they fail to obtain rooms at a given location, a 15-minute penalty representing their lodging-seeking attempts was added to the travel time and their destination was re-assigned to the next city along the evacuation route. If the evacuation route was split into multiple route options, the travelers were randomly assigned to one of the options based on pre-defined split probabilities. These probabilities were loosely based on the total lodging capacity along the route.

Based on existing hurricane evacuation literature (Mesa-Arango, Hasan et al., 2013), it was assumed that 25 percent of the total auto-based evacuation demand would seek hotel accommodation. A random selection was used to identify the evacuees that needed hotel/motel lodging.



Source: AECOM

Figure 2-5. Expanded Network with Lodging Capacity

2.3.4.2. *Lodging Searching Algorithm*

With the lodging information provided by EVAC, EVAC-equipped evacuees selected the lodging location with available capacity that had the shortest travel distance. It was assumed that evacuees reserved a room either via EVAC communication interface or other smartphone applications before they started their evacuation travel. The algorithm scans all lodging destinations and checks available capacity at the time of day when the trip was scheduled to depart from the origin. It then selects the destination with available capacity that was closest to the origin. Straight-line distances were used, and the ultimate destination may be in a completely different direction than the original destination (i.e., the destination used in the baseline simulation).

Evacuees without EVAC followed their selected path to their pre-defined evacuation area exit point. They then continued to the first lodging location outside of the evacuation region accessible from their exit roadway. Each exit roadway included a chain of potential lodging locations, and it was assumed that evacuees would select the first available lodging destination. As such, evacuees were assumed to stop at each location in the lodging chain until they found available space. If the route included multiple branches, the evacuees made a random branch selection based on probabilities that represented the hotel capacity of each branch. This was assumed to represent the evacuees' general knowledge of lodging capacity. For example, an evacuee traveling along westbound I-10 needed to decide whether to divert to I-49 or continue on I-10. They made this decision based on the total lodging capacity of the two routes. Since the actual lodging capacity was not available, their decision was based on the initial lodging capacity. Hence, an evacuee was more likely to favor I-10 since it possesses more lodging capacity.

Each time the traveler failed to find lodging, the TRANSIMS path builder added a 15-minute intermediate stop activity, scheduled the next leg of the trip, and assigned the next destination. The new leg was added to the previous path to create a travel path with multiple intermediate stops and total trip statistics. The difference between the trip chain from the baseline assignment and the trip chain from the EVAC assignment was calculated for each traveler (EVAC and non-EVAC).

In most cases, the EVAC travelers had shorter travel times while some of the non-EVAC travelers had longer travel times. These longer travel times were a result of an EVAC traveler reserving a room that the non-EVAC traveler originally secured during the baseline simulation, but was no longer available during the EVAC simulation.

2.3.5. Scenario 5: Provide Location of Fuel, Food, Water, Cash Machines, and Other Necessities

The experiences of prior evacuations revealed that evacuees delayed by heavy traffic congestion were often caught on the road while experiencing the need for basic necessities like food, water, fuel, and restroom facilities. In areas where contraflow operations have been used, it was not possible to serve the needs of evacuees in reverse-flowing lanes because there were not enough traffic enforcement personnel to control the movement of exiting and re-entering vehicles from reverse flowing on and off ramps onto arterial streets. Based on these conditions, several states have been examining potential plans for providing certain service resources at rest areas and other critical interchange locations to keep people and traffic moving safely and efficiently.

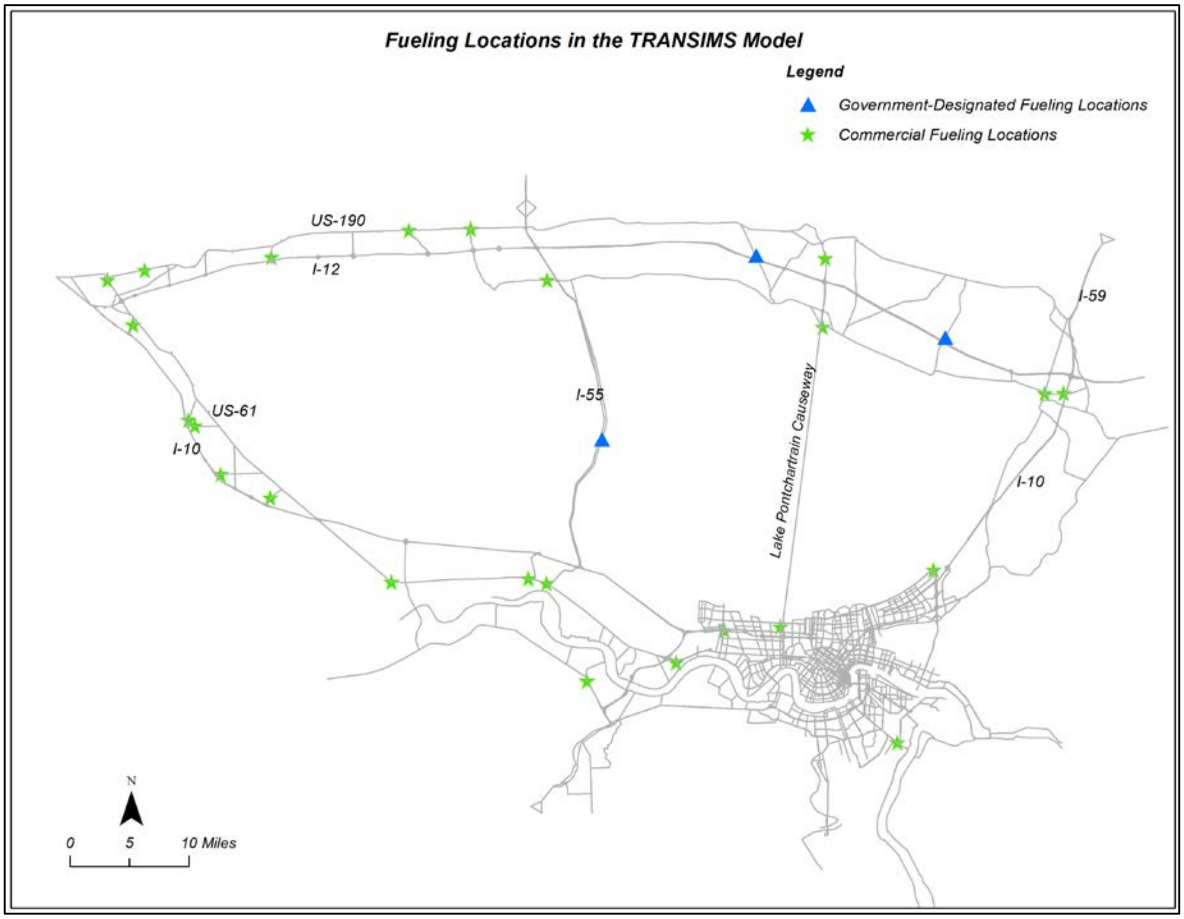
In Scenario 5, the focus of the analysis was on evaluating the impact of EVAC in guiding evacuees to these resources and assessing where they could best be located and how much capacity could be needed in an event the size of the Hurricane Katrina evacuation. Specifically, Scenario 5 examined vehicle re-fueling needs and processes. Table 2-6 summarizes the key assumptions, which are discussed in further detail in the following sections. Vehicle re-fueling was the primary consideration, although other necessities could be modeled in a similar fashion.

Table 2-6. Simulation Configurations for Scenario 5

Simulation Configuration	Description
Network	Identical to the baseline network with added fueling locations
Evacuation Demand	Mode, departure time distribution, destination, and transit operations were all identical to baseline scenario
EVAC Market Penetration	15 percent, 25 percent, 50 percent
EVAC Equipped Travelers	Randomly assigned to evacuees based on market penetration rate
EVAC Information	Available fuel at each fueling station
EVAC Evacuee Behavior	Go to the fueling station that EVAC recommends based on available fuel and distance
Non-EVAC Evacuee Behavior	Go to the nearest fueling station until the fuel was obtained. If an evacuee fails to obtain fuel before the tank empties, it was counted as a fulfillment failure and a travel time penalty was added to total travel time
Additional Inputs	Locations and supply level of commercial fueling stations and additional fueling stations during evacuation
Additional Assumption	Evacuees do not change their ultimate destination, but make intermediate stops along the path
Measures of Effectiveness	Number of fulfillment failures Vehicle distance traveled Vehicle hours of travel Vehicle hours of delay Congested vehicle distance Congested vehicle hours Percentage of time congested Travel time differences

2.3.5.1. Modeling Fueling Locations

To code the simulation model, the locations of commercial fueling stations were first identified using Google Maps. Commercial stations that were close to each other were aggregated into a single TRANSIMS activity location. Based on the examination of initial modeling results and discussion with stakeholders, some government-designated fueling supplies were added to the model in the strategy scenario. Figure 2-6 shows the activity locations with fuel supplies. The commercial fueling locations were near major freeway interchanges. One of the government-designated fuel supplies was placed on I-55 to prevent breakdowns on the lake. The initial supply of fuel at each location was based on the information from Steel Tank Institute (2012) that suggested that the general capacity of a commercial fueling station was about 40,000 gallons. This value was multiplied by the number of gas stations included in the aggregate location and divided by two to approximate the total amount of fuel available at the beginning of the simulation. It is assumed that a government-designated fueling facility has a supply of 50,000 gallons per location.



Source: AECOM

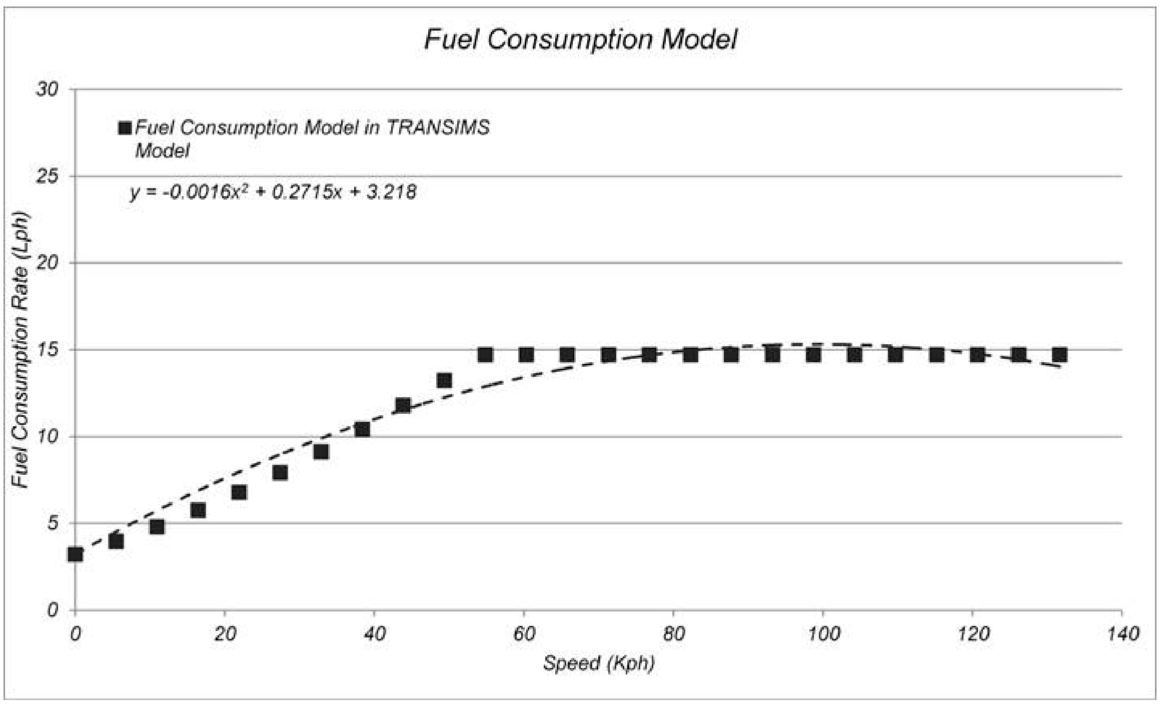
Figure 2-6. Fueling Locations in the TRANSIMS Model

2.3.5.2. Modeling Fuel Consumption

A vehicle fuel consumption rate based on vehicle speed was prepared for each vehicle type using the revised VT-Micro model (Ahn, 2002). The VT-Micro model relates the fuel consumption rate to instantaneous speed and acceleration. This model was simplified for this application to use the 15-minute link speeds generated by TRANSIMS to approximate the fuel consumption on each link along a traveler's path. The curves corresponding to multiple acceleration rates were integrated to best approximate the evacuation conditions by using a polynomial curve-fitting technique. For this work, the equation was specified as:

$$\boldsymbol{f = -0.0016 \times s^2 + 0.2715 \times s + 3.218} \quad \textbf{Equation 1}$$

where *s* is in kilometers per hour (kph) and *f* is in liters per hour (L/hr). This equation generated a consumption rate that ranges between 3 miles per gallon and 21 miles per gallon. This assumption was thought to be reasonable based on the wide variety of traffic conditions that would be expected during an evacuation though vehicle type was not explicitly considered. Figure 2-7 shows the polynomial curve.



Source: AECOM

Figure 2-7. Fuel Consumption Model

In the simulation, each traveler was randomly assigned an initial fuel level between half a tank and a full tank of gasoline. The model assumed that evacuees would begin seeking fuel when their tank was one-quarter full. The algorithm reduced the vehicle fuel supply using the consumption model shown in Figure 2-7, and the current travel time of each link along their path. The travel time was set based on the time of day that a vehicle entered the link and the overall link volume over a 15-minute period. If the remaining supply of fuel in the vehicle dropped below the one-quarter level, the TRANSIMS path builder reconfigured the trip to include an intermediate stop at the closest fueling location along their current travel path. The stop location was selected based on minimizing the sum of three distance values including:

1. The distance from the fueling location to the trip destination
2. Twice the distance from the current link to the fueling location
3. Twice the distance from the fueling location and the closest node along the travel path to the destination.

This logic was designed to select a location that was reasonably close to the current position and along the path toward the destination, but not behind the current position or beyond the destination.

Once selected, a new path was constructed from the current location to the fueling location and then from the fueling location to the final destination. A 10-minute activity duration was added at the fueling location to either re-fuel the vehicle or fail to re-fuel the vehicle. If the vehicle failed to re-fuel, the algorithm searched for the next available location along the new path between the current fueling location and the final destination. This continued until a vehicle acquired fuel or ran out of gas. If the traveler ran out of gas, they were flagged as a fuel problem and pulled off the road without blocking traffic.

2.3.5.3. EVAC Fuel Consumption

The primary difference between an EVAC-equipped vehicle and a regular evacuee was that the EVAC travelers had a priori knowledge if the fueling location had available fuel before they were routed to that location. This would help evacuees avoid failed attempts to find fuel and minimize the overall travel time and path circuity. If the algorithm determined that the EVAC traveler was likely to run out of gas before reaching a fueling location with available fuel, the EVAC traveler was sent to a fueling location earlier in their trip or before the trip began (i.e., initially assigned a full tank).

2.3.6. Scenario 6: Provide Pickup Time and Location Options

Although the New Orleans CAEP that was used for the first time during Hurricane Gustav in 2008 was generally considered to be effective and successful, there has been discussion of various ways in which it could potentially be improved. Among these ideas were ways to find locations that would decrease walking distances to bus pickup points and to shorten waiting times for these evacuees once they reached these locations.

The goal of Scenario 6 was to examine the effect of EVAC on the evacuation process if evacuees were provided information that would permit them to select departure times that would minimize their waiting time at pickup points and reduce the likelihood of overcrowded transit vehicles. Table 2-7 summarizes the primary assumptions used in the simulation configuration for Scenario 6, which are discussed in additional detail in the sections that follow. The primary goal of this scenario was to reschedule a traveler’s start time to minimize waiting time at pickup points and crowded transit vehicles.

Table 2-7. Simulation Configurations for Scenario 6

Simulation Configuration	Description
Network	Identical to the baseline network
Evacuation Demand	Mode, departure time distribution, destination, and transit operations were all identical to baseline scenario
EVAC Market Penetration	15 percent, 25 percent, 50 percent
EVAC Equipped Travelers	Randomly assigned to evacuees based on market penetration rate
EVAC Information	Pickup locations and time of arrival of the buses
EVAC Evacuee Behavior	Transit-based evacuees will adjust their departure time from home to minimize the wait time. Each individual evacuee can also reserve a seat on the bus
Non-EVAC Evacuee Behavior	Transit-based evacuees will depart their homes early to ensure that they do not miss the buses. They may also find that the bus was full and they need to wait for the next bus
Additional Inputs	Transit routes, pickup points, and schedules
Additional Assumptions	Evacuees do not change their ultimate evacuation destination
	Pickup and intercity bus schedules were fixed
Measures of Effectiveness	Average wait time for buses Average travel time to destination

The standard TRANSIMS router was used to build a transit path between the trip's origin and destination based on the scheduled start time of the trip and the transit schedules of each route. The simulation assumed that an evacuee walked from the residence of origin to a local pickup location, waited for the next bus, traveled to the central distribution locations, then waited for the next available intercity coach heading to the evacuation shelter destination. If there were more travelers waiting at a bus stop than the bus could accommodate in the simulation, a time penalty was added to the stop to discourage travelers from selecting that stop at that time. The transit trips were re-built multiple times until the time penalty stabilizes between iterations.

The time penalty was calculated based on the seating capacity and maximum load of the bus. In the simulation, the local pickup routes were assumed to have 40 seats and a maximum load of 50 passengers. Intercity coaches were assumed to have 60 seats and a maximum load of 60 passengers. In other words, 10 people could stand on a pickup route, but everyone needed a seat on an intercity coach. If the demand for a bus at any given time of day exceeds the maximum load, the traveler had to wait for the next bus to board.

2.3.6.1. EVAC Transit Assistance

The primary difference between an EVAC-equipped evacuee and a regular transit evacuee was that the EVAC travelers knew when to leave home to minimize their travel time and could reserve a seat on each bus on their trip. The algorithm used in the analysis examined each transit access point along the trip to identify opportunities to minimize waiting time by coordinating arrival times and transfers more effectively. If the trip did not require a transfer, EVAC would adjust the trip earlier or later to minimize the difference between the original start time and the bus schedule. The time required to walk to the bus stop was considered along with an optional minimum wait time parameter that could be used to provide a reasonable cushion. If the trip required a transfer, the algorithm searched various combinations of earlier and later start runs of both buses to find the combination that minimizes the transfer waiting time. It then rescheduled the trip departure time to reach the first bus at the appropriate time.

Since EVAC travelers could reserve seats on buses, they were not subject to the transit penalty. However, the fact that they were able to reserve seats had the potential to increase the travel time for non-EVAC equipped evacuees.

2.3.7. Scenario 7: A Combination of Route Information and Guidance, Location of Available Lodging and Shelter, Location of Fuel, and Pickup Time and Location Options

Scenario 7 was developed to examine the effect of implementing multiple EVAC strategies simultaneously. The idea was to estimate synergistic benefits of implementing multiple EVAC strategies at the same time. Table 2-8 lists the primary assumptions in these simulations.

Table 2-8. Simulation Configurations for Scenario 7

Simulation Configuration	Description
Network	Identical to the baseline network
Evacuation Demand	Mode, departure time distribution, and transit operations were all identical to baseline scenario
EVAC Market Penetration	15 percent, 25 percent, 50 percent
EVAC Equipped Travelers	Randomly assigned to evacuees based on market penetration rate
EVAC Information	Congestion level of all routes
	The locations of available lodging and shelter
	Available fuel at each fueling station
	Pickup locations and time of arrival of the buses
EVAC Evacuee Behavior	Follow EVAC's shelter/hotel recommendation
	Switch to a faster route that EVAC recommends
	Use EVAC recommended fueling locations
	Transit-based evacuees will adjust their departure time from home to minimize the wait time
Non-EVAC Evacuee Behavior	Travel to original destination plus all lodging options if needed
	Will not change path based on congestion information
	Will stop at each fueling location until they can fill their tank
	Transit-based evacuees do not change their start time
Additional Inputs	Fueling locations and supply levels
	Percentage of evacuees going to shelters and those going to hotels
	Approximate shelter and hotel capacity by distance

Simulation Configuration	Description
Additional Assumption	If EVAC algorithms recommend inconsistent responses, the responses with lodging and fuel options have priority
Measures of Effectiveness	Vehicle distance traveled Vehicle hours of travel Vehicle hours of delay Congested vehicle distance Congested vehicle hours Percentage of time congested Number of fulfillment failures Average wait time for buses

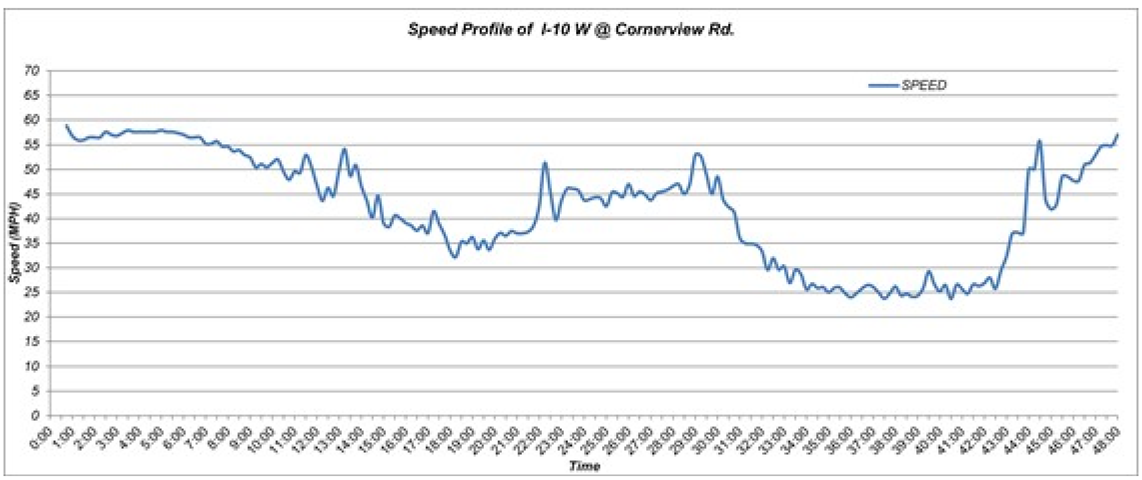
Chapter 3. Analysis and Results

This chapter presents the modeling analyses and their corresponding results. Combined, the results demonstrate the impact of an EVAC deployment during a regional mass with-notice evacuation event. The results are compared to the baseline Hurricane Katrina evacuation scenario to demonstrate the changes in system performance once the EVAC functionality is added.

3.1. Scenario 1: Baseline Scenario (i.e., the Katrina Scenario without EVAC)

3.1.1. Modeling Results

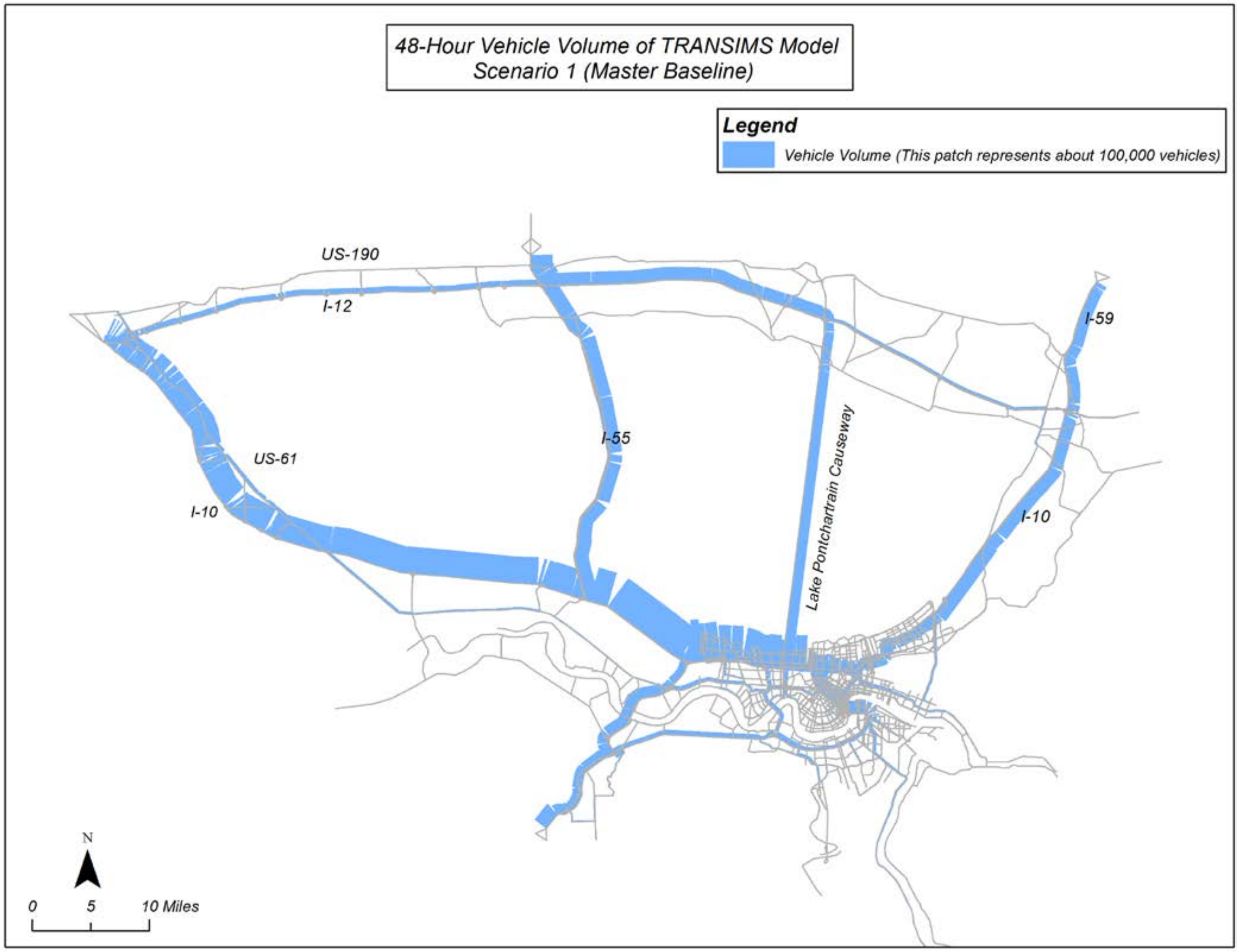
Scenario 1 was the master baseline case. As past experience has illustrated, freeways and other major arterial roadways are typically the routes that carry the most evacuation traffic volume and, correspondingly, also experience the highest levels of travel delay and traffic congestion during an evacuation. To illustrate the effect of various aspects of the EVAC functionality on the key regional evacuation routes during these scenarios, the performance measurement and analyses focused on these routes. Figure 3-1 shows the speed profile of a TRANSIMS link from westbound I-10 near Cornerview Road. As shown in the figure, congestion was heaviest during the afternoon of the second day (Sunday) of the evacuation. The simulated speed averages around 25 mph from about 11:00 am through 6:00 pm during that day.



Source: AECOM

Figure 3-1. Speed Profile on I-10 W in Baseline Scenario

Figure 3-2 shows the 48-hour vehicle volume distribution of the master baseline scenario. The evacuating traffic was concentrated on freeways. The width of the line segments in the figure is proportional to the total traffic volume carried during the evacuation. Specifically, I-10 W carried about 120,000 vehicles, I-55 carried about 66,000 vehicles, and the I-59 corridor carried about 60,000 vehicles. The figure also shows that I-10 carried a considerably higher volume of evacuation traffic than the parallel arterial US-61. This result is consistent with observed traffic patterns as well as with the results of prior modeling.



Source: AECOM

Figure 3-2. Volume Distribution for Scenario 1 (Baseline Scenario)

3.2. Scenario 2: EVAC Route Information and Guidance under No-Incident Condition

3.2.1. Modeling Results

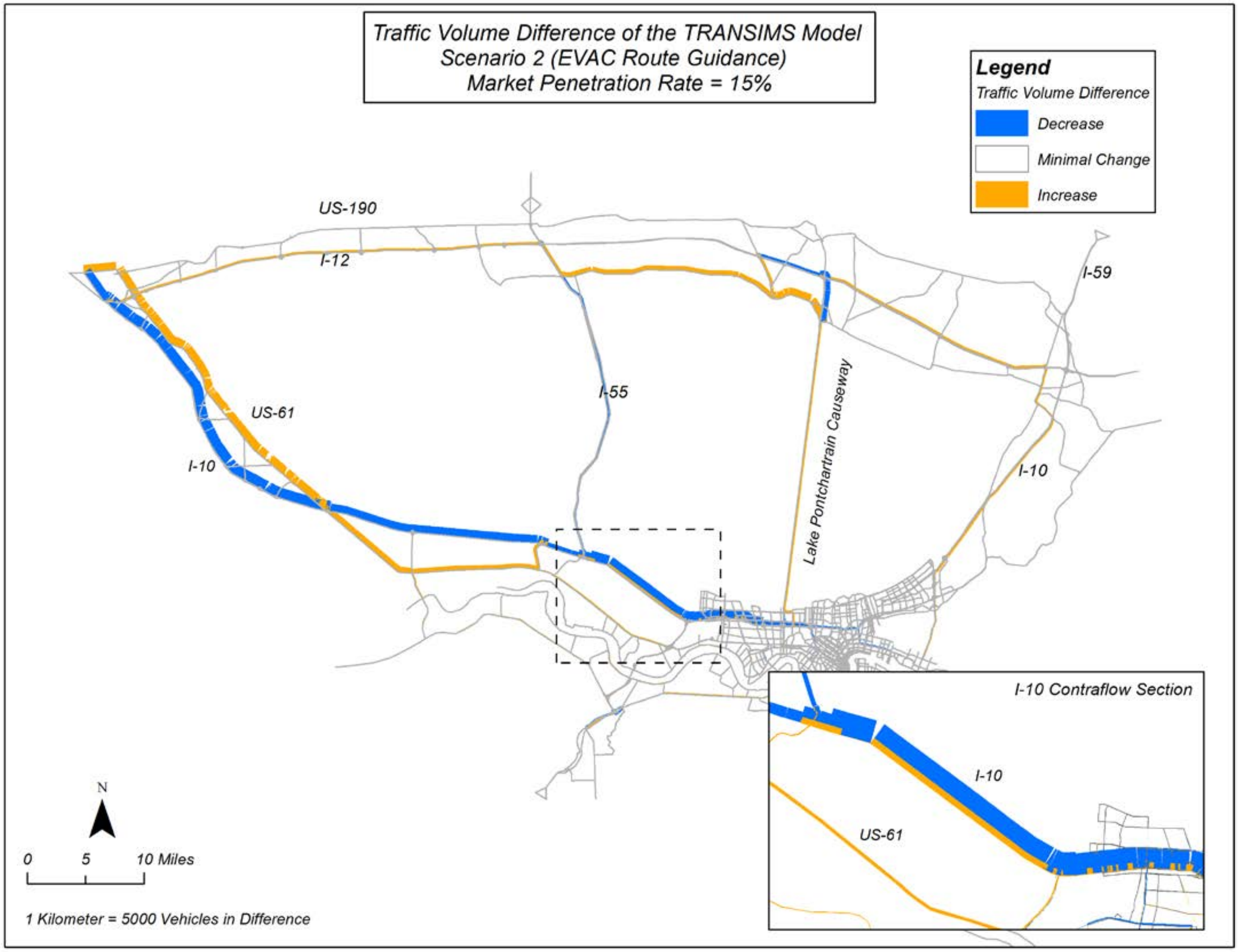
Table 3-1 summarizes the congestion performance measures for Scenario 2 in comparison to the baseline scenario (Scenario 1). Comparative results for the performance indicators are shown in both absolute numerical change as well as the percentage of change from the baseline scenario at the three different levels of EVAC market penetration. The total vehicle hours traveled by all evacuees decreased by about 3 percent at the expense of a slightly higher total vehicle distance traveled, which increased by about 1 percent over the no-EVAC baseline. This was due to the diversion of evacuees to longer, although more traditionally underutilized, routes, which offer travel time savings because they carry less volume and experience correspondingly lower congestion. The congested vehicle distance traveled, congested vehicle hours traveled, and percentage of time congested also showed significant reductions, indicating a net benefit from the EVAC information.

Table 3-1. Congestion Performance Measures for Scenario 2

Performance Measure	Baseline Total	15% Market Penetration		25% Market Penetration		50% Market Penetration	
		Abs. Change	Percent Change	Abs. Change	Percent Change	Abs. Change	Percent Change
Vehicle Kilometers of Travel	39,981,990	156,327	0.4%	219,103	0.5%	223,833	0.6%
Vehicle Hours of Travel	612,910	(18,449)	-3%	(20,782)	-3%	(22,927)	-4%
Vehicle Hours of Delay	197,420	(20,647)	-10%	(23,556)	-12%	(25,735)	-13%
Congested Vehicle Kilometers	6,449,246	(1,689,990)	-26%	(1,966,218)	-30%	(2,194,993)	-34%
Congested Vehicle Hours	177,556	(44,596)	-25%	(51,544)	-29%	(57,770)	-33%
Percentage of Time Congested	25%	-5%	-20%	-6%	-24%	-7%	-28%

Figure 3-3 shows the traffic volume difference between the with-EVAC and the without-EVAC cases. There was a substantial decrease in outbound traffic volume on westbound I-10 and increases in volume on several other outbound evacuation routes, most notably westbound on US-61 and northbound on the Lake Pontchartrain Causeway. These changes would be expected because, historically, non-freeway routes have been underutilized by evacuees as compared to the more familiar freeway routes like I-10. As a result, these alternate routes have excess capacity, which was more effectively utilized by the route guidance capability of EVAC.

Outbound evacuation volume was also shifted from westbound I-10 to the contraflow* lanes of this route. Although the contraflow lanes were available in both the EVAC and the non-EVAC cases, prior observation has shown that the contraflow lanes were underutilized in the non-EVAC base case because of various physical and knowledge constraints. In the EVAC case, EVAC users knew about these lanes and how to get on them, so they were used more efficiently. The zoomed inset frame of Figure 3-3 shows the traffic volume difference on the I-10 contraflow segment with EVAC guidance.



Source: AECOM

Figure 3-3. Vehicle Volume Difference for Scenario 2 (EVAC Route Guidance) with 15-Percent Market Penetration

Table 3-2. Travel Time Impacts for Scenario 2

	15% Market Penetration			25% Market Penetration			50% Market Penetration		
	EVAC-Equipped	Regular	All Evacuees	EVAC-Equipped	Regular	All Evacuees	EVAC-Equipped	Regular	All Evacuees
Number of Evacuees	56,175	319,048	375,223	93,687	281,536	375,223	187,664	187,559	375,223
Lower Bound of the 85-Percentile Travel Time Difference Interval (min.)	(49)	(20)	(20)	(40)	(29)	(20)	(30)	(29)	(29)
Higher Bound of the 85-Percentile Travel Time Difference Interval (min.)	0.0	9.2	9.1	9.0	9.4	9.3	9.2	9.4	9.3
Average Travel Time Difference (min.)	(10.0)	(2.5)	(3.6)	(8.8)	(3.7)	(5.0)	(6.4)	(3.8)	(5.1)
Total Travel Time Difference (hrs)	(9,356)	(13,151)	(22,507)	(13,712)	(17,439)	(21,881)	(19,920)	(11,933)	(31,853)

3.2.2. EVAC Deployment Impact

Table 3-2 shows the travel time impact of the EVAC deployment. The travel time benefit for all the evacuees exhibited an increasing trend from 3.6 minutes to 5.1 minutes. In addition, the travel time benefit for the 25-percent penetration rate was very close to that for the 50-percent penetration rate. The decreased marginal benefit from 25-percent to 50-percent penetration rate is possibly because as more evacuees have information, the evacuees could not gain the travel time benefit by switching routes.

A decreasing trend in travel time savings was exhibited among the EVAC-equipped evacuees with the increasing market penetration. Travel time difference between the base scenario and strategy scenario was computed for each evacuee. Two travel time difference values were identified to formulate the 85th percentile interval. The lower bound of the interval is the value below which the 7.5 percent of the travel time differences lie and the upper bound is the one above which 7.5 percent of the travel time differences lie. Therefore, the 85th percentile interval encompassed the travel time differences experienced by 85 percent of the evacuees. The size of the interval for the three different market penetration rates was generally comparable.

The effectiveness of EVAC's route guidance functionality was demonstrated by the reduction in network-wide congestion and individual travel times. The trend in the congestion performance measures and the travel time impacts suggested that a higher market penetration rate led to a small increase in both the congestion-relief benefit and the travel time savings. It is assumed that this resulted from the fact that the majority of the evacuees prefer freeways and a relatively small amount of evacuees diverting to other routes could already have reduced the congestion on main freeway corridors.

3.3. Scenario 3: Incidents and Road Closures Added to Scenario 2

3.3.1. Modeling Results

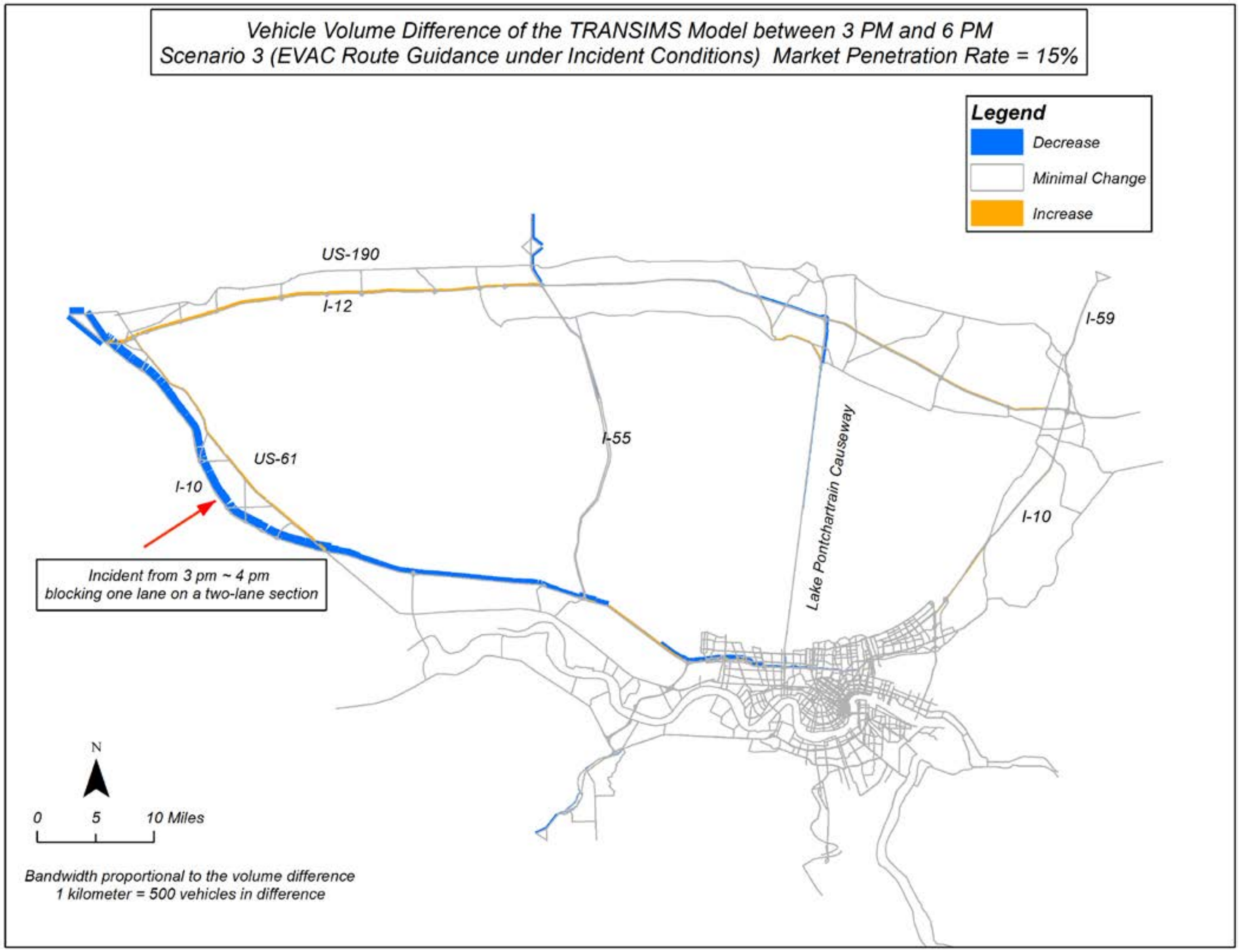
Scenario 3 was used to demonstrate the effect of EVAC functionality during incident and route closure conditions. To complete the Scenario 3 analyses, a separate baseline scenario needed to be modeled to reflect equivalent incident situations without EVAC information. This baseline was derived from the master baseline (Scenario 1) by introducing an incident while keeping all travelers on paths obtained in the baseline case. Table 3-3 comparatively summarizes the performance measures for Scenario 3 under these conditions. The congestion reduction benefit for the 50-percent market penetration rate was not as large as those for the 15-percent and 25-percent penetration rates, which indicates that more EVAC users decrease this benefit, although it should not be considered as a reason to discourage deployment. In fact, the 50-percent re-routing sends too many travelers to a "better" path, and that path becomes overloaded to the point of increasing the travel time for many travelers. This could be resolved through an algorithm within EVAC that anticipates the number of people likely to respond to the EVAC message and estimates the impact on the alternate route. The algorithm would then adjust the number of EVAC vehicles provided with the information to balance the flows more effectively.

Table 3-3. Congestion Performance Measures for Scenario 3

Performance Measure	Baseline Total	15% Market Penetration		25% Market Penetration		50% Market Penetration	
		Abs. Change	Percent Change	Abs. Change	Percent Change	Abs. Change	Percent Change
Vehicle Kilometers of Travel	39,982,478	54,955	0.1%	219,283	0.5%	23,502	0.1%
Vehicle Hours of Travel	613,648	(8,575)	-1.4%	(21,289)	-3.5%	(1,403)	-0.2%
Vehicle Hours of Delay	198,192	(9,720)	-4.9%	(24,125)	-12.2%	(2,132)	-1.1%
Congested Vehicle Kilometers	6,537,418	(1,299,722)	-19.9%	(2,327,688)	-35.6%	(920,814)	-14.1%
Congested Vehicle Hours	179,772	(29,163)	-16.2%	(59,011)	-32.8%	(16,197)	-9.0%
Percentage of Time Congested	25.0%	-4.0%	-16.0%	-7.0%	-28.0%	-2.0%	-8.0%

The effect of the incident was evidenced by the increased levels of congestion within the network. The vehicle hours of travel, vehicle hours of delay, congested vehicle kilometers, and congested vehicle hours in the baseline of Scenario 3 were all uniformly higher than their counterpart measurements of the master baseline (Scenario 1) shown previously in Table 3-1.

Figure 3-4 illustrates the traffic volume difference between the with-EVAC and the without-EVAC cases after the incident, which was present from 3:00 pm until 4:00 pm. As expected, the amount of diverting traffic was considerably less than that for the entire simulation period. Similar to Scenario 2, evacuees also diverted from I-10 to the underutilized US-61 and Lake Pontchartrain Bridge during the regular congestion and the incident-induced congestion conditions.



Source: AECOM

Figure 3-4. Traffic Volume Difference for Scenario 3 (EVAC Route Guidance under Incident Conditions) with 15-Percent Market Penetration

Table 3-4. Travel Time Impacts for Scenario 3

	15% Market Penetration			25% Market Penetration			50% Market Penetration		
	EVAC-Equipped	Regular	All Evacuees	EVAC-Equipped	Regular	All Evacuees	EVAC-Equipped	Regular	All Evacuees
Number of Evacuees	*56,175*	*319,048*	*375,223*	*93,687*	*281,536*	*375,223*	*187,664*	*187,559*	*375,223*
Lower Bound of the 85-Percentile Travel Time Difference Interval (min.)	*(59)*	*(30)*	*(30)*	*(40)*	*(29)*	*(30)*	*(20)*	*(19)*	*(20)*
Higher Bound of the 85-Percentile Travel Time Difference Interval (min.)	*19.0*	*29.2*	*29.1*	*9.2*	*9*	*9.4*	*9.5*	*9.5*	*9.5*
Average Travel Time Difference (min.)	*(8.7)*	*(2.0)*	*(3.0)*	*(8.8)*	*(3.7)*	*(5.0)*	*(3.4)*	*(1.5)*	*(2.4)*
Total Travel Time Difference (hrs)	*(8,184)*	*(10,638)*	*(18,822)*	*(13,742)*	*(17,521)*	*(31,263)*	*(10,482)*	*(4,604)*	*(15,086)*

3.3.2. EVAC Deployment Impact

Table 3-4 shows the travel time impacts for the EVAC deployment in Scenario 3. The travel time benefit for all the evacuees was highest, 5 minutes, at a 25-percent market penetration rate. When the market penetration rate reached 50 percent, the travel time benefit was 2.4 minutes, which was even lower than that in the 15-percent market penetration rate. A decreasing trend in travel time savings was exhibited among the EVAC-equipped evacuees with the increasing market penetration. The size of the 85th percentile interval for the three different market penetration rates showed a decreasing trend as the market penetration rate increased from 15 percent to 50 percent.

EVAC's route guidance capability under incident conditions reduced network-wide congestion and decreased individual evacuee travel time. The benefit for the 50-percent market penetration rate was smaller than that in the other two scenarios with a lower penetration rate. This trend in the travel time measures is similar to that exhibited in the congestion performance measures. This suggests that the EVAC benefit diminishes when there are many users, although this is not a reason to limit the EVAC deployment.

3.4. Scenario 4: EVAC Assistance in Locating Lodging and Shelter Options

3.4.1. Modeling Results

The modeling results of efforts to assess EVAC lodging and shelter guidance were compared based on two sets of performance measures. The first set of measures used the same general congestion-related measures as in Scenarios 2 and 3, which show the effects of EVAC's assistance in locating lodging on re-distributing the evacuation traffic and the subsequent change in congestion. The other set focuses on the lodging-seeking evacuees by examining their travel time differences between the baseline scenario and the with-EVAC strategy scenario. This comparison was used to assess EVAC's ability to assist evacuees with locating lodging. Table 3-5 summarizes the congestion performance measures. Note that these measures relate to the expanded network.

Table 3-5. Congestion Performance Measures for Scenario 4

Performance Measures	Baseline Total	15% Market Penetration		25% Market Penetration		50% Market Penetration	
		Abs. Change	Percent Change	Abs. Change	Percent Change	Abs. Change	Percent Change
Vehicle Kilometers of Travel	70,254,154	(4,371,046)	-6.2%	(5,322,397)	-7.6%	(4,736,803)	-6.7%
Vehicle Hours of Travel	878,491	(59,511)	-6.8%	(71,096)	-8.1%	(115,462)	-13%
Vehicle Hours of Delay	188,107	(19,692)	-10%	(22,488)	-12%	(72,033)	-38%

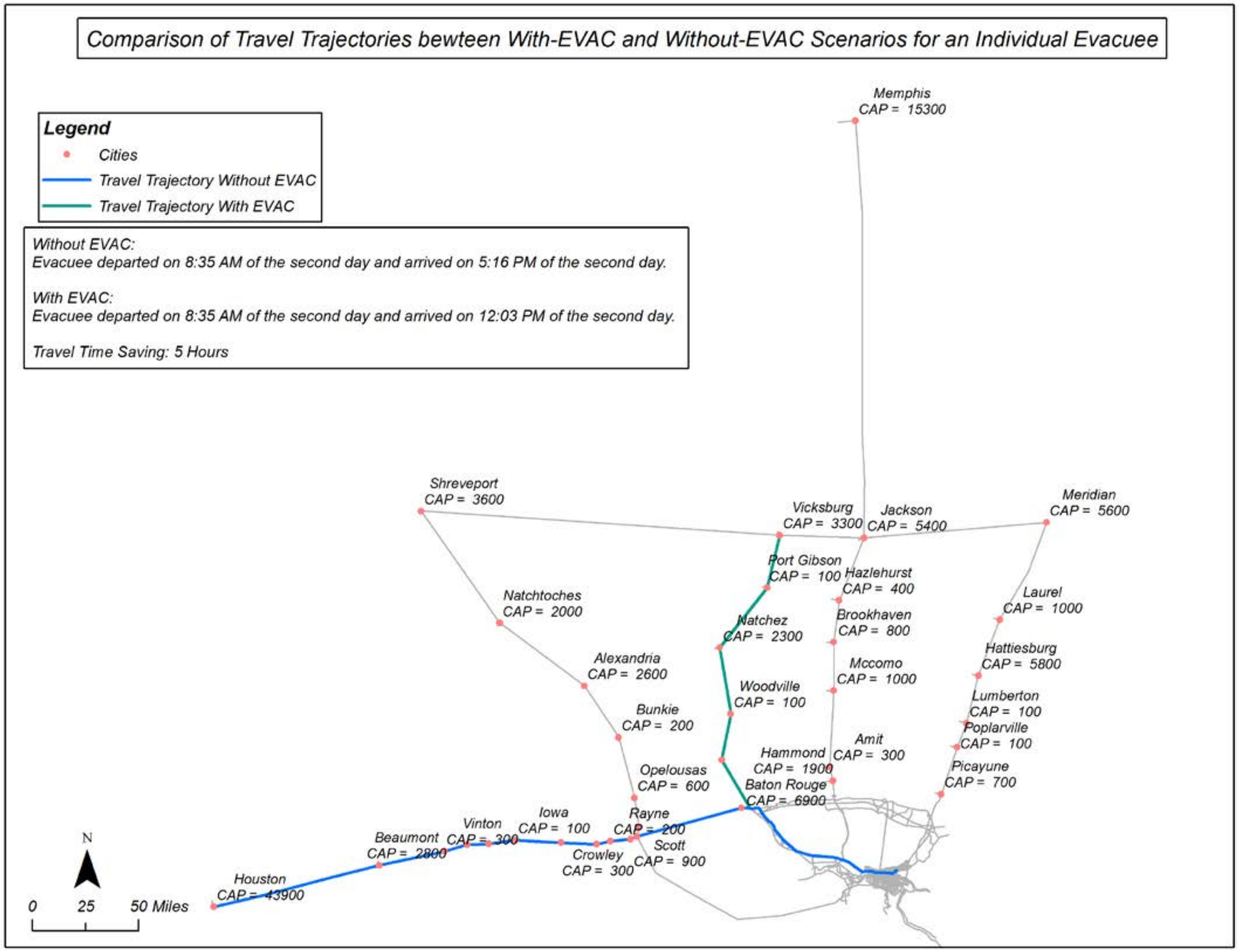
Performance Measures	Baseline Total	15% Market Penetration		25% Market Penetration		50% Market Penetration	
		Abs. Change	Percent Change	Abs. Change	Percent Change	Abs. Change	Percent Change
Congested Vehicle Kilometers	2,939,629	(748,459)	-25%	(955,756)	-33%	(1,284,497)	-44%
Congested Vehicle Hours	49,653	(20,090)	-40%	(25,811)	-52%	(26,754)	-54%
Percentage of Time Congested	12%	-3.0%	-25%	-4.0%	-33%	-5.0%	-42%

In the baseline of this scenario, the vehicle distance traveled was significantly higher than that of the master baseline (Scenario 1) because the lodging-seeking evacuees need to travel to distant lodging facilities. The total vehicle distance traveled by all evacuees decreased by 6 to 7 percent for the three market penetration scenarios. This was most likely because EVAC-equipped evacuees were able to use the lodging availability information and the reservation capability to significantly reduce their travel distance and travel time to a lodging facility. The change in the vehicle distance traveled was relatively stable across the market penetration rates, but the hours of travel, delay, and congested distance decreased substantially with higher market penetration rates. This suggests a wider distribution of lodging locations that ultimately improved overall travel time, but had minimal impact on the total distance traveled by all evacuees.

Figure 3-5 shows an example illustration of the destination-finding capability in the model. In this case, evacuees were able to achieve a travel time saving of nearly 5 hours by arranging for hotel or motel lodging in Vicksburg, MS, rather than traveling all the way to Houston, TX. The congested vehicle distance traveled, vehicle hours traveled, and percentage of time congested all showed significant reductions for all three market penetration rates. The higher penetration rate also led to a reduction in congestion measures.

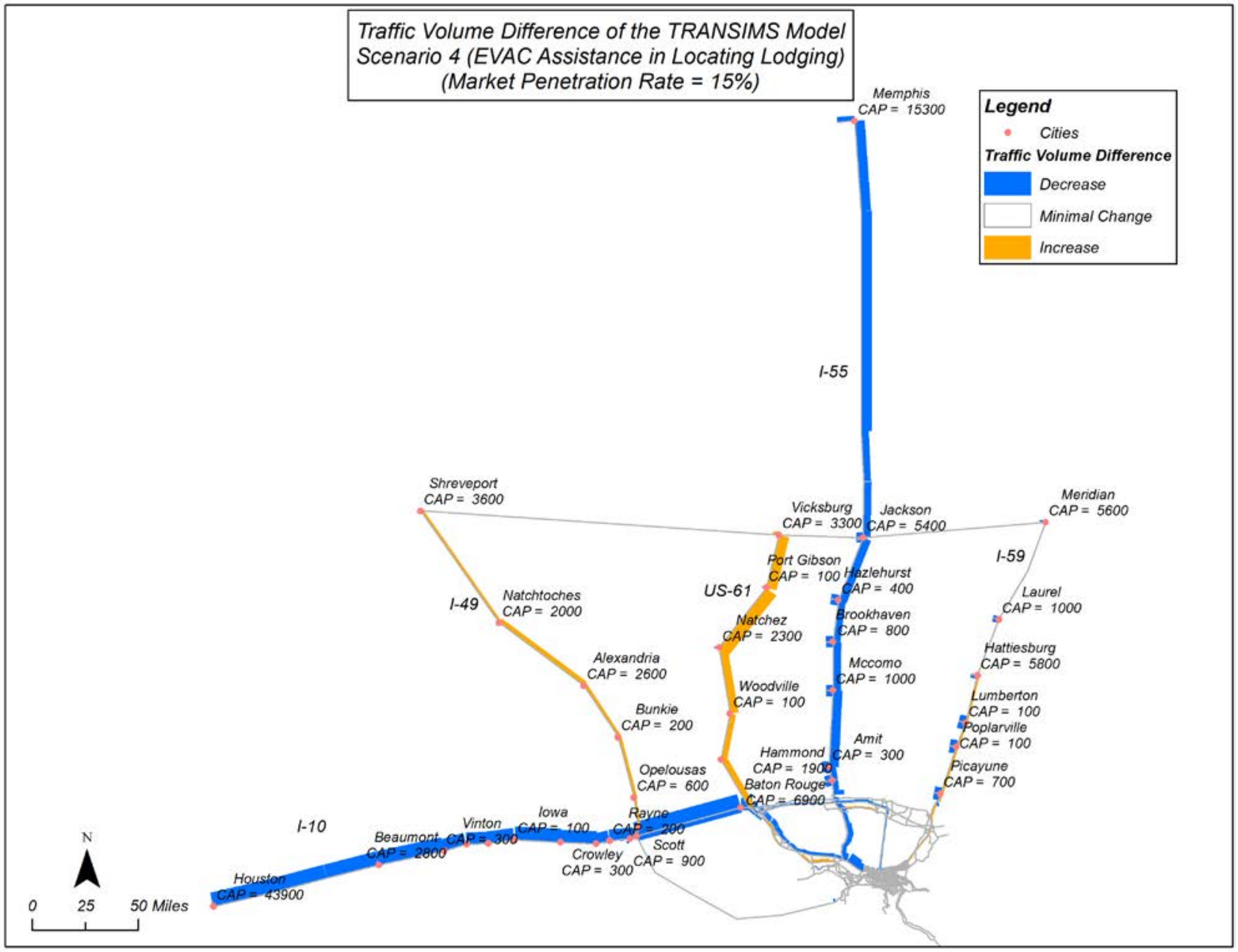
Table 3-6. Travel Time Impacts for Scenario 4

	15% Market Penetration			25% Market Penetration			50% Market Penetration		
	EVAC-Equipped	Regular	All Lodging-Seeking Evacuees	EVAC-Equipped	Regular	All Lodging-Seeking Evacuees	EVAC-Equipped	Regular	All Lodging-Seeking Evacuees
Number of Evacuees	*13,949*	*79,878*	*93,827*	*23,281*	*70,546*	*93,827*	*46,635*	*47,192*	*93,827*
Lower Bound of the 85-Percentile Travel Time Difference Interval (min.)	(320)	0.0	(209)	(310)	0.0	(230)	(300)	0.0	(260)
Higher Bound of the 85-Percentile Travel Time Difference Interval (min.)	0.0	60	39	10	99	79	10	119	80
Average Travel Time Difference (min.)	(176)	13	(15)	(155)	15	(27)	(117)	25	(44)
Total Travel Time Difference (hrs)	(40,872)	17,919	(22,952)	(60,025)	17,070	(42,392)	(90,701)	23,788	(66,912)



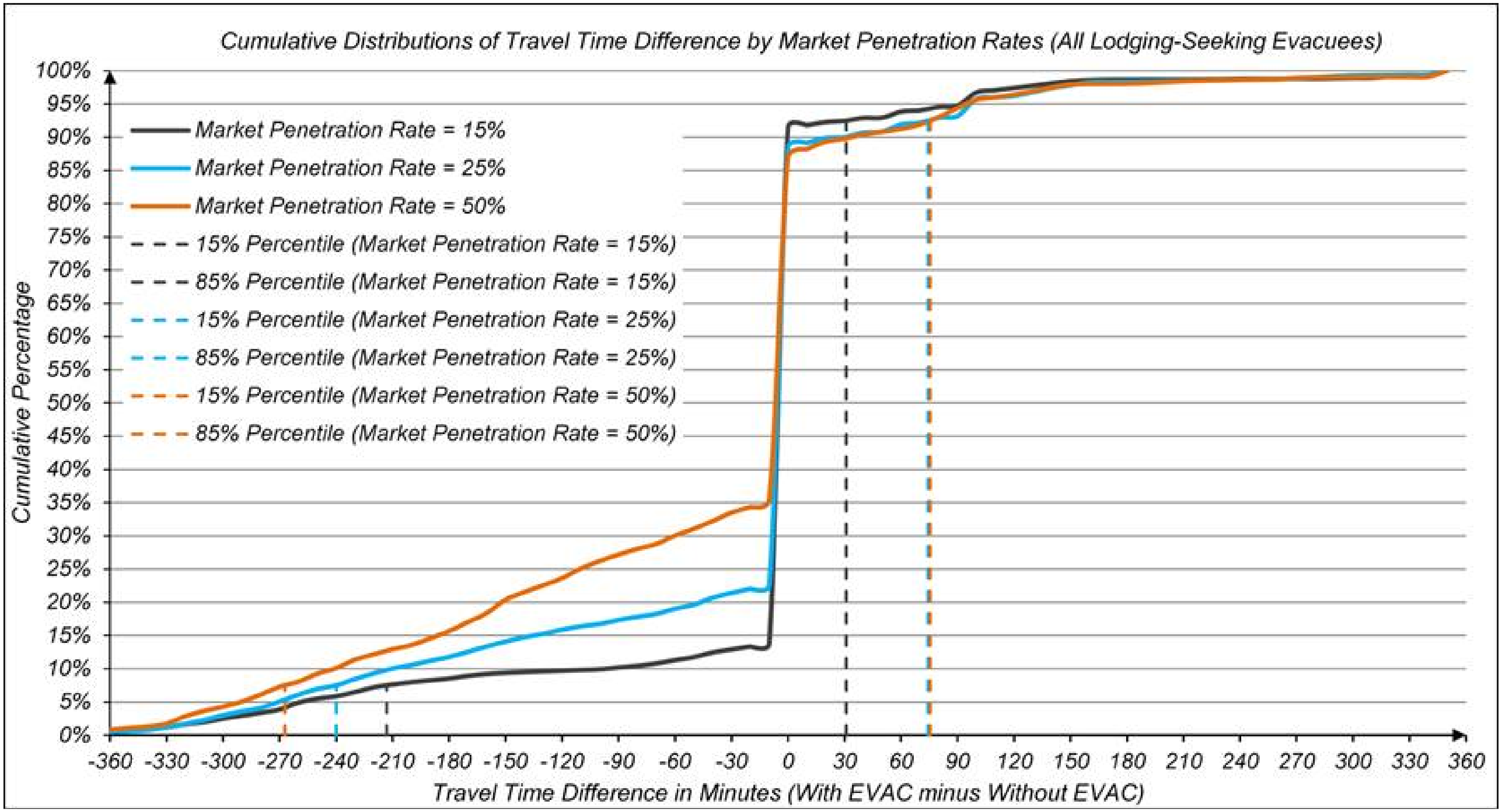
Source: AECOM

Figure 3-5. Trajectories of an EVAC-Equipped Evacuee



Source: AECOM

Figure 3-6. Traffic Volume Difference for Scenario 4 (EVAC Assistance in Locating Lodging) with 15-Percent Market Penetration



Source: AECOM

Figure 3-7. Distributions of the Travel Time Difference for Different Market Penetration Rates

3.4.2. EVAC Deployment Impact

The total travel time savings for the lodging-seeking evacuees grew from 22,952 hours at 15-percent market penetration to 66,912 hours at 50-percent market penetration. The average travel time savings was at least about 2 hours although this benefit decreased from 176 minutes to 114 minutes because of the increase in total number of EVAC-equipped evacuees. Compared to the case with a high penetration rate, the EVAC-equipped evacuees who depart relatively late might need to go to a farther location since the close locations might have been taken by other EVAC-equipped evacuees. When the capacity at close locations was depleted, the evacuees might still need to travel to distant locations even if they had EVAC devices. Figure 3-6 graphically shows that the traffic diverts away from routes leading to Houston and Memphis with EVAC assistance, enabling evacuees to find lodging in closer destinations such as the ones on branches leading to Shreveport, LA, and Vicksburg, MS.

Figure 3-7 graphically depicts the cumulative distribution of the travel time benefit for different penetration rates. A steep ascent is apparent for all three penetration rate distributions, suggesting that some evacuees did not experience a significant travel time benefit. The inflection point of the distribution for the 50-percent market penetration was the largest (at 35 percent), which suggests that a larger number of lodging-seeking evacuees experienced travel time savings compared to those of the other two market penetration rates. The figure also shows the 85th percentile interval. While some evacuees did not achieve any benefit, a majority of the evacuees experienced a shorter travel time. In addition, 14 percent of the lodging-seeking evacuees saved at least 10 minutes in travel time in the 15-percent market penetration rate scenario, 23 percent in the 25-percent market penetration rate scenario, and 35 percent in the 50-percent market penetration rate scenario. Combined, these results suggest that higher market penetration provided travel time benefits to more lodging-seeking evacuees.

3.5. Scenario 5: EVAC Assistance in Locating Fuel

3.5.1. Modeling Results

In Scenario 5, the focus of the effort was on assessing the ability of EVAC to support evacuation trip-making by assisting evacuees in acquiring fuel. In prior evacuations, long delays caused by significant congestion, combined with limited fuel supplies, resulted in numerous vehicles running out of fuel during the evacuation. In addition to the added risk and delay to evacuees during their journey, such out-of-fuel conditions also resulted in additional congestion as fuel-less vehicles blocked travel lanes and shoulders. This analysis compared the modeling results based on two sets of performance measures, including those related to congestion and those associated with travel time differences, between the base and the with-EVAC fuel-assistance scenarios.

Table 3-7. Congestion Performance Measures for Scenario 5

Performance Measure	Baseline Total	15% Market Penetration		25% Market Penetration		50% Market Penetration	
		Abs. Change	Percent Change	Abs. Change	Percent Change	Abs. Change	Percent Change
Vehicle Kilometers of Travel	41,022,218	(471,187)	-1.1%	(428,745)	-1.1%	(434,615)	-1.1%
Vehicle Hours of Travel	580,948	(13,434)	-2.3%	(16,336)	-1.9%	5,183	0.6%
Vehicle Hours of Delay	153,321	(8,679)	-5.7%	(11,897)	-2.7%	9,942	2.2%
Congested Vehicle Kilometers	1,934,843	(330,449)	-17.1%	(458,728)	-3.2%	113,912	0.8%
Congested Vehicle Hours	62,096	(14,679)	-23.6%	(22,309)	-4.3%	3,106	0.6%
Percentage of Time Congested	12.0%	-2.0%	-16.7%	-3.0%	-6.5%	0.01	2.2%

Table 3-7 shows the congestion-related performance measures. EVAC's capability to assist with locating fuel showed the most significant congestion-reducing benefit when the market penetration rates were 15 percent and 25 percent. Specifically, the congested vehicle distance traveled decreased by 17 percent and 3 percent for the 15-percent and 25-percent market penetration rates respectively. Similar reductions were also observed for other congestion performance measures under the 15-percent and 25-percent market penetration rates. The congestion reduction benefit was not evident when the market penetration rate was 50 percent. This suggests that providing the information about fuel availability to a large percentage of the evacuees may result in more travel on more congested facilities, which could increase the overall travel time. Non-EVAC evacuees who exited the freeway to seek fuel frequently continued at least a portion of their trip on the less congested parallel roadways to travel to the next fueling location. This tended to reduce their overall travel time impact and the congestion on the freeway for other travelers. When a high percentage of evacuees are EVAC-equipped, a larger percentage of trips continued on the major routes and failed to take advantage of higher speeds on parallel routes.

Table 3-8. Travel Impacts for Scenario 5

	15% Market Penetration			25% Market Penetration			50% Market Penetration		
	EVAC-Equipped	Regular	All Evacuees	EVAC-Equipped	Regular	All Evacuees	EVAC-Equipped	Regular	All Evacuees
Number of Evacuees	56,175	319,048	375,223	93,687	281,536	375,223	187,664	187,559	375,223
Number of Failures	(16)	(19)	(35)	(29)	(18)	(47)	(62)	(22)	(84)
Lower Bound of the 85-Percentile Travel Time Difference Interval (min.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Higher Bound of the 85-Percentile Travel Time Difference Interval (min.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Travel Time Difference (min.)	(6.0)	(3.1)	(3.6)	(6.1)	(1.4)	(2.6)	(6.6)	(2.7)	(4.7)
Total Travel Time Difference (hrs)	(5,599)	(16,707)	(22,306)	(9,575)	(6,427)	(16,002)	(20,754)	(8,442)	(29,196)

3.5.2. EVAC Deployment Impact

Table 3-8 shows the travel time differences for different evacuee group under different EVAC market penetration rates. In contrast to the congestion performance measures, a travel time benefit was observed for all three market penetration rates. For EVAC-equipped evacuees, the average travel time savings were about 6 minutes when the market penetration rate increased from 15 percent to 50 percent. The zero-length 85 percentile interval suggested that 85 percent of the evacuees did not increase or decrease their travel times. But on average, all evacuees experienced a travel time savings of 4 minutes at a 15-percent market penetration rate and about 5 minutes when the market penetration rate reached 50 percent. Perhaps most significantly, the number of failures to locate fuel steadily decreased when the market penetration rate increased. This demonstrated EVAC's potential to reduce fuel-related breakdowns, which could help maintain a relatively stable traffic flow.

3.6. Scenario 6: EVAC Communications about Pickup Time and Location Options for Special Needs Evacuees (i.e., Transit Services)

3.6.1. Modeling Results

The EVAC support to carless and various limited-mobility evacuees focused on the dissemination of pickup time and locations to help these evacuee groups minimize the total wait time at both the pickup location and intercity bus transfer locations. Table 3-9 summarizes the travel time statistics for different user groups under all three market penetration rates.

3.6.2. EVAC Deployment Impact

The walk time to the CAEP bus stops, including the pickup locations and the intercity stations, remained nearly constant for all user groups across all three market penetration rates. Similar results are evident in the in-vehicle travel time. The relatively small difference in walk time and in-vehicle time suggests that evacuees generally took identical routes to access the stations and identical bus routes to evacuate the city. These findings reflect the EVAC functionality, which only provided pickup time and location options instead of making routing suggestions. The benefit of this information can be seen in the significantly reduced delay as evacuees waited to be picked up by buses. Specifically, the EVAC group experienced over 90-percent (45 minutes) reduction in wait time for all three market penetration rates. This suggests that the EVAC communications about pickup time and location are very beneficial to the transit-based evacuees. In comparison, the regular evacuees did not experience nearly as significant a benefit. At a 25-percent EVAC market penetration, the transit-based evacuees without EVAC equipment (labeled as "regular") experienced a slight increase, about 3 percent, in their wait time.

The overall travel time benefit for all the local evacuees in the network increased primarily because of the higher EVAC market penetration. Hence, the increased market penetration does not lead to an increase in reduced wait time since the EVAC-equipped evacuees already minimized their total travel time and reserved a seat on each bus along their route.

Table 3-9. Travel Time Impacts for Scenario 6

	15% Market Penetration									
	EVAC-Equipped		Regular		Tourist		Local		All Evacuees	
Number of Evacuees	7,930		45,971		10,000		53,901		63,901	
Average Walk Time Difference (min.)	(0.5)	(0.0)	0.1	0.0	0.0	0.0	(0.1)	(0.0)	(0.1)	(0.0)
Average In-Vehicle Travel Time Difference (min.)	1.0	0.0	(0.3)	(0.0)	0.0	0.0	(0.1)	(0.0)	0.0	0.0
Average Wait Time Difference (min.)	(46)	-91%	(0.6)	-1.2%	2.0	22%	(7.2)	-14%	(5.8)	-13%
Average Travel Time Difference (min.)	(45)	-21%	(0.6)	-0.3%	2.0	3.2%	(7.2)	-3.3%	(5.7)	-3.0%
Total Travel Time Difference (hrs)	(5,955)	-21%	(483)	-0.3%	327	3.2%	(6,441)	-3.3%	(6,113)	-3.0%
	25% Market Penetration									
	EVAC-Equipped		Regular		Tourist		Local		All Evacuees	
Number of Evacuees	13,356		40,545		10,000		53,901		63,901	
Average Walk Time Difference (min.)	(0.5)	(0.0)	0.1	0.0	0.0	0.0	(0.1)	(0.0)	(0.1)	(0.0)
Average In-Vehicle Travel Time Difference (min.)	1.0	0.0	(0.3)	(0.0)	0.0	0.0	(0.1)	(0.0)	0.0	0.0
Average Wait Time Difference (min.)	(45)	-91%	1.3	2.6%	(2)	-17%	(10.2)	-21%	(8.9)	-21%
Average Travel Time Difference (min.)	(44)	-21%	1.0	0.5%	(2)	-3%	(10.3)	-4.8%	(8.9)	-4.7%
Total Travel Time Difference (hrs)	(9,870)	-21%	703	0.5%	(368)	-3%	(9,244)	-4.8%	(9,532)	-4.7%
	50% Market Penetration									
	EVAC-Equipped		Regular		Tourist		Local		All Evacuees	
Number of Evacuees	26,959		26,942		10,000		53,901		63,901	
Average Walk Time Difference (min.)	(0.4)	-2%	0.1	0.3%	0.0	0.0%	(0.3)	-1.3%	(0.2)	-1.3%
Average In-Vehicle Travel Time Difference (min.)	1.8	1%	(0.3)	-0.2%	0.0	0.0%	0.5	0.3%	0.4	0.3%
Average Wait Time Difference (min.)	(46)	-92%	0.0	0.0%	2.0	22%	(23)	-46%	(19)	-44%
Average Travel Time Difference (min.)	(44)	-21%	(0.3)	-0.1%	2.0	3%	(23)	-11%	(19)	-10%
Total Travel Time Difference (hrs)	(19,896)	-21%	(215)	-0.1%	327	3%	(20,267)	-11%	(19,926)	-10%

[a] *The total of regular evacuee (labeled as "Local") was 53,901.*

[b] *Percentage change from base for the same user group*

3.7. Scenario 7: Combination of Route Information and Guidance, Location of Available Lodging and Shelter, Location of Fuel, and Transit Pickup Time and Location Options

This scenario was used to illustrate the combined effect of providing EVAC-equipped evacuees with information about routes, lodging and fuel availability, and transit pickup times. The performance statistics are measured on the larger region used for lodging analysis.

3.7.1. Modeling Results

Once again, the modeling results were compared based on two sets of performance measures, including those associated with congestion and those associated with travel time. The first set of performance measures (congestion) is shown in Table 3-10. The overall kilometers of travel, hours of travel, and hours of delay decreased for all market penetration rates. Unlike the previous scenarios, congestion level increased slightly under the combined EVAC functionality. This was likely the result of the shift to more direct paths to fuel and lodging that kept traffic on the more highly congested freeways for a greater percentage of their trip. On the other hand, larger market penetration rates showed a decreasing trend in kilometers traveled and an increasing trend in hours of travel and delay, most likely because more evacuees chose short paths, which led to more congestion. The net impact, however, was an increase in overall travel speed with increasing market penetration.

Table 3-10. Congestion Performance Measures for Scenario 7

Performance Measure	Baseline Total	15% Market Penetration		25% Market Penetration		50% Market Penetration	
		Abs. Change	Percent Change	Abs. Change	Percent Change	Abs. Change	Percent Change
Vehicle Kilometers of Travel	70,272,120	(2,535,276)	-6.6%	(2,669,605)	-6.9%	(2,767,932)	-7.2%
Vehicle Hours of Travel	850,491	(27,647)	-3.3%	(27,187)	-3.2%	(26,558)	-3.1%
Vehicle Hours of Delay	159,588	(4,203)	-0.9%	(2,689)	-0.6%	(1,077)	-0.2%
Congested Vehicle Kilometers	746,493	112,179	0.8%	(11,260)	-0.1%	69,386	0.5%
Congested Vehicle Hours	19,599	1,866	0.4%	2	0.0%	1,630	0.3%
Percentage of Time Congested	5.0%	0.0%	0.0%	0.0%	0.0%	-	0.0%

Table 3-11. Travel Time Impacts for Scenario 7

	15% Market Penetration			25% Market Penetration			50% Market Penetration		
	EVAC-Equipped	Regular	All Evacuees	EVAC-Equipped	Regular	All Evacuees	EVAC-Equipped	Regular	All Evacuees
Number of Evacuees	64,105	375,019	439,124	109,781	329,343	439,124	219,562	219,562	439,124
Average Wait Time Difference (min)	(46)	(0.6)	(5.8)	(45)	1.3	(8.9)	(46)	0.0	(19)
Lower Bound of the 85-Percentile Travel Time Difference Interval (min.)	(58)	0.0	0.0	(27.5)	0.0	0.0	0.0	0.0	0.0
Higher Bound of the 85-Percentile Travel Time Difference Interval (min.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average Travel Time Difference (min.)	(49)	3.9	(4.1)	(18.8)	1.2	(3.8)	(9.6)	0.8	(4.4)
Total Travel Time Difference (hrs)	(50,690)	19,253	(31,437)	(39.282)	5,933	(33,349)	(50,020)	2,588	(47,432)

3.7.2. EVAC Deployment Impact

The travel time impacts shown in Table 3-11 were significantly influenced by the wait time reductions for transit-based travelers. The 85th percentile range and the average travel time were dominated by the large number of travelers that use automobiles. However, the total travel time savings were offset by transit-related benefits. The overall trend for automobile travelers was slightly downward with increased EVAC market penetration, but the transit-related benefits increased substantially with increased market penetration. The net result was an increasing trend in overall travel time benefits.

Chapter 4. Findings and Impact Assessment

4.1. General Findings

Based on the results of the modeling efforts, the EVAC functionalities that were evaluated showed overall positive impacts on several key aspects of hurricane evacuation. First, EVAC's functionality that provides route guidance under normal and incident conditions had positive impacts on alleviating congestion. The percentage of time congested decreased by about 20 percent for all penetration rates. EVAC's information helped in reducing congestion by encouraging evacuees to use underutilized arterial routes, which alleviated the congestion on major freeway corridors. The phenomenon of route underutilization is not unique to New Orleans. Observation of prior evacuations in other areas and for other types of hazards suggests that evacuation travelers tend to favor "familiar" routes and routes that are more heavily traveled during routine, non-emergency periods, even though they may be more congested during an evacuation.

Second, EVAC's functionality to provide pickup time and location options for low-mobility and carless evacuees (i.e., those requiring transit services under the CAEP) demonstrated significant mobility benefits for transit-based evacuees. For example, it reduced the wait time for transit services by over 90 percent for EVAC-equipped evacuees. This expedited the transit-based evacuation process. The average travel time savings ranged from 6 minutes to about 19 minutes when the penetration rate increased from 15 percent to 50 percent. While it is recognized that travel delay due to waiting for available buses could be reduced by adding more buses to the system, such resources are more often than not unavailable during major emergencies.

Third, EVAC's functionality to assist evacuees in locating resources like fuel and lodging proved to have positive impacts. EVAC showed the potential to reduce fuel-related breakdowns. When the penetration rate is 50 percent, the breakdowns were reduced by more than 50 percent. EVAC's capability to provide lodging information and make reservations could significantly reduce the lodging-seeking evacuees' travel time by relocating them to closer destinations. The lodging-seeking evacuees experienced a 2-hour travel time benefit on average.

In summary, EVAC functionalities such as route guidance, communications about transit services, and lodging and fueling assistance could be beneficial to evacuees in terms of reducing travel time and overall network congestion.

4.2. Impact Assessment

The results of this assessment suggest that the benefits expected from the various EVAC functionalities evaluated in this study would have great potential to significantly improve emergency traffic operations during large-scale evacuations. Benefits were observed in numerous areas of relevance and importance from the standpoints of both transportation and disaster resilience. Under EVAC guidance, benefits were seen in the EVAC's ability to:

- More effectively route evacuees to their destination, and thus better utilize the available capacity in the evacuation road network
- Guide evacuees to shelter lodging during the evacuation
- Help evacuees find and conserve fuel
- Provide en-route support resources to evacuees in need during their journey
- Support the effective movement of limited mobility evacuees.

Within the evacuation road network, each of these improvements, whether individually or in combination with others, resulted in decreases in:

- Travel time to shelter destinations
- Congestion
- Delay
- Travel distance
- Fuel consumption and presumably emissions.

The analysis also showed how various levels of EVAC market penetration impacted the results. This impact differed depending on the tested functionality.

While the value and the usefulness of the EVAC information were highlighted in this study, there are other considerations that could impact the overall effectiveness of the application. First among these is that the EVAC application and all of its intended functionalities rely on mobile communications. For this study, the communication failure was considered partially by using an effective penetration rate. However, the temporal and spatial effect of communication interruptions were not considered. Even when communications are fully operational, it is likely that the demand placed on the system by users seeking to use mobile communications would limit its effectiveness. As a result, an assessment of the vulnerability of communications would be beneficial, as this element can significantly impact the overall effectiveness of the provided information.

As those new connected vehicle applications move from the testing stages to eventual pilot deployments, it will be important to make sure that users of the technology and those relying on it to issue guidance are familiar with its capabilities and limitations as well as its basic operation. As such, it will be important to work with the range of stakeholders that constitute the potential users of the application, including agencies involved in emergency management as well as the public at large, to train them on the use of the application and highlight its potential benefits to accelerate its adoption.

Transferability is another important factor to consider. While this study assessed the potential impacts of the EVAC information on evacuation mobility in the Greater New Orleans area, there are factors that affect its potential transferability, both in terms of location as well as event condition. Among the key issues to consider would be the type of hazard and the type of evacuation (e.g., planned versus unplanned evacuation), as well as the particular economic, demographic, infrastructural, and geographical characteristics of an area.

4.2.1. Applicability in Other Regions

This impact assessment was conducted using the New Orleans TRANSIMS test bed. The New Orleans area has some unique geographical characteristics that may influence the transferability of the impact assessment to other regions. For example, US-61 is the only alternative to the freeway corridor I-10 W. Other regions may have multiple parallel routes. While the positive impact of EVAC can still be expected, the traffic diversion may be different. If there are no underutilized parallel routes to major evacuation destinations, the benefit of route guidance may not be fully realized. In addition, the long freeway segments across Lake Pontchartrain do not have any fueling locations, which compelled evacuees to make early stops for fuel before they cross the lake. The impact on transit-based evacuees is expected to be shown in other regions where a similar feeder system with similar service frequency is operated. If the transit service is more frequent, the wait time reduction benefit may diminish. The lodging-locating assistance can also be beneficial in other regions.

In general, the results observed in the New Orleans test model would be expected to be consistent with those in other areas of the country. While the specific characteristics of an area would be vastly different, the fundamental process of traffic movement, driver behavior, and transit operations would be expected to be relatively similar. A key difference that has been shown to be quite influential in prior evacuations is the amount of advanced planning that has gone into managing the road network and, perhaps even more critical, the amount of advance planning for carless and low-mobility evacuees that can have an enormous impact on the effectiveness of the process.

In terms of event-specific benefits, EVAC could be most effective in short- to no-advanced notice scenarios. During these conditions, general information may be limited, out of date, or incorrect due to the rapidly changing conditions of such events. EVAC could serve as an immediate, convenient, and rapidly accessible source of information and guidance during these periods. It should also be noted that the functionality of EVAC could also be used effectively down to the most “routine” events, including daily traffic events or incidents that may block a lane or close segments of key routes during commute periods.

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