Regional Traffic Simulation for Emergency Preparedness

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16. Abstract

This report presents the results of a case study that developed and tested responses to several hypothetical transportation emergencies in the Birmingham, Alabama region. The purpose was to demonstrate the usefulness of micro-simulation modeling in developing and refining appropriate response plans.

First, the CORSIM traffic simulation software was utilized to create a regional transportation model comprising the major traffic corridors in the Birmingham area. An innovation in this process included the development of computer code that automated the merging of multiple CORSIM files into one integrated transportation network. Then, the regional model was used to test and evaluate various emergency management strategies in response to hypothetical incidents in the Birmingham area. Emergency incidents considered include a traffic accident on a major freeway, a building evacuation in downtown Birmingham, and traffic influx into Birmingham due to an emergency at Anniston Army Depot. Response strategies evaluated include traffic diversion, signal optimization, access restriction, and emergency routing. Appropriate measures of effectiveness (MOEs) were selected to support the assessment process at the region-wide or corridor-level. Candidate response actions were compared and evaluated on the basis of these MOEs and recommendations were developed on best practices and future needs.

The project was successful in showcasing the utility of microscopic traffic simulation for regional emergency preparedness and assisting regional transportation officials and public safety agencies in considering effective traffic management strategies in the event of an actual regional emergency.

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Executive Summary

Good surface transportation system operation allows accessibility and mobility of people and goods, and economic productivity at the local and national levels. In case of emergencies, good transportation system operations are even more essential to ensure safe, continuous movement of people and goods as well as support response and recovery operations. Therefore, it becomes important to ensure the operation and integrity of the transportation system and enhance its ability to provide service in the event of an emergency through strategic planning and active management. An important step toward this direction is emergency preparedness.

Emergency preparedness typically involves the preparation of detailed plans that can be implemented in response to a variety of possible emergencies or disruptions to the transportation system. In the past, such emergency response plans ranged from small scale (e.g., response to an individual traffic accident) to large scale (e.g., hurricane evacuations) and a variety of scenarios in between. One shortcoming of past response plans was that they were based on only rudimentary traffic analysis, or in many cases none at all. Disruptions to the transportation system can generate complex interactions and unforeseen effects as drivers divert to alternate routes which themselves may already be congested or incapable of handling the increased demand. Therefore, emergency preparedness planning can greatly benefit from the use of micro-simulation models to evaluate the impacts of natural and man-made incidents and assess the effectiveness of various responses. This approach enhances the understanding of the scope and magnitude of the disruptions and their implications to the mobility of people and goods in the transportation system.

This report presents the results of a case study that developed and tested responses to several hypothetical transportation emergencies in the Birmingham, Alabama region. The purpose was to demonstrate the usefulness of micro-simulation modeling in developing and refining appropriate response plans. First, the CORSIM traffic simulation software was used to create a regional transportation model comprising the major traffic corridors in the Birmingham area. An innovation in this process included the development of computer code that automated the merging of multiple CORSIM files into one integrated transportation network. Then, the regional model was used to test and evaluate various emergency management strategies in response to hypothetical incidents in the Birmingham area. Appropriate measures of effectiveness (MOEs) were selected to support the assessment process at the region-wide and/or corridor-level. Candidate response actions were compared and evaluated on the basis of these MOEs and recommendations were developed on best practices and future needs.

This project demonstrates the potential benefits of using microscopic simulation models when developing emergency response strategies, and as such was not intended to develop detailed response plans for specific threats. That responsibility remains with local emergency management agencies. However, the project findings are expected to assist regional transportation officials and public safety agencies in developing effective traffic management strategies in the event of an actual regional emergency. This project also offers them a tool to evaluate the impact of proposed actions on transportation network operations.

Section 1
Introduction

1.1 Background

In the event of a natural or man-made disaster, emergency preparedness plays a vital role in ensuring the safety, security, and efficiency of the transportation system. Emergency preparedness greatly depends on the understanding of the scope and magnitude of potential incidents and the significance of their disruptions to the mobility of people and goods in the transportation system. Preparedness involves anticipating a range of emergency scenarios and developing and testing plans to respond to them. Emergency preparedness for a state or locality is often measured in terms of its ability to respond to an emergency in a timely and effective manner. In the case of emergencies that affect the transportation system, the response time is a critical factor in minimizing adverse impacts including fatalities and loss of property.

Following the events of September 11, 2001 the transportation community recognized the need for better emergency planning and prevention, crisis management, and response to threats and disasters affecting the operations of the transportation system. In response, the federal government allocated funds to assist state and local governments toward establishment or expansion of emergency management programs. Since March 1, 2003, the Department of Homeland Security has allocated or awarded over $8 billion to help our nation's first responders and state and local governments to prevent, respond and recover from potential acts of terrorism and other potential disasters. Across the Department of Homeland Security, the Department of Health and Human Services and the Department of Justice, a total of $13.1 billion dollars was allocated in direct homeland security grants from FY'02 to FY'04, as compared to only $1.2 billion allocated from FY'99 to FY'01 (DHS, 2004). As part of this commitment, the Office for Domestic Preparedness is providing financial assistance directly to each of the states and territories through the FY 2004 ODP Homeland Security Grant Program (HSGP). The funds can be used for activities within the areas of planning, organization, equipment, training and exercises.

So far a lot of emphasis has been put on developing policies and procedures, hardening the infrastructure, and training first respondents and agency officials in an effort to prevent, respond and recover from potential acts of terrorism and other disasters. The Federal Emergency Management Agency (FEMA), along with its local branches, has established procedures for activation and operation of emergency plans in response to potential local disasters.

While many communities have been actively involved in the development of emergency plans, more emphasis needs to be put toward assessment, comparison of alternative options, and refinement of the proposed plans to achieve improved solution. Toward this direction, this study looked at the potential of traffic simulation as a tool for evaluating various strategies in response of emergency situations. Traffic simulation models have become widely used over the past decades and can allow detailed traffic operation analysis to support decision making. The use of simulation enables the user to test different transportation related emergency preparedness strategies under a range of different emergency situations without the cost and risk involved in carrying out actual tests.

1.2 Project Objectives and Scope

The main objective of this research is to showcase the utility of microscopic traffic simulation for regional emergency preparedness. The report describes research efforts focusing on the use of traffic simulation to test hypothetical emergency scenarios and response actions and make recommendations based on the best practices available. Another objective of the project is to assist transportation officials in the Birmingham, Alabama region in implementing effective traffic management strategies in the event of actual emergencies. While it is very costly or impractical to carry out the testing of proposed scenarios in real life, traffic simulation offers a low cost and low risk control environment to assess the impacts of proposed emergency response scenarios on traffic operations.

As part of this study, a large scale regional transportation model was developed in CORSIM consisting of the primary freeways and arterial corridors in the Birmingham region. This regional model was used as a test bed for evaluating emergency scenarios and response actions that were developed as part of the project. The response actions involved a variety of strategies such as traffic diversion with information dissemination via deployment of ITS equipment, changing signal timings through traffic signal controllers, roadway clearance, and access restriction. The test bed developed in this study can be used for further analysis of traffic impacts of traffic management strategies at the regional level under incident and non-incident conditions.

The report is organized as follows. Section 2 reviews some related work on emergency management and the use of microscopic simulation tools in support of emergency preparedness. Section 3 describes the general methodology for simulating regional emergencies using microscopic simulation, while Section 4 provides details on the test bed and the development of the Birmingham regional CORSIM model used in this study. Section 5 presents three examples of emergency management simulation and discusses response scenarios tested and results obtained from the evaluation. Finally, Section 6 summarizes the main study conclusions and issues related to future research.

Section 2
Literature Review

An extensive review was performed of literature relevant to this topic. The literature review sought information on emergency preparedness related issues, computer simulation options, simulation model development, calibration and validation, and data requirements to accomplish the goal of this project. A brief summary of the most relevant literature resources follows.

2.1 Emergency Preparedness

Emergency management has ancient roots, but organized attempts to deal with disasters did not occur until much later in modern history. Understanding the history and evolution of emergency management is important because at different times the concepts of emergency management have been applied differently. In their work, Haddow and Bullock (Haddow, 2003) discuss in detail the historical, organizational and legislative history of modern emergency management in the United States.

In the aftermath of the terrorist attacks of September 11, 2001, there has been an increasing interest in the area of emergency management. The Regional Emergency Coordination Plan (RECP) prepared by the Metropolitan Washington Council of Governments Task Force on Homeland Security and Emergency Preparedness highlights the need for regional coordination in the event of a future incident or emergency. Its analysis of transportation coordination addresses the transportation aspects of moving people around or out of the regional area and moving required resources into the area in anticipation of and following a regional incident or emergency that requires evacuation (RECP, 2002).

From the Homeland Security perspective there are four emphasis areas where the transportation system condition is vital for supporting the goals of emergency management operations. These areas include mitigation, preparedness, response, and recovery. More specifically, mitigation refers to those activities that lessen the severity and impact of a potential emergency. Mitigation can be defined as sustained activities and measures aimed at reducing or eliminating long term risks of property damage and loss of life from disasters and their effects.

Preparedness focuses on understanding the scope and the magnitude of the security problem. It involves activities related to the development of emergency response plans, conduct of community hazard analysis, training of emergency responders, and exercising of prepared plans. More than anything else, preparedness should focus on the effective and timely coordination of local resources to respond to an emergency and evaluation of validity of plans and their underlying assumptions.

The response phase assumes that an emergency has occurred or is underway and is most effective when advanced planning has taken place that covered as many contingencies as possible. Response by emergency responders during an emergency will determine how quickly a community will be able to handle the emergency and return to normal conditions. Response consists of five stages including warnings and instructions, immediate public safety, property safety, public welfare, and restoration of services.

Last but not least, the recovery phase consists of deliberate and sustainable efforts in the direction of restoring and rebuilding the affected community's social, physiological, and economic life. This phase includes both immediate and long term recovery needs of the community.

The transportation system plays a vital role in all phases of emergency management. The transportation network has the responsibility to get responders to the affected site and get the public both out of danger and out of the way of responders. This is often a challenging task, especially when evacuation and emergency access needs have to be met simultaneously. In addition, the transportation network should provide information to responders and to the general public on incidents and available options. If the transportation system itself comes under attack, a primary concern is to keep the system running or restore operations to at least a minimum level as fast as possible (ITS America, 2002).

In order to ensure that the transportation system is ready to support rapid and effective response to emergencies, facilitate the movement of people and goods even in times of crisis, and capable to quickly restore services to full capacity, careful planning in anticipation of a crisis is required. This planning relates to activities undertaken as part of emergency preparedness.

The emergency preparedness of a state or locality is measured in terms of its ability to deploy emergency response quickly should an event (accident or incident) occur and, if necessary, evacuate the affected area while restoring transportation services in an efficient and timely manner. Time is a critical factor in an emergency and the ability of the response unit to provide an appropriate and timely response will affect the magnitude of adverse impacts. Emergency response time and evacuation time are primary considerations in deploying emergency response units and developing evacuation plans. Also important is the choice of the transportation route since it determines to a large extent the potential impacts of the incident to people involved and the operation of the transportation network during response and recovery.

Transportation officials have a very important role to play in preparing for emergencies and need to work closely with public safety agencies and other stakeholders to promote a smooth functioning transportation system during or following a natural or man-made emergency. Among other responsibilities, transportation officials should be actively involved in the preparation and testing of plans well in advance of an emergency. In an effort to keep America moving during emergencies, the U.S. Department of Transportation stresses that "if a community is not actively planning to optimize the operation and coordination of its transportation system during natural disasters or national security events, there's a missing link in their emergency preparedness plans" (U.S. Department of Transportation, 2003).

In planning for emergencies, one should consider the uniqueness of emergency situations, and behavioral aspects that may greatly affect the decision making process of the users of the transportation network. Planning an evacuation, for example, is altogether different from routine traffic planning. Emergency evacuation is an extreme response to a threat of mass destruction, and thus some of the standard traffic engineering principles do not apply. Thus transportation officials must identify and analyze sectors with high disaster potential and evaluate facilitating and limiting factors for each risk identified. Then evaluation and study of mitigation measures for these risks is necessary (Wolshon, 2002). This involves development of emergency scenarios and selection of the best response actions. After developing the best response, monitoring and evaluation of the recommended response action is important to ensure optimal system performance.

2.2 Emergency Response Assessment

Two approaches were used for testing and evaluation of emergency scenarios. The first one was the so-called mock-exercises or drills where emergency preparedness plans are tested using volunteers and participants from key agencies. The objectives of the drills were to test incident command structure, notification procedures, communications and coordination among agencies, as well as evacuation procedures and service restoration procedures. The ultimate goal was to understand possible vulnerabilities and weaknesses of the plan and revise it accordingly to better serve public safety interests. The second approach was through the use of simulation modeling. This is a good way to assess the impact of emergencies and response actions on the transportation network operations and test alternatives in a controlled environment without the need to disrupt traffic operations while testing.

The mock exercises are a critical component of any emergency management program because they enable participants to learn from simulated crises, rather than on-the-job training during actual disasters. Such exercises can: (1) reveal inconsistencies in response plans; (2) highlight efficiencies as well as deficiencies; (3) underscore the need for training; (4) assess emergency preparedness capabilities; and (5) identify recommendations and corrective actions to strengthen capabilities. Despite the value of such exercises for emergency responder training, their feasibility and applicability for studying transportation system conditions under emergencies is limited (FEMA, 1998). On the other hand, traffic computer simulation offers the opportunity to study traffic via the execution of experiments in a controlled environment without any disruption of actual traffic operations.

Traffic simulation is a numerical technique for conducting experiments on a digital computer. It involves replication of real world transportation systems through mathematical and logical representations of interactions of the entities present in the system. Traffic simulation may include stochastic characteristics, be microscopic or macroscopic in nature, and involve mathematical models that describe the behavior of a transportation system over extended periods of real time (May, 1990).

2.3 Traffic Simulation Modeling for Emergency Preparedness

Traffic simulation techniques have been used since the early days of the development of traffic theory. The ever-increasing power of personal computers and the search for traffic management solutions to address growing urban transport problems has led to the emergence of a number of simulation models as practical traffic analysis tools. Currently available traffic simulation packages can satisfy a wide range of requirements, from evaluation of alternative treatments, to testing of new designs, to safety analysis through the recreation of traffic accidents.

In general, the user of traffic simulation software specifies a “scenario” (e.g., highway network configuration, traffic demand) as model inputs. The simulation model results describe system operations in two formats: (1) statistical and (2) graphical. The numerical results provide the analyst with detailed quantitative descriptions of what is likely to happen. The graphical and animated representations of the system functions can provide insights so that the trained observer can gain an understanding of why the system is behaving this way. However, it is the responsibility of the analyst to properly interpret the wealth of information provided by the model to gain an understanding of cause-and-effect relationships (Gartner, 1996).

Traffic simulation models can be broadly classified as microscopic (high fidelity), mesoscopic (mixed fidelity), and macroscopic (low fidelity) (Boxill, 2000). Models that continuously or discretely predict the state of individual vehicles are termed as microscopic while models which aggregate the description of traffic flow are termed as macroscopic. Models having characteristics of both the classes are called mesoscopic. A mesoscopic model generally represents most entities at a high level of detail but describes their activities and interactions at a much lower level of detail than would a microscopic model. Lower fidelity models are easier to develop, execute and maintain. However, they carry a risk that their representation of the real-world system may be less accurate, less valid or perhaps, inadequate (Gartner, 1996).

Functionality can be also used to classify simulation models, i.e., arterial, freeway, or integrated. For the purposes of analyzing strategies at the regional level microscopic traffic simulation models that allow modeling of integrated transportation networks are desirable as they offer the greatest flexibility and result in more accurate estimations of measures of performance.

Numerous microscopic traffic simulation models have been developed and are currently being used successfully to study transportation network operations. Such models may be also used for assessment of emergency response actions in support of emergency preparedness planning. For example, CORSIM is a network based, microscopic simulation model developed for the Federal Highway Administration that is well suited for modeling urban traffic conditions. VISSIM can be used for modeling and simulation of complex dynamic systems. INTRAS (Integrated Traffic Simulator) is a microscopic simulation model that is used to simulate traffic on freeways, ramp highway segments, and also adjacent surface streets. This model has been used for incident analysis studies. AIMSUN II (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks), a component of the GETRAM (Generic Environment for Traffic Analysis and Modeling) environment, is a microscopic stochastic model developed in Spain for simulating traffic on roadway networks with advanced capabilities for simulating human behavior and

Intelligent Transportation Systems applications. PARAMICS is another microscopic traffic simulation model in wide use.

A number of studies are available comparing features, capabilities, and limitations of available microscopic traffic simulation packages and offering guidance on model selection. Examples include a comprehensive review and comparison of micro-simulation models developed as part of the SMARTEST Project (Algers, 1997) and a study funded through a University Transportation Center for Alabama grant (UTCA 02217) comparing three traffic software packages (namely CORSIM, GETRAM, and SimTraffic) using a common test bed in the Birmingham, Alabama area (Jones, 2003).

There are many different dimensions that require consideration when selecting a traffic simulation model. These include: flexibility of the model, ease for data collection and coding, cost, training requirements, user friendliness, accuracy of estimation of measures of performance, as well as expandability and ability of the model to interact with other software. The importance of each dimension will depend on the nature of the activity, its objective, resources available, and user preferences. The choice of the model is essential to the success of the experiment (Brooks, 1996) and this choice is usually a trade off between the accuracy and the precision of the model and the development costs, data needs, and the time required to execute the simulation.

2.4 Case Studies

In the recent years, traffic simulation models have been used in the context of emergency planning primarily for:

- Incident Management
- Evacuation Planning, and
- Emergency Response Routing.

In incident management planning, computer simulation modeling was applied to estimate and minimize travel times, improve delays, minimize congestion, and develop best route plans. Many of the models discussed above have in fact been applied to analyze incident management practices. For example, Stamatiadis and Culton (Stamatiadis, 1999) used computer simulation models to test different routes that could be used to divert traffic from a freeway, upstream of an incident, to other streets and back to the freeway, downstream of the incident using computer simulation/optimization models like PASSER II-90, TRANSYT-7F and TRAF-NETSIM. In their work they considered different routes and three MOEs, i.e., delay, average speed, and move/total time ratio. Using these MOEs, different route choices were tested and recommendations were developed for the most efficient routes.

In their work, Dia and Cottman (Dia, 2003) evaluated the benefits of ITS technologies on incident management by using a simulation approach. Several microscopic simulation models are now capable of modeling a variety of ITS-related features such as vehicle detectors, adaptive traffic control, coordinated traffic signals, ramp metering, static and dynamic route guidance, incident management, probe vehicles, and dynamic message signs. The results of the analysis suggest that a reduction of single lane incident duration from 30 to 15 minutes provides a 12% increase in average travel speed and 31% decrease in time spent in queue.

A number of studies are reported in the literature using traffic simulation to estimate transportation network performance under evacuation. In a study by Theodoulou, for example, (Theodoulou, 2003) contra flow operations were tested as a means of traffic flow regulation in case of an emergency using CORSIM. The basic aim was to develop a plan that could evacuate an area under hurricane threat in the minimum time possible. Ultimately, an optimum plan was developed based on travel times and roadway capacity. In another study, Pal and Greattinger developed a microscopic evacuation simulation model in which GIS was used to define the road network, population, and area being evacuated. The OREMS simulation software was used modeled the effect of evacuation on the traffic network (Pal, 2003).

Some studies looked into simulation as a means for determining the termination point of the contra flow operations. This is a very important issue in contra flow operations as the merging of vehicles in opposite direction can lead to congestion and accidents. In a study by Yu Yik Lim (Lim, 2003), the CORSIM model was used to simulate contra flow operations and test different termination points. It was concluded that exiting ramps upstream of the termination point reduce the conflicts and delay and is a better option as compared to one lane closure operation, which can create bottleneck conditions.

Agent-based modeling also has been used to simulate emergency evacuation plans. Using agent based simulation, Xuwei Chen (Chen, 2003) tested simultaneous and staged evacuation strategies for different roadway networks. The simulation was done using the microscopic simulation model PARAMICS. For the staged evacuation scenario, the considered area was divided into four zones. Multiple simulations were run on different types of networks after deciding upon the rules. 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 then simultaneous evacuation is a good option. Otherwise, staged evacuation using certain sequences helps to reduce the total evacuation time and improve network performance.

Another agent-based micro simulation technique was used by Church and Sexton (Church, 2002), to investigate how evacuation time can be affected by different evacuation scenarios. Evacuation scenarios considered include opening alternative exits, changing number of vehicles leaving a household, and applying different traffic control plans were tested. In another study, Batty et al. (Batty, 2002) used an agent base simulation model to study the changing of routes during a carnival event held for two days in a year. These studies demonstrated how appropriate traffic control can effectively address congestion and safety issues. Moreover, these studies showed that environment and other external factors have an impact on individual behavior and, in turn, influence the collective behavior, thus affecting the effectiveness of the evacuation plan.

In an effort to overcome limitations of microscopic simulation models in considering parameters such as population density, land use, etc. Essam Radwan et al. developed a macroscopic simulation model and applied it to study evacuations in case of natural disasters (e.g., hurricanes). Different evacuation times were found while keeping destination volumes and origin volumes optimum for different options. Then the option with the lowest evacuation time was further developed (Radwan, 2003).

A few other modeling efforts reported in the literature concentrated on emergency response planning. A good example is the work by Ali Haghani et al. (Haghani, 2003) who developed a simulation model to evaluate a real time emergency medical service vehicle response system. This system uses real time information to assist the emergency vehicle dispatchers to assign vehicles and route them through the least congested routes. The model works with a dynamic network wherein nodes can be added as required by treating each vehicle as a moving node. Different assignment strategies are available such as First Called, First Served, Nearest Origin Assignment, and Flexible Assignment Strategy. This work offers a useful tool for improving the emergency response capability of the first responders and confirms that dynamic travel time information and dispatching strategies help to significantly minimize the emergency response time.

2.5 The Role of Calibration

According to previous studies, calibration and validation of a simulation model are critical to obtaining meaningful results. Generally, calibration is an iterative process in which the engineer adjusts the simulation model parameters until the simulation results match field measurements; the comparison part is often referred to as validation.

Microscopic simulation models contain many independent parameters to describe traffic control operation, traffic flow characteristics, and driver behavior. Although these models contain default values for each variable, it is now universally accepted that to make simulation models to accurately replicate real world conditions, the process of calibration and validation is necessary. Recently, much research has been conducted on the techniques and procedures for calibrating and validating microscopic models. Jerome Sacks (Sacks, 2001) indicates that simulation model calibration and validation were often discussed and informally practiced among researchers, and provides a statistically-based validation method which developed an appropriate statistical theory for field experiments.

In their work, Park and Schneeberger (Park, 2002) proposed a detailed procedure for microscopic simulation model calibration and validation, and used a Latin Hypercube sampling and surface function to calibrate and validate the VISSIM model for coordinated actuated signal system in Virginia. Hourdakis presented a calibration methodology for obtaining the accuracy needed in high performance situations with an automated calibration procedure that saved significant amounts of time and effort (Hourdakis, 2002). Other researchers successfully applied genetic algorithm optimization techniques to search for the best combination of simulator parameters (Cheu, 1998).

No matter how sophisticated the simulation model, it is nearly impossible to fully model the complex human behavioral characteristics encountered in the real world. It should be recognized that in real world conditions, drivers often display erratic behavior which is very difficult to simulate (Dittberner, 2002). This is particularly true in emergency situations, where psychological factors may alter behavior, or even impair judgment and result in unexpected actions and reactions. Despite these limitations, traffic simulation modeling remains the best tool currently available to identify, in advance, the combinations of chance factors which could result in serious traffic problems in case of an emergency, and evaluate strategies that can be implemented in order to optimize the transportation network operations.

Section 3
Methodology

3.1 Background

Following the national example, transportation professionals and local officials in Alabama are looking into ways to ensure the safety and efficient management of the transportation system in Alabama in the event of a regional emergency. To effectively address this issue a need exists to plan in advance, to prevent and mitigate where possible, and to respond when necessary with flexibility, coordination, and speed. Simulation modeling and the presence of ITS can greatly assist this effort and play a major role in the quick restoration of services and of the economic vitality of the affected area.

The Alabama Department of Transportation (ALDOT) has technologies in place and ongoing projects that can be used to support emergency preparedness and response efforts. Over the past seven years ALDOT has been responsible for the installation of hundreds of miles of fiber optic cable and related equipment, closed-circuit television cameras on freeways and arterials, dynamic messages signs, the planning of a regional highway advisory radio program, and the implementation of traffic management centers at the ALDOT Third Division offices, the City of Hoover, and the City of Birmingham. ALDOT also sponsored the development of a diversion route plan for major parallel corridors in the region. The diversion routes along these corridors were identified using local knowledge of travel patterns and roadway geometrics and have been setup to provide detours in the event of major roadway incidents on either corridor.

In addition to its substantial ITS investment, ALDOT has sponsored numerous traffic simulation studies on individual corridors throughout the Birmingham area. This project utilized the results of the ITS deployment and diversion route development efforts, and capitalized on the data collection and model coding efforts already undertaken by ALDOT to develop a comprehensive, region-wide emergency/traffic management tool. The tool was then used to develop and test emergency response procedures to help ensure the safety of Birmingham's citizens, employees, and visitors should disaster strike. More specifically, within the context of emergency preparedness, the regional traffic simulation developed in this study was used to test the effects of various traffic control strategies including:

- Dissemination of traffic information using regional ITS;
- Implementation of strategies that offer priority treatment through signal timing modifications; and
- Consideration of parallel corridors (e.g. I-65 and U.S. 31) as diversion alternatives during evacuation and incident management.

3.2 Research Approach

The work performed in this project was organized as a list of tasks, as follows:

1. Examine existing simulation studies and data collection in the Birmingham region.
2. Define study boundaries for development of emergency preparedness simulation test bed.
3. Collect data for study corridors not covered in previous studies (as identified in Task 1).
4. Select traffic simulation model and code regional test bed (coding of missing network parts, merging existing corridors into one interconnected network).
5. Develop realistic emergency scenarios and candidate response actions.
6. Model emergency scenarios and response actions with the traffic simulation test bed and evaluate candidate response actions using appropriate preparedness and response measures of effectiveness (MOEs).
7. Develop recommendations on best practices or needs for technology deployment based on the results obtained in Task 6.

A Project Steering Committee was developed to oversee the study and offer expertise and guidance throughout the process. The Steering Committee comprised of representatives from the ALDOT, the Regional Planning Commission of Greater Birmingham (RPCGB), Jefferson County Emergency Management Agency, the University of Alabama at Birmingham, and the City of Birmingham Fire and Rescue Service. The Steering Committee members provided valuable input on local needs related to emergency preparedness and helped craft the emergency scenarios that were selected for testing as part of this study.

Figure 3-1 shows the simulation modeling approach as a flowchart. More details about the preparation of the simulation model for coding and the development and modeling of emergency scenarios and response actions are provided in Figures 3-2, and 3-3 respectively. The following paragraphs provide some discussion on the selection of the simulation model, its main features, and its feasibility to test the selected emergency scenarios. A detailed description of the study network and the scenarios modeled in this study is offered in Sections 4 and 5 of this document.

3.3 Traffic Simulation Model Selection

A variety of microscopic traffic simulation models was considered for performing the project tasks described in Section 3-2. Some details about the capabilities of such models were presented earlier as part of the literature review (Section 2-3). The review of the model capabilities and

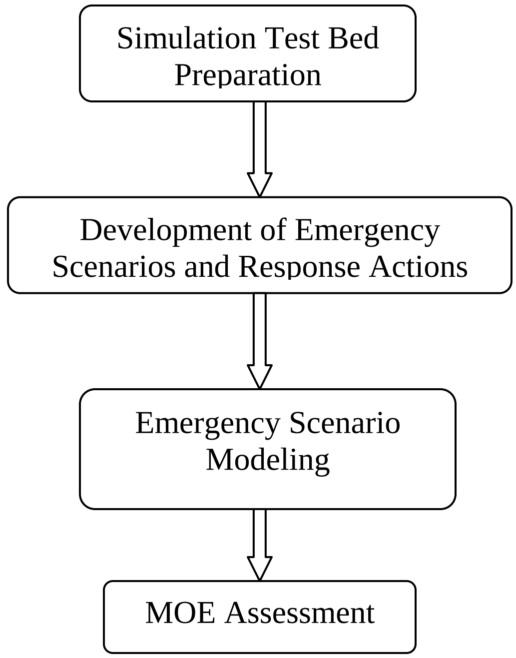

Figure 3-1. Steps of Traffic Simulation Modeling Approach

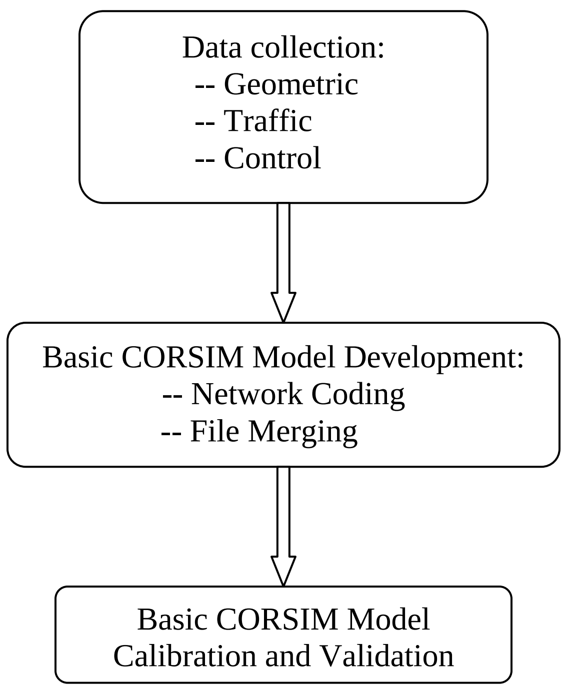

Figure 3-2. Simulation Test Bed Preparation

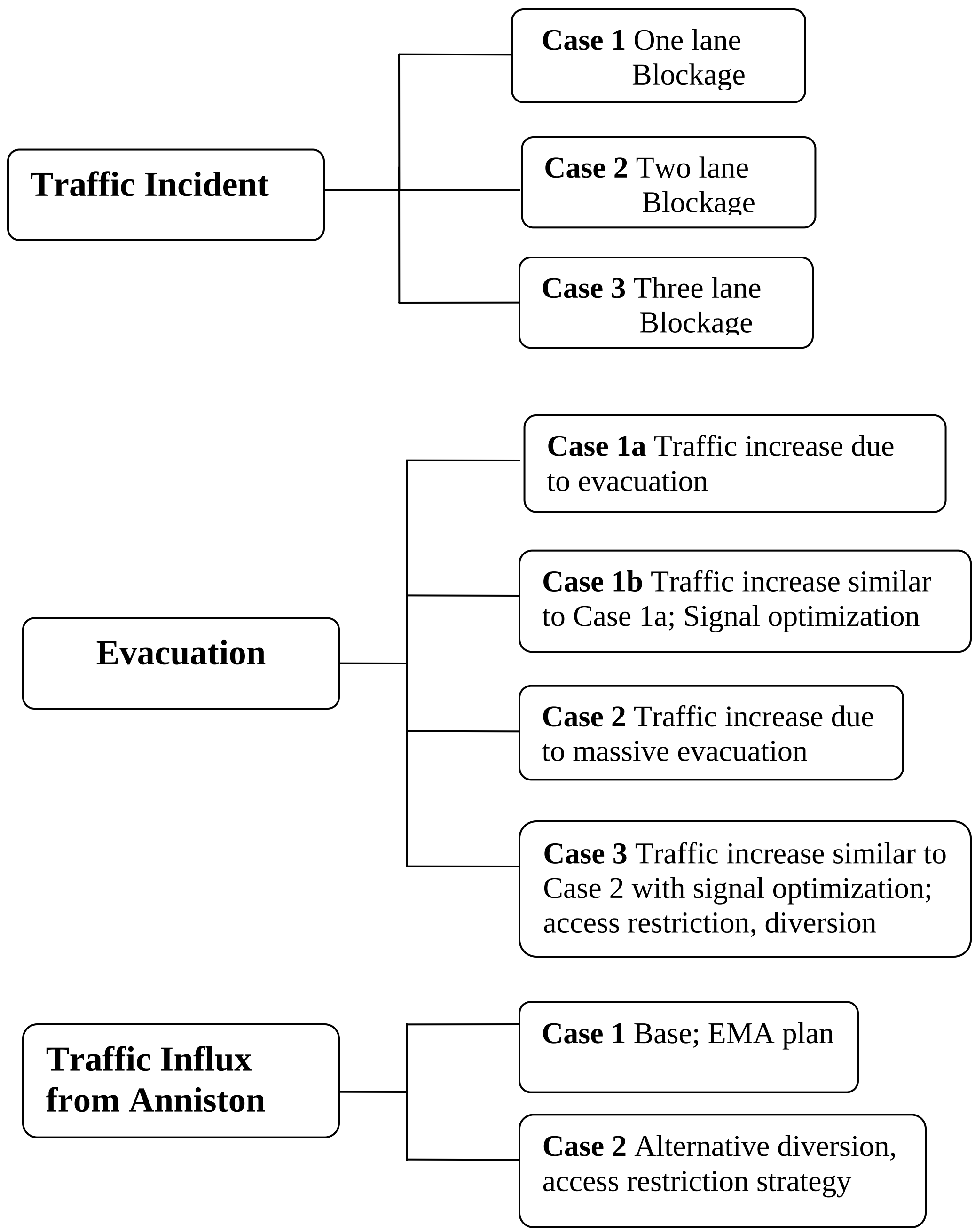

Figure 3-3. Emergency Scenario Development

limitations, along with consideration of project needs, and practical issues led to the selection of the CORSIM model as the simulation tool. The CORSIM model (Version 4.32) used in this study is part of the Traffic Software Integrated System (TSIS, Version 5.1) that represents a collection of software tools for traffic engineers and researchers. In addition to the CORSIM microscopic simulation model, TSIS provides TRAFED (a new graphical input editor that uses CORSIM to verify inputs), TRAFVU (an animator output processor), and TSHELL, the shell that forms the basis for TSIS (TSIS, 2003).

It should be noted that many traffic simulation models exist that offer useful features for simulation of emergencies. Examples include PARAMICS, INTEGRATION, and agent-base simulation models. Still the CORSIM model possesses some properties that make it an attractive model for experimentation within the scope of this study.

First of all, the CORSIM software microscopically simulates traffic and traffic control systems on an integrated network of freeways and surface streets, using commonly accepted vehicle and driver behavior models. In doing so, CORSIM combines two of the most widely used traffic simulation models, NETSIM for surface streets, and FRESIM for freeways and allows the study of the interactions among freeway and arterial network components. This is a desirable feature for this study since it is important to look at the effects of freeway traffic management strategies on arterial network operation and vice versa.

Moreover, a regional model (as the one developed in this study) is expected to be of large scale and thus software packages with strict limits in the number of nodes or links to be modeled had to be excluded. There is no limit in CORSIM to the number of links, segments or vehicles, other than the limitations imposed by the amount of available computer memory. This capability not only addresses the needs of the regional model proposed in this study, but also offers the opportunity for future expansion of the test bed to increase the modeling detail.

Another consideration that supported the decision to use CORSIM is the popularity of the software and its extensive use and prior validation. At the local level, state and local transportation agencies are familiar with the software and may be in position to use the test bed for further testing in the future without the need for training or additional capital investment. Moreover, several parts of the study network were already coded in CORSIM from previous studies and were validated. Thus they were available for use with only minor adjustments as part of this study. Given the amount of data to be collected, processed and coded to develop a regional simulation model, the opportunity to capitalize on earlier data collection and model coding efforts made this option very attractive.

3.3.1 CORSIM Features

This section provides a brief description of the CORSIM model, primarily based on work presented by Algers et al. (Algers, 1997), Owen et al. (Owen, 2000) and information on the CORSIM model available at the FHWA TSIS homepage (TSIS, 2003).

As mentioned earlier, CORSIM (CORridor microscopic SIMulation) is a combination of two other micro-simulators; the urban micro-simulator NETSIM and the freeway micro-simulator FRESIM. This has resulted in a simulation model is capable of representing traffic flow in large urban areas containing both surface streets and freeways. CORSIM is aimed at the development and evaluation of Transportation Systems Management (TSM) strategies. To test the effect of TSM schemes on trip patterns it is necessary to analyze an area that contains a substantial portion of the routes that the trip makers follow.

Main CORSIM Features

Both researchers and practitioners use CORSIM extensively because of its solid foundation of traffic engineering modeling and analysis. It offers rich modeling features that enable users to simulate traffic flow of a wide spectrum of practical or research applications. It has been ubiquitously accepted that CORSIM has specific strengths in the following areas (Owen, 2000):

1. Ability to model complicated geometric conditions.
   CORSIM can handle virtually all complicated geometric conditions that practically exit in the field. Geometry conditions accepted by CORSIM include surface streets with different combinations of through lanes and turning pockets, multi-lane freeway segments, and different types of on- and off-ramps. Due to flexibility in coding each individual component of the network, CORSIM can simulate traffic operation of virtually all types of freeway interchanges, and all types of surface street intersections. Special geometry such as lane-drop and lane-add can also be modeled.

2. Ability to simulate different traffic conditions.
   CORSIM has been calibrated to accurately simulate a wide range of traffic conditions, from moderate demand to very congested conditions. CORSIM can also effectively simulate traffic flow during an incident, from queue buildup to recovery to normalcy. The ability to simulate over-congested traffic flow conditions gives CORSIM a unique advantage over traditional empirical/analytical methods. Most traditional methods such as those described in the Highway Capacity Manual have serious limitations in accurately assessing traffic flow conditions when traffic demand is approaching capacity of the facility. CORSIM, however, has the ability of predicting congestion development and dissipation with acceptable accuracy.

3. Ability to simulate different traffic control, management and operation conditions.
   CORSIM can simulate different traffic control devices such as stop or yield sign control, fixed timing or actuated control at surface street intersections. It can simulate freeway ramp metering, and HOV (High Occupancy Vehicle) operation. CORSIM also has flexible bus operation simulation logic.

4. Ability to account for the interactions between different components of networks.
   CORSIM can simulate integrated networks with surface streets, freeway mainlines, and ramps as their components. Unlike most traditional methods that analyze traffic operations of each component separately, CORSIM is able to simulate the traffic flow of the network in an integrated fashion. This gives CORSIM the ability to simulate spillback/spill-over situations. The congestion spillover from one network component to another, such as queue spill-back from off-ramp to the freeway or from on-ramp to the surface street, can be modeled effectively.

5. Ability to interface with external control logic and programs.
   Through a specially designed TSIS interface, CORSIM is able to communicate with external control logic and programs. A typical process of this interfacing ability application is as follows:

- CORSIM moves vehicles in the network.
- The vehicle information (speeds, positions, etc.) is sent to an external control program via the special interface.
- The external program makes control decisions based on vehicle information.
- Control decisions are then sent back to CORSIM via the special interface. The control decisions immediately affect vehicle movement.

The two-way data exchange via the interface operates in real-time. This unique interfacing feature opens the door for CORSIM to be used in evaluating ITS technologies. This special feature has been successfully used in FHWA funded projects for evaluating RT-TRACS (Real-Time Traffic Adaptive Control) prototypes and ramp-metering strategies.

6. Ability to model time-varying traffic and control conditions.
   CORSIM uses Record Types (RTs) to organize data inputs for geometries, volume and pattern, surveillance and detecting devices, traffic control, engineering criteria, run control, and output requirements. CORSIM simulates the traffic conditions of a network over a period of time. The inputs accommodate specifications that not only differ from one point in the network to another, but that might also change with time. The time-varying portion of the simulation analysis is expressed as a sequence of time periods specified by the user. During each time period, CORSIM allows different traffic demand, and different traffic operations and control.

Technical Approach (Algers, 1997)

For the CORSIM model the spatial extent of the traffic environment is defined as a set of "sub-networks," which reflect the concept of network partitioning. In a multiple-model network, each of the component models of CORSIM simulates a different sub-network. The interfacing of adjoining sub-networks is accomplished by defining "interface nodes," which represent points at which vehicles leave one sub-network and enter another. Nodes of this type are assigned special numbers to distinguish them from other nodes in the network. The terms "entry interface links," which receive traffic from the adjoining sub-networks, and "exit interface links," which carry traffic exiting the sub-network to adjoining sub-networks, are used to describe links at the boundaries of the sub-networks.

The freeway sections can be modeled with FRESIM, while the urban sub-network can be modeled with NETSIM. Other sub-networks will be processed in a similar manner. Once the user identifies the appropriate sub-network representation, all interfacing processes are handled internally by the model by the interface logic. All types of traffic control can be modeled using CORSIM, including pre-timed and actuated signal control. Vehicle flow is guided by car-following, lane changing and other driver decision rules with vehicle movements simulated on a second-by-second basis. The software also models four different types of on-ramp freeway metering (clock-time, demand/capacity, speed control and gap acceptance merge control).

The CORSIM software allows modeling of some ITS and Transportation System Management options including coordinated traffic signals, adaptive signal control, vehicle preemption, high occupancy vehicle lanes (HOV), ramp metering and incident management applications.

CORSIM Inputs and Outputs

Input to CORSIM includes geometric specifications, traffic volumes entering the network, turning movement data, topology of the road network and information about heavy vehicles and buses. For the analysis performed at the arterial level using NETSIM, information about parking activity, actuated controllers, pedestrians, and special events can be also specified. For freeway modeling using the FRESIM model, the user can input incident specification and detection information, lane adds/drops, and ramp metering.

CORSIM provides a variety of numerical output that is link specific, aggregated for multiple links, and network wide. The user may specify time intervals for generating output reports. Measures of effectiveness are provided as outputs from the CORSIM software include average vehicle speed, vehicle stops, delays, travel times, vehicle miles traveled (VMT), fuel consumption, and pollutant emissions.

Reliability and Validation

TSIS, including the development, maintenance, and support of the CORSIM software is funded by the Federal Highway Administration's ATMS R&D Team at the Turner-Fairbank Highway Research Center. Since its initial development in the early 1970s CORSIM has evolved to become the most widely used microscopic simulation model in the U.S. and beyond. In addition to continuous enhancements to its logic, incomparable validation, verification, and calibration effort ensures that CORSIM results realistically reflect real world traffic flow conditions (Owen, 2004). CORSIM has been applied by thousands of practitioners and researchers worldwide over the past 30 years and embodies a wealth of experience and maturity. Numerous successful applications of the model have been documented in the literature, examples of which can be found at the FHWA TSIS homepage (TSIS, 2003).

3.4 Development of Emergency Scenarios and Response Actions

Following the selection of the simulation model and the definition of the test site, emphasis was devoted to the development of emergency scenarios and response actions. In order to develop detailed emergency scenarios, it is important to understand and consider the various steps of the disaster process as discussed in Section 2.1. Comprehensive emergency management should take into account not only the response to a specific emergency but also the conditions prior to and following the crisis.

With these considerations in mind and with input from the Project Steering Committee, a number of options were identified and three of them were selected for further consideration. These include:

a. traffic incident simulation,
b. evacuation simulation, and
c. evaluation of existing emergency preparedness plans.

General considerations related to the simulation of these three cases are discussed next while details of the scenarios as developed for the case study are presented in Section 5.

3.4.1 Traffic Incident Simulation

The CORSIM simulation model allows the user to test scenarios involving alternative geometric configurations (weaving, merging, diverging), incident and work zone impacts, and various ramp metering options (Adams, 2003). It is also feasible to simulate traffic incidents, vary their location, duration, and severity, and compare the resulting network performance against a non-incident base scenario.

At the heart of this approach is the traffic simulation model that can predict changes in the behavior of individual drivers on the road network in response to a set of conditions, and provide output in the form of MOEs. Furthermore, incident simulation can also be used to test the benefits of ITS technologies to incident management. Examples of incident management strategies which are feasible for testing and evaluation by the model are summarized as in the following paragraphs.

ITS Deployment

The presence of ITS may reduce the emergency response time and mitigate the negative impacts of a traffic incident. By varying the incident duration and percentage of traffic diversion in simulation scenarios, the user can evaluate the benefit of advanced technologies deployment related to incident management. In the presence of ITS, diversion can be achieved through the dissemination of traffic information using ITS systems. These include changeable message signs (CMS), highway advisory radio (HAR), advanced traveler information systems, etc. It should be pointed out that the CORSIM model by itself does not have the ability for real-time vehicle rerouting, thus the adjustments in the inputs must be manually performed to account for traffic diversion.

Signal Timing

It is feasible to test and evaluate the effect of adjusting signal timings in response to a traffic incident using the CORSIM model. The optimal signal timing strategies can be obtained through other optimization models (e.g. SYNCHRO), and then be coded into the CORSIM scenario to evaluate the impact of signal timing optimization as a strategy for incident management.

3.4.2 Emergency Evacuation Simulation

In general, simulation of an evacuation is a complex scenario. It should be noted that the type of data normally collected in system monitoring and management falls short of the data needed to fully characterize and model an evacuation event. Such characterizations include driver behavior under possible panic conditions, the degree to which the emergency overwhelms the environment (e.g. smoke limiting visibility), unusual driver behavior (e.g. leaving the roadway to cut across a landscaped lot), etc. But a micro-scale traffic simulation model can be used under certain assumptions to estimate clearing time for an emergency evacuation, even when an accurate calibration is simply not possible (Church, 2002). In addition, the methodology of evacuation modeling using micro-scale traffic simulation model should consider the following:

Shape and Size of Evacuation Area

The size and shape of an evacuation area may vary considerably depending on the size, strength and rate of growth of the emergency source. For micro-scale evacuation simulation, the evacuation scale is limited by the computer technology and the coded network. Based on the coded model in the Birmingham regional test bed, for example, scenarios involving evacuation can be modeled to test the use of parallel corridors (e.g. I-65 and U.S. 31) as diversion alternatives during evacuation. It is also feasible to simulate the evacuation of a major facility and test the ability of the local transportation network to handle the evacuation needs.

Traffic Demand Forecasting

The evacuation demand depends on the size of the evacuation area as well as the level and type of development contained within it. In forecasting the evacuation demand, it becomes essential to have information about the makeup of the population, including household size, age, income level etc. The demand also depends on the time of day and location of the evacuation area. The general steps involved in travel demand forecasting for evacuation include the following:

a. Evacuation traffic generation forecasting. Usually, the methods to forecast the traffic demand in the evacuation area are largely simplified. For example, often vehicles trips per household are used as the trip generation rate. It is practical to forecast the evacuation demand using the trip generation and attraction information of the Traffic Analysis Zone (TAZ) in the evacuation area to forecast the evacuation traffic.

b. Evacuation traffic distribution. Evacuation traffic distribution refers to evacuation destination choice. For an individual, the choice of destination depends on minimizing the perceived cost, such as travel time to destination, proximity of destination to origin, and time available to reach a safe area. The system management goal is to minimize the total system travel time and maximize distribution of emergency services.

c. Mode choice. Mode choice refers to the distribution of traffic among the various available modes. During evacuation some shift from one mode to another is expected due to mode accessibility issues, street closures and constraints on travel options. Mode choice that realistically depicts available options and user preferences should be modeled accordingly.

d. Evacuation route choice. The process refers to the traffic assignment in the network under evacuation. The user optimal route choice is based on the perception of shortest distance to destination, safety of the route, evacuation information and familiarity with the route.

Strategies to Facilitate the Evacuation

The strategies to facilitate the evacuation fall into two categories, namely highway system strategies and traffic demand strategies. Combinations of such strategies should be also considered along with transit system strategies, where feasible. More specifically, highway system strategies may include:

1) Changes in traffic signals and traffic control.

2) Dissemination of evacuation-related information through closed circuit television, and other communication options**.** This strategy is reflected in the simulation procedure as the reactive time needed for people to decide to evacuate.
3) Roadway clearance. For example, CORSIM has the ability to simulate on-street parking, so a strategy to clear the on-street parking in emergency can be coded in the simulation procedures.
4) Access Restrictions. Restricting access to ensure available capacity for access evacuation from the area at risk is both an access management and a demand strategy. This could entail ramp closures in the perimeter of the incident, for example, by deploying maintenance vehicles or physical barriers to impede access to the roads from outside the danger zone.
5) Reversing Lanes/ Roadway Directions. Modeling contra-flow operations along with the required access restrictions and traffic diversions may also be used, when practical, as a strategy in support of emergency evacuation.

Typical traffic demand strategies in support of emergency evacuations include:

1) Improved communications for demand management.
2) Staggered/ timed release, and
3) HOV management.

Such strategies are expected to control traffic demand during evacuation and improve the spatial and temporal distribution of traffic. The HOV management has the potential to change the vehicle occupancy and result in the change of total evacuation traffic on route. Traffic demand strategies may be used alone or in addition to highway system strategies to assist evacuation and minimize its adverse effect to traffic operations.

3.4.3 Testing of Existing Emergency Preparedness Plans

As mentioned earlier, the cornerstone of effective emergency management during a crisis is the execution of previously developed emergency plans that guide the decision-making process and address demands for travel and special services in the most efficient way. Many local and state agencies with the assistance of FEMA and the Department of Homeland Security developed emergency response plans for hypothetical emergencies.

Equally important to the preparation of emergency plans in anticipation of the crisis is their assessment through mock exercises (when practical) or simulation testing. Testing of the proposed plans' performance is expected to provide valuable information about emergency management and response and preparedness capabilities so that strengths and weaknesses can be identified and feedback can be obtained for improving the emergency plans, and consequently, optimizing the transportation network performance.

Determination of whether a proposed set of plans is the best option in case of an emergency can be reasonably estimated using traffic simulation outputs. Performance measures obtained from the simulation of traffic conditions and proposed actions detailed in one set plans can be compared to those obtained assuming an alternative set of plans. From the results of the comparison, the best possible plan can be selected for future implementation.

Section 4
Development of the Regional Simulation Model

This section discusses the development of a regional CORSIM simulation model for the City of Birmingham and its surrounding communities. The goal was to demonstrate both the benefits and limitations of using CORSIM to simulate regional traffic operations under emergency conditions.

4.1 Study Network Description

First, the study boundaries for the emergency preparedness test bed were defined. As this study performed simulation analysis at a regional level, a decision was made to involve all major interstates in and around the Birmingham area in the study network. The network also included selected highways and arterials in the city of Birmingham that are of great importance in serving traffic demand under non-emergency conditions. The coded network consists of a total of 2304 nodes and 2708 links that represent approximately 50 miles of freeways and 20 miles of arterial streets. A visual depiction of the test bed is shown in Figure 4-1 while a more detailed list of the study network components is provided in Table 4-1.

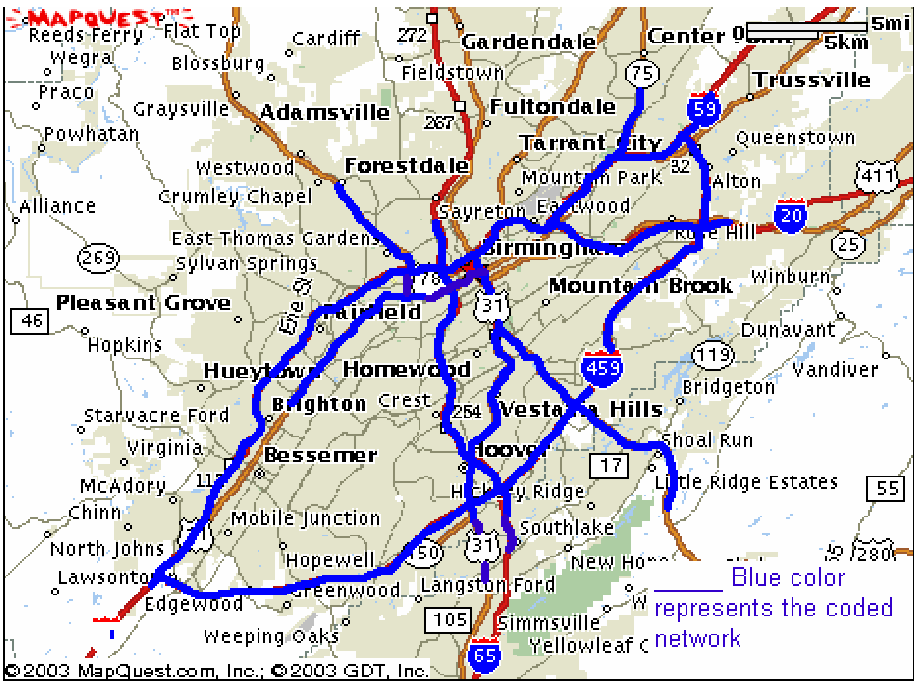

Figure 4-1. Regional study network

Table 4-1. Description of the study test bed modeled in CORSIM

No.	Name of Roadway	From	To	Length (miles)
1	I-459	Interchange with I-20/59 (exit no. 33)	Interchange with I-59 (exit no. 29)	32.71
2	I-20/I-59	Intersection with I-459 (exit no. 106)	The point where it splits into I-20 and I-59 (exit no. 130)	24.00
3	I-65	Intersection with 11th Street N (exit no. 260)	Intersection with Old Rocky Ridge Road (exit no. 250)	10.00
4	I-20	Point it bifurcates from I-20/59 (exit no. 130a)	Intersection with US459 (exit no. 136)	6.00
5	I-59	Point it bifurcates from I-20/59 (exit no. 130)	Point of intersection with I-459 (exit no. 137)	7.00
6	US280	Hugh Daniel Drive	US31/Red Mountain Expressway	10.10
8	US11	Fayette Avenue	Red Mountain Expressway	4.35
9	Red Mountain Expressway	Intersection with I-20/59	Point it converts into US31	3.10
10	University Boulevard	Intersection with I-65 (exit no. 259)	Intersection with the Red Mountain Expressway	1.37
11	US78	Pershing Road	Intersection with US11	8.29
12	US75	26th Avenue North	Intersection with I-59 (exit no. 134)	5.36
13	US31	Elton B. Stephens Expressway	Intersection with I-459	7.96

The facilities included in the test bed were selected on the basis of traffic volumes carried, localities connected, and overall importance in case of an emergency. The I-65 freeway is an Interstate highway of major importance to the mobility of Alabamians, and is also a north-south route of national significance for the movement of people and goods. Extending as far north as Lake Michigan, I-65 connects the City of Birmingham with Nashville, TN and Indianapolis, IN to the north and Montgomery and Mobile, AL to the south. On the other hand, I-459 and I-20/59 facilities connect Birmingham to the Tuscaloosa on the west and the Anniston, on the east. The I-459 and I-20/59 routes form a loop around Birmingham and intersect with other important transportation facilities including I-65, US11, US31, US280, US75, US79, and US78. All these facilities were coded in the regional simulation test bed, along with a section of University Boulevard and First Avenue North in downtown Birmingham. These arterials are expected to carry heavy volumes of vehicles requiring evacuation and serve as feeders to facilities that serve north-south traffic (such as I-65, US280, and US31) should an emergency occur in the Birmingham's central business district or the University of Alabama at Birmingham.

4.2 Data Collection

Data collection refers to the gathering of data required for coding of the study network into the CORSIM simulation model, as well as model calibration and validation. The input data requirements for the CORSIM model were presented in Section 3.3.1 and include detailed geometric characteristics, traffic demand data and traffic control information. Commonly used field measurements for CORSIM model validation include speeds, travel times, volumes, and queue lengths.

A unique aspect of this project is in the size of the proposed test bed. Covering roughly 70 miles of roadways the study network is very extensive and it imposes substantial demands for data collection, processing, and model coding. To minimize duplication of effort and avoid waste of valuable resources it was decided that this study would attempt to take advantage of data collection or CORSIM model coding efforts already undertaken as part of other local projects and traffic studies. This strategy was adopted for the project and endorsed by UTCA and ALDOT as a desirable practice for the accomplishment of the goals of the subject study, given the limited resources.

The first step of the CORSIM simulation model development consisted of identifying and cataloguing existing simulation studies and data collection activities in the Birmingham region that could be relevant to the subject study. Table 4-2 lists study segments where geometric or traffic data were available prior to the study. The information in Table 4-2 helped the research team identify data needs and discrepancies and develop a list of roadway segments that required additional data collection and coding. Such information is summarized in Table 4-3.

Table 4-2.Summary of data availability

Segment	From	To	Geometric and Traffic Data Availability	CORSIM Code Availability
US280	Intersection with US31	Hugh Daniel Drive	Yes	Yes
US11	Fayette Avenue	Red Mountain Expressway	Yes	Yes
US31	Elton B. Stephens Expressway	Point of intersection with I-459	Yes	Yes
US75	26th Avenue North	13th Avenue North	Yes	Yes
US78	Pershing Road	Persimmon Street	Yes	Yes

Table 4-3. Summary of data collection and coding requirements

Segment	From	To	Geometric &Traffic Data Collection Needed	CORSIM Coding Needed
I-65	11th Street North	Old Rocky Ridge Road	Yes	Yes
I-20/59	I-459	Point where it splits into I-20 & I-59	Yes	Yes
I-459	I-20/59	I-59	Yes	Yes
I-20	Point it bifurcates from I-20/59	I-459	Yes	Yes
I-59	Point it bifurcates from I-20/59	I-459	Yes	Yes
US75	13th Avenue North	I-20/59	Yes	Yes
US78	Persimmon Street	US11	Yes	Yes
University Boulevard	I-65	Red Mountain Expressway	Yes	Yes
Red Mountain Expressway	I-20/59	Point it converts into US 31	Yes	Yes

Following the identification of data collection needs, all missing traffic and geometric data were obtained from field studies. The traffic data consisted of evening peak hour volumes and truck counts. Moreover, existing signal timings in effect along study arterial segments were collected, along with required geometric data (such as number of lanes, lane widths and lane designation, grades, etc). Travel time data were also collected with the aid of a probe vehicle, to be used for CORSIM simulation model validation.

4.3 Model Building

The traffic network in CORSIM is based on a node-link structure. A node represents an intersection or a point where attributes of the link connecting the node to other nodes may change. A link represents a section of a roadway, i.e., either a freeway or an arterial. Each link specifies all details associated with the characteristics of the roadway such as the number of lanes, lane width, roadway type, design speeds, grades etc.

The test bed was constructed by placing the study network nodes and links while using an aerial bitmap background for reference. After the entire study network was modeled in links and nodes, the geometric and traffic data were entered. Such data included traffic volumes, sign posting, signal timings, forced lane changes, etc.

4.3.1 Integration of CORSIM Files

As mentioned earlier, many segments of the study network had been already coded into CORSIM as part of previous studies. While the research team was desired to use these files, recoding of the available segments into CORSIM was perceived as a tedious and undesirable approach. Thus an effort was undertaken to develop a custom-made computer program capable of automating the process of merging the CORSIM files into a single CORSIM file representing one integrated study network. The research team was successful in developing the required computer code and was able to overcome most of the challenges imposed by the structure of the CORSIM input file, and the need to properly rename links and adjust coordinates.

Both the Pearl Software and Active Server Pages (ASP) were considered for the compute code development process. Experimentation with both options showed that ASP offers greater flexibility, so it was selected for code development. Subsequently, a computer program was written in ASP that took CORSIM file entries from a user specific input file, manipulated the data in the file as required by the user (renamed links, updated coordinates, etc.) and saved the updated entries into an output file. The new output file was then ready to merge with additional CORSIM files, if desired.

The developed tool was named CORSIM Merging Software (COMES) and was used to integrate all available CORSIM files in this study. Some final adjustments to the input file were made to ensure that the network functioned properly. The main advantage of COMES was that it allowed the CORSIM user to add or delete any segment of the network quickly and effortlessly whenever desired without the need to recode the network. Details on how to use the COMES software for CORSIM file integration are offered in Appendix A. It should be noted that COMES served the needs of this study reasonably well, however, additional refinement is desirable to increase its user friendliness and transferability.

4.4 Model Calibration and Validation

The effectiveness of traffic simulation lies in its ability to accurately replicate actual traffic conditions, so it is crucial to calibrate and validate a traffic simulation model before applying it to evaluate transportation policy, planning, and operational decision-making.

Microscopic simulation models contain many parameters that describe traffic control operation, traffic flow characteristics, and driver behavior. Although these models provide default values for each variable, great attention should be paid to calibration so that the model accurately represents local conditions. Calibration is an iterative process in which the engineer adjusts the simulation model parameters until the results produced by the simulator match field measurements.

It should be noted that a large-scale simulation model (such as the CORSIM regional model used as the test bed in this study) introduces significant challenges with respect to calibration and validation due to its size and field data availability. In this case, however, the calibration needs were relatively limited since most of the arterial segments and some of the freeway segments had already been calibrated and validated in previous projects. Thus the efforts in this study concentrated on calibration and validation for freeway sections that had not been calibrated previously, as discussed in the paragraphs that follow.

4.4.1 Checking Input and Coding Accuracy

The integrated CORSIM model was run and the animation and model outputs were reviewed for traffic input and geometry coding accuracy. This process made sure that the traffic volumes from outputs files and the field counts were within the acceptable level of accuracy (Table 4-4), and the network geometry and sign positions reflected actual field conditions as closely as possible. This process is also referred to as uncontrollable input parameters validation, e.g., existing geometry, traffic counts, current signal timing plan, etc.

From Table 4-4 it can be seen that the difference in the field counted volumes and the model counted volumes lay in the range of 3 to 7 percent. According to Brockfeld, et al. (Brockfeld, 2003), an error of 12 to 30 percent cannot be suppressed in case of microscopic models. Thus the above percent differences lay well within the acceptable limits.

Table 4-4. Comparison of traffic volumes from simulation model and field counts

Location	Simulation Model Volume (veh/hr)	Field Counted Volume (veh/hr)	Percent Difference (%)
I-20/59 EB at I-65	3,951	3,692	7%
I-20/59 WB at I-65	3,942	4,080	-3%
I-65 SB at I-20/59	3,708	3,564	4%
I-65 NB at I-20/59	2,795	2,675	4%
I-65 NB at US31	1,897	2,015	-6%
I-459 SB at I-65	2,455	2,650	-7%
I-459 NB at I-65	2,613	2,540	3%

4.4.2 Determine the Measures of Effectiveness for Calibration

In this step the performance measures for calibrating controllable input parameters were determined. Such input refers to lane change distance, minimum headways, gap acceptance, waiting time before diffusion, etc. The CORSIM model has default values for all performance measures, but these default values had to be refined after comparing the simulated network performance to observed performance in the field. The choice of performance measures generally depends on the availability of field data and model output data. In our study, peak hour travel time data were collected along several freeway sections with the aid of a probe vehicle and were used as the performance measure for controllable parameters calibration. This measure is relatively easy to collect from field and model outputs.

4.4.3 Identification of Calibration Parameters

A number of simulation runs were performed using default values for all parameters. The results of those simulation runs were carefully reviewed to identify parameters to be used for calibration. Three such parameters were selected, namely car following sensitivity, time to complete a lane change maneuver, and gap acceptance.

After comparing certain MOEs of the test runs to those observed in the field, it was observed that the CORSIM model default values tended to overestimate the capacity of the roadway network. It was also observed that CORSIM systematically underestimated delays, particularly under congested conditions. So changing of default values of the above mentioned parameters was necessary. Thus the default values of parameters related to gap acceptance and the time taken to complete a lane change maneuver had to be reduced, while the default values of the car following sensitivity was increased to bring the network closer to reality, as far as local conditions are concerned.

4.4.4 Simulation Runs and Evaluation of Parameter Sets

It should be noted that CORSIM events are stochastic in nature, meaning they involve a random variable. Thus different results are expected as the random/seed numbers are varied. In order to reduce the stochastic variability of the outputs, multiple runs must be conducted for each parameter set from the experimental design. In our study ten runs were conducted for each scenario. The iterative process of parameter sets evaluation consisted of the following steps:

1. Run the scenario ten times and gather the model outputs,
2. Process model outputs and evaluate the parameter sets by statistically comparing selected performance measures with the field data, and
3. Calibrate the parameter sets based on the results of the analysis, then go back to step 1.

After completing several iterations, it was found that the differences of performance measures between model outputs and field data were within the acceptable level. The detailed analysis results are shown in Table 4-5.

Table 4-5. Travel time validation results

Freeway Segment	From	To	Model Travel Times (sec)	Observed Travel Times (sec)	Percent Difference
I-65 SB	I-20/59	I-459	1,479	1,381	7%
I-65 NB	I-20/59	I-459	804	958	-16%
I-20/59 EB	US78	Interchange of I-65 and I-20/59	162	186	-13%
I-20/59 WB	Interchange of I-65 and I-20/59	I-20/59 to US78	133	114	17%
I-459 WB	US280	Interchange of I-459 and I-65	834	768	9%
I-59 WB	US75	Split of I-20 and I-59	576	663	-13%

It should be noted that detailed validation was limited to key network segments. Those were determined on the basis of their potential influence on the proposed scenarios and mostly included roadway segments close to the downtown Birmingham area. Following the completion of the validation process, the regional simulation network was ready for testing of the developed scenarios.

4.5 Output Data Handling

The TSIS Output Processor supports three file formats: Microsoft Excel, Comma-Separated-Value (CSV), and Tabbed Text. The Excel option offers added processing convenience. The data is organized in the Excel file in a tabular format, where the columns represent the run number and the rows represent the intervals. In this study, all the simulations were performed for ten runs while the intervals were limited to two. To introduce randomness, different seed numbers were selected for each of the ten runs. When different cases were analyzed for the same scenario, the 10 seed numbers were kept the same for all cases to ensure that variations in the outputs were a result of differences in the assumptions in each case, rather than traffic randomness.

Using the Excel file, the means and standard deviations of selected MOEs were obtained. Summary results of are reported in Section 5. It should be noted that the output files generated by the developed CORSIM model were extremely large, due to the size of the network. This made the data processing somewhat tedious. Moreover, due to large size of the output file, the data were not always automatically transferred into the Excel file without errors. To overcome the above encountered problem, the results for the runs of each scenario were often obtained manually from the output files generated by CORSIM, and then organized in an Excel spreadsheet for further processing.

Section 5
Simulation Scenarios for Case Study

The coded regional simulation model in this study was used to simulate three types of emergency scenarios, namely:

1. Traffic incident simulation
2. Evacuation simulation, and
3. Testing of existing emergency response plans

These scenarios were developed to demonstrate the capabilities and limitations of microscopic simulation modeling when applied for testing and assessment of emergency preparedness plans. It is recognized that the type, degree, and impact of emergencies varies considerably and so do the actions that may be taken to address them. The reader should be cautioned that the analysis presented in the following sections and the results obtained should be considered only as examples of "what-if" scenarios and are bounded by the assumptions and the limitations of the simulation model and the scope of the study.

5.1 Description of a Traffic Incident Simulation Scenario – Scenario 1

An incident is any non-recurrent event than causes a temporary reduction in roadway capacity or an abnormal increase in traffic demand. Incidents may or may not be predictable events in terms of occurrence time, extent, and location. The most common type of unpredictable incident is a traffic accident. Incident management in response to a traffic accident may include on-site traffic control, motorist information dissemination and activation of emergency personnel to the incident location. The unique geographic, environmental, and institutional characteristics of the region, as well as available resources and local incident management goals and priorities often play a role in the selection of a plan of action in response to a traffic incident related emergency.

The scenario assumed the occurrence of a traffic accident at the interchange of I-20/59 and I-65, and studied its impact on the study network operations for various degrees of severity (expressed as number of lanes blocked and time duration). More specifically, the location of the accident simutated as part of this study was eastbound on I-59 (link 149 - 54 in the study CORSIM model) as in Figure 5-1. The accident was assumed to happen is a freeway link with three lanes.

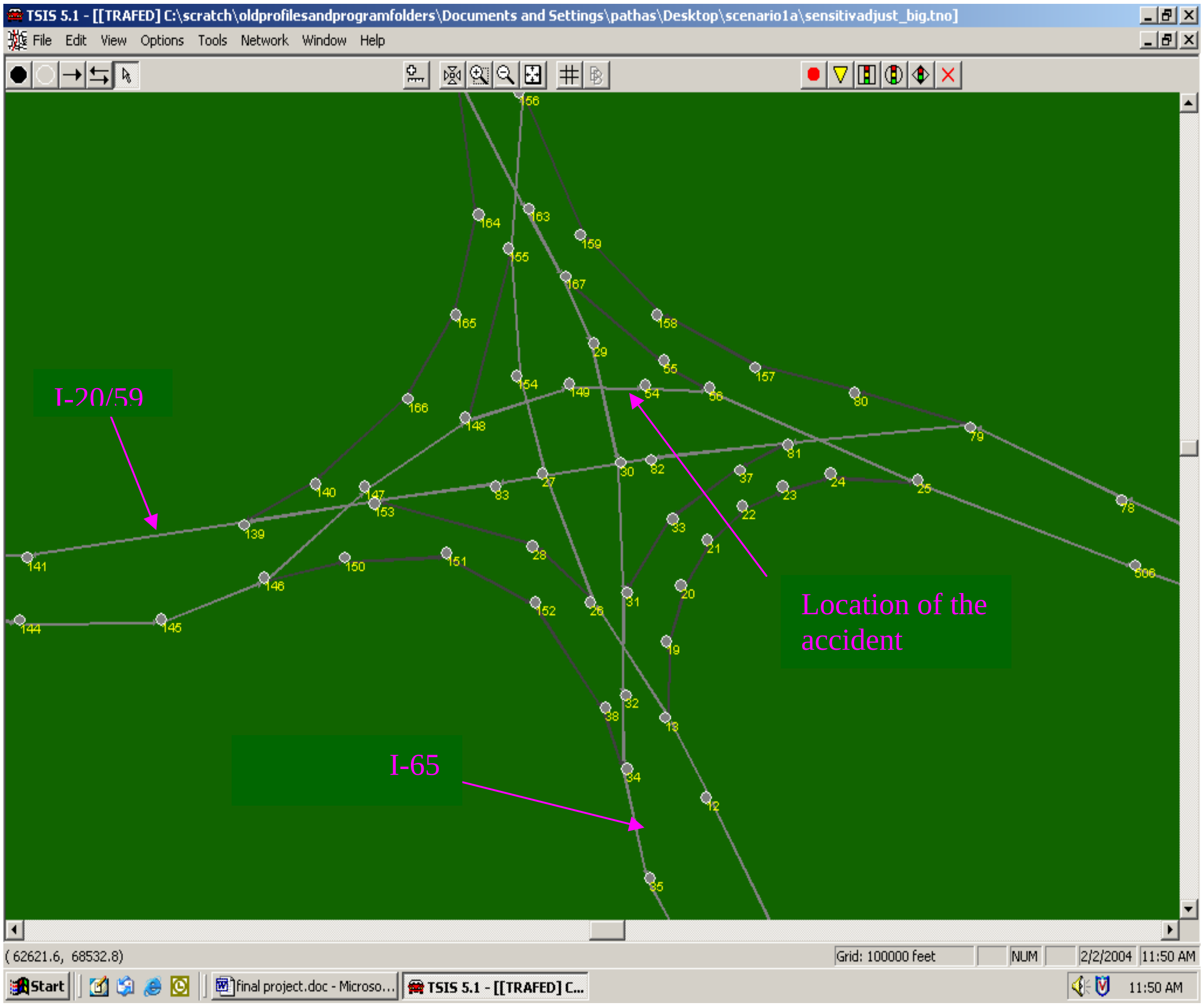

Figure 5-1. Location of accident in Scenario 1

Three different situations were simulated to represent various degrees of traffic accident severity. In the first case (Case 1a), the accident was assumed to block one lane of traffic in the eastbound direction for half an hour. In the second case (Case 1b) the accident resulted in a two lane closure for half an hour and one lane closure for an additional half hour. Finally, in Case 1c it was assumed that all three lanes remained closed for 15 minutes after the accident, followed by a gradual recovery of the lanes. The impact of the accident on traffic operations under each hypothetical scenario was evaluated, based on selected performance measures for various response actions.

5.1.1 Selection of Performance Measures

A freeway accident typically results in speed reduction, queue formation, and increase in travel time upstream of the accident. The extent of the impact of the crash on network performance can be assessed through the observation of micro-simulation model outputs. Relevant measures of performance include average speed, traffic volume, travel time, travel delay, and density for each link in any time interval. The queuing time (i.e., time from the start of platoon formation to the complete platoon dissipation) and the total length of queued links can also be observed through the on-screen animation. The performance measures that were selected for comparison purposes in this simulation include average vehicle speed, queuing time, and total length of queued links. All three MOEs where gathered from impacted links only.

5.1.2 Simulation Results from Scenario 1

Case 1: One Lane Blockage

In this case, it was assumed that the traffic accident caused one lane blockage that lasted for 30 minutes. After running the model ten times and reviewing the model outputs, it was concluded that the impact of the simulated accident on the network performance was minimal. Only three upstream links (total length 1,124 ft) demonstrated any statistical change of performance measures before and after the accident. This is reasonable because the traffic volume on these links is approximately 2,700 vehicles per hour and still much lower than the theoretical capacity of 5,700 vph.

Table 5-1 offers a comparison of selected performance measures with and without the accident presence. As expected, a drop in average speed was observed (from 55.8 mph without to 37.8 mph with accident presence). However, no queues were developed as a result of the accident and thus the queuing time and length of queued links remained zero. This implies that the location, timing, and extent of the incident were such that its impact was absorbed easily without any major disruptions in traffic conditions.

Table 5-1. Performance measures with and without accident in Case 1- Scenario 1

Performance Measure (for impacted links)	Without Accident	With Accident	Percent change (%)
Average speed (mph)	55.75	37.79	-32%
Queuing time (seconds)	0	0	0
Total length of queued links (ft)	0	0	NA

Case 2: Two Lane Blockage

Case 2 assumed that the incident occurred in the same location as in Case 1. However, this time it blocked two of the three lanes for half an hour; at which time one lane was recovered, and a half hour after that the second lane was recovered. In this case we considered two options.

Under the first option (Case 2a) it is assumed that no traffic was diverted to alternate routes, due to the lack of advanced information dissemination technologies. Under the second option (Case 2b), it was assumed that information about the accident was disseminated upstream of the incident 10 minutes after the accident occurred. As a result, 5 to 20 percent of traffic was diverted (based on alternative route travel times and distances) at the upstream ramps in response to the dissemination of accident information. After the accident was removed, traffic operations returned to their original pattern.

The scenario explored in Case 2a looked at the effect of diversion on traffic performance under incident conditions. Diversion, in turn, relates to the availability of technologies that:

a. Collect traffic information and use them for incident detection and verification, and
b. Deliver incident-related information to the travelers.

Examples of such technologies include Closed Circuit TV Cameras (CCTV), HAR, VMS, and web communications, etc. Thus, while testing the impact of diversion in Case 2a, and other scenarios described later, one can also indirectly assess the criticality of the presence of ITS in support of incident management.

The analysis results for Case 2 are summarized in Table 5-2. In the table, the average speed value is for all impacted links during the entire simulation time (5,400 seconds), and the queuing time refers to the time period from platoon formation to platoon dispersion.

Table 5-2. Performance measures for accident with and without diversion for Case 2- Scenario 1

Performance Measure (for Impacted Links)	Accident Without Traffic Diversion (Case 2a)	Accident With Diversion (Case 2b)	Change (%)
Average speed (mph)	24.81	26.93	9%
Queuing time (seconds)	5,174	3,825	-26%
Total length of queued links (ft)	10,553	6,278	-41%

First, compared to the results from Case 1 (Table 5-1) it can be seen that due to the additional lane closure in Case 2, the average speed on the impacted links dropped further (from 37.8 mph for one lane closure to 24.8 mph for the two lane closure). Moreover, closing two lanes resulted in traffic delays due to the formation of queues.

Comparison of the performance measures obtained in Cases 2a, and 2b (i.e., with and without diversion) demonstrates the potential gains from diverting traffic around an incident. The results reported in Table 5-2 show that diversion of vehicles upstream of the incident resulted in a significant reduction of the lengths of queues as well as the total time spent in queue. It also helped to increase the average speeds on the facility by 9% and contributed to the improvement of the overall performance of the facility.

Case 3: Three Lane Blockage

In this case, it was assumed that the hypothetical accident occurred in the same location as in Cases 1 and 2 but was more severe, resulting in a blockage of all three lanes for 15 minutes. At that time one lane was recovered, while 30 minutes later the second lane was recovered and finally all lanes were reopened one hour after the incident. The total simulation time was 6,600 seconds.

In this case two options were considered, similar to Case 2, to evaluate the impact of traffic diversion on traffic operations and thus the impact of ITS technology for information collection and dissemination in the event of an incident. More specifically, under the first option (Case 3a), it was assumed that there was no traffic diversion due to the lack of an information dissemination medium. Case 3b on the other hand assumed that traffic diversion took place in response to accident information disseminated 10 minutes after the incident. After the accident was removed, the traffic resumed its original pattern.

The analysis results for Cases 3a and 3b are shown in Table 5-3 below. Similar to the results reported in Case 2, it was observed that the diversion helped considerably in reducing the queue lengths and the queuing time, and in increasing the average speeds on the facility. Under the assumptions in this case, and for similar accident location and duration and traffic patterns, traffic diversion resulted in 16 percent increase in average speed on the links impacted by the accident presence, and in major decreases in queuing time and length of queued links (33 and 51 percent respectively). When compared with the results obtained from Case 2, it was apparent that the impact of diversion was greater as the severity of the incident increases, or the traffic conditions worsen, or both.

Table 5-3. Performance measures for various options in Case 3- Scenario 1

Performance Measure (for Impacted Links)	Accident Without Traffic Diversion (Case 3a)	Accident With Diversion (Case 3b)	Change (%)
Average speed (mph)	21.87	25.41	16%
Queuing time (seconds)	5,923	4,658	-33%
Total length of queued links (ft)	14,758	7,237	-51%

5.2 Description of an Evacuation Scenario – Scenario 2

Evacuation is one of the most common protective measures in regional emergencies in response to natural or man-made disasters. The goal of emergency evacuation is to assist the public in departing from the areas threatened by disasters in a timely and efficient manner. The subject of emergency evacuation is very broad and many agencies and researcher became involved in studies that developed and tested evacuation scenarios at the local level. While the type and magnitude of the threat and the local geometric and environmental conditions vary considerably from study to study, a common interest exists in understanding the potential impact of an evacuation on the traffic network operations, and in developing and assessing strategies for easing traffic congestion resulting from the evacuation.

In this scenario, a bomb scare was assumed to force officials to request evacuation of one building at the University of Alabama at Birmingham (UAB) campus. UAB is an urban university and medical center that encompasses 82 city blocks in the downtown Birmingham area, and is the largest employer in the state of Alabama. The significance of the University at the local level, the high concentration of population at one geographic location, and the uniqueness of the land development and access management in the university campus setting made the emergency evacuation at UAB an interesting as well as challenging scenario to consider.

The facility that was considered for evacuation was the Education Building located on 13th Street South, with access on 13th and 14th Streets South. University Boulevard was considered as the evacuation route used to reach I-65 or the Red Mountain Expressway. The evacuees would use I-65 and Red Mountain Expressway to reach their final destinations. A schematic of the location of the bomb threat and evacuation routes is shown in Figure 5-2.

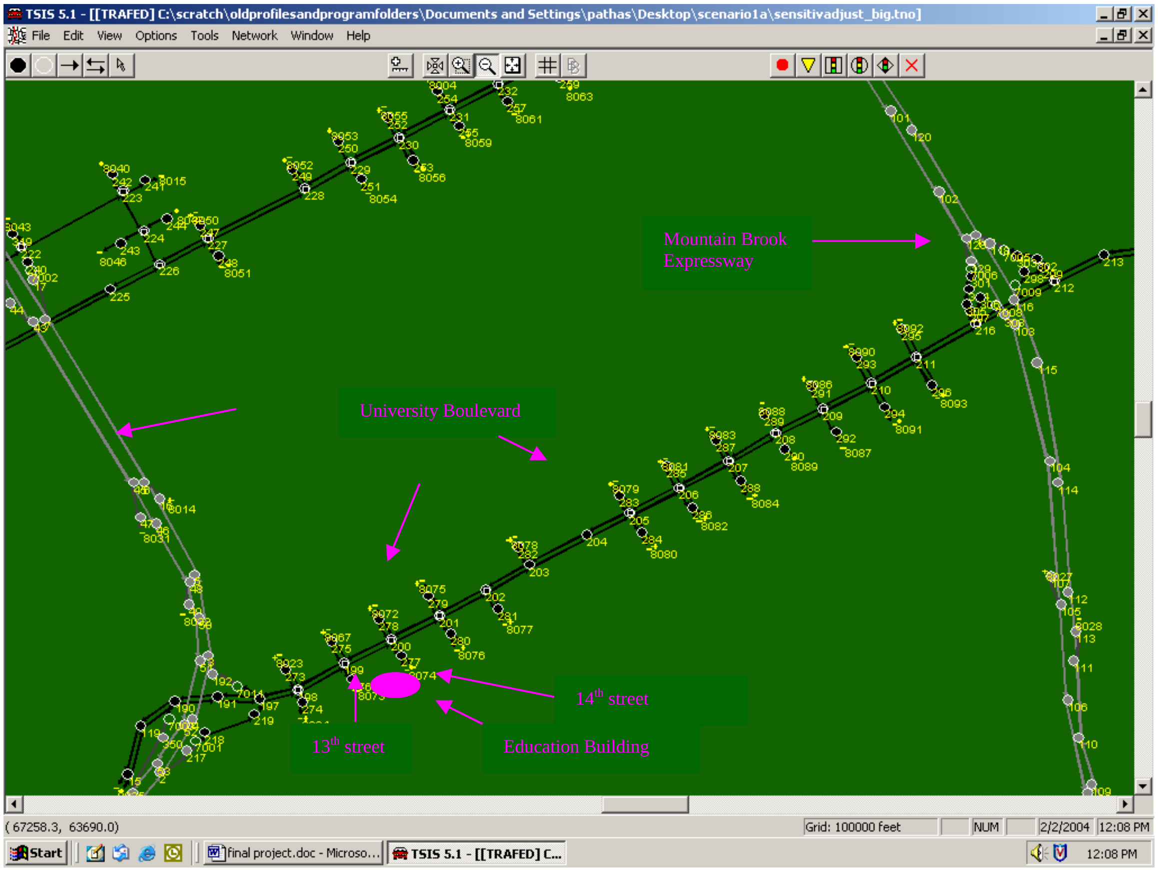

Figure 5-2. Location of the building under bomb threat and major evacuation routes- Scenario 3

Four different cases were considered to describe different options for the evacuation process. Case 1a deals with the influx of evacuation traffic onto the University Boulevard from feeder arterials. In this case the volume from 13th and 14th Streets South toward University Boulevard increased by 40 percent of the peak daily volume due to the evacuation, along with a 25 percent increase of volume from 12th and 15th Streets South. Case 1b assumed that traffic signals along the major evacuation route are optimized to improve flow away from the crisis area. Traffic signal optimization was performed with SYNCHRO to favor signal coordination along the University Boulevard. All other assumptions were similar to those in Case 1a. Case 2 assumes increased traffic volumes entering the University Boulevard (80 percent of peak daily volume from 13th and 14th Streets South, and 40 percent from 12th and 15th Streets South) after the complete dissemination of the information of bomb scare took place. In Case 3, different techniques were deployed to reduce delays, and queues developed on University Boulevard due to the evacuation conditions as described in Case 2. These included traffic diversion, access restrictions, and signal timing optimizations. There are presented in more detail in Section 5.2.2.

5.2.1 Selection of Performance Measures

An evacuation scenario involves increased traffic flows along the evacuation route and feeder facilities. The additional traffic demand is expected to affect the average speed, queue formation, and travel times in the vicinity of the affected area. The single most important MOE in evacuation models is the estimated time to evacuate the population at risk to a safe area. Other outputs such as travel time, link trips, and average speed may be also of interest.

More specifically, CORSIM outputs that may be used to evaluate the impact of evacuation strategies include average speed, traffic volumes, travel time, travel delay, and vehicle density for each link over a time interval. The queuing time and queue lengths can also be observed from the animation file. The MOEs considered for this scenario include travel times, total delay (veh-min), and delay time (sec/veh) along University Boulevard, which is the main evacuation route from the affected location to I-65 and the Red Mountain Expressway. These MOEs give a fair idea of the performance of the facility under the different assumptions.

5.2.2 Simulation Results from Scenario 2

<u>Case 1a: Increase in Traffic Influx on University Boulevard</u>

It was assumed that as the news of the bomb scare was disseminated the evacuation was initiated, leading to a 40 percent increase in the daily peak traffic on 13th and 14th Streets South entering University Boulevard within the first 15 minute of the information dissemination. Also a 25 percent increase in the daily peak traffic was assumed on 12th and 15th Streets South. In this case the simulation was run ten times keeping the existing signal timings and phases. No changes were made in the current distribution patterns. The MOEs considered were travel times, total delay, and delay time. The results of the Case 1a analysis are presented in Tables 5-4 and 5-5. The numbers in parenthesis show the values of the parameters under baseline conditions (i.e., without traffic influx due to evacuation).

From the results in Tables 5-4 and 5-5 it was observed that the average travel times, total delays, and delay times under evacuation conditions were excessive. Compared to the baseline conditions, the evacuation as described in Case 1a resulted in a considerable increase in travel times along University Boulevard. For example, as Table 5-4 indicates, the travel time on University Boulevard west bound from 14th Street South to I-65 increased from 4.86 min to 17 min as a result of the influx of traffic due to the evacuation. Significant increases in the vehicle and total delays were also observed (see Table 5-5). The results obtained from the simulation runs implied that improvements must be made in order to improve the operation of the facility under evacuation conditions.

Table 5-4. Travel times observed in Case 1a- Scenario 2

University Boulevard From	To	Travel Time (min)
12th Street South	I-65 (WB)	9.00 (3.83)[1]
13th Street South	I-65 (WB)	13.79 (4.42)[1]
14th Street South	I-65 (WB)	17.00 (4.86)[1]
15th Street South	I-65 (WB)	19.78 (7.64)[1]
12th Street South	Red Mountain Expressway	6.87 (5.56)[1]
13th Street South	Red Mountain Expressway	6.44 (5.19)[1]
14th Street South	Red Mountain Expressway	5.88 (4.67)[1]
15th Street South	Red Mountain Expressway	5.41 (4.21)[1]

[1]Numbers in parenthesis refer to results from the baseline conditions (without evacuation)

Table 5-5. Total delays and delay times observed in Case1a- Scenario 2

University Boulevard From	To	Total Delay (veh-min)	Delay time (sec/veh)
12th Street South	I-65 (WB)	11,835.5 (2,934.77)[1]	519.1 (201.2)[1]
13th Street South	I-65 (WB)	17,564.0 (3,309.57)[1]	793.1 (226.3)[1]
14th Street South	I-65 (WB)	21,069.5 (3,522.17)[1]	988.2 (241.6)[1]
15th Street South	I-65 (WB)	24,099.7 (6,552.37)[1]	1,145 (398.4)[1]
12th Street South	Red Mountain Expressway	81,72.2 (1,926.52)[1]	436.5 (169.9)[1]
13th Street South	Red Mountain Expressway	7,824.2 (1,802.12)[1]	420.9 (157.9)[1]
14th Street South	Red Mountain Expressway	7,377.6 (1,564.52)[1]	398.5 (137.4)[1]
15th Street South	Red Mountain Expressway	7,043.7 (1,230.62)[1]	381.5 (120.4)[1]

[1]Numbers in parenthesis refer to results from the baseline conditions (without evacuation)

Case 1b: Optimization of Signal Timings for Case 1a

This case evaluated the potential of signal optimization as a traffic management strategy under evacuation. More specifically, in Case 1b the assumptions regarding traffic demand were kept the same as in Case 1a, while the signal timings were altered to improve evacuation flow.

To improve the signal timings under evacuation, all the traffic data and the current signal timings were entered into SYNCHRO, a traffic signal timing optimization package. Signal timings were optimized giving priority to the east-west direction and the dominant evacuation flows. After the optimized signal timings and phases were derived from SYNCHRO, they were re-entered into CORSIM and the simulation was run ten times to obtain the desired MOEs. The results are summarized in Tables 5-6 and 5-7.

To facilitate the assessment of the improvements due to signal optimization, the results were compared to the Case 1a results (see Tables 5-4 and 5-5). The comparison confirmed that the optimization of the traffic signals improved the performance of the facility as it is evident from the reduction in travel time and delay. It was observed that the eastbound direction (toward Red Mountain Expressway) benefited the most where reductions in travel time in the range of 20 to 23 percent were achieved with signal optimization (compared to Case 1a).

Table 5-6. Travel times observed in Case 1b- Scenario 2

University Boulevard From	To	Travel Time (min)
12th Street South	I-65 (WB)	8.5
13th Street South	I-65 (WB)	13
14th Street South	I-65 (WB)	16
15th Street South	I-65 (WB)	18.8
12th Street South	Red Mountain Expressway	5.49
13th Street South	Red Mountain Expressway	5
14th Street South	Red Mountain Expressway	4.45
15th Street South	Red Mountain Expressway	4.13

Significant decrease in average vehicle delays was also observed (compared to Case 1a). For example, due to the adjustments in signal settings, the average vehicle delay was reduced from 436 sec/veh to 235 sec/veh along University Boulevard in the segment extending from 12th Street South to the Red Mountain Expressway (a 46 percent saving in traffic delay).

Table 5-7. Total delays and delay times observed in Case1b- Scenario 2

University Boulevard From	To	Total Delay (veh-min)	Delay time (sec/veh)
12th Street South	I-65 (WB)	1,666.4	504.4
13th Street South	I-65 (WB)	17,223	743.8
14th Street South	I-65 (WB)	21,150.3	955.5
15th Street South	I-65 (WB)	24,515.9	1,112.2
12th Street South	Red Mountain Expressway	4,175	235.1
13th Street South	Red Mountain Expressway	3,833.9	215.9
14th Street South	Red Mountain Expressway	3,360.4	194
15th Street South	Red Mountain Expressway	3,191	185.2

Case 2: 80 Percent Increase in Traffic Influx

In this case it was assumed that as news of the bomb was disseminated a massive influx of traffic took place on arterials feeding University Boulevard. This was modeled as an 80 percent increase in the daily peak hour traffic from 13th and 14th Streets South and 40 percent increase in the daily peak hour traffic from 12th and 15th Streets South. No changes were made to the currently employed traffic signal timings. The simulation was run ten times and the results obtained are summarized in Tables 5-8 and 5-9.

Table 5-8. Travel times observed in Case 2- Scenario 2

University Boulevard From	To	Travel Time (min)
12th Street South	I-65 (WB)	9.63
13th Street South	I-65 (WB)	14.88
14th Street South	I-65 (WB)	19.34
15th Street South	I-65 (WB)	23.0
12th Street South	Red Mountain Expressway	7.5
13th Street South	Red Mountain Expressway	7.0
14th Street South	Red Mountain Expressway	6.43
15th Street South	Red Mountain Expressway	6.02

Table 5-9. Total delays and delay times observed in Case 2- Scenario 2

University Boulevard From	To	Total Delay (veh-min)	Delay Time (sec/veh)
12th Street South	I-65 (WB)	12,531.2	548.7
13th Street South	I-65 (WB)	19,200.3	854
14th Street South	I-65 (WB)	63,121.3	1,110.3
15th Street South	I-65 (WB)	66,990	1,321.4
12th Street South	Red Mountain Expressway	4,873.2	258.2
13th Street South	Red Mountain Expressway	4,610.2	243.8
14th Street South	Red Mountain Expressway	3,995.4	215.3
15th Street South	Red Mountain Expressway	3,739.3	201.7

As expected the increase in the traffic volumes entering University Boulevard resulted in an increase in travel times, total delays, and delay times relative to both baseline conditions and Case 1a (see Tables 5-4 and 5-5). This reduced the capacity of the facility and increased the evacuation time. Under this evacuation plan motorists along University Boulevard will face a 23 minute travel time between 15th Street South and I-65, and 7.5 minutes between 12th Street South and the Red Mountain Expressway. These figures are significantly higher than those observed under Case 1a conditions (19.8 minutes and 5.4 minutes respectively). Moreover, oversaturated conditions were observed from the animation on the I-65 on ramp resulting in a spillback on University Boulevard which further contributed to the deterioration of traffic conditions along University Boulevard. The MOEs and the animation show that the evacuation will result in a gridlock along University Boulevard and improvements are required to improve traffic operations in the event of an evacuation in the vicinity of the University Boulevard.

Case 3: Testing Recommended Changes

The analysis performed above indicated that large queues were being formed on westbound University Boulevard heading toward the I-65 on-ramps. So Case 3 was considered where access restrictions, traffic diversion and signal optimization options were implemented in an effort to reduce the travel times and delays. The proposed changes are listed below.

1. All the traffic entering University Boulevard from Green Springs Highway was blocked. This traffic was diverted to I-65 south bound from the Green Springs Highway on-ramp.
2. All traffic entering University Boulevard was forced to move away from the incident. In doing so:
    a. No traffic was allowed to travel eastbound on University Boulevard between 11th, 12th, 13th, 14th, and 15th Streets South. This could be accomplished by placing barricades and a police officer at each intersection (see Figure 5-3), and
    b. No traffic was allowed to travel westbound on University Boulevard from the downstream of 15th Street South.
3. Signal timings were optimized in the east-west direction considering two zones. Streets west of 15th Street South comprise zone 1 and streets east of 15th Street South comprise zone 2.
4. In zone 1 the band widths of the signal timings were adjusted to give priority to the westbound traffic and in zone 2 the priority was given to the east bound vehicles.
5. The traffic volumes were the same as in Case 2.

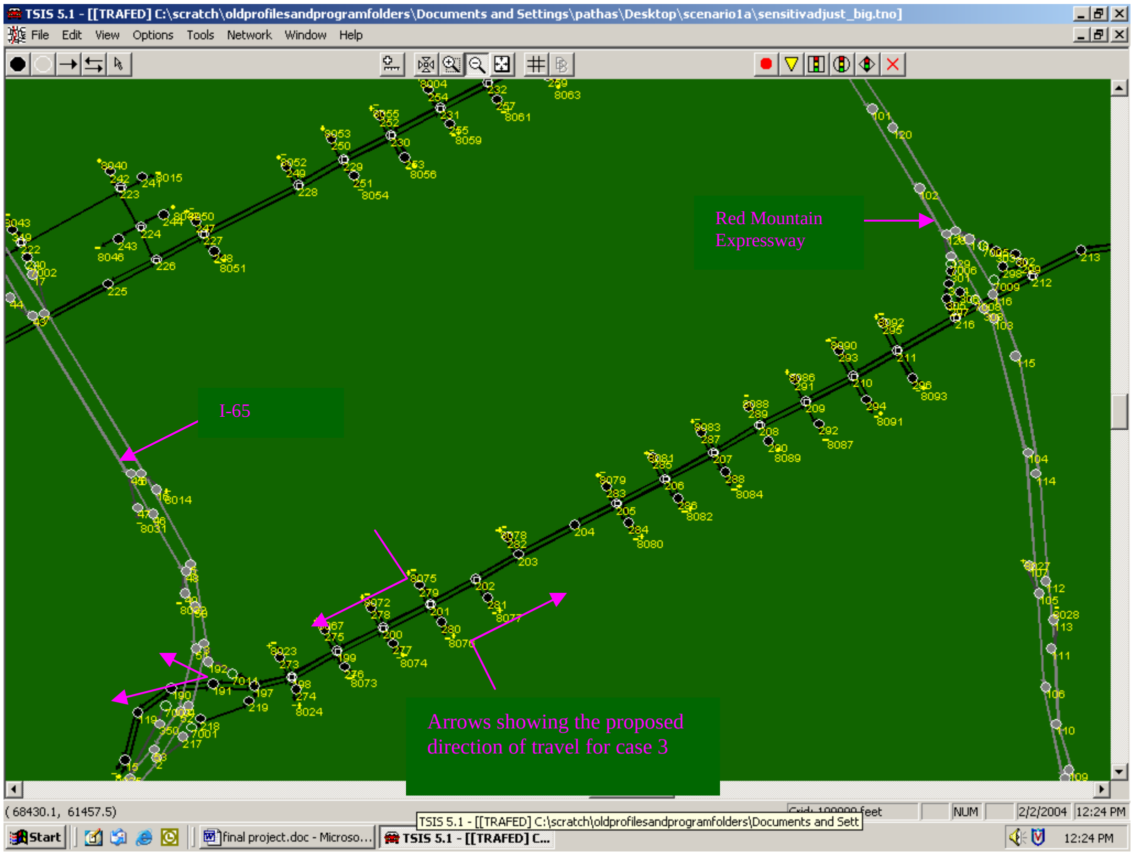

Figure 5-3. Vehicle movement restrictions in Case 3- Scenario 2

The results from Case 3 are presented in Tables 5-10 and 5-11. Travel times and delays from the 13th, 14th, 15th, and 16th Streets South to the Red Mountain Expressway are not applicable since all traffic from these streets is routed westbound on University Boulevard toward I-65.

Table 5-10. Travel times observed in Case 2- Scenario 2

University Boulevard		Travel Time (min)
From	**To**	
12th Street South	I-65 (WB)	0.83
13th Street South	I-65 (WB)	1.44
14th Street South	I-65 (WB)	1.87
15th Street South	I-65 (WB)	2.0

Table 5-11. Total delays and delay times observed in Case 3- Scenario 2

University Boulevard		Total Delay (veh-min)	Delay Time (sec/veh)
From	**To**		
12th Street South	I-65 (WB)	749.7	17.3
13th Street South	I-65 (WB)	1,247.5	37.6
14th Street South	I-65 (WB)	1580	58.8
15th Street South	I-65 (WB)	1,826.8	95.5

The results indicate that significant savings in travel times and delays were observed along University Boulevard under Case 3. Also from the animation file, there was no longer any queue formation at the I-65 on-ramp. These improvements were achieved through access restrictions and a better distribution of traffic along the study network in response to evacuation management needs. It should be also noted that travel times and delays achieved under the assumptions in Case 3 were below those obtain for baseline conditions (see Tables 5-4 and 5-5). This was an indication that the changes proposed and analyzed in Case 3 were somewhat extreme for the evacuation needs assumed as part of this scenario.

Overall, the results from this scenario show that traffic simulation can be used to:

a. identify problems in proposed plans
b. guide the development of alternative plans, and
c. allow for testing of alternative plans in an effort to optimize response procedures.

<u>Network Performance Results</u>

It should be pointed out that the results presented above focus on the impact of the proposed evacuation plans on the operations of the University Boulevard as part of the analysis performed in Scenario 2 (Cases 1a, 1b, 2, and 3). The overall network performance was also evaluated by comparing network wide MOEs under base conditions and under Cases 1a, 1b, 2, and 3. The results are summarized in Table 5-12 below and are organized by type of segment (i.e., freeway or arterial).

Table 5-12. Network wide average statistics- Scenario 2

Network Measure of Performance	Base Conditions	Case 1a	Case 1b	Case 2	Case 3
Freeway Segments					
Travel Time (min/veh-mile)	1.43	1.84	1.84	1.89	1.70
Delay (min/veh-mile)	0.44	0.85	0.85	0.90	0.70
Speed (mph)	41.97	32.55	32.68	31.76	35.40
Arterial Segments					
Travel Time (min/veh-mile)	6.35	8.38	8.34	8.60	7.96
Delay (min/veh-mile)	3.71	5.68	5.63	5.90	5.28
Speed (mph)	17.1	13.2	13.3	12.9	13.7

The results in Table 5-12 indicated that the evacuation considered in Scenario 2 had an impact on the overall network performance, resulting in an increase of the area wide average travel time and delay and reduction of the average speed on the study network.

Comparison of the network wide statistics for the strategies tested as part of Scenario 2 showed little variation as a result of the assumptions and actions taken in the various case studies (Cases 1a, 1b, 2, and 3). One of the reasons for this observation is that the size of the transportation network modeled is large while the changes made are relatively limited in scale and location. Overall, Case 3 appeared to be the best option when considering both local and regional network performance measures.

5.3 Description of a Scenario that Tests Existing Emergency Response Plans – Scenario 3

The purpose of development of emergency response plans is to ensure that operational policies, protocols, procedures, and practices are in place to facilitate quick response, rescue, and recovery operations in case of an emergency. Comprehensive emergency response plans should include a transportation component describing the procedures to be followed to enable people and goods to move safely and effectively during threatening situations while simultaneously enabling emergency access to the scene(s), and facilitating re-establishment of transportation services following an emergency.

Along these lines, in 2000 the Jefferson County Emergency Management Agency developed a plan for a Jefferson County Evacuee Reception Center that will provide services to residents of CSEPP Counties who may be required to evacuate westward toward Jefferson County via I-59 and I-20 due to an emergency at Anniston Army Depot.

The Anniston Army Depot is one of eight locations where chemical stockpiles are stored and destroyed. In 1985, Congress ordered the Army to destroy the stockpiles and to provide "maximum protection" to the public who live and work in communities near the stockpiles now and until the chemical agents no longer exist.

The Jefferson County Evacuee Reception Center (JCEMA, 2000) describes the roles, responsibilities, and actions required by local and state emergency services, and other officials to assist evacuees with their needs. Basic assumptions are made on the number of evacuees directed to the Birmingham area, the routes that they will take and the location of the Reception Center. As in most emergency plans of this nature, no detailed traffic analysis was performed to evaluate the impact of the traffic influx on traffic network operations in the Birmingham region.

To bridge this gap, Scenario 3 used simulation modeling and the Birmingham regional test bed to evaluate the impact of the plan prepared by the Jefferson County EMA on transportation network operations. The simulation considers vehicles traveling west from Anniston to Birmingham due to an emergency at the Anniston Army Depot. The main evacuation route toward Birmingham from Etowah County and North is I-59 whereas the main evacuation route from Calhoun County and East is I-20. The assumptions in this scenario are listed below:

- Under a full scale evacuation, 72,700 total evacuees will be leaving the Anniston area. Approximately 25,000 evacuees are assumed to arrive at Birmingham via I-20 and I-59.
- The general public is assumed to evacuate at 2.5 persons per vehicle resulting in an influx of 10,000 vehicles. It is assumed that 5,000 vehicles will be entering the Birmingham region from I-20 and another 5,000 from I-59.
- There is an evacuee reception area operated by the emergency management agency located on I-459 between I-20 and I-59 (see Figure 5-4). This stretch of I-459 will be open only for people entering the reception area for shelter. The number of people expected to enter the reception area is 2% of the total evacuees.
- Evacuees entering from I-20 not needing assistance are diverted onto I-459 southbound.
- Evacuees entering from I-59 who need assistance are diverted onto west bound I-20/59.
- I-20 and I-59 were shut down to eastbound traffic.
- Eastbound traffic on I-20/59 will have to travel east using either AL75 or AL79.
- Eastbound through traffic on I-459 will initially travel south using I-65, and then will be diverted east from Montgomery.

- Vehicles traveling on I-459 eastbound, downstream of the interchange with I-65, will be directed to make a U-turn at the interchange of I-20 and I-459. Most of the vehicles traveling east will be diverted south onto I-65 by using message signs and boards.
- Those traveling on I-20/59 east bound downstream of AL79 will be directed to make a U-turn at the interchange of I-459 and I-59. East bound vehicles will be diverted onto AL75 and AL 79 by using signs and boards.
- Vehicles traveling east on I-20 will be required to make a U-turn upstream of the I-20/I-459 interchange.
-

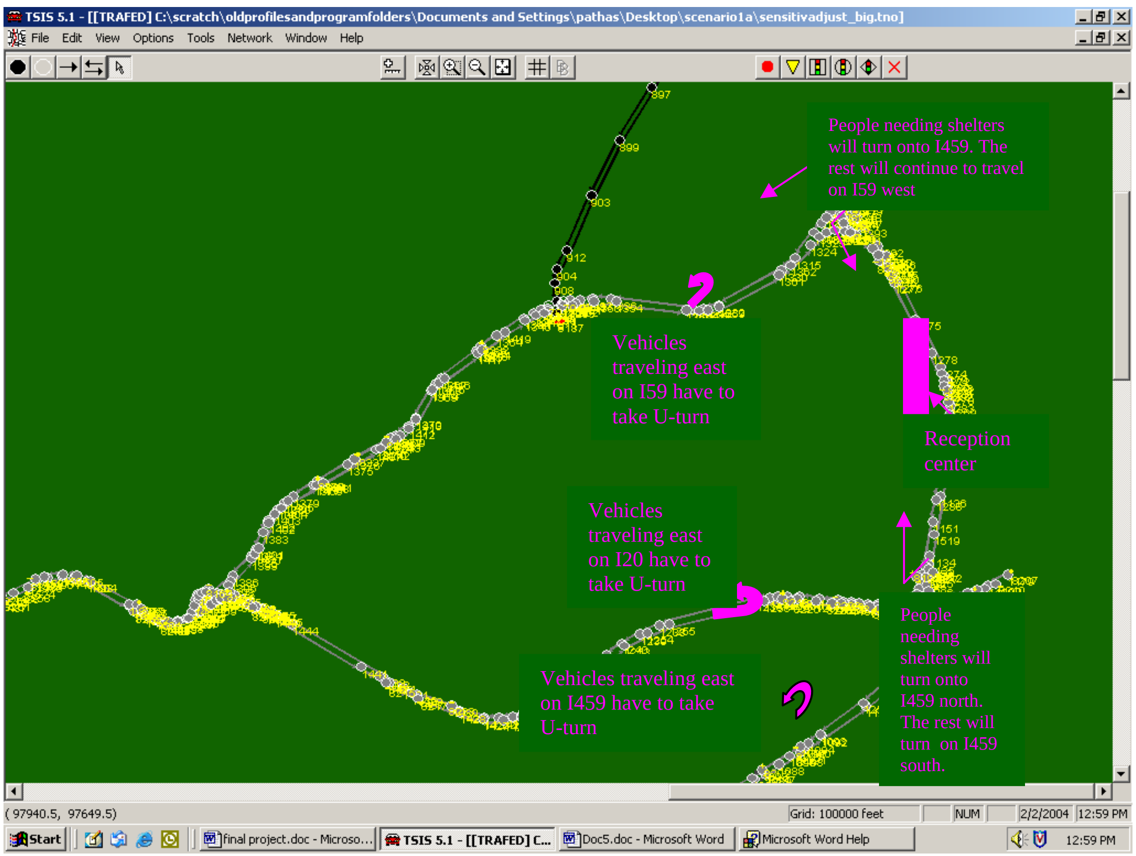

Figure 5-4. Vehicle movement restrictions according to the plan proposed by EMA- Scenario 3

The assumptions above represent traffic management activities based on the currently available plan and were coded into the regional simulation model (Scenario 3- Case 1). The simulation was performed over ten runs and appropriate MOEs were obtained to evaluate the impacts of the traffic influx and management plan on network operations. The results are summarized in Section 5.3.2. From the animation file it was observed that some roadway segments became heavily congested and experienced significant queue formation due to the increased traffic demand. To reduce the queue lengths and improve the efficiency of the transportation network, an alternative traffic management strategy was developed and tested (Case 2). Case 2 proposed that the following changes be incorporated in the simulation model:

- An increased number of vehicles (1,200 vehicles instead of 260 vehicles) were diverted onto US 31 southbound from I-459 northbound to ease vehicles queuing at the interchange of I-65 and I-459. These east bound vehicles were then diverted from US 31 to I-65 in Alabaster and then to the east from Montgomery.

- No vehicles were allowed to enter I-459 north from US 31.
- 500 south bound vehicles on I-459 were diverted on to US 280.
- 40% of the westbound traffic on I-59 was diverted onto southbound AL 79.
- 40% of vehicles traveling on I-20 EB were directed to U-turn and move to I-20 WB.
- 20% of vehicles getting onto westbound I-20/59 from AL79 were directed to continue traveling on southbound AL79.

Scenario 3 (Cases 1 and 2) assumed that the Birmingham Police Department and the Public Works Department will provide personnel and equipment to support traffic control activities as described above. Cooperation of evacuees and other motorists and compliance with traffic diversions and access restrictions were also assumed.

5.3.1 Selection of Performance Measures for Analysis

This scenario evaluated the impact of the influx of traffic toward the Birmingham area through I-20 and I-59. The increase in freeway traffic due to evacuation is expected to impact the speed and travel time, and may result in queue formation. Outputs of the CORSIM model that can be used as MOEs include average speed, traffic volume, travel time, travel delay, and density for each link in any time interval or period. The queued time and maximum queued length can also be observed through the on-screen animation. Performance measures selected for comparison in this simulation include queue lengths, delay times and average speeds on the impacted links. The main findings are discussed in the next paragraph.

5.3.2 Simulation Results from Scenario 3

Tables 5-13 through 5-15 provide a brief summary of selected performance measures from Case 1 and Case 2 conditions for Scenario 3 for selected freeway segments impacted from the evacuee influx. These include I-459, I-20, and I-59. Ten runs were performed for each study case (Cases 1 and 2) and summary network wide performance measures are provided in Table 5-16.

Table 5-13. Comparison of queue lengths in Cases 1 and 2- Scenario 3

Segment	From	To	Queue Length (in feet)	
			Case 1	Case 2
I-459 NB	I-65	US 31	2,912	0
I-459 SB	I-65	Acton Road	5,685	0
I-59 WB	I-459	US 75	20,246	0
I-20 EB	Old Leeds Road	I-459	1,935	0

Table 5-14. Comparison of delay times in Cases 1 and 2- Scenario 3

Segment	From	To	Delay Time (in sec/veh)	
			Case 1	Case 2
I-459 NB	I-65	US 31	60.8	2.9
I-459 SB	I-65	Acton Road	653.1	8.1
I-59 WB	I-459	US 75	330.4	2.8
I-20 EB	Old Leeds Road	I-459	1,332.2	268.7

Table 5-15. Comparison of average speeds in Cases 1 and 2- Scenario 3

Segment	From	To	Average Speed (in mph)	
			Case 1	Case 2
I-459 NB	I-65	US 31	20.78	50.2
I-459 SB	I-65	Acton Road	8.7	56.8
I-59 WB	I-459	US 75	4	54.7
I-20 EB	Old Leeds Road	I-459	8.6	31.85

The analysis showcased the value of simulation modeling as a tool to evaluate existing emergency plans and test recommended changes. From the results presented in Tables 5-13 through 5-15 it was seen that great savings in delay and queue lengths were obtained on impacted links by applying the revised plan described in Case 2. Moreover, the adjustments proposed in Case 2 have helped increase the average speed on critical sections of the transportation network considerably.

As always, it is important to consider traffic migration related issues and evaluate the overall network performance under the alternative plans. To assist in this assessment, Table 5-16 presents network wide performance measures for base conditions (without evacuation) and for Scenario 3 (Cases 1 and 2).

Table 5-16. Network wide average statistics- Scenario 3

Network Measure of Performance	Base Conditions	Case 1	Case 2
Freeway Segments			
Travel Time (min/veh-mile)	1.43	1.72	1.46
Delay (min/veh-mile)	0.44	0.73	0.47
Speed (mph)	41.97	34.94	41.01
Arterial Segments			
Travel Time (min/veh-trip)	6.35	6.03	6.16
Delay (min/veh-trip)	3.71	3.40	3.54
Speed (mph)	17.1	18	17.5

The results in Table 5-16 indicate that the traffic management strategy proposed in Case 2 is advantageous compared to the initial emergency plan described in Case 1 as far as network performance is concerned. The aggregated statistics for the network freeway links demonstrate that Case 2 produced a 35 percent savings in delay and a 6 mph increase in average speed when compared to Case 1. Actually, comparison to the baseline network statistics revealed that when the actions described in Scenario 3 of Case 1 took place the impact of the traffic influx from Anniston on the overall transportation network performance in the Birmingham regional network was minimal.

From the findings above it can be inferred that the changes made in the original plan are desirable and may be adopted since they result in improvements in local and network wide performance in case of an emergency evacuation from Anniston. Alternative strategies may also be developed and simulated and selection of the best strategy can be based on its impact on transportation network operations.

Moreover, the analysis in Scenario 3 reaffirms that transportation and other emergency response agencies need to interact regularly in preparing emergency plans, and should test and evaluate alternative strategies in order to obtain a full understanding of transportation’s role and capabilities and optimize the operation and coordination of the transportation system accordingly.

Section 6
Conclusions and Future Scope

Transportation officials and professionals alike recognize the vitality of the transportation system in case of emergencies. Terrorist acts or natural disasters may directly target the transportation system infrastructure and disrupt traffic operations. In other instances, transportation system components may be used as the method of delivery of an attack. Even when emergencies do not directly occur on the transportation system they still have a transportation component since the transportation network is the primary method through which response and recovery are carried out. Therefore, it becomes imperative to safeguard the transportation system and take all necessary steps to ensure acceptable system performance under emergency conditions.

Emergency preparedness is vital to ensure the safety, security, and efficiency of the transportation system in the event of natural or manmade disasters. It has been recognized that emergency preparedness can greatly benefit from the development of a range of realistic emergency scenarios and testing of plans to respond to each scenario. More specifically, after emergency scenarios are developed, the consequences of emergencies on the operation of the transportation infrastructure should be assessed. Given the magnitude of the problem and availability of resources, possible response actions can be identified and evaluated and necessary adjustments be made to the original plans, when feasible, to minimize the disruption to transportation operations resulting from the emergency. Assessment of emergency scenarios and response actions can be performed through tabletop exercises, mock exercises (drills) or simulation modeling. The latter approach is particularly important for assessing the impact of emergencies and response actions on the transportation network operations without the need to disrupt traffic operations while testing.

This report shows how microscopic traffic simulation can be used to assist decision making for regional emergency preparedness through a series of case studies implemented on Birmingham's regional transportation network. Details are offered on simulation model selection, data collection, model calibration and validation, emergency scenario development and testing. The objective of each case study was twofold. First, to offer examples of common emergencies (such as traffic accident, evacuation etc) and evaluate their impact on network performance. Second, to introduce strategies for traffic management (e.g. traffic diversion, access restriction, signal optimization to favor evacuation flow etc) and assess their potential benefit on traffic operations.

The results of the first case study showed significant improvement of network performance with the traffic diversion strategy. The findings may lead to the conclusion that investment in ITS technologies that support dissemination of traffic information (such as Changeable Message Signs, Highway Advisory Radio, etc) would provide a great advantage in traffic management under emergency situations. The second case study shows how an evacuation could be carried out with different strategies (e.g., optimization of traffic signals, diversion strategies, and staged evacuation strategies). The third case study shows how previously prepared plans can be tested using simulation to assess their validity. Overall, the work reported in this research study demonstrates the feasibility of the simulation approach in emergency preparedness and highlights some of the challenges in the development of large scale microscopic simulation models.

The study contributions can be briefly summarized as follows:

1. An extensive CORSIM regional transportation model was developed, comprised of all major highways, and some major arterials in the Birmingham area. The coded network consists of 2304 nodes and 2708 links. The simulation model development was a major undertaking that involved extensive data collection, processing, data coding, and validation efforts. The developed model will be available in future testing and evaluation studies, with minimum requirements for data collection and coding
2. A computer code was developed to enable the merging of various CORSIM files into one file. Using input from the user, the code is capable of adjusting node numbers and coordinates and creating a merged file where the various network components are successfully integrated into one interconnected network. This tool can be useful to transportation practitioners working with CORSIM and can minimize the time required for re-coding files that have been previously coded for other studies.
3. The study identified and addressed issues critical to emergency preparedness through literature synthesis and application of the simulation model. Through the strategies developed and tested in this study, it was confirmed that development and testing of emergency response actions is important in identifying potential deficiencies or comparing alternative options. The assessment of emergency management options through simulation enhances the understanding of the scope and magnitude of the security problem, and the implications of the disruption to the mobility of people and goods in the transportation system.
4. The results of this research have demonstrated the potential benefits of using the traffic simulation model CORSIM for emergency preparedness modeling. The testing exercises are expected to provide some guidance to future research efforts focusing on simulation modeling for assessment and testing of traffic management options under emergencies, and support the efforts that advocate improved emergency preparedness planning to include transportation operations.
5. The CORSIM animation output files can be a useful tool for demonstrating the impact of a simulated strategy on the transportation network operations. This capability can be particularly useful for helping participating stakeholders visualize the impacts associated with adoption of a particular plan.

It should be noted, however, that this study is simply a demonstration of how traffic simulation can be used as a tool to support emergency management. While the network coded in CORSIM is a significant achievement, it is limited in its ability to simulate emergencies in real time and does not model travel behavior at the network level. As a result the tested scenarios have only limited impacts and do not capture the real dynamics of emergency planning at the regional level.

A future extension of this work should involve the integration of the CORSIM microscopic transportation model and a dynamic traffic assignment model in an attempt to develop a comprehensive model for emergency planning at the regional level. The addition of the traffic assignment model will allow modeling of travel behavior at a network level and will produce route choices of users under emergency conditions, providing a more comprehensive representation of the distribution of traffic in a dynamic way. The CORSIM Birmingham regional transportation network developed in this study can be used as the test bed for the development and testing of the integrated model. This will be a very valuable tool for incident and emergency management. Moreover, the integrated model will have the potential to support a variety of ALDOT and RPCRB goals related to traffic management and alternatives assessment at the regional level, including access management, traffic impact analyses, and asset managements studies. The PI is currently investigating application areas and funding opportunities.

Some future work that can be derived from this research and analysis study includes:

- Conducting simulations for large-scale evacuation scenarios such as a terrorist attack on the Birmingham airport or a release of hazardous materials in downtown Birmingham.
- Using the network to test additional emergency management strategies such as contra flow operations in response to an emergency evacuation or traffic signal preemption for emergency vehicles.
- Using the model to determine the shortest paths for routing emergency response units to and from the affected area. Knowledge of the exact location of emergency response units would enable estimation of response time for areas likely to be affected, and would facilitate an effective deployment of emergency responders.
- Investigating the potential of using high performance computing for three-dimensional (3-D) traffic flow visualization. This will involve development and testing of a 3-D animation software as an extension of CORSIM. The outputs from the CORSIM model and geographical and topographical data can be used for demonstration purposes. Such a tool will allow transportation and emergency response agencies to clearly visualize traffic conditions and better grasp the impact of proposed emergency management strategies on transportation network operations.

Additional recommendations for future research include the following:

- Conducting a study to determine current needs for deployment of ITS technologies in support of emergency management objectives in the Birmingham region and options for integrating/sharing information (data, voice, images) from traffic management centers with emergency management centers and/or other first responder centers.
- Determine routes in the Birmingham region that are critical under regional emergencies and develop an inventory of traffic signal timing plans and information signing for the predetermined routes; and use simulation software to develop and assess signal coordination plans along key evacuation and response/recovery routes.

Section 7
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APPENDIX A

CORSIM MERGING SOFTWARE (COMES) - Information for Users

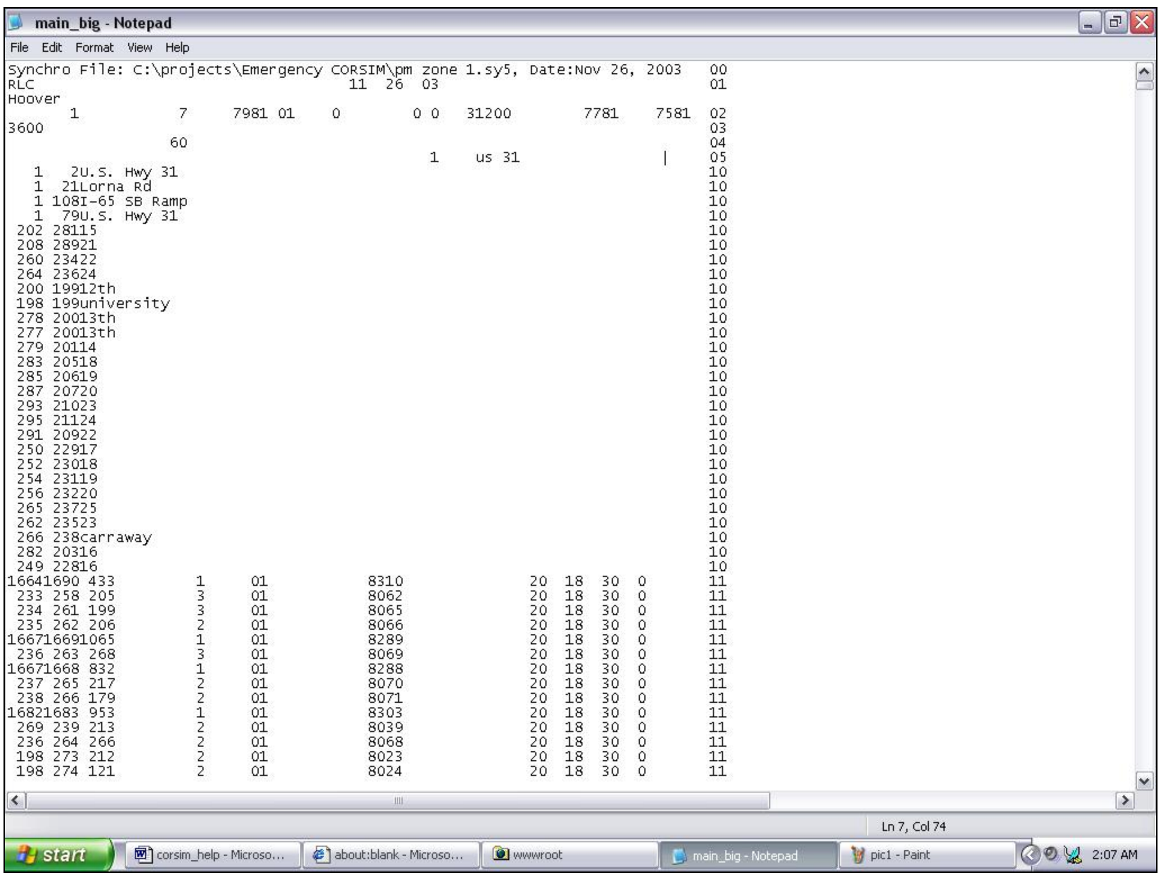
The COMES program is written in Active Server Pages (ASP) and is aimed at automating the merging of CORSIM files into one integrated file. The merging of the files to build the network in CORSIM involves the following steps:

1) Preliminary preparation of file
2) Uploading the files to the server (e.g., UAB's Translab server)
3) Putting in the values to merge the files in the webpage
4) Downloading the files from the server.

Currently, the program is installed on the UAB Translab server, with password protected access to the machine. The requirements on any of the local machines include availability of a Windows 2000 or higher operating system with Internet Information Services (IIS) installed and running. (IIS comes with the operating system.)

<u>Step 1: Preliminary preparation of file</u>

Before the merging of CORSIM files, the files being processed have to be trimmed at the top and bottom. The top any CORSIM network file will begin as shown in Figure A-1.




```
Synchro File: C:\projects\Emergency CORSIM\pm zone 1.sy5, Date:Nov 26, 2003   00
RLC                                             11  26  03                    01
Hoover
       1          7      7981 01     0        0 0   31200        7781    7581  02
3600                                                                          03
                 60                                                           04
                                                 1    us 31              |    05
   1   2U.S. Hwy 31                                                           10
   1  21Lorna Rd                                                              10
   1 108I-65 SB Ramp                                                          10
   1  79U.S. Hwy 31                                                           10
 202 28115                                                                    10
 208 28921                                                                    10
 260 23422                                                                    10
 264 23624                                                                    10
 200 19912th                                                                  10
 198 199university                                                            10
 278 20013th                                                                  10
 277 20013th                                                                  10
 279 20114                                                                    10
 283 20518                                                                    10
 285 20619                                                                    10
 287 20720                                                                    10
 293 21023                                                                    10
 295 21124                                                                    10
 291 20922                                                                    10
 250 22917                                                                    10
 252 23018                                                                    10
 254 23119                                                                    10
 256 23220                                                                    10
 265 23725                                                                    10
 262 23523                                                                    10
 266 238carraway                                                              10
 282 20316                                                                    10
 249 22816                                                                    10
16641690 433       1      01          8310            20  18  30  0           11
 233 258 205       3      01          8062            20  18  30  0           11
 234 261 199       3      01          8065            20  18  30  0           11
 235 262 206       2      01          8066            20  18  30  0           11
16671669 1065      1      01          8289            20  18  30  0           11
 236 263 268       3      01          8069            20  18  30  0           11
16671668 832       1      01          8288            20  18  30  0           11
 237 265 217       2      01          8070            20  18  30  0           11
 238 266 179       2      01          8071            20  18  30  0           11
16821683 953       1      01          8303            20  18  30  0           11
 269 239 213       2      01          8039            20  18  30  0           11
 236 264 266       2      01          8068            20  18  30  0           11
 198 273 212       2      01          8023            20  18  30  0           11
 198 274 121       2      01          8024            20  18  30  0           11
```


Figure A-1 Initial lines of a CORSIN file

In this step the card types 01 to 09 should be removed. The file has to be trimmed to the point where card type 10 is present. For example in the file which is shown in Figure A-1, the card types 01 to 05 exist, meaning that the parts in Figure A-2 should be deleted.

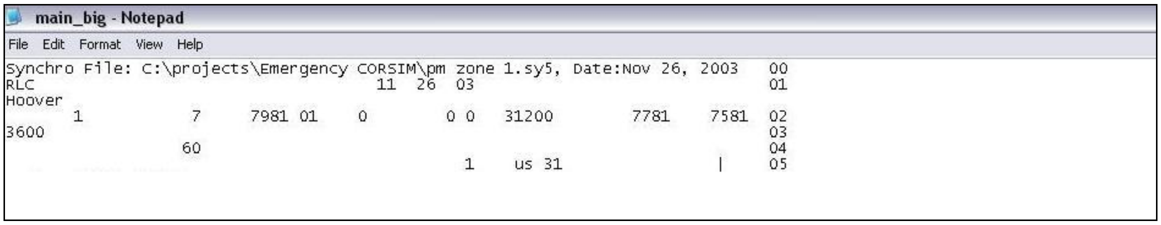


Figure A-2 CORSIN lines to be deletes

The updated files shall begin with card type 10. After this step is performed the file is ready to be uploaded to the server.

Step 2: Uploading the files to Server (UAB's Translab server)

This step involves using any File Transfer Protocol (FTP) to upload the files to the server. There are many popular FTP programs available for free download. The simplest one is the WS_FTP download and should be installed in the local machine. Alternatively, it can be downloaded from http://www.ftpplanet.com/download.htm. After the program is installed, the next step is to login to the server to upload the files. When the WS_FTP program is started it will prompt for the servers IP address username and password. The screen will look like Figure A-3:

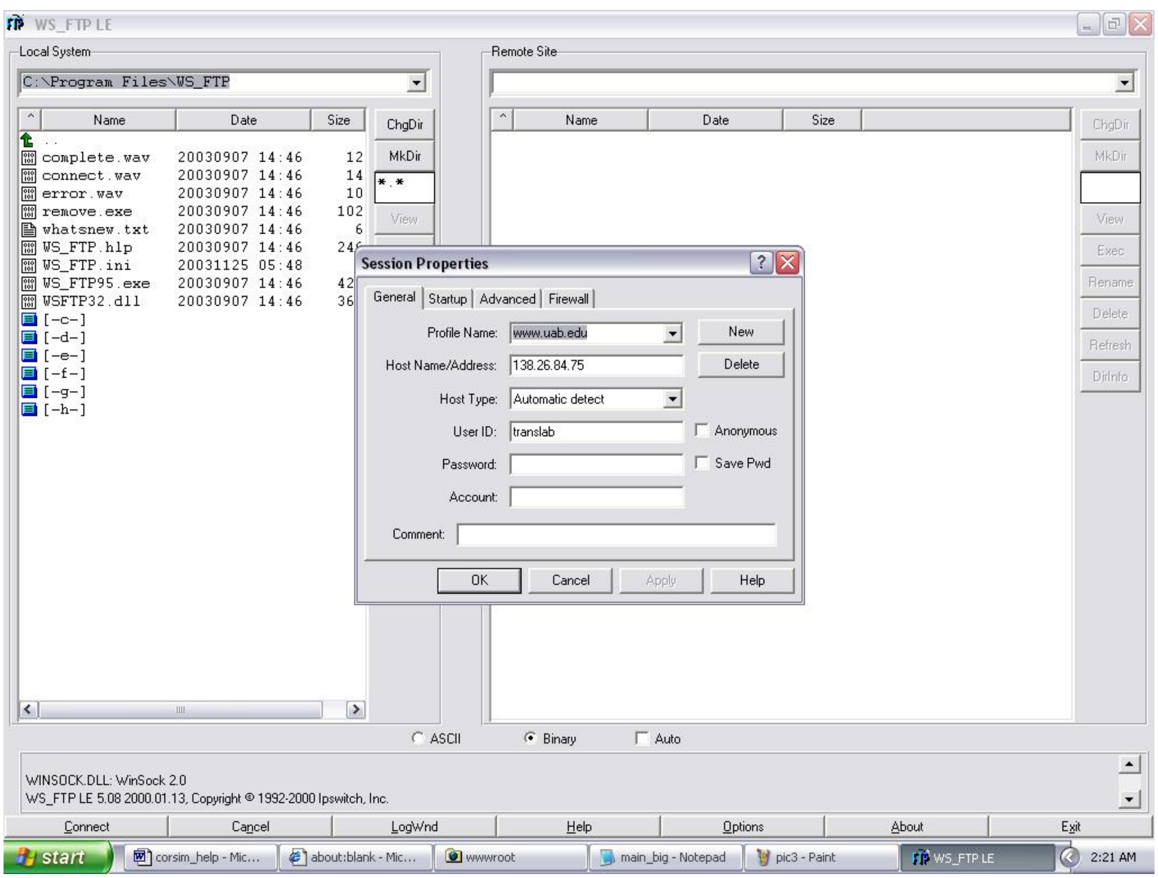


Figure A-3 Uploading files to the server

Enter the following values:

IP Address: 138.26.84.75d
Username: translab
Password: Tc76xZ9

After logging in, the user can view two columns. The left column represents the local machine and the right one the server. The user should navigate to the file where it is saved in the local machine. On the server side (right column) the user can see a folder named "data." Double click on the file in the local machine (left column), and the file will be automatically uploaded to the data folder in the server. A similar procedure is used to upload all required files.

Step 3: Parameter Modification for Merging

After the file is uploaded, the next step is to process it. This includes renaming the node numbers as needed to avoid duplications and properly adjusting X and Y coordinates. The user can open the web browser and type the following address: http://138.26.84.75/submit.asp. This opens a webpage and prompts the user to enter the input file name, output file name, number to be added for external nodes, and X and Y co-ordinates. The screen will looks like Figure A-4:

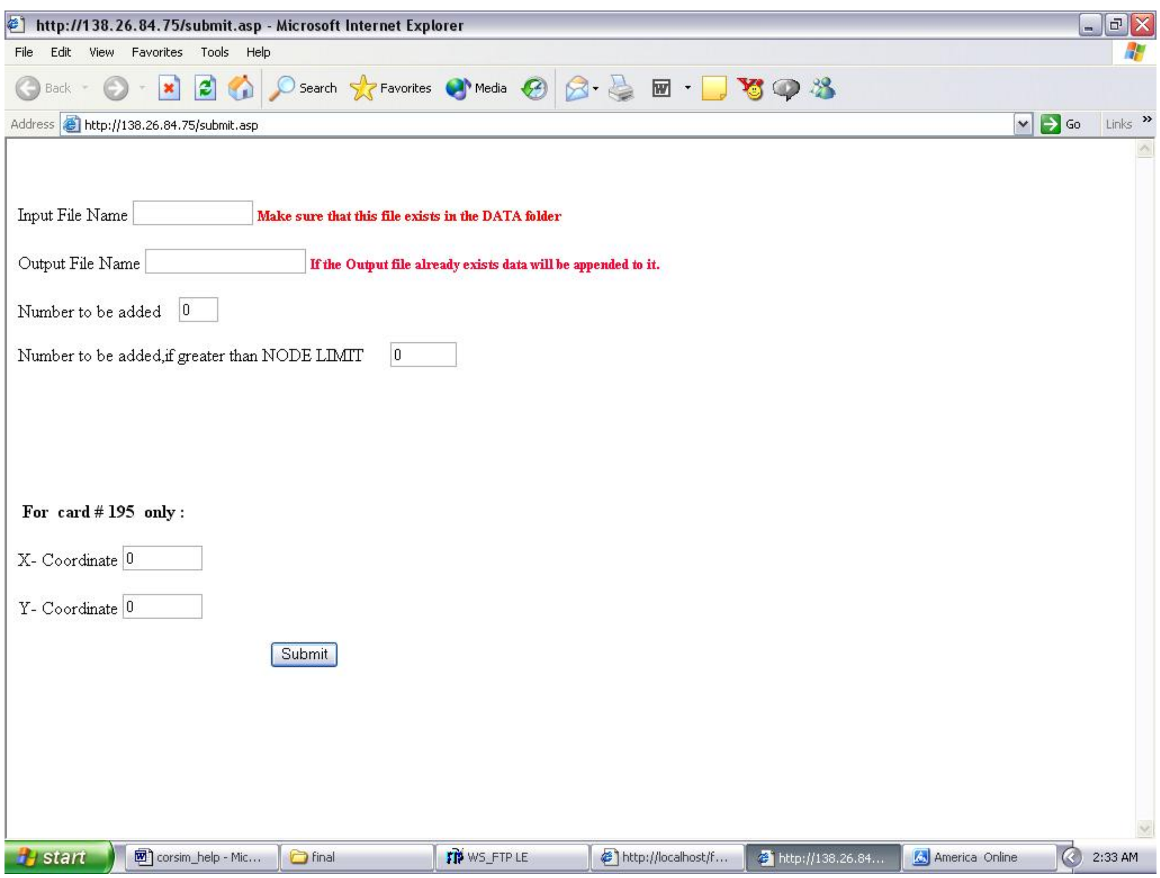


Figure A-4 Parameter modification for merging

The user should enter the input file name; i.e., the file where the parameter modifications should be entered. This file should be present in the data directory (uploaded to the directory in the previous step). Output file is the name of the file where the user wants the changes to reflect. If the file already exists, the program would append the previous input file with changes to the output file, but if the output file is not present, it would create the file with the name specified.

Then the value by which the nodes are to be incremented is entered, as well as the value for the external node. The X and Y co-ordinates which are specific to card type 195 are also entered.

After clicking the submit button the file is created. The user should specify the input and output file names with extensions. The number to be added should be selected carefully so that once the files are merged, the adjusted node numbers are not duplicate values of the node numbers in the first file. The second incremental value is specifically for the external nodes which have a node value greater than 8000. CORSIM has a 10,000 limit on the number of nodes, so if the node value is greater than 8000 and the value to be added causes it to increment above 10,000, then the second value (which will be a smaller value) is used to increment the value of such nodes.

Step 4: Downloading the files from Server

The final step is to download the merged file to be used in CORSIM. The user should connect to the server as in step 2. After connecting, a file can be seen in the right column (server side) with the name specified as the output file in step 3 can be seen. Double clicking on the file name will download the file to the local machine.

At this time the file is ready to be processed in CORSIM.