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Transit-based emergency evacuation modeling with microscopic simulation

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TRANSIT-BASED EMERGENCY EVACUATION MODELING WITH MICROSCOPIC SIMULATION

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Abstract

Several recent mass evacuations, including those in advance of Hurricane Katrina in New Orleans and Hurricane Rita in Houston, have demonstrated the effects of limited planning for carless populations. The lack of planning left a significant portion of the mobility-limited population of both these cities unable to flee in advance of the storms. Since 2005 however, both of these cities (as well as others across the United States) have developed transit assisted mass evacuation plans at various levels of detail. Since these plans are relatively recent and do not have a history of experience on which to base their performance, it is difficult to know how well, or even if, they will work.

This research describes one of the first attempts to systematically model and simulate transit-based evacuation strategies. In it, the development of and the results gained from an application of the TRANSIMS agent-based transportation simulation system to model assisted evacuation plans of New Orleans are described. In the research, a range of varying conditions were evaluated over a two-day evacuation period, including two alternative evacuation transit routing scenarios and four alternative network loading and demand generation scenarios resulting in eight evacuation scenarios.

In the research, average travel time and total evacuation time were used to compare the results of a range of conditions over a two-day evacuation period, including two alternative transit evacuation routing plans and four alternative network loading scenarios. Among the general findings of the research was that the most effective scenarios of transit-based evacuation were those that were carried out during time periods during which the auto-based evacuation was in its "lull" (non-peak/overnight) periods. These conditions resulted in up to a 24 percent reduction in overall travel time and up to 56 percent reduction in the total evacuation time when

compared to peak evacuation conditions. It was also found that routing buses to alternate arterial routes reduced the overall travel time by up to 56 percent and the total evacuation time by up to 22 percent.

The impact of including transit evacuation on the network traffic operation was also tested using average evacuation speed and queue length, it was found that the transit evacuation had no impact on arterial traffic operation but it increased the average queue length on the interstate evacuation route.

An evaluation of the transit-based evacuation plan was also completed. It was found that at least 68 percent of the transit dependent evacuees spent half an hour or less not on transit (walking towards the bus stop and/or waiting at the bus stop) and only 0.19 percent of them spent more than an hour not on transit in their evacuation trip. Finally, the number of buses needed for the carless evacuation under each evacuation scenario was estimated. A total of 56, 42, 61, and 43 local buses, for transporting people from the pickup locations to the processing centers, were required for network loading scenarios A, B, C, and D respectively. Also, 601 RTA buses, for transporting people from the processing centers to shelters, were needed.

Chapter 1. Introduction

General

Federal Emergency Management Agency (FEMA) statistics show that between 45 and 75 major emergency incidents occur annually in the United States (US) that require evacuation (FEMA 2008). Interestingly, only eight percent of these are caused by hurricanes. However, it is worth noting that over the past 20 years, the average number of hurricane events on the Atlantic and Gulf Coast of the (US) has increased significantly and between 1997 and 2006, these areas have experienced the highest annual average number of hurricanes in history (NOAA 2006). The 2005 season, in particular, stands out as the busiest on record.

In the fall of 2005, two major hurricanes impacted Louisiana and Texas with Hurricane Katrina making landfall near New Orleans and Hurricane Rita arriving near Houston Texas. In the days prior to their landfall more than million citizens evacuated each of these cities (Wolshon and MacArdle 2008: USDOT 2006). In Louisiana, Governor Kathleen Blanco estimated that 92 percent of the total population of New Orleans fled prior to the storm (United States/The White House 2006). When compared to 2000 U.S. Census statistics that showed that only 82 percent of New Orleans households had automobile access, it suggests that about 90,000 people were required to evacuate with friends, neighbors, or family (Cox 2006). Even more alarming were statistics that showed that as much as eight percent of the population (perhaps 30,000 or more people) were unable or chose not to evacuate at all. It was these citizens that caught the attention of the world in the days following the disaster.

Despite the highly visible and publicized failings associated with Hurricane Katrina in New Orleans, the overall evacuation of southeast Louisiana was relatively effective. This has been attributed to several factors, including the timing of the evacuation (on a weekend), extensive public information campaigns, and the implementation of a regional traffic management and contraflow system. Unfortunately, however, this roadway management plan was targeted exclusively at auto-based self-evacuators. The failure of the evacuation was the inability to adequately evacuate those without access to personal transportation (Litman 2006: TRB 2008: Renne et al. 2008).

Ultimately, more than 1,500 people perished from direct effects of the storm and related flooding (NOAA 2006). To many, the inability to evacuate the vulnerable carless population is assumed to not have been the result of lack of transportation resources, but from poor communication and coordination of available resources (USDOT 2006: Renne 2006). One highly publicized example was the story of how 197 city transit buses and 24 out of 36 vans were flooded and not used to evacuate carless residents (Renne 2006). While it is unknown how many of these lives may have been saved through transportation assistance, the allocation of additional resources to the problem has become a priority in Louisiana and elsewhere since 2005.

After Hurricane Katrina, the U.S. Department of Transportation (USDOT 2006) stressed the importance of more comprehensive and systematic planning and coordination of all available resources as a critical issue for a successful mass evacuation plan. In their report to congress, they stated:

> Because there had been little advance planning and intergovernmental communication for mass evacuations by other than private vehicles, officials on the scene were sometimes unable to assemble or stage significant numbers of evacuees to use vehicles provided to some areas. Some trains and buses left the area with very few passengers. The evacuation problems were compounded by the lack of communication with buses and local officials.

Despite these findings and subsequent improvements, serious deficiencies in the evacuation planning remain throughout the nation. Evacuation planning continues to focus heavily on auto-based strategies while virtually ignoring transit-based evacuations for disadvantaged and dependent populations. Giuliano (2005) defined disadvantaged populations as "those who are unable or unwilling to drive, or who do not have access to a private vehicle".

The critical role transit can play during an emergency evacuation was clearly demonstrated when transit evacuated 1.2 million people out of lower Manhattan after the terrorist attacks of September 11, 2001 (TRB, 2008). It is assumed that transit could have also assisted in evacuating carless residents before the landfall of Hurricane Katrina if it had been integrated in the evacuation plan (TRB, 2008).

Research Goals and Objectives

This research describes a project to address the limited knowledge and experience in the use of transit in mass evacuation planning. Among the objectives of this research was to develop a first-of-its-kind model to integrate both auto-based and the transit-based aspects within an urban mass evacuation traffic simulation. As part of this work, alternative evacuation transit routing scenarios and network loading scenarios were modeled to simulate conditions that could occur in a transit-assisted evacuation in New Orleans. Such assessments are thought to be critically important because despite of the fact that they are now being incorporated into the local emergency plans, the conditions associated with transit use during emergencies remains largely unknown.

Simulation is a tool that has a long track record of use and success within the field of transportation engineering. Recently, it has also proven to be a useful tool for testing and evaluating evacuation plans (Theodoulou and Wolshon 2004: Kwon and Pitt 2005: Jha el at., 2004). It also has limitations. Unlike the analysis of routine daily traffic patterns, mass evacuation require the coding of road networks over large geographic areas with many hundreds of thousands of people and vehicles over durations as long as several days. The TRANSIMS traffic simulation system, with its ability to microscopically model multiple modes of transportation over vast geographic areas, was thought to be particularly well-suited for the analysis of region-wide evacuation process.

In the following sections, the adaptation of the TRANSIMS system for the development of a New Orleans transit-based evacuation is described, including the data preparation process and computational resource requirements. This research also describes several other key project objectives, such as the:

- Development of a transit-based evacuation model in TRANSIMS by creating a coding procedure to represent the carless population and their activities within the evacuation plans
- Development of alternative evacuation routing and network loading scenarios based on the 2007 New Orleans City Assisted Evacuation Plan and The Jefferson Parish Publicly Assisted Evacuation Plan
- Integration of the transit-based evacuation component into a recently developed auto-based evacuation component
- Analysis and comparison of the results of all scenarios using relevant measures of effectiveness (MOEs) including total evacuation time and average travel time
- Test the impact of including the transit evacuation on the network traffic operation using relevant measures of effectiveness including average evacuation speed and average queue length

It should be noted that plans at the state and parish level for New Orleans carless evacuation have only been implemented post-Katrina. The microscale simulation modeling of existing plans for carless populations present an innovative approach that may be of interest to many other regions across the United States, particularly in New York, Washington, D.C., Baltimore, Philadelphia, Boston, Chicago, and San Francisco, which all had higher percentages and higher absolute numbers of carless households compared to the 27 percent (130,000 residents) which resided New Orleans in 2000 (Renne 2006).

Chapter 2. Literature Review

The literature review focuses on emergency preparedness related issues, transit evacuation, traffic simulation modeling for emergency preparedness, TRANSIMS, and managing evacuation. A brief summary of the literature follows.

Sisiopiku et al. (2004) defined emergency preparedness as "the preparation of a detailed plan that can be implemented in response to a variety of possible emergency or disruption to the transportation system". Effective management of traffic operations prior to, during, and after all-hazards emergencies is a critical issue in mitigating the catastrophic impact of a disaster (Kwon and Pitt 2005).

There are four major components to be addressed in an emergency management plan: mitigation, preparedness, response, and recovery (TRB 2008: Nakanishi et al. 2003: Sisiopiku et al. 2004).

Mitigation refers to implementing actions to reduce or minimize the severity and impact of damage caused by an emergency situation. Mitigation can be defined as measures aimed at reducing or eliminating property damage and loss of lives from a disaster.

Preparedness phase refers to the development of an emergency response plan in advance. Preparedness should focus on the effective coordination of the available resources to respond to an emergency.

The response can be defined as taking action when an emergency situation takes place to save lives and reduce damage. Response determines how fast the community will return to normal conditions.

Recovery phase consists of activities taken to rebuild the affected areas and restore normal life, economically, physiologically, and socially. This phase includes the short and long term recovery needs.

The transportation system plays an important role in the four components or phases of an emergency preparedness plan. The transportation system not only has the responsibility to get responders to the dangerous areas, but also to evacuate people from these areas. This is not an easy task, particularly when evacuation and emergency response needs must be met simultaneously. Besides, information on the transportation network should be provided to responders and to the public on incidents and available alternatives. If the transportation system itself is disrupted, the primary concern is to restore the system operation to a minimum level as fast as possible (ITS America 2002).

Transit Evacuation

Interest in the topic of transit evacuation has increased significantly in the wake of the terrorist attacks of September 11, 2001, where transit played a major role in the evacuation of Lower Manhattan and after Hurricane Katrina, in which the evacuation plans failed to evacuate carless residents (TRB 2008: Renne et al. 2009). Numerous studies have been undertaken over the last half decade that discusses this lack of planning to evacuate the disadvantaged population, including several of those summarized below.

The Department of Homeland Security (DHS 2006) reported that few states or urban areas have adequate planning for carless evacuees and only one out of ten urban areas are adequately prepared for the evacuation of the disadvantaged population. The DHS reports that most evacuation planning focuses on evacuation via privately owned vehicles, ignoring the public transportation system component. The U.S. Government Accountability Office (GAO

2006) also conducted a national study concerning disadvantaged population evacuation preparedness. The GAO found that state and local governments are not adequately prepared for evacuating disadvantaged population and the extensive focus is on the automobile based evacuation. The GAO report recommends that evacuation plans should focus on all transportation modes and not only on the automobile based evacuation. Similarly, the Conference of Minority Transportation Officials (COMTO 2007) reports that existing emergency plans do not address the disadvantaged population needs. Hess and Gotham (2007) studied counties in rural New York and found that multimodal evacuation planning was not seriously considered in most evacuation plans. Bailey et al. (2007) surveyed the emergency response and evacuation plans in 20 metropolitan areas with higher than average proportions of minorities, low income levels, limited English proficiency, and households without vehicle access. It was found that few agencies had included transportation disadvantaged population in their emergency plans.

> …. with some exceptions, the agencies reviewed in this study have taken very limited steps towards involving populations with specific mobility needs in emergency preparedness planning, identifying the location of and communicating emergency preparedness instructions to these populations, or coordinating with other agencies to meet the specific needs of these populations in emergency.

Recently, Wolshon (2009) conducted a survey of evacuation policies and practices. The survey showed that only half of the surveyed transportation agencies have accommodations for dependent and special needs populations.

Finally, Turner el at. (2010) reviewed the existing literature and state-of-practice to discuss the current practices and needs for better communication with the disadvantaged population during an emergency evacuation. The study demonstrates the complexity of communication with the disadvantaged population during an emergency evacuation. This work is presented as foundation for agencies to create effective communication strategies, policies, and practice that focus on disadvantaged population before, during, and after an emergency situation.

Traffic Simulation Modeling for Emergency Preparedness

Simulation models are tools for representing the movement of vehicles on the transportation network. Simulation models enable transportation planners to develop and compare different evacuation plans for different hypothetical emergency situations to predict traffic conditions and duration of evacuation (Yuan el at. 2006).

Cova and Johnson (2002) propose a method for using microsimulation model to develop and test neighborhood evacuation plans in fire-prone wild lands. Jha el at. (2004) applied MITISLab for evaluating five evacuation scenarios for Los Alamos National Lab (LANL). Kwon and Pitt (2005) studied the feasibility of applying Dynasmart-P for evaluating the effectiveness of alternative strategies for evacuating the traffic in a large urban network downtown Minneapolis, Minnesota, under hypothetical emergency situations. Xuwei used agent-based microsimulation model to estimate minimum evacuation clearance time and the number of evacuees who will need to be accommodated in case of the route disruption. Another agent-based microsimulation technique was used by Church and Sexton (2002) who investigated how different evacuation scenarios would affect evacuation time. Evacuation scenarios included alternative exits, changing number of vehicles, and applying different traffic control plans. Mastrogiannidou et al. (2009) used an integrated transit vehicle assignment module within VISTA, DTA model, for evacuating high-density clusters using transit. Three evacuation scenarios, relating to the availability of buses for the evacuation of three marine terminals in Port Elizabeth-Newark area of the Port of New York and New Jersey, were tested.

Boxill and Yu (2000) classify traffic simulation models as either microscopic, mesoscopic, or macroscopic simulation based. Models that simulate individual vehicles at small time intervals are termed as microscopic while models that aggregate traffic flow are termed as macroscopic. Mesoscopic refers to models in between microscopic and macroscopic. The main disadvantage of microscopic simulation based models is the extensive data required and the need for advanced computer resources, while the main advantage of them is that they provide more realistic representation of traffic operations on the transportation network and can provide detailed outputs such as estimated travel speed, delay and travel times which are very useful measures of effectiveness for evaluating traffic performance.

Microscopic simulation based models have been used for many decades to simulate small-scale cases, such as signal phasing design. The new available feature of microscopic simulations is that it can be used now to simulate large-scale cases, such as simulating hurricane evacuation for entire regions with very dense population (Nagel and Rickert 2000).

The available evacuation models vary in their sophistication and ability to realistically model travel behavior. The assignment models are either static or dynamic. Regional models generally use Static Traffic Assignment (STA) models. The main disadvantage of the STA models is their inability to adequately capture the dynamics of the evacuation procedure since evacuation traffic is assigned to specific travel routes at the beginning of the simulation and those routes are preserved regardless of the traffic conditions.

Peeta and Ziliaskopoulos (2001) characterize Dynamic Traffic Assignment (DTA) as the new generation models in traffic simulation since the DTA addresses the unrealistic assumptions of the STA and deal with time varying flows.

There are many important prerequisites for the success of the traffic simulation model (Sisiopiku el al 2004). These include model elasticity, data collection and coding needs, cost, training requirements, user friendliness, estimated measures of effectiveness accuracy, and capability of the model to interact with other software. The choice of the model is usually a trade off between the accuracy level and the cost, data requirements, and time required for the simulation (Brooks 1996).

Numerous traffic simulation models have been developed for the assessment of emergency preparedness plans. Table 1 illustrates the most commonly used simulation models found in literature.

Transportation Analysis and Simulation System (TRANSIMS)

One of the reasons that the analysis of planning options associated with carless, special needs, and transit-based evacuations has been limited is the lack of appropriate modeling tools with the capability to incorporate the characteristics of various modes, behavior, and scale of the modes and evacuation.

The **TR**ansportation **AN**alysis and **SIM**ulation **S**ystem (TRANSIMS) was developed at Los Alamos National Laboratory (LANL) as part of the Federal Highway Administration's (FHWA) Travel Model Improvement Program (TMIP) to replace traditional macroscopic transportation planning models with microscopic, disaggregated demand models with one possessing the ability to model complex stochastic and dynamic nature of transportation systems (Rilett et al. 2000: Rilett and Doddi 2003).

With such capabilities, TRANSIMS was also theorized to be ideally suited for the purpose of wide-scale multimodal evacuation modeling. Although it was never developed or considered specifically for the purpose of evacuation, several previous reports have suggested its adaptability for such purposes.

Table 1. Traffic Simulation Models

Simulation Model	Classification	Use
TRANSIMS	Large scale microscopic	Modeling regions with several millions
CORSIM	microscopic	Modeling urban traffic conditions and advanced traffic control scenarios
VISSIM	mesoscopic	Modeling complex dynamic systems such as transit signal
INTRAS	microscopic	Modeling traffic conditions on freeways, ramps, and highway segments
INTEGRATION	microscopic	Simulate both freeways and arterials and evaluate ITS scenarios
MASSVAC	macroscopic	Forecast hurricane evacuation performance
MITSIMLab	microscopic	Model traffic operations
TransCAD	macroscopic	Conventional static model
Tranplan	macroscopic	Conventional static model
EMME/2	macroscopic	Conventional static model
Dynasmart-P	mesoscopic	Model route choice behavior
OREMS	microscopic	Model emergency and disaster evacuation
DYNEV	macroscopic	Enhanced to model regional hurricane planning process
NETVAC	macroscopic	Evacuation model
CTM	macroscopic	Evacuation model
PARAMICS	microscopic	Provides complete visual display
CORFLO	macroscopic	Simulates design control devices
GETRAM	microscopic	Simulates traffic and human behavior
PARAMICS	microscopic	High-performance microsimulation software
HUTSIM	microscopic	Object-oriented urban traffic micro-simulator
AIMSUN II	microscopic	Urban and non-urban networks
ETDFS	macroscopic	Evacuation model

Barrett et al. (1997) discussed the implementation of TRANSIMS in a test case study within the Dallas-Fort Worth region. This location was selected by LANL to be the first site for experiment to demonstrate the functionality of the TRANSIMS traffic microsimulation module.

The study simulated morning peak period (between 5:00 A.M and 10:00 A.M) traffic conditions for about 200,000 trips, with 3.5 million travelers, over 25 square miles. Later, Barrett et al. (2002) explored the effects of different types of data and sensitivity of TRANSIMS in Portland, Oregon. Detailed network coding, including that required by transit vehicles, for all urban streets and signalized intersections was built for the simulation. In 2000, Rilett, Kim, and Raney used a section of I-10 in Houston, Texas as a test bed to compare the TRANSIMS low-fidelity mesoscopic simulation model with CORSIM high-fidelity medium scale simulation model. It was found that the two models did equally well in replicating the baseline volume data with the coarsely calibrated TRANSIMS model able to predict the mean travel time within about 20 percent of a much more carefully calibrated high-fidelity CORSIM model. Kikuchi (2004) also evaluated TRANSIMS performance and feasibility in Delaware. As part of this work, two case studies were undertaken. One was on a detailed urban network (the Newark study), and the other was a less detailed suburban/rural network (the New Castle County Study). In these cases TRANSIMS was found to be a reasonable program for applications where information on congestion and emission were needed.

TRANSIMS provides a fundamental shift from the four-step model because each vehicle in the network is treated individually, rather than an aggregated flow type modeling as in the case of the four-step model, resulting in a more realistic simulation of the traffic conditions, and level-of-service (LOS) values can be associated with confidence or tolerance intervals. In contrast, the four step model tends to have range values at each step (Rilett 2001: Rilett, Kumar and Doddi 2003: Eeckhout el at. 2006). Rilett, Kumar and Doddi (2003) compared TRANSIMS to the traditional four-step process using TRANPLAN. It was found that TRANSIMS requires substantially more and different input data than the amount of data required for TRANPLAN.

Managing Evacuation

Many evacuation strategies have been suggested by researchers and planners to improve the efficiency of the evacuation process focusing on traffic conditions and highway network characteristics for the auto based evacuation (Wolshon et al. 2006: Kiefer and Montjoy 2006) ignoring the vital question on evacuating the disadvantaged population. Some researchers suggested scheduling evacuation where evacuation is conducted sequentially which would allow for more efficient use of the transportation network. In their study Mitchell and Radwan (2006) showed that evacuation clearance times can be improved by staging departure time strategies. Sbayti and Mahmassani (2006) investigated the benefits of zonal evacuation rather than simultaneous evacuation. It was found that scheduling evacuation improved network clearance time, total trip times, and average trip time. In another study, Chen and Zhan (2004) experienced simultaneous and staged evacuation strategies for different network configurations. The results indicated that the effectiveness of staged evacuation depends on the network configuration and traffic conditions.

Others researchers suggested reallocating the available capacity by reversing the direction of traffic in a tactic known as "contraflow". Theodoulou and Wolshon (2004) evaluated the traffic flow conditions on the entry/exit of contraflow segments on I-10 out of New Orleans under hurricane threat. In another study, Lim and Wolshon (2005) studied the contraflow termination points. Termination points are a critical issue in contraflow operations because they merge vehicles from the opposite direction of traffic which can lead to congestion and can affect safety. Ten models were developed to test different termination configurations. It was concluded that the split configuration is more advantageous than the merge configuration. Another finding is that by reducing the volume entering the termination point, the delay will be reduced. Another optimized evacuation contraflow model was anticipated by Tuydes and

Ziliaskopoulos (2004), using a modified CTM model. The proposed model determines roadway segments where contraflow tactics should efficiently be applied.

Another way to manage traffic during emergency evacuation which includes operational action to better utilization of the existing road network is signal optimization. Sisiopiku, el at. (2004) used CORSIM to simulate the evacuation effect as percentage increase in peak hour volume on the road network and found that signal optimization for evacuating traffic decreased the delay resulting from the increased traffic.

Also Cova and Johnson (2003) presented a network flow model for identifying optimal lane-based evacuation routing plans in a complex road network. The relative efficiency of various evacuation routing plans in nine intersection network were compared. It was found that channeling evacuation traffic at intersections significantly decreased the network clearance time by up to 40 percent compared to no routing plan.

Chapter 3. Methodology

The evacuation of New Orleans during Katrina in August 2005 did not include provisions to evacuate carless residents, tourists, and individuals with special mobility needs. Wolshon (2002) estimated that 200,000 – 300,000 people in New Orleans did not have access to reliable personal transportation and that only 60 percent of the region's 1.4 million inhabitants would evacuate. Fortunately, the Katrina evacuation was one of the most successful in American history, with approximately 1.2 million people evacuating by automobile within a 48 hour period (Wolshon and McArdle 2008). Despite this success, it received harsh criticism because many of the region's most disadvantaged citizens, including the elderly and disabled, were unable to evacuate (Cahalan and Renne 2007).

Since Katrina, the Federal government, the State of Louisiana, the City of New Orleans and Jefferson Parish have shown great interest in evacuation planning for low-mobility populations. The Department of Homeland Security's Catastrophic Hurricane Evacuation Plan Evaluation: A Report to Congress (2006) and the U.S. Government Accountability Office's (GAO's) Transportation – Disadvantaged Populations: Actions Needed to Clarify Responsibilities and Increase Preparedness for Evacuations (2006) highlight the need for research that can inform policy on carless and special needs evacuation planning.

This chapter describes a project to apply the TRansportation Analysis and Simulation System (TRANSIMS) for the non-auto based evacuation component of the microscale simulation in New Orleans Metropolitan Area.

The project was undertaken within a two-phase model development process. The first was the development of a baseline condition model and the second was the modification of this "Base Model" to reflect the multimodal regional evacuation plan that was developed after

Hurricane Katrina. The need to create the Base Model was important for several reasons. First, it sought to recreate the conditions that existed in the study area at the time of Hurricane Katrina. Since Hurricane Katrina, the population and land use characteristics have changed over vast areas of the city. Many people no longer live and/or work where they used to. Since the Base Model relied to a great degree on pre-2005 population and land use information and travel patterns, the model condition could be validated and calibrated to the observed travel patterns that occurred at that time. The following sections summarize the key steps of the model development methodology.

Base Model Development

In a previous work conducted by Wolshon et al. (2009), the Base Model was constructed using existing network and behavioral data. The base model was based on the events of Katrina evacuation of August 2005 so that its output results could be validated against actual field data collected during the Katrina evacuation.

The Base Model road network was constructed based on TransCAD network files that were made available by the Louisiana Department of Transportation (LA DOTD). In addition to the area road network, it also incorporated the population distribution databases collected and maintained by researchers at the University of New Orleans (UNO), evacuation decision structures, and routing option hierarchy in place during Hurricane Katrina. It also included critical temporal and spatial aspects such as the utilization of contraflow operation on several freeway routes and the timed closure of several other freeway routes as implemented by the LA DOTD and Louisiana State Police (LSP).

Evacuee departure times in the model were assigned to reflect the cumulative temporal pattern of traffic movements observed during the Katrina evacuation. Figure 1 shows the cumulative traffic volume distribution recorded during this period by the LA DOTD traffic data stations that ringed the New Orleans metropolitan region. As expected, the data from these stations revealed the commonly observed S-curve characteristic. More specifically, Figure 1 actually shows a double S-curve form since the New Orleans evacuation for Katrina took place over a two-day period. As the slope steepness of the curve is a function of the amount of traffic observed from hour to hour, the steepest curve segments reflect the peaks of the evacuation during the daylight hours of Saturday August 27th and Sunday August 28th. Similarly, the curve is much flatter during the beginning and ending of the evacuation as well as through the overnight hours of Saturday and Sunday when the rate of evacuee departures ebbed.

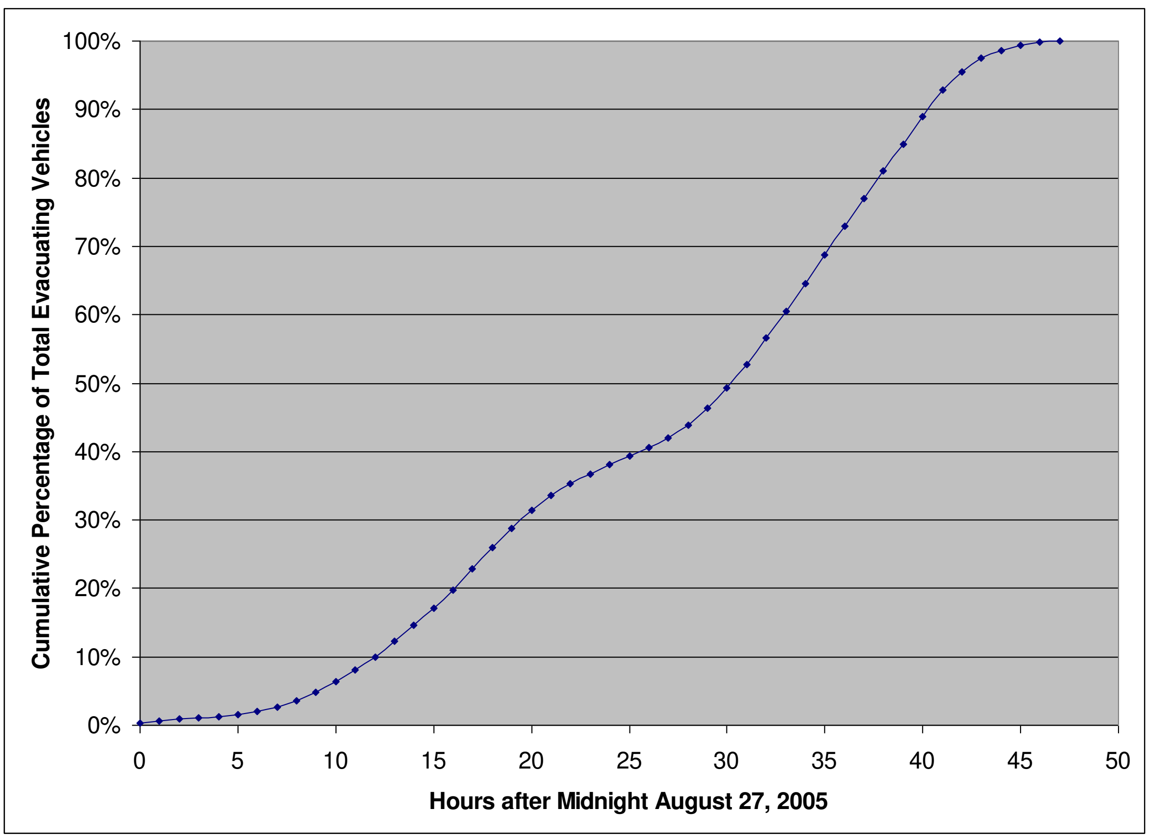


Figure 1. Temporal Cumulative Evacuation Outbound Traffic Distribution

The curve includes data from eleven different LA DOTD count stations located at various points along on three interstate and three US highways. A map showing the approximate locations of these stations within the New Orleans metropolitan region is shown in Figure 2. Together, these stations effectively cordoned the area to give a gross estimate of the number of evacuees and the general distribution of the direction of travel. It was from this distribution that the spatial assignment of evacuee departures was developed.

Departures in the simulation were generated on an hourly basis. The actual number of departures during any single hour of the 48 hours of the evacuation period was calculated by first determining the percentage of total number of evacuees from Figure 1, then multiplying it by the total number of evacuees in the study area which was 1,007,813 people. So, for example, since approximately five percent of the total evacuation traffic was recorded between the beginning of Hour 33 to the beginning of Hour 34 (i.e., 9:00 AM to 10:00 AM on Sunday August 28th), it was inferred that (0.05 * 1,007,813) or 50,391 evacuees departed during that one hour period.

After the Base Model was coded and verified, its output was validated. The validation process was based on the distribution of outbound evacuation traffic volumes throughout the metropolitan New Orleans region. The "ground-truth" volume distribution patterns that served as the basis of comparison came from data recorded during the Katrina evacuation by the LA DOTD. These volume patterns have been analyzed in rigorous detail in several prior studies (Wolshon and MacArdle 2008) and served to demonstrate the degree to which the TRANSIMS model output replicates the actual travel patterns observed during a real emergency.

Validation was accomplished using an iterative process by adjusting various model parameters and traffic assignment patterns to match the Katrina distribution patterns. The model was assumed to be "validated" once the observed-to-predicted volume discrepancies were within about 10 percent. Prior to concluding the validation process, the base model was also presented to representatives of the LA DOTD for their feedback as related to the 2005 Katrina evacuation.

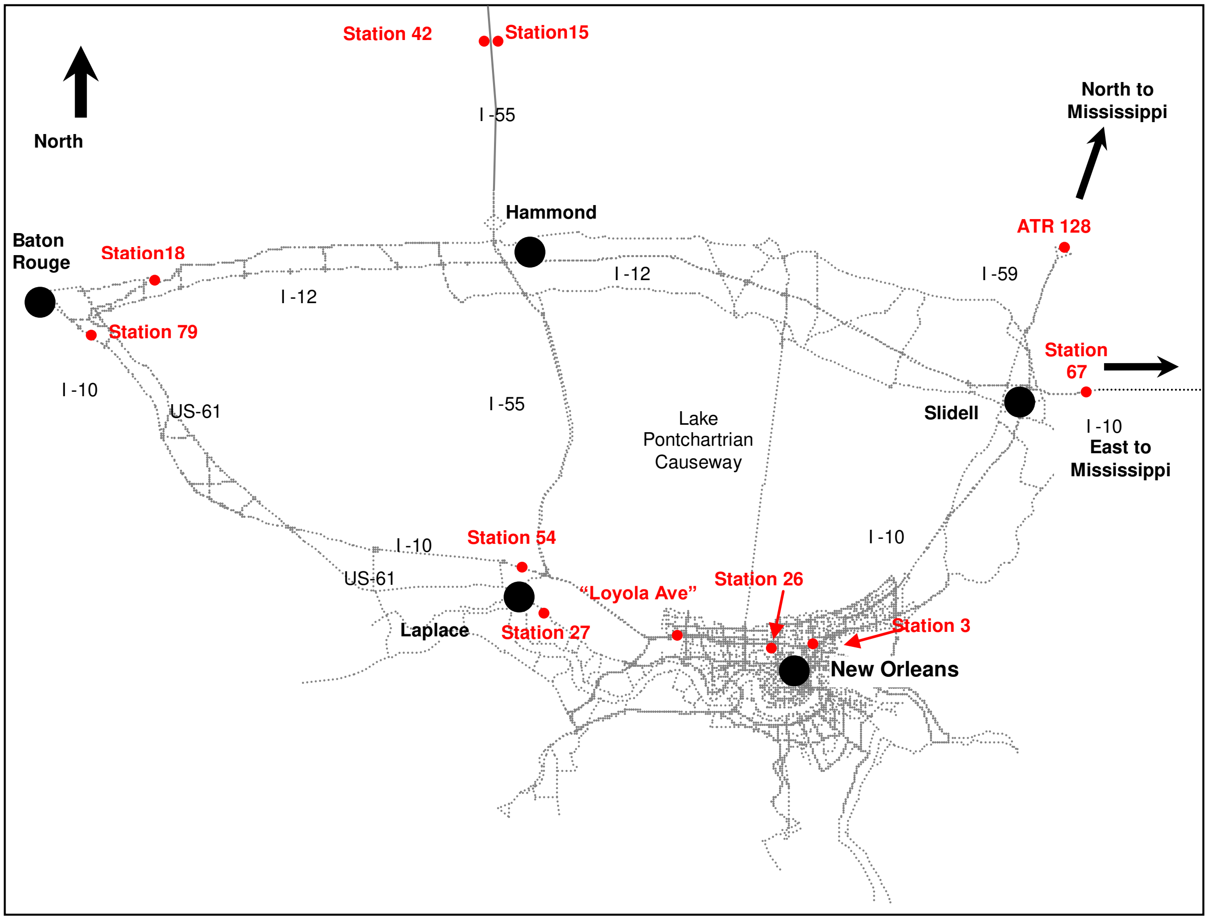


Figure 2. LA DOTD New Orleans Area Data Collection Stations

Using the Base Model as a starting point, the model was modified to reflect the multimodal approach to more effectively evacuate the region's low mobility populations.

Transit-Based Model Development

The original, "Base Model" focused solely on the auto-based self-evacuation traffic and did not explicitly incorporate any of the assisted evacuation plans - as they did not exist at that time. This section summarizes the application of TRANSIMS for the development non-auto based evacuation component of the microscale simulation of the New Orleans Metropolitan Area. It involved five primary component steps. The sequence of the steps is shown in Figure 3.

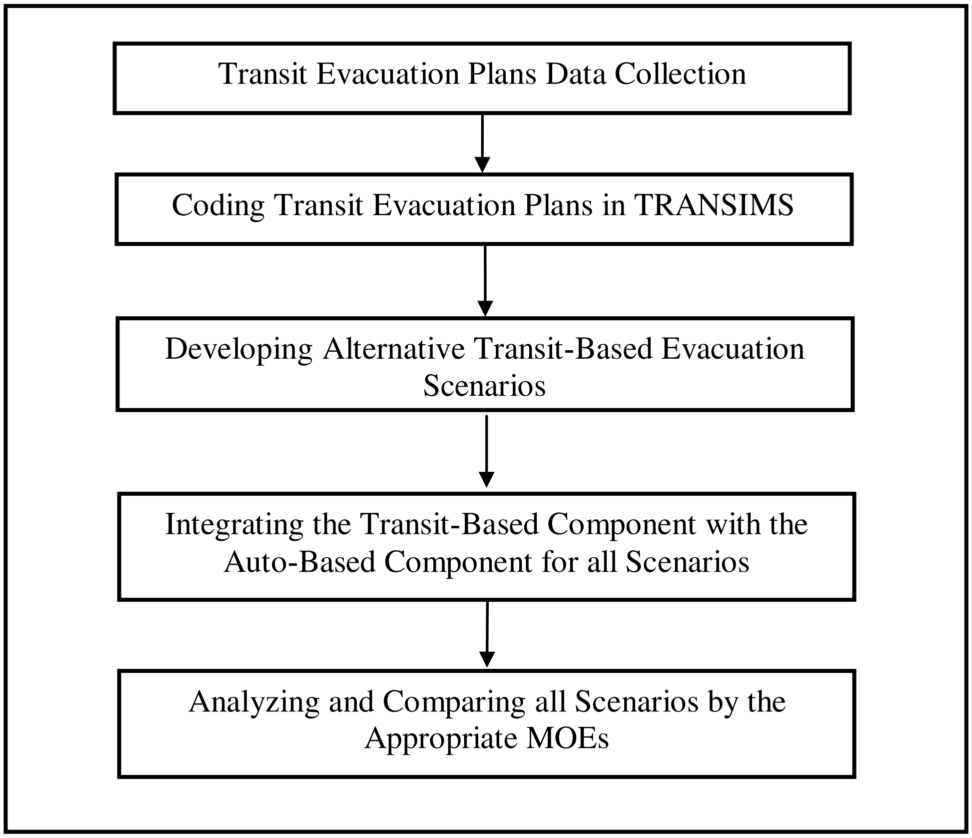


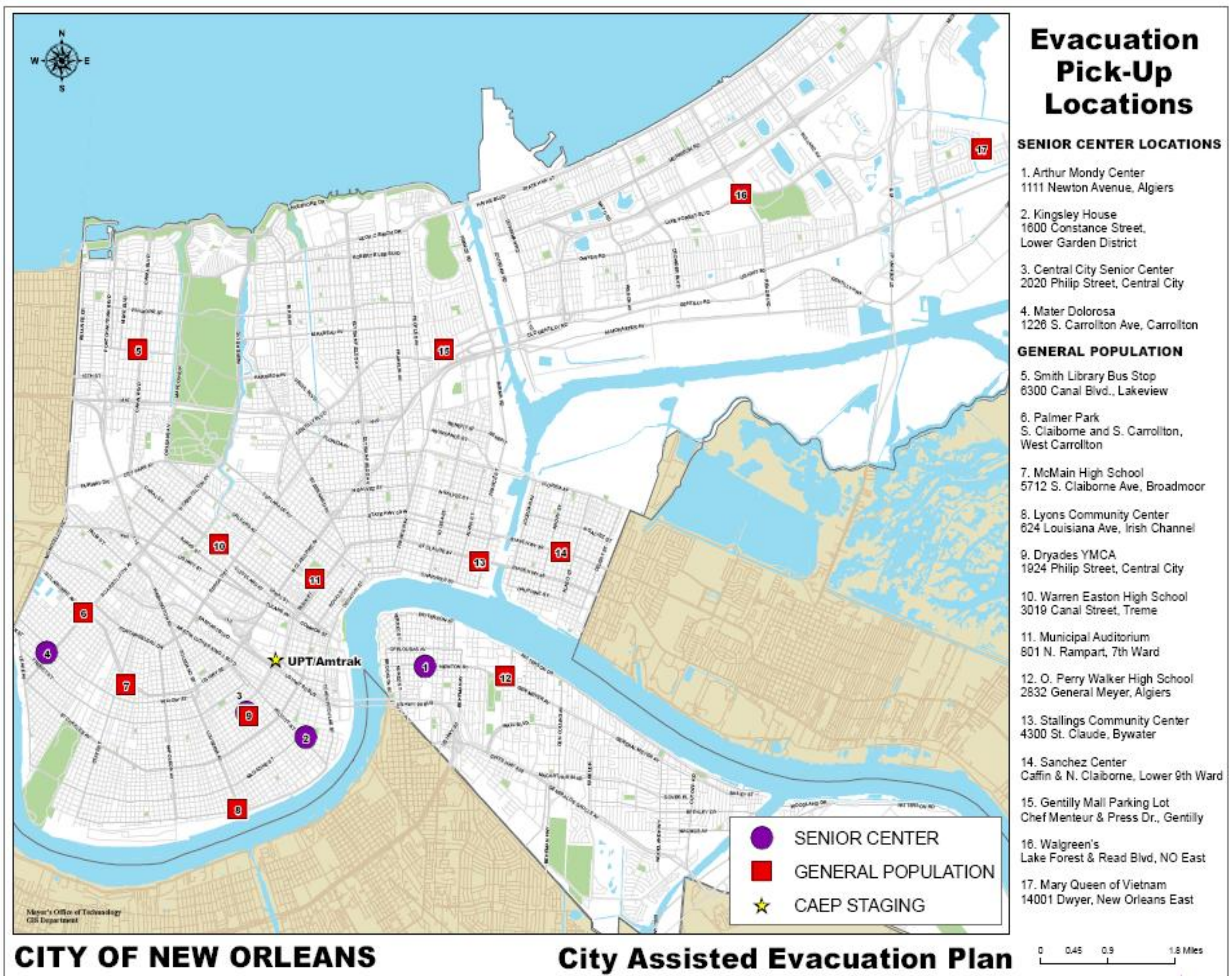
Figure 3. Study Methodology

Transit Evacuation Plans Data Collection

The key data necessary to code the model were drawn from The New Orleans 2007 City Assisted Evacuation Plan (CAEP, 2007) and from the 2007 Jefferson Parish Publicly Assisted Evacuation Plan. The following sections present the key assumptions, components, and statistics that were used by local authorities for the development of these plans.

<u>General Carless Evacuation Plan for the City of New Orleans</u>

The CAEP for the City of New Orleans estimated that 20,000 people would utilize transportation services during an evacuation of the area. Seventy percent of this total (14,000 people) would be expected to evacuate through the New Orleans Arena (NOA) on buses provided by the State of Louisiana. The remaining 6,000, assumed to be senior citizen evacuees, were expected to be evacuated by Amtrak at the Union Passenger Terminal (UPT). To reach the NOA or UPT, residents would need to first go to one of seventeen pick-up locations dispersed at various strategic points around the area. Of the seventeen locations, four are Senior Center Pick-up Locations (SCPLs) and the other thirteen were General Public Pick-up Locations (GPPLs). Figure 4 shows Orleans Parish senior and general pick-up locations.



(Source: CAEP)

Figure 4. Orleans Parish Pick-Up Locations

Tourist Evacuation

The CAEP has estimated that at any given time, the tourist population of New Orleans ranges from 5,000 to 50,000 people depending on any specific event that may be occurring. Assuming that a large percentage of the tourist population would be able to self-evacuate using personal vehicles or rental cars, not more than 20 percent of them should need evacuation assistance. For simulation development purposes it was assumed that not more than 10,000 tourists would need evacuation assistance.

The CAEP also states that tourists would be processed at one of two hotel staging centers (HSCs), although the location of the HSCs would not be announced until 84 to 60 hours before the projected arrival of tropical storm force winds and RTA would not begin airport runs until the hour 58 before landfall of tropical storm force winds (H58). For the purpose of this study, it was assumed that all assisted tourist evacuees would be processed in the French Quarter area, the main tourist hub of the city. These tourists would then be transported to the New Orleans International Airport (MSY) where they would be flown out of the region. Also it was assumed that RTA will begin airport runs at H54 instead of H58 to be able to evacuate all tourists before the airport shuts down its service.

Jefferson Parish Publicly Assisted Evacuation Plan

Jefferson Parish is the neighboring jurisdiction to the west and south of the City of Orleans. It also encompasses several of the most highly populated cities in the area, including significant percentages of households known to lack access to personal transportation.

The Jefferson Parish Publicly Assisted Evacuation Plan has assumed that 10,000 – 15,000 residents are carless. The public assisted evacuation plan includes six bus routes, three on the east bank side of the Mississippi River and three on the west bank. Figure 5 shows Jefferson

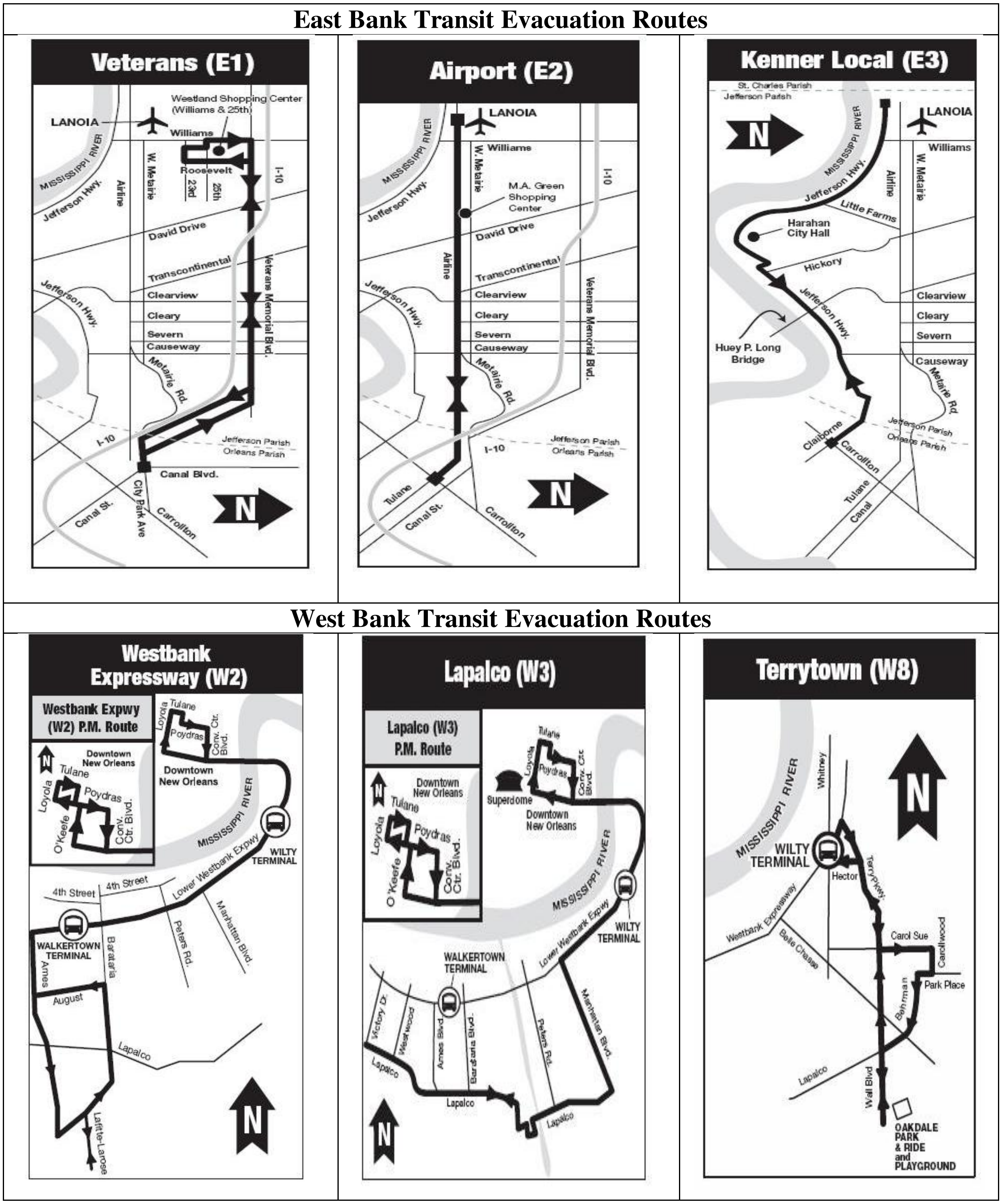
Parish transit evacuation routes. The plan also calls for at least one processing center on each side of the Mississippi River (referred to as PPP sites). For the purposes of this study, it was assumed that 10,000 people would utilize these services in Jefferson Parish.

Coding Transit Evacuation Plans in TRANSIMS

Figure 6 shows a schematic diagram summarizing the general flow of the coding methodology that translated the assumed assisted evacuation characteristics into TRANSIMS model. The first step in the process required the creation of the model *Highway Network* of the region including its key characteristics (speed, number of lanes, control, etc). This network also served as an input to the *Transit Network* and to spatially distribute the synthetic population.

The second step of the development process involved the creation of a representative population of people and households in the study area using the TRANSIMS Population Synthesizer module. The synthetic population was based on the 2000 US Census aggregated data and the disaggregate data from Public Use Microdata Samples (PUMS). Land use data was also used to locate households relative to the transportation networks. In the third step, the Transit Network for the transit evacuation plans was coded into TRANSIMS. The synthetic population and the household activity survey files were used to feed the TRANSIMS Activity Generator module. The Activity Generator assigned travel activity patterns to individual household members and distributed these activities to location and modes. In the special case of the assisted evacuation model, these were all distributed to the transit mode.

The synthetic activity and the Transit Network served as inputs to the TRANSIMS Router module to generate travel plans for evacuation trips. Finally, all of the transit movements and their interactions within the network were generated by the TRANSIMS Microsimulator module using the travel plans generated by the Router.



(Source: Publicly Assisted Evacuation Plan)

Figure 5. Jefferson Parish Transit Evacuation Routes

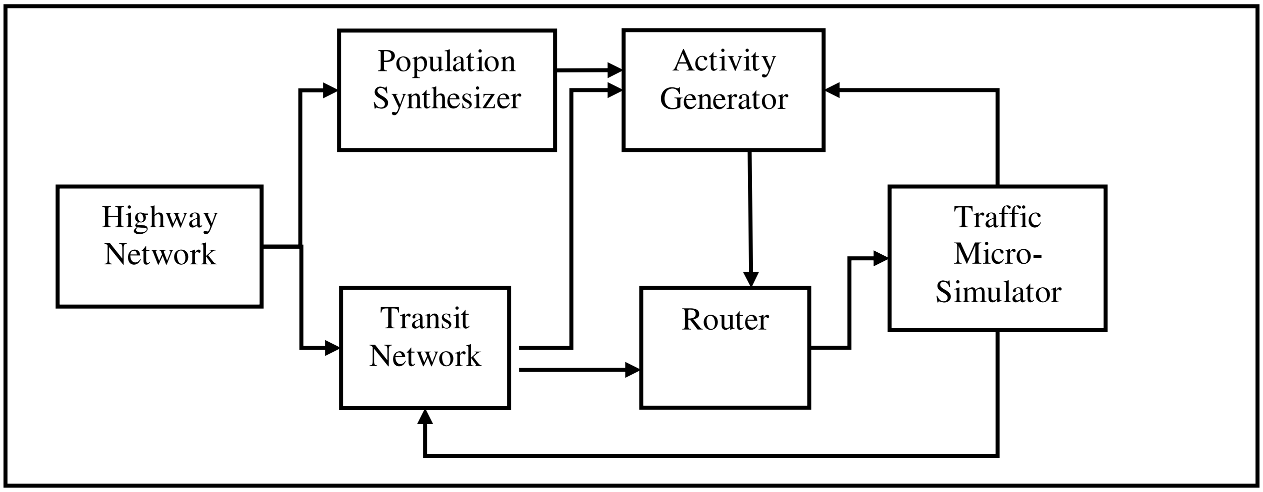


Figure 6. Coding Methodology

<u>Transit-Based Model Development Programs</u>

The most useful programs within the TRANSIMS system used in developing and modifying the transit-based emergency evacuation model for the carless population along with a brief description of the manner in which they were used, are described below:

- TransitNet: reads input data associated with transit routes, such as bus headways, route nodes, etc. This routine also produced a complete set of TRANSIMS transit files.
- ArcNet: enables us to display and edit the transit network on ArcGIS maps.
- ActGen: allocates activity patterns to household members and then distribute those activities to activity locations and defines the travel mode used to travel to that location.
- Route-Planner/Router: creates a Plan file for trips with minimum impedance between origin and destination based on the travel conditions at the specific time of the day.
- PlanPrep: organizes the Plan files for efficient implementation of the Microsimulator. Plan files were typically sorted by start time. If they were not, the Microsimulator was found to encounter errors that would result in an inability to run the program.

- Microsimulator: executes the plans generated by the *Router*.
- ReSchedule: reschedules the transit arrival/departure trips upon the actual field conditions produced by the Microsimulator.

Each of these programs is described in greater detail in Appendix.

<u>Transit Network Development</u>

For the study, transit evacuation routes were modeled using two categories. The first category, referred to as the "internal evacuation routes," was created to move evacuees from the designated pick-up locations around the parishes into the Orleans and Jefferson Parish processing points. These internal routes included:

- 17 routes from the seventeen pick-up locations in Orleans Parish to the NOA /UPT processing centers,
- Six transit routes in Jefferson Parish,
- One tourist evacuation route from the French Quarter to the New Orleans airport (MSY).

The second category was created for the "external evacuation routes." These were coded to transport evacuees from the processing centers to safe shelters outside of the immediate threat area within metro New Orleans and to designated regional shelter areas and included:

- Three evacuation routes from the NOA processing center to evacuate people to shelter locations in Hammond, Baton Rouge and the Alexandria areas, and
- Two evacuation routes from each processing center in Jefferson Parish to evacuate people to areas in Hammond and Baton Rouge.

Assumptions Used in Coding the Transit Network

This section presents general and specific assumptions used in coding the transit network into TRANSIMS. TRANSIMS TransitNet program was used for this purpose.

- Routes in Orleans parish followed Google Earth and Map Quest shortest path while routes in Jefferson parish followed their specified paths.
- No other local or RTA regular buses were assumed to run.
- The bus routes would only stop at two locations which are at the pick-up locations and the processing centers for the internal evacuation routes and at the processing center and the final destination for the external evacuation routes.
- Train routes were not considered because it would not affect the traffic operation during evacuation.
- The loading and unloading times were assumed to be 1,200 seconds.
- Two separate control files were created, one for the tourist evacuation route and the other one for Orleans and Jefferson Parishes, internal and external, evacuation routes. That is because the tourist population was not considered part of New Orleans carless population.

In order to review the synthetic transit network, the TRANSIMS transit network was converted to a series of *ArcView* shape files using *ArcNet* program which enables us to display and edit the transit network on *ArcGIS* maps.

External Evacuation Routes Scenarios

In the study, two alternative transit-based evacuation scenarios were developed and tested for each external evacuation route. In the first routing scenario, Scenario 1, bus trips were all required to travel on I-10, the only Interstate freeway serving the New Orleans region. In the second routing scenario, Scenario 2, bus trips were routed exclusively to US-61 a four-lane non-accessed-controlled regional arterial route known locally as Airline Highway.

The routing alternatives were developed to reflect potential plans that could be used to gain a better utilization of the available capacity within the network by shifting transit traffic to the historically more-underutilized parallel route to the freeway. It was thought that this might also have the added benefit of reducing traffic congestion on I-10, thereby improving the overall efficiency of the evacuation process. Another reason for developing the evacuation routing scenarios was that they could also be used to assess alternative evacuation routing strategies in the event of incident-induced closure of the freeway.

Figure 7 shows the internal evacuation routes in Orleans and Jefferson Parishes and Figure 8 shows the external evacuation routes and scenarios.

Transit Headways

The first step to determine the transit headways for each internal evacuation route was to determine the number of transit dependent evacuees at each pick-up location. Geographic Information System (GIS) technique was used for this purpose. The number of households with zero vehicle ownership within 3,000 meter, the maximum assumed walking distance, catchment area for each pick-up location was determined then it was proportionally distributed to represent the 30,000 transit dependent evacuees in the metropolitan area. Then, the transit headway time periods were divided according to the evacuees' departure times determined from the assumed demand generation and network loading scenarios which will be discussed in more details in the temporal distribution section of this chapter. Finally, the transit headways for each route were assigned values to serve the expected number of evacuees at each pick-up location for each time period.

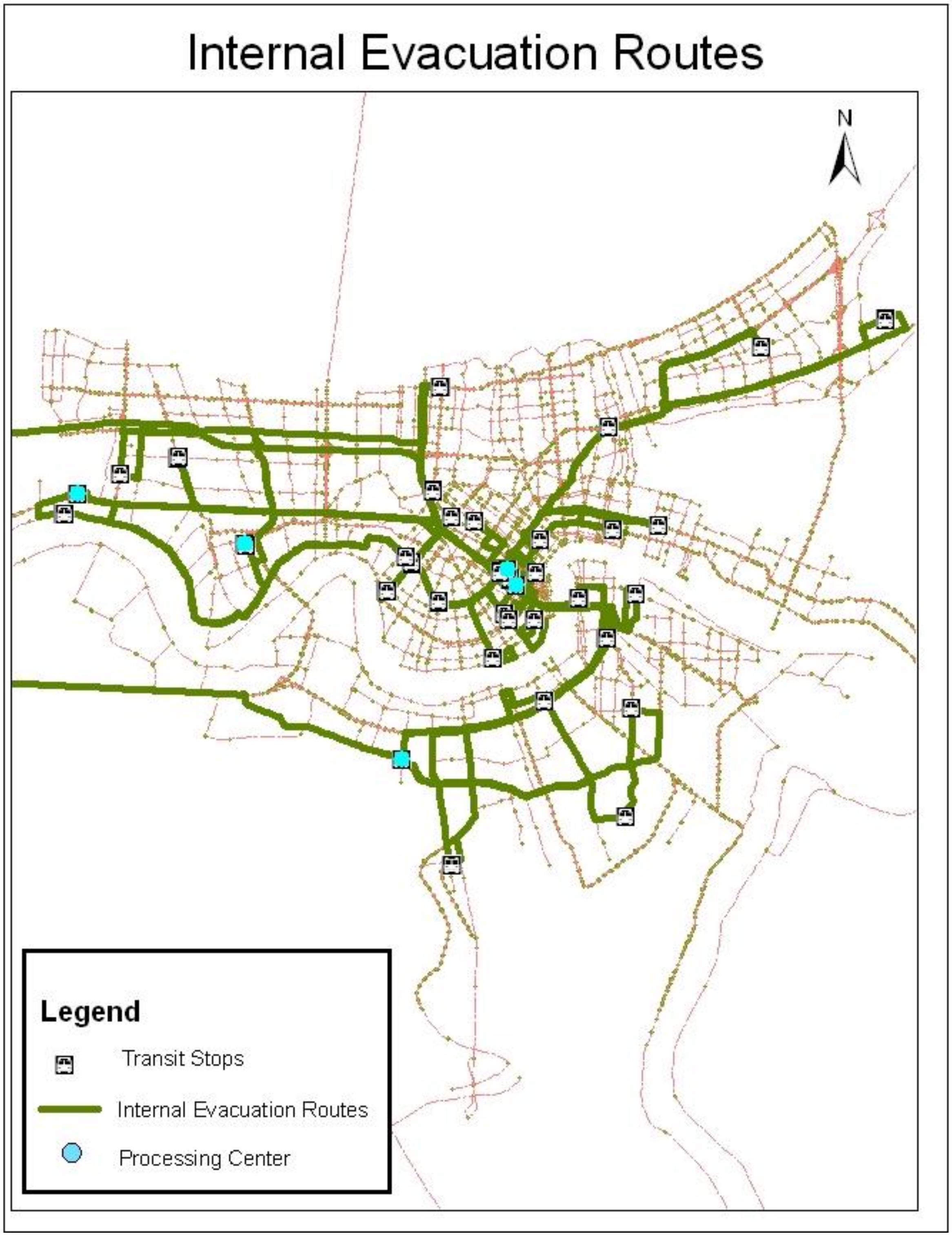


Figure 7. Internal Evacuation Routes

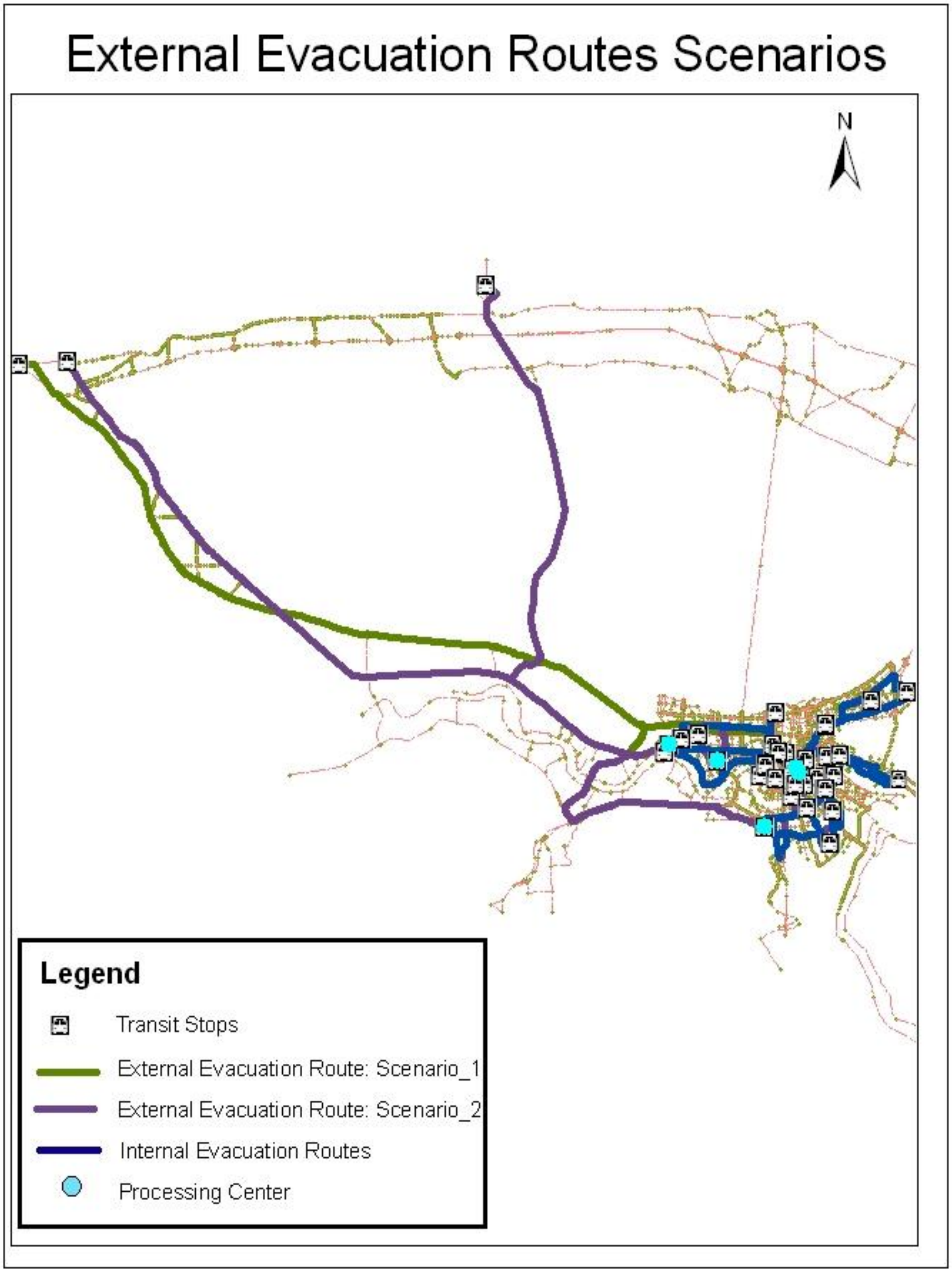


Figure 8. External Evacuation Routes and Scenarios

The same procedure was done to determine the transit headways for the external evacuation routes except for the first step, because the number of evacuees arriving at each processing center at each time period was known from knowing the departure rate for the internal evacuation routes.

Table 2 shows the estimated number of evacuees served by pick-up location in Orleans Parish and Table 3 shows the estimated number of evacuees served each route in Jefferson Parish.

Generation of Evacuation Travel Activity

This section describes the processes and assumptions used to develop travel activities for the TRANSIMS simulation of the carless evacuation of New Orleans. TRANSIMS uses the ActGen program to allocate activity patterns to household members and then distribute those activities to activity locations and define the travel mode used to travel to that location. The ActGen program uses household activity survey to define the activity patterns, activity schedule, and travel modes assigned to each household member in the synthetic population. Since no household activity survey for evacuation purposes was found, a new household activity survey was created with the following temporal and spatial assumptions.

Temporal Distribution

After the basic conditions, configuration, and characteristics of the model were developed, efforts focused on loading transit traffic onto the network to reflect the various expected conditions. Within the two routing strategies, four network loading and departure time scenarios were also developed to suggest different conditions that could occur during the evacuation process as well as to investigate the movements of carless citizens as they departed the threatened areas in increasingly urgent levels.

Table 2. Evacuees Distribution Across Pick-up Locations in Orleans Parish

Route ID	Pick-up Location	Households Per Catchment Area	Population Per Catchment Area	Population Per Pick-up Location
1	French Quarter		10,000	10,000
2	Arthur Mondy Center	2,679	5,636	988
3	Kingsley House	8,573	11,243	1,971
4	Central City Senior Center	5,613	11,865	2,080
5	Mater Dolorosa	2,260	5,482	961
6	Lyons Community Center	4,919	4,860	852
7	Mary Queen of Vietnam	909	1,785	313
8	Walgreen's Lake Forest	1,946	2,795	490
9	McMain High School	4,614	4,883	856
10	Municipal Auditorium	8,738	8,898	1,560
11	Perry Walker High School	2,187	3,827	671
13	Stallings Community Center	4,506	5,242	919
14	Warrens Easton High School	7,663	11,614	2,036
15	Sanchez Center	3,272	3,810	668
73	Smith Library Bus Stop	856	935	164
75	Gentilly Mall Parking Lot	1,377	2,333	409
90	Palmer Park	6,301	6,737	1,181
105	Dryades YMCA	8,464	8,773	1,538
	NOA	9,130	13,359	2,342
Total		84,007	124,077	30,000

Table 3. Evacuees Distribution Across Pick-up Locations in Jefferson Parish

Route ID	Route Name	# HH Per Catchment Area	Pop. Per Catchment Area	Pop. Per Pick-up Location
42	West bank Expressway	2,809	12,766	2,238
45	Lapalco	1,075	6,138	1,076
47	Terrytown	1,556	7,085	1,242
PPP/West Bank	Alario Center	865	2,533	444
48	Veterans	3,071	7,113	1,247
50	Airport	4,421	6,674	1,170
52	Kenner Local	7,492	13,787	2,417
PPP/East Bank	Yenni Building	408	947	166
Total		21,697	57,041	10,000

Using these ideas, a total of eight scenario-specific test cases were developed and executed as part of this portion of the study. Table 4 summarizes the assumptions made in creating these scenarios. As shown in leftmost column of Table 4, each of the two primary scenarios (I-10 and US-61) was accompanied by four sets of network loading scenarios. Each of these four network loading sub-scenarios is shown in the next column of the table (A through D). These sub-scenarios were used to represent different levels of urgency at which the transit-assisted evacuation could be required to be carried out. Such conditions could occur if all busses were or were not available or in the case of changing storm characteristic when conditions might limit the amount of time available to carry out an evacuation. To be able to make direct comparison between only varying transit conditions and to limit the number of scenarios to a reasonable number, the auto-based self evacuation was assumed to take place over the "typical" period of 48 hours in all cases.

In sub-scenario A, the transit-assisted evacuation was assumed to take place over a 24 hour period. In sub-scenario B, it was over a 42 hour period, then over 18 hours and 34 hours for sub-scenarios C and D, respectively. Also of note in the table are the evacuee departure periods for each of these sub-scenarios. These periods were used to reflect how individuals within the carless households would depart. The conditions were varied so that they would tend to cluster their evacuations within various combinations of daytime and night time hours. These variations were used to test the effect of offsetting the potentially competing peaks of the auto-based and transit-assisted evacuation processes.

The four loading scenarios developed for the study are also graphically represented by the response curves shown in Figure 9 which reflect the cumulative rates of departure of each scenario shown in Table 4. Each of the response curves are expressed as cumulative rate of evacuee departure times by time period and follow a general S-shape following the recent state-of-the-practice (FEMA and Army Corps of Engineers). The shape of the curve for any particular scenarios was based on the specific assumptions of the network loading and evacuee departure time that was coded into TRANSIMS then produced as output from the *Activity Generator*. Although each of the evacuation scenarios differed in terms of the urgency at which evacuees departed, all over the curves extend to Hour 42. This was because the tourist departure time extended through 42 hour period in all cases. Although all curves also extend to Hour 48 (as that was the total length of the simulation) no additional assisted-evacuees were introduced into the system beyond Hour 42.

Spatial Distribution

The final component to the generation of evacuation travel activity was the assignment of evacuee shelter destinations or travel direction based on The New Orleans 2007 City Assisted Evacuation Plan (CAEP) and the Jefferson Parish Publicly Assisted Evacuation Plan.

Table 4. Evacuation Scenarios Summary

Evacuation Route Scenario	Network Loading Scenario	Evacuee Departure Time Periods (hr)	Cumulative Rate (Percent)
Scenario 1: Transit Evacuation on I-10	1A	0-8	22
		8-20	89
		20-24	100
	1B	0-6	8
		6-22	59
		22-28	62
		28-42	100
	1C	0-10	60
		20-28	100
	1D	0-6	8
		6-22	74
		22-28	82
		28-34	100
Scenario 2: Transit Evacuation on US-61 (Airline Highway)	2A	0-8	22
		8-20	89
		20-24	100
	2B	0-6	8
		6-22	59
		22-28	62
		28-42	100
	2C	0-10	60
		20-28	100
	2D	0-6	8
		6-22	74
		22-28	82
		28-34	100
Tourists	*	0-**	100
Seniors	*	8-**	100

Notes: (*) All Network Loading Scenarios and (**) Until all tourists and seniors evacuate

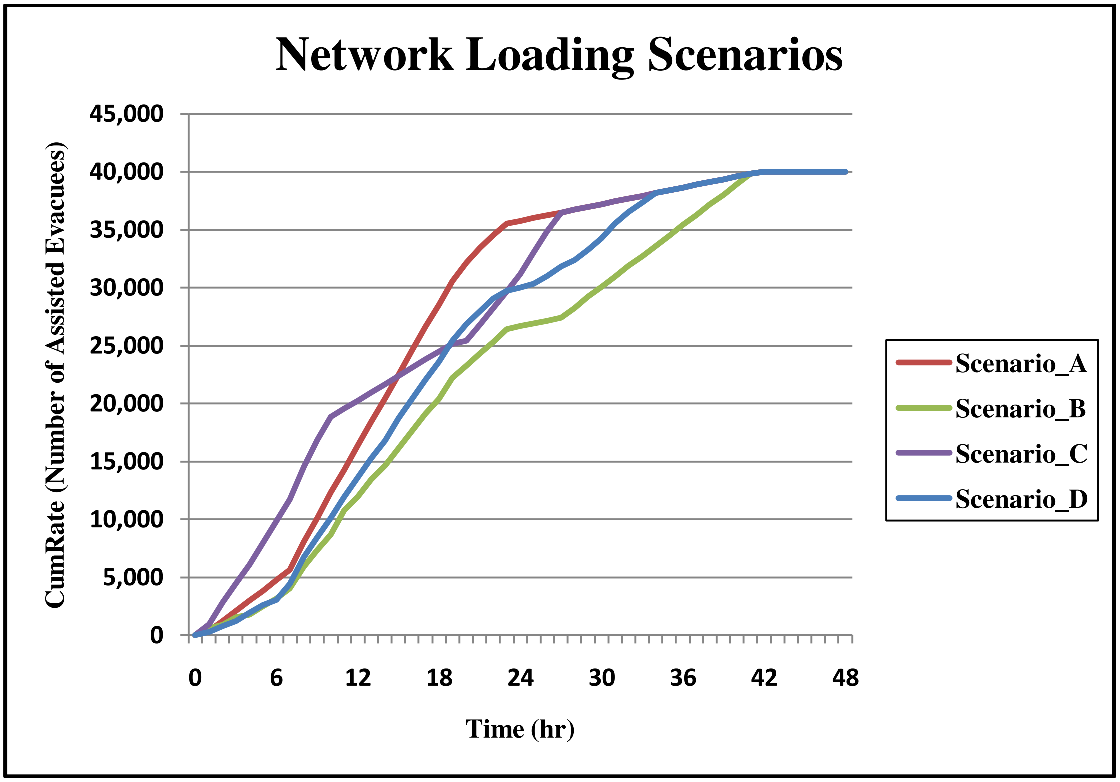


Figure 9. Network Loading Scenarios

Table 5. Evacuee Travel Direction

	Destination	Demand (Persons)	Percentage of Evacuation Demand
New Orleans Carless Population	**Hammond**	9,667	5.65%
	Baton Rouge	9,667	5.65%
	Alexandria	4,666	2.72%
	UPT	6,000	3.51%
	Auto Evacuation	141,124	82.47%
	Total	171,124	100%
Tourist Carless Population	**MSY**	10,000	100%*
Total Carless Population		181,124	100%

Note (*) Tourists were not included in the population of the study area

In the transit-based evacuation model 171,124 people were classified as carless evacuees. Of these persons 141,124 persons (14.1 percent of New Orleans total population and 82.47 percent of the carless population) were assumed to be able to be transported by friends, family members, or other acquaintance, the remaining 30,000 carless individuals (17.53 percent of New Orleans carless population) were assumed to require transportation assistance through the publically supported evacuation assistance program. An additional 10,000 tourists were also part of the transit-based evacuation model.

Table 5 shows the percentage of evacuees assigned to each travel direction. It can be seen that:

- 5.65 percent of New Orleans carless population will evacuate to the Hammond (4667 person from Orleans Parish and 5000 person from Jefferson Parish).
- 5.65 percent of New Orleans carless population will evacuate to Baton Rouge (4667 person from Orleans Parish and 5000 person from Jefferson Parish).
- 2.73 percent of New Orleans carless population will evacuate to Alexandria (4667 person from Orleans Parish)
- 3.51 percent of New Orleans carless population will evacuate to the UPT (6000 senior evacuees from Orleans Parish)

Survey Files Preparation

The survey data are presented in three files: a household file which describes the number of persons and vehicles in the household, a population file which consists of a data record for each person in the household; (these records identify the person's age, gender, and work status), and an activity file which includes the sequence of activities carried out by each household member over the course of a day. The purpose, start time, end time travel mode, vehicle number, number of passengers, and location is provided for each activity.

Separate survey files were created for each network loading scenario. The household activity survey was composed of 1,150 households (3795 persons) representing the 171,124 carless people. Households with zero vehicle ownership, who were expected to represent transit evacuees, were randomly selected from the synthesized population which was an output of the population synthesizer. The evacuees' departure time followed the following distribution:

- Network loading scenario A: 124 persons departed in the time period (0-8), 379 persons departed in the time period (8-20), and 63 persons departed in the time period (20-24).
- Network loading scenario B: 45 persons departed in the time period (0-6), 289 persons departed in the time period (6-22), 17 persons departed in the time period (22-28), and 215 persons departed in the time period (28-42).
- Network loading scenario C: 340 persons departed in the time period (0-10), and 226 persons departed in the time period (20-28).
- Network loading scenario D: 45 persons departed in the time period (0-6), 374 persons departed in the time period (6-22), 45 persons departed in the time period (22-28), and 102 persons departed in the time period (28-34).
- 141 persons representing the 6,000 senior populations departed in the time period (0-11) under all network loading scenarios.
- The remaining 3,317 persons represented the 141,124 persons who were assumed to be able to be transported by friends, family, or neighbors.

In the survey, under all network loading scenario, 228 persons evacuated to Hammond, 228 persons evacuated to Baton Rouge, 110 persons evacuated to Alexandria, and 141 persons evacuated to the union passenger terminal.

The tourist population was not considered part of the synthesized New Orleans population. Separate population files representing 10,000 tourists were created as well as a separate household activity survey. The tourist activity survey was composed of 100 households. The tourist departure time started at the hour 0 and was extended to the hour 42. 100 percent of the tourist transit dependent evacuees evacuated to New Orleans international airport. All surveys were assumed to be conducted over 48 hours. Each person activity started at home and ended at home and included walking from their home to the bus stop then loading and unloading from the local to the regional buses and finally returning home. It was also assumed that maximum of 40 people would fit in each bus. Finally H54, the time when transit evacuation started, was assumed to be 12:00 am representing Hurricane Katrina conditions. A sample of the survey files is provided in Appendix.

Generation of Evacuation Travel Demand

In TRANSIMS, the Route Planner or Router generates the travel demand by creating travel paths called plans for the synthesized household activities produced by the activity generator. It creates paths with minimum impedance between origin and destination based on the travel conditions at the specific time of the day.

General Assumptions

- Maximum walking distance per leg was 3,000 meter,
- Walking speed was1.5 m/sec,
- Maximum possible number of transfers was assumed as two to transfer travelers from local to regional buses, and
- No more than 180 minutes of maximum waiting time at any bus stop.

Transit-Based Model Simulation

The TRANSIMS Microsimulator program simulated the transit movement and its interaction with the network using the travel plans generated by the Route Planner and assuming that only transit vehicles are on the network. In this part of the study multiple iterations were done between the Microsimulator and the Activity Generator or between the Microsimulator and the TransitNet programs in order to produce the 30,000 transit dependent evacuees in Orleans and Jefferson Parishes and the 10,000 tourist transit dependent evacuees. The iterative process was accomplished by adjusting the departure times and the transit headways.

Model Integration

This section describes the process of integrating the auto-based evacuation component with the transit-based evacuation component of the project for comparing and evaluating the performance of different transit-based evacuation scenarios. As mentioned earlier, the auto-based component of the project had been already coded into TRANSIMS as a previous study and the transit-based component of the project was built and tested as described in the previous sections. TRANSIMS PlanPrep program was used to merge both components of the model into a single integrated model representing New Orleans multimodal regional evacuation plan. It worth mentioning here that the Transportation Analysis and Simulation System (TRANSIMS) is the only program capable of modeling such an integrated model.

The integration process simply starts with merging the plan files of the auto-based evacuation model with the transit-based evacuation model using the PlanPrep program which generates one single plan file for both models. This plan file was organized by traveler ID. In order to simulate the integrated plan file, the plan file should be sorted by time. If it was not, the Microsimulator was found to encounter errors that would result in an inability to run the program. The PlanPrep program was used again to sort the integrated plan file by time of the day. Finally, the Microsimulator was used to execute the sorted plans and generate the reaction of the transportation system to the travel demand or the interaction between the demand and supply.

At this stage, the Microsimulator produced unrealistic transit travel times because the transit evacuation plan file was constructed in the transit-based evacuation model assuming only transit vehicles are on the network and not taking into consideration the traffic conditions on the network when integrating the transit-based evacuation model with the auto-based evacuation models. To address this issue, the LinkDaly file from the first integration process, which represents the traffic conditions on the network, was fed into the TRANSIMS ReSchedule program which generated new sets of transit files. Then new travel demand (plan) files were reproduced by the Router for the transit-based evacuation models and finally the rescheduled transit-based evacuation models were reintegrated with the auto-based evacuation model as described in the previous paragraph.

Once the separately developed transit-based and auto-based (the original "base model") models were integrated into a single unified model, the New Orleans multimodal evacuation simulation model was ready for execution. A total of five individual simulation runs, each using different random seed numbers, were executed for each of the eight integrated evacuation model scenarios. Five simulation runs were considered adequate because we were looking at the aggregated values over the entire simulation period (Jha et al., 2004). This resulted in a total test set of forty simulation runs. The additional simulation runs were also necessary to establish stochasticity within the output so that statistical testing could be carried out. Although the specific computational time varied for each run, the average computer run time was about eight hours for each case. This eight hour run time was consistent among all of the model runs. The results reported in the next chapter reflect the average of the comparative measures of effectiveness computed for each of the five separate scenario-specific runs.

Selection of Performance Measures for Analysis

An evacuation condition involves increased traffic demand along the evacuation routes as well as the feeder facilities. The additional traffic demand is expected to affect the average travel time, average travel speed, queue length and most importantly the total evacuation time.

The performance measures that were selected for scenario comparison purposes included average travel time and total evacuation time and the performance measures used for testing the impact of including transit vehicles on the network traffic operation included average travel speed and average queue length at specific roadway sections.

Chapter 4. Results

Two alternative evacuation transit routing scenarios and four alternative transit network loading scenarios were developed as described in Chapter 3. In this research study, average travel time and total evacuation time were selected to compare the effectiveness of different transit-based evacuation scenarios. Average travel speed and average queue length were used to evaluate the potential impact of including the transit-based evacuation on the network traffic operations. Further analysis was also done to evaluate the transit-based evacuation plan such as average time spent not on transit (e.g. evacuees walking to and/or waiting at pickup locations) and the estimated number of buses needed for the carless evacuation. The main findings are discussed in the following sections.

Comparison of Various Evacuation Scenarios

The first set of performance comparisons focused on the different network loading scenarios within each routing scenario (e.g. 1A vs. 1B vs. 1C vs. 1D, etc.) followed by comparisons of same network loading scenarios under the two different evacuation routing scenarios (e.g. 1A vs. 2A, 1B vs. 2B, and so on). The two performance measures used for the basis of comparison were the “total evacuation time” and the “average travel time.” These two performance measures were selected because of their relevance to the development and evaluation of evacuation plans. They also demonstrated the overall efficiency of the evacuation plans. Total evacuation time is among the most important measures of evacuation performance to emergency planning decision-makers because it reflects the time required to complete the full evacuation of the population at risk. Average travel time, defined as “the average time spent travelling on transit from the beginning to the end of an evacuation trip,” is of interest to transportation planners because it reflects time spent moving as well as any delay time that results from en route congestion.

Total Evacuation Time

The analysis of total evacuation time began by comparing the different network loading scenarios on the same routing scenario and then comparing similar network loading scenarios on different routing scenarios focusing on the most efficient one. In this research, the aggregate total evacuation times from both parishes (Orleans and Jefferson) were compared first. Then separate evacuation times were computed and compared based on the various possible evacuation travel directions from each parish.

Comparing Different Network Loading Scenarios on the Same Routing Scenario

A comparison between the total evacuation time required to evacuate all transit-dependent evacuees using different network loading scenarios (A, B, C and D) on the same evacuation route (I-10 or US-61) is included in Table 6 through Table 13. The analyses also include the statistical significance of the difference between the scenarios. Statistical analyses of the data were performed using analysis of variance (ANOVA) testing at a 95 percent level of confidence to determine if the total evacuation time differed among the four network loading scenarios. To accomplish this, the following null and alternative hypotheses were used:

- Ho: Total evacuation time, on the same routing scenario, for the four network loading scenarios are equal
- H_1: Total evacuation time, on the same routing scenario, for at least one of the four network loading scenarios differs

If the test confirmed that the total evacuation time for at least one network loading scenarios were different then additional statistical analyses using the two sample t-tests were performed. The t-testing was used to compare relative effectiveness, by determining if the total evacuation time was shorter than another of any specific scenario. The t-tests, carried at 95 percent level of confidence, also help to show which scenarios were different and the statistical significant difference between them. In these tests, the following null and alternative hypotheses were used:

- Ho: Total evacuation time, on the same routing scenario, between two different network loading scenarios is equal
- H_1: Total evacuation time, on the same routing scenario, between two different network loading scenarios differs

Table 6 presents the ANOVA results of the aggregate total evacuation time from both parishes, using different network loading scenarios, on the same evacuation route (I-10 or US-61). From Table 6, it was concluded that a significant difference existed in the total evacuation time in the network loading scenarios and at least one network loading scenario differed for both routing scenarios. This meant that at least one network loading scenario had an overall shorter total evacuation time than the others and that more analyses were required to determine which was the most effective network loading scenario.

Table 6. Aggregated Total Evacuation Time under Different Network Loading Scenarios

Evacuation Route	Total Evacuation Time by Scenario (hr)				Hypothesis Test Result
I-10	**1A**	**1B**	**1C**	**1D**	Reject
	34.95	47.27	29.89	41.35	
US-61	**2A**	**2B**	**2C**	**2D**	Reject
	32.79	46.44	25.76	36.49	

The results from the ANOVA analysis prompted the need for a series of t-tests to compare the total evacuation time under different network loading scenarios so that they could be ranked according to their resulting effectiveness. Table 7 shows the results of these tests. The table is arranged as matrix in which the percent reduction in total evacuation time for each paired combination of network loading scenarios is shown. It should be noted that although the percentages are all shown as positive values, all of the value represent a time reduction (improvement) between the corresponding scenarios.

The total evacuation time taken under each network loading scenarios is ranked from left-to-right and top-to-bottom from the shortest (Scenario C) to the longest (Scenario B) for both routing scenarios (I-10 and US-61). The numbers in bold show that significant difference existed between the two loading scenarios. The percentages in the table indicate the significant reduction in total evacuation time from one scenario to another. So, for example, the reduction in total evacuation time that was observed from evacuation scenario 1A (34.95 hours) to 1B (47.27 hours) was 26.07%. Similarly, the reduction in total evacuation time from 1C (29.89 hours) to 1A (34.95 hours) was 14.47% and so on.

Table 7. Significant Reduction in Total Evacuation Time between Network Loading Scenarios

I-10				
Evacuation Scenario	**1C**	**1A**	**1D**	**1B**
1C				
1A	**14.47%**			
1D	**27.71%**	**15.49%**		
1B	**36.76%**	**26.07%**	**12.52%**	
US-61				
Evacuation Scenario	**2C**	**2A**	**2D**	**2B**
2C				
2A	**21.44%**			
2D	**29.42%**	**10.16%**		
2B	**44.53%**	**29.40%**	**21.42%**	

The information from Table 7 is particularly helpful to illustrate where the biggest gains were made. From the standpoint of increasing the overall effectiveness of the evacuation, the table suggests that the most significant benefits were gained by carrying out the transit-based evacuation during periods opposite of the auto-based evacuation. This is not necessarily a surprising result since it would be logical to expect less overall traffic volume (and congestion) within the network during the overnight period. Another area of improvement was experienced by carrying out the transit-based evacuation during the earlier stages of the overall evacuation. This benefit likely occurred because the majority of auto-based self-evacuation trips did increase markedly until the late morning to mid-day period of the first day and even more so throughout the second day.

By contrast, the data also show that the lower levels of improvement occurred between evacuation scenarios which were carried out during longer periods (durations greater than 34 hours) as opposed to the shorter ones (24 hours). Although, some improvements did occur because there was not as much "internal" traffic congestion within the city to conflict with the circulation of busses, the gains were not as significant as those from not coinciding the transit and auto peaks.

A more detailed comparison of the disaggregated total evacuation time, by travel directions from each parish, using different network loading scenarios on I-10 evacuation route and US-61 evacuation route are provided in Table 8 through Table 13.

Table 8 and Table 9 present the ANOVA results of the disaggregated total evacuation time from both parishes, using the four different network loading scenarios for I-10 and US-61 evacuation routes respectively. Based on the statistical analysis, it can be concluded that a significant difference existed in the total evacuation time for the four network loading scenarios and at least one network loading scenario differed for both routing scenarios. This meant that at least one of the scenarios demonstrated an overall shorter total evacuation time than the others this also meant that more analyses were required to determine which was the most effective network loading scenario.

Table 8. Disaggregated Total Evacuation Time on I-10 Evacuation Route

Evacuation Destination	Total Evacuation Time by Scenario (hr)				Hypothesis Test Result
	1A	1B	1C	1D	
Orleans Parish					
Hammond	32.40	43.55	23.36	38.16	Reject
Baton Rouge	29.94	44.66	25.91	36.46	Reject
Alexandria	29.33	46.61	28.65	41.21	Reject
Jefferson Parish/ East Bank					
Hammond	23.96	45.69	20.03	33.59	Reject
Baton Rouge	34.17	44.41	28.8	38.27	Reject
Jefferson Parish/ West Bank					
Hammond	26.66	45.55	21.16	37.1	Reject
Baton Rouge	34.95	47.00	29.83	40.05	Reject

Table 9. Disaggregated Total Evacuation Time on US-61 Evacuation Route

Evacuation Destination	Total Evacuation Time by Scenario (hr)				Hypothesis Test Result
	2A	2B	2C	2D	
Orleans Parish					
Hammond	32.24	43.56	23.85	35.65	Reject
Baton Rouge	29.84	43.90	21.12	34.91	Reject
Alexandria	32.61	43.53	22.42	33.67	Reject
Jefferson Parish/ East Bank					
Hammond	24.35	41.78	19.99	32.20	Reject
Baton Rouge	31.88	45.69	25.67	34.71	Reject
Jefferson Parish/ West Bank					
Hammond	24.17	45.48	20.29	36.39	Reject
Baton Rouge	32.62	45.52	23.93	35.85	Reject

The results from the ANOVA analysis prompted the need for a series of t-tests to compare the disaggregated total evacuation time, by travel direction from each parish, under different network loading scenarios so that they could be ranked according to their resulting effectiveness. Table 10 through Table 13 shows the results of these tests from Orleans and Jefferson parishes for both routing scenarios (I-10 and US-61). As described earlier the tables are arranged as matrix in which the percent reduction in total evacuation time for each paired combination of network loading scenarios is compared. The numbers in bold show that significant difference existed between the two loading scenarios. The total evacuation time taken under each network loading scenarios is ranked from left-to-right and top-to-bottom from the shortest (Scenario C) to the longest (Scenario B) for both routing scenarios (I-10 and US-61). It can be seen that the results from Table 10 through Table 13 were consistent with the results provided by Table 7 and for the same reasons.

Table 10. Significant Reduction in Total Evacuation Time between Network Loading Scenarios on I-10 Evacuation Route from Orleans Parish

Origin	**Orleans Parish**			
Destination	**Hammond**			
Evacuation Scenario	**1C**	**1A**	**1D**	**1B**
1C				
1A	**27.89%**			
1D	**38.77%**	**15.09%**		
1B	**46.35%**	**25.60%**	**12.38%**	
Destination	**Baton Rouge**			
	1C	**1A**	**1D**	**1B**
1C				
1A	**13.46%**			
1D	**28.94%**	**17.88%**		
1B	**41.98%**	**32.96%**	**18.36%**	
Destination	**Alexandria**			
	1C	**1A**	**1D**	**1B**
1C				
1A	**2.32%**			
1D	**30.47%**	**28.82%**		
1B	**38.53%**	**37.07%**	**11.59%**	

Table 11. Significant Reduction in Total Evacuation Time between Network Loading Scenarios on I-10 Evacuation Route from Jefferson Parish

Origin	Jefferson Parish/ East Bank								
Destination	Hammond				Baton Rouge				
Evacuation Scenario	1C	1A	1D	1B		1C	1A	1D	1B
1C					1C				
1A	16.40%				1A	15.72%			
1D	40.37%	28.67%			1D	24.75%	10.71%		
1B	56.16%	47.56%	26.48%		1B	35.15%	23.06%	13.83%	
Origin	Jefferson Parish/ West Bank								
Destination	Hammond				Baton Rouge				
Evacuation Scenario	1C	1A	1D	1B		1C	1A	1D	1B
1C					1C				
1A	20.63%				1A	14.65%			
1D	42.96%	28.14%			1D	25.52%	12.73%		
1B	53.54%	41.47%	18.55%		1B	36.53%	25.64%	14.79%	

Table 12. Significant Reduction in Total Evacuation Time between Network Loading Scenarios on US-61 Evacuation Route from Orleans Parish

Origin	Orleans Parish			
Destination	Hammond			
Evacuation Scenario	2C	2A	2D	2B
2C				
2A	26.02%			
2D	33.10%	9.57%		
2B	45.25%	25.99%	18.16%	
Destination	Baton Rouge			
Evacuation Scenario	2C	2A	2D	2B
2C				
2A	29.22%			
2D	39.50%	14.52%		
2B	51.89%	32.02%	20.48%	
Destination	Alexandria			
Evacuation Scenario	2C	2A	2D	2B
2C				
2A	31.25%			
2D	33.41%	3.15%		
2B	48.50%	25.09%	22.65%	

Table 13. Significant Reduction in Total Evacuation Time between Network Loading Scenarios on US-61 Evacuation Route from Jefferson Parish

Origin	Jefferson Parish/ East Bank								
Destination	Hammond				Baton Rouge				
Evacuation Scenario	2C	2A	2D	2B		2C	2A	2D	2B
2C					2C				
2A	17.91%				2A	19.48%			
2D	37.91%	24.38%			2D	26.04%	8.15%		
2B	52.15%	41.72%	22.93%		2B	43.82%	30.23%	24.03%	
Origin	Jefferson Parish/ West Bank								
Destination	Hammond				Baton Rouge				
Evacuation Scenario	2C	2A	2D	2B		2C	2A	2D	2B
2C					2C				
2A	16.05%				2A	26.64%			
2D	44.24%	33.58%			2D	33.25%	9.01%		
2B	55.39%	46.86%	19.99%		2B	47.43%	28.34%	21.24%	

Comparing Similar Network Loading Scenarios on Different Routing Scenarios

After comparing the total evacuation time for the different network loading scenarios, and finding that the most effective scenarios occurred when the transit-based evacuation was carried out during off-peak period of the auto-based evacuation, interest shifted to evaluating the total evacuation time on different evacuation routes. Once again, a two sample t-test was performed at 95 percent confident level to determine statistically significant difference between routing scenarios. The following null and alternative hypotheses were used:

- Ho: Total evacuation time, for the same network loading scenario, on different routing scenarios are equal
- H_1: Total evacuation time, for the same network loading scenario, on different routing scenarios differs

Table 14 through Table 16 provides a comparison of the total evacuation time for all network loading scenarios using I-10 versus those using US-61 (e.g. 1A vs. 2A, 1B vs. 2B, etc). Table 14 shows a comparison of the aggregated, from both parishes, total evacuation time for all network loading scenarios using I-10 versus those using US-61. The table also shows the percentage difference between each routing scenario comparison and the statistical significance of the difference. The numbers in the italicized numbers in rightmost column show that a significant difference existed between the two routing scenarios. It can be seen that the total evacuation time for all network loading scenarios were all significantly better using US-61 as opposed to I-10. The most likely explanation of this was the higher level of congestion on the I-10. This finding also confirms that significant gains in evacuation effectiveness can be made by shifting traffic to more underutilized routes.

It can also be seen that the estimated total evacuation time needed to evacuate the senior citizens and the tourists did not statistically differ between the two routing scenarios. That is due to the fact that the tourists and the seniors' evacuation routes remained unchanged for the two routing scenarios because they were considered as internal evacuation routes.

Table 14. Total Evacuation Time under Different Routing Scenarios

	Evacuation Scenario	**Total Evacuation Time (hr)**		**Percent Reduction**
		I-10	**US-61**	
New Orleans Population	**A**	34.95	32.79	*6.18%*
	B	47.27	46.44	*1.76%*
	C	29.89	25.76	*13.83%*
	D	41.35	36.49	*11.75%*
Tourist	*	42.28	42.28	0.00%
Seniors	*	11.82	11.85	0.25%

Notes: (*) All Network Loading Scenarios

A comparison of the total evacuation time disaggregated by direction from each parish for all network loading scenarios using the I-10 versus those using US-61 are included in Table 15 and Table 16 for Orleans and Jefferson Parishes respectively. The tables show the percentage difference between each routing scenario comparison and the statistical significance of the difference also numbers in the italicized numbers in rightmost column show that a significant difference existed between the two routing scenarios.

Table 15 generally shows that the total evacuation time needed for the evacuation of the carless households from Orleans Parish under most network loading scenarios were significantly better using US-61 as opposed to I-10. The case of evacuating people to the Hammond using the Network loading Scenarios A, B and C showed no statistical difference between the two routing scenarios which indicates that the difference can be neglected. This is because the segments of I-10 and US-61which were used to connect traffic from the NOA to I-55 intersection (I-55 is the external evacuation route to Hammond) are within the metropolitan area and are expected to have the same level of congestion.

Also it can be seen that evacuating people to Baton Rouge using the Network loading Scenarios A and B showed no statistical difference between the two routing scenarios which indicates that the difference can also be neglected. Surprisingly, it was found that evacuating people to Alexandria using network loading Scenario A was significantly better using I-10 as opposed to US-61. This is explained by the “internal” traffic congestion at the processing center which caused some delay for that route.

Table 15. Orleans Parish Total Evacuation Time

Destination	Evacuation Scenario	Total Evacuation Time (hr)		Percent Reduction
		I-10	US-61	
Hammond	A	32.40	32.24	0.50%
	B	43.55	43.56	0.02%
	C	23.36	23.85	2.06%
	D	38.16	35.65	***6.58%***
Baton Rouge	A	29.94	29.84	0.33%
	B	44.66	43.90	1.70%
	C	25.91	21.12	***18.49%***
	D	36.46	34.91	***4.25%***
Alexandria	A	29.33	32.61	***10.05%***
	B	46.61	43.53	***6.61%***
	C	28.65	22.42	***21.75%***
	D	41.21	33.67	***18.30%***

Table 16 shows that the total evacuation time needed for the transit-based evacuation from Jefferson Parish under all network loading scenarios were significantly better using US-61 as opposed to I-10 except for the case of evacuating people to the Hammond from the West Bank of Jefferson Parish which showed no statistical difference between the two routing scenarios which indicates that the difference can be neglected.

This is because the road segments which were used to connect traffic from the Alario Center, the processing center in the West Bank of Jefferson Parish, to I-10 or US -61 and before I-55 intersection happens to be on the south side of the Mississippi river and first extends west before heading north across the Mississippi river. These local roads are ringing the metropolitan area and were expected to have less levels of congestion.

Table 16. Jefferson Parish Total Evacuation Time

Destination	Evacuation Scenario	Total Evacuation Time (hr) I-10	US-61	Percent Reduction
Jefferson Parish/East Bank				
Hammond	A	23.96	24.35	1.60%
	B	45.69	41.78	***8.56%***
	C	20.03	20.00	0.15%
	D	33.59	32.20	***4.14%***
Baton Rouge	A	34.17	31.88	***6.70%***
	B	44.41	45.69	2.80%
	C	28.80	25.67	***10.87%***
	D	38.27	34.71	***9.30%***
Jefferson Parish/West Bank				
Hammond	A	26.66	24.17	9.34%
	B	45.55	45.48	0.15%
	C	21.16	20.29	4.11%
	D	37.10	36.39	1.91%
Baton Rouge	A	34.95	32.62	***6.67%***
	B	46.99	45.52	3.13%
	C	29.83	23.93	***19.78%***
	D	40.05	35.85	***10.49%***

Average Travel Time

In the research, average travel time was also used as a performance measure of effectiveness for comparing the different evacuation scenarios. Again the analysis process for the average travel time measure included a comparison of the aggregate average travel times from both parishes (Orleans and Jefferson). Then separate average travel times were computed and compared based on the various possible evacuation travel directions from each parish.

Tourist Evacuation: The longest travel time taken to evacuate the tourists from the French Quarter Processing center to the MSY was 51 minutes and 26 seconds; the shortest travel time was 29 minutes and 27 seconds and the average travel time was 33 minutes and 57 seconds.

Senior Evacuation: The longest travel time taken to evacuate senior citizens to the UPT processing center was 13 minutes and 21 seconds; the shortest travel time was 5 minutes and 30 seconds and the average travel time was 9 minutes and 22 seconds.

Carless Households: The analysis begins with comparing the average travel time for different network loading scenarios on the same routing scenario and then comparing similar network loading scenarios focusing on the most efficient one on different routing scenarios.

Comparing Different Network Loading Scenarios on the Same Routing Scenarios

A comparison between the average travel time experienced by transit-dependent evacuees using different network loading scenarios on the same evacuation route are provided in Table 17 through Table 23. Similar to the previous analyses, the comparisons also included the statistical significance of the difference between the scenarios. Statistical analyses were performed using ANOVA testing at a 95 percent level of confidence to determine if the average travel time differed among the four network loading scenarios using the following null and alternative hypotheses:

- Ho: Average travel time, on the same routing scenario, for the four network loading scenarios are equal
- H_1: Average travel time, on the same routing scenario, for at least one of the four network loading scenarios differs

Table 17shows a comparison of the aggregate average travel times, from both parishes, using different network loading scenarios, on the evacuation route (I-10 or US-61). From the results in this table it can be concluded that significant difference in the average travel time existed on I-10 for the four network loading scenarios. This meant that at least one network loading scenario had a different average travel time than the others on I-10 and more analyses were required to determine the relative differences. Interestingly, it was also concluded that since the average travel time for none of loading scenarios on US-61 differed statistically, all of loading scenarios used for travel could be considered equally effective. This indicates that US-61 evacuation route had almost the same levels of congestion during the two day evacuation period.

Table 17. Average Travel Time under Different Network Scenarios

Evacuation Route	Average Travel Time by Scenario (hr)				Hypothesis Test Result
I-10	**1A**	**1B**	**1C**	**1D**	Reject
	4.81	5.03	4.54	4.80	
US-61	**2A**	**2B**	**2C**	**2D**	Fail to Reject
	2.55	2.84	2.20	2.61	

The findings from the ANOVA analysis necessitated a follow up series of t-tests to compare the average travel times on I-10 to rank them according to their efficiency. Table 18 shows the results of these tests. Once again, the comparison table is arranged as a matrix in which the average travel time for each loading scenario is ranked from the shortest (Scenario C) to the longest (Scenario B) and the numbers in bold show that significant differences existed between the two loading scenarios. The results indicates that significant difference in the average travel time existed between all network loading scenarios except between scenarios A and D so the network loading scenarios efficiency can be ranked with Scenario C as the most efficient, followed by Scenarios (A and D with equal efficiency), and Scenario B as the "least efficient." Overall, these results were consistent with the results of the total evacuation time analyses for what is assumed to be the same reasons.

Table 18. Significant Reduction in Average Travel Time between Network Loading Scenarios

I-10				
Evacuation Scenario	**1C**	**1D**	**1A**	**1B**
1C				
1D	**5.42%**			
1A	**5.61%**	0.21%		
1B	**9.74%**	**4.57%**	**4.37%**	

A more detailed comparison of the average travel time, disaggregated by direction from each parish, for the four network loading scenarios on I-10 and US-61 evacuation routes are provided in Table 19 and Table 20 respectively. From the results in Table 19 it was concluded that a significant difference in the average travel time existed on I-10 for the four network loading scenarios except for the West Bank evacuation to Baton Rouge. This meant that at least one network loading scenario had a shorter average travel time than the others on I-10 and more analyses were required to determine the relative differences. From the results in Table 20 it was concluded that since the average travel time for none of loading scenarios demonstrated statistically significant difference, all loading scenarios used for travel on US-61 could be considered equally effective except for evacuation from Orleans Parish to Hammond. This meant that more analyses were required just for this direction of evacuation to determine the relative differences. These results were consistent with the aggregated average travel time results.

Also, it can be seen that the average travel time on US-61 differed more among the alternative scenarios than on the I-10 and yet they are found to be statistically different on the I-10 and not on US-61. This can only occur if the variances are much larger on US-61 than on the I-10.

Table 19. Average Travel Time under Different Network Loading Scenarios on I-10 Evacuation Route

Evacuation Destination	Average Travel Time by Scenario (hr)				Hypothesis Test Result
	1A	1B	1C	1D	
Orleans Parish					
Hammond	2.09	2.35	2.10	2.20	Reject
Baton Rouge	4.80	5.03	4.33	4.79	Reject
Alexandria	4.76	5.02	4.44	4.80	Reject
Jefferson Parish/ East Bank					
Hammond	1.91	1.91	1.91	1.88	Fail to Reject
Baton Rouge	4.41	4.43	4.15	4.33	Reject
Jefferson Parish/ West Bank					
Hammond	2.51	2.61	2.46	2.47	Reject
Baton Rouge	4.81	4.56	4.54	4.76	Fail to Reject

Table 20. Average Travel Time under Different Network Loading Scenarios on US-61 Evacuation Route

Evacuation Destination	Average Travel Time by Scenario (hr)				Hypothesis Test Result
	2A	2B	2C	2D	
Orleans Parish					
Hammond	1.76	2.22	1.69	1.90	Reject
Baton Rouge	2.26	2.26	1.99	2.22	Fail to Reject
Alexandria	2.22	2.43	1.95	2.33	Fail to Reject
Jefferson Parish/ East Bank					
Hammond	1.61	1.60	1.45	1.58	Fail to Reject
Baton Rouge	2.07	2.26	1.82	2.06	Fail to Reject
Jefferson Parish/ West Bank					
Hammond	2.05	2.18	1.83	2.02	Fail to Reject
Baton Rouge	2.55	2.78	2.05	2.56	Fail to Reject

Table 21 and Table 22 show the results of the t-tests that were used to compare the average travel times of the four network loading scenarios on I-10 and to rank them according to their efficiency. The average travel time for each loading scenario is ranked from the shortest to the longest. The numbers in bold indicate the statistical significant percent reduction in average travel time. It should be noted that Scenario C did not always have the shortest average travel time (Scenario A had the shortest average travel time for Orleans evacuation to Hammond but no significant difference existed between Scenario A and Scenario C so the difference in the average travel time between them can be neglected and they can be considered equally efficient) also Scenario B did not always have the longest average travel time (Scenario A had the longest average travel time for the West Bank evacuation to Hammond but also no significant difference existed between Scenario A and the four network loading scenarios so the difference can be neglected). As a result, the network loading scenarios efficiency can be ranked with Scenario C as the most efficient, and Scenario B as the "least efficient."

Table 21. Significant Reduction in Average Travel Time between Network Loading Scenarios on I-10 Evacuation Route from Orleans Parish

Origin	Orleans Parish			
Destination	Hammond			
Evacuation Scenario	1A	1C	1D	1B
1A				
1C	0.48%			
1D	**5.00%**	**4.55%**		
1B	**11.06%**	**10.64%**	**6.38%**	
Destination	Baton Rouge			
Evacuation Scenario	1C	1D	1A	1B
1C				
1D	**9.60%**			
1A	**9.79%**	**0.21%**		
1B	**13.92%**	**4.77%**	**4.57%**	
Destination	Alexandria			
Evacuation Scenario	1C	1A	1D	1B
1C				
1A	**6.72%**			
1D	**7.50%**	**0.83%**		
1B	**11.55%**	**5.18%**	**4.38%**	

Table 22. Significant Reduction in Average Travel Time between Network Loading Scenarios on I-10 Evacuation Route from Jefferson Parish

Origin	Jefferson Parish/ East Bank			
Destination	Baton Rouge			
Evacuation Scenario	1C	1D	1A	1B
1C				
1D	4.15%			
1A	5.90%	1.81%		
1B	6.32%	2.26%	0.45%	
Origin	Jefferson Parish/ West Bank			
Destination	Hammond			
Evacuation Scenario	1C	1B	1D	1A
1C				
1B	0.44%			
1D	4.62%	4.20%		
1A	5.61%	5.19%	1.04%	

Table 23 Table 23shows the results of the t-tests that were used to compare the average travel times on US-61 to rank the network loading scenarios according to their efficiency. The results indicate that significant difference in the average travel time existed between all network loading scenarios on US-61 evacuation route. In the table, the network loading scenarios efficiency can be ranked with Scenario C as the most efficient, followed by Scenarios A and Scenario B as the "least efficient."

Table 23. Significant Reduction in Average Travel Time between Network Loading Scenarios on US-61 Evacuation Route

Origin	Orleans Parish			
Destination	Hammond			
Evacuation Scenario	2C	2A	2D	2B
2C				
2A	3.98%			
2D	11.05%	7.37%		
2B	23.87%	20.72%	14.41%	

Comparing Similar Network Loading Scenarios on Different Routing Scenarios

The final set of analyses were conducted to determine the most efficient evacuation route, a two sample t-test was performed at 95 percent confidence level to determine statistically significant difference between average travel times using similar network loading scenarios on different routing scenarios. These were based on the following null and alternative hypotheses:

- Ho: Average travel times, for the same network loading scenario, on different routing scenarios are equal
- H_1: Average travel times, for the same network loading scenario, on different routing scenarios differs

Table 24 through Table 26 provides a comparison of the average travel time for all network loading scenarios using I-10 versus those using US-61. Again, the aggregate average travel times from both parishes were compared first. Then separate average travel time were computed and compared based on the various possible evacuation travel directions from each parish.

Table 24 shows a comparison of the aggregated average travel time, from both parishes, reductions and differences for all network loading scenarios using I-10 and US-61. The table shows that the average travel times for all network loading scenarios were significantly better for US-61 when compared to I-10, with a percent difference ranging from 45.63 to 51.54 percent. Again, these results are thought to be occurring because of the additional available capacity on US-61 that available to busses.

A comparison of the disaggregated average travel time by direction from each parish for all network loading scenarios on I-10 versus those using US-61 is include are Table 25 and Table 26 for Orleans and Jefferson Parishes respectively.

Table 24. Aggregated Average Travel Time under Different Routing Scenarios

Evacuation Scenario	Average Travel Time (hr)		Percent Reduction
	I-10	US-61	
A	4.81	2.55	*46.99%*
B	5.03	2.84	*43.54%*
C	4.54	2.20	*51.54%*
D	4.80	2.61	*45.63%*

Table 25 shows that the average travel times for all network loading scenarios were significantly better for US-61 when compared to I-10 with a significant difference ranging from 13.46 to 56.08 percent except for evacuation to Hammond under network loading scenarios A, B and C which showed no statistical differences between the two routing scenarios. These results were very consistent with the results of the total evacuation time analyses for what is assumed to be the same reasons.

Table 26 shows that the average travel times for all network loading scenarios were significantly better for US-61 when compared to I-10 with a significant difference ranging from 15.71 to 56.14 percent except for evacuation to Hammond under network loading scenarios B and D which showed no statistical differences between the two routing scenarios.

Table 25. Orleans Parish Average Travel Time

Destination	Evacuation Scenario	Average Travel Time (hr)		Percent Reduction
		I-10	US-61	
Hammond	A	2.09	1.76	15.79%
	B	2.35	2.22	5.53%
	C	2.10	1.69	19.52%
	D	2.2	1.90	***13.64%***
Baton Rouge	A	4.80	2.26	***52.92%***
	B	5.03	2.26	***55.07%***
	C	4.33	1.99	***54.04%***
	D	4.79	2.22	***53.65%***
Alexandria	A	4.76	2.22	***53.36%***
	B	5.02	2.43	***51.59%***
	C	4.44	1.95	***56.08%***
	D	4.80	2.33	***51.46%***

Table 26. Jefferson Parish Travel Time

Destination	Evacuation Scenario	Average Travel Time (hr)		Percent Reduction
		I-10	US-61	
Jefferson Parish/East Bank				
Hammond	A	1.91	1.61	***15.71%***
	B	1.91	1.60	16.23%
	C	1.91	1.45	***24.08%***
	D	1.88	1.58	15.96%
Baton Rouge	A	4.41	2.07	***53.06%***
	B	4.43	2.26	***48.98%***
	C	4.15	1.82	***56.14%***
	D	4.33	2.06	***52.42%***
Jefferson Parish/West Bank				
Hammond	A	2.51	2.05	***18.33%***
	B	2.61	2.18	16.48%
	C	2.46	1.83	***25.61%***
	D	2.47	2.02	18.22%
Baton Rouge	A	4.81	2.55	***46.99%***
	B	4.56	2.78	***39.04%***
	C	4.54	2.05	***54.85%***
	D	4.76	2.56	***46.22%***

Evaluating the Impact of Transit Evacuation on the Network Traffic Operation

It should be pointed out that the results presented in the preceding sections focused on comparing the proposed evacuation scenarios in an attempt to find the most effective transit-based evacuation scenario and evaluate evacuation under different conditions. The overall network performance was also evaluated by comparing the network performance for the auto-based evacuation model to the integrated evacuation models (eight evacuation scenarios described in chapter 3). The two performance measures used for the basis of comparison were the "average evacuation speed at specific roadway sections" and the "average queue length at specific roadway sections." These two performance measures were selected because of their direct effect on the traffic operations. They also demonstrated the overall network performance under evacuation conditions.

Average Evacuation Speed at Specific Roadway Sections

A comparison of the average speed distribution for the auto-based evacuation model versus the integrated "auto + transit" evacuation models over 48 hour evacuation simulation period are shown in Figure 10 and Figure 11 for both routing scenarios (I-10 and US-61) respectively. The comparison is provided at station 54 on I-10 in LaPlace immediately after the I-10 contraflow termination and station 27 on US-61 in LaPlace parallel to I-10 and near Station 54. The approximate location of these stations was illustrated previously in Figure 2 of Chapter 3. It can be seen that the integrated models followed the same average speed pattern as the auto-based model.

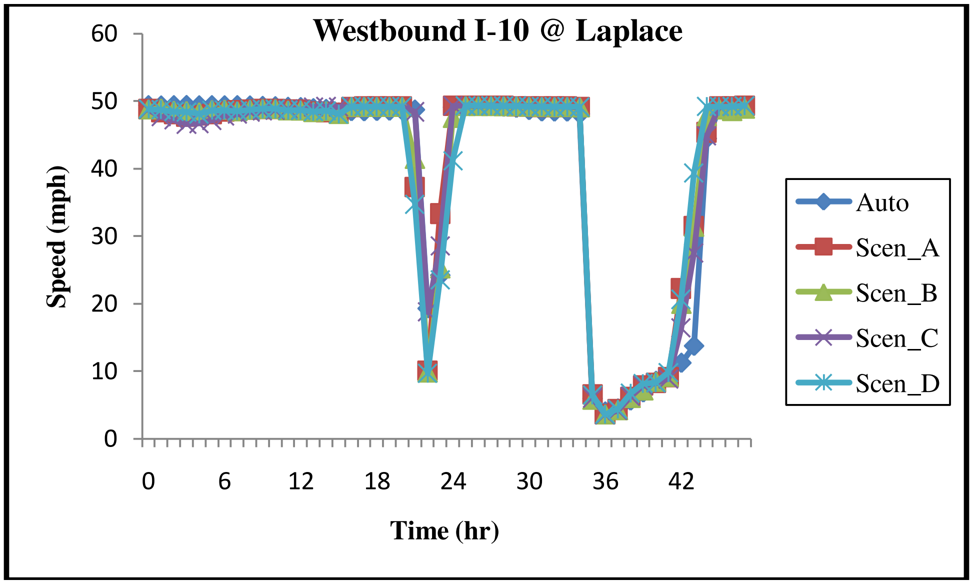


Figure 10. Evacuation Scenarios Average Speed Distribution on I-10 @ Laplace

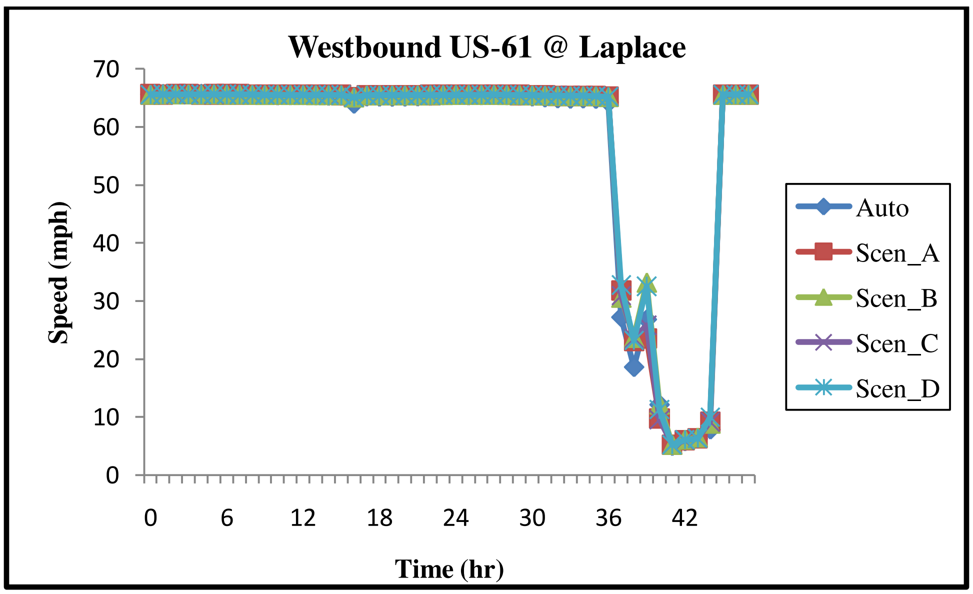


Figure 11. Evacuation Scenarios Average Speed Distribution on US-61 @ Laplace

The analyses also include the statistical significance of the difference between the auto-based evacuation model and the integrated evacuation models. The Chi-square (χ^2) Goodness-of-fit tests were performed at 95 percent level of confidence to determine whether the difference between the average speed distribution for auto-based evacuation model and the average speed distribution for each integrated evacuation model is significant. To accomplish this, the following null and alternative hypotheses were used:

- Ho: The average speed distribution of the auto-based evacuation model and the integrated evacuation model are similar
- H_1: The average speed distributions of both models differ

Table 27 presents the Chi-square (χ^2) tests results. The results demonstrated no significant difference existed in the average speed distributions between the auto-based evacuation model and the eight integrated evacuation models on both routing scenarios. This meant that including transit evacuation has no impact on the network evacuation speed under all network loading scenarios.

Table 27. Chi-square (χ^2) Speed Results

External Evacuation Routes Scenarios	Network Loading Scenarios	Hypothesis Test Result
	1A	*Fail to Reject*
	1B	*Fail to Reject*
	1C	*Fail to Reject*
Scenario 1: Evacuation on I-10	**1D**	*Fail to Reject*
	2A	*Fail to Reject*
	2B	*Fail to Reject*
	2C	*Fail to Reject*
Scenario 2: Evacuation on US-61	**2D**	*Fail to Reject*

Average Queue Length at Specific Roadway Sections

In the research, average queue length was also used as a performance measure of effectiveness for evaluating the impact of including transit evacuation on the network traffic operation.

A comparison between the average queue length of the auto-based evacuation model and the integrated evacuation models over 48 hour evacuation simulation period is provided in

Figure 12 and Figure 13 for both routing scenarios (I-10 and US-61) respectively. The comparison was provided at the same stations at which the average speed distributions were evaluated. It can be seen that the integrated evacuation models produced similar average queue length patterns to the auto-based evacuation model, although the impact of the addition of transit to I-10 auto traffic is evident.

The Chi-square (χ^2) Goodness-of-fit tests were performed at 95 percent confident level to determine whether the difference between the average queue length for auto-based evacuation model and the integrated evacuation model is significant. The following null and alternative hypotheses were:

- Ho: The queue length distribution of the auto-based evacuation model and the integrated (auto + transit) model are similar
- H_1: The queue length distributions of both models differ

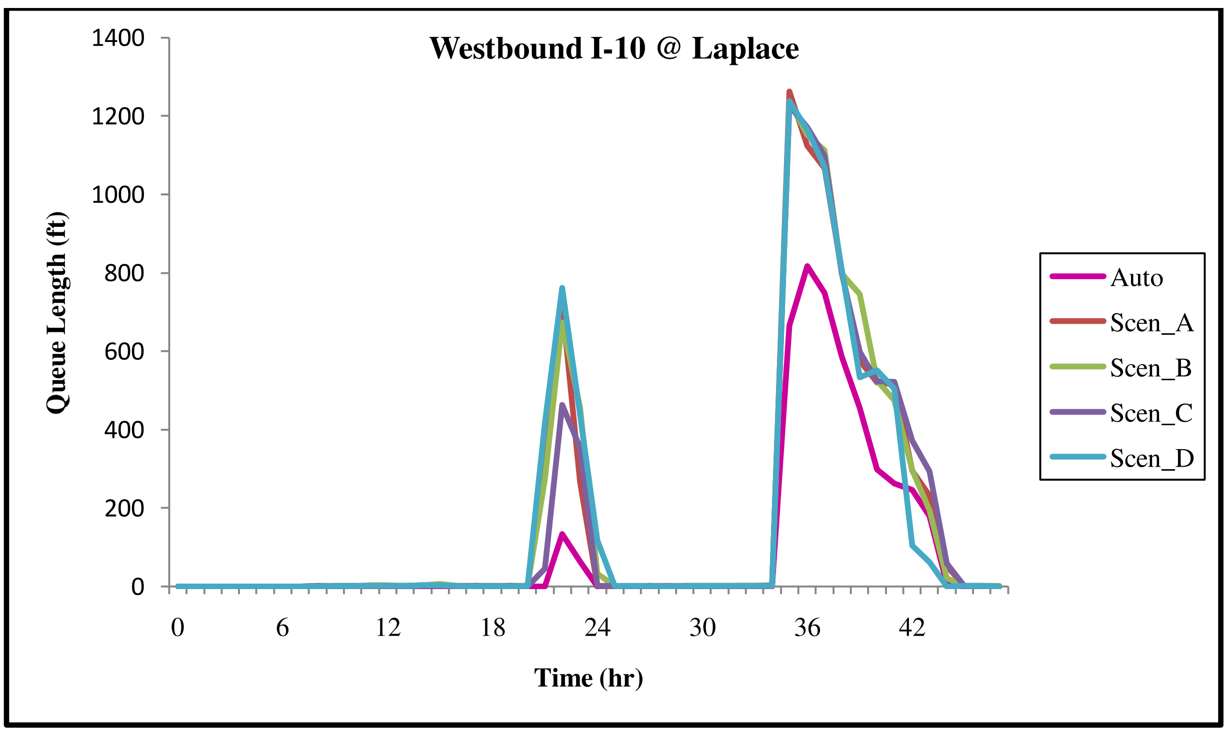


Figure 12. Queue Length Distribution for Different Evacuation Scenarios on I-10 @ Laplace

Results of the Chi-square (χ^2) analysis are shown in Table 28. Based on the statistical analysis, it can be concluded that significant difference existed in the average queue length distribution between the auto-based evacuation model and the four integrated evacuation models on I-10 evacuation route. This meant that including transit evacuation would impact the average queue length on I-10. Interestingly, it was also concluded that since the average queue length distribution for none of integrated models differed statistically from the auto-based model for travel on US-61 that evacuation scenarios which were carried out on US-61 evacuation route have no impact on the traffic operations due to the expected lower overall traffic volume (and congestion).

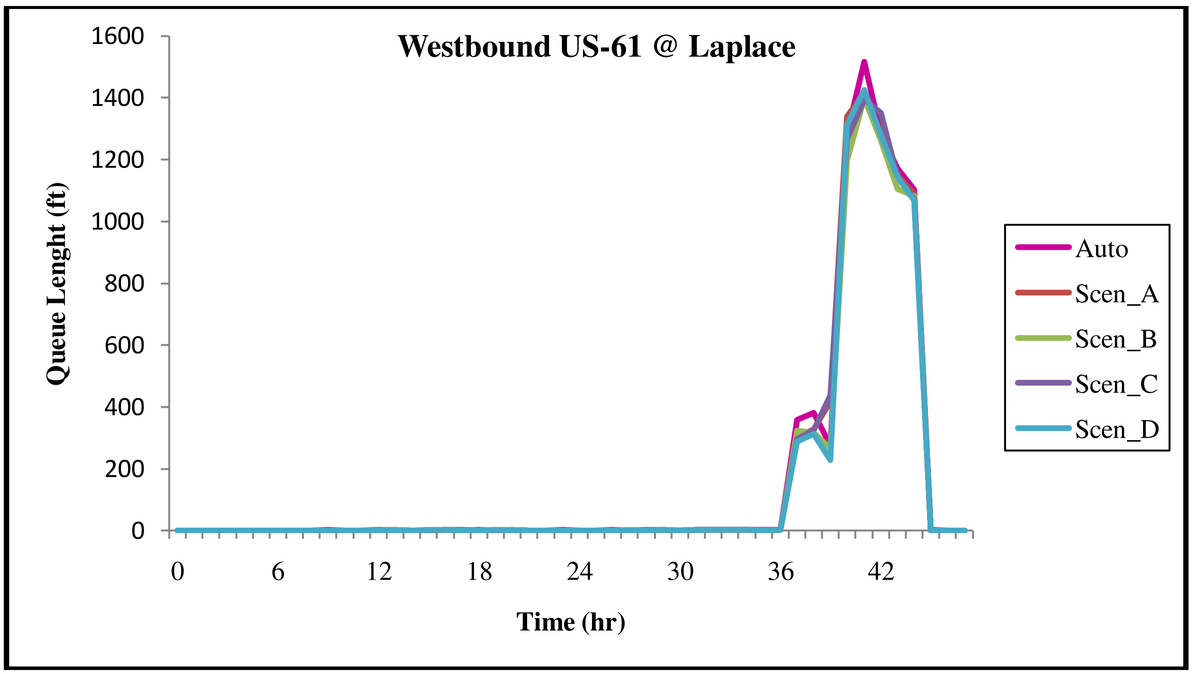


Figure 13. Queue Length Distribution for Different Evacuation Scenarios on US-61 @ Laplace

Table 28. Chi-square (χ^2) Queue Length Results

External Evacuation Routes Scenarios	Network Loading Scenarios	Hypothesis Test Result
Scenario 1: Evacuation on I-10	1A	*Reject*
	1B	*Reject*
	1C	*Reject*
	1D	*Reject*
Scenario 2: Evacuation on US-61	2A	*Fail to Reject*
	2B	*Fail to Reject*
	2C	*Fail to Reject*
	2D	*Fail to Reject*

Evaluation of the Evacuation Plan

Walking and Waiting Time

The TRANSIMS models were also able to provide information about the time spent walking to the pickup locations plus the time spent waiting at the pickup locations which is the first leg in the evacuation trip. Also it provides information about the time spent waiting at the processing center.

As long as the eight integrated evacuation scenarios have fixed pickup locations, processing centers and evacuation routes, they all produced almost the same not on transit time. Not on transit time is defined as the time spent walking to the pickup location, waiting at the pickup location, transfer time at the processing centers, and the waiting time at the processing centers. Results reported represent the average of the eight transit-based evacuation scenarios.

Table 29 shows the minimum, average and maximum time spent walking to the pickup locations and waiting at the pickup locations. It can be seen that the average time spent in the first leg of an evacuation trip is less than 10 minutes.

Table 29. Evacuation First Leg Duration

Duration (Sec)		
Min.	**Avg.**	**Max.**
5	534.55	2000

Table 30 shows the minimum, average and maximum time spent not on transit, walking, waiting and transfer time, for the carless households in their evacuation trip to safe shelters. It can be seen that the average time spent not on transit was not more than 22 minutes.

Table 30. Not on Transit Duration

Duration (Sec)		
Min	**Avg.**	**Max**
5	1314.63	4105

Figure 14 shows the not on transit time distribution for the transit dependent evacuees. It can be seen that at least 68 percent of the transit dependent evacuees spent half an hour or less not on transit and only 0.19 percent of them spent more than an hour not on transit in their evacuation trip.

Number of Buses Needed

The estimated number of buses needed for the transit-based evacuation of New Orleans Metropolitan Area is shown in the Table 31 and Table 32. Table 31 shows the number of buses needed to complete the internal evacuation, transporting transit dependent evacuees from the pickup locations in Orleans and Jefferson Parishes to the processing centers, under each evacuation scenario. A total of 56, 42, 61, and 43 local buses were required for network loading scenarios A, B, C, and D respectively. Table 32 shows the number of buses needed for external evacuation, transporting transit dependent evacuees from the processing centers to safe shelters. A total of 601 RTA buses were needed for external evacuation.

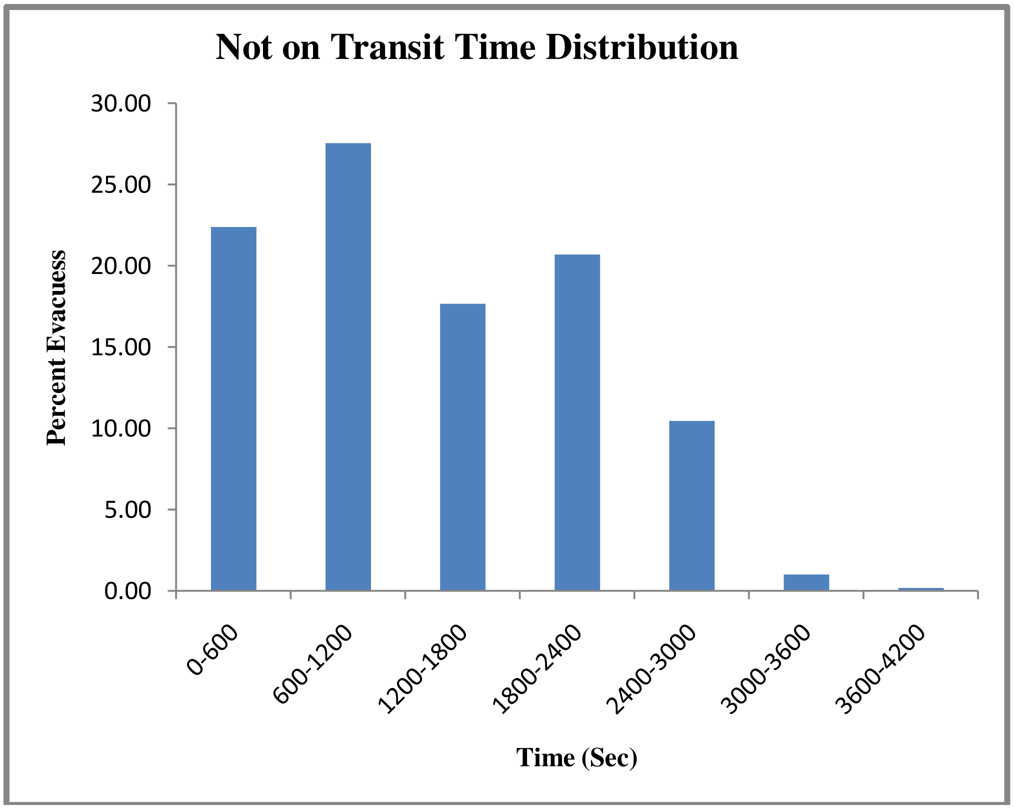


Figure 14. Not on Transit Time Distribution

Table 31. Estimated Number of Buses Needed for the Internal Evacuation

Evacuation Origin-Destination	Number of Buses Needed			
	A	B	C	D
Orleans Parish				
French Quarter -MSY	6	6	6	6
SCPLs – UPT (four routes)	14	14	14	14
GPPLs – NOA (thirteen routes)	21	13	26	13
Jefferson Parish				
GPPLs - Yenni Building (three routes)	9	6	9	6
GPPLs - Alario Center (three routes)	6	4	6	4
Total				
	56	42	61	43

Table 32. Estimated Number of Buses Needed for the External Evacuation

Evacuation Origin-Destination	Number of Buses Needed
Orleans Parish	
NOA – Hammond	117 buses
NOA – Baton Rouge	117 buses
NOA – Alexandria	117 buses
Jefferson Parish	
PPP - Hammond	125 buses
PPP – Baton Rouge	125 buses
Total	
	601

Chapter 5. Summary and Conclusion

This research was motivated by persistent unanswered questions related to mass evacuation traffic processes; in particular those associated with citizen-assisting transit-based bus evacuations which, although developed on paper, have little history of use. The emergence of large-scale high-fidelity transportation simulation systems like TRANSIMS permit such scenarios to be tested before dangerous conditions exist. From an operational standpoint, simulation systems like TRANSIMS can also be used to analyze, assess, and perhaps answer questions related to the implementation of temporal and spatial evacuation control strategies during evacuations. In this study, these included an assessment of evacuation processes if that can control, guide, or influence:

- the routes that evacuees were able to take within the transportation network,
- how urgently the evacuation took place,
- the amount of time that was available to carry out an evacuation, and
- the departure windows during which evacuees departed their origins in the threat zone.

The project and results described in this dissertation centered on an evacuation of New Orleans using a model calibrated to reproduce the temporal and spatial traffic patterns observed in Hurricane Katrina evacuation of 2005. Prior to the Katrina event there was no systematic evacuation plan for carless residents (tourists, elderly and disabled) of the city. Soon after, however, a plan was developed. In this project, the newly developed City Assisted Evacuation Plan was coded into and integrated into the auto-based model. Two alternative evacuation transit routing scenarios and four alternative transit network loading scenarios were developed and tested. Average travel time and total evacuation time were selected to compare the effectiveness of different transit-based evacuation scenarios. Average travel speed and average queue length were used to evaluate the potential impact of including the transit-based evacuation on the network traffic operations. Further analysis was also done to evaluate the transit-based evacuation plan such as average time spent not on transit and the estimated number of buses needed for the carless evacuation.

Among the overall findings of the study was that the most effective scenarios of transit-based evacuation were those that were carried out during time periods during which the auto-based evacuation was in its off-peak periods. These conditions resulted in a 6 to 24 percent reduction in overall average travel time and a 35 to 56 percent reduction in the total evacuation time depending on the evacuation origin-destination when compared to peak evacuation conditions. While the fact that non-coinciding peaks would yield a better over result is not surprising, the extent to which it improved the overall effectiveness of the process was greater than anticipated. It also suggests that staggered evacuation timing could be a worthy avenue for exploration during the development of phased evacuation plans, particularly in major metropolitan areas.

Another general finding was the use of alternative routes to highly traveled freeway can also provide significant benefits. In the case of this New Orleans study, it was found that the exclusive utilization of US-61 under the Katrina conditions would reduce the average travel time of the transit-assisted evacuees by 14 to 56 percent compared to the exclusive use of I-10 and would reduce the total evacuation time by about two to 22 percent depending on the network loading scenario. This result suggests several things. Most importantly, it demonstrates the potential for significant gains to be realized if some traffic was encouraged or perhaps even required to travel on roadways that provide alternative routes to the much more familiar (and crowded) interstate freeways. Such route guidance could also be used to better disperse traffic, helping equalize demand across available routes within the network.

Interestingly, it was also found that transit evacuation had no impact on the network average speed but it increased the average queue length on the interstate evacuation route.

A Final finding, as an evaluation of the evacuation plan, was that at least 68 percent of the transit dependent evacuees spent half an hour or less not on transit (walking towards the bus stop and waiting for the bus) and only 0.19 percent of them spent more than an hour not on transit in their evacuation trip.

Although it should be realized that as rare events with highly variable conditions each evacuation is unique and specific recommendations, even with the enormous amount of data produced in this study, are not possible and the results of the project described in this dissertation, only represent the first step toward a more quantitative understanding and visualization of transit evacuation conditions. The results from this effort also demonstrate the applicability of large scale multimodal traffic simulations for evacuation processes. In the future, as the model is further refined and more detailed relationships studied, similar simulation modeling will continue to expand, improve, and further demonstrate how the effects of planning decisions can be evaluated in advance of potentially harmful events.

References

Bailey, D., S. Swiacki, A. Byrnes, J. Buckley, D. King, P. Piper, M. Marino, S. Mundle, G., Pierlott, and A. Lynd. Transportation Equity and Emergency Preparedness: A Review of the Practices of State Departments of Transportation, Metropolitan Planning Organizations, and Transit Agencies in 20 Metropolitan Areas. Final Report FTA-PA-26-8001-2007. U.S. Department of Transportation, Federal Transit Administration, Washington, DC, 2007. Available on Line: http://www.fta.dot.gov/documents/ (accessed Mar. 2008).

Barrett, C.L. et al., " TRansportation ANalysis SIMulation System (TRANSIMS) Portland Study Reports" Los Alamos National Laboratory, NM. 2002. Available on Line: http://ndssl.vbi.vt.edu/Publications/PS-Vol7-FrontMatter.pdf (accessed Mar. 2008).

Barrett, C.L. et al., Dallas-Ft. Worth Study Reports (Electronic Report), Los Alamos National Laboratory, NM. 1997. Available on Line: http://www.lanl.gov/news/dateline/Dateline0498.pdf (accessed Mar. 2008).

Blake, E. S., Rappaport, E. N., and Landsea, C.W. "The Deadliest, Costliest, and Most Intense United States Tropical Cyclones from 1851 to 2006 (and other Frequently Requested Hurricane Facts" NOAA Technical Memorandum NWS TPC-5. Available on Line: http://www.nhc.noaa.gov/pdf/NWS-TPC-5.pdf (accessed Mar. 2009).

Boxill, S. A., and Yu, L., 2000," An Evaluation of Traffic Simulation Models for Supporting ITS Development". Available on Line: http://swutc.tamu.edu/Reports/167602-1.pdf (accessed Jan. 2009).

Brooks, RJ and Tobias, AM., "Choosing the Best Model: Level of Detail, Complexity and Model Performance, Mathematical and Computer Modeling", 24(4), pp. 1-14, 1996a.

Cahalan, C. and Renne, J., 2007, "Emergency Evacuation of the Elderly and Disabled". Available on line: http://www.connectingcommunities.net/documents/useful/evacelderly.pdf. (accessed Jan. 2010).

Chen, X., and Zhan, F.B., 2004," Agent-Based Modeling and Simulation of Urban Evacuation: Relative Effectiveness of Simultaneous and Staged Evacuation Strategies," TRB 83rd Annual Meeting CD-ROM.

Church, R.L., and Sexton, R.M. "Modeling Small Area Evacuation: Can Existing Transportation Infrastructure Impede Public Safety? Final Report to the California Department of Transportation, 2002.

Comprehensive Hurricane Data Preparedness Study Web Site, Federal Emergency Management Agency & Army Corps of Engineers, Available on line: http://chps.sam.usace.army.mil/USHESdata/heshome.htm (accessed Dec. 2009).

Cova T.J. and Johnson, J. P., 2003, "A network flow model for lane-based evacuation routing" Transportation Research Part A, Vol. 37A 257-275.

Cova, T. J. and Johnson, J. P., 2002, "Microsimulation of neighborhood evacuations in the urban-wildland interface". Environ. Plan. B: Plan. Dec., 34, 2211–2229.

Cox, W. 2006, "Emergency Evacuation Report Card 2006". New Research findings by the American Highway Users Alliance, Washington, D.C., Available on line from: http://www.highways.org/pdfs/evacuation_report_card2006.pdf (accessed Mar. 2009).

Eeckhout, Ed V., Romero, Ph., Henson K. and Dauelsberg L., 2006, "Traffic Planning at Los Alamos: Evacuation and Other Planning Simulations".

Emergency Preparedness and Response for Vulnerable Populations, Conference of Minority Transportation Officials (COMTO), July 2007, available from TCRP.

FEMA, 2008, "Producing Emergency Plans: Comprehensive Preparedness Guide (CPG) 101: A Guide for all-Hazard Emergency Operations Planning for State, Territorial, Local and Governments". Washington, D.C.

GAO. 2006. Transportation-Disadvantaged Populations: Actions Needed to Clarify Responsibilities and Increase Preparedness for Evacuations. GAO-07-44. Washington, D.C., Dec. www.goa.gov/new.items/do744.pdf (accessed Jan. 2009).

Giuliano, G., 2005, "Low income, Public Transit and Mobility," TRB 84th Annual Meeting CD-ROM, 2005.

Hess, Daniel Baldwin and Gotham, Julie C., 2007, "Multi-Modal Mass Evacuation in Upstate New York: A review of Disaster Plans". Journal of Homeland Security and Emergency Management. Vol. 4: ISS. 3, Article 11. Available on Line: http://www.bepress.com/jhsem/vol4/iss3/11 (accessed Jan. 2008).

ITS America and U.S.DOT. Homeland Security and ITS. Using Intelligent Transportation Systems to Improve and Support Homeland Security, Supplement to the National ITS Program Plan: A Ten-Year Vision, 2002.

Jefferson Parish Publicly Assisted Evacuation Plan. Available on line: http://www.jeffparish.net/downloads/5288/5702-PubliclyAssistedEvacPlan.pdf (accessed Jan. 2009).

Jha, M., Moore, k. and Pashaie, B., 2004, "Emergency Evacuation Planning with Microscopic Traffic Simulation". In Transportation Research Record: Journal of the Transportation Research Board, No. 1886, Transportation Research Board of the National Academies, Washington, DC, pp. 40–48.

Kiefer, J. J., and R. J. Montjoy. Incrementalism Before the Storm: Network Performance for the Evacuation of New Orleans. *Public Administration Review*, Special Issue, 2006, pp. 122-130.

Kikuchi, S. and Pilko, P., "TRANSIMS Evaluation and Feasibility: Application in Delaware", 2004.

Kwon, E. and Pitt, S., 2005, "Evaluation of Emergency Evacuation Strategy for Downtown Event Traffic Using A Dynamic Network Model," TRB 84th Annual Meeting CD-ROM.

Lim, E., and Wolshon, B., 2005, "Modeling and Performance Assessment of Contra-flow Evacuation Termination Points. TRB 84th Annual Meeting. CD-ROM.

Litman, T., 2006, "Lessons Learned From Katrina and Rita: What Major Disasters Can Teach Transportation Planners," Journal of Transportation Engineering, Vol. 132, January 2006

Mastrogiannidou, C., Boile, M., Golias, M., Theofanis, S., Ziliaskopoulos, A., 2009, "Using Transit to Evacuate Facilities in Urban Areas: A Micro-Simulation Based Integrated Tool" TRB 88th Annual Meeting CD-ROM.

Mitchell, S.W., and Radwan, E., 2006, "Heuristic Prioritization of Emergency Evacuation Staging to Reduce Clearance Time," TRB 85th Annual Meeting CD-ROM.

Nagel, K. and Rickert, M., 2000, "Parallel implementation of TRANSIMS micro-simulation", Available on line from: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V12-43RD4C85&_user=3787556&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000061383&_version=1&_urlVersion=0&_userid=3787556&md5=6dbc350fead2884706f4ce204e6fed94 (accessed Jan. 2009).

Nakanishi, Y., Kim, K., Ulusoy, Y., and Bata, A., 2003," Assessing Emergency Preparedness of Transit Agencies: A Focus Performance Indicators," TRB 82nd Annual Meeting CD-ROM, Paper Number 03-2991

Peeta, S. and Ziliaskopoulos, A., 2001, "Foundations of Dynamic Traffic Assignment: The Past, The Present and the Future". Networks and Spatial Economics. Vol. 1, pp. 233-265. Available on line from: http://cobweb.ecn.purdue.edu/~peeta/Peeta-Ziliaskopoulos-2001.pdf (accessed Jan. 2010).

Renne, J. "Evacuation and Equity: A Post-Katrina New Orleans Diary". May 2006. American Planning Association. Available on line: www.planning.org/planning/member/2006may/evacuation.htm (accessed Jan. 2009).

Renne, J. L., Sanchez, Th. W., and Litman, T., "National Study on Carless and Special Needs Evacuation Planning: A Literature Review." Oct. 2008, available on line: http://planning.uno.edu/docs/CarlessEvacuationPlanning.pdf (accessed Jan. 2009).

Rilett, L., Kumar A., and Doddi S., 2003, "El Paso TRANSIMS Case Study", FHWA/TX-03/ 0-2107-1

Rilett, L.R., 2001, "Transportation Planning and TRANSIMS Microsimulation Model: Preparing for Transition", Transportation Research Record, 1777.

Rilett, L.R., Kim. K, and Raney B., 2000, "Comparison of Low-Fidelity TRANSIMS and High-Fidelity CORSIM Highway Simulation Models with Intelligent Transportation System Data," Transportation Research Record 1739, TRB, National Research Council, Washington, D.C., PP 1-8.

Sbayti, H., and Mahmassani, H.S., 2006, "Optimal Scheduling of Evacuation Operation", TRB 85th Annual Meeting CD-ROM.

Sisiopiku, V. P., Jones, S. L., Sullivan, A. J., Patharkar, S. S., and Tang, X., 2004, "Regional Traffic Simulation for Emergency Preparedness,". Available online: http://utca.eng/projects/complete list of all projects/03226fnl.pdf (accessed Jan. 2009).

The Federal Response to Hurricane Katrina: Lessons Learned, Washington: The White House. http://www.crid.or.cr/digitalizacion/pdf/eng/doc17272/doc17272.htm (accessed Mar. 2009).

The New Orleans 2007 City Assisted Evacuation Plan. New Orleans Office of Emergency Preparedness http://www.nocitycouncil.com/newsfiles/2008/gustav/CAEPPickUpSiteMap08.pdf (accessed Jan. 2007).

Theodoulou, G., and Wolshon, B., 2004," Modeling and Analyses of Freeway Contra-flow", TRB 83rd Annual Meeting. CD-ROM.

Transportation Research Board of the National Academies. 2008. The Role of Transit in Emergency Evacuation. Special Report 294.

Turner, D. et al., 2010, "Issues, Practices, and Needs for Communicating Evacuation Information with Vulnerable Populations," TRB 89th Annual Meeting CD-ROM, Paper Number 10-3775

Tuydes, H., Zikiaskopoulos, A., 2004,"Network Re-design to Optimize Evacuation Contraflow," TRB 83rd Annual Meeting CD-ROM.

U.S. Department of Homeland Security, 2006, Nationwide Plan Review Phase 1 Report, Washington, DC.

U.S. Department of Transportation, 2006, Report to the Congress on Catastrophic Hurricane Evacuation Plan Evaluation, in cooperation with the U.S. Department of Transportation and U.S. Department of Homeland Security. June 1. Available on line: www.fhwa.dot.gov/reports/hurricanevacuation/ (accessed Jan. 2009).

Wolshon et al. 2009 "Application of TRANSIMS for Multimodal Microscale Simulation of the New Orleans Emergency Evacuation Plan" submitted to the United States Department of Transportation, Federal Highway Administration.

Wolshon, B. and McArdle, B., 2008, "Temporospatial Analysis of Hurricane Katrina Regional Evacuation Traffic Patterns, ASCE Journal of Infrastructure Systems – Special Infrastructure Planning, Design, and Management for Big Events Issue.

Wolshon, B., 2002, "Planning for the Evacuation of New Orleans, ITE Journal, Institute of Transportation Engineers", February 2002, Vol. 72, No. 2, pp. 44-49.

Wolshon, B., A. Catarella-Michel, and L. Lambert, 2006, "Louisiana Highway Evacuation Plan for Hurricane Katrina: Proactive Management of a Regional Evacuation". Journal of Transportation Engineering, vol. 132, pp. 1-10.

Wolshon, B., NCHRP Synthesis 392, "Transportation's Role in Emergency Evacuation and Reentry", Washington D.C., 2009, 142 PP. Available on Line: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_392.pdf (accessed Feb. 2010).

Xuwei C. Agent-Based Simulation of Evacuation Strategies under Different Road Network Structures. Available on Line: http://www.ucgis.org/summer03/studentpapers/xuweichen.pdf (accessed Aug. 2008).

Yuan, F., L. D. Han, S. Chin., and H. Hwang, 2006, "Proposed Framework for Simultaneous Optimization of Evacuation Traffic Destination and Route Assignment. In Transportation Research Record" Journal of the Transportation Research Board, No. 1964, Transportation Research Board of the National Academies, Washington, DC, pp 50–58.

Appendix: Transit-Based Evacuation Model Development Programs

TransitNet

TRANSIMS TransitNet program was used for the transit network development purpose. The transit network development starts with two files: Route_Header file which contains information about route headways that represent the service level of the routes and Route_Nodes which contains information about node lists that represent the route paths.

Route Header Data

The Route_Header file presents information about the route ID, transit mode which is bus in our case, and transit headways throughout the day. Table 33 shows a sample Route_Header file. It contains the following fields: ROUTE, NAME, MODE, TTIME, HEADWAY_x, and OFFSET_x. The "_x" stands for the time period. The hours of the day included in each time period are defined in the control file for the TransitNet program. Four different Route_Header files were created for the four network loading scenarios.

Route Nodes Data

The Route_Nodes file includes information about the path of each transit route, the travel time between nodes, and stop locations. Table 34 shows a sample Route_Nodes file. It contains the following fields: ROUTE, NODE, DWELL, TTIME, and SPEED.

TransitNet Control File

The file "TransitNet.ctl" is a text file that can be reviewed and edited using a standard text editor. A sample control file for the TransitNet program is shown Table 35.

Assumptions:

- The program assumes that the first time period starts at midnight and the last time period ends at midnight.
- The values listed in the TRANSIT_TIME_PERIODS represent the breakpoints between time periods, so time period 1 will cover the time period between 0:00 am and 8:00 am and will be represented in the Route_Header file by Headway_1 and so on.
- A travel time adjustment factor of 1.25 was used assuming that the evacuation conditions will be similar to peak hour conditions.

Table 33. Sample Route_Header File

ROUTE	NAME	MODE	TTIME	HWAY_1	HWAY_2	HWAY_3	HWAY_4	HWAY_5	OFFSET_1	OFFEST_2
1	EVA1	BUS	0	10	10	10	10	10	0	0
2	EVA2	BUS	0	0	25	0	0	0	0	0
3	EVA3	BUS	0	0	13	0	0	0	0	0
4	EVA4	BUS	0	0	25	0	10	10	0	0
5	EVA5	BUS	0	0	12	0	25	60	0	0
6	EVA6	BUS	0	40	30	40	0	0	0	0
7	EVA7	BUS	0	50	35	40	0	0	0	0
8	EVA8	BUS	0	30	20	30	30	60	15	0
9	EVA9	BUS	0	60	30	60	0	0	0	0
10	EVA10	BUS	0	60	30	60	0	0	0	0
11	EVA1	BUS	0	10	10	10	10	10	0	0
12	EVA2	BUS	0	0	25	0	0	0	0	0
13	EVA3	BUS	0	0	13	0	0	0	0	0
14	EVA4	BUS	0	0	25	0	10	10	0	0
15	EVA5	BUS	0	0	12	0	25	60	0	0
16	EVA6	BUS	0	40	30	40	0	0	0	0
17	EVA7	BUS	0	50	35	40	0	0	0	0
18	EVA8	BUS	0	30	20	30	30	60	15	0
19	EVA9	BUS	0	60	30	60	0	0	0	0
20	EVA10	BUS	0	60	30	60	0	0	0	0
21	EVA11	BUS	0	10	20	10	0	0	0	0

Table 34. Sample Route_Nodes File

ROUTE	NODE	DWELL	TTIME	SPEED
1	3171	0	0	0
1	3159	0	0	0
1	3123	0	0	0
1	3124	0	0	0
1	3139	0	0	0
1	3137	0	0	0
1	3138	0	0	0
1	3117	0	0	0
1	3118	0	0	0

Table 34 Continued

1	3141	0	0	0
1	3142	0	0	0
1	3145	0	0	0
1	3155	0	0	0
1	3153	0	0	0
1	3154	0	0	0
1	3147	0	0	0
1	3148	0	0	0
1	2771	0	0	0
1	2772	0	0	0
1	2998	0	0	0
1	2989	0	0	0
1	2954	0	0	0
1	2955	0	0	0
1	2968	0	0	0
1	2843	0	0	0
1	2842	0	0	0
1	2879	0	0	0
1	2865	0	0	0
1	2827	0	0	0
1	1702	0	0	0
1	1703	0	0	0
1	2299	0	0	0
1	2292	0	0	0
1	2293	0	0	0
1	1949	0	0	0
1	1950	0	0	0
1	796	0	0	0
1	882	0	0	0
1	2071	0	0	0

TransitNet Results

The TransitNet program was performed using the following batch file given in the control directory:

TransitNet.bat

The printout file “TransitNet.prn” was created including warning messages. New data files were also created and stored in the network directory which are: transit stop, transit route, transit schedule, and transit driver.

Table 35. TransitNet Control File

TITLE	Convert New Orleans Transit Network
DEFAULT_FILE_FORMAT	TAB_DELIMITED
PROJECT_DIRECTORY	../network
#---- Input Files ----	
ROUTE_HEADER_FILE	Route_Header
ROUTE_NODES_FILE	Route_NodesNO
#PARK_AND_RIDE_FILE	Park_Ride
#ZONE_EQUIVALENCE_FILE	Fare_Zone
NET_DIRECTORY	../network
NET_NODE_TABLE	Node
NET_ZONE_TABLE	Zone
NET_LINK_TABLE	Link
NET_PARKING_TABLE	Parking
NET_ACTIVITY_LOCATION_TABLE	Activity_Location
NET_PROCESS_LINK_TABLE	Process_Link
NET_LANE_CONNECTIVITY_TABLE	Lane_Connectivity
#---- Output Files ----	
NEW_DIRECTORY	../network
NEW_PARKING_TABLE	Parking
NEW_ACTIVITY_LOCATION_TABLE	Activity_Location_1RT
NEW_PROCESS_LINK_TABLE	Process_Link_Scen1RT
NEW_TRANSIT_STOP_TABLE	Transit_Stop_Scen1RT
NEW_TRANSIT_ROUTE_TABLE	Transit_Route_Scen1RT
NEW_TRANSIT_SCHEDULE_TABLE	Transit_Schedule_Scen1RT
NEW_TRANSIT_DRIVER_TABLE	Transit_Driver_Scen1RT
CREATE_NOTES_AND_NAME_FIELDS	YES
#---- Parameters ----	
STOP_SPACING_BY_AREATYPE	2000, 2000, 2000,2000, 2000, 2050
TRANSIT_TIME_PERIODS	8:00, 20:00, 24:00, 32:00, 36:00
TRANSIT_TRAVEL_TIME_FACTOR	1.25, 1.25, 1.25, 1.25
MINIMUM_DWELL_TIME	5
INTERSECTION_STOP_TYPE	FARSIDE
TRANSITNET_REPORT_1	FARE_ZONE_EQUIVALENCE

ArcNet

In order to review the synthetic transit network, the TRANSIMS transit network was converted to a series of ArcView shape files using ArcNet program which enables us to display and edit the transit network on ArcGIS maps.

ArcNet Control File

A sample control file for the ArcNet program is shown in Table 36. The file "ArcNet.ctl" is a text file that can be reviewed and edited using a standard text editor.

Assumptions:

- The routes in each direction would be offset from the roadway centerline by 5 meters,
- The stops would be offset by 10 meters, and
- The activity locations would be offset by 15 meters.

ArcNet Results

The ArcNet program was performed using the following batch file included in the control directory:

ArcNet.bat

The printout file "ArcNet.prn" was created as well as new ArcView shape files which were stored in the arcview subdirectory of the network directory.

Shape files were created for the new activity locations and process link files. These files would display the connections to the transit stops. Also another two shape files for the transit service were created: one for transit stops and one for the transit routes which contains information from the transit route, schedule, and driver files.

Table 36. ArcNet Control File

TITLE	New Orleans Transit Network Shape Files
#---- Input Files ----	
NET_DIRECTORY	../network
NET_NODE_TABLE	Node
NET_LINK_TABLE	Link
NET_SHAPE_TABLE	Shape
NET_PROCESS_LINK_TABLE	Process_Link_1RT
NET_PARKING_TABLE	Parking
NET_ACTIVITY_LOCATION_TABLE	Activity_Location_1RT
NET_TRANSIT_STOP_TABLE	Transit_Stop_Scen1RT
NET_TRANSIT_ROUTE_TABLE	Transit_Route_Scen1RT
NET_TRANSIT_SCHEDULE_TABLE	Transit_Schedule_Scen1RT
NET_TRANSIT_DRIVER_TABLE	Transit_Driver_Scen1RT
#ROUTER_NODES_FILE	Route_Nodesscen1RT
#---- Output Files ----	
ARCVIEW_DIRECTORY	../network/arcview
#---- Parameters ----	
LINK_DIRECTORY_OFFSET	0.0
POCKET_LANE_SIDE_OFFSET	2.0
ACTIVITY_LOCATION_SIDE_OFFSET	15.0
PARKING_SIDE_OFFSET	5.0
UNSIGNALIZED_NODE_SIDE_OFFSET	10
UNSIGNALIZED_NODE_SETBACK	25.0
TRANSIT_STOP_SIDE_OFFSET	8.0
TRANSIT_DIRECTION_OFFSET	4.0
TRANSIT_TIME_PERIODS	6:30, 9:30, 15:30,18:30

ActGen

TRANSIMS uses the ActGen program to allocate activity patterns to household members and then distribute those activities to activity locations and define the travel mode used to travel to that location.

Input Data Files

The ActGen program requires three types of input files:

- The network files that describe the network such as nodes, links, activity locations, and parking lots files.
- The population files which contain information about the synthetic households and persons.
- The survey files that consist of the household activity survey and information about households and persons in the households.

It is very important here to distinguish between the **household** and **population** files in the **survey files** (created to describe the households in the activity survey) and the **household** and **population** files in the **population files** (output from the population synthesizer).

The ActGen program uses household activity survey to define the activity patterns, activity schedule, and travel modes assigned to each household member in the synthetic population.

Survey Files Preparation

The survey data are presented in four files: a household file (Survey_Household.txt), a population file (Survey_Population.txt) an activity file (Survey_Activity.txt), and survey weights file (Survey_Weights.txt). There was no need to create a survey weight file because the survey weights were considered in the household, population and activity files. Sample survey files are shown Table 37 through Table 39.

Household Matching

A household type script was used to match the synthetic households to the survey households. Activities for each person in the survey household were copied to the appropriate person in the synthetic household. Two variables were used in creating household type script: vehicle ownership and edge. Table 40 shows New Orleans household matching script.

Table 37. Household File

HHOLD	PERSONS	WORKERS	VEH	INCOME	TYPE	LOCATION
2000000	1	2	0	20000	1	-1
2000001	1	2	0	20000	1	-1
2000002	1	2	0	20000	1	-1
2000003	1	2	0	20000	1	-1
2000004	1	2	0	20000	1	-1
2000005	1	2	0	20000	1	-1
2000006	1	2	0	20000	1	-1
2000007	1	2	0	20000	1	-1
2000008	1	2	0	20000	1	-1
2000009	1	2	0	20000	1	-1
2000010	1	2	0	20000	1	-1
2000011	1	2	0	20000	1	-1
2000012	1	2	0	20000	1	-1
2000013	1	2	0	20000	1	-1
2000014	1	2	0	20000	1	-1
2000015	1	2	0	20000	1	-1
2000016	1	2	0	20000	1	-1
2000017	1	2	0	20000	1	-1
2000018	1	2	0	20000	1	-1
2000019	1	2	0	20000	1	-1
2000020	1	2	0	20000	1	-1
2000021	1	2	0	20000	1	-1
2000022	1	2	0	20000	1	-1
2000023	1	2	0	20000	1	-1
2000024	1	2	0	20000	1	-1
2000025	1	2	0	20000	1	-1
2000026	1	2	0	20000	1	-1
2000027	1	2	0	20000	1	-1
2000028	1	2	0	20000	1	-1
2000029	1	2	0	20000	1	-1
2000030	1	2	0	20000	1	-1
2000031	1	2	0	20000	1	-1
2000032	1	2	0	20000	1	-1
2000033	1	2	0	20000	1	-1

Table 38. Population File

HHOLD	PERSON	AGE	GENDER	WORK	RELATE
2000000	1	40	1	2	4
2000001	1	40	1	2	4
2000002	1	40	1	2	4
2000003	1	40	1	2	4
2000004	1	40	1	2	4
2000005	1	40	1	2	4
2000006	1	40	1	2	4
2000007	1	40	1	2	4
2000008	1	40	1	2	4
2000009	1	40	1	2	4
2000010	1	40	1	2	4
2000011	1	40	1	2	4
2000012	1	40	1	2	4
2000013	1	40	1	2	4
2000014	1	40	1	2	4
2000015	1	40	1	2	4
2000016	1	40	1	2	4
2000017	1	40	1	2	4
2000018	1	40	1	2	4
2000019	1	40	1	2	4
2000020	1	40	1	2	4
2000021	1	40	1	2	4
2000022	1	40	1	2	4
2000023	1	40	1	2	4
2000024	1	40	1	2	4
2000025	1	40	1	2	4
2000026	1	40	1	2	4
2000027	1	40	1	2	4
2000028	1	40	1	2	4
2000029	1	40	1	2	4
2000030	1	40	1	2	4
2000031	1	40	1	2	4
2000032	1	40	1	2	4
2000033	1	40	1	2	4
2000034	1	40	1	2	4
2000035	1	40	1	2	4
2000036	1	40	1	2	4
2000037	1	40	1	2	4

Table 39. Activity File

HHOLD	per	act	purpose	START	END	DUR	mod	veh	loc	pass
2000000	1	1	0	0:00	11:00	11:00:00	1	0	1	0
2000000	1	2	5	11:05	44:00:00	32:55:00	3	0	2	0
2000000	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000001	1	1	0	0:00	12:00	12:00:00	1	0	1	0
2000001	1	2	5	12:05	44:00:00	31:55:00	3	0	2	0
2000001	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000002	1	1	0	0:00	19:00	19:00:00	1	0	1	0
2000002	1	2	5	19:05	44:00:00	24:55:00	3	0	2	0
2000002	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000003	1	1	0	0:00	2:00	2:00:00	1	0	1	0
2000003	1	2	5	2:05	44:00:00	41:55:00	3	0	2	0
2000003	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000004	1	1	0	0:00	0:17	0:17:00	1	0	1	0
2000004	1	2	5	0:20	44:00:00	43:40:00	3	0	2	0
2000004	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000005	1	1	0	0:00	6:00:00	6:00:00	1	0	1	0
2000005	1	2	5	6:05	44:00:00	37:55:00	3	0	2	0
2000005	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000006	1	1	0	0:00	11:15	11:15:00	1	0	1	0
2000006	1	2	5	11:20	44:00:00	32:40:00	3	0	2	0
2000006	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000007	1	1	0	0:00	24:00:00	24:00:00	1	0	1	0
2000007	1	2	5	24:05:00	44:00:00	19:55:00	3	0	2	0
2000007	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000008	1	1	0	0:00	19:00	19:00:00	1	0	1	0
2000008	1	2	5	19:05:00	44:00:00	24:55:00	3	0	2	0
2000008	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000009	1	1	0	0:00	12:00	12:00:00	1	0	1	0
2000009	1	2	5	12:25	44:00:00	31:35:00	3	0	2	0
2000009	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000010	1	1	0	0:00	1:00	1:00:00	1	0	1	0
2000010	1	2	5	1:02	44:00:00	42:58:00	3	0	2	0
2000010	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000011	1	1	0	0:00	27:00:00	27:00:00	1	0	1	0
2000011	1	2	5	27:23:00	44:00:00	16:37:00	3	0	2	0
2000011	1	3	0	45:00:00	46:00:00	1:00:00	8	0	1	1
2000012	1	1	0	0:00	7:00	7:00:00	1	0	1	0

Table 40. New Orleans Household Matching Script

```
IF (Household.VEH==0) THEN
IF (Household.P65<=0) THEN
RETURN (1)
ELSE
PROB1 = RANDOM ()
IF (PROB1 >= COND1) THEN
RETURN (2)
ELSE
RETURN (1)
ENDIF
ENDIF
ELSE
RETURN (3)
ENDIF
```

Location Choice

New attributes representing the Hammond, Baton Rouge, Alexandria, MSY and the UPT station destinations were added in the Activity_Location_File and each activity location representing any of the destinations was given a value of 1 (equal weight). In this case all destinations were given the same weights because the percent of evacuees evacuating to different destinations were considered in the activity file. Location choice scripts were created for each destination. A Sample location choice script is shown in Table 41.

Table 41. Hammond Location Choice Scripts

```
IF (Tour.DISTANCE1 == 0) THEN

RETURN (0)
ENDIF

Tour.UTILITY = Location.N

RETURN (1)
```

The ActGen Control File

A sample control file for the ActGen program is shown in Table 42. The file "ActGen.ctl" is a text file that can be reviewed and edited using a standard text editor.

Assumptions:

- Five activity generation models were included for the four evacuation destinations.
- The five of them were used for serving passengers with no schedule constraints.
- Three modes of transportation were considered: walk, bus, and magic move.

Program Execution

The ActGen program was performed using the following batch file included in the control directory:

ActGen.bat

The printout file "ActGen.prn" was created besides new activity file in the activity folder. Three reports were requested to summarize the results of the household type model:

ACTGEN_REPORT_1	HOUSEHOLD_TYPE_SCRIPT
ACTGEN_REPORT_2	HOUSEHOLD_TYPE_SUMMARY
ACTGEN_REPORT_3	SURVEY_TYPE_SUMMARY

Table 42. ActGen Control File

```
TITLE                              ActGen Application
PROJECT_DIRECTORY                  ../

NET_DIRECTORY                      ../network
NET_NODE_TABLE                     Node
NET_LINK_TABLE                     Link
NET_ACTIVITY_LOCATION_TABLE        Activity_Location_1RT
NET_PARKING_TABLE                  Parking
NET_PROCESS_LINK_TABLE             Process_Link_1RT
HOUSEHOLD_FILE                     population/HouseholdTransit.txt
POPULATION_FILE                    population/PopulationTransit.txt
VEHICLE_TYPE_FILE                  vehicle/VehType
VEHICLE_FILE                       vehicle/Vehicle1.txt
HOUSEHOLD_TYPE_SCRIPT              population/Household_Type2.txt

SURVEY_HOUSEHOLD_FILE              SurveyTransit/Household.txt
#SURVEY_HOUSEHOLD_WEIGHTS          SurveyTransit/Weights.txt
```

Table 42 Continued

SURVEY_POPULATION_FILE	SurveyTransit/transitPopulation.txt
SURVEY_ACTIVITY_FILE	Survey/Activity.txt
#survey_type_script	population/Household_Type.txt
NEW_ACTIVITY_FILE	activity/TransitActivityRT1
ACTIVITY_FORMAT	TAB_DELIMITED
NEW_PROBLEM_FILE	results/ActGen_ProblemRT1.txt
ACTGEN_REPORT_1	HOUSEHOLD_TYPE_SCRIPT
ACTGEN_REPORT_2	HOUSEHOLD_TYPE_SUMMARY
ACTGEN_REPORT_3	SURVEY_TYPE_SUMMARY
RANDOM_NUMBER_SEED	1234
TIME_OF_DAY_FORMAT	24_HOUR_CLOCK
DISTANCE-TRAVEL_SPEED	RIGHT_ANGLE
AVERAGE_TRAVEL_SPEED	1.0,15.0,10.0
ADDITIONAL_TRAVEL_TIME	900, 1800, 1800
ACTIVITY_PURPOSE_RANGE_1	1
ACTIVITY_ANCHOR_FLAG_1	FALSE
SCHEDULE_CONSTRAINT_1	PASSENGER
MODE_DISTANCE_FACTORS_1	-0.05, -0.006, -0.07
LOCATION_WEIGHT_FIELD_1	N
LOCATION_CHOICE_SCRIPT_1	Survey/LocationNorth.txt
ACTIVITY_PURPOSE_RANGE_2	2
ACTIVITY_ANCHOR_FLAG_2	FALSE
SCHEDULE_CONSTRAINT_2	PASSENGER
MODE_DISTANCE_FACTORS_2	-0.07
LOCATION_WEIGHT_FIELD_2	BR
LOCATION_CHOICE_SCRIPT_2	Survey/LocationBR.txt
ACTIVITY_PURPOSE_RANGE_3	3
ACTIVITY_ANCHOR_FLAG_3	FALSE
SCHEDULE_CONSTRAINT_3	PASSENGER
MODE_DISTANCE_FACTORS_3	-0.07
LOCATION_WEIGHT_FIELD_3	AL
LOCATION_CHOICE_SCRIPT_3	Survey/LocationAL.txt
ACTIVITY_PURPOSE_RANGE_4	4
ACTIVITY_ANCHOR_FLAG_4	FALSE
SCHEDULE_CONSTRAINT_4	PASSENGER
MODE_DISTANCE_FACTORS_4	-0.07
LOCATION_WEIGHT_FIELD_4	UPT
LOCATION_CHOICE_SCRIPT_4	Survey/LocationUPT.txt

ActGen Results

Figure 15 through Figure 18 shows the demand generation and network loading model generated by TRANSIMS for the four network loading scenarios described in the methodology chapter.

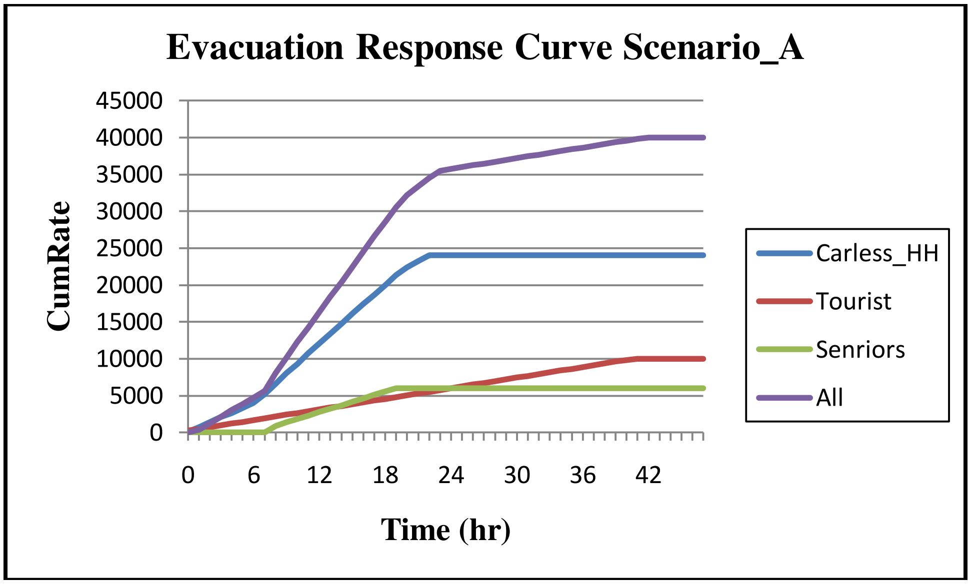


Figure 15. Network Loading Rates for Scenario-A

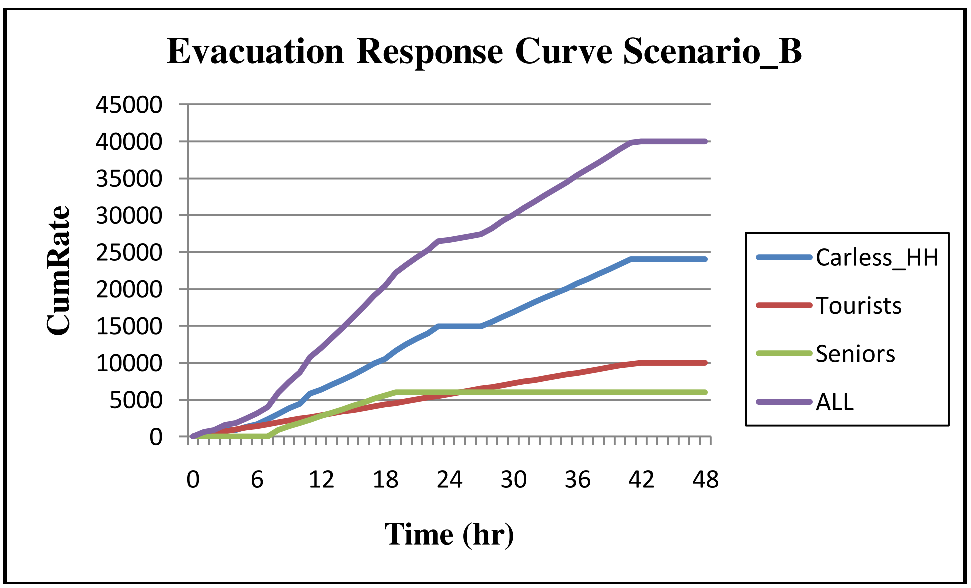


Figure 16. Network Loading Rates for Scenario-B

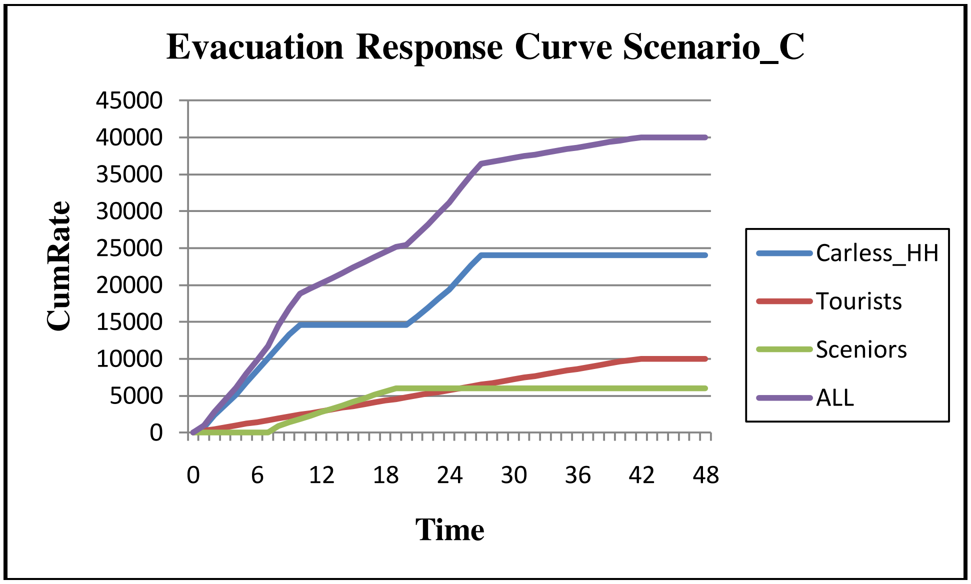


Figure 17. Network Loading Rates for Scenario-C

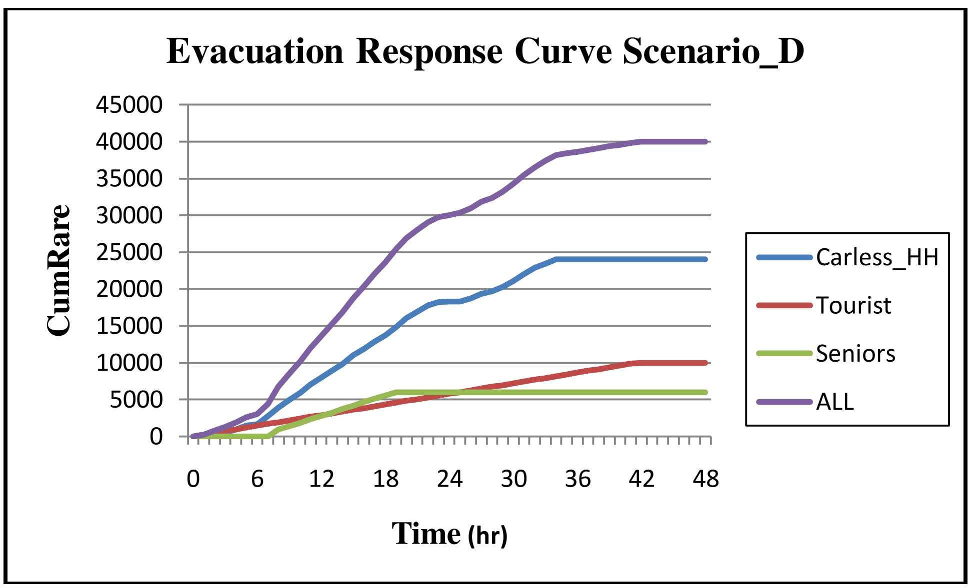


Figure 18. Network Loading Rates for Scenario-D

Route Planner

In TRANSIMS, the Router creates travel paths called plans for the synthesized household activities created by the ActGen program. It creates paths with minimum impedance between origin & destination (one activity location to another) based on the travel conditions at the specific time of the day. The results are stored in the output plan file.

Input Data Files

The following input files are required by the Router to build multimodal paths:

- Highway network (nodes, links, lane connectivity, activity locations, process links, and parking files),
- Transit network (transit stops, transit routes, and transit schedule files),
- Activity files which define the start time, end time, and locations of the activities a traveler is engaged in over the course of the day which reflects the travel demand by time, and
- Vehicles file (availability and location).

Router Control File

A sample control file for the Router program is shown in Table 43. The file “Router.ctl” is a text file that can be reviewed and edited using a standard text editor.

The Router control file describes a variety of parameters that control the path-building procedure in TRANSIMS.

Assumptions:

- The impedance for each link is determined by weighted walking time, waiting time, in-vehicle-travel time, and transfer time.
- The time spent walking is assigned 90.0 impedance units per second.
- The waiting time at the first transit boarding is assigned 20.0 impedance units per second. The waiting time at subsequent transit boarding locations is assigned 60.0 impedance units per second.

- Time spent in transit vehicles is valued at 15.0 impedance units per second.

Program Execution

The Router program was performed using the following batch file included in the control directory:

Router.bat

The printout file “Router.prn” was created besides a plan file and a problem file. The plan file included a separate set of records for each mode specific leg of the trip for each person in each household. The problem file included travelers who could not be routed.

Table 43. Router Control File

```
TITLE                               Transit Router Step for New Orleans Study
PROJECT_DIRECTORY                   ../
NET_DIRECTORY                       ../network/
NET_NODE_TABLE                      Node
NET_LINK_TABLE                      Link
NET_POCKET_LANE_TABLE               Pocket_Lane
NET_PARKING_TABLE                   Parking
NET_LANE_CONNECTIVITY_TABLE         Lane_Connectivity
NET_ACTIVITY_LOCATION_TABLE         Activity_Location_1RT
NET_PROCESS_LINK_TABLE              Process_Link_1RT
NET_TRANSIT_STOP_TABLE              Transit_Stop_Scen1RT
NET_TRANSIT_ROUTE_TABLE             Transit_Route_Scen1RT
NET_TRANSIT_SCHEDULE_TABLE          Transit_Schedule_Scen1RT
NET_TRANSIT_DRIVER_TABLE            Transit_Driver_scen1RT

ACTIVITY_FILE                       ACTIVITY/TransitACTIVITYRT1
VEHICLE_FILE                        vehicle/Vehicle.txt
HOUSEHOLD_FILE                      population/HouseholdTransit.txt
HOUSEHOLD_TYPE_SCRIPT               population/Household_Type2.txt

NEW_PLAN_FILE                       demand/TransitPlanRT1
NEW_PROBLEM_FILE                    results/TransitRoute_ProblemsRT1

TIME_OF_DAY_FORMAT                  SECONDS
#PERCENT_RANDOM_IMPEDANCE           20
RANDOM_NUMBER_SEED                  12345

NODE_LIST_PATHS                     YES
ROUTE_SELECTED_MODES                3
ROUTE_WITH_SPECIFIED_MODE           3
LIMIT_PARKING_ACCESS                YES
IGNORE_TIME_CONSTRAINTS             TRUE
```

Table 43 Continued

WALK_SPEED	1.5
WALK_TIME_VALUE	90
FIRST_WAIT_VALUE	20
TRANSFER_WAIT_VALUE	60
VEHICLE_TIME_VALUE	15
MAX_WALK_DISTANCE	3000
MAX_WAIT_TIME	180
MAX_NUMBER_TRANSFERS	1

Router Results

Table 44 shows a sample plan file. Some of the plans included one activity: staying at home, five activities: stay at home, walk to bus stop, ride the bus, walk to activity location and finally come back home by magic move, or eight activities: stay at home, walk to bus stop, ride the bus, walk to bus stop, ride the bus, walk to activity location, stay at the destination location and finally come back home by the magic move.

Table 44. Seven Leg Plan Example

```
200000001 0 1 1
0 8106 1 8106 1
105778 105778 1 0 0
0 4
0

200000001 0 2 1
105778 8106 1 1 3
5 105783 1 0 750
0 2
0

200000001 0 2 2
105783 1 3 4 3
2777 108560 1 0 27770
0 1
1
19

200000001 0 2 3
108560 4 3 8109 1
5 108565 1 0 750
0 2
0
```

Table 44 Continued

```
20000001 0 3 1
108565 8109 1 8109 1
49080 157645 1 0 0
0 4
0

200000001 0 4 1
157645 8109 1 8106 1
4297 161942 1 0 1
0 6
1
2

200000001 0 5 1
161942 8106 1 8106 1
3658 165600 1 0 0
0 4
0
```

Traffic Microsimulator

TRANSIMS Microsimulator simulates the transit movement and its interaction with the network using the travel plans generated by the Router.

Input Data Files

- Network files (highway and the transit network),
- Time-sorted plan file,
- Vehicle file (describes the location of each vehicle on the network).

The travel plans that are required by the Microsimulator needed to be sorted by time of day. In order to sort the plan file, PlanPrep program was used.

Microsimulator Control File

A sample control file for the Microsimulator program is shown in Table 45. The file is a text file that can be reviewed and edited using a standard text editor.

Assumptions:

- The default value for CELL_SIZE is 7.5 meters,

- The default value for TIME_STEPS_PER_SECOND is 1 second,
- The simulation starts at time 0:00 (i.e., midnight) and ends at 50:00 (i.e., 2:00 AM).
- The MAXIMUM_WAITING_TIME value of 180, which indicates that vehicles remaining in the same cell for more than 180 minutes will be removed from the simulation,
- Both the MAX_DEPARTURE_TIME_VARIANCE and the MAX_ARRIVAL_TIME_VARIANCE keys have values of 180, indicating that any vehicle that is unable to be loaded to the network within 180 minutes after its scheduled departure time or that has not completed its trip within 180 minutes after its scheduled arrival time will be removed from the network.
- The PLAN_FOLLOWING_DISTANCE key is set to 525 meters, which controls lane-changing behavior of vehicles before turning.
- The three look-ahead parameters (LOOK_AHEAD_TIME_FACTOR, LOOK_AHEAD_LANE_FACTOR, and LOOK_AHEAD_DISTANCE) control optional lane changing. In this simulation, the traveler will look ahead 260 meters and will value 4 seconds of travel time saved as comparable to one lane change maneuver.
- The minimum car following distance is equal to the distance that that a vehicle can travel in 0.7 seconds at the current speed. This is controlled by the DRIVER_REACTION_TIME key.

Program Execution

The Microsimulator program was performed using the following batch file included in the control directory:

Microsimulator.bat

The printout "Microsimulator.prn" file was created, as will be the Snapshot, Link Delay, Performance, Ridership and Problem files.

Table 45. Microsimulater Control File

```
TITLE                          New Orleans Microsimulation

#---- Input Files ----

PROJECT_DIRECTORY              ../
NET_DIRECTORY                  ../network/
NET_NODE_TABLE                 Node
NET_LINK_TABLE                 Link
NET_POCKET_LANE_TABLE          Pocket_Lane
NET_PARKING_TABLE              Parking
NET_LANE_CONNECTIVITY_TABLE    Lane_Connectivity
NET_ACTIVITY_LOCATION_TABLE    Activity_Location_1RT
NET_PROCESS_LINK_TABLE         Process_Link_1RT
NET_UNSIGNALIZED_NODE_TABLE    Unsignalized_Node
NET_SIGNALIZED_NODE_TABLE      Signalized_Node
NET_TIMING_PLAN_TABLE          Timing_Plan
NET_PHASING_PLAN_TABLE         Phasing_Plan
NET_DETECTOR_TABLE             Detector
NET_SIGNAL_COORDINATOR_TABLE   Signal_Coordinator
#NET_LANE_USE_TABLE            ../../ReportBaseModel/Lane_Use
NET_TRANSIT_STOP_TABLE         Transit_Stop_scen1RT
#NET_TRANSIT_FARE_TABLE        Transit_Fare_scen1RT
NET_TRANSIT_ROUTE_TABLE        Transit_Route_scen1RT
NET_TRANSIT_SCHEDULE_TABLE     Transit_Schedule_scen1RT
NET_TRANSIT_DRIVER_TABLE       Transit_Driver_scen1RT

VEHICLE_FILE                   vehicle/Vehicle.txt
VEHICLE_TYPE_FILE              vehicle/VehType

PLAN_FILE                      Demand/TimePlanRT
NODE_LIST_PATHS                Yes

#---- Parameters Controlling the Simulation ----

CELL_SIZE                      7.5
TIME_STEPS_PER_SECOND          1
TIME_OF_DAY_FORMAT             24_HOUR_CLOCK
TIME_OF_DAY_FORMAT             SECONDS
SIMULATION_START_TIME          0:00
SIMULATION_END_TIME            50:00
SPEED_CALCULATION_METHOD       CELL-BASED

PLAN_FOLLOWING_DISTANCE        525
LOOK_AHEAD_TIME_FACTOR         1.0
LOOK_AHEAD_LANE_FACTOR         4.0
LOOK_AHEAD_DISTANCE            260

MAXIMUM_SWAPPING_SPEED         22.5
```

Table 45 Continued

```
SLOW_DOWN_PROBABILITY                 8
SLOW_DOWN_PERCENTAGE                  10

DRIVER_REACTION_TIME                  0.7
RANDOM_NUMBER_SEED                    333333333
MINIMUM_WAITING_TIME                  180
MAXIMUM_WAITING_TIME                  9000
MAX_DEPARTURE_TIME_VARIANCE           180
MAX_ARRIVAL_TIME_VARIANCE             180

#---- Output Files and associated control keys -----

NEW_PROBLEM_FILE                      results/Msim_ProblemsRT
#NEW_PROBLEM_FORMAT                   VERSION3
#MAX_SIMULATION_ERRORS                100000

OUTPUT_SNAPSHOT_FILE_1                results/Snapshot1RT
OUTPUT_SNAPSHOT_FORMAT_1              VERSION3
OUTPUT_SNAPSHOT_TIME_FORMAT_1         SECONDS
OUTPUT_SNAPSHOT_INCREMENT_1           1
OUTPUT_SNAPSHOT_TIME_RANGE_1  21600..22200
##OUTPUT_SNAPSHOT_LINK_RANGE_1        2..10, 14..16, 18, 20

OUTPUT_SNAPSHOT_FILE_2                results/Snapshot2RT
OUTPUT_SNAPSHOT_FORMAT_2              VERSION3
OUTPUT_SNAPSHOT_TIME_FORMAT_2         SECONDS
OUTPUT_SNAPSHOT_INCREMENT_2   1
OUTPUT_SNAPSHOT_TIME_RANGE_2  46800..47400
##OUTPUT_SNAPSHOT_LINK_RANGE_2        2..10, 14..16, 18, 20

OUTPUT_SNAPSHOT_FILE_3                results/Snapshot3RT
OUTPUT_SNAPSHOT_FORMAT_3              VERSION3
OUTPUT_SNAPSHOT_TIME_FORMAT_3         SECONDS
OUTPUT_SNAPSHOT_INCREMENT_3   1
OUTPUT_SNAPSHOT_TIME_RANGE_3  64800..65400
##OUTPUT_SNAPSHOT_LINK_RANGE_3        2..10, 14..16, 18, 20

OUTPUT_SNAPSHOT_FILE_4                results/Snapshot4RT
OUTPUT_SNAPSHOT_FORMAT_4              VERSION3
OUTPUT_SNAPSHOT_TIME_FORMAT_4         SECONDS
OUTPUT_SNAPSHOT_INCREMENT_4   1
OUTPUT_SNAPSHOT_TIME_RANGE_4  48600..49200
##OUTPUT_SNAPSHOT_LINK_RANGE_4        2..10, 14..16, 18, 20

OUTPUT_SNAPSHOT_FILE_5                results/Snapshot5RT
OUTPUT_SNAPSHOT_FORMAT_5              VERSION3
OUTPUT_SNAPSHOT_TIME_FORMAT_5         SECONDS
OUTPUT_SNAPSHOT_INCREMENT_5   1
OUTPUT_SNAPSHOT_TIME_RANGE_5  49200..49800
##OUTPUT_SNAPSHOT_LINK_RANGE_5        2..10, 14..16, 18, 20

OUTPUT_SNAPSHOT_FILE_6                results/Snapshot6RT
OUTPUT_SNAPSHOT_FORMAT_6              VERSION3
```

Table 45 Continued

```
OUTPUT_SNAPSHOT_TIME_FORMAT_6          SECONDS
OUTPUT_SNAPSHOT_INCREMENT_6    1
OUTPUT_SNAPSHOT_TIME_RANGE_6  0..86400
##OUTPUT_SNAPSHOT_LINK_RANGE_6         2..10, 14..16, 18, 20

OUTPUT_SUMMARY_TYPE_1            PERFORMANCE
OUTPUT_SUMMARY_FILE_1            results/PerformanceRT
OUTPUT_SUMMARY_FORMAT_1                TAB_DELIMITED
OUTPUT_SUMMARY_TIME_FORMAT_1           24_HOUR_CLOCK
OUTPUT_SUMMARY_INCREMENT_1    900
OUTPUT_SUMMARY_TIME_RANGE_1  0..27
##OUTPUT_SUMMARY_LINK_RANGE_1          2..10, 14..16, 18, 20

OUTPUT_SUMMARY_TYPE_2            LINK_DELAY
OUTPUT_SUMMARY_FILE_2            results/LinkDelayRT
OUTPUT_SUMMARY_FORMAT_2                VERSION3
OUTPUT_SUMMARY_INCREMENT_2    900
OUTPUT_SUMMARY_TIME_RANGE_2  0..172800

OUTPUT_PROBLEM_TYPE_1           LANE_CONNECTIVITY, WAIT_TIME
OUTPUT_PROBLEM_FILE_1           ProblemLink
OUTPUT_PROBLEM_FILTER_1          100
OUTPUT_PROBLEM_INCREMENT_1       3600
OUTPUT_PROBLEM_TIME_RANGE_1       0..172800

OUTPUT_RIDERSHIP_FILE_1            results/RidershipRT
OUTPUT_RIDERSHIP_FORMAT_1          TAB_DELIMITED
OUTPUT_RIDERSHIP_TIME_FORMAT_1          24_HOUR_CLOCK
OUTPUT_RIDERSHIP_TIME_RANGE_1  0..172800
#OUTPUT_RIDERSHIP_ROUTE_RANGE_1         0
```

PlanPrep

TRANSIMS PlanPrep program organizes the plan file. The PlanPrep program can be used for two purposes: first sorting the plan file by time in order to prepare it to be used by the Microsimulator or merging the plan files in order to integrate the plan files of both the transit-based evacuation with the auto-based evacuation components of the project.

Input Data Files

- Router plan file

PlanPrep Control File

The PlanPrep control file is a text file that can be reviewed and edited using a standard text editor. Table 46 shows the control file for sorting the plan file by time and Table 47 shows the control file for merging two plan files.

Program Execution

The PlanPrep program can be executed using the following batch file:

PlanPrep.bat

A printout file, “PlanPrep.prn,” and a new sorted plan file, “TimePlans,” were created by the process. The sorted plan file could then be used for the Microsimulator process.

Table 46. PlanPrep Control File for Sorting

```
TITLE                     Sort  Plan Files
PROJECT_DIRECTORY         ../

#---- Input Files ----

INPUT_PLAN_FILE          demand/TransitPlanRT1

#---- Output Files ----

OUTPUT_PLAN_FILE         demand/TimePlanRT

#---- Parameters ----

PLAN_SORT_OPTION          TIME
```

Table 47. PlanPrep Control File for Merging

```
TITLE                       Merge Plan Files
#---- Input Files ----

INPUT_PLAN_FILE          ../plans/TimePlans19A
MERGE_PLAN_FILE          ../plans/TimePlan_ALLScen_1C
#---- Output Files ----

OUTPUT_PLAN_FILE          ../plans/Plan_1C
#---- Parameters ----

#INPUT_PLAN_SORT               TRAVELER
PLAN_SORT_OPTION               TRAVELER
```

ReSchedule

TRANSIMS Reschedule program reschedules the transit arrival/departure trips upon the actual field conditions produced by the Microsimulator.

Input Data Files

- Highway network (nodes, links, lane connectivity, activity locations, process links, and parking files),
- Transit network (transit stops, transit routes, and transit schedule files),
- The link delay file
- The ridership file
- The vehicle file

ReSchedule Control File

A sample control file for the ReSchedule program is shown in Table 48. The file is a text file that can be reviewed and edited using a standard text editor.

Program Execution

The ReSchedule program can be executed using the following batch file:

ReSchedul.bat

A printout file, "ReSchedule.prn," and a new transit schedule file were created by the process.

Table 48. ReSchedule Control File

```
TITLE                         Reschedule Transit Network

#---- Input Files ----

PROJECT_DIRECTORY             ../results
NET_DIRECTORY                 ../../network/network/
NET_NODE_TABLE                Node
NET_ZONE_TABLE                Zone
NET_LINK_TABLE                Link
```

Table 48 Continued

NET_PARKING_TABLE	Parking
NET_LANE_CONNECTIVITY_TABLE	Lane_Connectivity
NET_TRANSIT_STOP_TABLE	../../TransitRoutes/network/Transit_Stop_NOScen1
#NET_TRANSIT_FARE_TABLE	Transit_Fare
NET_TRANSIT_ROUTE_TABLE	../../TransitRoutes/network/Transit_Route_NOScen1
NET_TRANSIT_SCHEDULE_TABLE	../../TransitRoutes/network/Transit_Schedule_ALLNOScen1.txt
NET_TRANSIT_DRIVER_TABLE	../../TransitRoutes/network/Transit_Driver_NOScen1
RIDERSHIP_FILE	../results/Ridership_Scen1A
VEHICLE_TYPE_FILE	../vehicle/VehType
Link_Delay_File	../results/LinkDelay19
LINK_DELAY_FORMAT	TAB_DELIMITED
TRANSIT_TIME_PERIODS	8:00, 20:00,24:00, 32:00, 44:00, 48:00, 50:00
#-- output --#	
NEw_TRANSIT_SCHEDULE_TABLE	../../TransitRoutes/Transit_Schedule_RS_NOScen1A
NEW_TRANSIT_SCHEDULE_FORMAT	TAB_DELIMITED
RESCHEDULE_REPORT_1	TOTAL_CHANGE_DISTRIBUTION
RESCHEDULE_REPORT_2	PERIOD_CHANGE_DISTRIBUTIONS
RESCHEDULE_REPORT_3	TIME_PERIOD_SUMMARY

Vita

Hana holds a Bachelor of Science degree in civil engineering from the University of Jordan. She also received her Master of Science degree in civil engineering/ highway and traffic from the University of Jordan. Hana is scheduled to obtain her doctoral degree in civil engineering from Louisiana State University the spring of 2010. After graduation, Miss Naghawi plans to enter the teaching and research profession as an assistant professor at a four-year university.

Hana worked in the field of highway design and traffic engineering at the Municipality of Greater Amman for seven years. She also worked as an instructor at Al Isra University in Jordan before she decided to pursue her doctoral degree. Hana taught a traffic engineering course, and engineering drawing course, a highway laboratory course, and a survey laboratory course.

Miss Naghawi's research interests lie within the broad area of transportation engineering with a specific interest in traffic operation and congestion prevention, with special concentration on issues related to the planning and management of traffic during mass evacuations.