KENTUCKY TRANSPORTATION CENTER

College of Engineering

UK
UNIVERSITY OF KENTUCKY

UNIVERSITY OF KENTUCKY
College of Engineering

KENTUCKY TRANSPORTATION CENTER

Our Mission

We provide services to the transportation community through research, technology transfer and education. We create and participate in partnerships to promote safe and effective transportation systems.

We Value...

Teamwork -- Listening and Communicating, Along with Courtesy and Respect for Others
Honesty and Ethical Behavior
Delivering the Highest Quality Products and Services
Continuous Improvement in All That We Do

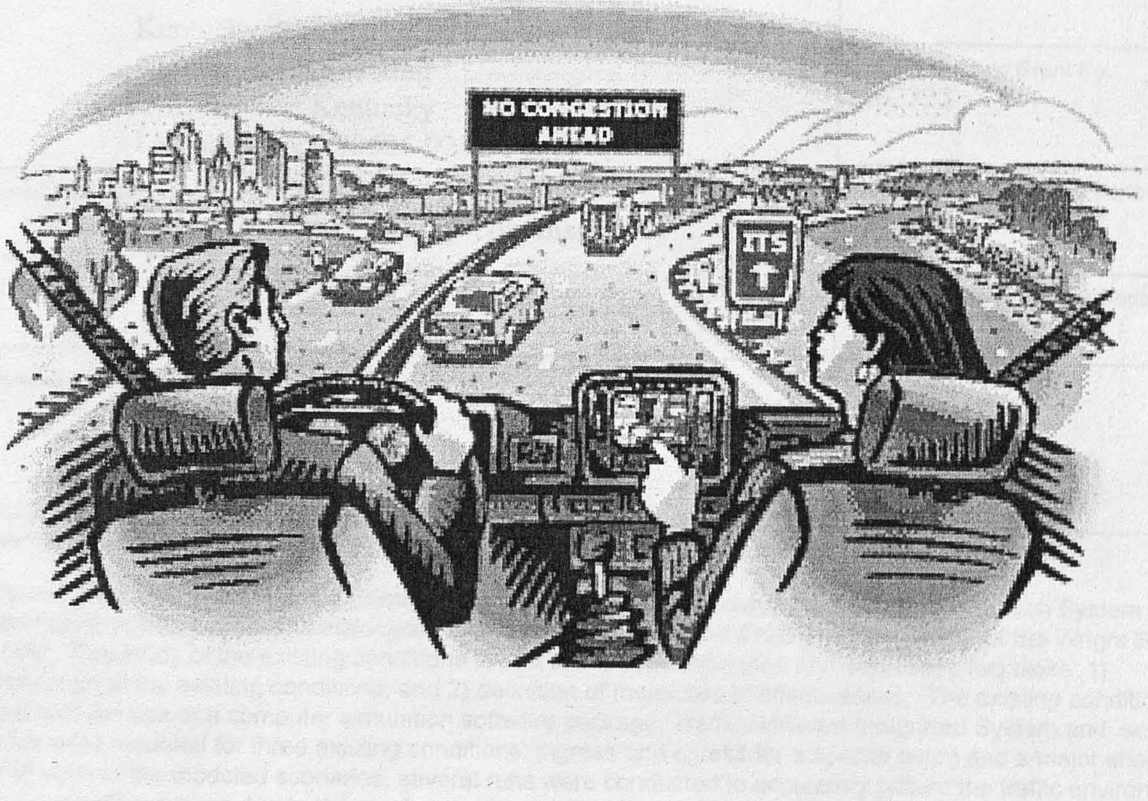
For more information or a complete publication list, contact us at:

Kentucky Transportation Center
176 Raymond Building
University of Kentucky
Lexington, Kentucky 40506-0281

(859) 257-4513
(859) 257-1815 (FAX)
1-800-432-0719
www.engr.uky.edu/ktc
ktc@engr.uky.edu

The Dayton ITS Demonstration Project

Simulating Existing Conditions



Prepared by
Jill Swaynos
University of Kentucky

1. Report No.
KTC-99-64

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

The Dayton ITS Demonstration Project: Simulating Existing Conditions

5. Report Date
December 1999

6. Performing Organization Code

7. Author(s)
J. A. Swaynos and N. Stamatiadis

8. Performing Organization Report No.6
KTC-99-64

9. Performing Organization Name and Address

Kentucky Transportation Center
College of Engineering
University of Kentucky
Lexington, KY 40506-0281

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
462722

12. Sponsoring Agency Name and Address
Miami Valley Regional Planning Commission
Dayton, OH 45402

13. Type of Report and Period Covered
Final

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The Miami Valley Regional Planning Commission is incorporating an Advanced Traveler Information System to alleviate real-time traffic problems associated with special events at the Ervin J. Nutter Center of the Wright State University. This study of the existing conditions is part of the evaluation plan and addresses two tasks: 1) documentation of the existing conditions; and 2) definition of measures of effectiveness. The existing conditions were depicted with the use of a computer simulation software package, Traffic Software Integrated System and separate scenarios were modeled for three existing conditions: ingress and egress for a special event and a major shopping day. For each of the modeled scenarios, several runs were conducted to accurately picture the traffic environment and avoid possible outliers due to the stochastic nature of the simulation program. Model calibration and validation was also used by conducting travel time studies. Several measures of effectiveness were chosen including travel times, delays, and system speeds. Finally, specific routes were studied for each of the scenarios and problem areas were identified.

17. Key Words
Intelligent Transportation Systems
Advanced Travel Information Systems
Simulation
Special events

18. Distribution Statement
Unlimited, with approval of the
Miami Valley Regional Planning Commission

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
37

22. Price

TABLE OF CONTENTS

Appendices

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The concept of Intelligent Transportation Systems (ITS) has grown due to the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21). The Miami Valley Regional Planning Commission (MVRPC) is using one form of ITS, specifically an Advanced Traveler Information System (ATIS), as a part of the Dayton ITS Demonstration Project to alleviate real-time traffic problems associated with special events at the Ervin J. Nutter Center of the Wright State University. The Dayton ATIS system will consist of five Changeable Message Signs (CMS), video surveillance for incident verification, a congestion detection system and several static highway signs.

The primary objective of the Dayton ITS Demonstration Project is to demonstrate the effectiveness of the ATIS devices in providing real-time information to travelers accessing the Nutter Center during special events and managing congestion and traffic circulation during such events. The secondary objective of the project is the mitigation of recurring congestion in the same area. This report presents the development of the simulation for the existing conditions as part of the evaluation plan necessary, according to ISTEA, in all ITS demonstration projects to assess the project benefits and show system improvements after the implementation. The two tasks completed in this study are 1) documentation of the existing conditions; and 2) definition of measures of effectiveness. Once the ATIS is fully operational the final task, evaluation of project components, will be completed.

The documentation of existing conditions during Nutter Center special events is necessary to establish a baseline for comparing the impact of the proposed ATIS components. Additionally, the potential for recurring congestion during the non-event times will also be documented to achieve the second objective of the proposed demonstration project. To accurately depict the existing conditions a computer simulation software package, Traffic Software Integrated System (TSIS), was used. TSIS provides a realistic simulation of current conditions and allows for simulating different roadway components, such as arterials and freeways, simultaneously. To properly simulate all aspects of the existing traffic environment, separate scenarios were modeled for three existing conditions: ingress, egress, and a major shopping day. For each of the three modeled scenarios, five runs were conducted with separate random numbers to improve accuracy, measures of effectiveness, capture daily traffic variations, and avoid possible outliers due to the stochastic nature of the simulation program.

Once the simulations were complete, the models were validated by conducting travel time studies to account for stability and comparing them to simulated travel times. Additionally to further validate the model and account for stability, the standard deviations of the runs for each scenario were studied. Since the standard deviations were small and the field travel times were similar to the simulated times, no adjustments were made to the model.

To evaluate the existing conditions several measures of effectiveness (MOE) were chosen. First the network-wide MOE of total vehicle-miles, move time, delay time, total time, speed and the move to total ratio were measured for each of the three scenarios. In addition to comparing the overall network statistics, several specific routes were studied for each of the scenarios. The MOE studied along the individual routes included total delay, system speed, and move to total ratio.

The simulations identified several specific problem areas. The first problem area may be attributed to the uncoordinated signal systems. There are currently three signal systems in the Nutter Center area, however none of the systems are coordinated with each other and significant system breaks occur during the ingress and egress of Nutter Center events. Another problem area occurs along North Fairfield Road from the I-675 interchanges north to Colonel Glenn Highway. Although this is only a 0.25-mile section of roadway, significant delays occur along the route. This congestion indicates the next problem area which is the need to disperse traffic to surrounding areas. Although there are alternative entrances to the Nutter Center, patrons not familiar with the area are directed to the North Fairfield Road intersection, adding to the congestion. The proposed CMS will attempt to solve this problem by dispersing traffic throughout the network.

Throughout the project, TSIS has been a powerful demonstration tool accurately representing the existing conditions and identifying specific problem areas with the complex actuated signal system of the area. As the study progresses, it is anticipated that the CORSIM network will be used to evaluate the effectiveness of the ATIS devices in providing real time information to patrons attending the Nutter Center events and managing traffic during those events.

1.0 INTRODUCTION

With the implementation of programs such as the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21), the concept of Intelligent Transportation Systems (ITS) has grown in hope of providing continuous transportation systems to users of various modes of transportation with separate jurisdictional boundaries (1). In a continuous transportation system, all jurisdictions ideally work together coordinating systems to create seamless mobility of all modes of transportation throughout the system. In particular, the ITS customer services of incident management, traffic control, pre-trip traveler information and route guidance will be given high priority for development in the next few years according to the Integrated Transportation Management Strategies Master Plan (2).

The advent of ITS in many cities throughout the United States has spawned development of several specific technologies. One such ITS technology is the use of Road Transport Informatics (RTI). This technology optimizes the use of existing facilities within a transportation system to achieve three goals: alleviate congestion, decrease air pollution and reduce incidents (3). By providing drivers real-time traffic information through RTI such as roadside displays and radio data systems, the difference between the driver's perceived travel time and system calculated travel time is reduced. Knowing the real-time traffic information a driver is able to make an informed route choice, which also has the potential to decrease traffic congestion within the urban network since alternate routes are used. Besides displaying travel times, RTI are used to direct traffic, thus mitigating traffic throughout the network reducing congestion and air pollution (4).

The Miami Valley Regional Planning Commission (MVRPC) is using one type of RTI to alleviate real-time traffic problems associated with special events at the Ervin J. Nutter Center of the Wright State University. Specifically, MVRPC will implement a series of Advanced Traveler Information Systems (ATIS) to the roadway system as a part of the Dayton ITS Demonstration Project. The primary objective of this project is to demonstrate the effectiveness of the ATIS devices in providing real-time information to travelers accessing the Nutter Center during special events and managing congestion and traffic circulation during such events. The secondary objective of the project is the mitigation of recurring congestion in the same area (5).

A consultant team headed by TRW designed the ATIS system. That system consists of an ATIS server used to coordinate Changeable Message Signs (CMS) along the I-675 exits, video surveillance for incident verification, and a congestion detection system. Additionally, a series of static highway signs will be placed to assist motorists in understanding the flow around and through the facility. It is expected that the proposed plan should alleviate both special event and recurring congestion surrounding the Nutter Center area.

As part of any ITS demonstration project, an evaluation plan to assess the benefits of the project and show system improvements after the implementation is required. A team from the Kentucky Transportation Center and the Department of Civil Engineering at the University of Kentucky (UK) is performing this evaluation. The evaluation plan consists of three essential tasks: 1) documentation of the existing conditions; 2) definition of measures of effectiveness; and 3) evaluation of project components. To complete these tasks the UK team will use a traffic simulation, statistical analysis and focus groups to evaluate the ATIS components. However, this report focuses only on the first two tasks since the implementation of the ITS components will occur next year.

2.0 BACKGROUND

2.1 CMS Background

The proposed ATIS system for the Dayton ITS Demonstration Project includes three highway CMS along the I-675 freeway and two arterial CMS along Colonel Glenn Highway. Changeable message signs, like those to be used in the Dayton ITS Demonstration Project, have become increasingly important in improving highway safety, operations and use of existing facilities. CMS are used as a means of relating real-time information to individual drivers. Because of their inherent flexibility, a variety of information regarding current traffic conditions and diversion routes can be displayed to avoid problems often associated with incidents and congestion (1).

There are four functional requirements for an effective CMS: 1) conspicuity, defined as the ability of an object to appear prominent or noticeable in the visual field; 2) legibility, a measure of how well an observer can recognize the words or symbols of the CMS; 3) comprehensibility, a measure of how understandable the CMS message is to an observer; and 4) credibility, which refers to the "extent to which motorists believe that a traffic control device has a message that is reliable, accurate, up-to-date, and pertinent" (1). Credibility is essential since a CMS system can be fully operational, but if the drivers do not trust the information provided by it, the system will not be successful. Therefore, it is important that these functional requirements are addressed throughout any project.

Besides the functional requirements for individual signs, there are several critical properties that must be addressed when determining an applicable CMS technology for a project area. Critical properties include life cycle costs, operational temperature range and cooling or heating requirements, power consumption and service requirements, vibration effects on components, manufacturing experience, and maintenance and operation experience. Once the critical properties of the site are determined, then a sensitivity analysis determining the weight of each of the properties should be conducted to rank the various CMS technologies (6). Also important in a sensitivity analysis is the evaluation of areas with excess capacity if traffic is being diverted (1). This evaluation can be accomplished through simulation studies that can assess the use of alternative routes for diversion and compare and substantiate analysis results.

Once the site is determined, a physical location for sign placement within the site must be specified. With regards to placement, all signs should be placed so drivers have sufficient time to see and comprehend the sign prior to reaching another (1). There are several factors to be considered regarding sign placement: sign size, letter height, visibility, conspicuity, arterial speed, driver vigilance and complexity of the driver environment (1).

Related to sign placement, environment is another important factor in the operation of an arterial CMS, which refers to the driving environment and the local land use. For example, if the area is cluttered with extraneous signage, the CMS may not be effective because it may fade in the background. Additionally, if the environment is comprised of residencies or businesses, the brightness of the signs may not be appreciated.

Even when the CMS system is in place and fully operational, several issues regarding their use and operation need to be addressed, which include message type, size and visibility. Message type is an important issue in the operation of a CMS. Messages should employ an attention statement describing the incident, identifying the section of the arterial being addressed, and an action statement describing the necessary action that drivers need to execute to avoid the incident (7). Furthermore, a functional analysis should be conducted to determine a proper message library based on the messaging capabilities and assessing diversion plans (6). Another important issue in arterial CMS is the size and number of features such as the characters, lines and the physical size of the sign. It is important to note that factors such as driver work load, message load, message lengths, message familiarity and display format affect the sizing of the CMS factors (7). The final aspect affecting the use and operation of CMS is visibility, which depends on the visual capabilities of the motorists and the photometric qualities of the device. Specific factors affecting legibility include character height, font style, pixel size and spacing, sign border size, contrast ratio, spacing of characters, lines and words.

Although the UK team has no control over the selection or the placement of the CMS in the Dayton ITS Project, it is still necessary to understand the important issues in CMS choice such as the functional requirements, critical properties, and site locations. An effective CMS can be key in an ITS project by improving safety and increasing the use of facilities. Therefore to ensure success of the Dayton ITS Project, it is imperative to ensure that the functional requirements are addressed throughout the scope of the project.

2.2 ITS Background

In addition to understanding the specifics of the CMS within the project, it is also important to fully understand the ITS concept. In general, the purpose of an ITS system is to receive source (raw) data from the field and process them into useable information for the driver or system operator (8). Raw data can be obtained from detectors providing information such as occupancies, vehicle counts, vehicles speeds and queue lengths. Also raw data can be provided by probes or test vehicles that supply their link travel times and cruise times. Other data includes anecdotal data provided by motorists, police or other emergency personnel. This type of data includes information such as incident occurrence, incident location, incident type, expected incident duration, long queues, low speeds and lanes congested. Additional necessary data needed by an ITS system is network geometry, free flow speeds and traffic control information. Finally, expert knowledge can be integral in understanding the impact of bottlenecks, spillbacks and incidents on traffic flow.

The compilation of raw data is used to provide processed information in the form of congestion maps, estimated travel times between network point or traffic incidents, which is then used by the route optimizer, traveler or traffic management center (8). However, to successfully process the raw data the data processing unit must be able to account for three discrepancies. The first discrepancy is data sparsity, since data in many ITS systems may be unavailable during some periods or at some locations. Because the data is often sparse, large sections of the network might not have real-time data available for a large periods of time. This problem can be accounted for with the use of historical trends to supply missing information. The second discrepancy is data redundancy. This is necessary because there are often periods within an ITS system when several separate data sources provide essentially the same information. The extra information can improve the confidence level of the system if the data source with the highest level of confidence is chosen or used to cross validate the information. The final discrepancy is data uncertainty due to traffic randomness and data incompleteness. The estimation used to account for randomness or incomplete data can lead to uncertainty and sometimes errors within the output reports.

In addition to accounting for discrepancies, there are three capabilities that a data processor should possess. The first capability necessary in a data processor is the ability to infer traffic information for one link from information obtained at neighboring links. The second capability that a data processor should possess is handling information uncertainty. The final capability needed in a data processor is the ability to combine information from multiple sources (8).

2.3 Simulation Background

Traffic simulation models and their evaluation abilities can be used to help account for the voids found in many ITS data processing units. Specifically, traffic simulations can be used to determine historical trends to account for data sparsity. Simulation is also a powerful tool used to account for the data uncertainty of traffic randomness. Since many of the software packages like CORSIM model traffic stochastically, the traffic randomness can be taken into account and simulated correctly. Additionally, simulations already contain some of the necessary capabilities of ITS data processor. In particular, many simulations can infer data from corresponding links with limited information from the neighboring links. For example, in CORSIM only the entry and exit volumes are necessary, the volumes throughout the network can be computed with the turning percentages assigned to each intersection.

Not only are simulations important in filling ITS voids, but they are key in facilitating the current changes in traffic control and system management. With the growth of ITS technologies, the concept of traffic control is moving towards a broader philosophy of transportation system management. Under the ideology of transportation system management, the purpose of traffic engineering has grown from solely moving vehicles to optimizing the transportation resources, such as carpools, HOV lanes, trucks and buses, increasing the efficiency of movements of people and goods without impairing the surrounding communities (9). Simulation programs such as CORSIM, as used in this project, allow for evaluation of these alternatives in system management through its ability to model buses, carpools and HOV lanes. Additionally, CORSIM has the ability to model complex traffic systems such as actuated signals and the coordination of those signals often found in newer systems.

There are a significant number of benefits to using simulation. Simulations such as CORSIM have the ability to address analytical stochastic processes found in many of today's traffic environments. Also through the use of simulation programs a user can focus on a specific aspect of the overall problem while experimenting with otherwise impractical ideas. Additionally, the real risk of failure is avoided because each alternative can be evaluated in the lab environment prior to implementation, eliminating the cost of unnecessary construction. With simulation users have the ability to simulate over large areas with a variety of combinations of roadway facilities. Simulated evaluations are quicker, more flexible and cheaper than if the implementation had to occur prior to the evaluation. Simulation also provides several measures of effectiveness not readily obtainable in the field and allows for future demand impacts. Finally, simulation allows control of variables which are often difficult or impossible in field tests (10).

Although there is a variety of benefits for using simulation, there are also some disadvantages. The first disadvantage is the simplification frequently required for the computer, which results in lost detail and accuracy. Although some simulation programs account for some variation between drivers and their driving patterns, it is still a computer based simulation and cannot account one hundred percent for the real world traffic environment. Also because of the expertise needed for complete and effective results, there is some risk of error from the users and inputs. (11) A user must fully understand the simulation program and be knowledgeable of all the entries on all the card types. Therefore, some risk of input error can occur if the users are not certain of what they are modeling. Additionally, with the advent of computer interface programs that automatically create the simulation network, a user can run the programs with even less understanding of the intricacies of the program itself. This lack of knowledge creates a high risk of errors.

Despite the disadvantages, there are a number of applications for simulation software programs. Through simulation a variety of experimental physical changes can be attempted with constant variables for comparison between alternatives. Other applications of simulation software are signal timing plan evaluation, left-turn pocket evaluation, signal systems boundaries evaluation, and the evaluation of new signal designs. Simulation is also a useful tool for traffic impact studies as well as before and after studies (12).

The microscopic model used in this project, CORSIM, consists of two separate simulation models, NETSIM and FRESIM which are described below, which provide substantial flexibility in representing traffic operations with unique geometric configurations (13). The first simulation model is the NETSIM model originally developed for the Federal Highway Administration (FHWA) in 1971 (9).

2.3.1 NETSIM

NETSIM is a microscopic computer software program that simulates individual vehicle behavior traveling over an urban network. NETSIM works by allowing vehicles to enter the network following a stochastic approach and using probability distributions that simulate vehicle characteristics. The user can assign variable vehicle characteristics such as acceleration/deceleration rates, headways and free-flow speeds or default values can be used (9). Random number seeds are used to generate vehicle and driver characteristics. The NETSIM program models the response of the vehicle to factors such as traffic volume, signal operation and turning movements. Specifically, NETSIM works by applying interval-based simulation to collect traffic data. The software defines each vehicle as a distinct object that is moved throughout the network in 1-second intervals. While the vehicle moves throughout the network, all events and traffic control devices are updated every second. When the vehicle is moved, the vehicle's lateral and longitudinal position on the link along with the vehicle's relationship to nearby vehicles are calculated. All vehicles within the network are moved according to the programmed car-following logic and the vehicle's response to traffic control devices and other drivers. The turning movements, freeflow speeds, headways and other vehicle behaviors are assigned stochastically by the software.

Other major features modeled in the NETSIM model are fleet components with up to 16 different vehicle types, load factors, turning movements, bus operations, HOV lanes, queue discharge distribution, incidents and temporary events. Also, detailed approach geometry with various control devices such as stop and yield signs or pre-timed/actuated signal controls can be modeled.

2.3.2 NETSIM Input

Although the NETSIM network can be modeled with intensive user input, some of the inputs are optional and have default values so that extensive data is not required to run the program. NETSIM recognizes the network as a series of user-specified links and nodes. Nodes are used to represent the intersections and their geometry within the network and links connect to those nodes. Within the entire network, the user can model information such as distance or time, maximum speed, maximum acceleration, discharge headway factor, average occupancy, fuel consumption rates and emission rates. Relating to the node, the user can input the type of control, number of links, link lengths, approach lanes and allowable movements by lane, turning volumes and/or turning percentages, turning pockets, grade, headways, lost time, free-flow speeds, right turn on red, pedestrian information and the percent of trucks or carpools. While modeling the type of signal control the user can either specify a pre-timed signal or actuated signal. Using pre-timed signals the cycle length, number of phases, phase sequence, and splits can be modeled. When using actuated signals the user can model the controller logic, phase information, extension information, gaps, the number of actuations during the minimum interval, single or double entry, minimum or maximum recall, yellow or red lock, overlap phase and the red revert time. The detector location, size and delay time can also be specified in the program. Finally, the coordination of pre-timed or actuated signals can be specified with regards to cycle length, yield point, permission periods and force-off time (9).

2.3.3 NETSIM Output

In NETSIM, the output is presented as information by link with several subcategories such as turning-movements, passing information, queue lengths and vehicle delays. More specifically, the output by link and whole network are vehicle travel; delay and travel times in vehicle minutes and minutes per mile; delay, travel queue and stop times in seconds per vehicle; percentage of stops; average speed in miles per hour; and the number of phase failures. The phase failures are determined per link and are used to detect the hotspots within the network. The output by link is the number of queued vehicles by lane; number of vehicles discharged; number of vehicle stops; number of vehicles by turning movement; signal indications; and whether or not a detector was actuated. Finally, the output by link and turning movements are fuel consumption by vehicle type; emission by vehicle type; delay and travel times in vehicle minutes; delay, travel, queue and stop times measured in seconds per vehicle; speed in miles per hour; percent of stops; vehicle travel in miles; and number of vehicle trips (12).

Other outputs include the move/travel ratio and the network mean speed. The move/travel ratio is the total time in which a vehicle spends within a network. This ratio is an average for all vehicles equal to the delay time of the vehicles divided by the total time. The mean speed is the average speed in miles per hour of vehicles in a network.

2.4 FRESIM

In addition to the NETSIM model, FRESIM is a component of the CORSIM simulation model. FRESIM models the freeway operations of a network and it can also handle one to three inter-freeway connectors, grade variations, radius of curvature, superelevations, lane adds/drops, incidents, work zones, and auxiliary lanes (9).

2.4.1 FRESIM Input

Like NETSIM, FRESIM can be used with limited input through the use of default values. Necessary inputs include the freeway link geometry such as number of lanes and lengths of auxiliary lanes; freeway link operation such as grade superelevation, free-flow speed, start-up delay; and location of warning signs. Identifying either the percentage or the number of vehicles that travel to the off-ramp and continue through on the freeway specifies the freeway turning movements. Also the entry link volumes must be specified. Finally, some of the optional inputs include lane drops or additions, freeway incident specification surveillance specifications, freeway metering, and vehicle type specifications (9).

2.4.2 FRESIM Output

All output in the FRESIM network is provided on a link by link basis. For each link, statistics such as number of lane changes, vehicle-miles, volume, density, speed and delay are reported. FRESIM also provides the cumulative values of fuel consumption, and emissions on a link level (9).

3.0 EXISTING CONDITIONS

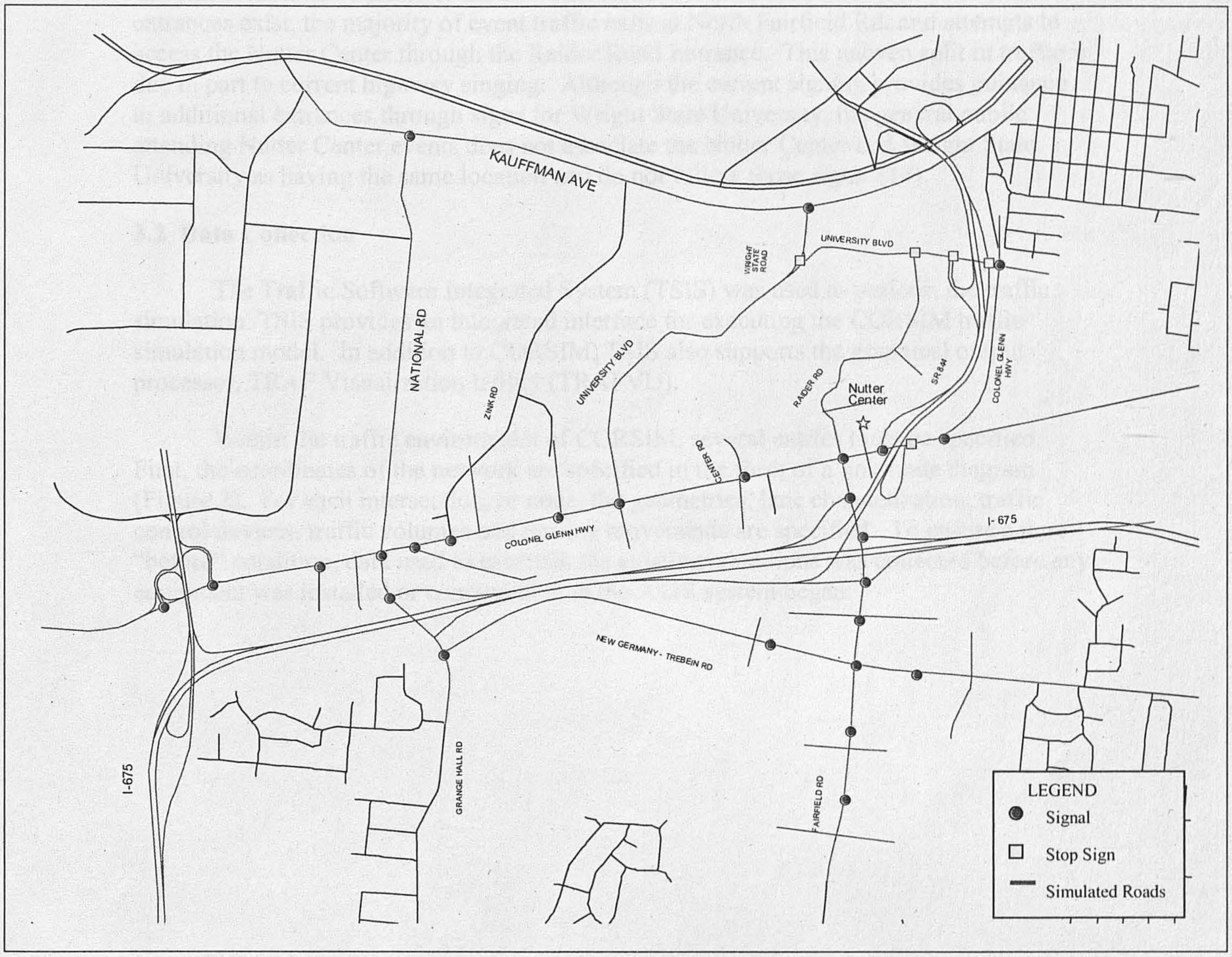
The documentation of existing conditions during Nutter Center special events is necessary in order to establish a baseline for comparing the impact of the proposed ATIS components. Additionally, the potential for recurring congestion during the non-event times will also be documented to achieve the second objective of the proposed demonstration project.

3.1 Study Area

The Nutter Center is a 13,000-seat multi-purpose entertainment and sports arena complex located at the northeast corner of North Fairfield Road and Colonel Glenn Highway (CGH) on the Fairborn, Ohio campus of Wright State University. The Nutter Center holds such events as college basketball games, professional hockey games and national touring concerts. Although there is only 0.25-mile between the Nutter Center and the I-675 exit along N. Fairfield Rd., significant congestion occurs during the ingress and egress of popular events along N. Fairfield Rd. and other surrounding routes as field studies indicate. Besides the Nutter Center, trips to and from Wright-Patterson Air Force Base, the Mall at Fairfield Commons with nearby dining complexes, multiple large corporate office complexes, and Wright State University also impact the congestion along I-675 and the local streets (14).

The study area is comprised of approximately 7-sq. mi. surrounding the Nutter Center area. The study area consists of two major arterials, Colonel Glenn Highway and North Fairfield Road (Figure 1). Additionally two freeway segments, I-675 and S.R. 844, are also encompassed within the study area. Throughout the study area there are 26 signalized intersections with actuated signals and 4 sign controlled intersections (Figure 1). Within the study area there are 33.5 miles of simulated roads.

Figure 1. Area Map



To properly simulate the existing traffic environment, three separate scenarios were modeled for the three existing conditions. These conditions include the ingress for the Aerosmith Concert on Tuesday December 3, 1998 (6:00 P.M. – 8:00 P.M.), the egress for the same Aerosmith Concert (10:15 P.M. – 11:45 P.M.), and a major shopping day on Wednesday December 23, 1998 (3:00 P.M. – 4:00 P.M.). With the exception of the shopping day, the entry node volumes were varied on a 15-minute interval to accurately represent the flow in and out of the Nutter Center area. Within each of these three scenarios, specific routes representing several alternate routes to the Nutter Center were studied. The specifics of these routes can be seen in detail in Section 3.4.

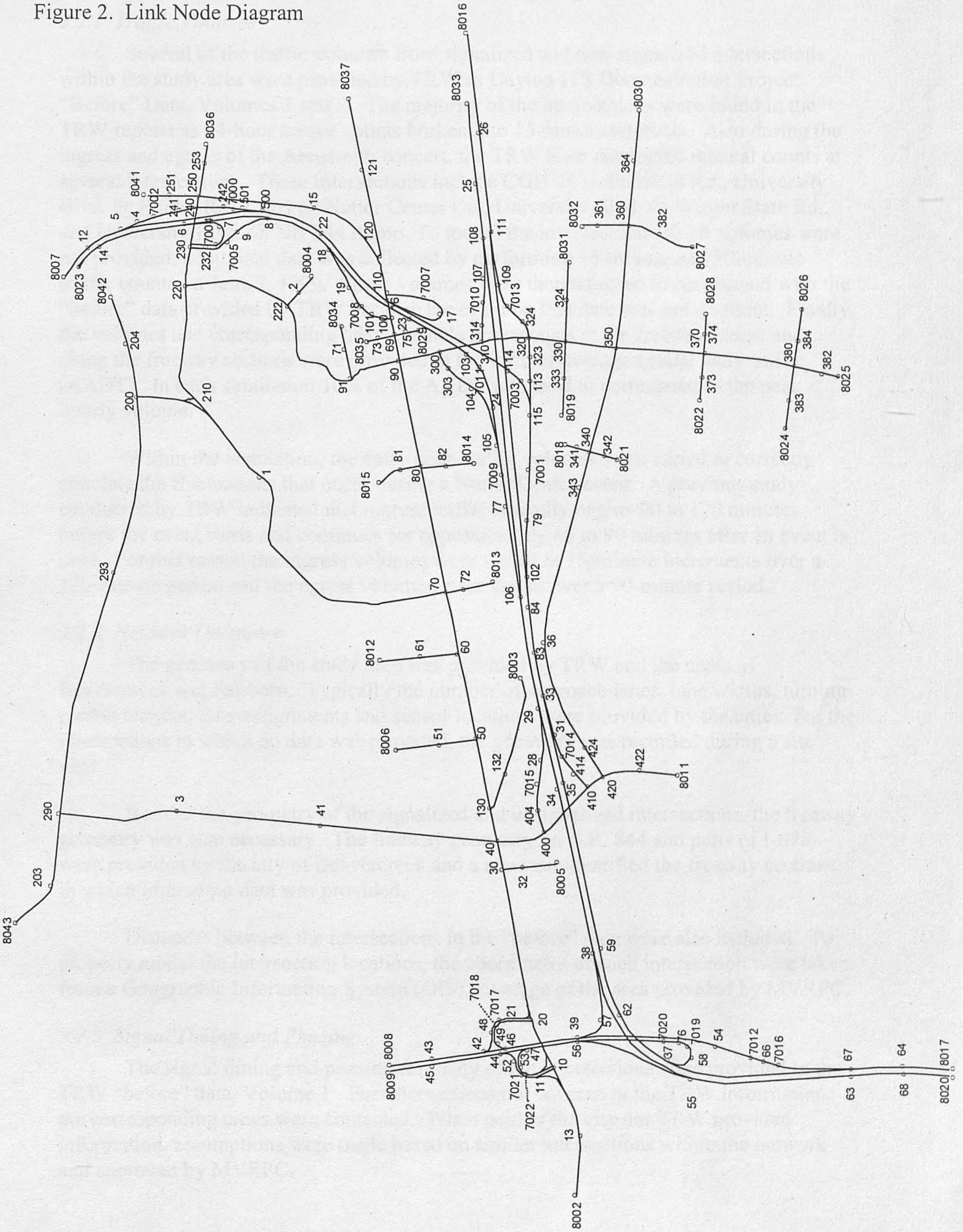
The Nutter Center can be accessed through two primary entrances. The first entrance is along Raider Road / North Fairfield at its intersection with CGH. The second entrance is located along University Boulevard, via either S.R. 844, Wright State Road / Kauffman Avenue or either of the two intersections with CGH. Although these two entrances exist, the majority of event traffic exits at North Fairfield Rd. and attempts to access the Nutter Center through the Raider Road Entrance. This uneven split in traffic is due in part to current highway singing. Although the current signing provides guidance to additional entrances through signs for Wright State University, the general public attending Nutter Center events does not associate the Nutter Center and Wright State University as having the same location and do not follow those signs (14).

3.2 Data Collection

The Traffic Software Integrated System (TSIS) was used to perform the traffic simulation. TSIS provides an integrated interface for executing the CORSIM traffic simulation model. In addition to CORSIM, TSIS also supports the graphical output processor, TRAF Visualization Utility (TRAFVU).

Within the traffic environment of CORSIM, several entries must be specified. First, the coordinates of the network are specified in the form of a link-node diagram (Figure 2). For each intersection, or node, the geometrics, lane channelization, traffic control devices, traffic volumes and turning movements are specified. To ensure a pure "before" condition, data used to establish the existing conditions was collected before any equipment was installed or construction on the ATIS system began.

Figure 2. Link Node Diagram



3.2.1 Traffic Volumes

Several of the traffic volumes from signalized and non-signalized intersections within the study area were provided by TRW as Dayton ITS Demonstration Project "Before" Data, Volumes 1 and 2. The majority of the intersections were found in the TRW reports as 24-hour sensor counts broken into 15-minute intervals. Also during the ingress and egress of the Aerosmith concert, the TRW team conducted manual counts at several intersections. These intersections include CGH @ N. Fairfield Rd., University Blvd. @ Raider Rd., CGH @ Nutter Center Cut, University Blvd. @ Wright State Rd., and University Blvd. @ NB 844 Ramp. To model the intersections which volumes were not provided, additional data was collected by performing 15-minute and 30-minute traffic counts on June 7, 1999. These volumes were then adjusted to correspond with the "before" data provided by TRW because the event on that date was not a sellout. Finally, the volumes and corresponding heavy vehicle percentages at the freeway ramps and along the freeway sections were provided in the form of average annual daily traffic (AADT). In each simulation 10% of the AADT was used to correspond to the peak hourly volume.

Within the simulation, the entry node traffic volumes were varied to correctly simulate the fluctuations that occur during a Nutter Center event. A previous study conducted by TRW indicated that ingress traffic typically begins 90 to 120 minutes before the event starts and continues for approximately 60 to 90 minutes after an event is over. For this reason the ingress volumes were varied in 15-minute increments over a 120-minute period and the egress volumes were varied over a 90-minute period.

3.2.2 Network Geometry

The geometry of the study area was provided by TRW and the cities of Beavercreek and Fairborn. Typically the number of approach lanes, lane widths, turning pocket lengths, lane assignments and sensor locations were provided by the cities. For the intersections in which no data was provided, the geometry was recorded during a site visit.

Besides the geometry of the signalized and unsignalized intersections, the freeway geometry was also necessary. The freeway geometry for S.R. 844 and parts of I-675 were provided by the city of Beavercreek and a site visit identified the freeway sections in which little or no data was provided.

Distances between the intersections in the "before" data were also included. To properly model the intersection locations, the coordinates of each intersection were taken from a Geographic Information System (GIS) coverage of the area provided by MVRPC.

3.2.3 Signal Timing and Phasing

The signal timing and phasing for many of the intersections were provided in the TRW "before" data, Volume 1. For intersections not covered in the TRW information, the corresponding cities were contacted. When neither the city nor TRW provided information, assumptions were made based on similar intersections within the network and approved by MVRPC.

Within the system there are 26 signals grouped into 3 closed loop systems. All of the signals are actuated with the call-to-non-actuated phase being the (major) system street. None of the subsystems are synchronized with each other, which can create delays and stops that could be avoided with a coordination. Additionally, system breaks occur during Nutter Center events at CGH @ Old Zink Rd., CGH between Meijer's and University Blvd./ S. Main, CGH @ N. Fairfield Rd., and at N. Fairfield Rd. @ I-675 SB (14). Due to the high number of system breaks, the signals throughout the system were not coordinated in the simulation.

Since all signals are fully actuated, the cycle length often varies and some phases are eliminated if there is no vehicle call; therefore, cycle lengths cannot be easily measured in the field. For this reason there were several assumptions made with regards to the signal timings in the NETSIM network when no data was given. Specifically, the signal timing and phasing for N. Fairfield Rd. @ Commons Blvd. was applied to New Germany Trebin Rd. (NGT) @ Mall entrance, NGT @ Wal-Mart Entrance, N. Fairfield Rd. @ N. Mall, and N. Fairfield Rd. @ S. Mall. This assumption was used since all of the intersections had similar geometry to N. Fairfield @ Commons Blvd., and all intersections were entrances to shopping centers. In addition to the previous intersections, the signal timing and phasing for N. Fairfield Rd. @ SB I-675 off ramp was applied to Grange Hall Rd. @ I-675 and the signal timing and phasing for CGH @ Zink Rd. was applied to Grange Hall Rd. @ NGT since no signal timings were provided. The assumption for Grange Hall Rd. @ I-675 was used since both intersections had similar geometry and were freeway interchanges. Finally, the assumption for Grange Hall Rd. @ NGT was used since both intersections had similar geometry.

In addition to signal timing and phasings, assumptions were made with regard to actuation. Several loops were added throughout the network to ensure that the actuated intersections could operate in a fully actuated mode as described in the data. This was also necessary to simulate the free environment found during egress. Also, when the actuation loop sizes were not specified in the drawings, their size was assumed to be 6' x 6', a standard size used in several locations by the cities and MVRPC.

3.3 Measures of Effectiveness

Within the simulation program CORSIM, there are a variety of measures of effectiveness (MOE) available for the NETSIM and FRESIM networks. These measures are used to quantify performance and effectiveness of network components. For the project there are several MOE that will be used, although the list is not exhaustive.

The first set of MOE used are travel measures such as average stopped delay, average total delay, and average moving time on a link by link basis. These delay measures are easily understood by the public and will indicate problem areas where modifications may be needed. Delay is also related to other measures such as level of service, which are used to show the quality of traffic flow within the system. The delay time can be combined with the moving time to determine a ratio of delay to total time. This ratio describes the percent of time that vehicles are actually moving within the system and indicates the efficiency of the network. Finally, the system speed is included to provide a system-wide measure showing the effect of traffic progression along the network.

Besides these travel measures, queue lengths are used as a MOE within the project. Queue lengths are generally used to determine the adequacy of turning lanes and examine the possibility of through movement blockage by the turning movements. The queue lengths are often used as an indicator of where geometric improvements may be needed.

The next MOE used for evaluation is the percent of vehicles stopped. This percentage is used as an indicator of flow quality throughout the network. Because average delay only addresses the time that vehicles are stopped, the percent of vehicles stopped can be used to address the frequency of stops and further describe the network conditions. It is important to note that short delays do not necessarily mean low percentages of vehicles stopped, which may indicate a bad coordination.

While choosing the MOE for evaluation, it is also important to understand what each of the MOE represents. One of the most frequently supplied MOE is delay time. The delay time is the additional average time that vehicles are detained in a network. Depending on the table in which the MOE is found, the unit of measurement varies from veh-min to sec/veh but still represents the same measure. Another MOE found in the CORSIM output is the move/travel ratio. This ratio is equal to the delay time of a vehicle divided by the total time and is an average for all vehicles within the link or system. Phase failures are also an important MOE used to detect the hotspots within a network.

In addition to understanding the MOE provided by the CORSIM software, it is also important for the user to understand the interrelation between them. For example, within the NETSIM Cumulative Statistics there are only three items of collected data: number of vehicles discharged, total time when discharged, and total queue time. From these three types of collected data nine other MOE are calculated which are the number of stops, vehicle miles (trips times the link length), move time (vehicle miles divided by the Free Flow Speed specified by the user), delay (total time minus the move time), delay in min/mi (total time divided by the vehicle miles), delay in sec/veh (total time divided by the number of trips), queue time (total queue time divided by the sum of the trips and the queued vehicles), volume (vehicle trips divided by the time), and speed (vehicle miles divided by the total time). Also in the NETSIM output there are 4 additional items of collected data. The collected data includes queue time, stop time number of phase failures and queue length. NETSIM presents the results in three tables: 1) Network Statistics by Link; 2) Turning Movement Statistics by Link; and 3) Person Measures Statistics. From the collected data found in the second table, all the data in the third table is calculated (15).

In addition to the MOE chosen from the CORSIM software, parking lot usage and customer interviews are two additional measures that will be used in this project. Parking lot usage will be measured to determine how effectively each parking lot is filled and when it is filled. The parking lot usage can be used to determine the effectiveness of the intended traffic volume balancing after the installation of the ATIS components.

Customer interviews will also be conducted to determine the market penetration of the different means to deliver the routing information to the drivers. Due to the nature of these MOE, the interviews and parking studies will be conducted after the implementation of the system and will not be included in the Existing Conditions report.

3.4 Data Analysis

To simulate the traffic conditions surrounding the Nutter Center area, the TSIS traffic simulation model was used. TSIS provides a simulation of current conditions and allows for simulating freeway and local street operation simultaneously while providing a wide range of measures of effectiveness.

For each one of the three scenarios modeled in the project, five runs were conducted with separate random numbers. The five runs were performed to avoid possible outliers due to the stochastic nature of the CORSIM program. The results are then averaged to obtain the final MOE estimates.

3.4.1 Validation of Simulation Model

A travel time study was conducted along the major paths of travel during the Glenn Campbell concert on June 7, 1999. The ingress and egress travel paths can be seen in Figures 3 through 9. These travel times were used for validating the simulation model to be used in the evaluation process.

Figure 3. Ingress Route 1

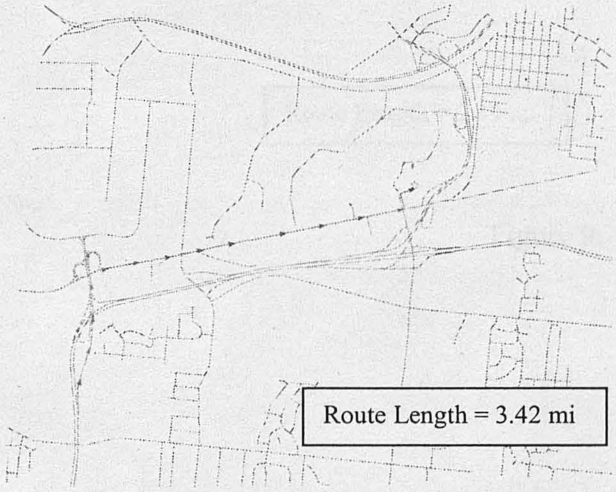


Figure 4. Ingress Route 2

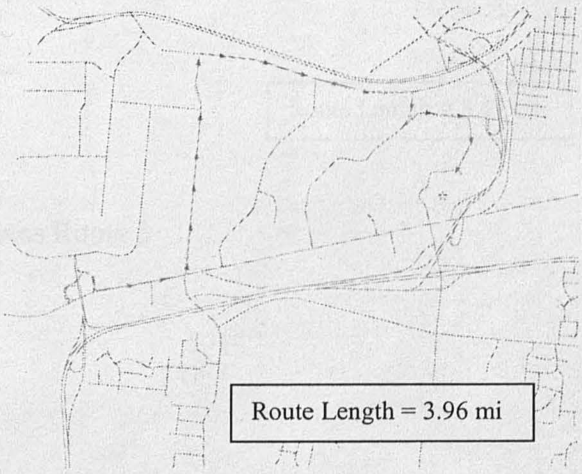


Figure 5. Ingress Route 3

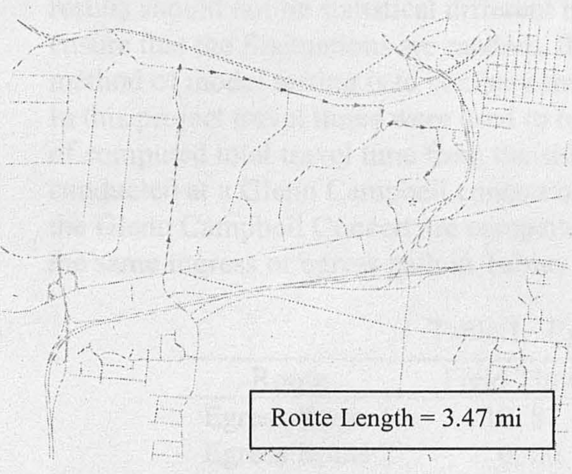


Figure 6. Ingress Route 4

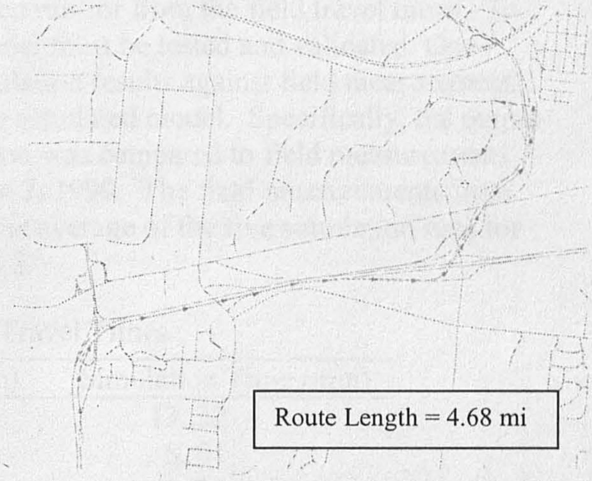


Figure 7. Egress Route 1

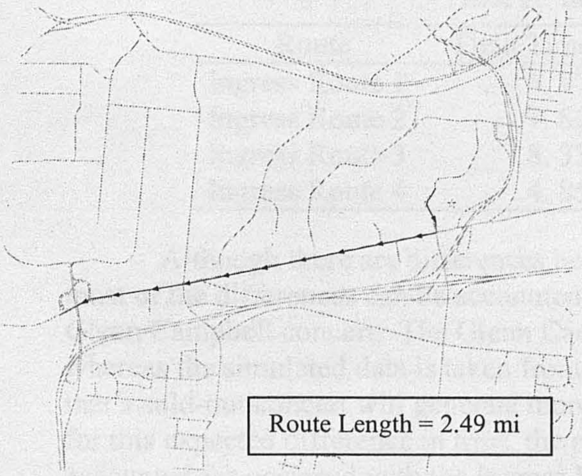


Figure 8. Egress Route 2

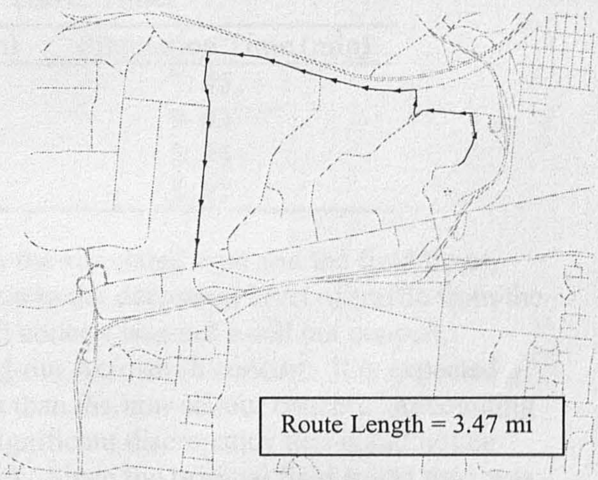
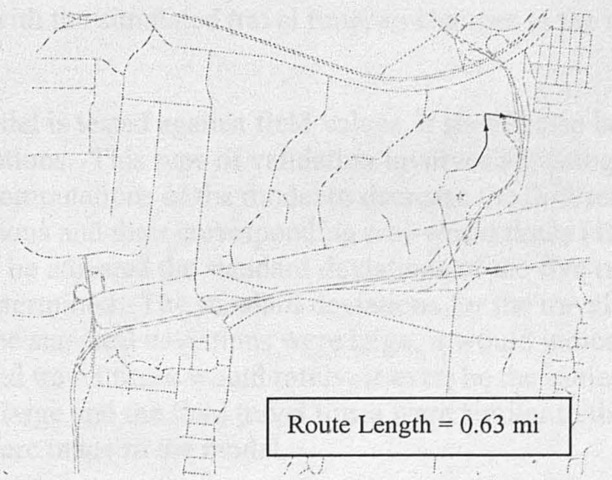


Figure 9. Egress Route 3



Although the stochastic nature of the program creates expected fluctuations, the results should not be statistical different between runs or from the field travel times. To ensure that the fluctuations are random, the model must be tested and validated. One method of model testing is to compare the simulation results against field measurements. In this project travel times were used to test the simulated model. Specifically, the output of computed total travel time from the simulation was compared to field measurements conducted at a Glenn Campbell concert on June 7, 1999. The field measurements from the Glenn Campbell Concert are compared to the average of the five simulation runs for the same ingress or egress path in Tables 1 and 2.

Table 1. Egress Travel Times

Route	Field Time (min)	Simulation Time (min)
Egress Route 1	10. 87	13. 32
Egress Route 2	6. 20	8. 01
Egress Route 3	1. 70	1. 30

Table 2. Ingress Travel Times

Route	Field Time (min)	Simulation Time (min)
Ingress Route 1	6. 97	7. 45
Ingress Route 2	7. 80	9. 93
Ingress Route 3	8. 33	8. 38
Ingress Route 4	4. 85	5. 97

Although there are differences between the simulated time and the field times, most of the differences can be accounted for due to the decreased level of traffic from the Glenn Campbell concert. The Glenn Campbell concert was not a sell out concert, whereas the simulated data is taken from a sold-out Aerosmith concert. It is expected that a sold-out concert will generate more trips than the non-sellout concert. Accounting for this expected difference in trips, the only significant discrepancy that could not be accounted for occurred with the Ingress Route 3. Since the original field travel time was significantly less than the simulated travel time, an additional travel time study was conducted along that route at a ZZ Top concert, October 12, 1999. The new field travel time corresponded with the simulated travel time, so changes to the model were not made.

Once the model is tested against field values, it should also be validated against possible traffic variations. This type of validation involves adjusting uncertain variables within the internal computations of the model to decrease the differences in travel time between the simulations and their corresponding real-world times (16). To determine if the model needed to be adjusted the standard deviations of the five runs of each ingress or egress route were determined. The standard deviations for the travel times can be seen in Tables 3 and 4. If the standard deviations were large, it would indicate that the model was very unstable and travel times would rarely, if ever, be the same. Since the standard deviations were not large and the field travel times were similar to the simulated travel times, no changes were made to the model.

Table 3. Ingress Travel Time Validation

	Ingress Route 1	Ingress Route 2	Ingress Route 3	Ingress Route 4
Mean (min)	7.47	10.31	8.70	5.96
Standard Deviation (min)	0.17	0.45	0.46	0.14
95% Confidence Interval (min)	±0.18	±0.47	±0.48	±0.15
Upper Limit (min)	7.70	10.93	9.34	6.16
Lower Limit (min)	7.24	9.70	8.07	5.77

Table 4. Egress Travel Time Validation

	Egress Route 1	Egress Route 2	Egress Route 3
Mean (min)	13.31	8.01	1.30
Standard Deviation (min)	1.49	0.67	0.01
95% Confidence Interval (min)	±1.85	±0.84	±0.01
Upper Limit (min)	15.16	8.85	1.31
Lower Limit (min)	11.46	7.18	7.18

3.4.2 Simulation Results

The UK team examined network wide statistics along with several specific MOE. The network wide statistics by scenario can be seen in Table 5.

Table 5. Network-wide Statistics

	Ingress	Egress	Shopping
Total Travel (veh-mi)	60441.10	41945.30	34956.00
Move Time (veh-hr)	1340.79	1226.27	796.46
Delay Time (veh-hr)	637.66	1251.55	720.04
Total Time (veh-hr)	1978.46	2477.83	1516.51
Speed (mph)	30.55	17.53	23.06
Move/Total Ratio	0.68	0.49	0.52
Delay Time (min/mi)	0.63	1.83	1.24
Total Time (min/mi)	1.96	3.65	2.60

Based on these estimates, the ingress simulation had the highest total vehicle miles indicating the highest number of vehicles within the system. This correctly reflects the current conditions because it accounts not only for the ingress traffic of the concert but for the additional PM peak traffic which coincides with the concert ingress. However, despite the higher number of vehicles, the move time for the ingress simulation as well as the move to total ratio was also the highest among the three scenarios indicating that there were relatively few problems within the ingress network. Contrary to the ingress simulation, the egress simulation encountered the lowest move to total ratio and the highest delay times. This can be due to the differences in vehicle distribution over the time period of interest. For example, patrons attending a concert are more likely to arrive early for a concert thus spreading out their arrivals, whereas once a concert is complete all patrons typically leave at the same time. Specifically, a TRW study found that ingress traffic typically begins 90 to 120 minutes before the event starts. However with the different events, varying patrons attend and with that variation a different temporal dispersion of traffic can be observed. To further understand the problem areas within the study area, specific routes need to be studied in detail.

Besides the network statistics, several route specific MOE were studied. For a better comprehension of the MOE results, each of the measures were computed for the predefined ingress and egress routes (Figures 3-9) along with an additional route defined by MVRPC (Figures 10-11).

Figure 10. Ingress Route 5

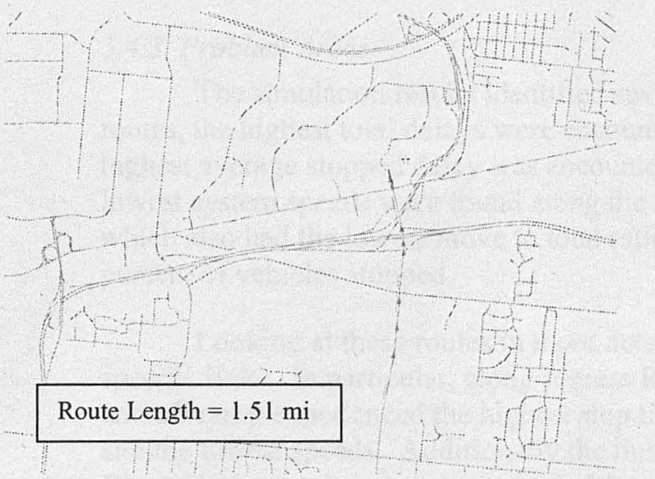
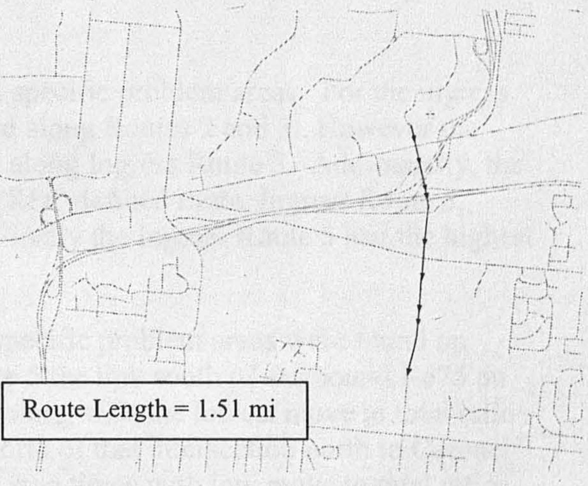


Figure 11. Egress Route 4



For the additional shopping study, various routes from the ingress and the egress were used. Ingress Routes 1,4, and 5 represent Shopping Routes 1 through 3 respectively and Egress Routes 1 and 4 represent Shopping Routes 4 and 5 respectively. The resulting average MOE values by routes can be seen in Tables 6, 7 and 8. Additional MOE and supporting calculations including total delay (veh-min), moving time (s/v), maximum queue lengths (veh), stopped delay (s/v), percent of vehicles stopped (%) and density (veh/ln-mi) are shown in appendices B – G. A discussion of these MOE follows in the next section.

Table 6. Egress Routes MOE

MOE	Egress Route 1	Egress Route 2	Egress Route 3	Egress Route 4
Average Total Delay (s/v)	30.10	18.95	8.13	55.38
Average System Speed (mph)	16.26	24.62	24.02	7.69
Average M/T ratio	0.41	0.68	0.74	0.19

Table 7. Ingress Routes MOE

MOE	Ingress Route 1	Ingress Route 2	Ingress Route 3	Ingress Route 4	Ingress Route 5
Average Total Delay (s/v)	13.73	31.28	33.29	11.77	20.90
Average System Speed (mph)	24.95	22.21	22.61	40.42	16.35
Average M/T ratio	0.57	0.54	0.56	0.92	0.40

Table 8. Shopping Routes MOE

MOE	Shopping Route 1	Shopping Route 2	Shopping Route 3	Shopping Route 4	Shopping Route 5
Average Total Delay (s/v)	35.18	11.69	23.33	23.48	39.88
Average System Speed (mph)	17.47	41.81	15.41	18.68	10.69
Average M/T ratio	0.37	0.93	0.37	0.46	0.26

3.4.3 Problem Areas

The simulation results identified several specific problem areas. For the ingress routes, the highest total delays were encountered along Routes 2 and 3. However the highest average stopped delay was encountered along Ingress Route 5. Additionally, the lowest system speeds were found along the MVRPC defined route, Ingress Route 5, which also had the lowest move to total ratio. Finally the Ingress Route 5 had the highest percent of vehicles stopped.

Looking at these routes in more detail, specific problem areas were found on specific links. In particular, along Ingress Route 5 the link south of eastbound I-675 on and off ramp experienced the highest stop time along with the lowest move to total ratio and the lowest speeds. Additionally the links north of that intersection north to Colonel Glenn Highway also experience high delay and stop times with low move to total ratios and low speeds.

Next along the shopping routes, the most problems were encountered along the Shopping Route 5. Along this route the average total delay per vehicle was the highest and the move to total ratio and the speed were the lowest. Additionally Shopping Routes 1 and 3 experienced low move to total ratios. Shopping Route 1 also had the highest total delay and the highest average stopped delay per vehicle.

A detailed analysis of the shopping routes revealed that along the Shopping Route 5 high delays were experienced between the westbound I-675 on and off ramps. As in the ingress routes, these problems continued up to Colonel Glenn Highway. Shopping Route 3 covers the same roadway sections, but in the other direction. Along Shopping Route 3, delays were experienced along the same sections of N. Fairfield Rd. Problems were also experienced around the N. Mall entrance along N. Fairfield Road. This is expected since the mall is a destination of trips within this simulation. Finally, Shopping Route 1 along Colonel Glenn Highway experienced delays. Specific problem areas occurred along Colonel Glenn Highway between University Blvd. and Raider Road. Incidentally, this is also where signal systems are divided between jurisdictions.

Problems also occurred at CGH @ National, which is one intersection adjacent to another system break, CGH @ Old Zink Road.

Finally, along the egress routes, Egress Route 5 experienced the highest total delays, highest stopped delay and highest average percent of vehicles stopped. This route also encountered the lowest system speed and move to total ratio. Egress Route 1 had the second highest total delay, stopped delay, and % vehicles stopped, coupled with the second lowest system speed and move to total ratio.

Egress Route 1 experienced problems along CGH from the exit of the Nutter Center until traffic passed the National Road intersection. Problems also occurred after the signal system break at Zink Road. Looking at specific links along Egress Route 5 problem areas were found along many of the same sections where problems were experienced in the other two simulations. Specifically in Egress Route 5, problems occurred along N. Fairfield Rd. from CGH until the eastbound I-675 exits. TRW noted these same problem areas while observing the egress system on a sold-out concert. Specifically, a study team from TRW observed the egress on a sold-out Phil Collins concert at the Nutter Center on Tuesday, March 11, 1997. The team observed that queuing along southbound N. Fairfield Road was due to egress traffic desiring to turn left onto eastbound I-675, as opposed to traffic turning right onto westbound I-675. The westbound traffic levels during the concert egress were similar to what is experienced during the PM-peak on a daily basis when there are no Nutter Center events. However the eastbound traffic levels during the concert egress were 2.5 times the typical PM-peak volumes. This indicates the need to disperse Nutter Center traffic over multiple interchanges (14).

This need to disperse traffic leads to another problem area, the roadway geometry with regards to freeway connections. Specifically there is no direct freeway-to-freeway connection between Westbound I-675 and Northbound S.R. 844. Also there is no direct freeway-to-freeway connection between Southbound S.R. 844 and Eastbound I-675. This creates an unusual situation where vehicles desiring to travel east on I-675 must exit S.R. 844 at Colonel Glenn Highway and make a series of left turns conflicting with egressing traffic from the Nutter Center (14).

The final problem area encountered in the TRW study is the lack of sufficient parking. The parking areas of the Nutter Center, capable of holding a 13,000-person crowd, have a total of 4,033 spaces. With the current parking situation, vehicle occupancy rates need to exceed an unusually high and often unattainable rate of 3.2 persons per car to handle the Nutter Center capacity (14). Although parking is a problem in the area, the associated problems will not be addressed in detail throughout this report

4.0 SUMMARY AND CONCLUSIONS

The primary objective of the Dayton ITS Demonstration project is to demonstrate the effectiveness of the ATIS devices in providing real-time information to travelers accessing the Nutter Center during special events and managing congestion and traffic during such events. This project, the study of existing conditions, is part of the evaluation plan required by ISTEA to assess the benefits of the project and show system improvements after the implementation. The first task completed in this study is the documentation of the existing conditions through a simulation model. This model was created using TSIS and validated using travel time studies. The second task completed in this project was the definition of MOE. The MOE were selected from the simulation output and presented for each predefined route.

In conclusion, it can be speculated that the majority of the traffic problems surrounding the Nutter Center area can be attributed to the uncoordinated signal systems and the need to disperse traffic through alternative routes. The proposed CMS can help to alleviate the problems associated with appropriate warning signs, a problem noted by the UK team through site visits. Currently the signage around the Nutter Center directs traffic to one major exit, although several more exits exist. The proposed CMS and additional static signs have the potential to redirect traffic and distributing traffic more evenly throughout the study.

The proposed CMS will attempt to disperse traffic throughout the network, trying to alleviate some of the existing traffic problems. The system's success in alleviating congestion will be evaluated in future reports. In addition to the proposed CMS and ATIS system, coordination of the signal systems would further decrease the problems experienced in the Nutter Center area.

Throughout the study CORSIM, and its ability to handle the complex actuated signal system of the area, has been a powerful demonstration tool accurately representing the existing conditions and identifying specific problem areas. As the study progresses after the CMS are in place, the CORSIM network will again be used to evaluate the effectiveness of the ATIS devices in providing real time information to patrons attending Nutter Center events and managing traffic during those events.

5.0 REFERENCES

1. Rao, K., S. Venglar, R. Sarma, and V. Bogarapu, *Real-time Assessment and Use of Arterial Street Capacity for Freeway Diversion Routing.* Report No. TX-97/2978-1F. Texas: Texas Department of Transportation, 1996.

2. Parsons Brinckerhoff, *Intelligent Transportation Systems Measures of Effectiveness. Final Report.* New Jersey: New Jersey Department of Transportation, 1996.

3. Hamerslag, R., and E. VanBerkum, "Effectiveness of Information Systems in Networks With and Without Congestion". *Transportation Research Record* 1306 (1991): 14-21.

4. Mahmassani, H. and P. Chen, "Comparative Assessment of Origin-Based and En Route Real-Time Information Under Alternative User Behavior Rules". *Transportation Research Record* 1306 (1991): 69-81.

5. *Dayton ITS Demonstration Project: Project Evaluation.* Proposal to MVRPC. Kentucky Transportation Center and Department of Civil Engineering, University of Kentucky. Kentucky: University of Kentucky, 1998.

6. Vorce, K. and M. Plass, "A Practical Approach to Changeable Message Sign System Design and Deployment; The I-595 Experience in South Florida". *Third Annual World Congress on Intelligent Transport Systems.* Florida: 14-18 October 1996.

7. Dudek, C., *Guidelines on the Use and Operation of Changeable Message Signs.* Report No. FHWA/TX-92/1232-10. Texas: Texas Transportation Institute, 1992.

8. Tarko, A. and N. Rouphail, "Intelligent Traffic Data Processing for ITS Applications". *Journal of Transportation Engineering.* July/August 1997: 298-307.

9. Kaman Sciences Corporation, *Traffic Software Integrated System 97 User's Guide.* Washington, D.C.: Federal Highway Administration, 1997.

10. Boone, J. and J. Hummer, "Calibrating and Validating Traffic Simulation Models for Unconventional Arterial Intersection Designs". *Transportation Research Record* 1500 (1995): 184-192.

11. Sulzberg, J. and M. Demetsky, *Demonstration of Traf-Netsim for Traffic Operations Management.* Final Report. Virginia: Virginia Transportation Research Council, 1991.

12. Wong, S., "TRAF-NETSIM: How It Works, What It Does". *ITE Journal.* April 1990: 22-27.

13. Dixon, M., "Calibrating and Validating TRAF-NETSIM Model of Single-Point Urban Interchange". *Transportation Research Record* 1591 (1997): 38-44.

14. TRW Inc. with L.J.B. Engineers and TEC Engineering, *The Dayton ITS Demonstration Project (I-675, Colonel Glenn Hwy., N. Fairfield Rd).* Formal Deliverable #1: The Preliminary Engineering Document. 1 November 1998.

15. Federal Highway Administration, *Advanced Intersection Analysis with Computer Models.* Seminar Notes. Orlando, FL: 17-21 January 1994.

16. Nsour, S. and A. Santiago, "Comprehensive Plan Development for Testing, Calibration and Validation of CORSIM". *64th ITE Annual Meeting, Compendium of Technical Papers.* Dallas, TX 16-19 October, 1994: 486-490.

Appendices

Appendix A. Acronyms

AADT	Average Annual Daily Traffic
ATIS	Advanced Traveler Information System
CGH	Colonel Glenn Highway
CMS	Changeable Message Sign
FHWA	Federal Highway Administration
GIS	Geographic Information System
ISTEA	Intermodal Surface Transportation Efficiency Act
ITS	Intelligent Transportation Systems
MOE	Measures of Effectiveness
MVRPC	Miami Valley Regional Planning Commission
NGT	New Germany Trebin Road
RTI	Road Transport Informatics
TEA-21	Transportation Equity Act for the 21st Century
TRAFVU	TRAF Visualization Utility
TSIS	Traffic Software Integrated System
UK	University of Kentucky

Appendix B. Egress MOE Values

Egress Route 1

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop delay
20-10	131.57	835.40	175.42	295.00	7,186.62	0.16	26.83	38,273.20	3,593.88
30-20	460.38	1,030.00	613.86	762.50	8,904.50	0.45	36.32	35,469.00	2,352.10
40-30	101.95	1,079.80	135.92	235.20	5,959.76	0.09	26.02	14,127.00	1,674.46
60-50	421.71	1,310.20	562.28	1,030.32	28,127.82	0.32	24.58	83,141.40	14,021.18
70-60	312.22	1,460.80	416.30	696.82	16,815.28	0.21	26.89	60,379.00	4,930.74
80-70	423.52	1,212.40	730.82	1,785.16	63,257.16	0.35	14.43	102,161.00	38,347.30
90-80	408.29	1,314.60	704.50	1,690.58	59,185.28	0.31	14.80	103,382.80	38,181.46
130-40	145.80	1,449.80	194.40	755.00	33,671.32	0.10	11.63	92,548.60	21,903.12
50-130	171.39	1,439.60	228.52	392.46	9,816.16	0.12	26.26	24,597.80	2,431.88
91-90	204.48	974.40	352.84	2,673.06	139,235.18	0.21	5.49	81,577.40	203,794.72

Egress Route 2

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop delay
41-40	309.48	522.40	534.00	788.82	15,300.96	0.59	23.54	39,893.40	12,539.84
210-200	49.55	327.60	99.10	195.64	5,784.08	0.15	15.33	24,726.60	3,489.80
220-210	217.00	729.80	374.44	715.34	20,463.72	0.30	18.65	51,542.60	6,668.30
293-290	256.62	473.60	442.80	750.70	18,472.22	0.54	21.18	19,084.80	4,332.06
200-293	339.59	477.00	585.96	794.46	12,516.14	0.71	26.06	0.00	0.00
3-41	179.58	525.60	216.46	223.78	442.08	0.34	48.16	0.00	0.00
290-3	186.49	526.40	224.82	268.30	2,611.62	0.35	41.71	0.00	0.00
222-220	292.07	1,049.60	584.12	798.94	12,896.42	0.28	21.93	104,960.00	5,584.58

Egress Route 3

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop delay
220-230	79.61	656.60	137.34	191.38	3,241.96	0.12	24.92	0.00	2,191.10
230-240	49.78	412.40	85.92	100.20	854.20	0.12	29.81	169.20	66.64
222-220	292.07	1,049.60	584.12	798.94	12,896.42	0.28	21.93	104,960.00	5,584.58

Egress Route 4

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop delay
91-90	204.48	974.40	352.84	2,673.06	139,235.18	0.21	5.49	81,577.40	197,095.72
90-300	183.25	1,636.40	273.32	2,962.98	161,414.58	0.11	4.04	134,088.40	200,410.98
300-310	164.80	1,318.40	245.80	3,639.26	203,634.96	0.13	2.83	120,148.60	144,462.28
310-320	221.49	1,719.80	330.36	4,237.22	234,427.90	0.13	3.17	168,467.20	127,124.58
320-330	282.12	1,969.80	420.78	977.88	33,419.64	0.14	17.29	99,973.40	19,942.04
330-350	231.88	1,834.60	345.86	1,165.32	49,197.22	0.13	11.95	105,962.60	26,556.08
350-370	207.02	1,651.20	308.78	667.20	21,517.08	0.13	18.63	105,383.60	6,989.36
370-380	266.25	931.20	397.10	590.46	11,583.26	0.29	27.15	40,640.80	4,959.00

Appendix C. Egress MOE Calculations

Egress Route 1

Average Total Delay = **3.10 s/v**
103.35 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = **20.37 s/v**
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = **16.25 mph**
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = **0.41**
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= **52.36 %**
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= **N/A veh/ln-mi**
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = **28.01 s/v**
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Egress Route 2

Average Total Delay = **18.95 s/v**
24.57 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = **39.66 s/v**
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = **24.62 mph**
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = **0.68**
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= **51.80 %**
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= **N/A veh/ln-mi**
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = **6.75 s/v**
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Egress Route 3

Average Total Delay = **8.13 s/v**
5.92 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = **22.96 s/v**
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = **24.02 mph**
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = **0.74**
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= **50.08 %**
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= **N/A veh/ln-mi**
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = **5.51 s/v**
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Egress Route 4

Average Total Delay = **55.38 s/v**
126.96 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = **13.37 s/v**
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = **7.69 mph**
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = **0.19**
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= **68.86 %**
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= **N/A veh/ln-mi**
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = **77.71 s/v**
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Appendix D. Ingress MOE Values

Ingress Route 1

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop Delay(s)
21-20	3.62	75.80	7.22	23.72	990.60	0.05	9.18	6,635.00	836.90
20-30	642.38	1,437.20	856.52	1,092.48	14,143.38	0.45	35.27	39,940.20	4,369.06
30-40	133.34	1,408.40	177.80	1,200.72	61,386.62	0.09	6.68	121,691.60	45,385.46
50-60	490.94	1,524.80	654.58	964.08	18,566.00	0.32	30.56	42,384.60	6,277.54
60-70	374.31	1,749.00	499.08	1,057.78	33,499.98	0.21	21.24	144,816.40	14,439.20
70-80	316.51	903.80	546.14	886.02	20,400.52	0.35	21.44	57,472.00	13,282.36
80-90	446.65	1,433.20	770.70	1,051.92	16,886.16	0.31	25.49	104,362.20	7,544.04
7018-21	4.18	75.80	6.32	6.32	0.00	0.06	39.51	0.00	0.00
40-130	175.84	1,780.20	234.44	442.96	12,527.66	0.10	23.81	44,477.60	3,271.60
130-50	191.20	1,597.60	329.92	819.68	29,382.94	0.12	14.01	96,548.20	20,564.84
90-91	289.61	1,383.00	499.74	806.62	18,411.86	0.21	21.56	266.80	138.30
7016-66	14.88	467.60	8.06	8.06	0.00	0.03	114.54	0.00	0.00
66-7012	11.95	467.40	23.90	24.22	18.24	0.03	29.69	0.00	0.00
	Vehicle Miles	Vehicles Out	Move time (veh-min)	Total time (veh-min)	Total Delay (s/v)	Distance (mi)	Speed (mph)	Density(veh/ln)	
39-46	182.20	809.40	241.60	250.71	550.92	0.23	43.47	0.70	
46-49	2.34	76.00	3.76	4.12	22.80	0.03	32.80	0.03	
49-7018	2.44	76.00	3.87	4.14	15.20	0.03	35.69	0.03	
54-39	136.58	467.60	178.66	181.11	140.28	0.29	44.94	0.75	
67-7016	38.14	467.80	34.63	42.34	467.80	0.08	54.35	0.18	
7012-54	42.06	467.80	38.70	63.09	1,403.40	0.09	41.50	0.27	

Ingress Route 2

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop Delay(s)
20-30	642.38	1,437.20	856.52	1,092.48	14,143.38	0.45	35.27	39,940.20	4,369.06
30-40	133.34	1,408.40	177.80	1,200.72	61,386.62	0.09	6.68	121,691.60	45,385.46
40-41	389.95	659.60	470.06	553.90	5,044.66	0.59	42.27	0.00	0.00
200-210	69.20	462.80	119.38	197.48	4,676.56	0.15	21.04	9,343.60	1,728.88
210-220	176.92	595.00	305.30	428.40	7,383.28	0.30	25.04	0.00	0.00
290-293	649.23	1,201.20	1,120.24	1,885.76	45,930.70	0.54	20.72	0.00	0.00
293-200	827.83	1,162.80	1,428.40	3,384.30	117,339.88	0.71	14.84	91,907.40	23,138.90
41-3	225.09	658.80	271.34	342.78	4,290.66	0.34	39.57	136.00	27.20
3-290	234.09	656.40	282.20	582.44	18,017.92	0.36	24.29	55,624.80	6,529.92
220-222	377.03	1,344.60	754.06	1,111.30	21,436.50	0.28	20.38	10,229.20	0.00

Ingress Route 3

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop Delay(s)
40-41	389.95	659.60	470.06	553.90	5,044.66	0.59	42.27	0.00	0.00
200-210	69.20	462.80	119.38	197.48	4,676.56	0.15	21.04	9,343.60	1,728.88
210-220	176.92	595.00	305.30	428.40	7,383.28	0.30	25.04	0.00	0.00
290-293	649.23	1,201.20	1,120.24	1,885.76	45,930.70	0.54	20.72	0.00	0.00
293-200	827.83	1,162.80	1,428.40	3,384.30	117,339.88	0.71	14.84	91,907.40	23,138.90
41-3	225.09	658.80	271.34	342.78	4,290.66	0.34	39.57	136.00	27.20
3-290	234.09	656.40	282.20	582.44	18,017.92	0.36	24.29	55,624.80	6,529.92
220-222	377.03	1,344.60	754.06	1,111.30	21,436.50	0.28	20.38	10,229.20	0.00

Ingress Route 4

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop Delay(s)
230-220	155.33	1,242.60	268.00	359.70	5,464.04	0.13	25.93	6,697.20	323.22
240-230	110.21	909.20	190.18	227.22	2,217.70	0.12	29.13	0.00	90.92
242-240	34.15	745.00	68.30	160.18	5,512.22	0.05	12.80	74,199.40	3,232.62
7000-242	22.17	745.60	25.98	25.98	0.00	0.03	50.97	0.00	0.00
220-222	377.03	1,344.60	754.06	1,111.30	21,436.50	0.28	20.38	10,229.20	0.00
7001-115	68.72	3,422.80	79.94	79.94	0.00	0.02	52.42	0.00	0.00
115-7003	44.64	2,288.20	89.28	96.12	457.64	0.02	28.09	0.00	0.00
	Vehicle Miles	Vehicles Out	Move time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Density(v/ln)	
500-501	55.68	747.00	94.54	99.00	298.80	0.07	33.13	0.81	
501-7000	29.30	745.60	48.05	51.69	223.68	0.04	34.51	0.43	
16-22	689.74	2,596.20	823.51	869.07	2,648.06	0.27	47.58	3.62	
114-16	940.28	2,278.80	1,130.21	1,158.42	1,823.82	0.41	48.54	4.81	
59-35	3,056.56	5,912.80	3,350.01	3,472.27	7,686.64	0.52	52.87	9.64	
37-62	1,034.04	5,913.80	1,118.84	1,193.29	4,494.84	0.17	52.11	3.32	
62-59	1,321.32	5,912.40	1,432.30	1,493.09	3,547.44	0.22	53.00	4.16	
65-37	332.64	5,001.00	351.27	371.23	1,500.30	0.07	53.94	1.03	
67-65	707.40	5,001.60	766.81	803.61	2,500.80	0.14	52.49	2.22	
22-500	595.80	2,590.60	720.92	750.71	1,657.62	0.23	47.86	3.14	
102-79	948.76	3,426.80	1,265.65	1,309.29	2,604.32	0.28	43.52	5.44	
79-7001	679.90	3,423.40	1,139.51	1,192.54	3,217.98	0.20	34.37	4.99	
7003-114	215.26	2,286.80	198.91	334.09	7,866.14	0.09	39.96	1.44	
33-83	590.80	6,348.40	632.16	703.05	4,190.68	0.09	50.61	1.46	
83-84	1,147.86	6,347.00	1,246.57	1,317.74	4,442.90	0.18	52.42	2.74	
84-102	638.12	6,347.60	710.87	828.28	6,982.64	0.10	46.52	1.73	
35-33	1,352.26	5,910.40	1,471.26	1,582.14	6,619.72	0.23	51.29	4.39	

Ingress Route 5

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop Delay (s)
380-370	638.73	2,241.20	952.68	1,693.72	44,419.18	0.28	22.63	124,150.80	22,951.22
370-350	326.26	2,605.20	486.64	1,581.04	65,660.60	0.13	12.40	187,021.60	47,942.48
350-330	292.05	2,321.00	435.58	1,166.20	43,863.98	0.13	15.05	126,246.60	26,224.82
330-320	408.78	2,863.00	609.70	1,879.50	76,167.76	0.14	13.06	217,603.60	43,869.36
320-310	302.70	2,350.40	451.50	895.34	26,602.46	0.13	20.27	94,469.60	11,748.10
310-300	389.49	3,121.80	580.94	1,811.02	73,831.20	0.12	12.97	153,627.60	37,102.66
300-90	260.61	2,255.80	388.70	1,240.60	51,115.36	0.12	12.61	178,579.80	31,304.58
90-91	289.61	1,383.00	499.74	806.62	18,411.86	0.21	21.56	266.80	138.30

Appendix E. Ingress MOE Calculations

Ingress Route 1

Average Total Delay = 13.73 s/v
3,814.45 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = 18.41 s/v
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = 24.95 mph
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = 0.57
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= 46.04 %
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= 2.61 veh/ln-mi
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = 8.12 s/v
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Ingress Route 2

Average Total Delay = 31.28 s/v
4,994.26 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = 36.21 s/v
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = 22.21 mph
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = 0.54
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= 34.31 %
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= N/A veh/ln-mi
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = 8.47 s/v
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Ingress Route 3

Average Total Delay = 33.29 s/v
3,735.38 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = 42.29 s/v
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = 22.61 mph
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = 0.56
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= 24.81 %
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= N/A veh/ln-mi
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = 4.67 s/v
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Ingress Route 4

Average Total Delay = 1.20 s/v
1,612.81 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = 13.24 s/v
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = 40.42 mph
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = 0.92
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= 8.52 %
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= 16.69 veh/ln-mi
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = 0.34 s/v
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Ingress Route 5

Average Total Delay = 20.90 s/v
6,668.56 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = 13.81 s/v
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = 16.35 mph
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = 0.40
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= 56.53 %
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= N/A veh/ln-mi
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = 11.56 s/v
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Appendix F. Shopping MOE Values

Shopping Route 1

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop Delay (s)
21-20	1.84	38.60	3.68	13.10	564.60	0.05	8.59	3,584.40	477.96
20-30	385.11	861.60	513.48	722.96	12,548.84	0.45	32.01	34,651.20	4,981.70
30-40	80.22	847.40	106.96	920.62	48,827.68	0.09	5.55	76,102.60	36,129.72
50-60	245.08	761.20	326.80	483.66	9,410.52	0.32	30.42	21,714.40	3,341.54
60-70	185.68	867.60	247.58	700.46	27,159.02	0.21	16.12	66,468.00	17,782.80
70-80	365.78	1,044.20	631.16	3,449.60	169,093.86	0.35	6.49	98,995.60	124,779.62
80-90	440.26	1,411.00	759.68	1,688.48	55,746.00	0.31	15.75	130,400.60	40,343.36
7018-21	2.13	38.60	3.16	3.16	0.00	0.06	39.98	0.00	0.00
40-130	98.08	991.20	130.78	249.42	7,103.70	0.10	23.69	26,394.00	1,786.58
130-50	105.49	881.40	182.04	492.10	18,610.30	0.12	12.89	58,187.60	13,265.50
90-91	112.64	541.80	194.36	219.70	1,527.84	0.21	30.75	0.00	0.00
7016-66	7.80	245.00	4.32	4.32	0.00	0.03	108.30	0.00	0.00
66-7012	6.27	245.20	12.54	12.86	19.34	0.03	29.32	0.00	0.00
	Vehicle Miles	Vehicles Out	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Density(v/lane)	
39-46	94.74	419.60	126.00	130.74	293.72	0.23	43.47	0.73	
46-49	1.22	38.60	1.96	2.14	10.90	0.03	33.75	0.03	
49-7018	1.26	38.60	2.00	2.14	7.72	0.03	36.34	0.04	
54-39	71.56	244.20	94.18	95.32	78.38	0.29	44.81	0.79	
67-7016	19.96	244.60	18.20	22.16	234.96	0.08	54.01	0.18	
7012-54	22.00	244.80	20.33	33.13	739.14	0.09	41.27	0.29	

Shopping Route 2

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop Delay (s)
230-220	66.90	535.20	115.46	154.22	2,328.24	0.13	26.04	4,665.00	316.92
240-230	43.76	361.00	75.50	87.46	710.62	0.12	30.01	67.80	28.00
242-240	17.83	389.00	35.66	94.70	3,551.38	0.05	11.35	38,900.00	2,270.64
7000-242	11.62	390.60	13.86	13.86	0.00	0.03	50.98	0.00	0.00
220-222	101.87	363.40	203.76	222.42	1,119.00	0.28	27.47	0.00	0.00
7001-115	35.60	1,773.20	43.38	43.38	0.00	0.02	49.64	709.20	141.66
115-7003	23.16	1,187.00	46.32	50.20	237.40	0.02	27.66	0.00	0.00
	Vehicle Miles	Vehicles Out	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s/v)	Distance (mi)	Speed (mph)	Density(v/lane)	
500-501	29.22	391.20	49.61	51.95	156.48	0.07	33.20	0.85	
501-7000	15.32	390.80	25.16	27.15	117.24	0.04	34.09	0.45	
16-22	368.36	1,385.40	442.77	468.53	1,550.70	0.27	47.34	3.90	
114-16	486.84	1,178.20	586.15	602.73	1,037.80	0.41	48.49	5.01	
59-35	1,543.38	2,986.20	1,694.62	1,759.45	4,062.08	0.52	52.77	9.74	
37-62	521.70	2,984.20	564.48	604.14	2,328.34	0.17	52.01	3.36	
62-59	666.74	2,984.00	722.75	754.75	1,790.40	0.22	52.92	4.21	
65-37	165.46	2,488.00	174.72	184.98	746.40	0.07	53.69	1.03	
67-65	352.10	2,487.00	383.09	400.69	1,193.98	0.14	65.20	2.21	
22-500	317.36	1,378.60	384.65	401.15	992.46	0.23	47.74	3.36	
102-79	491.82	1,774.80	655.11	679.70	1,455.40	0.28	43.37	5.66	
79-7001	352.04	1,772.80	591.41	620.98	1,807.78	0.20	34.17	5.20	
7003-114	111.72	1,188.00	103.90	174.73	4,086.90	0.09	39.74	1.50	
33-83	305.34	3,281.60	327.32	366.41	2,297.12	0.09	49.99	1.52	
83-84	593.32	3,277.40	641.97	682.32	2,359.78	0.18	52.22	2.85	
84-102	329.26	3,280.80	368.77	437.26	4,068.28	0.10	45.40	1.82	
35-33	682.50	2,983.40	741.18	802.61	3,580.08	0.23	51.09	4.46	

Shopping Route 3

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop Delay (s)
380-370	250.83	880.80	374.10	707.30	20,007.48	0.28	21.29	51,764.00	11,885.08
370-350	169.50	1,353.40	252.80	840.92	35,296.88	0.13	12.11	92,850.00	25,902.40
350-330	158.97	1,265.00	237.12	701.66	27,885.98	0.13	13.65	73,086.60	17,388.74
330-320	216.44	1,515.20	322.84	877.58	33,326.94	0.14	14.82	106,281.20	17,795.52
320-310	140.20	1,088.60	209.12	511.16	18,103.30	0.13	16.53	59,444.00	10,183.34
310-300	165.03	1,322.00	246.14	783.14	32,217.70	0.12	12.70	63,750.20	18,466.80
300-90	110.01	952.20	164.06	826.06	39,742.82	0.12	8.07	80,742.60	32,041.70
90-91	112.64	541.80	194.36	219.70	1,527.84	0.21	30.75	0.00	0.00

Shopping Route 4

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop Delay (s)
20-10	120.69	766.20	160.92	305.88	8,697.60	0.16	23.70	39,821.80	4,422.12
30-20	425.25	951.40	567.02	790.08	13,369.82	0.45	32.28	38,422.60	3,103.32
40-30	95.00	1,005.40	126.68	393.26	16,016.10	0.09	14.59	47,533.40	8,303.52
60-50	308.69	958.80	411.58	842.74	25,860.28	0.32	22.03	64,620.80	14,857.40
70-60	256.75	1,200.80	342.34	579.48	14,238.70	0.21	26.63	51,875.40	4,563.32
80-70	306.91	879.80	529.56	1,333.88	48,247.94	0.35	13.92	76,017.60	31,482.04
90-80	253.19	814.00	436.86	932.64	29,753.92	0.31	16.33	63,943.60	17,828.92
130-40	127.34	1,266.20	169.80	975.38	48,338.86	0.10	7.85	99,986.60	33,202.82
50-130	151.71	1,278.40	202.28	354.54	9,143.78	0.12	25.75	20,677.60	2,144.86
91-90	74.58	355.40	128.68	275.82	8,824.56	0.21	16.27	26,089.40	7,389.76

Shopping Route 5

Link	Vehicle Miles	Vehicle Trips	Move Time (veh-min)	Total Time (veh-min)	Total Delay (s)	Distance (mi)	Speed (mph)	Veh. Stopped	Stop Delay (s)
91-90	74.58	355.40	128.68	275.82	8,824.56	0.21	16.27	26,089.40	7,389.76
90-300	150.44	1,379.40	224.40	804.78	34,815.54	0.11	12.35	77,493.80	21,938.26
300-310	135.78	1,086.20	202.52	1,460.10	75,480.88	0.13	7.07	82,296.00	53,965.14
310-320	189.03	1,467.80	281.96	2,460.74	130,747.00	0.13	4.67	137,685.60	82,569.42
320-330	255.09	1,782.80	380.48	1,035.98	39,362.08	0.14	14.80	108,367.60	19,450.94
330-350	177.24	1,401.60	264.34	964.44	42,015.92	0.13	11.04	102,592.20	27,694.98
350-370	151.28	1,208.00	225.66	621.52	23,756.56	0.13	14.62	75,121.00	13,715.28
370-380	330.02	1,159.40	492.24	1,107.10	36,900.26	0.28	18.03	79,547.40	19,215.34

Appendix G. Shopping MOE Calculations

Shopping Route 1

Average Total Delay = 35.18 s/v
5,866.85 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = 20.27 s/v
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = 17.47 mph
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = 0.37
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= 58.86 %
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= 2.72 veh/ln-mi
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = 27.67 s/v
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Shopping Route 2

Average Total Delay = 1.01 s/v
694.17 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = 13.09 s/v
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = 41.81 mph
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = 0.93
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= 8.87 %
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= 17.21 veh/ln-mi
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = 0.55 s/v
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Shopping Route 3

Average Total Delay = 23.33 s/v
3,466.98 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = 13.46 s/v
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = 15.41 mph
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = 0.37
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= 59.20 %
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= N/A veh/ln-mi
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = 14.98 s/v
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Shopping Route 4

Average Total Delay = 23.48 s/v
3,707.98 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = 19.47 s/v
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = 18.68 mph
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = 0.46
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= 55.82 %
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= N/A veh/ln-mi
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = 13.44 s/v
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips

Shopping Route 5

Average Total Delay = 39.88 s/v
6,530.20 veh-hr
avg. delay (s/veh) = sum total delay (s)/sum vehicle trips
avg. delay (veh-hr) = sum total delay (veh-min)/(60 min/hr)

Average Moving Time = 13.42 s/v
avg. moving time (s/veh) move time (veh-min)*(60s/min)/vehicle trips

System Speed = 10.69 mph
system speed = sum distance (mi)/total time (s/veh)*3600s/hr

Average M/T ratio = 0.26
avg. M/T ratio = total move time (veh-min)/total time (veh-min)

% Vehicles Stopped (NETSIM)= 70.05 %
% veh = # stopped/sum veh. trips

Average Density (FRESIM)= N/A veh/ln-mi
avg. density = density (veh/ln)/total distance

Average Stopped Delay (NETSIM) = 25.03 s/v
avg. stopped delay (s/veh) = sum stop delay (s)/sum vehicle trips