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16. Abstract

In response to both natural and man-made disasters, more and more emergency evacuation plans have been put forward and consistently aims to move a large disaster affected population through a multimodal transportation network towards safer areas as quickly and efficiently as possible. The objectives of this paper are 1) to verify the feasibility of applying the DYNASMART-P model to simulation of traffic characteristics in both normal and emergency conditions for the urban transportation system in the Greater Jackson metropolitan area in Mississippi and 2) to develop and evaluate emergency evacuation strategies for a large scale evacuation of people under emergency conditions in the Greater Jackson area. In this paper, traffic network including Hinds, Madison and Rankin was built through the mesoscopic traffic-network planning and simulation model DYNASMART-P based on the dynamic traffic assignment methodology, and applied the model to a highway network on the route of the evacuation. The background OD demand as input for the simulation program was calibrated using observed traffic volume data collected in several critical routes of evacuation. An evacuation scenario was designed to study the impacts of the evacuating traffic from southeastern Louisiana to the Greater Jackson Metropolitan Area of Mississippi due to an assumed approaching hurricane disaster. Critically congested freeway segments under two evacuation intensity levels were identified based on the criterion of the average queue length percentage and level of service. The causes for the congestion of roads were analyzed and explained.

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EXECUTIVE SUMMARY

In response to both natural and man-made disasters, emergency evacuation aims to move a large disaster affected population through a multimodal transportation network towards safer areas quickly and efficiently. Effective emergency evacuation depends on careful planning and adaptive real-time management from an integrated system-level perspective, calling for the coordination of transportation agencies, metropolitan planning organizations, emergency management authorities, and highway patrol centers to enable collaborative metropolitan highway network evacuation. The first objective of this study is to verify the feasibility of applying the DYNASMART-P model to simulation of traffic characteristics in both normal and emergency conditions for the urban transportation system in the Greater Jackson metropolitan area in Mississippi. The second objective is to develop and evaluate emergency evacuation strategies for a large scale evacuation of people under emergency conditions in the Greater Jackson area. This report consists of the following chapters:

Chapter 1 Introduction
- Highlights the research objectives and outlines the report.

Chapter 2 Background
- Reviews various evacuation simulation packages that were developed, using microscopic, mesoscopic, or macroscopic simulation approaches, and effective traffic control strategies that were used to improve efficiency and capacity of transportation infrastructure during emergency evacuations.
- Introduces the research background of the project and states the research methodology adopted in the project.

Chapter 3 Development of Network Model with DYNASMART-P
- Describes the network modeling with three types of data, which are geographic data, hourly traffic volume data, and origin-destination demand matrix data.

Chapter 4 Development of Network Model with DYNASMART-P
- Presents the calibration of data inputs for the simulation program.

Chapter 5 Evacuation Simulation and Traffic Control Strategy
- Introduces the evacuation scenario.
- Calculates OD demand matrixes including background and evacuation demands.
- Explains the causes for the congestion of road links in simulation tests.

Chapter 6 Summary
- Summarizes the findings of the study.

1. INTRODUCTION

In response to both natural and man-made disasters, emergency evacuation aims to move a large disaster affected population through a multimodal transportation network towards safer areas quickly and efficiently. Effective emergency evacuation depends on careful planning and adaptive real-time management from an integrated system-level perspective. This calls for the coordination of different organizations including transportation agencies, metropolitan planning organizations, emergency management authorities and highway patrol centers to enable collaborative metropolitan highway network evacuation.

The recent evacuation of New Orleans was a wakeup call for designing comprehensive evacuation of citizens without means of personal transportation in a multimodal network environment. The extremely long queues clogged along evacuation routes in the Houston evacuation event, on the other hand, highlight the need to provide a staged evacuation plan and real-time traffic information to assist evacuees in making rational pre-trip decisions. Specifically, managing traffic operations during or after major emergency events such a terrorist attacks or hazardous weather conditions, is one of the critical components in emergency management of the transportation system in order to effectively respond to, recover from, and mitigate the impacts of a disaster. The key abilities in effective emergency operation include the determining of the best set of evacuation routes and scheduling for large-scale movement of people under time-sensitive, hazardous conditions. Such an evacuation strategy under threats ranging from terrorists to hurricanes must reflect various resources/constraints of transportation systems network at different levels, i.e. local and regional, under dynamically changing traffic and emergency conditions.

One of the challenges in pre-evacuation planning and post-evacuation response is accurately modeling the traffic congestion evolution (queue build-up, spillback, and dissipation) in a dynamic and complex network after emergency events. It has been widely recognized that the analytic congestion functions used in static traffic assignment models are unable to realistically describe the propagation and dissipation of system congestion under time-varying traveler demand patterns. Alternatively, Dynamic Traffic Assignment (DTA) modeling tools uniquely address the needs of evaluation network performance under various traveler information and traffic management strategies. DYNASMART-P, in particular, is a new generation of traffic analysis tool developed under the FHWA DTA research project in support of traffic operations and planning decisions. The FHWA is currently promoting the use of DYNASMART-P in the professional community for region-wide transportation operations planning to (1) address operational issues in the transportation planning process and (2) develop and evaluate traffic management and control strategies, e.g. in contexts of Integrated Corridor Management and Emergency Transportation Operations.

1.1. Study Objectives

The specific objectives of this study include:

1. Verifying the feasibility of applying DYNASMART-P model to simulate traffic characteristics in both normal and congested road conditions for the urban transportation system in the Great Jackson area.
    a. Reviewing state of the art literature and products of traffic simulation models that are capable of solving traffic problems of time-varying demands using static/dynamic traffic assignment methodologies;
    b. Becoming familiar with DYNASMART-P model in an intensive learning process;
    c. Modeling and calibrating the transportation network inputs using DYNASMART-P and routinely collected traffic volume, speed, and density data at specific locations. Zonal demands and network mapping data is available from the Mississippi Department of Transportation (MDOT).
2. Simulation study of impacts of large scale evacuation of people in the Greater Jackson metropolitan area of Mississippi.
    a. Developing emergency scenarios for said network and preparing data inputs for DYNASMART-P model;
    b. Simulation study of impacts of evacuating traffic on highway network in the Greater Jackson Area;
    c. Developing and presenting research findings.

1.2. Outline of Report

The rest of the report is organized as follows: Chapter 2 provides a wide scope review of the most feasible strategies that have been used to improve efficiency and maximize transportation infrastructure capacity on evacuation conditions such as contra-flow operation, evacuation order coordination, and mass transit utilization. Popular evacuation simulation packages developed using microscopic, mesoscopic, or macroscopic modeling approaches were reviewed. Chapter 3 describes the study area and introduces three kinds of data required in the project: geographic data, hourly traffic volume vs. speed data, and origin-destination demand matrix data. The next part of the chapter presents the detail preparation process for each category of input data including network Excel files, Node/Link/TAZ GEO files, and OD demand files. The building of a network model in the DYNASMART-P is introduced at the end of the chapter. Chapter 4 presents the calibration of data inputs for the simulation program. Chapter 5 introduces an evacuation scenario and then calculates OD demand matrixes including background and evacuation demand respectively. The simulation tests were run with different OD demands under evacuation conditions. All congested road segments are found and the causes for the congestions are explained based on the simulation results. In Chapter 6, the findings in the project are summarized.

2. BACKGROUND

There has been an immense amount of work in modeling evacuation that has been published (*1*, *2*, *3*, *4*, *5*, *6*, *7*). Early studies, published as early as in 1963, dealt with traffic management under emergency conditions and presented empirical solutions. The most feasible strategies that have been used to improve efficiency and maximize transportation infrastructure capacity on evacuation conditions are contra-flow operation, coordinated or staged evacuation, and mass transit utilization. Meanwhile, several evacuation simulation packages were developed using microscopic, mesoscopic, and macroscopic simulation approaches.

2.1. Evacuation Strategies

Contra-flow Operation

Contraflow strategy involves the reversal of flow in one or more inbound lanes of a freeway as traffic in the outbound direction. Contraflow operation significantly increases the outbound capacity by taking advantage of the untapped capacity of the inbound lanes without the need to construct additional lanes. This method has been widely used in the coastal states that are threatened frequently by hurricanes (*5*).

An approach was introduced by Tuydes and Ziliaskopoulos (*8*) who used a modified cell transmission model (*9, 10*) to optimize the system travel time and calculate the optimal capacity reversibility on a traffic network under unusual demand patterns. The proposed model addresses some of the problems such as representation of vehicle-level movements, spatio-temporal changes in the disaster conditions, and optimal capacity reversibility calculation capabilities. One shortcoming of the model is the high computation cost associated with the analytical nature which prevents its use for actual urban networks. In (*11*), they developed a simulation-assignment tabu search-based heuristic algorithm to compute optimal reversibility designs for large scale networks in order to reduce total system time.

Wolshon et al. (*12*, *13*, *14*) compared two alternative scenarios for this same segment using CORSIM microscopic traffic simulation program to model the freeway configuration. The results show the critical role played by the entry point and the plan to load vehicles into contraflow lanes. They also give suggestions to significantly improve the effectiveness of the contraflow operation with design of contraflow entry points.

Lim and Wolshon (*15*) conducted a study to evaluate the effects of the various contraflow termination designs planned for the Atlantic and Gulf Coast states. Six generic configurations capable of representing traffic operations in the vicinity of the termination point were developed using CORSIM as the analysis tool. The network performance measures were used to rank the configurations. The study revealed important trends relative to the use of contraflow evacuation strategy.

Coordinated or Staged Evacuation

Inefficient issuance of evacuation orders would result in a high rate of loading from all origins leading to avoidable congestion and putting people most vulnerable to disaster

at a high risk. There is a definite need to co-ordinate the issuance of an evacuation order for efficient evacuation operations.

Ozbay et al. (*16*) conducted a critical analysis on demand generation and network loading models for determining optimal evacuation staging (scheduling) schemes. They reviewed three widely used models; S-curves, Tweedie's, and Sequential Logit Models. Using the system optimal traffic assignment, they concluded that the S-curve and Tweedie's demand generation resulted in unrealistic delays and the Sequential Logit model provided more realistic results. Mitchell and Radwan (*17*) evaluated various heuristic strategies to improve evacuation clearance time of people evacuating from Ormond Beach. This research showed the advantage of staging demand during evacuation. Liu et al. (*18*) proposed a cell based network model using Tweedie's demand generation model in order to determine optimal staging schemes. In light of the research conducted by Ozbay et al. (*16*), there was a need to incorporate Sequential Logit Models as demand generation model for determining optimal staging schemes during hurricane evacuations. A major drawback was the assumption that the demand from an origin was generated only after the issuance of the evacuation order. Sbayti and Mahmassani (*19*) realized that by staggering the evacuating load onto the network, the onset of congestion may be delayed, and people can be evacuated faster. Hence, they considered the problem of scheduling evacuation trips between a selected set of origin nodes and destinations, with the objective of minimizing the network clearance time. Shen et al. (*20*) proved that an optimal traffic pattern always exists that contains no holding in the context of evacuation planning. They proposed a dynamic network simplex method for solving the simplified SO-DTA model which represents traffic flow propagation by a point-queue model. For the original cell-based SO-DTA, they suggested an iterative procedure that can effectively eliminate holdings in a solution obtained from a conventional linear programming algorithm. Vinayak and Essam (*21*) proposed an optimization model based on the cell transmission model to determine optimal scheduling of evacuation orders. This model used a Sequential Logit model and did not require a closed form for the evacuation demand as part of the optimization model. It only required that the demand be generated for every possible evacuation order. For the numerical problem the scheduled evacuation order provided an improvement of 11% in total vehicle hours. Chen (1) studied the simultaneous staged evacuation for a road network. The results showed that the effectiveness of staged evacuation depends upon the type of roadway network available and the population density of the area. The results also confirmed that if there is no congestion on the roadway, simultaneous evacuation would be a good option.

Transit Utilization

Although several previous studies have been done to improve the capacity of existing road network during evacuation conditions, it is not always enough to use the contra-flow and other general traffic control strategies in many metropolitan regions. This is true because there are some high population density areas with limited capacities in existing road networks. Therefore, a specific emergency response plan based on the existing transit system was studied to deal with the difficulties of evacuations in these regions.

In order to enhance the evacuating ability of rescue vehicles (i.e. to increase their load factors), conserve capacities of existing road networks, avoid potential traffic chaos and congestion during the evacuation, and take care of the requirements of disabled and

indigent persons, an initial framework of transit-based evacuation plan was developed by Chen and Chou (*22*). Based on the research results, Chen and Chou (*23*) used a bi-level optimization model to determine the waiting locations and corresponding shelters of the transit-based emergency evacuation plan and also dispatch rescue buses toward the combinatorial locations. Furthermore, a contra-flow simulation was elaborated to disperse the inside and ambient traffic of the target area. They found the transit-based evacuation plan with the contra-flow operations to be better than the same base plan without the contra-flow operations. If more people should select to evacuate via transit systems, that plan would reduce the difficulties of dispersing traffic and improve the system performance remarkably. ElMitiny et al. (*24*) used VISSIM traffic simulation tool to evaluate alternative plans for the deployment of transit during an emergency situation in a transit facility such as a bus depot. A total of nine evacuation scenarios were simulated and analyzed to reach the best evacuation strategy for the local transit company's main bus depot. Evacuation strategies evaluated included traffic diversion, bus signal optimization, access restriction, different destinations, and evacuation as pedestrians. Total network delay for each of the scenarios was compared to the base case and the results showed that evacuation as pedestrians at assumed conditions was better than using buses for evacuation. It was also found that traffic rerouting could have potential reduction in delay and evacuation clearance time. Mastrogiannidou et al. (*25*) used a dynamic network model in their study of transit assisted emergency evacuation procedures. They considered three different scenarios with different numbers of available evacuation transit vehicles for the design of the evacuation container terminals in the Port Elizabeth-Newark area of the Port of New York and New Jersey.

2.2. Evacuation Simulation Models

NETSIM (KLD, 1980)

The network simulation package of NETSIM was developed by KLD Associates, Inc. It is a microscopic, stochastic highway traffic simulation model and can be used to simulate traffic performance under different control strategies and under heavy traffic demand. The vehicles simulated in the network are processed for each time interval, subjected to the imposition of traffic control systems.

HMM Associates (*26*) and Urbanik (*27*) first used NETSIM to estimate evacuation time for a nuclear plant area. Though the NETSIM model is a widely validated procedure and found to perform reasonably well, the application of NETSIM to evacuation analysis has some drawbacks, including limited capacity to handle large regional networks and lack of a dynamic route selection model (every turning movement at an intersection has to be specified).

Sheffi et al (*28*) also pointed out that validations of using NETSIM were all conducted in small urban network under normal operating conditions which were probably not indicative of an emergency evacuation in a rural setting. In addition, travel demand models are not incorporated into NETSIM, which means traffic demand has to be submitted to the model as an external input.

NETVAC (MIT, 1981)

The NETVAC was developed by Sheffi et al. (28) specifically for nuclear evacuation analysis. NETVAC is a fixed-time macro traffic simulation model using established traffic flow models and relationships to simulate the flow of vehicles through a network. NETVAC was used to estimate network clearance time for areas surrounding nuclear power plant sites. It was specifically designed to model evacuation traffic patterns including queue formation process, dynamic route selection, and a wide variety of options designed to simulate alternative evacuation scenarios.

The major disadvantages (29) of the model include 1) It is insensitive to evacuees' behavior; 2) It is structured in a descriptive mode rather than design and planning mode; and 3) It is a deterministic model rather than a probabilistic and dynamic simulation model. In addition, as indicated from the input requirements, NETVAC is not given the capability of estimating the travel demand associated with evacuations, and the spatial and temporal loading pattern has to be input to NETVAC as given information.

DYNEV (KLD, 1982)

The DYNEV model was developed by KLD Associates, Inc. It is a macroscopic model for simulating evacuation from sites around a nuclear power plant which employs the principles of flow continuity and flow dynamics. In the DYNEV model, the road network is represented as a series of links connected at nodes representing the intersection of these segments. The outputs can help identify the bottlenecks on the evacuation route so that appropriate measures can be taken to improve the operations. The improved computational efficiency serves to substantially reduce the computing time and storage. The number of trips entering and leaving the roadway system is required as input data for both the DYNEV models.

MASSVAC (VP, 1985)

The MASSVAC was developed by Hobeika et al (30). It is a macroscopic model for the evacuation process and utilizes the all-or-nothing traffic assignment or Dial's algorithm to simulate the traffic movements during evacuation. The inputs to the program include the trip production at each origin node, loading rate curve factors, as well as link characteristics such as link length, road capacity, number of lanes, free-flow speed, link type, and coordinates of each origin and destination point. The program loads evacuating vehicles onto the highway network according to loading rate curves, determines their best evacuation routes, estimates network clearance time, and identifies highway bottlenecks. This program includes a trip distribution model. Since people need to be evacuated as quickly as possible from a nuclear disaster area, the model has been developed so that the evacuees choose the shortest routes to get out of the at-risk area first and afterwards seek the proper destination shelter. This is completely different from hurricane evacuation trip distribution, which is usually well planned before the evacuation begins.

MASSVAC was applied to develop a hurricane transportation evacuation plan for the city of Virginia Beach (31). In this study, four scenarios with different hurricane intensity levels and operational strategies were evaluated. The factors significantly affecting the overall evacuation times under hurricane/flood conditions were found to be the size of the population to be evacuated, the location and number of shelters, the capacity of the

evacuation routes, the time available for evacuating from the threatened areas, and the specific traffic operations strategies used for alleviating the congested links.

HURREVAC (COE, 1994)

The HURREVAC program was developed by Sea Island Software, Inc. beginning in 1988, in response to a need for computer based management of data produced by various federal Hurricane Evacuation Studies. It assists government emergency managers in making decisions for their states/communities when under a hurricane threat. First major use of the program came with Hurricane Hugo (*32*) in South Carolina and Georgia. Subsequently, the program was developed for 13 states, the US Virgin Islands and Puerto Rico.

HURREVAC tracks hurricanes on computer plot maps using information from the National Hurricane Center (NHC) and estimates when various evacuation decisions should be made, using data from the federal hurricane evacuation study for the area. The process works this way: a) The arrival of gale-force (34 knots or 39mph) winds in the area is computed using the NHC projections with adjustment for a direct-hit or worst-case approach to the community; b) Clearance times are computed using Saffir-Simpson scale category of storm, response of the public, and occupancy readings for the area. The basic data for the clearance times is produced by a local hurricane evacuation study usually performed by the Corps of Engineers, National Weather Service, and Federal Emergency Management Agency (FEMA). The clearance time is subtracted from the gale arrival time to reach a suggested evacuation decision time. This approach is based on the need to have the at-risk population out of vulnerable areas before gales reach the coast.

OREMS (ORNL, 1999)

Another hurricane emergency model is the Oak Ridge Evacuation Modeling System (OREMS) (33). This microcomputer-based system was developed by the Center for Transportation Analysis at the Oak Ridge National Laboratory (ORNL) to simulate the traffic conditions of a highway network as evacuation progresses. It is an integrated system consisting of three major components: a data input manager, a traffic simulation model, and an output data display manager.

The analytical core of OREMS is a FORTRAN program ESIM (Evacuation SIMulation), which combines the trip distribution and traffic assignment sub-model with a detailed traffic flow simulation sub-model. The combined trip distribution and traffic assignment sub-model was developed by the researchers at ORNL, and the traffic simulation model was derived primarily from the TRAF simulation system developed by FHWA and therefore has many similarities to that system. The combined algorithm of trip distribution and trip assignment expands the original network by introducing super-destination nodes and adding a set of pseudo-links, which connect the super-destination nodes to the original destination nodes.

Each super-destination node is connected to a subset of destination nodes. These subsets of destination nodes are designed in such a way that the flow needs to be assigned from any origin to a single super-destination node. The algorithm solves this problem by using the assignment model on the expanded network. The flows on the expanded

network are converted into flows on the original network by deleting the super-destination and the pseudo-links.

Given evacuation travel demand, ESIM determines the destinations selected by evacuees and the routes taken to reach the selected destinations through traffic distribution and assignment. It then performs a detailed simulation of vehicular traffic operations on the evacuation network using these projected flows and routes under prevailing roadway and traffic conditions. The model can identify evacuation routes, estimate service rates in the evacuation network by location and time, identify traffic operational characteristics and bottlenecks, estimate evacuation times across various categories, and provide information on other elements of an evacuation plan.

It also allows the analyst to experiment with alternative routes and destinations, various alternative traffic control and management strategies, and different evacuee participation rates.

TransModeler (Caliper, 2000)

TransModeler is a powerful and versatile traffic simulation package applicable to a wide array of traffic planning and modeling tasks (*34*). TransModeler can simulate all kinds of road networks, from freeways to downtown areas, and can analyze wide area multimodal networks in great detail and with high fidelity. It can model and visualize the behavior of complex traffic systems in a 2-dimensional or 3-dimensional GIS environment to illustrate and evaluate traffic flow dynamics, traffic signal and ITS operations, and overall network performance.

TransModeler breaks new ground in ease-of-use for complex simulation applications and integrates with TransCAD, the most popular travel demand forecasting software in the U.S., to provide a complete solution for evaluating the traffic impacts of future planning scenarios. Moreover, the TransModeler mapping, simulation, and animation tools allow you to present study findings to decision-makers in a clear and compelling fashion.

Based upon the latest research, TransModeler employs advanced methodological techniques and software technology to bring traffic simulation into a new era. TransModeler models the dynamic route choices of drivers based upon historical or simulated time dependent travel times, and also models trips based on origin-destination trip tables or turning movement volumes at intersections. It simulates public transportation as well as car and truck traffic, and handles a wide variety of ITS features such as electronic toll collection, route guidance, and traffic detection and surveillance. TransModeler works with travel demand forecasting software to provide an integrated capability to perform operational analysis of transportation projects and plans. Traffic simulation results can also be recalled for use in travel demand forecasting.

DYNASMART-P (FHWA, 2002)

DYNASMART-P, or the Dynamic Network Assignment-Simulation Model for Advanced Roadway Telematics supports transportation network planning and traffic operations decisions, including evaluation of ITS deployment options, through the use of simulation-based dynamic traffic assignment. This tool combines dynamic network assignment models, used primarily in conjunction with demand forecasting procedures

2.3. Summary

However, the potential impacts of traffic evacuating from a disaster area due to an approaching hurricane on the network performance of area passed by have not been underscored and estimated so far. Because an emergency evacuation has never happened in the study area and no field data under such conditions exists, traffic simulation was used to carry out this study. There are two main categories of evacuation simulation packages: microscopic and macroscopic simulation based models. The main disadvantage of the microscopic model was the extensive data and computer resource requirements, while the macroscopic models did not have the capability of keeping track of individual driver decisions. Given the size of the simulation area and the level of traffic demand involved in the study, a mesoscopic simulation model namely DYNASMART-P was used (meso models denote greater geographic area than micro models and enable for precise results than macro models as they track each vehicle when it traverses through links between specific origin and destination). Additional reasons for choosing this model is based mainly on its wide acceptance within the transportation community as well as the fact that it produces a wealth of detailed measures of effectiveness.

3. DEVELOPMENT OF NETWORK MODEL IN DYNASMART-P

3.1. Study Area

The study area is located in the southwest geographic center of the state of Mississippi, the east of the Mississippi River and the north of New Orleans. The area is trisected by the Pearl River which divides Madison, Hinds and Copiah counties on its west bank from Rankin, Simpson counties to the east, and Big Black River which divides Yazoo, Warren Counties to the west bank from Madison, Hinds counties to the east.

The study area includes substantial portions of the Greater Jackson area of the tri-counties including Hinds, Madison, and Rankin counties. The estimated population and the area of the study area, as recorded by the 2000 census, were 440,801 and 2,400 square miles.

The study area, a radial system of major through-routes including I-20, I-55 and US 49, is bisected east and west by Interstate 55 (I-55) and north and south by Interstate 20 (I-20). Interstate 220 (I-220) provides an additional connection between I-20 West and I-55 North, establishing a closed loop around the core study area. In addition to US 49 there are two other federal highways in the study area that have been partially displaced by newer interstate routes; US 51, which runs roughly north and south just east of I-55, and US 80 which runs east and west primarily north of I-20. The principal state-maintained routes that link the study area to other parts of Mississippi are highways 16, 43, 25, 18, 22, and 469. The scenic Natchez Trace Parkway also runs north and south.

In the study we assume that the evacuation traffic volumes are loaded from six main highways including I-20EB, Natchez Trace Parkway NB, and MS-18 EB west of I-55, I-55 NB, and HW-469 NB, US-49 NB and MS-18 WB, which are to the east of I-55

3.2. Data Collection and Preparation

In this study, three kinds of data are required which are geographic data, hourly traffic volume vs. speed data, and origin-destination demand matrix data.

Geographic Data

The geographic data which includes an amount of basic network characteristics for the tri-counties in the Greater Jackson area are used to create the highway network model. The "shapefile" format, developed by ESRI (Environmental Systems Research Institute) for spatial data in a geographic information system (GIS), features the shape files for nodes, links and traffic analysis zones (TAZ) which were provided by MDOT. There are in total 4607 nodes, 10288 links and 691 TAZ zones in the study area.

Traffic Flow Data

The hourly traffic volume vs. speed data consists of two parts: the number of vehicles that pass a point on a highway facility during a specified time period (traffic

volume) and the arithmetic mean of all speeds of observed vehicles. The data is needed to calibrate the traffic flow model in DYNASMART-P and was provided by MDOT.

Origin-Destination Demand Data

The origin-destination demand matrix as a necessary input data for DYNASMART-P was provided by MDOT and stored in TransCAD format.

In this study, the graphic user interface (GUI) program Nexta developed specifically for DYNASMART-P by the University of Utah team was used to build the network model. There are three types of data files to be imported: network definition files, node/link/taz geographic property files, and origin-destination (OD) demand files. The network definition file includes 4 spread sheets named NODE, LINK, ZONE and SIGNAL in Excel (Appendix 2). The Node/Link/TAZ.GEO files can be produced directly from the TransCAD program (Appendix 3). The OD demand file contains daily traffic trip demands which need to be converted into a peak hour volume matrix by multiplying the daily trip demands by peak hour percentages (Appendix 4).
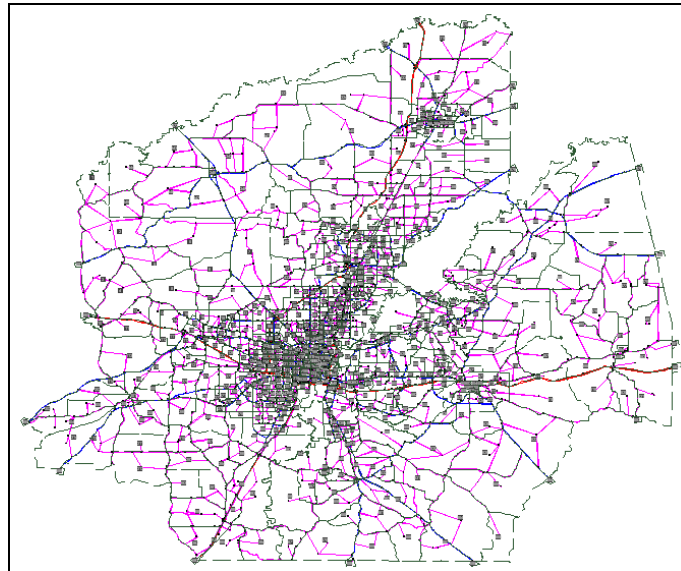
Figure 1 Road Network in Nexta

3.3. Network Modeling with DYNASMART-P

The program Nexta provides an import wizard to allow the users to create a network model. The steps are shown below.

1) Start Nexta and choose *File, Import Files, Import GIS Data Set, and Import Network Table* to display the Open dialog box

2) Choose the network Excel file prepared in 4.1.1 and click Open

3) Choose *File , Import Files , Import GIS Data Set, and Import Node/Link/Zone Geo Files* to display the Open dialog box

4) Choose node.geo, link.geo and zone.geo in order and click Open.

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An example highway network model built in the Nexta program is shown in Figure 1. In the figure, red solid lines are used to represent freeways. Arterials highways are represented with blue solid lines and the collector roads by pink solid lines. The grey solid lines represent local roads. Finally, traffic analysis zones (TAZ) are also shown with green solid lines in the network for the Greater Jackson area.

4. CALIBRATION AND SETUP FOR SIMULATION

4.1. Calibration Method

To evaluate the accuracy of the dynamic traffic assignment model in DYNASMART-P and to determine input parameters of hourly volume percentages, the calibration comparison method was used. The calibration method is an iterative process of determining the optimum input parameters and making output results meet predefined tolerance criteria under specified background traffic conditions by comparing simulation output results with corresponding observed traffic flow data. In this process of judging input parameters, MAPE (Mean Absolute Percentage Error) was used as the standard. It is one of the most popular equations and mostly utilized in engineering practice. The complete calibration process is shown in Figure 2.
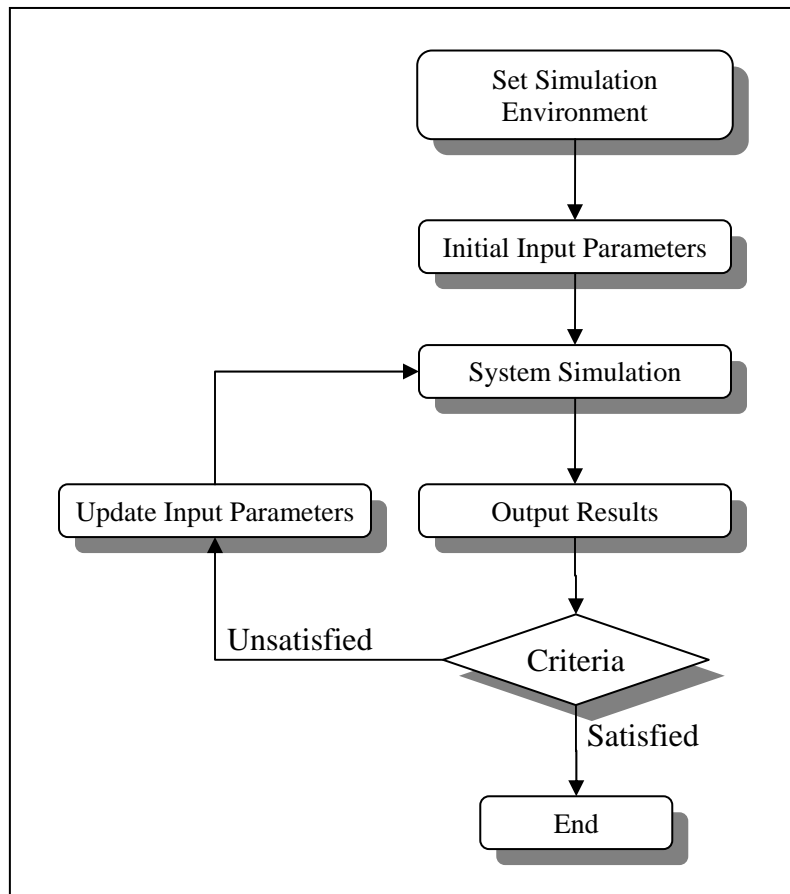
Figure 2 Calibration Flow Chart

The above figure shows that network model calibration is the set of operations which evaluate the difference between the simulation output results under specified simulation environment conditions and the corresponding known value of the measured values. Next, the model input parameters were adjusted to make the simulation estimated results to be as close to the observed actual traffic characteristics as possible at selected locations. A

comparison indicator computed from measured and observed traffic data based on a selected numerical model is used as the goodness-of-fit criteria.

Traffic Volume Data Collection

As calibration is the comparison between two different quantities, traffic data need to be collected and compared to the network's simulation results. The first step in this process was to record videos at several predetermined locations within the network area as shown in Figure 3 (*36*). In this figure, 12 video camera locations were chosen and their positions were described in Table 1. Most of these locations were freeways because the evacuating traffic generally uses freeways.

The videos were recorded for 20 minutes during the each of the morning peak hours from 7 to 10 AM. It was then played back and counted for 15 minutes to determine the vehicle volumes. At the end of each 15 minutes, the count of cars that passed was recorded along with the location of the camera and the time the video was recorded. This process was repeated for every location within a designated hour. Then, the locations were counted again for a different hour. The data collection cycle was not completed until each of all locations had a volume reading for every peak hour. The 15-minute volumes were then multiplied by 4 to estimate the corresponding hourly vehicle volumes. The final results were then put into the calibration worksheet. This was a laboring and very time consuming process which was however extremely important to the accuracy and quality of the simulation results of the study.

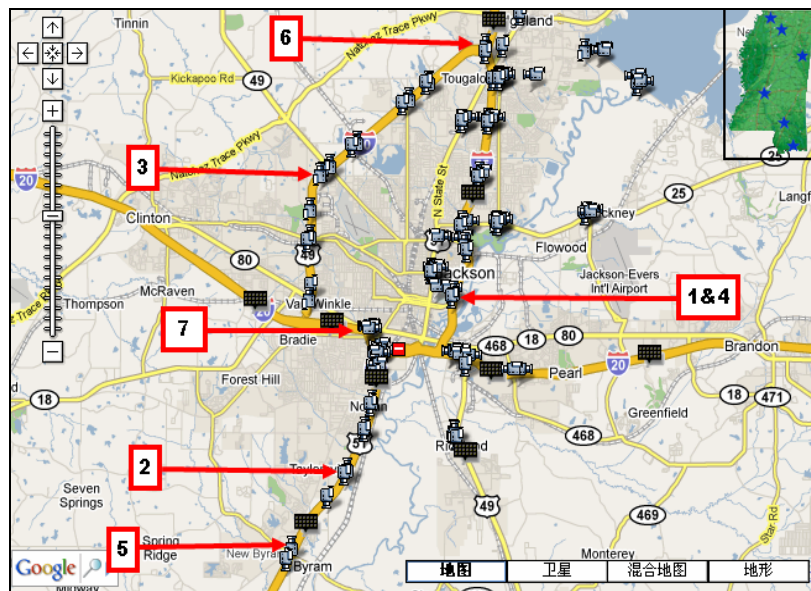**Figure 3 Camera Locations in Jackson Area (Source: MDOT)**

A seemingly trivial step was to match the locations that were recorded to the exact location in the network model. This allowed for readings from the simulation at the exact locations where the vehicle volumes were manually counted. The locations were found on the network model and the identified link ID was then recorded. The results are shown in Table 1.

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Table 1 CCTV Camera Locations

No	Link ID	Location
1	5768	I-55 South of High Street
2	1959	I-55 S North of Elton Rd
3	2603	I-220 North at Medgar Evers
4	5761	I-55 North of High Street
5	1800	I-55 North of Siwell Rd
6	6685	I-55N North at I-220
7	3508	I-20 West of Valley St.

Simulation Calibration Criteria

In the calibration process, Mean Absolute Percent Error (MAPE) was chosen as the numerical model to evaluate the closeness of comparisons for the calibration of the network model. Each item in the MAPE equation is the absolute difference between the actual value A_t and the estimate value F_t divided by the actual value A_t, where t is a fitting (comparison) point. The summation of all absolute items over all comparison points along time and/or location divided by the number of fitted points *n* is MAPE, as shown in Equation 1.

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \tag{1}$$

In this study, the calibrations were based on three different levels: the first is on an areawide basis by comparing the overall aggregate assignment volume for all links in the network model with the overall aggregate assignment volume provided by MDOT with MAPE following the rule of plus or minus five percent (±5%) as recommended by FHWA (*12*); the second level is based on roadway functional classification by comparing the assignment volumes by road functional classification (freeway, principal arterials, minor arterials and collectors) with the observed traffic volumes and the MAPE's by road functional classification are within the limits by FHWA (±7% for freeways, ±10% for principal arterials, ±15% for minor arterials, and ±25% for collectors); the third one is on specific road links by comparing the assignment volumes for specific highways with observed results following the rule of thum of ± 20%.

4.2. Simulation Calibration and Results

Initial Hourly Volume Percentages

The background demand is related to a typical day's travel pattern. In this study, we only consider the worst case, i.e. the peak hours of a day when the evacuation also happens and simply assume that the traffic demand during the peak time is a percentage of the 24-hour OD demand. The 24-hour OD demand data was available in MDOT.

In order to assign total 24-hour background traffic demand in simulations to specific hours of the day, the traffic volume percentage at each hour during a typical day is necessary. Hourly Volume Percentages (HVP) were initially characterized from the 24-hour traffic volume data (2007) in the Jackson area from MDOT. The 24-hour traffic volume data were collected by MDOT's Traffic Engineering Division for specific locations in the area during special events, from which a 24-hour traffic pattern was depicted and shown in Figure 4 to approximately characterize the pattern of the background traffic condition.
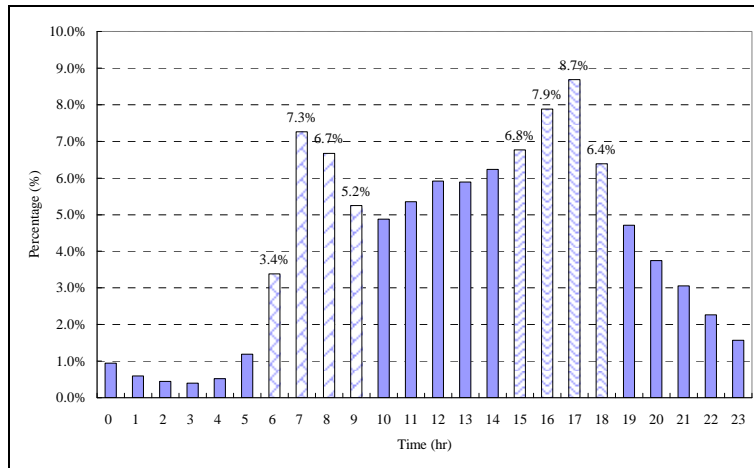

Figure 4 Background Traffic (24-hr) Pattern

In the figure, two volume peaks appeared around 8:00 and 18:00. If a four-hour duration encompassing a volume peak is simulated in the DYNASMART program, the traffic conditions before and after the peak hour may be approximately studied. Two such four-hour durations may be from 6:00 to 10:00 and from 15:00 to 19:00 based on Figure 4. The hourly volume percentages of these two time periods are shown in Table 2.

Table 2 Hourly Volume Percentage of Daily Trip Demand

Start Time	End Time	HVP (%)	Start Time	End Time	HVP (%)
6:00	7:00	3.4	15:00	16:00	6.8
7:00	8:00	7.3	16:00	17:00	7.9
8:00	9:00	6.7	17:00	18:00	8.7
9:00	10:00	5.2	18:00	19:00	6.4

The hourly traffic volumes for the four morning peak hours for background demand in normal condition are 3.4%, 7.3%, 6.7%, and 5.2% of the 24-hourly traffic OD demand, respectively.

Calibration Results

The initial hourly traffic volumes for background demand in normal traffic conditions were input to DYNASMART for the calibration simulation runs. These data inputs are shown in Figure 5
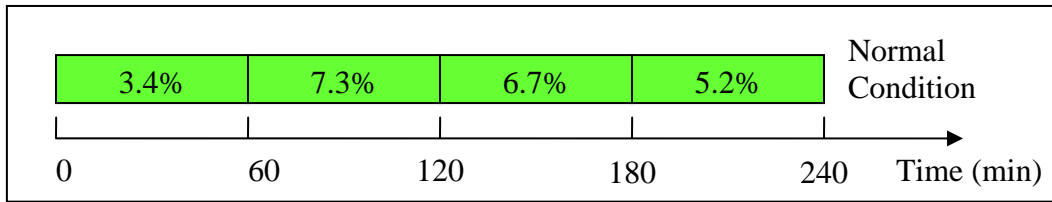
16

Figure 5 Volume Distribution during Simulation Time

In order to avoid the effect of randomness in individual simulation runs, each set of input parameters was simulated for 6 times. For each simulation run, the result was recorded for specific links of the network and was stored in an Excel table.

After more than thirty simulation runs, the optimum input parameters were determined which satisfied all of the FHWA criteria. The optimal results are shown in Tables 3 through 6.

Table 3 Optimal Hourly Volume Percentages

Time	6:00-7:00	7:00-8:00	8:00-9:00	9:00-10:00
HVP	6.0%	9.3%	5.6%	4.0%

Table 4 Overall Assignment Volume

Classification	Error Limit	Average Assigned Volume	ADT	Diff	PCT Diff
Freeways	5%	363455	377169	-13714	-3.6%

Table 5 Assigned Volume by Roadway Classification: Freeway

Classification	Error Limit	Average Assigned Volume	ADT	Diff	PCT Diff
Freeways	7%	60748	65024	-4276	-6.6%

Table 6 Hourly Assigned Volume by Specific Links

ID No	Error Limit	Error			
		7:00-8:00	8:00-9:00	9:00-10:00	Total
5768	20%	-17.1%	N/A	-1.1%	-11.5%
1959	20%	-9.0%	-7.9%	-7.1%	-8.2%
2603	20%	4.2%	17.9%	4.2%	8.7%
5761	20%	-15.0%	-16.5%	-0.3%	-12.3%
1800	20%	-7.4%	-4.2%	-13.5%	-7.9%
6685	20%	-11.7%	7.5%	6.0%	-1.6%
3508	20%	-18.7%	11.8%	1.4%	-4.7%

5. SIMULATION OF EVACUATION SCENARIO

5.1. Evacuation Scenario

This study is based on the scenario assuming that there are different amounts of traffic evacuating from southeast Louisiana due to an approaching hurricane and is prepared to analyze the potential impacts of these evacuating vehicles on the highway network of Mississippi, specifically the Greater Jackson area.

To estimate the number of potential evacuating vehicles entering Mississippi for various hurricanes threatening both southeast Louisiana and Mississippi, previous hurricane evacuation study work was examined. PBSJ completed a hurricane traffic modeling analysis for southeast Louisiana in the 1990-1992 timeframe. The work was done under contract to the US Army Corps of Engineers, New Orleans District. Looking at various evacuating vehicle volumes exiting the southeast Louisiana area by specific routes and the origin parish of that modeled exiting traffic, a table was constructed showing the percentage of each parish exiting traffic on each route. Table 7 shows the data that was developed and includes Interstate10, Interstate 59, and Interstate 55 into Mississippi (*37*).

5.2. Evacuation OD Traffic Demand

In this study, the emergency evacuation was assumed to happen in the morning peak four-hour period 6:00-10:00 AM. That is to say the two traffic components (background and evacuation) are concurrently present in the simulation duration of 240 minutes.

Demand during an evacuation may be divided into two portions: the background demand and the evacuation demand. The background demand is unrelated to the zones in the hazard area and occurs under normal travel situations. Evacuation demand is generated within an area around the disaster, consisting of a set of TAZ's. The combination of these two types of demand is estimated in order to provide input data for evacuation simulation (*38*). To generate the evacuation trips, several things need to be determined besides the trip origins and destinations. First of all, evacuation trip production and attraction for each TAZ should be estimated. Secondly, trips need to be distributed over the network and produce evacuation traffic volumes on road links.

Locations of Origin and Destination

Before an evacuation trip is generated and distributed, the origin and destination zones of the trip must be determined. For the study scenario, the origin zones could be determined based on information from previous studies and experiences from state DOT and emergency management agencies. The destination zones can be determined based on the location of shelters.

(1) Origins

As a result of the previous research (*37*), three routes which may influence the performance of the highway network and traffic in the study area, US 61 westbound to MS, I-55 northbound to MS and I-59 northbound to MS, are highlighted in Table 8. In

the study area, the evacuation traffic volume from US-61 can be loaded to I-20, MS-18 eastbound west of I-55, and Natchez Trace Parkway. The volume from I-59 northbound to MS can be loaded to US-49, HW-469 and MS 18 eastbound east of I-55, as shown in Figure 6.
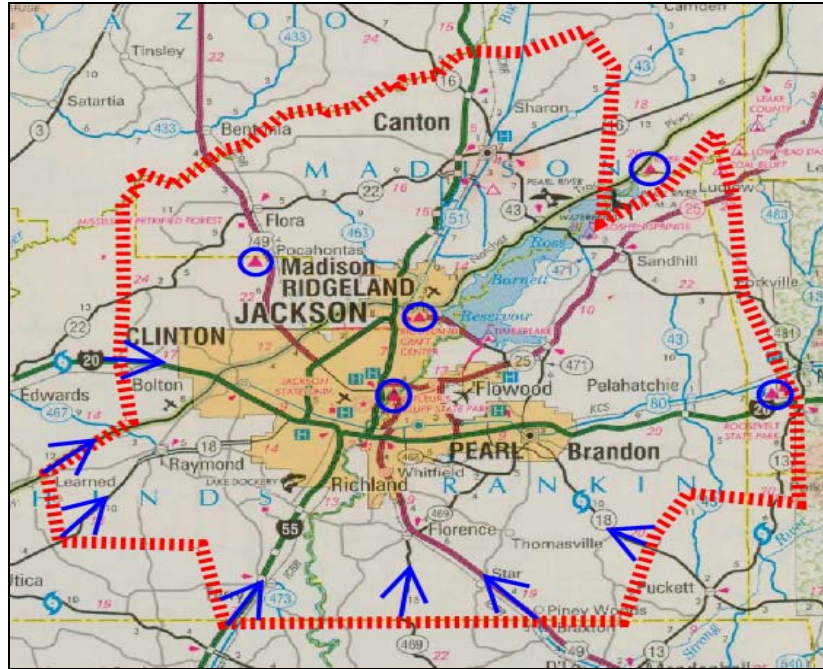

Figure 6 Locations of Origin and Destination in Study Area

So the origins in the network were assumed zones which are located on the study boundary, and contain these highways. Figure 6 and Table 7 illustrate information on the study area boundary (red dotted line) and evacuation highway routes (blue arrows).

Table 7 Origin Point and Trip Production

Major Evacuation Routs	Loaded Link Name	Capacity (vehicle/h)	Capacity Percentage	Origin Zone	Production (vehicle)
	Natchez Trace Pkwy	1900	12%	689	2105
	MS 18 west of I-55	1900	12%	688	2105
I-55 (8900)	I-55	4400	28%	687	4875
I-59 (8606)	HW 469	1900	12%	686	2105
	US 49	3800	24%	685	4210
	MS 18 east of I-55	1900	12%	684	2105

(2) Destinations

In Figure 7, shelters are symbolized by red triangles and highlighted by blue circles. There are four shelters located in the study area and another one located outside and near the boundary of the study area. Considering the attracting effect of the outside shelter, it was still treated as a shelter for the study area. So the total number of shelters in this study was five. According to the location of the shelters, their zone numbers were identified as 6, 449, 534, 493, 674 and 678.

Evacuation Trip Generation and Attraction

(1) Evacuation Trip Production

In the study, the numbers of evacuating vehicles from route I-55 was assumed approximately 8,900 vehicles and I-59 northbound about 8,606 vehicles based on a "slow moving category 1/fast category 2 storm". In the second simulation, the numbers of evacuating vehicles from route I-55 was assumed approximately 20,955 vehicles and I-59 northbound about 21,815 vehicles based on a "slow moving category 1/fast category 2 storm" as shown in Table 8.

Table 8   Evacuating Vehicles by Critical Highway Segment

Critical Roadway Segment	Directional Serv Vol LOS D	Cat 1/Fast Cat 2 Evac Veh Low Occ	Cat 1/Fast Cat 2 Evac Veh High Occ	Cat 2/Fast Cat 3 Evac Veh Low Occ	Cat 2/Fast Cat 3 Evac Veh High Occ	Fast Cat 3-4 Evac Veh Low Occ	Fast Cat 3-4 Evac Veh High Occ	Fast Cat 3-4/Cat 5 Evac Veh Low Occ	Fast Cat 3-4/Cat 5 Evac Veh High Occ
I-12 westbound	3,000	688	694	1,197	1,204	1,599	1,605	2,693	2,699
I-10 east over Lake Ponchartrain	3,000	7,586	8,651	22,991	24,070	56,851	57,942	94,095	95,185
I-10 eastbound into Mississippi	3,000	2,160	2,359	6,063	6,267	12,033	12,239	19,643	19,849
I-59 northbound into Mississippi	3,000	7,719	8,606	20,917	21,815	50,148	51,055	83,426	84,333
Lake Ponchartrain Causeway	2,500	4,203	4,982	12,828	13,606	40,890	41,675	69,589	70,374
US61 westbound	1,800	791	946	1,925	2,081	7,700	7,857	14,775	14,932
I-10 westbound east of I-55	3,000	9,409	10,794	27,476	28,878	72,444	73,859	122,920	124,334
I-55 northbound into Mississippi	3,000	8,092	8,900	20,126	20,955	44,135	44,973	77,816	78,652
I-10 westbound west of I-55	3,000	3,925	4,548	12,166	12,788	35,024	35,653	61,169	61,797
Louisiana Highway 1	1,000	8,783	9,510	17,750	18,564	18,402	19,241	28,692	29,528

The temporal characteristics of evacuation travel time estimation are based on evacuation response rate curve that predicts the cumulative evacuation demand with time after an evacuation is ordered. The response rate curves are shown in Figure 7. The response rate was important because it determined how many vehicles would enter the study area during the simulation period. Therefore the evacuation production for the origin zone is determined, shown in Table 9.
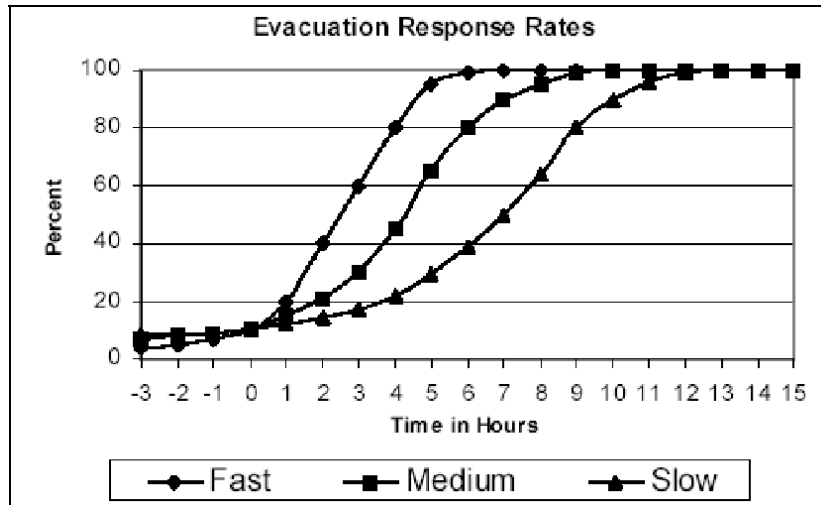
Figure 7 Response Rate Curves

In this study, the medium response rate curve was used to determine the evacuation rate. The simulation period will begin two hours after the evacuation process has started. From the above chart, the simulation evacuation period will start at two and end at six. These hours are used because of the rapid increase in the evacuation vehicle volume. As shown in Figure 7, that is approximately 60 percent of the total evacuation volume which will appear in the simulation period. 10 percent of the total evacuation volume is for the first hour (hour 2 to hour 3), 15 percent is assigned for the second hour (hour 3 to hour 4), 20 percent is for the third hour (hour 4 to hour 5), and 15 percent is for the fourth hour (hour 5 to hour 6).

Table 9   Origin Points and Trip Generation

Loaded Link Name	Zone	Capacity (vehs/hr)	Capacity Percentage	Traffic #1 (vehs)	Traffic #2 (vehs)
Natchez Trace Pkwy	689	1900	12%	1,263	3,086
MS 18 west of I-55	688	1900	12%	1,263	3,086
I-55	687	4400	28%	2,925	7,146
HW 469	686	1900	12%	1,263	3,086
US 49	685	3800	24%	2,526	6,172
MS 18 east of I-55	684	1900	12%	1,263	3,086
Total	--	15800	100%	10503	25662

The numbers of evacuating vehicles from routes I-55 northbound and I-59 northbound were used based on a lower demand level at "Category 1/Fast Category 2 evacuation vehicles at high occupancy" and a higher demand at "Category 2/Fast Category 3 evacuation vehicle at high occupancy", as shown in Table 8. The evacuation origin points were chosen at the boundary of the study area with evacuation traffic corridors including the Natchez Trace Parkway and MS-18 EB which are west of I-55, I-55, and US-49, Hwy-469 and MS-18 WB which are east of I-55. The traffic amount for each highway was determined based on the highway's capacity percentage, as shown in Table 9. The total vehicle volumes of 10,503 and 25,662 were computed by multiplying

coefficient 0.6 to sums of the volumes highlighted in Table 8 under the two intensity columns respectively. The coefficient 0.6 is based on the aforementioned medium response rate curve.

 (2) Evacuation Trip Attraction
   The evacuation traffic can be attracted to any zone where a shelter is located. We assumed that 50 percent of the total evacuation traffic would pass by Jackson area and continue to go northward. Since there was no capacity information about the shelters available, attraction traffic was assigned to the five shelters equally. The trip attraction for each destination (i.e. shelter) was determined, as shown in Table 10.

Table 10 Destination Points and Trip Attraction

Destination Zone	Attraction (vehs)	Attraction (vehs)
6	1050	2566
449	1050	2566
493	1050	2566
534	1050	2566
674	5252	12831
678	1050	2566
Pass-by	5252	12831
Total	10503	25662

 (3) Evacuation Trip Distribution
   When trip generation at the origin zones and trip attraction at the destination zones are determined, a traffic assignment method needs to be employed to determine traffic volumes on the highway network. Before the dynamic traffic assignment (DTA) model DYNASMART could be used for this purpose, the gravity model in the static traffic assignment model TransCAD was used. TransCAD model was used to generate the evacuation O-D demand matrix, which was required as an input to DYNASMART. The steps of using TransCAD to generate O-D demand matrix are described in Appendix 5.

5.3.   Simulation with DYNASMART-P

   In this study, it was assumed that emergency evacuation would happen in the four-hour period 6:00-10:00 Am. That is to say the two traffic components (background and evacuation) would be concurrently present in the simulation duration of 240 minutes. The hourly traffic volume for background demand in normal condition was set as 6.0%, 9.3%, 5.6%, and 4.0% of the daily total trip demand, respectively. In the second simulation test, the evacuation demand of 10,503 vehicles under the first evacuation intensity condition was added to the background demand at the start of the simulation. In the third simulation test, the evacuation demand of 25,662 vehicles under the second evacuation intensity condition was also added to the background demand since the start of the simulation.

For simulation results, the average queue length percentage was used as the criterion to identify the twenty most congested freeway links in the network in each simulation. In addition, in order to avoid the random effect of individual simulations, a total of 10 simulations using different random seed numbers were run for each evacuation intensity level. Therefore, for each intensity level, 200 output records including link ID, average speed, queue length, delay, and density were obtained. Ten freeway links with the highest frequencies of being included in the 200 records were identified.

5.4.   Results and Analysis

Simulation Results
The result of the first evacuation intensity level showed that the average trip travel time increased from 13.7 minutes to 15.2 minutes, and the second evacuation intensity level, increased the average trip travel time to 16.8 minutes.
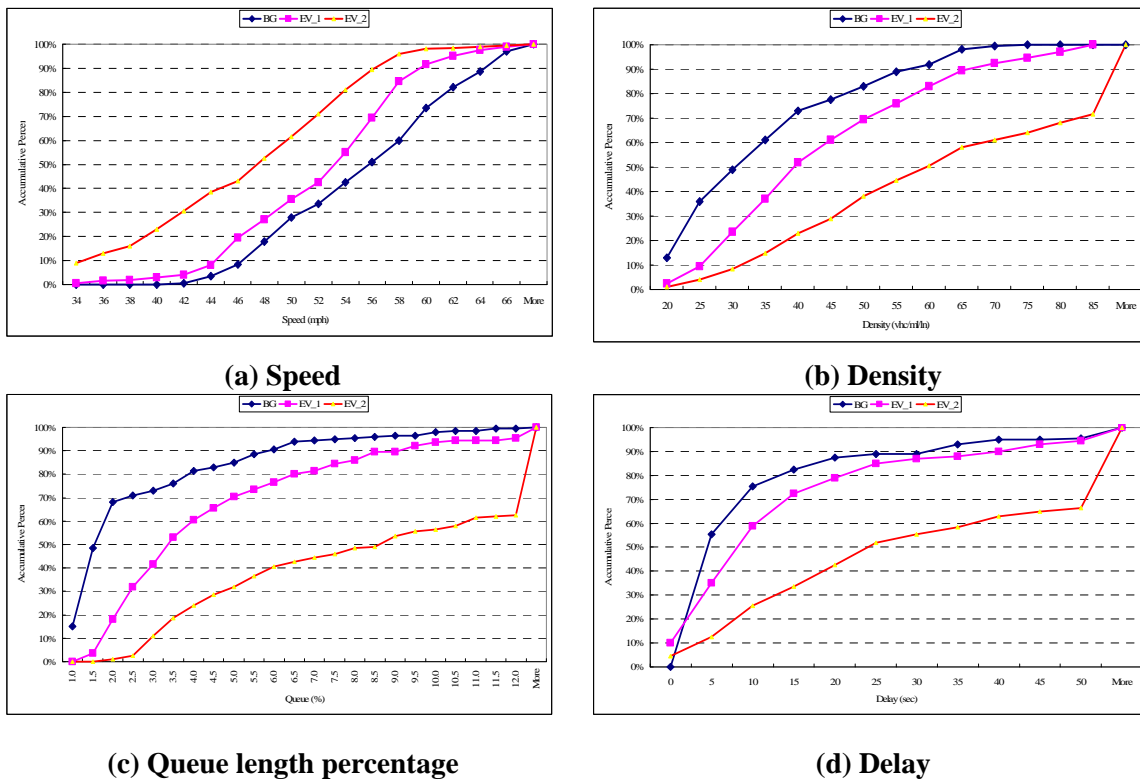

(a) Speed

(b) Density

(c) Queue length percentage

(d) Delay

Figure 8 Traffic Performance Curves

Cumulative frequency curves were drawn for the background demand simulation, the first evacuation intensity, and the second evacuation intensity, as shown in Figure 8. Three different color lines were used to symbolize different simulation results. The blue lines, pink lines, and red lines represent the background, the first evacuation intensity, and the second evacuation intensity, respectively. As shown in Figure 8(a), the average speeds at the two evacuation intensity levels are significantly lower than the background demand condition. For example, the 85 percentile speed at the background demand

condition is about 62 mph, and the speeds are 58 mph and 54 mph for the two evacuation intensity levels respectively. In Figure 8(b), the 85 percentile density is 53 vehicles per hour per lane for the background demand condition, and 62 veh/hr/ln and 85 veh/hr/ln for the two evacuation intensity levels respectively. In DYNASMART, queue evolution and dissipation are tracked and expressed as queue length percentage to check when the queue on a link spills back to an upstream link if the queue percentage is close to 100%. In Figure 8(c), the 85 percentile queue length percentage is 50% at the background demand condition, and 75% and 120% for the two evacuation conditions respectively. In Figure 8(d), the 85 percentile average trip delay is 18 sec under the background demand condition, and 25 sec and 50 sec in the two evacuation situations.

Analysis

   In the first evacuation intensity simulation, there were seven critical congested locations in the network. All of them were located at highway interchanges and congested by conflicting traffic to or from ramps. Five of them appeared again in the second evacuation intensity simulation, as shown in Figure 9.

Figure 9 Congestion Locations

   The first congested location was the Hwy-468 interchange with I-20 eastbound. Congestion occurred on I-20 eastbound interchange with Hwy-468 because many of evacuation vehicles entered I-20 eastbound from Hwy-468 through the on-ramp, as shown in Figure 10. The average speed decreased from 47 mph for the background

demand condition, to 44 mph for the first evacuation condition, and to 43 mph for the second evacuation condition. The average delay increased from 79 seconds for the background demand condition, to 107 seconds for the first evacuation condition, and to 130 seconds for the second evacuation condition.
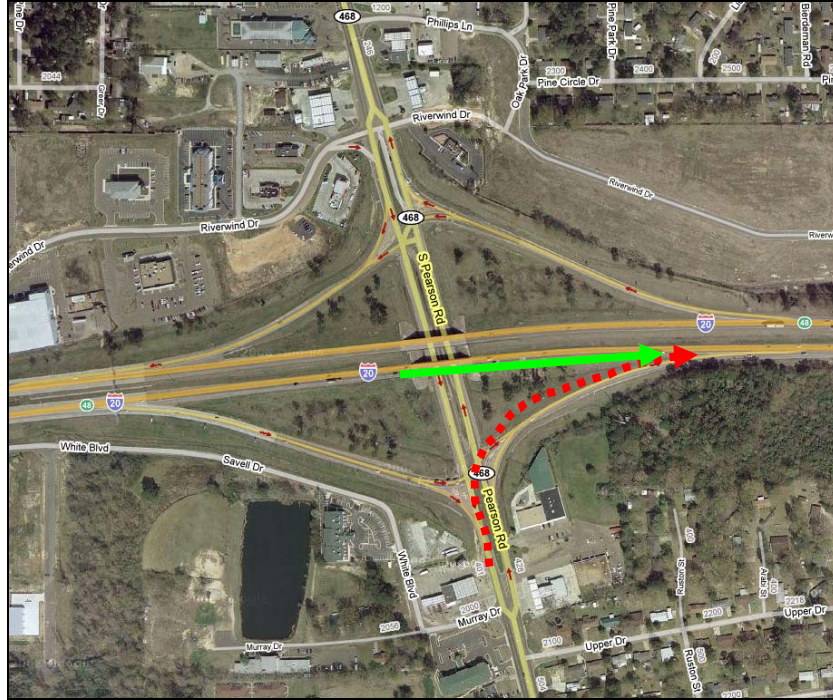

Figure 10 Hwy-468 Interchange with I-20 EB

The second congested location was the West Cunningham Avenue interchange with I-55 northbound where large amounts of evacuating traffic left from I-55 northbound to West Cunningham Avenue through the off-ramp and congested West Cunningham Avenue eastbound, as shown in Figure 11. The average speed decreased from 62 mph for the background demand condition, to 52 mph for the first evacuation intensity condition, and to 33 mph for the second evacuation intensity condition. The average delay increased from 0.0 seconds for the background demand condition, to 20 seconds for the first evacuation condition, and to 104 seconds for the second evacuation condition.
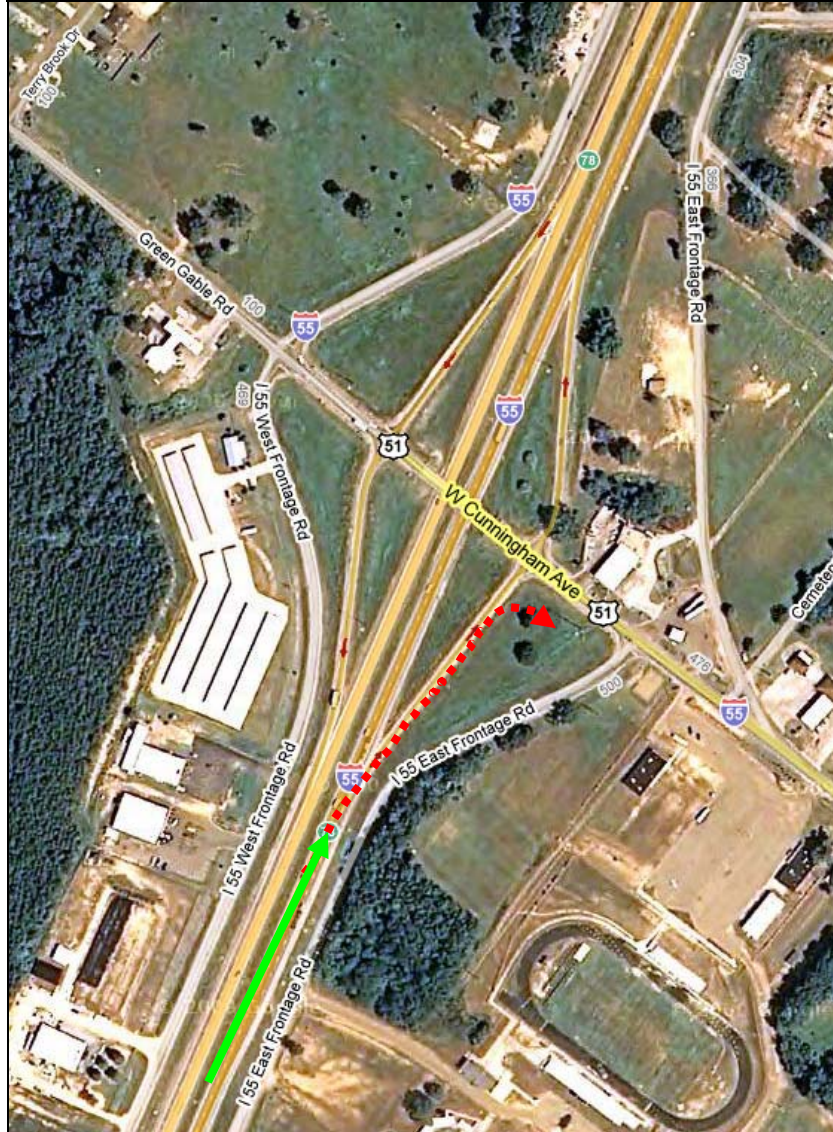
Figure 11 W Cunningham Ave Interchange with I-55 NB

The third congested location was the Elton Road interchange with I-55 northbound where large amounts of evacuating traffic exited from I-55 northbound to Elton Road through the off-ramp, as shown in Figure 12. The average speed decreased from 62 mph from the background demand condition, to 58 mph for the first evacuation condition, and to 50 mph for the second evacuation condition. The average delay increased from 0.0 seconds for the background demand condition, to 12 seconds for the first evacuation condition, and to 86 seconds for the second evacuation condition.

Figure 12 Elton Road Interchange with I-55 NB

The fourth congested location was the Natchez Trace Parkway interchange with I-55 northbound where a large amount of evacuating traffic left from I-55 northbound to Natchez Trace Parkway through the off-ramp, as shown in Figure 13. The average speed decreased from 59 mph for the background demand condition, to 49 mph for the first evacuation condition, and to 39 mph for the second evacuation condition. The average delay increased from 2.0 sec for the background demand condition, to 16 sec for the first evacuation condition, and to 30 sec for the second evacuation condition.

Figure 13 Natchez Trace Parkway Interchange with I-55 NB

The fifth congested location was MS-18 westbound (west of I-55) interchange with I-20 eastbound where a large amount of evacuating traffic left from MS-18 westbound to I-20 eastbound through the on-ramp, as shown in Figure 14. The average speed decreased from 58 mph for the background demand condition, to 56 mph for the first evacuation condition, and to 54 mph for the second evacuation condition. The average delay increased from 3.0 sec for the background demand condition, to 5 sec for the first evacuation condition, and to 7 sec for the second evacuation condition.

Figure 14 MS-18 WB Interchange with I-20 EB

5.5. Traffic Control Strategies

The primary improvement methods on the most current evacuation practices and plans include the use of ITS during evacuation and design and operation of contraflow operation for evacuation which have both used in the Georges and Floyd evacuations. A more recent study focused on ITS technologies in the states of North Carolina, South Carolina, Georgia, and Florida (*39*) recommended applications of closed circuit television (CCTV) cameras, Highway Advisory Radio (HAR), Variable Message Signs (VMS), count stations, and weather stations.

Contraflow operation (*40*) on roadways is not a new concept that is an operation of turning one or more lanes of one direction to the opposite direction. It can greatly expand the roadway capacity without building new facilities and is used to address the issue of inadequate outbound capacity. Many cities like Washington D.C. and Boston, Massachusetts, have been using reverse lane operations to improve the outflow of traffic for decades. Contraflow for hurricane evacuation was first used during Hurricane Floyd in 1999 to lessen traffic congestion in Georgia and South Carolina.

In order to relieve traffic congestion to a certain extent, the effects of contraflow and ITS strategies will be tested in a related project (State Study #210: Emergency

Evacuation Study of the Greater Jackson Area – Deployment of DYNASMART-P in the Mississippi Department of Transportation) funded by the Mississippi Department of Transportation. The research report describing these research findings will be published after the MDOT project is completed.

6. OBSERVATIONS AND SUMMARY

6.1. Summary

After reviewed various evacuation simulation packages that were developed, using microscopic, mesoscopic, or macroscopic simulation approaches, and effective traffic control strategies that were used to improve efficiency and capacity of transportation infrastructure during emergency evacuations, a mesoscopic simulation package, DYNASMART-P, was adopted in the simulation and analysis in this study. In order to build the traffic network model on DYNASMART-P for the study area, three types of data were collected. The geographic data which includes the highway network topology characteristics (i.e. nodes, links and traffic analysis zones) of the Greater Jackson area including Hinds, Madison, and Rankin counties, was provided by MDOT. The origin-destination (OD) trip demand matrix provided by MDOT which was then processed by TransCAD is a required input data for DYNASMART-P. The 24-hour hourly traffic volume data which was manually collected is needed for simulation calibration.

In order to determine input parameters of hourly volume percentages for the simulation program DYNASMART-P, calibration was conducted for the network model. The Mean Absolute Percent Error (MAPE) was used as the error model for the calibtration. The calibration was an iterative process of determining the optimal input parameters by minimizing the error between simulation outputs with corresponding observed traffic characteristics under specified background traffic conditions. After more than 30 simulation trials, the optimal input parameters of hourly volume percentages were determined as 6.0%, 9.3%, 5.6% and 4.0%, satisfying all FHWA limits. The difference between the overall assignment volume for all links in the network and that given by MDOT was -3.6% (within the ±5% limit). The difference between the total assigned freeway volume and the observed total was -6.6% (within the ±7% limit). The errors on specific links between assigned hourly volumes and observed ones were all within the ±20% limit.

In this report, an evacuation scenario was designed to study the impacts of the evacuating traffic from southeastern Louisiana to the Greater Jackson metropolitan area of Mississippi due to an assumed approaching hurricane disaster. Critically congested freeway segments under two evacuation intensity levels were identified based on the criterion of the average queue length percentage and level of service. The causes for the congestion of roads were analyzed and explained.

The simulation results show that:

1) The feasibility of applying the DTA program DYNASMART-P to simulate emergency evacuation traffic conditions and analyzing the potential impacts of the evacuation traffic on the Greater Jackson, Mississippi metropolitan area is verified.

2) The whole traffic network service level under evacuation conditions will significantly decrease from the normal condition. With increased evacuation intensity traffic performance of the urban highway network may have some resilience at low evacuation intensities and deteriorate quickly with an accelerated cascading tendency at higher evacuation intensities.

For example, the average trip travel time in the first evacuation intensity level increased from 13.7 minutes to 15.2 minutes, and the second evacuation intensity level, increased the average trip travel time to 16.8 minutes. The 85 percentile speed at the background demand condition was about 62 mph, and the corresponding speeds were 58 mph and 54 mph for the two evacuation intensity levels respectively. The 85 percentile density was 53 vehicles per hour per lane for the background demand condition, and 62 veh/hr/ln and 85 veh/hr/ln for the two evacuation intensity levels respectively. The 85 percentile queue length percentage was 50% at the background demand condition, and 75% and 120% for the two evacuation conditions respectively. The 85 percentile average trip delay was 18 sec under the background demand condition, and 25 sec and 50 sec in the two evacuation situations.

3) The congested highways under the evacuation conditions identified in the study suggest that congestion usually happens in highway interchanges.

Highway interchanges may become the most possible weak points in an urban highway network undergoing evacuation. For example, in the first evacuation intensity simulation, there were seven critical congested locations in the network. All of them were located at highway interchanges and congested by conflicting traffic to or from ramps. Five of them appeared again in the second evacuation intensity simulation. The first congested location was the Hwy-468 interchange with I-20 eastbound. Congestion occurred on I-20 eastbound interchange with Hwy-468 because many of evacuation vehicles entered I-20 eastbound from Hwy-468 through the on-ramp. The second congested location was the West Cunningham Avenue interchange with I-55 northbound where large amounts of evacuating traffic left from I-55 northbound and merged to West Cunningham Avenue through the off-ramp and congested West Cunningham Avenue eastbound. The third congested location was the Elton Road interchange with I-55 northbound where large amounts of evacuating traffic left from I-55 northbound and merged to Elton Road through the off-ramp. The fourth congested location was the Natchez Trace Parkway interchange with I-55 northbound where a large amount of evacuating traffic left from I-55 northbound and merged to Natchez Trace Parkway through the off-ramp. The fifth congested location was MS-18 westbound interchange with I-20 eastbound where a large amount of evacuating traffic left from MS-18 northbound and merged to I-20 eastbound through the on-ramp.

4) Precaution procedures such as traffic control strategies, implementation of intelligent transportation systems devices such as dynamic message signs, and/or deployment of police officers at these weak points are recommended at emergency evacuations.

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Appendix 1 Geographic Data Structures

Table A-1 Node Data Structure

Field Name	Contents
ID	A number that uniquely identifies the node
Longitude	Longitude of a point
Latitude	Latitude of a point

Table A-2 Link Data Structure

Field Name	Contents
ID	A number that uniquely identifies the link
Length	Length of a link
Dir	Direction of a link. A zero is a two-way link and one is one-way link.
NAME	The name for a link
AB_SPEED	Speed on link from A to B
BA_SPEED	Speed on link from B to A
AB_TIME	Travel time for link from A to B
BA_TIME	Travel time for link from B to A
AB_LANES	The number of lane on link from A to B
BA_LANES	The number of lane on link from B to A
AB_MDOT	Function classification of link from A to B
BA_MDOT	Function classification of link from B to A

Table A-3 TAZ Data Structure

Field Name	Contents
ID	A number that uniquely identifies the zone
POP	Population within a zone
TOTDU	Total number of occupied dwelling units
OCCDU	The number of occupied dwelling units
RETEMP	The number of retail employees
TOTEMP	The total number of employees
SCHATT	The number of students attending school
HHS1	The number of household with 1-2 occupants
HHS2	The number of household with 3-4 occupants
HHS3	The number of household with 5 or more occupants

Appendix 2 Creation of Input Files for Highway Network

Step 1: Import Link Files
   a. Start TransCAD 5.0 and choose *File-Open* to display the File Open dialog box
   b. Choose ESRI Shapefile (*.shp) in the Files of type drop-down list
   c. Choose links.shp and click Open to display ESRI Shapefile dialog box, as shown in Figure A-1
   d. Type the layer name of "links" in the Layer Name box and check Import Layer
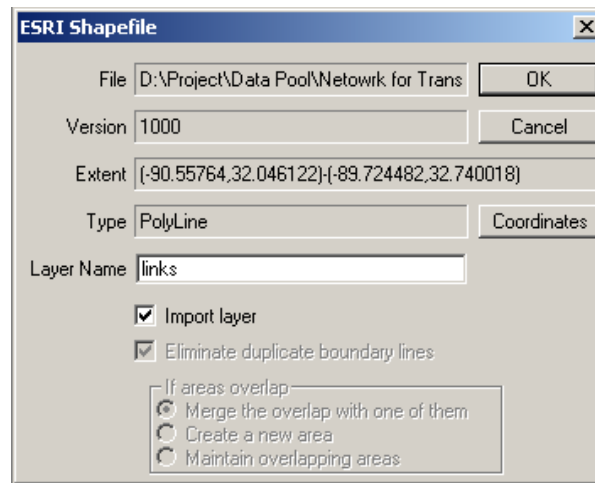
Figure A-1 ESRI Shape File Dialog Box

   e. Click OK to display the Save As dialog box will. Type a file name for the geographic file and click Save
   f. Choose *File-Save* and choose Save to display the Save As dialog box
   g. Type a name for the file and click Save

Step 2: Import TAZ Files
   a. Click the right mouse button on the map window and choose Layers to display the Layer dialog box
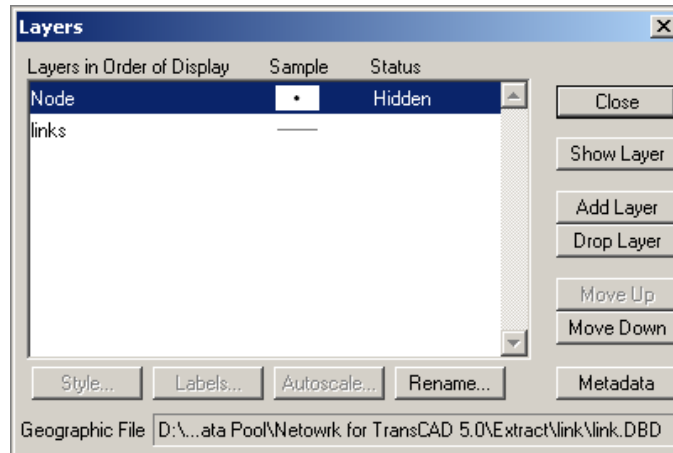
Figure A-2 Layers Dialog Box

b. Click Add Layer button to display File Open dialog box
c. Choose ESRI Shapefile (*.shp) in the Files of type drop-down list and choose taz.shp file and click Open to display the ESRI Shapefile dialog box, as shown in Figure A-2
d. Click OK
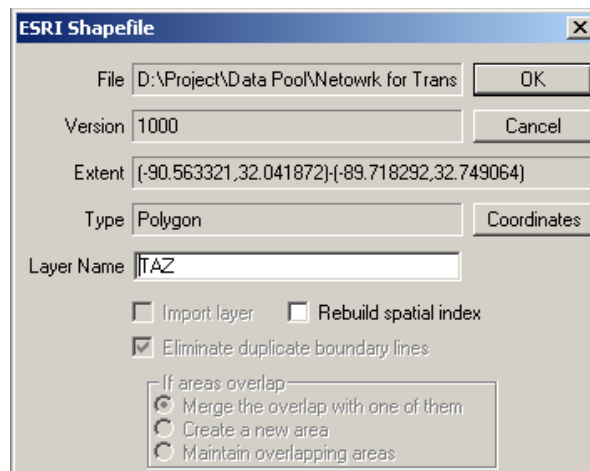
Figure A-3 ESRI Shape File Dialog Box

Step 3: Display Node Layer
    a. Right-click on the map window and choose Layers to display the Layer dialog box, as shown in Figure A-3
    b. Choose the nodes' layer and click Show Layer button.
    c. Click Close

Step 4: Display From and To Node
    a. Choose the Link layer from the drop-down list on the Standard toolbar
    b. Click New Dataview button on the Standard toolbar
    c. Choose Edit-Fill to display the Fill dialog box, as shown in Figure A-4.
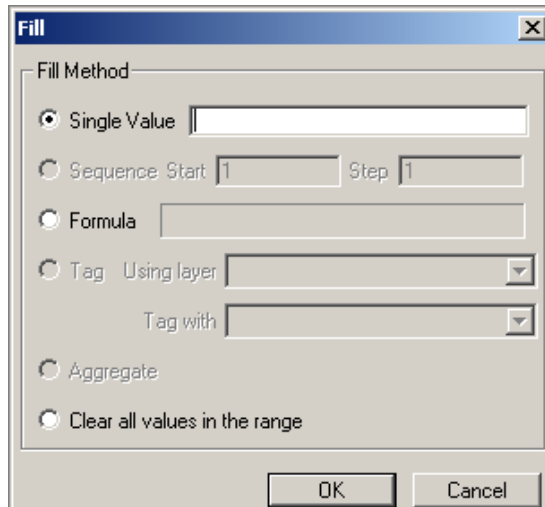
Figure A-4   Fill Dialog Box

d. Click Formula tab to display the Formula (Dataview: Link) dialog box
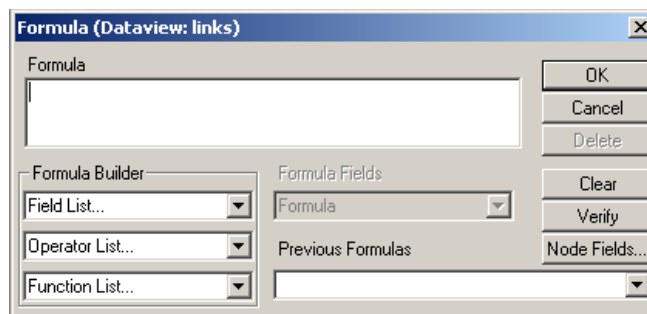
Figure A-5   Formula Dialog Box

e. Click the Node Fields button to display the Node Formula Fields dialog box, as shown in Figure A-5
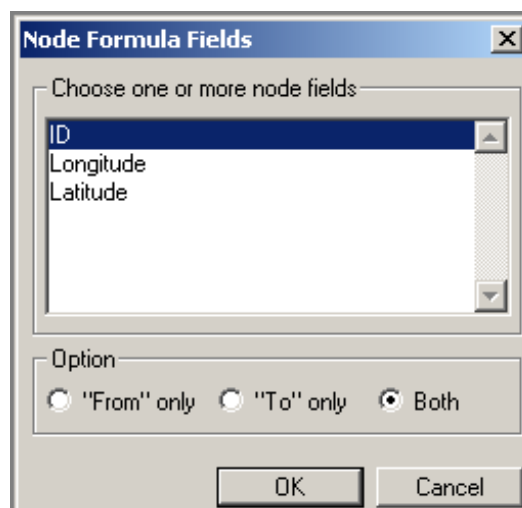
Figure A-6   Node Formula Fields Dialog Box

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f. Choose ID in Choose One Or More Nodes Fields list and check the Both radio button and click OK

Step 5: Export Geographic Data from Dataview
a. Choose Link layer from the drop-down list on the Standard toolbar.
b. Click New Dataview button on the Standard toolbar
c. Choose File-Save As to display Save As dialog box
d. Choose dBASE file (*.dbf) in the Files of Type drop-down list
e. Type a file name and click OK
f. Repeat steps a-e for node and TAZ layer to import their data

Step 6: Import Geographic Data into Excel File
a. Import the link, node and taz dBASE file into the Network Excel file
b. Copy the data into table in its corresponding sheet

Appendix 3 Creation of Node/Link/TAZ GEO Files

1) Start TransCAD 5.0 and choose the Node layer from the drop-down list on the Standard toolbar

2) Choose Tools-Export to display the Export Node Geography dialog box, as shown in Figure A-7
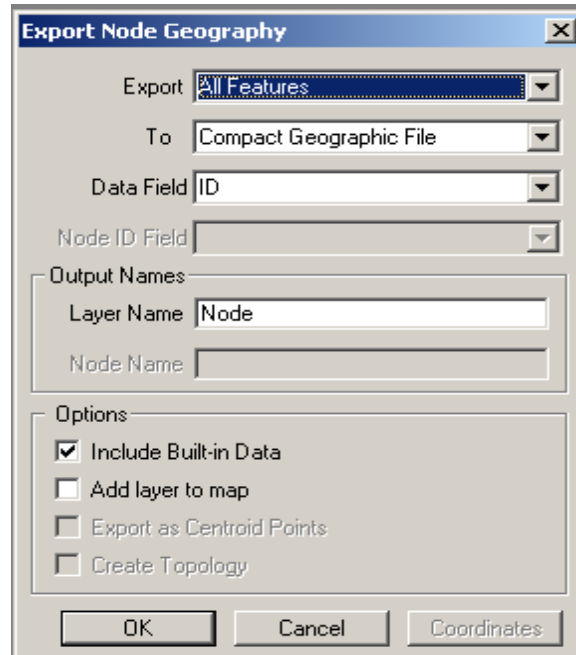
Figure A-7 Export Node Geography Dialog Box

3) Choose Text/Geography from the To drop-down list
4) Make sure that the Include Built-in Data box is checked. Click OK
5) Type a name and click Save button in the Save As dialog box
6) (Repeat from 1 to 4) to produce link and TAZ GEO files

Appendix 4 Generation of Peak Hour Demand Matrix

1) Start TransCAD 5.0 and choose the 24-hour OD demand by choosing it from the Windows menu

2) Choose Matrix-Contents to display Matrix File Contents dialog box, shown in Figure A-8.
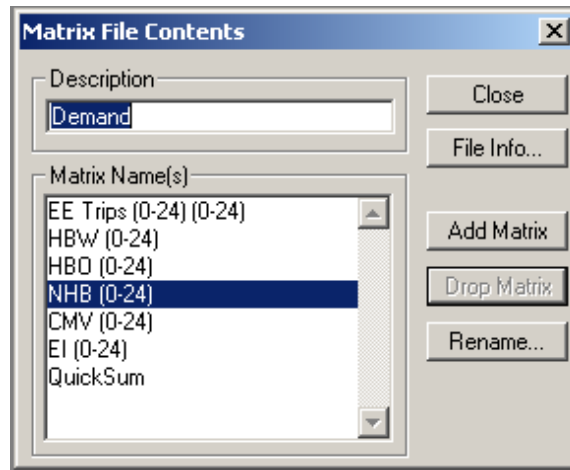
Figure A-8 Matrix File Contents Dialog Box

3) Click Add Matrix button and choose it in Matrix Name list and click Close button

4) Choose the new matrix from the drop-down list on the Standard toolbar

5) Choose Matrix-Fill to display the Fill Matrix dialog box and click the Formula page, as shown in Figure A-9.
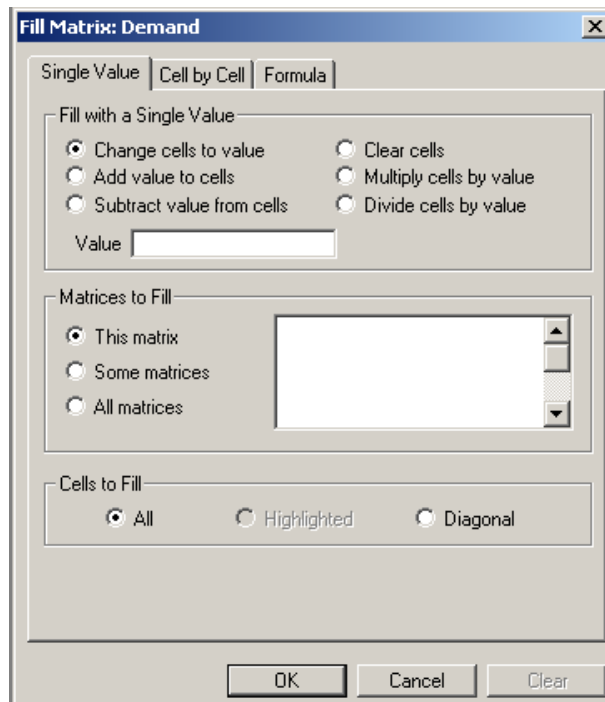
Figure A-9 Fill Matrix: Demand Dialog Box

6) Choose QuickSum Matrix from Matrix List and chose sign multiplication from Operator List and type peak hour factor in Formula edit box
7) Click OK
8) Choose Matrix-Export to display Matrix Export dialog box, as shown in Figure A-10
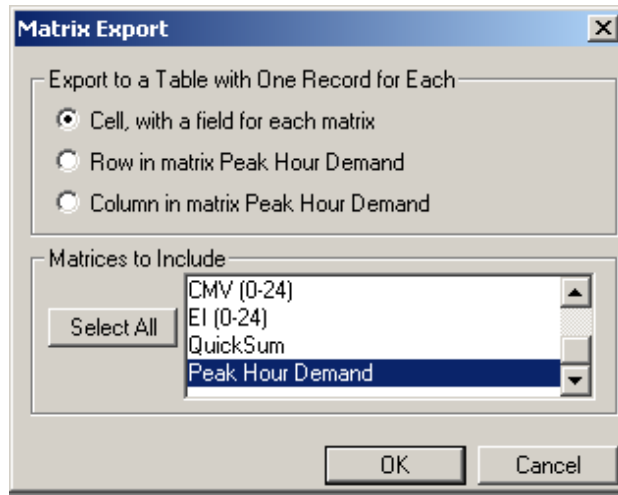
Figure A-10   Matrix Export Dialog Box

9) Click Cell with A Field for Each Matrix radio box and choose the new matrix in the Matrices to Include list. Click OK
10) Type a name and save it as Comma-delimited Text file

Appendix 5 Trip Distribution with TransCAD

These operating processes are followed after the step 4 in Appendix 2.

Step 5: Create Centroid Connectors
1) Choose the TAZ layer from the drop-down list on the toolbar
2) Choose *Tools-Map Editing-Connect* to display the Connect dialog box shown in Figure A-11.
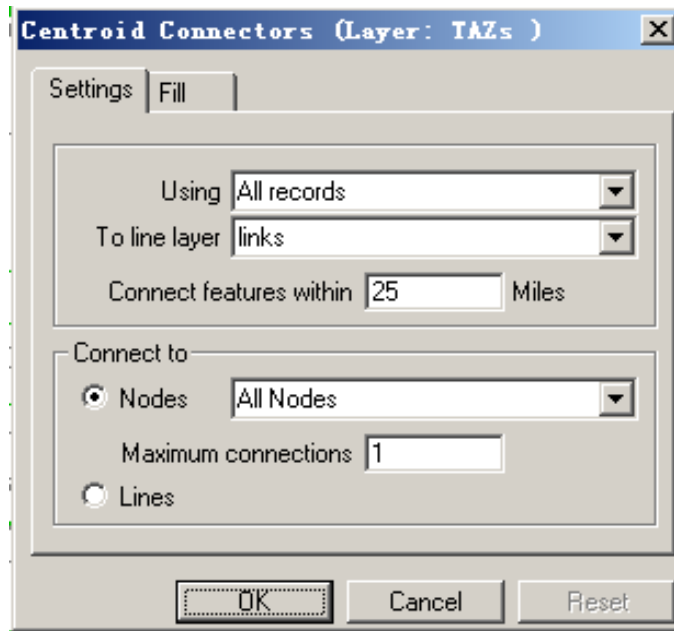3) Choose the links layer to which the connections are added from the To Line Layer.
4) Click OK.

Figure A-11 Centroid Connector Dialog Box

Step 6: Create Network file
1) Choose the links layer from the drop-down list on the toolbar
2) Choose *Network/Paths-Create* to display the Create Network box shown in Figure A-12.
3) Choose the filed of *_time from the Read Length From drop-down list
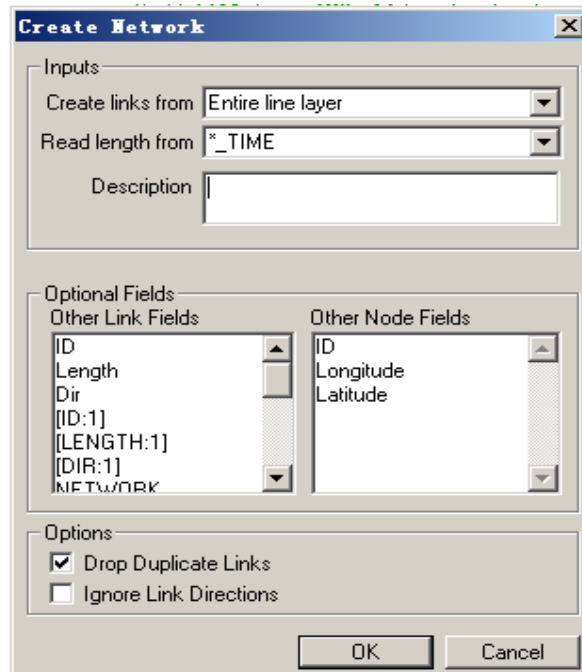4) Click OK and Save the network

Figure A-12 Create Network Dialog Box

Step 7: Produce Shortest Travel Time Matrix

1) Open the nodes dataview and choose *Selection-Select by Condition* to display the Select by Condition dialog box. Enter condition link centroids > 0, as shown in Figure A-13. Click OK
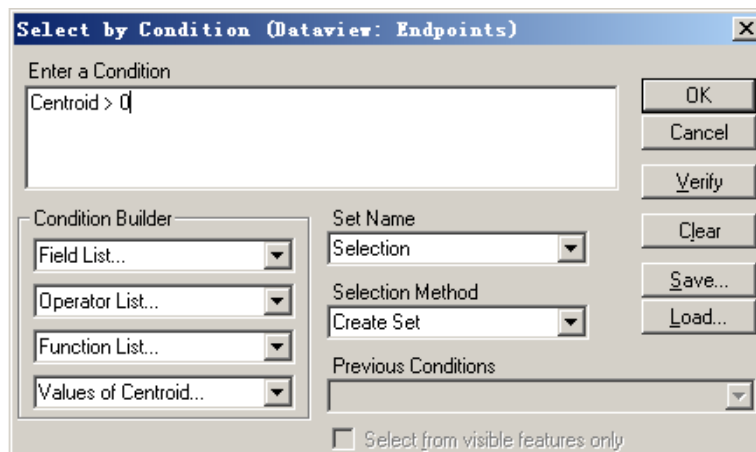2) Choose the nodes layer from the drop-down list on the toolbar

Figure A-13   Select by Condition Dialog Box

3) Choose *Network/Paths-Multiple Paths* to display the Multiple Path dialog box as shown in Figure A-14
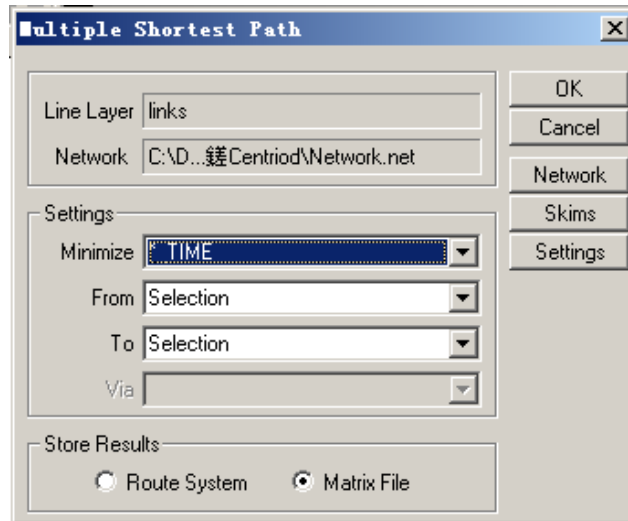4) Choose the cost variable as time from the Minimize drop-down list. Click OK

Figure A-14 Multiple Shortest Path Dialog Box

5) Type the name for the shortest travel time file in the Save As dialog box and click Save.
Fill the diagonal of shortest travel matrix by computing Intrazonal Travel Times by
TransCAD
1) Choose File-Open and open the shortest travel time matrix
2) Choose Planning-Trip Distribution-Intrazonal Travel Times to display the Intrazonal
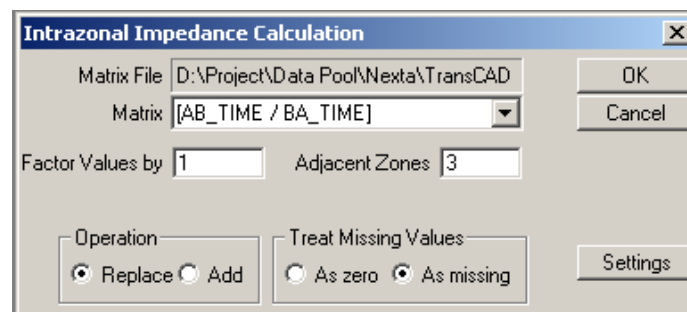Impedance Calculation dialog box, as shown in Figure A-15.

Figure A-15 Intra-zonal Impedance Calculation Dialog Box

3) Choose the shortest travel time matrix from the Matrix drop-down list
4) Check Missing radio button, and click OK

Step 8: Gravity Model Application
1) Add production and attraction data into TAZ layer and Balancing
2) Open the shortest travel time matrix
2) Choose Planning-Trip Distribution-Gravity Application to display the Gravity Application
dialog box, as shown in Figure A-16
3) Choose TAZ layer from the Table drop-down list. Choose shortest travel time matrix from
the Impedance Matrix drop-down list
4) Click Add in the General box and choose production from the Production list and attraction
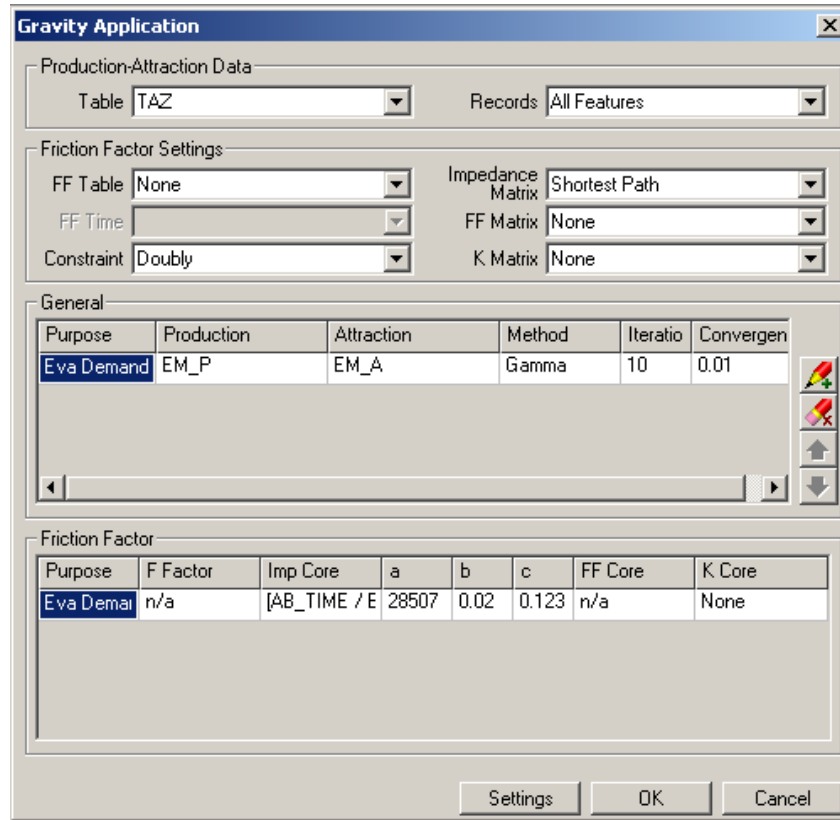from the Attraction list
5) Click OK
6) Type a file name and Save it

K

Figure A-16   Gravity Application Dialog Box

Step 9: Convert P-A Matrix to O-D Matrix

1) Open the 24-hour PA matrix file to be converted
2) Choose Planning-PA to OD to display the Convert P-A Matrix to O-D Matrix dialog box
3) Choose the matrix file that contains the 24-hour production-attraction flows from the PA Matrix File drop-down list
4) Make sure the Report each hour separately box is NOT checked and the value "0" is in the Report Hour edit box and the value "23" is in the Through edit box
5) Click OK to display the Save As dialog box
6) Type a name for the output file matrix and click Save