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Verification and validation of TRAF-NETSIM model through actual field observations in Amman-Jordan

Sami Said Ghezawi

To the Graduate Council:

I am submitting herewith a dissertation written by Sami Said Ghezawi entitled "Verification and validation of TRAF-NETSIM model through actual field observations in Amman-Jordan." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Civil Engineering.

Steve Richards, Major Professor

We have read this dissertation and recommend its acceptance:

Arun Chatterjee, John Hungerford, Fred Wegmann

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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VERIFICATION AND VALIDATION OF TRAF-NETSIM MODEL THROUGH ACTUAL FIELD OBSERVATIONS IN AMMAN - JORDAN

A Dissertation
Presented for the
Doctor of Philosophy Degree
The University of Tennessee, Knoxville

SAMI SAID GHEZAWI
December 1999

DEDICATION

This dissertation is dedicated to my wife and two daughters

Tammi, Natasha, & Jana

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There are many people to whom I am thankful for giving me this wonderful experience. First and far most all praise and thanks are due to God for his merciful divine direction throughout my study.

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ABSTRACT

As urban traffic continues to increase in metropolitan cities around the globe, transportation engineers are constantly attempting to improve the utilization of existent transportation systems. Their objective is to achieve maximum efficiency of these systems, in terms of movement of persons, services, and goods in a safe and convenient manner. Although congestion problems have existed in some major cities for some time, it has become a significant issue until recent years. The substantial increase in automobile ownership to meet our changing lifestyles in the last few decades, coupled with a decline of new highway construction, has stretched many roadway networks beyond their design capacity. To evaluate different traffic management strategies and their effect on the behavior of an urban street system is a very complex process due to the interrelationships between its components. Therefore, engineers have to rely on mathematical, computer-based simulation models to accurately predict the behavior of the system over a period of time. One of the most effective tools of traffic management is the application of computer simulation models to represent the traffic system, in order to determine the effects of traffic management strategies on the system's operational performance. This performance can be stated in terms of Measures of Effectiveness (MOE) on specific traffic parameters such as average vehicle speed, average travel time, vehicle stops, maximum queue length and fuel consumption. These MOE's can provide the traffic engineer with valuable insight into the responsiveness of the traffic stream to different operational strategies.

Among the many computer simulation programs, the TRAF-NETSIM, an Integrated Traffic Network Simulation model, is probably one of the most widely used

and accepted traffic simulation models in The United States of America. TRAF-NETSIM is a very complex microscopic simulation model, which simulates the individual car movements stochastically. This research used TRAF-NETSIM Version 5.0 to determine the applicability and adaptability of this model to assess the traffic performance in Amman – Jordan, which was accomplished by the following steps:

- A typical street network in Amman – Jordan, was selected and all the required input information to run NETSIM was collected from the field (The Test Network).
- Two Measures of Effectiveness, Travel Time and Route Delay Time, were measured concurrently during the collection of traffic related input data.
- The Test Network was used to collect the following traffic parameters needed to calibrate the NETSIM model.
    - Mean Start-Up Lost Time
    - Mean Queue Discharge Headway
    - Distribution of Start-Up Lost Time
    - Distribution of Queue Discharge Headway
- Calibration on TRAF-NETSIM, in which the simulated results were compared with the observed field values using both the default and calibrated parameters.
- A second street was selected in the same city to test the performance of the calibrated model (The Validation Network).

It was found that the TRAF-NETSIM model using the default traffic parameters did not adequately predict the traffic performance in the test network. However, after changing the embedded default parameters in TRAF-NETSIM with the measured values in the field, the simulated travel times and delay times, for weekdays other than Fridays, were similar to those observed for both street networks. Conversely, for Friday the model did not predict the measured travel time and delay time within a given accuracy for both the test and validation networks. It should be brought to the reader's attention that Friday is a holiday in Jordan and that the traffic on Friday is synonymous to Sunday traffic found in the United States of America.

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INTRODUCTION

Background

The Hashemite Kingdom of Jordan is situated in the northwest corner of the Arabian Peninsula. Located in the heart of the Arab world, Jordan shares its borders with Syria on the north, the Kingdom of Saudi Arabia and Iraq on the east, Saudi Arabia on the south, and on the west it borders both Palestine and Israel (figure 1-1).

Jordan is approximately 91,862 square kilometers, which is about 35,468 square miles. In comparison, it is slightly smaller than the size of the State of Indiana, and is about 4/5 the size of the State of Tennessee. The population of Jordan according to the 1997 census is estimated at about 4,322,255. (According to the Jordanian Department of Statistics), this figure has more than doubled in less than two decades since the official figure of 2,132,997, given in 1979 [(1)]. According to the United Nations Population Fund, Jordan's average population growth rate is approximately 3.3%. Thus Jordan ranks 6th in world countries with the fastest growing population. The population increase has been boosted by a high birth rate, along with and primarily, the migration of Jordanian citizens from Saudi Arabia and other Gulf countries during the 1990-1991 Gulf War.

The majority of urbanized areas are located in the Northern and Central highlands. And according t 1996 figures, about 72% of the population live in urban areas and the reminder 28% in rural areas.

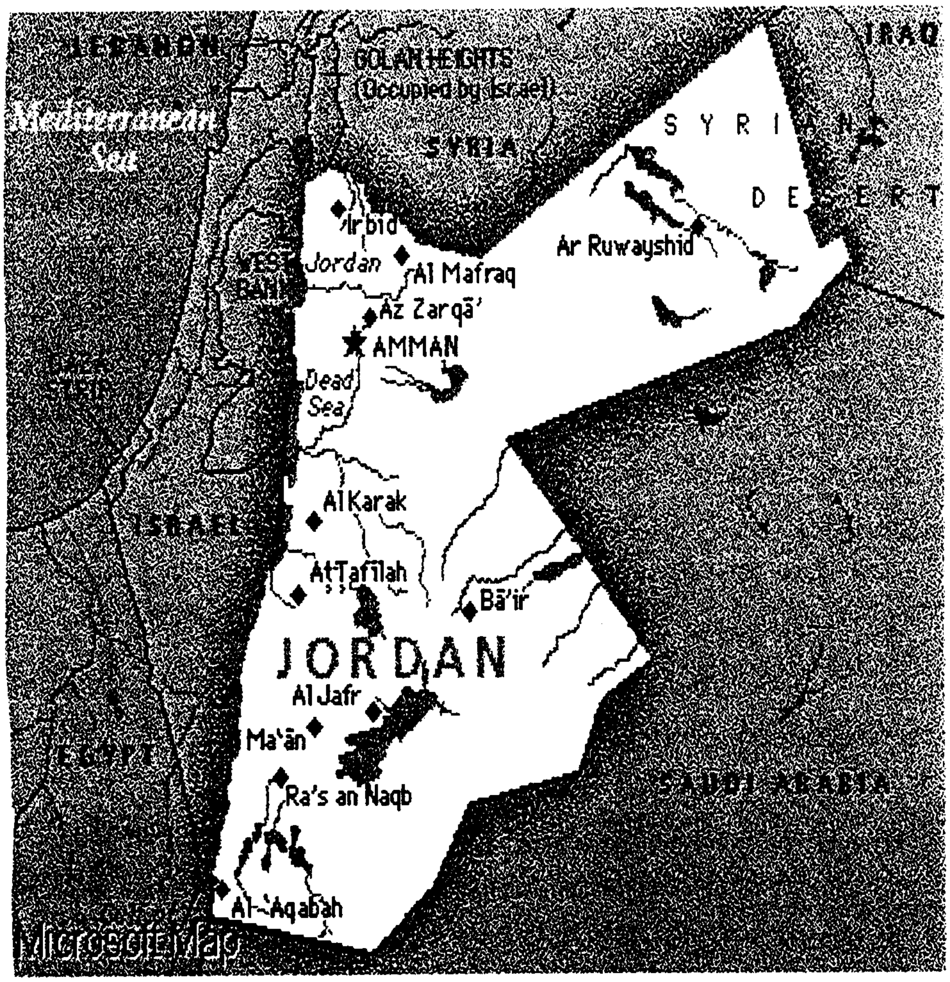


Figure1-1

Jordan and Surrounding Countries

Amman, the capital of Jordan lies about 40 kilometers (about 25 miles) northeast of the Dead Sea. It is the largest city in terms of population and land area within Jordan. The city of Amman is a major commercial, economic, and cultural center of about 1,231,000 people. The population of "Greater Amman", which includes the major surrounding urbanized counties (Muhafazat) is estimated at about 1,940,500 according to the 1991 official figures [1].

The city of Amman, which was originally built on seven hills, and had spread in recent years over another five, as well as, a large area of the surrounding country-side, giving the city it's characteristic roller - coaster appearance. The size of this city, which contains about one third of the country's overall population, and its associated automobile ownership, is a major cause of concern for both traffic engineers and city planners. According to official figures, the car ownership in Jordan has dramatically grown from about 22,000 in 1970 to about 362,800 in 1997, and this figure is expected to reach 380,000 vehicles by the end of 1999. [26, 27]

The rapid increase in population and car ownership has degraded the mobility and traffic performance in Amman. Like most urbanized areas, traffic congestion on the street network is becoming an ever-increasing problem, which the road user must deal with on a daily basis. Now, more than ever, transportation engineers are applying different traffic management strategies in order to ease traffic congestion. There is a well established roadway network connecting the suburban areas with downtown Amman, with approximately 120 traffic control signals, ranging from a simple fixed control to fully actuated traffic signals. In addition, there is a good public transit system serving the main arterial streets comprising of mini buses, jitney service and taxi cabs which serves the large majority of the working force.

Statement of the Problem

As urban traffic problems continue to increase in many metropolitan cities around the globe, traffic engineers and urban planners are increasingly challenged to insure a safe and efficient transportation system. The traffic engineer's responsibility goes beyond optimization of movement on a limited network to a complete and comprehensive evaluation of different strategies on a system wide basis.

The evaluation of different alternatives on the actual street system is a very complex process due to the interrelationships between its components, which are often time consuming, labor intensive, unsafe and sometimes unrealistic to implement on the road network. Therefore, to accurately predict the impact of various geometric and traffic control schemes, traffic engineers have relied on numerical, computer-based simulation programs that can be used to imitate the behavior of the system over time.

The recent surge in technology has made personal computers extremely powerful with massive computing capabilities at a very reasonable cost. In addition, the availability of programming languages, and advances in simulation methodologies have aided in the development of a wide variety of computer models. These models give the practicing traffic engineer a practical method of developing and evaluating solutions that could vary from changing signal timings on an isolated intersection, to looking at signal progression along arterial streets or within a network. The Handbook of Computer Models for Traffic Analysis, [2] lists some of the computer models that are available for traffic engineers and planners, which can be used to solve different transportation management problems.

The majority of computer models have been developed in the United States of America. These models have been calibrated to best describe the characteristics of the user, including drivers and pedestrian, the different vehicle mix and their operating performance. Also, many field experiments have been performed in order to validate and further enhance the credibility of the computer simulation models. In order for traffic engineers in other countries around the world to use existing simulation models in their own cities, computer simulation programs must be fine-tuned or modified to accurately represent the local environment.

The transportation system is made-up of the following three parts: The human, the vehicle, and the roadway. The road user, including drivers and pedestrians, is a very important part of the street network. The capabilities, limitations, and performance of the road user have an effect on the type, frequency, and quickness, in which a person might respond to a stimulus. Social and cultural differences from one region to another effect the behavioral and performance characteristic of humans thus it is a vital input influencing the operation of a transportation system. Therefore, driver performance measures in Amman, Jordan such as: Gap acceptance, headway, and response to traffic signals will be different when compared to driver performance in the United States.

In order to use existing simulation programs in Amman, such performance measures must be determined in the field. Furthermore, the computer simulation model should be validated and calibrated to best replicate the local driving environment.

Research Scope and Objective

Traffic engineers have been applying empirical models such as the Highway Capacity Software (HCS), to evaluate the effect of different geometric and traffic control alternatives. In such models, the basic relationships among the different variables in the model have been developed by actual field measurements. However, within the last decade, the increasing traffic demand and its accompanying congestion have become apparent in most urbanized cities and hence, no longer restricted to isolated locations or within the central business district. Consequently, traffic engineers have found that such models can not adequately provide the insight needed to address traffic related problems on a system wide basis.

The recent development in computer technology has given the practicing traffic engineer a wide selection of computer models that can be used as a tool to help manage and hopefully alleviate the traffic problems. The Network Simulation Model (abbreviated NETSIM) is an example of a computer simulation model used by traffic engineers. Although, it was originally developed for the Federal Highway Administration (FHWA), NETSIM is a very widely used and accepted traffic network simulation model among different public and private agencies in the United States of America. The Traff-Netsim software, as well as a wide variety of traffic and transportation related software, can be purchased from The Center for Microcomputers in Transportation “McTrans", University of Florida, Transportation Research Center, 512 Weil Hall, P O Box 116585, Gainesville, Florida 32611.

NETSIM a very complex model, is a microscopic, urban street network program which simulates the individual car movements stochastically. However, to use NETSIM in

Amman-Jordan, it should be modified accordingly through field experiments, to accurately replicate the Jordanian driving environment, which is the main objective of this research. This will be accomplished by the following:

STEP 1: Identify a typical street network in Amman (Test Network), and collect all the required input information to run NETSIM.

A- Geometric input data:

- Link length
- Number of full lanes
- Number of turning lanes
- Length of turn bays
- Lane channelization
- Lane alignment

B- Traffic input data:

- Traffic volumes at entry nodes
- Turn movements for each link
- Traffic composition
- Bus routes
- Location of bus stations

C- Control input data:

- Type of traffic control devices (Traffic signal or Traffic sign)
- Mode of traffic signal (Fixed time or Actuated)
- Phase sequence
- Number of phases and their duration

STEP 2: Collect the following measures of effectiveness (MOE's) from the test network on specific links. These will be measured concurrently during the collection of traffic input data in step 1b above.

A- Travel Time: (sec/vehicle) defined as the average link travel time for a single vehicle. [3, 15, 16]

B- Delay Time: (sec/vehicle) defined as the average delay on a link for a single vehicle (computed as the difference between the total travel time and idealized travel time for link) [3, 15, 16]

STEP 3: Collect the following traffic parameters from the Test Network to calibrate the TRAF-NETSIM model.

A- Mean Start-Up Lost Time

B- Mean Queue Discharge Headway

C- Distribution of Start-Up Lost Time

D- Distribution of Queue Discharge Headway

STEP 4: CALIBRATION OF TRAF-NETSIM:

Model calibration involves the comparison of the simulated results with the observed field data in which changes are made to the model's embedded default parameters collected from step 3 above. (Record types 140 to 150 inclusive)

STEP 5: Repeat step 1 for a new arterial street (Validation Network).

STEP 6: Repeat step 2 for the Validation Network.

STEP 7: MODEL VALIDATION:

The purpose of the validation phase is to determine whether or not the calibrated model is transportable. Specifically, to test if the model can simulate traffic conditions at a second network (Validation Network) without changes to any of the field collected traffic parameters from step 3 above. The only change would be the input data directly related to the characteristics of the validation network collected from step 5.

STEP 8: Compare the output of the calibrated NETSIM with the appropriate MOE's measured from step 6 (travel time and delay time) on the validation network and present the findings.

CHAPTER II

LITERATURE REVIEW

Introduction

Transportation engineers have been using computer models extensively in the last couple of decades to solve many transportation problems. Some of these models were developed to simulate traffic performance on different geometric configuration. For example, **SOAP**, which stands for Signal Operations Analysis Package, is a traffic signal optimization model. It can be used to evaluate present timing plans or as a design tool to determine the optimal signal-timing plan for any three or four legged intersection. SOAP was programmed and designed by the Transportation Research Center at the University of Florida. **TEXAS**, which is an acronym for Traffic EXperimental and Analytical Simulation, is mainly used to evaluate and analyze isolated intersection ranging from a simple uncontrolled intersection to a complex signalized intersection. Thus, it is not used to optimize signal-timing plans. However, it enables researchers to evaluate proposed designs in the safety of their office without the need to implement potentially dangerous and expensive field observations. TEXAS, as the name suggests was developed by The University of Texas' Center for Highway Research at Austin, Texas. **PASSER II**, which stands for Progression Analysis and Signal System Evaluation Routine, was created by Texas Transportation Institute at the University of Texas A&M. The model can be used by traffic engineers to determine the optimal cycle length for progression along a signalized arterial. **TRANSYT-7F**, TRAffic Network StudY Tool release #7 of the FHWA, and **TRAF-NETSIM**, Integrated TRAFic NETwork SIMulation are both traffic network simulation models. TRANSYT-7F is used to optimize signal timings for both arterial streets and grid networks. It can simulate up to 50 intersections with a maximum of 250 directional links. Where as TRAF-NETSIM, a network analysis simulation program is developed primarily to aid traffic engineers to evaluate and analyze complex network strategies. It is particularly useful in the analysis of highly integrated and dynamically controlled traffic systems. NETSIM can simulate in great detail a maximum of 250 intersections with up to 500 unidirectional links. Table 2-1 compares the different features of TRAF-NETSIM release 5.0 with some of the widely used computer models discussed earlier. [2,4,15,16]

Simulation

A computer simulation is the imitation of the physical system or traffic performance over a specified time. Simulation involves the creation of the real system, and the observation of that system over time to evaluate the operating characteristics of the actual system. Since the real-world system is very complex in nature and difficult to observe, numerical, simulation models have been developed and data generated from these models is used to estimate the measures of performance of the simulation model as if a real system were actually being observed.

Applications in simulations:

In the past decade, the increase use of personal computers and the several programming languages have made computer simulation one of the most and widely used

Table 2-1
A comparison of TRAF-NETSIM 5.0 with other computer models

	SOAP	TEXAS	PASSER II	TRANST-7F	TRAF-NETSIM
Macroscopic vs. Microscopic	Macro.	Micro.	Macro.	Macro.	Micro.
Deterministic vs. Stochastic	Deter.	Deter. & Stoc.	Deter.	Deter.	Deter. & Stoc.
Evaluation vs. Optimization	Opt.	Eva.	Opt.	Opt.	Eva.
MODEL FEATURES					
Simulates Isolated Intersections	Yes	Yes	Yes	Yes	Yes
Simulates Pre-Timed Control	Yes	Yes	Yes	Yes	Yes
Simulates Actuated Control	No	Yes	No	No	Yes
Simulates Arterial	No	No	Yes	Yes	Yes
Simulates Networks	No	No	No	Yes	Yes
Simulates Stop & Yield conditions	No	Yes	No	Yes	Yes
Simulates saturated conditions	No	No	No	No	Yes
Simulates Buses	No	No	No	Yes	Yes
Simulates Parking	No	No	No	No	Yes
Simulates Pedestrians	No	No	No	No	Yes
Simulates Lane Closures	No	No	No	No	Yes
Simulates Intra-Link lane changing	No	No	No	No	Yes
Simulates Shared turn lanes	No	No	No	No	Yes
Simulates Urban interchanges	No	No	No	No	Yes
Simulates detailed maneuvers within an intersection	No	No	No	No	Yes

tools in traffic operations analysis. Simulation can be applied (put not limited to) the following situations:

- To gain knowledge of how an actual transportation system or a specific strategy is going to perform prior to its implementation on the existing street network. The actual development of new theories or systems such as the construction of a new highway, widening an existing roadway, or even implementing certain traffic regulations such as one-way streets, establishing of a high-occupancy vehicles (HOV) lanes, etc. All of which are, very costly, unsafe, and time-consuming to implement on the actual street network.

- The need to evaluate certain measures of effectiveness on an existing facility may cause unnecessary interruptions to the actual street network. For instance, the effect of different signal plans, speed limits, and access control strategies all can be evaluated in great detail without confusing or alarming drivers.

- To test alternative designs such as a Before-and-After study under identical traffic conditions. For example, the behavior of traffic flow in the real world involves many changeable factors and complex interactions between the driver, the vehicle, and the roadway itself. Therefore, it may be highly improbable to insure identical traffic flow behavior in the field to accurately assess a Before-and-After study. However, in a computer simulation it is very easy to reproduce similar traffic volumes, and traffic composition under similar traffic conditions to evaluate several alternative system designs, assuming the simulation model is capable of producing identical traffic steam.

Different types of simulation models:

A model can be classified as being physical or mathematical. Physical models involves' the actual construction of a model. An example of a physical model might be the building of a bridge to a scale of 1:100. On the other hand, numerical, computer-based simulation model is a particular form of a mathematical model. It is a mathematical representation of the sequence of events over time comprising a certain process. The sequence of events is repeated several times to study the outcome. Because of the availability of digital computers and the ease in performing many computations at a very high speed, mathematical simulation models are incorporated into what is known today as computer simulation models.

Simulation models are further categorized as being static or dynamic, deterministic or stochastic, event scan or time scan, and microscopic or macroscopic in nature. A brief discussion is presented.

A static simulation model represents a system at a particular point in time. Where as a dynamic simulation model represents the way in which a system changes over time? The simulation of a bank from 9:00 a.m. to 2:00 p.m. is an example of a dynamic simulation.

Simulation models that have no laws of chance incorporated into the models are classified as deterministic. Deterministic models have no randomness what so ever. An example of such models is if all the vehicles arrived at an intersection exactly 10 seconds apart. A stochastic or probabilistic model is used in the simulation of traffic systems whose state is affected by the laws of chance. The randomness in stochastic models is introduced by a random number generator; While the distribution functions describe the relative frequencies of possible outcomes, they can be considered only as statistical estimates to the true characteristics of the model.

Simulation models are further classified as being either event scan or time scan models. With event scan models the process being analyzed is updated upon each event that occurs. On the other hand, time scan models update the process under consideration at constant time intervals. For example, in a time-scan model the position and status of vehicles in a queue at a single-pump gas station could be calculated at specified time intervals (i.e. at one second intervals), or it could be calculated each time a vehicle enters or leaves the gas station.

Furthermore simulation models are either microscopic or macroscopic in nature. Macroscopic simulation models represent traffic in terms of aggregate measures on each section of the street. Macroscopic models simulate vehicle in-groups (platoons) and report measures of effectiveness collectively. In a microscopic simulation models each vehicle is handled as a distinct entity. It is moved and monitored through the street network based on time-scan principle. This means that each movement of all the vehicles on the street network and every variable control (traffic lights) and event are updated, for example every 1 second interval. Table 2-2 summarizes the three main characteristics of traffic flow at both the macroscopic and microscopic levels.

In general, microscopic simulation models are believed to be more realistic in their description of the process being simulated. However, they normally require much more detailed information about the system being modeled in the form of input data requirements and their execution time will be substantially longer given the same computer hardware and street network.

Table 2-2
Characteristics of Traffic Flow

TRAFFIC CHARACTERISTIC	MICROSCOPIC LEVEL INDIVIDUAL UNITS	MACROSCOPIC LEVEL GROUPS OF UNITS
Speed	Individual Speed mph or km/h	Average Speed mph or km/h
Flow	Time Headway (seconds)	Flow Rates vehicle / hr / lane
Density	Distance Headway Spacing (feet)	Density Vehicle / mile / lane

In summary, simulation is a very powerful tool and should be resorted to when the system under consideration is too complex to be analyzed analytically. An analytical approach to problem solving involves the use of a well-established equation to yield the answer directly. However, the increased use of simulation studies and the corresponding lack of experience on the part of some users can lead to a sort of pseudo-simulation. Researchers and decision-makers should not be misled or even fooled by the vast pile of computer printouts, and accept them as absolute truth. In fact the simulation output should be viewed with a certain amount of skepticism until it has been validated. "GIGO" or "Garbage-In Garbage-out" is a basic concept in the computer science world, which also applies to computer simulation programs.

Studies using NETSIM

Transportation engineers have applied NETSIM to a wide spectrum of traffic related issues. These have ranged from evaluating signal timings on an isolated intersection, to studying different traffic signal control schemes and geometric designs for an arterial or street network. The following abstracts are some of the published literature by transportation engineers that have used NETSIM to compare different design alternatives or to actual field verification of the models estimated output parameters.

Nemeth and Mekemson, 1983 [(7)], have applied both SOAP, a macroscopic, optimization model and NETSIM, which is a microscopic, simulation model in the analysis of a signalized intersection. They looked at three hypothetical cases. The first two involved the intersection of two two-lane highways controlled by a pre-timed and traffic-actuated two-phase traffic signal respectively. The third case involved a two four-lane intersection with left-turn bays controlled by a pre-timed multi-phase signal. In each of the above cases, about 80 different combinations of traffic volumes and left-turn percentages were analyzed. The two measures of effectiveness selected by Nemeth and Mekemson were delay and fuel consumption. The study indicated that for the first two cases, the pattern of average delay under various volumes was similar with higher values produced by NETSIM. This increase can be related to travel-time delay due to vehicles traveling along both approach and departure links as simulated by NETSIM. For the pre-timed multi-phase intersection (case3), NETSIM and SOAP produced delays that are very similar. However, NETSIM delays were larger at high traffic volumes. Due to the fact that both NETSIM and SOAP defines fuel consumption differently, the authors looked at the differences between NETSIM fuel consumption and SOAP excess fuel consumption. The report indicated that after differences in definitions had been taken into consideration, both SOAP and NETSIM fuel-consumption values were similar in all three cases. However, in their study, no grades, parking activity, different vehicle composition, or pedestrian conflicts were assumed.

Grantz and Mekemson 1990 [(8)], compares the macroscopically flow profiles produced by TRANSYT-7F model to the microscopically flow profiles generated by TRAF-

NETSIM. In comparing the flow profiles it appears that TRAF-NETSIM is modeling aggressive, higher speed drivers more than TRANSYT-7F. On the other hand, it seems that TRANSYT-7F is emphasizing the non-aggressive drivers trailing the platoon more than TRAF-NETSIM. However, authors point out that due to the stochastic nature of TRAF-NETSIM in assigning free flow speeds for individual vehicles. And the recognition that the version of TRAF-NETSIM used in their study did not permit vehicle lane changing to allow movement around a slower moving vehicle as the main causes of the free flow differences.

Labrum 1981 [(9)] describes Utah's experience with NETSIM in analyzing different traffic control problems for single intersections, arterial, and street networks. They tested the model generated traffic volumes to actual field observations on a network consisting of two intersecting arterial streets in the SALT LAKE suburban area. The study indicates that there was no significant difference in vehicle volumes at the 10% level. However, Utah's DOT has found NETSIM to be a very useful tool for engineers and have recommended it for solving a wide spectrum of problems.

Hurely and Radwan [(10)] wrote on the experience gained while using NETSIM by undergraduate, graduate, and faculty members at Virginia Polytechnic Institute (VPI). However, most of their research focused on determining the signal timing requirements for minimizing fuel consumption rates for isolated signalized intersection with fixed control.

Davis and Ryan [(11)], describes two cases in 1979 of user experience with NETSIM (version of Netsim supplied by the FHWA in 1978). The first case, an isolated T-intersection with semi-actuated control was analyzed by NETSIM, and the simulated results where compared to actual field observations. In this study, the only MOE compared was that of queue length at the start of the green interval. NETSIM was run for 30-minutes using two

15-minute periods, each with a different seed for the random number generator. The study shows that the average queue lengths seems to be similar and that queues estimated by NETSIM were shorter than what was observed in the field. However, the variance was larger in the observed queue lengths than in NETSIM. It should be mentioned that this study used the default value of 2.1 sec/vehicle for queue discharge headway and a free flow speed of 30 mph for each link. Also, the findings were limited to only one study period with no trucks or buses present.

The second case reported by Davis and Ryan, dealt with the comparison of average delay per vehicle calculated by Webster's Technique and NETSIM on a hypothetical four-legged intersection, with fixed time control. The study shows that the simulated average delay by NETSIM was similar or less than those computed by Webster's technique until volumes approached capacity at which NETSIM predicted higher values.

Yagar and Case, 1974 [12], have studied and applied UTCS-1 the forerunner of NETSIM on a network in Toronto, Canada. The network consisted of an arterial street with its intersecting links. The floating-vehicle technique was used to collect field observations on travel time and speed on each link along the arterial. The study concludes that the "UTCS-1 appears to predict traffic speeds quite accurately", and that the simulated results seems to be similar when using a different seed number for the random number generator.

Robert Ferlis and Richard Worrall, [25] have applied the UTCS-1 network simulation model to three different experiments to suggest potential uses of the model as an aid to traffic engineers. The first experiment, the validation of the simulation model is presented to illustrate the high degree of conformity and reliability of the model's ability to simulate actual traffic conditions on a street network. The second experiment, the arterial demonstration describes how the UTCS-1 can be used by researchers as a design tool to aid in the evaluation of different design schemes. The third experiment is the San Jose experiment which demonstrates the adaptability of the simulation model to different traffic conditions from those used in the validation network in Washington, D.C. Validation of the UTCS-1 Model:

The UTCS-1 network simulation model was originally calibrated for a grid network located in downtown Washington DC. The model's ability to predict traffic conditions was accomplished by setting up aerial and ground-based time-lapse photography to aid in the collection of a comprehensive set of field data which was used in the comparison of two sets of model runs, the a.m. peak and the a.m. off-peak traffic conditions. The simulation model was run three times (replications) with common sets of inputs for both the a.m. peak and a.m. off-peak conditions in order to minimize the influence of the model's stochastic variations on the data set. The simulation model was run for 32 minutes of real time for each replication. The results of the validation exercise is presented in Table 2-3, in which field measured and simulated values for different MOE's are compared.

As can be seen from the table, in the a.m. peak conditions the simulated MOE's where similar to the field observed values (all within a 2% difference) with the exception of average speed, the difference between field and simulated values was around 2.4%. However, the study indicates that the differences between field and simulated MOE's where not statistically significant at the 5 percent level. In the a.m. off peak traffic conditions, the differences are more obvious. It appears that the model had considerable underestimation during that period. The study indicates that the simulated values produced by the model where significantly different at the1 percent level. The authors suggest that the model

Table 2-3
Comparison between field and simulated MOE's

CHARACTERSTIC	FIELD	RUN 1 SIMU-LATED	RUN 1 DIFFER-ENCE	RUN 1 %	RUN 2 SIMU-LATED	RUN 2 DIFFER-ENCE	RUN 2 %	RUN 3 SIMU-LATED	RUN 3 DIFFER-ENCE	RUN 3 %
Total Link Output vph										
Peak	36108	36345	237	0.7	36399	291	0.8	36.345	237	0.7
Off peak	27433	27731	298	1.1	27930	497	1.8	27.731	298	1.1
Vehicles in Network										
Peak	328.4	327.9	-0.5	-0.2	332.0	3.6	1.1	329.5	1.1	0.3
Off peak	276.4	246.3	-30.1	-10.9	243.3	-33.1	-12.0	238.7	-37.7	-13.6
Vehicle minutes										
Peak	10506	10502	-4	0.0	10616	110	1.0	10539	33	0.3
Off peak	8841	7891	-950	-10.7	7781	-1060	-12.0	7634	-1207	-13.7
Vehicle miles										
Peak	1701	1705	4	0.2	1710	9	0.5	1710	9	0.5
Off peak	1285	1293	8	0.6	1302	17	1.3	1306	21	1.6
Total Delay veh min										
Peak	6475	6455	-20	-0.3	6561	86	1.3	6483	8	0.1
Off peak	5806	4831	-975	-16.8	4700	-1106	-19.0	4541	-1265	-21.8
Average travel time										
Peak	5.4	5.5	0.1	1.9	5.4	0.0	0.0	5.4	0.0	0.0
Off peak	6.4	6.0	0.4	-6.3	5.2	-1.2	-18.8	5.1	-1.3	-20.3
Average speed mph										
Peak	16.43	16.08	-0.35	-2.1	15.99	-0.44	-2.7	16.03	-0.40	-2.4
Off peak	15.35	16.48	1.13	7.4	16.88	1.53	10.0	16.71	1.36	8.9

seemed to impede traffic flow less than necessary in order to reproduce the field data in the off-peak traffic conditions.

The second experiment conduced by the authors was to demonstrate the possible use of the model as an aid in iterative design. The network chosen for the study was an arterial 1.1miles long in Washington, DC. Actual traffic volumes, geometry, and signal timing data were also used in this experiment. The study examined and compared selected MOE's of different design strategies to the existing arterial traffic conditions. They have looked at reversible lanes, eliminating some left turns, construction of additional lane, and different traffic signal designs. In summary, the second experiment illustrated the ability of the UTCS-1 network simulation model as a tool to aid traffic engineers in evaluating different transportation management schemes.

The third experiment chosen by the authors was to examine the different signal timing plans produced by SIGOP and TRANSYT to a street network in San Jose, California. The results of this study suggests that the signal timing produced by TRANSYT showed consistently lower delay and higher average speeds than the equivalent settings produced by SIGOP.

In conclusion, the following remarks can be drawn from the above literature:

- NETSIM is used as a tool by researchers and practitioners to evaluate a wide range of transportation related problems. Most of the studies evaluated the performance of isolated, hypothetical intersections without considering the effect of grade, different vehicle mix, or pedestrian conflicts.
- It appears that NETSIM produces higher delays and more models aggressive higher speed drivers when compared to SOAP and TRANSYT-7F respectively.

- NETSIM's simulated travel-time and speed seem to be similar to actual field conditions.
- In the original validation of the UTCS-1, the forerunner of NETSIM, actual field data was collected and compared to simulated values. The model was run three times with different random number seeds in order to reduce the variability from one simulation run to the next. It was shown that the model was able to produce similar values under peak conditions. However, the model produced considerable underestimation on some of the selected measures of effectiveness during the off peak period.
- Transportation engineers can use traffic simulation programs to gain added insight at traffic performance under a very wide range of design concepts.
- It appears that NETSIM is one of the most widely used and accepted traffic simulation models among the profession.

TRAF-NETSIM Model

As the world's population reaches approximately 6 billion, global over crowding may be the most pressing issue we face as we enter the new millennium. Transportation engineers throughout the world are constantly trying to alleviate progressively greater congestion levels and traffic delays in our major metropolitan areas. Previously, traffic engineers would simply widen the existing facilities or even construct new highways to reduce traffic congestion. However, due to the increasing environmental concerns, construction cost, and right-of-way restrictions, transportation engineers must use different transportation system management (TSM) strategies in order to optimize the efficiency of the existing road network in order to harmonize the traffic congestion problems we encounter on a daily basis. To evaluate the effect of different TSM strategies on trip patterns, transportation engineers have to examine a large portion of the street network in which a trip maker may use in order to reach his/her destination. This can be accomplished if there is a comprehensive traffic simulation model that simulates the behavior of traffic progressing along different types of street segments. For example, a person may first travel along a two lane rural road, and then a four lane divided highway or a signalized arterial and finally back to a two lane urban road, in order to reach their destination. To accomplish this idea of a single integrated simulation model, The Federal Highway Administration (FHWA) has been pursuing several simulation programs since the mid 1970's which have lead to the evolution of a system of simulation models known as TRAF.

TRAF (for integrated TRAFfic simulation models) is basically a group of simulation models which are integrated together to represent the aggregate traffic environment. Each traffic simulation model in TRAF is designed to represent traffic behavior on a particular street network. For instance, TRAF can simulate the traffic flow on an arterial street or a two-lane roadway each with a desired level of simulation detail. As can be seen from Table 2-4, TRAF consists of three microscopic and two macroscopic simulation programs.

The naming of these models is made up of a prefix and a suffix. The prefix in an indication of the type of network being simulated and the suffix shows the level of simulation detail. For example, the prefix NET, FRE and ROAD, stands for network, freeways, and two-lane road respectively. Where as the suffixes SIM and FLO shows if the simulation is microscopic or macroscopic in nature.

Table 2-4
TRAF family of models

TRAF	MICROSCOPIC	MACROSCOPIC
Surface Street Network	NetSim	NetFlo 1 & 2
Freeway Network	FreSim	FreFlo
Two Lane Roads	RoadSim	

A brief description of the TRAF models is presented in the following section from TRAF user reference guide [16].

FRESIM:

The FRESIM simulation model is the newest addition to the TRAF family of models. It is a microscopic, time-scanning freeway simulation program. FRESIM model is capable of simulating with great detail a wide variety of design features and operational characteristics, which includes the following:

- Simulation of freeway with up to 5 through lanes
- Auxiliary lanes, lane additions, and lane drops
- Ramp metering
- Driver reaction to warning signs and geometric changes

ROADSIM:

ROADSIM is a microscopic traffic simulation program that simulates traffic flow along a two lane rural road. Because it is of a microscopic detail each vehicle is handled as an individual entity and is moved along the traffic stream once every second of simulation clock time.

NETFLO:

NETFLO 1 and NETFLO 2 (also called NETFLO level 1 or level 2) are two macroscopic traffic simulation models of urban traffic. Each vehicle is modeled explicitly and its behavioral attributes such as its' free flow speed, queue discharge headway and turn movements are simulated in a stochastic (probabilistic) manner. In addition, nearly all traffic conditions encountered in an urbanized environment can be realistically simulated with either NETFLO level 1 or level 2 models. However, since those models represent the traffic condition at a macroscopic level of simulation detail, each vehicle is moved whenever an event occurs (event scan), and that vehicle is moved downstream as possible in a single motion. Macroscopic level implies that no Car-following logic is being considered by either of these traffic simulation programs. The main difference in NETFLO 1 and NETFLO 2 is that NETFLO 2 does not simulate carpools. In addition buses are treated at a lower level of simulation detail. It should be mentioned that NETFLO 2's logic adapted from TRANSYT (TRAffic Network Study Tool). However, NETFLO 2 differs from TRANSYT in its ability to handle more than one cycle length along with time varying traffic flow conditions. Also data inputs were simplified to match that of the TRAF family of models. But the main difference is that TRANSYT is used for optimizing the traffic signal plan on both arterial and grid networks, where as the TRAF family of model's are mainly used for the evaluation and analysis of different traffic control strategies. Instead of optimizing signal timings, it optimizes the utilization of transportation resources to improve the movement of people and goods in an efficient and safe manner.

FREFLO:

The FREFLO model is also a macroscopic simulation program, which simulates the traffic environment in terms of aggregate measures of freeways (Highways). The aggregate measures for each freeway section includes entry and exit flow rates, density, and space-mean-speeds. Furthermore, it can accommodate three types of vehicles such as buses, carpools and passenger cars, which includes trucks. High Occupancy Lanes (HOV) can be modeled explicitly as well as merging and diverging of traffic on a highway segment.

NETSIM:

Finally, the last model in the family of TRAF is NETSIM, which stands for NETwork SIMulation. It is a FORTRAN-based microscopic, stochastic simulation program, which models in great detail, a wide range of traffic operations in a network of surface streets. This program formally known as the UTCS-1 network simulation model was originally designed to assist in the development and evaluation of complex urban street control strategies. Ever since the introduction of the UTCS-1 model researchers have been extensively applying this simulation program to a wide variety of problem areas and it is undoubtedly the most widely used network simulation program. It's wide application can range from evaluation of traffic performance on a single isolated intersection to a very complex urban network that might have special HOV lanes one-way and two-way streets, and a full range of fixed-time and vehicle-actuated traffic signal control strategies.

Since the release of the UTCS-1 by the FHWA in 1971, which has evolved into NETSIM, it has been subsequently updated in 1973 and 1978. Netsim's name was later changed to TRAF-NETSIM when it was integrated in to the TRAF family of models in the 1980's. And as part of TRAF, NETSIM has undergone major enhancements in the past few years, thus improving its capabilities to simulate a wide variety of transportation system management (TSM) strategies. These enhancements include the addition of actuated control logic, the ability to produce identical traffic streams, and conditional turning- movement [5]. These features are briefly described in the following:

1- Actuated Signal Logic:

TRAF-NETSIM has been updated to allow the simulation of a wide range of traffic actuated control signals. These include isolated traffic actuated signals, actuated coordination of traffic signals (free actuated mode), volume-density controllers, and semi-actuated traffic signals. Phase operations for TRAF-NETSIM actuated signals is based on the National Electrical Manufactures Association (NEMA) or type - 170 traffic controllers. In addition, this new traffic actuated signal logic allows for two types of detector groups. Each group has three different detector characteristics. The only limitation is that the total number of detectors on any link may not exceed 10. In addition detectors can be passage or presence. In passage operation, a constant 0.3 seconds pulse is generated whenever a vehicle is detected, regardless of the length of time the vehicle spends over the sensor. In presence operation, the length of the pulse generated is equivalent to the length of time a vehicle spends over the sensor. Additional traffic actuated control features have been added to TRAF-NETSIM V. 5.0 which is used by this research. The new features are left-turn extensions, lag left - turn hold, conditional service, and simultaneous gap out all of which adds to the credibility and realism of the simulation program.

TRAF-NETSIM simulation program can handle up to 100 traffic actuated control signals, with a maximum of five approaches could be specified for each signalized intersection. Additional traffic actuated control features have been added to NETSIM Version 5.0 used in this research. The new features are left-turn extensions, lag left-turn hold, conditional service, and simultaneous gap out all of which adds to the degree of conformity, reliability and realism of the simulation program.

2- Identical Traffic Streams: (ITS)

The TRAF-NETSIM simulation program uses a number of stochastic processes such as random sampling from discrete and continuous distributions to represent the traffic environment adequately. However, due to this highly attractive probabilistic nature of Netsim, the simulation output generally contains a great deal of variability from one simulation run to the next. This output variability is normally more obvious in TRAF-NETSIM due to the microscopicity of the model. [6,18,19,24] More importantly, the presence of high variability in simulation output can have a negative effect concerning the reliability and realism of the simulation model. Since the older versions of Netsim model used only one random number seed as a basis for all stochastic decisions including the determination of driver and vehicle characteristics, the traffic engineer had no control over the traffic stream and its operational and behavioral performance from one run to the next. This means that one cannot test different control strategies or alternative designs with the certainty that the changes in the output are due solely to the control variables and not to the random variations which is a characteristic of all stochastic simulation models.

Due to the limitations discussed above, and to increase the credibility and statistical validity of the simulation results, an added feature was implemented in TRAF-

NETSIM which allows the modeler to simulate the traffic stream exhibiting the same routing patterns, driver-vehicle characteristics through a series of simulation runs. To accomplish the identical traffic stream movement a unique random number seed is generated for each vehicle entering the network, which in turn is used for all stochastic decision's associated with that vehicle. This vehicle specific random seed; hereafter referred to as the 'base seed' is used to determine driver type, vehicle type, turn decisions and other behavioral and operational decisions.

TRAF-NETSIM employs two random number seeds specified by the user in entries 11 and 12 on card type 2. [16] The first random number seed is the 'base seed' and it is used to generate the traffic movement for a given simulation run. The second random number seed is the 'common seed' and it is used for all time-dependent stochastic decisions (i.e. accepting available gaps for turns, determining location and duration of events, and so on and so forth).

Based on the above, one can conclude that there are two possible scenarios in performing traffic simulation experiments with TRAF-NETSIM. The first is when the researcher is interested in comparing different system designs or operating strategies. The other is when the researcher is trying to determine the performance characteristics of an individual system, each of which are discussed below.

In the case of comparing alternatives, the user wishes to minimize the variance in the traffic performance measures of effectiveness which are due to variations in the traffic movement encountered from one simulation run to the next. This can be accomplished by keeping the same value for the base and common seeds for alternative designs in different runs, hence, the same driver/vehicle mix and routing pattern will be simulated. Thus, the difference in the calculated MOE's between alternative simulation runs will be due solely to the differences in effectiveness on the control strategy or system design, as long as the same turn percentages, and traffic volumes are used. By employing the identical traffic stream feature in this manner, the user can compare alternative designs with the assurance that the same traffic stream in employed for all cases.

In the second case, the researcher is trying to determine the performance characteristics of an individual system. In this case, the user is interested in performing independent replications. Independent replications in simulation experiments refers to the execution of the simulation model several times for a given set of identical input data, except that the random number seed will differ from one simulation to the next. Here, the user uses a different random number 'base seed' for each simulation run and does not change any other input data. Thus, the set of independent replications would reflect the differences in the measures of effectiveness that might be observed between the traffic stream on one weekday morning to that of another. Based on the above, this research will evaluate different MOE's on the selected street networks based upon independent replications. It should be mentioned that the ability to perform independent replications in a true statistical sense was not possible with the previous versions of Netsim, because only one random seed was used for all stochastic decisions throughout the simulation program.

Finally, if the user wishes to change only the common random number seed from one simulation run to the next, the output of such runs will reflect differences due to time-dependent stochastic processes. That is, the user can simulate with traffic stream exhibiting identical routing and driver/vehicle characteristics, but in a different traffic environment. According to A. Rathi and A. Santiago [19], such a simulation run will generate statistics that are of no practical use in analyzing the simulation results.

3- Conditional Turning Movements:

The conditional turning movement feature is designed to constrain vehicles from making a series of unrealistic turns. For example, the user may want to restrain certain vehicles from making a series of consecutive right turns. Depending on the type of network simulated, TRAF-NETSIM users may apply conditional turning movement on certain links to restrain vehicles from going around the block.

In addition to the three major enhancements mentioned above, four new modifications to the simulation program have been made to the TRAF-NETSIM logic used in this research.

These enhancements will help to model traffic behavior more realistically and are briefly described here.

1- Intra-Link Lane Changing:

Prior to TRAF-NETSIM V. 5.0, vehicles were only allowed to change traffic lanes when they entered a new segment of a roadway. This logic is unrealistic in the real world since drivers may change lanes at any point on a link. In this new version, vehicles will know their next turn movement and will try to change into an appropriate lane for that turn movement as they travel along the network. The decision to make a lane change is based on parameters such as duration of a lane change, deceleration rates during lane changes, unacceptable headway, and cooperation of drivers to vehicles trying to perform a lane change. All of which can be altered by the traffic engineer if he or she feels that the default values are unrealistic.

2- Shared Turn Lanes:

Shared turn logic was added to TRAF-NETSIM to further enhance its capabilities when simulating the traffic stream. Previous versions of Netsim would not allow the left most or right most lanes to service more than one turn movement. For example, a left most lane on a link approaching an intersection could only allow for either a left-turn movement or a through movement. As of TRAF-NETSIM v. 5.0, a left most turn lane can accommodate both through and left turn traffic which might be the case in many signalized intersections. Five new channelization codes where added to netsim's logic to allow all possible lane configurations to be modeled and thus improving the reliability and credibility of the simulation program.

3- Urban Interchanges:

With the added enhancement of Intra-link lane changing phenomena discussed earlier, Traf-Netsim can now simulate the behavior of traffic when performing weaving and merging maneuvers. Furthermore, this new feature gives Traf-Netsim the capability to simulate multilevel urban interchanges. This allows for more realistic presentation of multilevel interchanges using the newly developed computer animation graphics system, which will be discussed later in this chapter. In addition, the graphic capability of presenting curved links and grade separation has also been added to Traf-Netsim model.

4- Intersection Simulation "Micronodes":

Traf-Netsim has the ability to model intersections in great detail. In this version, left-turn vehicles will proceed into the intersection and will wait in the middle of the intersection until there is a gap long enough to permit a left turn movement. In all the previous models, left turns would stop and wait at the stop line until an appropriate gap for left turn was available in opposing traffic. In addition, this new intersection logic allows for the simulation of vehicle blockage, which may be present within an intersection. Up to 20 intersections can be simulated as Micronodes.

The Logic Underlying NETSIM Model

TRAF-NETSIM is a microscopic stochastic simulation program which models the individual vehicular behavior in response to a wide range of traffic conditions encountered in most cities around the globe. In order to truly understand how TRAF-NETSIM works internally, a brief description of the model has been summarized and is presented below. [2,4,15,16]

Every simulation program developed describes some process that extends over time. While there are several ways of representing the passage of time, the TRAF-NETSIM model uses an interval scanning approach, which is driven by an internal clock. In TRAF-NETSIM, all system elements that vary with time are updated either at the end or during a 'one second' interval. For example, the active indications displayed by the traffic signal are updated at the end of each second. Since vehicles in the system are moved during each second if such movement is permissible. Vehicles are actually moved during the one-second interval in accordance to the car-following rules and gap-acceptance process.

Vehicles enter the traffic network at entry links, at a uniform rate, and are proportional to the input volume. Upon entering the network, a right-turn vehicle and a left-turn vehicle are assigned to the right-most lane and left-most lane respectively. Whereas a through vehicle is assigned to the lane that has the least number of vehicles. Upon entering a lane, each vehicle reacts according to the car-following rules. If the vehicle is a leader, and acceleration rate is applied to the vehicle until it reaches a free-flow speed.

Subsequent vehicles in the traffic stream will accelerate to the free flow speed similarly while maintaining a safe stopping distance between one another. The mean free-flow speed and acceleration rates for each vehicle type are user specified or impeded as defaults. The TRAF-NETSIM program can accommodate four vehicle fleet components such as automobiles, trucks, buses and carpools, each with a different acceleration, speed, vehicle length, headway, and occupancy. All of which can be modified by the user in order to reflect certain operating characteristics for a specified vehicle fleet. Even within the same vehicle fleet, say automobiles; drivers may behave somewhat differently to the same stimuli. TRAF-NETSIM manages to represent such a highly variable environment by modeling traffic stochastically, using statistical and probabilistic techniques. For example, Table 2-5 presents default values used by NETSIM for different driver types ranging from aggressive drivers to very timid drivers.

Columns 1 through 10 in Table 2-5, represents 10 different driver types and the values in each column are percentages obtained from a decile distribution. These percentages are multiplied to the mean values (user input) to reflect a specific type of driver. As each vehicle enters the network, a random number between 1 and 10 inclusive is tagged to that vehicle. This number is used to extract the proper element of the distribution representing the vehicle's driver characteristics.

Table 2-5
Default values used by NETSIM

DRIVER TYPE	1	2	3	4	5	6	7	8	9	10
% multiplier of mean free-flow speed	75	81	91	94	97	100	107	111	117	127
% multiplier of mean start-up lost time	218	140	125	118	102	86	78	63	47	23
% multiplier of mean queue discharge headway	170	120	120	110	110	110	90	70	70	50

For example, suppose the traffic engineer specifies a mean Free-Flow speed of 60 Km/h, a mean Start-Up Lost-Time of 2.5 seconds, and a mean Queue Discharge Headway of 2.0 seconds and TRAF-NETSIM assigns a random number of 9 to a vehicle as it enters a specified link. This vehicle will have a free flow speed of 70.2 Km/h (1.17*60), a start-up lost time of 1.18 seconds (0.47*2.5), and a queue discharge headway of 1.40 seconds (0.70*2.0), representing what one might call an aggressive driver. When another vehicle enters the same link, and if its random number is 4, it will have a free-flow speed of 56.4 Km/h (0.94*60), a start-up lost time of 2.95 seconds (1.18*2.5), and a queue discharge headway of 2.20 seconds (1.10*2.0). Therefore, even if similar vehicles are on the same link, they may have different operating characteristics representing a wide spectrum of human behavior.

Another example of how Netsim works is to explain what happens when a lead vehicle approaches a traffic signal. The simulation program keeps track of the time and position of each vehicle in the network. Depending on the traffic signal indication facing the vehicle as it travels downstream, one of the following scenarios will occur. First, if the signal indication is red, the vehicle will reduce its speed at a deceleration rate of one foot/second^2 until its speed has dropped 10 percent. Then a deceleration rate of 7 feet/second^2 is applied until the vehicle comes to a complete stop.

The second scenario is if the traffic signal indication turns from green to yellow, the vehicle may either proceed through the intersection or stop. If the position of the vehicle is at a distance closer than the calculated safe stopping distance from the stop line, the vehicle will travel through the intersection without stopping. However, if the vehicle's position is at a distance greater than its safe stopping distance, the vehicle will stop at the stop line.

The last scenario is if the traffic signal is green, the vehicle will continue traveling along its path without stopping.

One of the objectives of this research project is to observe and collect the start-up lost time and queue discharge headway encountered by vehicles as the signal turns from red to green. This is discussed in great depth in the methodology chapter (Chapter 3). The way NETSIM discharges vehicles when the traffic signal indication turns from red to green is shown in Figure 2-1.

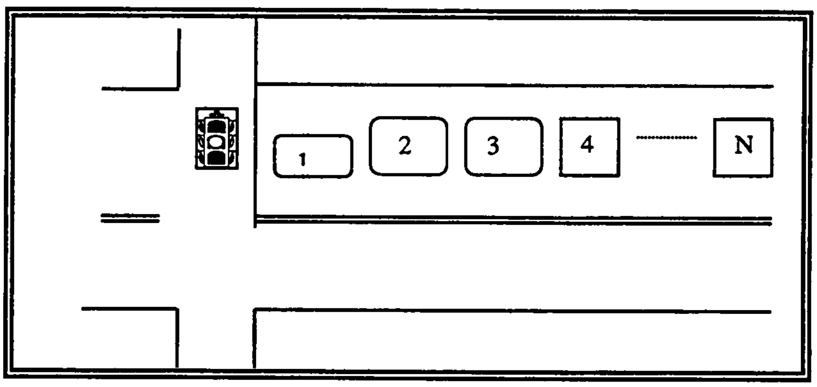


Figure 2-1
Vehicles Discharging from a Traffic Signal

As can be seen from figure 2-1, the first vehicle in queue will have a delay equal to the start up lost time, then it will accelerate at a specified rate until it reaches a free flow speed. The second vehicle in the queue will have a start-up lost time equal to the mean headway plus 0.5 seconds. The third vehicle in the queue will have a start-up lost time equal to the mean headway plus 0.2 seconds. The fourth and subsequent vehicles will leave the stop line at a rate equal to the mean headway.

Similar simulation logic is applied in great detail to all vehicles traversing the network as they perform different driving tasks. Such as approaching a stop sign, yield sign, or even how a lead vehicle may react to a lane obstruction due to a bus loading or unloading in its travel path.

TRAF-NETSIM model uses a number of stochastic processes such as random sampling from discrete distributions to represent the traffic environment in the real world. Many behavioral and operational decisions such as free flow speeds, acceleration rates, and gap acceptance are represented in the model as random processes. The way TRAF-NETSIM generates random numbers is presented below:

Random number generation in TRAF-NETSIM is based on linear recursive procedure. This implies that the initial random number seed forms the basis for all stochastic decisions in the model. Using a multiplicative congruence technique, the internal logic of the model will generate a sequence of random numbers by calculating the next random number from the last random number, given the initial random number seed. In the current TRAF-NETSIM model the initial value of the random number seed in user defined or default. The user is asked to provide an odd number of up to eight digits ending in 1, 3, 7, or 9. The selection of an odd number (except 5) will guarantee a full period for the random numbers. That is, the simulation internal logic procedure will randomly generate, non-negative integer numbers between 10,001 and 99,999,999 before any number is repeated in the simulation of random processes.

Input Requirements:

TRAF-NETSIM, a microscopic stochastic simulation program, which simulates the traffic behavior and traffic control conditions of a network over a period of time, is a very data intensive program. And in light of the complexity of NETSIM'S capabilities, the developers of TRAF have strive to make the task of input data as simple as possible. They have provided a TRAF support program called TRAFEdit to ease the task of data entry. TRAFEdit is an interactive, menu-driven, micro computer based data program which allows the users to create an input data file or modify an existing input data file for the TRAF family. TRAFEdit has two component editors for data entry. The first is the "smart edit" editor, which is designed to facilitate the creation on new data sets. It is particularly useful for unfamiliar users on Netsim because it provides information about the entry fields on individual cards and will disallow many illegal entries. The second is the "Quick edit" editor, which is designed to ease the task of data "debugging" or modification changes which are required when developing an input data set.

In order to simulate the traffic behavior on a street network a detailed representation of the traffic environment must be specified by the user. Specifically, the following input data are required to run TRAF-NETSIM:

1. The Topology of the roadway system is represented in the form of nodes and unidirectional links. Nodes may represent intersections or where geometric changes

in the roadway occur (e.g. added lanes, change of grade, etc.). In addition, traffic generators; such as off street parking lots and minor streets may be represented by special purpose nodes referred to as 'sink or source' nodes. Each link represents one directional segment of a roadway or as an approach to a node.

2. Geometric information for each roadway segment (link). The user must specify for each link the following:

   - Number of traffic lanes.
   - Link length.
   - Number and length of left or right turn pockets.
   - Percent grade.
   - Mean start-up lost time and queue discharge headway.
   - Free-flow speed.
   - Pedestrian volumes.
   - Lane channelization.
   - Down stream node number receiving through or turning traffic.
   - Lane alignment.

3. Control input data for each intersection (node). For each node the type of traffic control device should be specified in great detail. Here, the user specifies if the intersection is under sign control (Stop or Yield sign) or signal control (Pre-timed or actuated). If the intersection is under signal control additional information such as phase sequence, number of phases, duration of phases, offsets, type and location of detectors, and so on and so forth may be required to run Netsim.

4. Traffic input data. The user must specify traffic demand at entry links and source nodes in the form of flow rates (VPH). Traffic composition in terms of percent of trucks, percent of passenger cars, and percent of carpools. And surface-street turning movements at each intersection coded in terms of percent of traffic or actual flow rates.

5. Duration of simulation. TRAF-NETSIM allows for the simulation of traffic and traffic control strategies which may change over a period of time. The user may specify up to 19 time periods to accommodate conditions which not only differ from one location to another, but which may also change with time.
6. As an option, Pedestrian volumes at intersection, bus routes, bus volumes and location of bus stops may also be specified.

In addition to the input requirement just mentioned, there is a wide range of traffic parameters which may be modified by the user, specially if calibration of the simulation model is necessary, in order to more accurately represent the microscopic behavioral characteristics of the traffic environment under study. These include vehicle type specifications, vehicle responses to events in the traffic stream, characteristics of vehicle flow, and duration of certain events effecting the traffic flow.

Measures of Effectiveness Available from TRAF-NETSIM

After the creation of the required input data and the execution of the model, TRAF-NETSIM will produce a comprehensive set of statistical tabulations describing the different measures of effectiveness. These MOE's are on a link specific basis, aggregated over each sub-network, or specified over the entire network. In addition, TRAF-NETSIM could produce a cumulative output that provides data accumulated since the beginning of simulation excluding statistics gathered during worm-up or initialization period. Table 2-6 shows the various statistical outputs available from TRAF-NETSIM.

In addition to the intensive data output produced by TRAF-NETSIM in a statistical tabular format, an interactive computer graphics system which provides the

Table 2-6

Various MOE's available from TRAF-NETSIM

LINK SPECIFIC MEASURES	NETWORK-WIDE MEASURES
Vehicle Miles or Kilometers	Vehicle Miles or Kilometers
Vehicle Trips	Vehicle Trips
Moving Time (vehicle-minutes)	Moving Time (vehicle-hour)
Delay Time (vehicle-minutes)	Delay Time (vehicle-hour)
Total Travel Time (vehicle-minutes)	Total Travel Time (vehicle-hour)
Moving/Total Time (percent)	Moving/Total Time (percent)
Total Time (minutes/ km or mile)	Total Time (minutes/mile or km)
Delay Time (minutes/ km or mile)	Delay Time (minutes/mile or km)
Total Travel Time (seconds/vehicle)	Total Travel Time (minutes/vehicle-trip)
Delay Time (seconds/vehicle)	Delay Time (minutes/vehicle-trip)
Queue Time (seconds/vehicle)	Stopped Delay Time (minutes/vehicle-trips)
Stop Time (seconds/vehicle)	Stop Percentage
Percent Stops	Average Speed (mph or km/h)
Average Volume (vph)	Network Occupancy (vehicles)
Average Speed (mph or km/h)	Phase Failure
Average Occupancy (vehicles)	
Queue Length by lane (vehicles)	
Number of Lane Changes (vehicles)	
Phase Failure	

users with means of analyzing and evaluating simulation results graphically has been added as a support program to the TRAF family of models. GTRAF version 5.0, which was developed for the Federal Highway Administration of the U.S. Department of Transportation was designed as an interactive graphics display program for a traffic simulation model known as TRAF-NETSIM version 5.0. GTRAF is subdivided into two parts: SNETG and ANETG. SNETG is used to present "static" displays in a graphical format while ANETG is used to presents "dynamic" or animated displays. Figure 2-2 shows the hierarchy of the logical structure of the GTRAF program.

GTRAF, a microcomputer-based interactive program is a very useful feature, which has been added as a support tool to graphically display the wealth of information produced by TRAF-NETSIM. This graphics program provides transportation engineers with a highly effective capability of reviewing the input data and analyzing the results generated by TRAF-NETSIM. In addition, it aides researchers in presenting their findings or recommendations to policy makers in a graphical or animated format which is an efficient, and somewhat entertaining way to gain insight into the specific traffic strategies being analyzed.

This research has relied on the animated feature in GTRAF to check the geometric input data (number of lanes, turning bays, etc.), the traffic input data (traffic volumes), and the traffic control input data (signal timings, phase sequence), to the actual data observed in the field.

In summary, TRAF_NETSIM produces a vast amount of simulation output in the form of statistical tables, and it will be very time consuming and would require considerable skills to manually convert these statistical data presented by NETSIM into

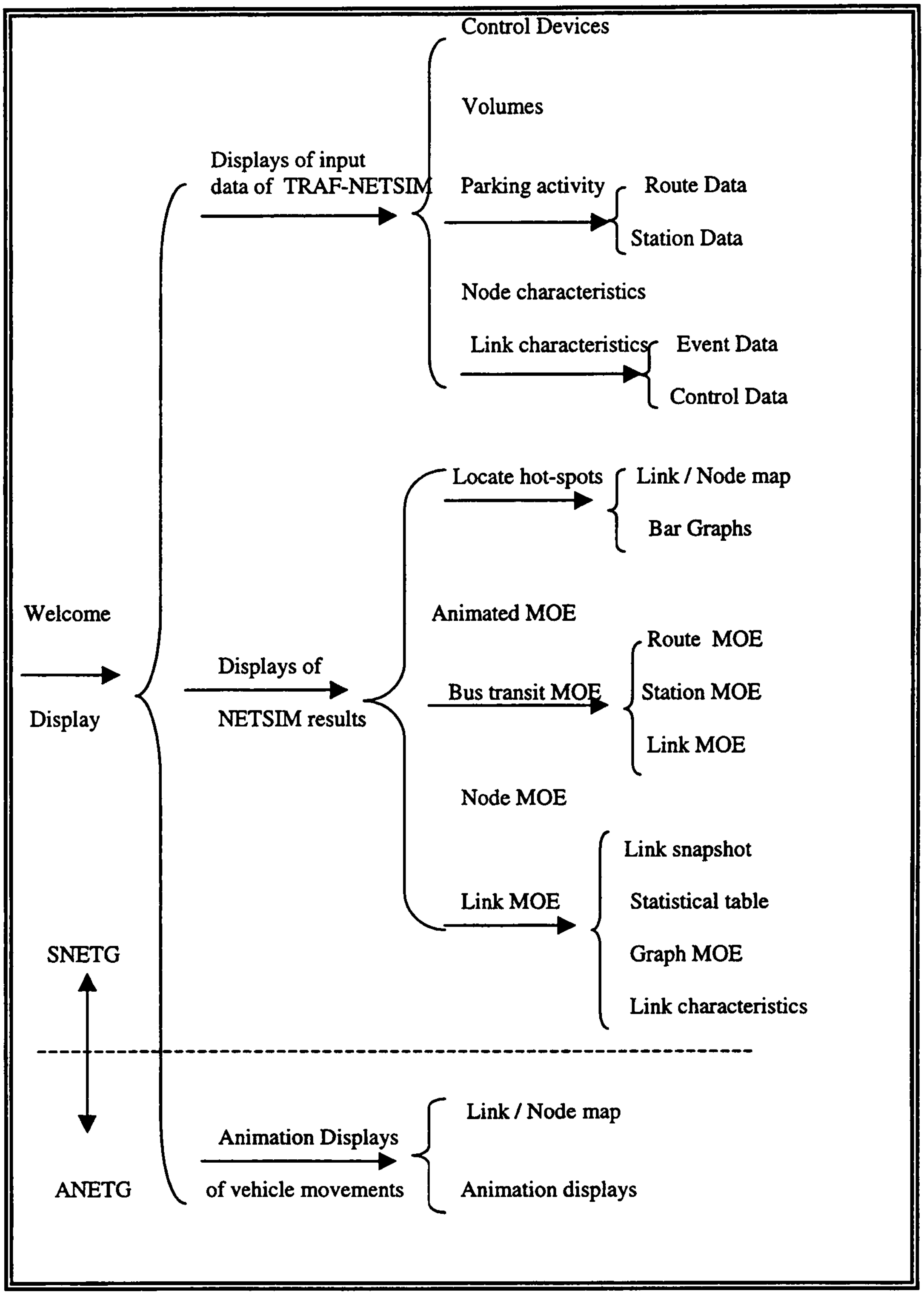


Figure 2-2
Hierarchy of the Logical Structure of GTRAF

graphical information. In addition, there are some professionals who are reluctant to accept the idea that a computer simulation can actually describe the complex process of traffic flow at an acceptable level of accuracy and reliability. The GTRAF graphics software was designed to specifically demonstrate TRAF-NETSIM'S ability to realistically represent the traffic environment, thus increasing the validity and credibility of the simulation program.

Microcomputer Version of TRAF-NETSIM Model

The TRAF-NETSIM computer program is written in FORTRAN language and was originally indented for mainframe computers. However as part of the maintenance and support activity for the TRAF simulation software, a microcomputer version of the TRAF-NETSIM simulation program has also been developed. This microcomputer version of TRAF-NETSIM requires an IBM XT, AT, with a 386 microprocessor (or compatible) with 640 kilobytes of conventional memory, a 25 megabytes of free hard disk and a monitor. To be able to view graphic outputs, a VGA (Video graphic adapter) color monitor is required along with at least 8 megabytes of extended memory (8 megabytes of RAM). Simulation time varies depending on the size of the network being simulated, the traffic volumes specified, and the hardware available on the computer running TRAF-NETSIM.

CHAPTER III

RESEARCH METHODOLOGY

Introduction

During the past decade, transportation engineers have been utilizing computer-based simulation programs to aid in the design and evaluation of a wide range of transportation management strategies. TRAF-NETSIM, a microscopic computer simulation program, which simulates the behavior of traffic flow stochastically, is probably one of the most widely used and accepted traffic simulation model in the United States of America. The methodology utilized in this research used the TRAF-NETSIM version 5.0[16], which is part of the TRAF family of models, to determine the adaptability and applicability of this model in predicting the traffic flow performance in Amman, Jordan. This was accomplished by measuring specific traffic parameters from an actual street segment, collecting all the required input data from the street network, comparing the simulated output with specific field measurements, calibrating the model, and validating the calibrated model in a second street network.

Analytical Analysis

A wide range of embedded, default traffic parameters in TRAF-NETSIM model reflects drivers' performance and traffic conditions that exist in The United States of America. Some of these parameters were expected to be different in Jordan and if so, modified accordingly to better represent the local driving environment. These include driver and vehicle response to changes in the traffic environment and characteristics of vehicle flow.

The following is a list of the calibration parameters that are embedded within the TRAF-NETSIM model.

1. Mean value of start-up lost time for the first vehicle.
2. Mean queue discharge headway.
3. Desired free flow speed.
4. Distribution for start up lost time.
5. Distribution for queue discharge headway.
6. Distribution of free flow speed.
7. Left-turn jumper probabilities.
8. Maximum allowable turning speeds.
9. Lane switching acceptable lag.
10. Probability of a vehicle joining a spillback.
11. Left turn lagger turn probability.
12. Effective length of vehicle type.
13. Acceptable gap in near-side cross traffic for vehicles at a stop sign.
14. Additional time for far-side cross traffic for vehicles at a stop sign.
15. Amber phase response.
16. Acceptable gaps in oncoming traffic for left-turners.
17. Acceptable gaps in oncoming traffic for right-turners.
18. Delay due to pedestrian conflicts.
19. Distribution for short-term event duration.

As can be seen, there is a wide variety of embedded default parameters used internally by NETSIM, some of which may, or may not be applicable to the local environment being simulated. In addition, some of the parameters are more important than other parameters, since they may have a greater impact on the selected MOE'S. To identify which parameters meet the above criteria a detailed look at each embedded parameter is presented.

1. Mean value of start-up lost time for 1st vehicle:

The new version of TRAF-NETSIM (release 5.0) has modified the default value of start-up lost time from 2.5 seconds to 2.0 seconds according to a recent study conducted in Maryland and published by NCHRP. [16] The start-up lost time value is the delay experienced by lead vehicles in a standing queue when the traffic signal changes from red to green. Start-up lost time is a representation of how fast or slow a driver may react to a given stimulus. This value will be measured in the field to determine the appropriate value needed to accurately calibrate the model.

2. Mean queue discharge headway:

The new version of TRAF-NETSIM release 5.0 has also modified the default value of mean queue discharge headway from 2.2 seconds to 1.8 seconds according to the latest study conducted in Maryland and published by NCHRP. [16] By definition, it is the time-gap between vehicles discharging from a standing queue. This value is a representation of how aggressive drivers may react as they move up to the stop line. This value will be measured in the field to determine the appropriate value needed to calibrate the NETSIM model.

3. Desired free flow speed:

As each vehicle enters an approach (link), it is assigned an unimpeded free-flow speed. This is obtained by multiplying the specified unimpeded mean free-flow speed for that link by a percentage. The default used by NETSIM is 30 mph (48 km/h). The desired free flow speed does influence the travel time and delay values on a particular link.

Therefore, this parameter will be modified according to the posted speed limit on the selected street network in Amman, Jordan.

4. Distribution for start up lost time:

The first vehicle in the queue will incur some start-up lost time. This is calculated by multiplying the free-flow speed by a percent obtained from the following decile distribution.

Driver Characteristic K	1	2	3	4	5	6	7	8	9	10
Link Type 1	218	140	125	118	102	86	78	63	47	23
Link Type 2	258	190	143	114	95	76	57	38	29	0

For example, as a vehicle enters a link it will be assigned a random number from 1 to 10 inclusive. Assuming that this number is 7 with a start-up lost time of 2.0 seconds. Then the start-up lost time of this vehicle would be 2.0 * 0.78 or 1.56 seconds. This decile distribution will be changed to reflect the local driving environment.

5. Distribution for queue discharge headway:

As each queued vehicle moves up to the stop line, it is assigned a delay until discharged, reflecting the queue discharge headway. This is calculated by multiplying the mean queue discharge headway by a percent obtained from the following decile distribution.

Driver Characteristic K	1	2	3	4	5	6	7	8	9	10
Link Type 1	170	120	120	110	100	100	90	70	70	50
Link Type 2	180	140	120	110	100	90	80	70	60	50

For example, as a vehicle enters a link it will be assigned a random number from 1 to 10 inclusive. Assuming that this number is 7 and the specified mean queue discharge headway is 1.8 seconds. Then the discharge headway for this vehicle would be 1.8 * 0.9 or 1.62 seconds. This decile distribution will be change to reflect the local driving environment.

6. Distribution of free flow speed

As each vehicle enters an approach (link), it is assigned a free flow speed. This is obtained by multiplying the unimpeded free-flow speed by a percent obtained from the following decile distribution.

Driver Characteristic K	1	2	3	4	5	6	7	8	9	10
% Multiplier of Free-Flow Speed	75	81	91	94	97	100	107	111	117	127

For example, as a vehicle enters a link, it will be assigned a random number from 1 to 10 inclusive. Assuming that this number is 7 and a free flow speed of 30 mph was entered by the user. Then the free flow speed of this vehicle would be 30 * 1.07 or 32.1 mph. This decile distribution seems to be reasonable and will remain the same.

7. Left-turn jumper probabilities:

A left turn jumper is a vehicle that is first in queue when the signal changes from red to green, and executes the left-turn maneuver (immediately) before the on-coming queues can discharge. This is applicable only when there is a permitted left turn and will not be applicable in Amman since all left-turns at signalized intersections have a protected phase. This embedded value will not be applicable.

8. Maximum allowable turning speeds:

A moving vehicle unimpeded by others must slow as they approach an intersection if they are to negotiate a right or left turning maneuver. The embedded default speeds applied deterministically are 13 fps (4 m/s) and 22 fps (7 m/s) for right and left turners respectively. This parameter will not have a great impact on travel time or delay on the arterial street. Therefore it will not be changed.

9. Lane switching acceptable lag:

A vehicle cannot switch lanes unless an acceptable lag is available in the target lane. The embedded default applied deterministically is 3.1 seconds. This parameter might have a significant effect on travel times and delay. However, it is difficult to measure in the field due to the limited resources available to the analyst.

10. Probability of a vehicle joining a spill-back:

A vehicle, which faces a spillback condition on its receiving link at the time it is about to discharge, must decide whether to discharge or wait until the spillback ahead dissipates. The probability of a vehicle joining a spillback comprised of I vehicles is shown below:

I	1	2	3	4
Probability	100	81	69	40

These probabilities seems reasonable, therefore will not be changed.

11. Left turn lagger turn probability:

A left turn lagger is a queued vehicle that executes a left-turn across opposing traffic during a NO GO interval immediately following a left-turn GO (and AMBER) interval. If a left-turner is at the stop line within 2 seconds after the start of the NO GO interval, the probability that he will execute the turn movement is stored in LTLAGP(1); if within 4 seconds, in LTLAPG(2); if within 5 seconds, in LTLAGP(3). The embedded default values are:

LTLAGP(1) = 97%
LTLAGP(2) = 77%
LTLAGP(3) = 37%

These probabilities seem reasonable and if modified slightly will not significantly effect the travel times and delay at the main arterial street. Therefore these values will not be changed.

12. Effective length of vehicle type:

The effective length of vehicles includes the vehicle length plus an inter-vehicle spacing of 3-ft (1m). The embedded default values are:

I	Fleet Component	Length
1	Auto	20 feet (6 meters)
2	Truck	37 feet (11 meters)
3	Carpool	20 feet (6 meters)
4	Bus	50 feet (15 meters)

These values seem reasonable since the traffic fleet in the United States and Jordan are similar. (There are American cars, German cars, and Japanese cars etc.) However, a 5th fleet will be added since Amman has both Mini buses (20 to 25 seats) and large buses operating as public transit vehicles on the proposed network.

13. Acceptable gap in near-side cross traffic for vehicles at a stop sign:

A vehicle at a stop-line facing a STOP sign cannot discharge until an acceptable gap is available in the nearside cross street. The nearside cross street is always the approach to the left of the STOP sign approach. The acceptable gap (in tenths of a second) is based upon driver characteristic code I, and is chosen from a decile distribution. The embedded default values are:

Driver Characteristic I	1	2	3	4	5	6	7	8	9	10
Acceptable Gaps	56	50	46	42	39	37	34	30	26	20

14. Additional time for far-side cross traffic for vehicles at a stop sign:

Time in addition to acceptable gap required for vehicles to cross the far side cross street at a STOP sign. The far side cross street is always the approach to the right of the STOP sign approach. The additional time (in tenths of a second) required to cross the far side cross street depends on the total number of lanes to be crossed, and is chosen from a decile distribution.

The embedded default values are:

Total lanes to clear the intersection	1	2	3	4	5	6	7	8	9	10
Additional time	12	21	26	31	35	39	42	46	49	51

Acceptable gaps at stop signs will not be changed because the proposed study period is the afternoon peak, and the majority of vehicles will be turning into the side streets, as opposite to turning into the main street. This is true for both of the proposed networks, since there are residential neighborhoods at both sides of the main arterial street.

15. Amber phase response:

The response of a lead-moving vehicle in a lane that has no queue at the instant the signal turns amber, is expressed in terms of an acceptable deceleration rate. The embedded default values, in ft/sec^2 are:

Driver Characteristic K	1	2	3	4	5	6	7	8	9	10
Acceptable Deceleration	21	18	15	12	9	7	6	5	4	4

This parameter will not be changed since it will be difficult to observe due the limited resources and equipment available for the analyst.

16. Acceptable gaps in oncoming traffic for left-turners:

Acceptable gaps for left-turning vehicles in the oncoming traffic. The embedded default values, in tenths of a second, are:

Driver Characteristic K	1	2	3	4	5	6	7	8	9	10
Acceptable Gaps	78	66	60	54	48	45	42	39	36	27

This parameter will not apply since all left-turners in the proposed network will have their own signal phase indication.

17. Acceptable gaps in oncoming traffic for right-turners:

Acceptable gaps in oncoming traffic for right-turners to complete a RTOR maneuver. The embedded default values, in tenths of a second, are:

Driver Characteristic 10 + K	11	12	13	14	15	16	17	18	19	20
Acceptable Gaps	100	88	80	72	64	60	56	52	48	36

This parameter will not be applied since RTOR is prohibited in Jordan.

18. Delay due to pedestrian conflicts:

The amount of pedestrian conflict is determined by the intensity of the pedestrian flow and the elapsed time since the beginning of the green phase. There are two kinds of conflicts defined by a statistical decile distribution, along with the duration of vehicle delay, in seconds. The embedded default values are:

I	1	2	3	4	5	6	7	8	9	10
Weak Interaction	0	0	0	0	0	0	0	1	2	6
10 + I	11	12	13	14	15	16	17	18	19	20
Strong Interaction	0	0	0	1	2	3	4	5	8	15

Here, I reflect a random number between 1 and 10, inclusive. The time between strong and weak interaction is expressed in terms of the elapsed time since the beginning of green. At the beginning of the phase, strong interaction prevails. However, for the rest of that phase, weak interaction is in effect. The embedded default values for the duration of a strong pedestrian interaction are:

Light Pedestrian Flow	0 seconds
Moderate Pedestrian Flow	10 seconds
Heavy Pedestrian Flow	25 seconds

The proposed network has very few, if any pedestrian crossing at the signalized intersection. Therefore these values will not be changed.

19. Distribution for short term event duration:

The duration of a short-term event is assigned by multiplying the specified duration (Record Type 54), for that link, by a percentage extracted from a decile distribution. A short-term event is applicable only if vehicles are illegally parked, standing, or stopping in lane 1 (Curb lane). The embedded default duration of short-term event, in percent are:

I	1	2	3	4	5	6	7	8	9	10
% Multiplier of short term event duration	10	20	30	40	50	70	100	130	180	370

Here, I reflect a random number between 1 and 10, inclusive. This parameter seems reasonable and will not be changed.

A brief description of the traffic parameters embedded into TRAF-NETSIM model has been presented. These parameters are treated in the model as default values representing traffic conditions that may be applicable in the absence of actual field values. This research will measure the following five traffic parameters in the field under normal driving conditions. These values will be used to calibrate the TRAF-NETSIM model to best represent the Jordanian driving environment.

1. Mean value of start-up lost time for 1st vehicle.

2. Mean queue discharge headway.
3. Desired free flow speed.
4. Distribution for start up lost time.
5. Distribution for queue discharge headway.

In order to reach the desired goals and objectives of this research mentioned in chapter I, several steps where taken and are presented in the following:

Network Selection

The first task taken by this research was to identify two arterial streets in Amman - Jordan. The first arterial street was used in the evaluation and calibration of TRAF-NETSIM; the second arterial street was used in the validation of the calibrated model.

After studying and touring the streets of Amman for several days, two main arterial streets that contained both signalized and unsignalized intersections were chosen for the purpose of this research. To assure the successfulness of this project and to insure that the two arterial streets were typical streets representing traffic conditions in Amman-Jordan, the following guidelines were established to facilitate in the selection of the study sites.

1. The study sites had to be within the city limits due to the willingness of The Greater Amman's Traffic Engineering Department to assist in supplying the traffic signal timings.
2. The street network should contain intersections that are controlled by stop signs, pre-timed and/or actuated signals, and signals with different cycle lengths.
3. The street network should be traveled by a variety of automobiles such as: Private and public automobiles, trucks, and buses.

4. The street network should not contain any abnormal traffic conditions such as road maintenance, detours, or special events.
5. The site should contain near-by buildings to permit for the appropriate camera setup used in the collection of all traffic input data required to run the TRAF-NETSIM simulation model.

It should be mentioned that the last criteria presented above, was related to the accuracy of the data collection technique utilized by this research. The exact location and procedural information will be discussed in more detail later in the chapter.

The first arterial street network (presented in Figure 3-1), here after referred to as the Test Network, is a 4 lane divided arterial. The major arterial street name is Mecca Street, which contains three fully actuated signalized intersections and is approximately 2500 meters long (1.562 miles).

The second arterial street network (shown in Figure 3-2), here after referred to as the Validation Network, is a 4 lane divided arterial. The major arterial name is Al-Shareef Nasser Bin Jameel Street, (or Safeway Street) which contains four actuated signalized intersections and is approximately 1500 meters long (0.937 miles).

The Test Network was utilized in the following manner:

1. Evaluate and test the TRAF-NETSIM model using the embedded default values.
2. Collect the five traffic parameters to replace the TRAF-NETSIM'S embedded default values.
3. Evaluate and test the calibrated model using the parameters obtained from 2 above.

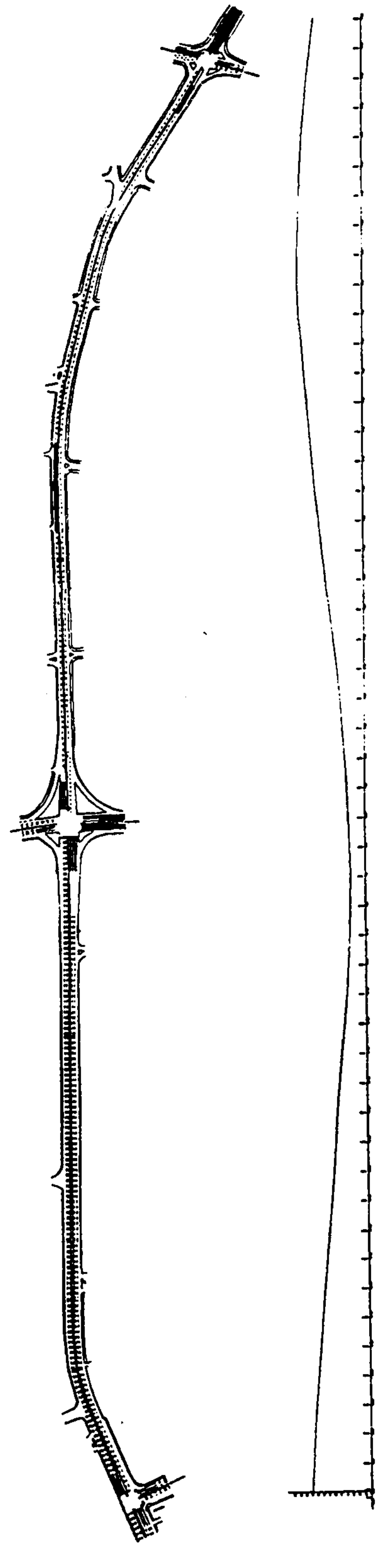


FIGURE 3-1: Test Network (Plan View)

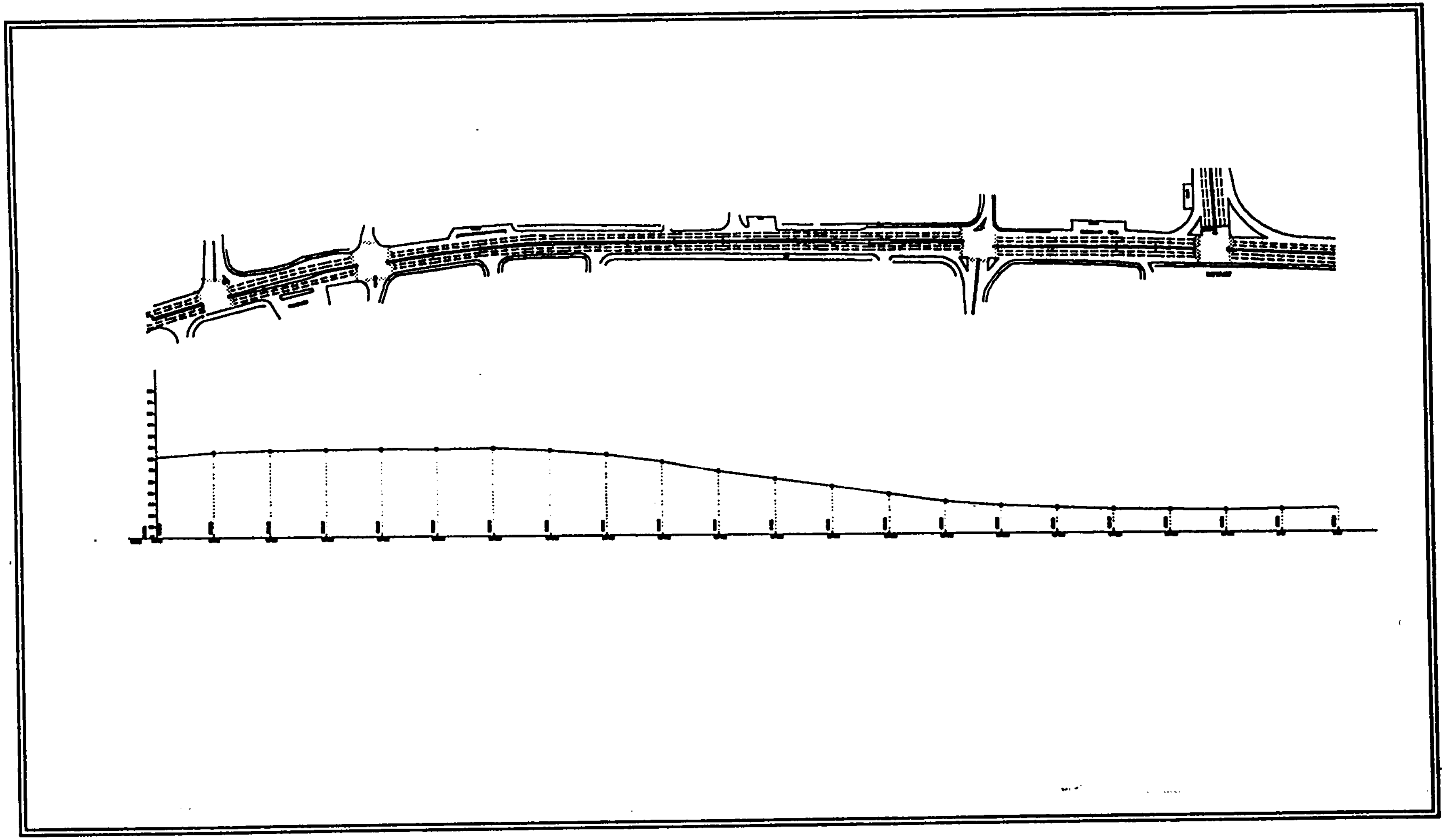


FIGURE 3-2: Validation Network (Plan View)

The Validation Network was utilized in the following manner:

- Model Validation, the purpose of this step is to determine whether of not the calibrated model can accurately simulate traffic conditions in the Validation Network.

Measures of Effectiveness (MOE's)

TRAF-NETSIM, a microscopic simulation program, that simulates the traffic system and predicts the effects of different traffic engineering and transportation systems management strategies on the system's operational performance, expressed in terms of measures of effectiveness. These MOE's are calculated for each specific link or for the network as a whole and are presented by the model in a statistical tabulation format. The specific measures of effectiveness selected for the evaluation of driver performance in Amman, Jordan were as follows:

1. Link Travel Time:

   Travel Time is defined as the average travel time for a single vehicle on a specific link expressed in terms of seconds per vehicle.

2. Delay Time (Route Delay Time):

   Delay Time is defined as the average delay time for a single vehicle on a specific link expressed in terms of seconds per vehicle.

Figure 3-3 shows the relationship between Travel Time, Moving Time, and Delay Time for vehicles travelling along a link.

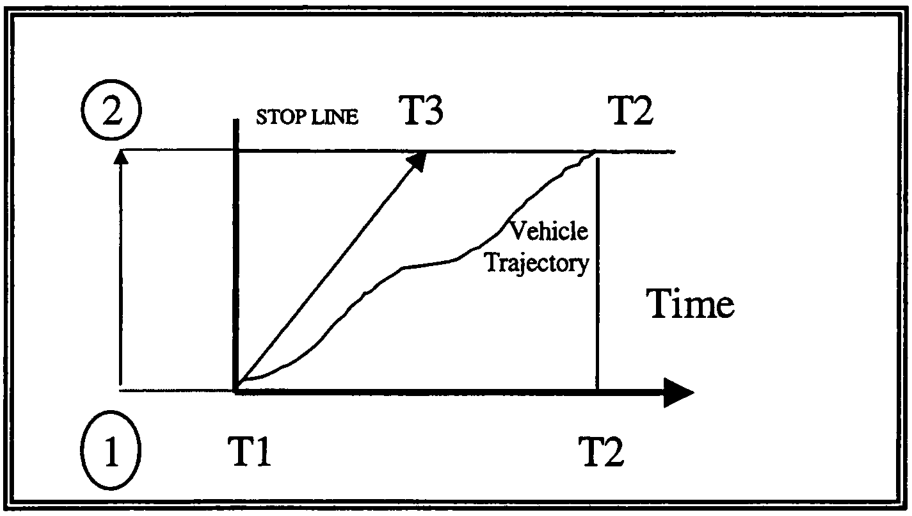


Figure 3-3
Relationship between Travel Time and Delay Time

A vehicle traveling from node 1 to node 2 would enter the link at time T1 and would exit the link at time T2. Therefore the travel time for this vehicle would simply be the difference between entry time and exit time. This is expressed as:

Travel Time = T2 - T1

Assuming that there is no impedance on the road, then the vehicle would enter the link at time T1 and would exit the link at time T3, while traveling along the link at the vehicle's free flow speed. Therefore, this travel time would represent the fastest travel time possible, for this vehicle, as it travels along the link. This time is referred to Ideal Travel Time and it is expressed as:

Ideal Travel Time (Moving Time) = T3 - T1

Delay time is the time spent on the link by a vehicle in excess of its' Ideal Travel Time. This is expressed as:

Delay Time = T2 - T3

These measures of effectiveness were selected because they are good indications of the system's performance and most importantly are relatively easy to observe in the field.

Field Study

The field study was a major step in this research project. The TRAF-NETSIM simulation program is very data intensive and requires detailed information to accurately represent the traffic environment being analyzed. The simulation program requires information concerning the geometric representations for each roadway segment, traffic volumes and turn movements at each intersection, and type of traffic control being used along with its duration.

The Municipality of Amman did not have detailed maps or traffic volumes for the selected sites. Therefore, a local surveying firm was hired to map the selected sites, which were needed to accurately code the network into TRAF-NETSIM. In addition a local video camera crew was hired to video tape all the traffic volumes at main intersections in order to produce traffic counts, turning percentages and traffic composition needed to execute accurately the TRAF-NETSIM model.

Video Study

As mentioned earlier, a local video camera crew equipped with the state of the art equipment was hired to setup and record the traffic activities for both the Test Network and Validation Network. These tapes were later used to gather detailed information on traffic counts, turn percentages, and traffic composition through out the study period.

Test Network:

In order to capture all of the traffic activities along the Test Network (Figure 3-1), a total of seven video cameras were setup strategically on the roofs of three buildings. Each of the buildings were close to the three signalized intersections and were elevated adequately to permit the video lens to capture all turning movements at the signalized intersections. Figure 3-4 shows the approximate locations of the buildings along with the number of video cameras and their respective angle of view. Due to social and cultural circumstances in Amman, Jordan, the official public holiday of each week, is Friday. In addition, the majority of government agencies work from 8:00 AM until 2:00 PM. The data-collection phase started on Saturday, May 10, 1997 and continued for a total of seven days until Friday, May 16, 1997. The video cameras recorded traffic volumes continuously for a period of 2 hours, from 12:30 PM until 2:30 PM of every day. At the end of seven days of video filming, a total of 49 videos each 2 hours long were collected. The videotapes were at a later date viewed by the researcher with the help of an associate, in order to retrieve traffic volumes; turning percentages and vehicle classifications along the Test Network. This phase of data viewing and recording took an extensive amount of time, since all of the videotapes were viewed several times, in order to capture all the traffic activities.

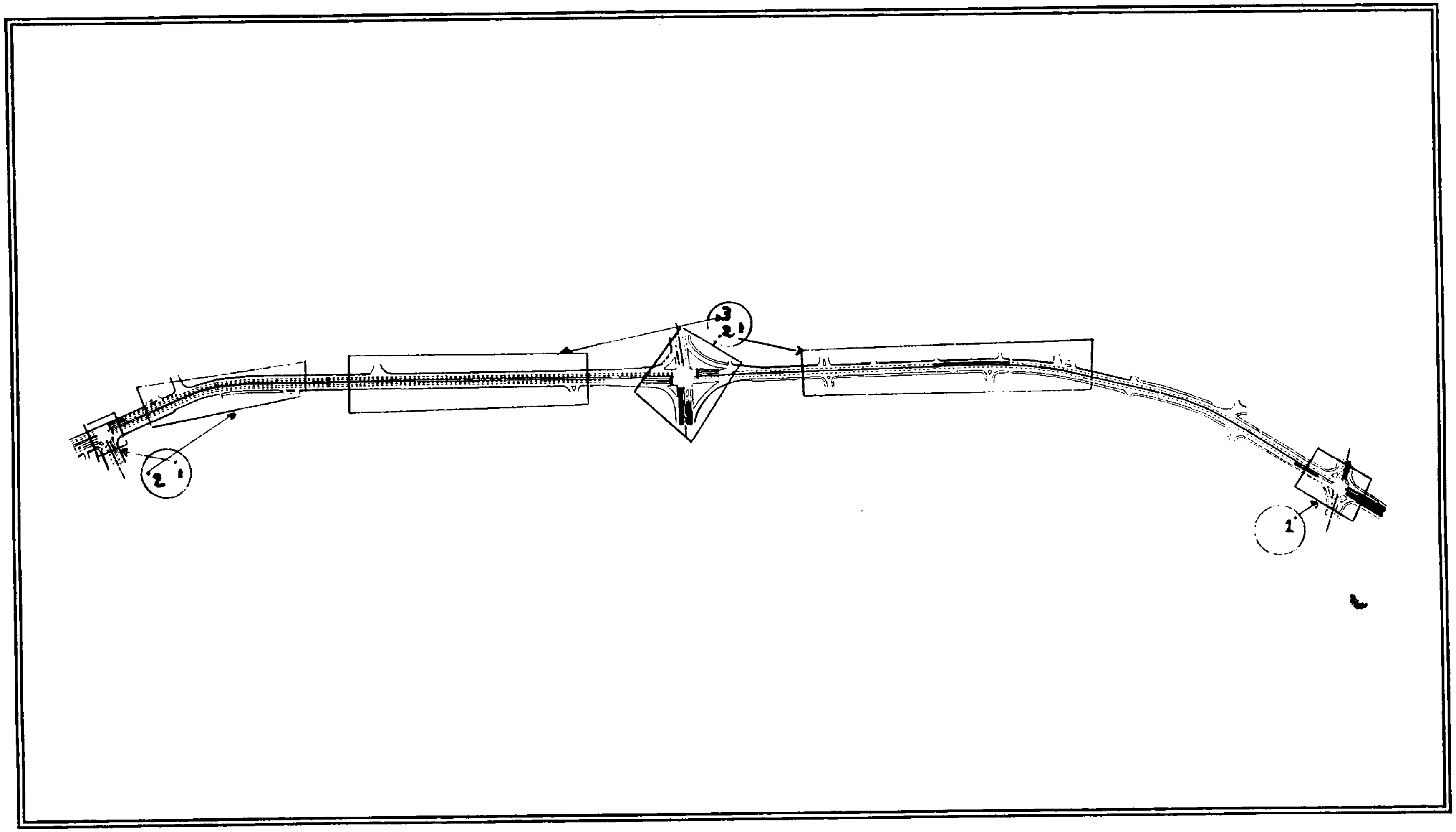


FIGURE 3-4: Building locations and number of video cameras for Test Network

Validation Network:

In order to video tape all the required traffic volumes from the Validation Network (Figure 3-2), a total of five video cameras were setup strategically on top of two buildings. Each building was close to two signalized intersections and their elevation allowed the video camera lens to record all the traffic volumes and turning movements, within the arterial. Figure 3-5 presents the approximate locations of the buildings, along with the number of video cameras and their prospective views. The data-collection phase for the validation network started on Saturday, June 27, 1998 and proceeded for seven days until Friday, July 3, 1998. The camera operators recorded traffic volumes continuously for a period of 2 hours from 12:30 P.M. until 2:30 P.M. of every day. At the conclusion of seven days of video filming, a total of 35 videos, each 2 hours long, had been compiled. The videotapes were at a later date viewed by the researcher and colleague, in order to recover traffic volumes, turning percentages, and vehicle classifications along the Validation Network. This phase of data viewing and recording also required an extended period of time, since each videotape had to be viewed multiple times, to capture all the traffic activities.

Prior to filming on both the Test and Validation Networks, the owners of all the selected buildings were informed by the researcher on the scope of this project. After which, permission for the filming crew to setup and access a power supply for our video cameras was granted. Each video camera was equipped with a supplementary battery, in the event of probable local power failures. In addition, all the video camera's internal clocks were calibrated to the closest minute, so that all the data collection would start at the same time.

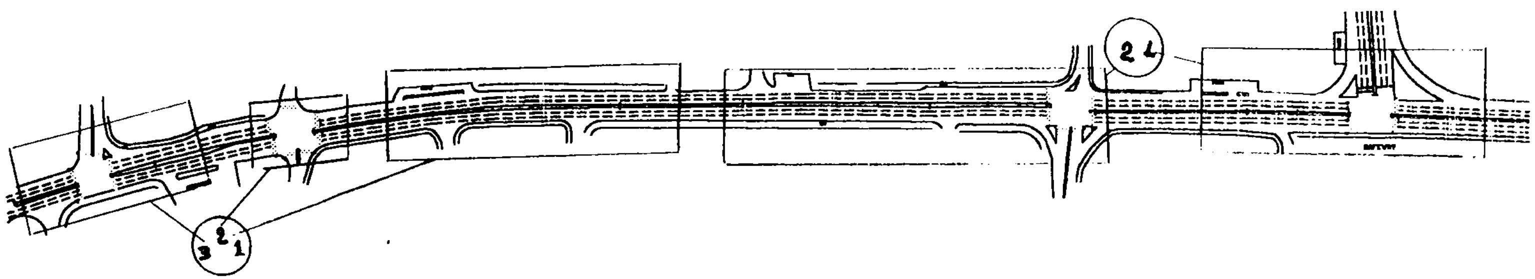


FIGURE 3-5: Building locations and number of video cameras for Validation Network

Furthermore, to avoid any interruptions from police officers questioning the purpose of our activities, official permits for filming were obtained. This necessitated that the researcher, along with the Head of the Municipality of Amman's Traffic Department, contacted the Traffic Police Authority and informed them on the scope, location and duration of each phase of video filming, previous to the scheduled collection date.

Floating Car Study

The specific measures of effectiveness selected for the evaluation of driver performance were Average Travel Time and Average Delay Time of vehicles along the arterial street. The first measure of effectiveness, The Average Travel Time, was measured in the field, in accordance to the Test Car Technique presented in the Manual of Transportation Engineering Studies [(13)]. A Travel Time study measures the time required to transverse a given section of the roadway. Historically, there are two driving strategies used to obtain representative travel times. The first is the "floating car" method, in which the driver attempts to approximate the average speed by passing as many vehicles, as pass the driver. The second the "average speed" method, in which the driver travels at a speed that in his opinion, is representative of the speed of the traffic at every point. In other words the driver attempts to "go with the flow" as he travels along the roadway. The latter method was chosen for this research, since it had shown by previous tests excellent correlation with actual average travel times [(14)]. The researcher along with a colleague, each drove their car measuring travel times between designated points along the arterial street. In order to compare the field measured and computer simulated Travel Times under similar traffic-volume conditions, the data collection was performed simultaneously during the video camera procedure outlined in the video study above for both the Test and Validation networks. A 9-lap memory stopwatch was used to keep track of the travel times between intersection along the arterial. The driver would start the stopwatch at the beginning of the test site and would press the lap button at successive control points along the route. The driver would then record the lap times on a designated worksheet at the end of each run. The test runs started at different time points in the signal cycle, to avoid having all trips be a first in the platoon placement. The number of runs recorded on the Test Network was 7 runs per direction (WB, EB) and on the Validation Network ranged from 8 to 10 runs per direction of travel (NB, SB) per recording day. The statistical analysis of the Travel Time Study is presented in the next chapter.

Calibration Parameters

A brief description of the traffic parameters embedded into TRAF-NETSIM model was presented in the Analytical Analysis section. These embedded parameters are treated in the model as default values representing traffic conditions that may be applicable in the absence of actual field values. This research will measure the Mean Discharge Headway and the Mean Start-Up lost time along with their respective distributions in the field under normal driving conditions. These modified or calibrated traffic parameters will replace the default values in TRAF-NETSIM in order to calibrate the simulation model.

1. Mean Discharge Headway (Saturation Headway)

In order to collect Average Discharge Headway's at intersections a Saturation Flow study using a stopwatch was performed. This study was accomplished by observing vehicle's discharging from a link when the signal turns from red to green. The observer situated on the rooftop of a three-story building located near an approach to a signalized intersection measured Discharge Headway's of passenger cars. This assured a clear view of the approach being observed, the stop line, and the signal indication. In addition, it made the observer extremely inconspicuous, thereby minimizing any disturbance in the natural behavior of traffic flow. The observer started the stop watch when the rear axle of the third vehicle in a queue, that had been stationary while waiting for the green phase crossed the stop line, and stopped the stop watch when the rear axle of the seventh, eighth, or ninth vehicle in queue, crossed the stop line (which was the last vehicle in the stopped queue at the instant the signal turned green). This study was performed mid-week during the month of April on Monday the 28th, Tuesday the 29th, and Wednesday the 30th, 1997. This study followed the procedure for studying saturation flow with a stopwatch outlined in both the Manual of Transportation Engineering Studies, and Traffic Engineering Handbook. [13,14] The statistical analysis for the mean discharge headway is presented in the next chapter.

2. Mean Start-Up Lost Time

Start-up lost time by definition is that time that occurs between the instant the green signal indication starts and the queue begins moving efficiently. Therefore, Start-up lost time for the first vehicle in queue when the signal turns to green can be computed by subtracting the difference in time between the start of the green phase and the passing of the rear axle of the first vehicle in queue. This study was performed simultaneously during the measurement of the Mean Discharge Headway discussed above. The observer measured the

Start-up lost time for the first vehicle by starting the stopwatch when the signal turned from green to red and stopped the stopwatch when the rear axle of the same vehicle crossed the stop line. The statistical analysis of the Start-Up Lost Time study along with its distribution is presented in the next chapter. It should be mentioned that this study followed the procedure for Start-Up Lost Time Studies as outlined in the Manual of Transportation Engineering Studies.[13] The statistical inquiry of this study is discussed in the Statistical Analysis Chapter.

Simulation Study

The TRAF-NETSIM model, which simulates the behavior of individual driver-vehicle combinations in an urban street network, is a microscopic, stochastic simulation program. The simulation output produced by TRAF-NETSIM contains a great deal of variability from one simulation run to the next. This variability is present in the model due to the highly attractive probabilistic nature in TRAF-NETSIM and tends to be more apparent in microscopic simulation programs. To reduce the variability in the model's generated output, which can have a negative effect concerning the reliability and realism of the simulation model, a new feature was added to the TRAF-NETSIM model that allows the users to simulate with traffic streams exhibiting the same routing patterns and driver-vehicle combinations. This new feature, the Identical Traffic Streams, which was discussed in depth in chapter II, allowed the user to specify two random numbers seeds to control all stochastic decisions. The first random number seed is the "base seed" and is used to generate the traffic movement for a given simulation run. The second random number seed is the 'common seed' and is used for all time-dependent stochastic decisions (i.e. accepting available gaps for turns, determining location and duration of events, etc.).

In order to reduce the variance between simulation runs, this research will use multiple independent replications. Independent replications in simulation experiments refers to the execution of the simulation model several times for a given set of identical input data, except the random number seed is changed between runs [19]. This research will use a set of identical random numbers for the "base seed" for each simulation run and will not change any other input data. This variance reduction technique is known as the Common Random Numbers (CRN) reduction procedure in simulation experiments' [18,28]. It should be emphasized that the reason for making several runs in TRAF-NETSIM is to increase the probability that the mean of the runs is accurately representative of the mean of the distribution, thus obtaining more reliable results. [15] However, other issues concerning the statistical aspects of simulation experiments have not been answered. This research will attempt to resolve issues of concerns such as:

- How many simulation runs should be made?
- How long should each simulation run be?
- How long should the initialization period be?

In order to get meaningful simulation results with a desired level of accuracy these questions will be addressed in the Statistical Analysis presented in the next chapter.

Input Data

TRAF-NETSIM, a microscopic stochastic simulation program, which simulates the traffic behavior and traffic control conditions of a network over a period of time, is a very data intensive program. In order to simulate the traffic behavior on both the Test Network and the Validation Network, a detailed representation of the traffic environment had to be specified. Specifically, the following input data were required to run TRAF-NETSIM model.

1- The Topology of the Network.

The topology of both arterial streets in the form of nodes and uni-directional links was specified. Nodes represented intersections or where geometric changes in the roadway occurred (e.g. added lanes, change of grade, etc.). In addition, each link represented one directional segment of a roadway or as an approach to a node. Figures 3-6 and 3-7 shows both the Test and Validation Street Networks respectively, in the form of Link-Node diagrams.

2- Geometric' for each roadway segment (link).

The following was specified for each link through out the arterial street network:

- Number of traffic lanes.
- Link length.
- Number and length of left or right turn pockets.
- Percent grade.
- Mean start-up lost time, queue discharge headway, and free-flow speed.
- Lane channelization.
- Down stream node number receiving through or turning traffic.
- Lane alignment.

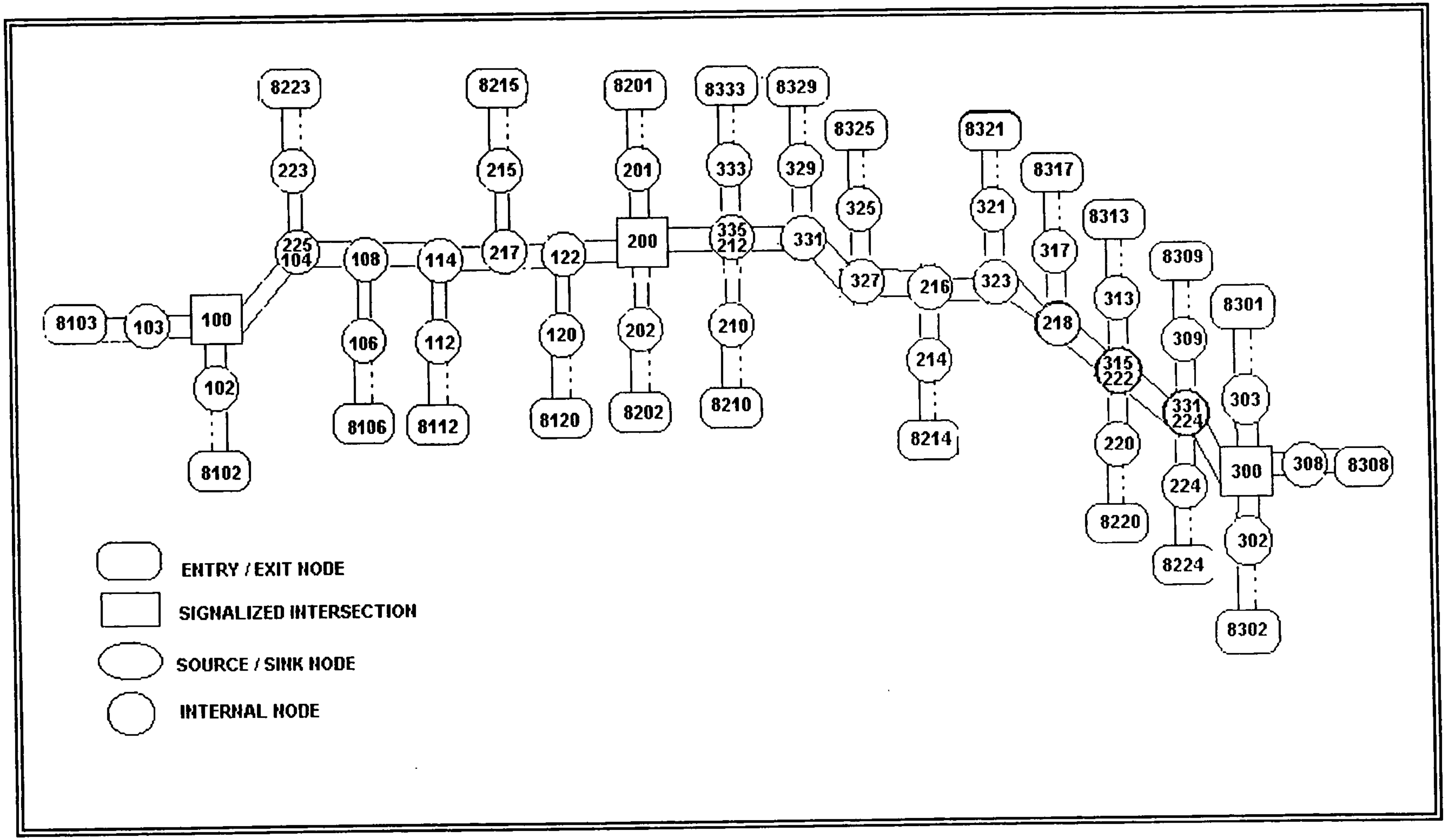


FIGURE 3-6: Test Network in the form of Link-Node diagram

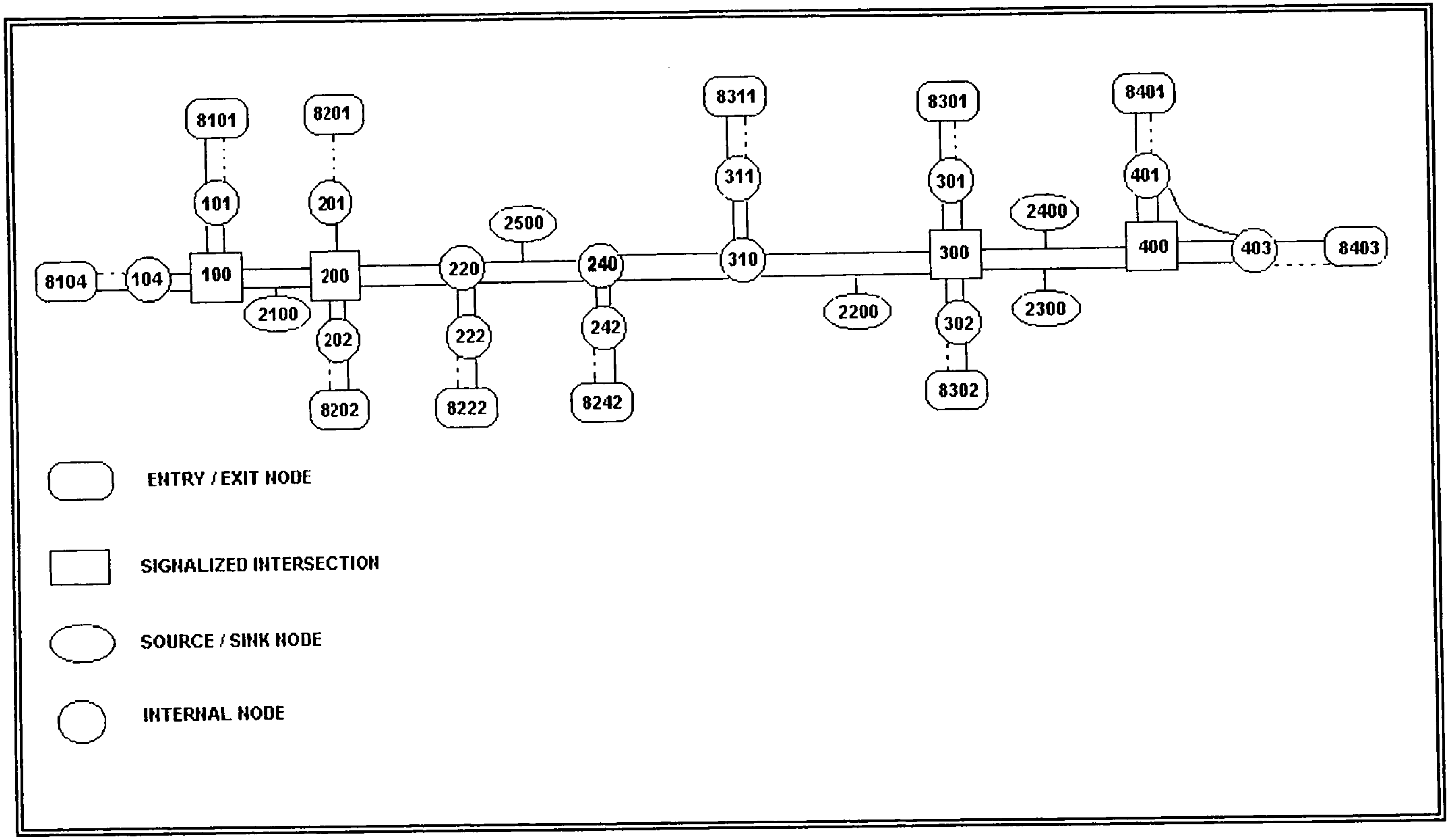


FIGURE 3-7: Validation Network in the form of Link-Node diagram

3. Control input data for each intersection (node).

For each node the type of traffic control device was specified in great detail. Both arterial street networks had intersections controlled by stop signs and actuated traffic signals. For those intersections under traffic signal control, additional information such as phase sequence, number of phases, duration of phases, offsets, type and location of detectors, and so forth and so on, was required to run TRAF-NETSIM. The test and validation networks had three and four fully actuated traffic signals respectively. The Amman Traffic Engineering Department supplied signal timings for all the signalized intersections on both arterial streets. Tables 3-1 and 3-2 shows the signal timing on both the test and validation networks.

4. Traffic Volumes.

This research collected all the required traffic volume data using video cameras located at advantage points to capture the traffic volumes through out the arterial street. The traffic demand at entry links and source nodes were defined in the form of flow rates (VPH); surface street turning movements at each intersection were also coded in terms of percent of traffic. In addition, traffic composition in terms of percent of trucks, and percent of passenger cars were also coded into the TRAF-NETSIM simulation model for both street networks. Tables 3-3 and 3-4 shows a summary of total traffic volumes expressed in VPH during the first (12:30 – 13:30) and second hour (13:30 – 14:30) of data collection on both the test and validation networks.

TABLE 3-1

Signal Timing for the Test Network

TEST NETWORK (MECCA STREET)								
JABER INTERSECTION (NODE 100)								
Phase	From node	To node			Stage Times (sec)		Amber	All Red
		Left	Through	Right	Min.	Max.	Time (sec)	(sec)
A	225	102	103		7.0	30.0	3.0	1.0
B	225 103		103 104		7.0	25.0	3.0	1.0
C	102	103		104	7.0	17.0	3.0	1.0
KILO INTERSECTION (NODE 200)								
Phase	From node	To node			Stage Time (sec)		Amber	All Red
		Left	Through	Right	Min.	Max.	Time (sec)	(sec)
A	201	212	210	122	6.0	25.0	3.0	1.0
B	335	202	122	201	6.0	30.0	3.0	1.0
C	202	122	201	212	6.0	20.0	3.0	1.0
D	122	201	212	202	6.0	35.0	3.0	1.0
RABIA INTERSECTION (NODE 300)								
Phase	From node	To node			Stage Time (sec)		Amber	All Red
		Left	Through	Right	Min.	Max.	Time (sec)	(sec)
A	308	302	331	303	7.0	30.0	3.0	1.0
B	302	331	303	308	7.0	20.0	3.0	1.0
C	224	303	308	302	7.0	30.0	3.0	1.0
D	303	308	302	331	7.0	20.0	3.0	1.0

TABLE 3-2

Signal Timing for the Validation Network

VALIDATION NETWORK (SAFEWAY STREET)

ABU ANZ 1 INTERSECTION (NODE 100)

Phase	From node	To node Left	Through	Right	Stage Times (sec) Min.	Max.	Amber Time (sec)	All Red (sec)
A	104 200		200 104	 101	7.0	30.0	3.0	1.0
B	101	200		104	7.0	25.0	3.0	1.0
C	104	101	200		5.0	20.0	3.0	1.0

ABU ANZ 2 INTERSECTION (NODE 200)

Phase	From node	To node Left	Through	Right	Stage Time (sec) Min.	Max.	Amber Time (sec)	All Red (sec)
A	220 100		100 220		7.0	30.0	3.0	1.0
B	202	100	201	220	7.0	25.0	3.0	1.0
C	220 100	202 201			5.0	20.0	3.0	1.0

EMBASEDOR INTERSECTION (NODE 300)

Phase	From node	To node Left	Through	Right	Stage Time (sec) Min.	Max.	Amber Time (sec)	All Red (sec)
A	310	301	400	302	5.0	10.0	3.0	1.0
B	310 400		400 310	302 301	5.0	80.0	3.0	1.0
C	400	302	310	301	5.0	30.0	3.0	1.0
D	302	310	301	400	5.0	15.0	3.0	1.0

SAFEWAY INTERSECTION (NODE 400)

Phase	From node	To node Left	Through	Right	Stage Time (sec) Min.	Max.	Amber Time (sec)	All Red (sec)
A	300	401	403		5.0	40.0	3.0	1.0
B	300 403		403 300		5.0	50.0	3.0	1.0
C	401	403		300	5.0	45.0	3.0	1.0

TABLE 3-3

Tabular Summary of Vehicle Counts Test Network (Mecca Street)

ESTIMATED ADT FOR EAST/WEST DIRECTION = 30,000

		SATURDAY VPH			SUNDAY VPH			MONDAY VPH			TUESDAY VPH			WEDNESDAY VPH			THURSDAY VPH			FRIDAY VPH		
JABER INTERSECTION NODE 100		L	T	R	L	T	R	L	T	R	L	T	R	L	T	R	L	T	R	L	T	R
FROM SOUTH	1ST HR	522		764	542		850	575		841	547		797	600		888	513		872	298		648
	2ND HR	663		922	655		876	619		878	619		885	605		861	592		931	342		726
FROM EAST	1ST HR	953	729		1024	772		1048	780		1050	759		971	725		1107	808		693	368	
	2ND HR	1097	812		1197	895		1225	910		1172	867		1213	926		1305	818		886	432	
FROM WEST	1ST HR		999	244		944	221		973	290		877	252		929	259		1067	335		427	113
	2ND HR		1031	326		1009	302		1025	291		1069	282		995	297		1079	299		525	155
PERCENT TRUCKS			1% to 2%			1% to 2%			1% to 2%			1% to 2%			1%			1% to 2%			1%	
KILO INTERSECTION NODE 200		L	T	R	L	T	R	L	T	R	L	T	R	L	T	R	L	T	R	L	T	R
FROM NORTH	1ST HR	734	494	522	606	417	386	699	433	580	608	397	505	624	405	476	603	434	553	313	248	251
	2ND HR	721	516	627	680	521	557	753	539	584	732	497	551	709	499	578	624	441	594	406	356	349
FROM SOUTH	1ST HR	258	539	71	233	436	99	289	508	96	271	520	62	239	515	83	246	520	79	172	282	64
	2ND HR	320	686	68	309	600	79	298	608	93	284	589	89	284	598	89	277	617	95	207	414	79
FROM EAST	1ST HR	436	873	287	445	803	208	552	920	357	399	855	296	458	858	290	443	956	301	283	422	40
	2ND HR	497	967	325	542	1120	291	576	1082	342	570	1083	381	570	1099	320	601	1125	316	373	572	13
FROM WEST	1ST HR	1197	804	85	1083	673	54	1322	835	68	1214	762	71	1261	715	83	1247	827	82	684	452	65
	2ND HR	1355	833	83	1376	785	80	1419	849	86	1355	818	88	1357	818	65	1456	840	72	819	1084	82
PERCENT TRUCKS			1% to 2%			1% to 2%			3%			2% to 3%			1% to 2%			1% to 2%			1%	
RABIA INTERSECTION NODE 300		L	T	R	L	T	R	L	T	R	L	T	R	L	T	R	L	T	R	L	T	R
FROM NORTH	1ST HR	46	353	195	213	327	32	228	398	41	186	393	75	202	398	44	200	382	48	172	219	30
	2ND HR	52	433	240	209	379	41	237	370	27	208	366	51	224	387	41	224	438	66	143	247	33
FROM SOUTH	1ST HR	197	307	141	172	265	132	229	306	141	203	334	130	217	314	148	185	344	139	194	226	58
	2ND HR	277	424	153	265	347	124	252	393	191	285	442	123	312	352	148	233	409	150	271	230	77
FROM EAST	1ST HR	579	887	214	499	815	195	580	846	246	545	805	218	512	825	240	620	928	286	344	773	131
	2ND HR	569	1069	304	510	934	252	508	1051	315	544	1087	325	557	1074	318	580	987	331	325	534	147
FROM WEST	1ST HR	296	767	112	307	737	160	323	845	138	290	786	154	308	714	124	311	884	158	194	442	79
	2ND HR	358	846	150	286	743	135	321	842	172	305	839	155	345	781	135	388	877	117	271	580	100
PERCENT TRUCKS			1%			1% to 2%			1% to 2%			2%			1% to 2%			1% to 2%			1%	

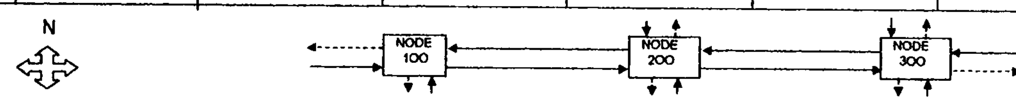
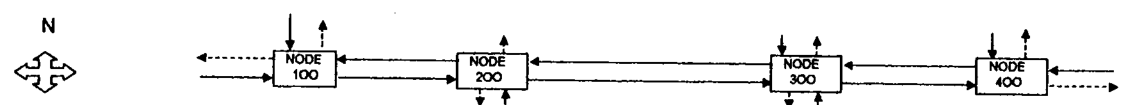


TABLE 3-4
Tabular Summary of Vehicle Counts Validation Network (Safeway Street)

ESTIMATED ADT FOR EAST/WEST DIRECTION = 36,000

		SATURDAY VPH			SUNDAY VPH			MONDAY VPH			TUESDAY VPH			WEDNESDAY VPH			THURSDAY VPH			FRIDAY VPH		
		L	T	R	L	T	R	L	T	R	L	T	R	L	T	R	L	T	R	L	T	R
ABU ANZ 1 INTERSECTION NODE 100																						
FROM NORTH	1ST HR	738		101	783		104	826		112	746		113	769		113	797		126	406		67
	2ND HR	703		93	732		100	761		107	745		103	755		94	793		87	410		50
FROM EAST	1ST HR		1183	814		1206	906		1273	952		1118	960		1227	969		1298	1010		559	360
	2ND HR		1084	848		1078	820		1112	938		1141	880		1062	852		1108	924		570	421
FROM WEST	1ST HR	334	1032		396	990		385	1078		408	1089		374	1023		362	1209		133	495	
	2ND HR	333	950		407	907		377	956		395	865		400	969		438	1107		92	501	
PERCENT TRUCKS		1% to 2%			2%			1% to 2%			1% to 2%			2%			2%			1%		
ABU ANZ 2 INTERSECTION NODE 200																						
FROM SOUTH	1ST HR	324	34	46	322	33	42	367	32	38	349	23	49	372	23	38	393	42	48	161	30	26
	2ND HR	313	41	44	299	43	49	343	32	36	306	61	49	346	30	31	333	40	40	129	10	27
FROM EAST	1ST HR	116	1624	34	106	1763	36	116	1871	40	116	1733	27	90	1786	37	94	1851	43	66	752	17
	2ND HR	86	1708	38	101	1665	27	104	1727	29	114	1690	28	119	1575	34	105	1661	32	69	843	16
FROM WEST	1ST HR	38	1503	57	40	1414	77	35	1619	53	37	1523	67	41	1534	44	37	1597	63	22	773	47
	2ND HR	41	1411	83	40	1423	59	31	1511	84	40	1380	71	35	1449	75	56	1541	68	16	819	21
PERCENT TRUCKS		1% to 2%			1% to 2%			1% to 2%			1%			1% to 2%			2%			1%		
AMBASSADOR INTERSECTION NODE 300																						
FROM NORTH	1ST HR			163			191			177			169			153			210			54
	2ND HR			185			183			150			166			151			222			48
FROM SOUTH	1ST HR	259	30	1011	275	42	1092	283	28	1056	252	39	1073	245	29	903	294	32	1152	142	10	401
	2ND HR	235	29	1215	223	25	1118	239	26	1098	229	24	1147	215	25	1098	245	23	1220	123	14	486
FROM EAST	1ST HR	645	1463	66	763	1556	58	682	1620	55	702	1531	71	597	1226	61	664	1572	63	232	704	29
	2ND HR	683	1381	64	664	1340	57	685	1424	60	635	1457	53	687	1414	72	590	1338	52	298	788	26
FROM WEST	1ST HR	46	1466	177	51	1508	182	48	1549	204	47	1607	190	29	1328	150	42	1480	179	24	873	76
	2ND HR	27	1613	120	50	1452	172	35	1599	160	31	1480	134	38	1420	135	36	1686	109	13	874	65
PERCENT TRUCKS		1% to 2%			1% to 2%			1% to 2%			2%			3%			2%			1%		
SAFEWAY INTERSECTION NODE 400																						
FROM NORTH	1ST HR	1214		934	1211		932	1098		845	1284		1070	1268		1057	1503		1074	476		433
	2ND HR	1183		876	1083		802	1345		961	1145		961	1340		1031	1196		995	604		498
FROM EAST	1ST HR		1573	948		1687	945		1785	1105		1632	916		1863	1051		1732	966		759	479
	2ND HR		1565	939		1493	847		1603	962		1679	940		1633	946		1438	820		835	520
FROM WEST	1ST HR	1064	1330		1023	1292		1045	1311		1092	1289		1194	1380		1090	1352		487	593	
	2ND HR	1065	1272		1055	1252		1081	1311		1101	1323		1128	1263		1140	1458		491	667	
PERCENT TRUCKS		3%			2%			1% to 2%			1% to 2%			1% to 2%			2%			1%		



CHAPTER IV

STATISTICAL ANALYSIS

Introduction

The data analysis of the applicability and adaptability of a microscopic urban simulation model is presented in this chapter. Engineers and scientists rely on statistical analysis techniques as a tool to aid researchers in conducting scientific experiments. However, the major aspect of statistical inquiries, is to incorporate specific procedures for reasoning mathematically from numerical observations of variables in the form of raw data, into what is known as statistical conclusions; which comprise the object of a specific study.

This research utilized Traf-Netsim (version 5.0), a highly accepted network simulation model among the profession, to test the general hypothesis of whether or not Traf-Netsim can simulate the traffic behavior on selected roads in the city of Amman, Jordan. The verification and validation of the simulation model was accomplished through actual field observations on two selected sites. The two sites are The Test Network and The Validation Network, both of which were presented in the Methodology chapter.

The Test Network was used for the following:

1. To collect the Mean Start-Up Lost Time and Mean Queue Discharge Headway along with their distributions to be used in the calibrated Netsim model.

2. To measure Travel Time at predetermined locations along the arterial.
3. Compute Delay Time. This is route delay time not intersection delay time, and it is defined as the difference between Travel Time and Ideal Travel time. Where;
    - Travel Time is the actual time traveling on a specific links under the existing traffic and roadway conditions.
    - Ideal Travel Time is the time traveling on a specific link under free flow conditions. This is computed by dividing the link length by the posted speed limit.
4. To determine if the simulated travel times and delay times derived from Traf-Netsim are different when using the default or calibrated parameters. Also to determine if the simulated values are different from the measured values obtained during the floating car study.

The Validation Network was used for the following:

1. To measure Travel Time at predetermined locations along the arterial.
2. To compute Delay Time.
3. Model Validation: To evaluate if the simulated travel time and delay time using the calibrated Netsim model differ from the measured values obtained from the floating car study while traveling along the validation network.

This research will use the Statistical Analysis Software version 7.0 (abbreviated *SAS*), a known and respected statistical package among scientists and engineers, to test and analyze data collected in the field against data produced by the Traf-Netsim model while simulating the traffic environment in Amman, Jordan. Specific statistical test procedures in *SAS* will be employed to evaluate and test the different hypotheses underlined in this research. The reminder of this chapter is devoted to hypotheses testing, evaluating and data presentation.

Test Network

The first site, referred to as the Test Network, is a segment of Mecca Street and is approximately 2.5 Kilometers long (or 1.562 miles). The Test Network as the name implies was used to test the following:

In order to calibrate the Traf-Netsim model, several traffic parameters were collected under existing traffic conditions to reflect the behavior of the local environment and thus, the behavior of a Jordanian driver to a specific stimulus. The traffic parameters used to calibrate the Traf-Netsim model are:

a- The mean Start-Up Lost Time for the first vehicle when the traffic signal indication changes from red to green.

b- The mean Queue Discharge Headway of vehicles standing in queue when the traffic signal indication change from red to green.

These traffic parameters along with their respective distributions replaced the default parameters impeded in Traf-Netsim model to produce what this research refers to as the calibrated Traf-Netsim model.

Defining the Hypotheses

To test if the measured Start-Up Lost Time and Queue Discharge Headway are statistically significant from the default values embedded in TRAF-NETSIM the following Hypotheses were constructed.

Start-Up Lost Time:

- The Null Hypothesis states that there is no statistical significance between the observed (calibrated) Start-up Lost Time of 1.8 seconds and the default value of 2.0 seconds.
- The Alternative Hypothesis states that there is a statistical significance between the calibrated Start-up Lost Time of 1.8 seconds and the default value of 2.0 seconds.

To perform statistical tests for the above Hypotheses the Univariate Procedure in SAS was invoked. Table 4-1 shows the output of the statistical test performed by SAS. The complete statistical output produced by the Univariate Procedure in SAS software is presented in Appendix A.

Interpretation of the Statistical Results:

For the Start-Up Lost Time study, a total of 163 observations were collected in the field under normal driving conditions. The field study indicates that the Average Start-Up Lost Time observed in Amman is approximately 1.8 seconds, with a Standard Deviation 0.69.

In order to test the above stated Hypotheses, several steps were performed:

1. To test both the Null and Alternative hypotheses, one should decide whether to use a parametric or non-parametric test.
2. At what significant level (or alpha level) should the rejection region be set?

Table 4-1
Statistical analysis for Start-Up Lost Time

THE UNIVARIATE PROCEDURE			
Variable: losttime (Start-Up Lost Time for the first vehicle in Queue)			
Moments			
N	163	Sum Weights	163
Mean	1.8245	Sum Observations	297.4
Std Deviation	0.6920	Variance	0.4788
Skewness	1.2768	Kurtosis	1.2493
Uncorrected SS	620.19	Corrected SS	77.579
Coeff Variation	37.928	Std Error Mean	0.0542

Tests for Location : Mu0=0

Test	--- Statistic---		---------P Value--------	
Student's t	t	33.66151	Pr > | t |	< .0001
Sign	M	81. 5	Pr > | M |	< .0001
Signed Rank	S	6683	Pr > | S |	< .0001

Tests for Normality

Test	--- Statistic---		--------P Value-------	
Shapiro-Wilk	W	0.8761	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.16037	Pr > D	<0.0001
Cramer-Von Mises	W-Sq	1.19401	Pr > W-Sq	<0.005
Anderson-Darling	A-Sq	6.6296	Pr > A-Sq	<0.005

$\mathbf{H_o : u_{losttime} = 2.0}$

$\mathbf{H_a : u_{losttime} \neq 2.0}$

The second question involves the rejection or failing to reject the specified null hypothesis given a predetermined alpha level. Traditionally, engineers have used significant levels of 0.01, 0.05, and 0.1. These three levels can be thought of as "extremely significant," "significant," and "moderately significant," respectively. However, the Traffic Engineering Handbook [14] suggests that traffic engineers should consider results significant at the 0.05 level for most traffic engineering studies and should consider results significant at the 0.01 level when performing safety-related studies. This research will use an alpha level equal to 0.05 in all the statistical tests presented. An alpha level of 0.05 gives a confidence coefficient equal to 0.95 (1 – alpha) or 95% confidence level. In other words, we are 95% sure that a sample collected from a population will yield a confidence interval that includes the true population mean.

The first question addresses the issue of Normality. If the data is normally distributed, then a parametric test is considered. Otherwise an equivalent non-parametric test should be employed. Looking at Table 4-1, under the heading "Tests for Normality" a Shapiro-Wilk test gives a p-value of 0.0001. This is a very small value and is close to zero indicating the data for the Start-Up Lost Time are not a sample from a normal distribution. This suggests that a non-parametric test should be used. However, since the sample size of 163 is fairly large, the parametric test should be reasonably accurate. Therefore both parametric and non-parametric tests will be performed.

For a non-parametric test:

The Signed Rank test, gives a p-value of $Pr >= |S| < 0.001$

For a parametric test:

The Student's t test, gives a p-value of $Pr > |t| < 0.001$

Since the attained probability or the p-value is less than the reference probability or the alpha value (0.001 < 0.05), for both parametric and non-parametric tests, the null hypothesis is rejected.

Based on the above, this research concludes that the average Start-Up Lost Time of 1.8 seconds collected in Amman is significantly different from the Start-Up Lost Time of 2.0 seconds used by Netsim as a default value.

Queue Discharge Headway:

- The Null Hypothesis states that there is no statistical significance between the calibrated Queue Discharge Headway of 1.5 seconds and the default value of 1.8 seconds
- The Alternative Hypothesis states that there is a statistical significance between the calibrated Queue Discharge Headway of 1.5 seconds and the default value of 1.8 seconds.

To perform statistical tests for the above Hypotheses the Univariate Procedure in *SAS* was invoked. Table 4-2 shows the output of the statistical test performed by *SAS*. The complete statistical output produced by the Univariate Procedure from the *SAS* software is presented in Appendix A.

Interpretation of the Statistical Results:

For the Queue Discharge Headway study, a total of 780 observations were collected in the field under normal driving conditions. The study indicates that the Average Queue Discharge Headway observed in Amman is approximately 1.5 seconds.

Table 4-2
Statistical analysis for Queue Discharge Headway

THE UNIVARIATE PROCEDURE

Variable: headway (Queue Discharge Headway)

Moments

N	780	Sum Weights	780
Mean	1.5064	Sum Observations	1175.
Std Deviation	0.5483	Variance	0.3006
Skewness	1.7176	Kurtosis	4.0901
Uncorrected SS	2004.3	Corrected SS	234.17
Coeff Variation	36.396	Std Error Mean	0.0196

Tests for Location : Mu0=0

Test	--- Statistic---		---------P Value--------	
Student's t	t	76.73606	Pr > | t |	< .0001
Sign	M	390	Pr > | M |	< .0001
Signed Rank	S	152295	Pr > | S |	< .0001

Tests for Normality

Test	--- Statistic---		---------P Value-------	
Shapiro-Wilk	W	0.8589	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.12771	Pr > D	<0.0100
Cramer-Von Mises	W-Sq	4.97415	Pr > W-Sq	<0.005
Anderson-Darling	A-Sq	29.3306	Pr > A-Sq	<0.005

$\mathbf{H_o : u_{headway} = 1.8}$

$\mathbf{H_a : u_{headway} \neq 1.8}$

To test the above null and alternative hypotheses the following is presented:

Looking at Table 4-2, under the heading "Tests for Normality" a Shapiro-wilk test gives a p-value of 0.0001. This is a very small value and is close to zero indicating the data for the Queue Discharge Headway are not a sample from a normal distribution. This suggests that a non-parametric test should be used. However, since the sample size of 780 is very large, the parametric test should be reasonably accurate. Therefore both parametric and non-parametric tests will be performed.

For a non-parametric test:

The Signed Rank test, gives a p-value of Pr >= | S | < 0.001

For a parametric test:

The Student's t test, gives a p-value of Pr > | t | < 0.001

Since the attained probability or the p-value is less than the reference probability or the alpha value (0.001 < 0.05), for both parametric and non-parametric tests, the null hypothesis is rejected.

Based on the above, this study concludes that the average Queue Discharge Headway of 1.5 seconds collected in Amman is significantly different from the mean Queue Discharge Headway of 1.8 seconds observed in Washington D.C. and is used by The Traf-Netsim model as a default value.

Up to this point this research has only shown that the observed values for Start-Up Lost Time and Queue Discharge Headway of 1.8 and 1.5 seconds respectively are statistically significant from the default values impeded into Traf-Netsim model. This doesn't imply that model's ability to simulate the actual traffic conditions on the street network will improve. To found out how the model will perform the following is presented.

1- To determine if the Traf-Netsim model using the impeded default parameters can simulate Travel Time and Delay Time along the test network "Mecca Street" within an acceptable range. This was accomplished by comparing the simulated values produced by the default model against the measured values obtained during the flouting-car study.

2- To determine if the Traf-Netsim model using the calibrated parameters can simulates Travel Time and Delay time along the test network "Mecca Street" within an acceptable level of accuracy. This was also accomplished by comparing the simulated values produced by the calibrated model against the observed values collected in the field.

Defining the Hypotheses for Travel Time and Delay Time

To test if the mean Travel Time and Delay Time between the simulated model, the simulated calibrated model, and the observed values obtained from the floating car study are statistically significant from one to another the following hypotheses were constructed:

Travel Time along the Arterial:

- The Null Hypothesis states that the mean Travel Times for the three groups are the same.

The three groups are:

1. Simulated model with default parameters.

2. Simulated model with calibrated parameters.

3. Observed values form the field.

In terms of a mathematical expression the Null Hypothesis is:

$$\mathbf{H_o : u_{default} = u_{calibrated} = u_{observed}}$$

- The Alternative Hypothesis states that at least the mean Travel Time of one group is statistically significant from another group.

In terms of a mathematical expression the Alternative Hypothesis is:

$$\mathbf{H_a : \text{At least one mean is different}}$$

Delay Time along the Arterial:

Similar null and alternative hypotheses for the mean Delay Time were also constructed.

$$\mathbf{H_o : u_{default} = u_{calibrated} = u_{observed}}$$

$$\mathbf{H_a : \text{At least one mean is different}}$$

It should be brought to the readers attention that the above hypotheses are comparing three groups to one another, and that the Alternative Hypotheses for both the Travel Time and Delay time does not specify which means are different from one another. It only tells us that some differences exist. In order to find out which means are different, an appropriate multiple comparison procedure will be employed.

To test and evaluate if the three groups presented in the above hypotheses are statistically significant from one to another a statistical procedure referred to Analysis of Variance "or ANOVA" will be used and is presented below:

Analysis of Variance:

The analysis of variance in a single-factor study is mainly to determine whether or not the factor level means are equal. Expressed mathematically, is $\mu_1 = \mu_2 = \mu_3$. If the answer is true, then we fail to reject the Null hypothesis and conclude that the three means are the same. On the other hand, if the answer is false, we would reject the Null hypothesis and conclude that at least one mean is different.

Obviously, the more that these groups would differ from each other in terms of the dependent variable, the more variability we would expect among their means. This variability is measured in terms of how the group means vary about the mean of all groups put together. This mean is referred to as the grand mean and is abbreviated as $Y_{GRAND.}$ In fact, analysis of variance calculates the groups' variance about the grand mean. This variance is called the between-groups variance. Therefore, it would be expected that the more differences there are among the groups, the larger would be the value of the between-groups variance. In addition, analysis of variance looks at how much variability among individual scores would be expected. Mainly, what is the probability of this variance occurring under the terms of the null hypothesis due to sampling error? In analysis of variance, this value is based on the amount of variability that was observed within each of the groups. This is appropriately referred to as the within-groups variance. The point to remember thus far in analysis of variance is that if there are no differences among the groups, then the between-groups variance and the within-group should be approximately equal. Therefore, the larger the value of the between-groups variance to within-groups variance, the greater is the probability that at least one of the group means is different. The test statistic used by ANOVA for choosing between the above hypotheses is:

$$F = \text{Variance between groups} / \text{Variance within groups}$$

If the null hypothesis is true and there is no sampling error at all, one would expect the value of F to be exactly 1. But in the true world of data collection sampling error is present. Therefore, under the assumptions of the null hypothesis, the sampling distribution of F tells us the probability that one can expect the between-groups variance to be so many times larger than the within-groups variance. And if this probability is less than the preset probability level, say 0.05, then the null hypothesis is rejected in favor of the alternative hypothesis. Thus, the researcher concludes that there is adequate evidence to suggest that at least one of the population means is significantly different from the rest.

Assumptions of a one-way Analysis of Variance:

Before performing any statistical tests with a one-way analysis of variance the following assumptions should be evaluated.

1- Observations are independent random samples.

2- Observations are sampled from a normal distribution.

3- Groups have equal variances.

First, the assumption of independent observations is met, since in this research the measurement for one item in the data set did not affect the measurement for another item. That is, the value of Travel Time for one simulation is unrelated to the value of Travel Time for another simulation. This was easily accomplished by using a different random number seed for each run which generates a different pattern of driver types and vehicle paths moving through the analysis network.

Second, the assumption of normality is difficult to meet, since there were only 7 observations in each group. To truly test this assumption, a normality test should be performed for each group. And since the data in each group is small, this research didn't have enough data to perform an appropriate normality test. However, even if the assumption of normality is not met, it is not too critical since we are basing the analysis of variance test on group means, and hence the Central Limit Theorem should still be applicable [20]. Also the F test for the equality of the population means is slightly effected by the lack of normality and is considered to be a robust test against departures from normality [29].

Third, the last assumption required by analysis of variance is that the populations have a common variance. The data in this research appeared in some situations to have unequal values for standard deviation, and thus the variance. Concerning this assumption, the F test used by analysis of variance procedure is slightly affected by unequal variance, if all factor level sample sizes are close or equal [20]. In order to minimize the effects of unequal variances on inferences with the F distribution and related tests this research will use equal sample sizes for all factor levels. To accomplish the equal sample size in each factor level for both the Test and Validation Networks, equal number of simulation runs were performed in both the default and calibrated Netsim models to match the observed values obtained from the floating car method.

In summary, Since the data set in each factor level is fairly small several assumptions required by analysis of variance procedure where not satisfied. Therefore, to guard against violations of the normality and unequal variance assumptions, both ANOVA, which is a parametric test, and Kruskal-Wallis test which is a non-parametric analogue to the one way analysis of variance will be employed.

Before presenting the data and statistical findings several factors related to the variability in the simulation output follows:

Simulation of Traf-Netsim

Traf-Netsim is a discrete event simulation model that simulates the traffic flow on urban street networks by representing the movement of individual driver-vehicle combinations. The simulation output produced by Traf-Netsim contains some variability from one simulation run to the next. This variability is more apparent in Traf-Netsim due to the fact that the model represents the behavior of traffic flow microscopicity. That is, each vehicle is handled as a distinct entity. Of course, the presence of high variability in simulation output can lead to questions concerning the model's reliability. However, the amount of variability in a given situation depends on several factors such as:

1. The number of simulation runs
2. The length of each simulation
3. The length of worm-up time (initialization time)

In order to achieve meaningful simulation results and to reduce the risk of drawing incorrect conclusions, the above issues concerning the variability of the output will be addressed in the following.

Traf-Netsim model uses two random number seeds the "base seed" and the "common seed" to generate the traffic movement and all the time-dependent stochastic decisions for a given simulation run. Therefore, to reduce the variance between simulation runs, this research will use multiple independent replications. This means that the simulation model will be executed several times for a given set of identical input data, except that the base random number seed will be changed. This type of variance reduction technique is known as the Common Random Numbers (CRN) reduction procedure, in simulation experiments [18,28].

In summary a series of runs with different values for the base seed will be used in this study to show the variance in the selected traffic performance measures of effectiveness (i.e. Travel Time and Delay Time) which are due to variations in individual vehicle traffic patterns. This type of variance reduction technique has been shown to significantly reduce the simulation output variability even though the simulation time for each run was only 900 seconds [28]. The only requirement to apply this variance reduction procedure is the matching of the set of the random number seeds in simulation experiments.

Table 4-3 shows the set of random numbers for the "base seed", entry 11 on card type 2, used for all simulation runs trough out this study. The random numbers where picked from a table of random number digits and are presented below [29]:

The set of random numbers used had to meet the criteria set by Traf-Netsim simulation model. Which basically states that the random number seed must be an odd number of up to eight digits is size and that the last digit in every number is not 5. If a seed number didn't meet the above criteria, Traf-Netsim will print a fatal error message and will terminate the simulation run.

Table 4-3
Random Numbers

REPLICATION NUMBER	BASE RANDOM NUMBER
1	132841
2	21224003
3	9905247
4	199509
5	6057
6	91240283
7	974581
8	352493
9	10750527
10	3624727

The second factor affecting the output variability is the simulation length. In simulation studies there are two methods available for performing simulation experiments. The first method is to make a single run and execute the simulation for a long duration. Then use the data generated in this single, continuous, long run to estimate Travel Time and Delay Time. The second method for conducting simulation experiments is to make several independent simulation runs. Independent replications are achieved by starting each run with a different random number seed. The second method was used by this research since it produced several samples in each group as opposed to one in the case of a single long run. Also, by applying the Common Random Number technique discussed earlier the variability in the simulation output should be reduced. In addition simulating with independent replications is very simple to implement in Traf-Netsim through the use of the base random number seed.

The third issue of concern is how long should the initialization period be to assure a steady state condition. That is, to estimate the transient phase (or initialization period) to reduce the effects of early unstable observation on the output results. To ensure that equilibrium is reached (Input = Output), the user must specify a large initialization period that is longer than the time needed to reach equilibrium. It is recommended that the initialization period should be equal to the travel time at free flow speed along the longest path in the network [(16)]. This research used an upper bond for initialization of 10 minutes (600 seconds) and 30 minutes (1800 seconds) for both the validation and test networks respectively. These values are extremely high. However, if Traf-Netsim attains equilibrium before the specified time, then the remaining time available for initialization will be discarded and the program will immediately enter the simulation phase and will start accumulating statistics. It should be mentioned that in all the simulation runs through out this study, equilibrium was attained at around 5 to 7 minutes into the initialization phase of simulation, well before the specified initialization period.

In summary, this research observed and recorded traffic conditions on each of the test and validation networks. The floating car method was performed concurrently during the collection of traffic volumes required to execute the simulation model. The data was recorded for two continuous hours on seven consecutive days. For each day, two simulations were performed in order to reflect the changes in traffic conditions that occurred during the first and second hours of data collection respectively.

For each hour, eight to ten independent replications were made for traffic operations under the default model using the set of random number seeds presented in Table 4-3 above. Each simulation run was executed for 3600 seconds and the simulated

Travel times and Delay times were compared with those observed in the field during the same hour (i.e. first hour or second hour of observation). It should be mentioned that statistics were collected on specific sections along the test network (Mecca Street), at the end of each simulation run. This was repeated for all seven days during which data was collected. The same procedure was also followed for traffic operations under the modified or calibrated Netsim model. That is, all the data remained constant except the calibrated parameters were changed in Traf-Netsim.

As mentioned earlier both the Analysis of Variance and the Kruskal-Wallis tests were invoked by *SAS* to test the null and alternative hypotheses at the 0.05 confidence interval.

Recall that for both the Travel Time and Delay Time, the Null Hypothesis states that the means for the three different groups are the same. And that the Alternative Hypothesis states that at least the mean of one group is statistically significant from another group.

Statistical Interpretation

The following section will present the statistical summaries of the above null and alternative hypotheses for travel time and delay time on the test network. But, before interpolating the statistical results it should be brought to the readers attention that the naming of the links were modified for added clarity and simplicity when looking at the tables. For example, road segment A1 represents in Netsim the aggregate links from node 100 to node 114, A2 represents the aggregate links from node 114 to node 122 and so on and so forth. This is best demonstrated by looking at figure 4-1.

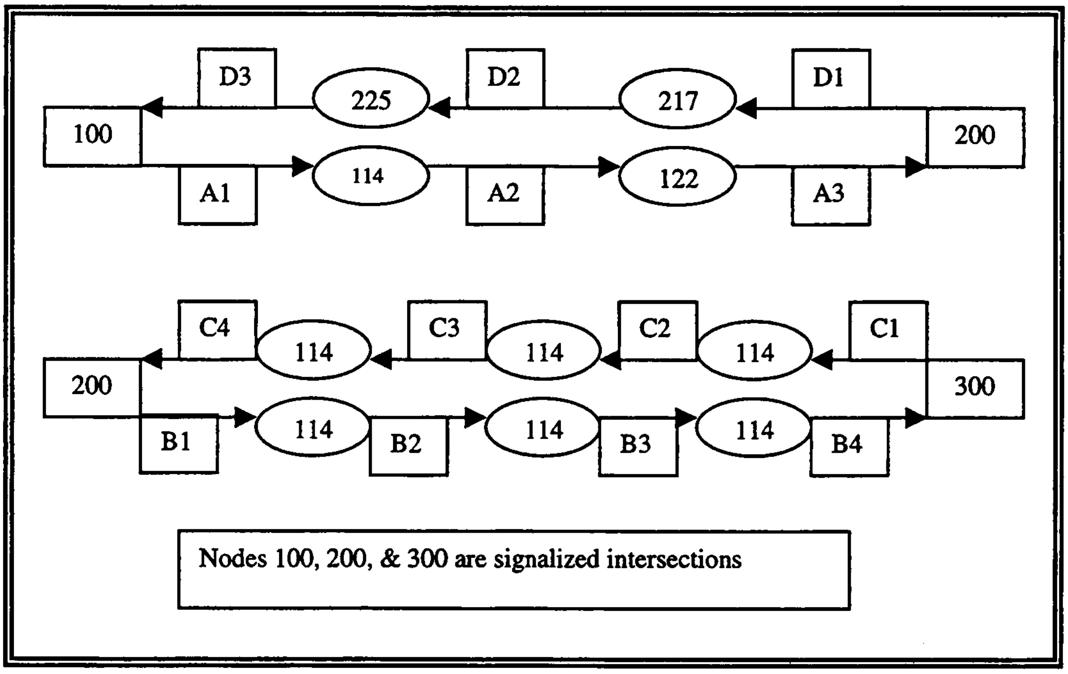


Figure 4-1
Test Network

Travel Time on Test Network "First Hour":

Looking at the statistical analysis of Travel Time on the Test Network for the first hour (Table 4-4) the following comments and interpretations are presented:

First, the column labeled ANOVA Pr > F gives the p-values for comparing the three groups. The numbers in this column are all below the reference probability of 0.05 set by this study. This is true for all the road segments through out the week, with the exception of Thursday in which link A3 had a p-value of .0529 slightly larger than 0.05. In conclusion, since the p-values are less than 0.05, the stated null hypothesis is rejected in favor of the alternative hypothesis. Therefore this study concludes, based on the statistical analysis presented during the first hour of observation, that the mean Travel Time is significantly different among the three study groups (observed, default, and calibrated).

This is very true, especially when comparing the default travel time versus observed travel time. It appears that the observed values of travel time are always shorter than the simulated default values. This finding supports the overall statement made by this research that the driver behavior in Jordan is different from those observed in Washington D.C. In addition, the observed traffic parameters in Amman - Jordan, such as queue discharge headway and start-up lost time for vehicles of 1.5 seconds and 1.8 seconds respectively also enhances this finding. This could suggest that the Jordanian driver is more aggressive than the American driver since the observed values of queue discharge headway of 1.5 seconds and start up lost time of 1.8 seconds are lower than the default parameters of 1.8 and 2.0 embedded in Traf-Netsim.

Table 4-4
Statistical Analysis of Travel Time on Test Network "First Hour"
First hour of observation (12:30 - 13:30)

Saturday May 10, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	35.4	A	2.3	40.1	B	0.3	37.2	A	0.2	<.0001	0.0007
A2	35.9	A	2.8	45.5	B	0.2	36.9	A	0.2	<.0001	0.001
A3	52.1	A	4.5	57.4	B	1.9	53.6	A,B	2.4	0.0148	0.0169
B1	20.2	A	1.7	24.6	B	0.2	20.9	A	0.1	<.0001	0.0008
B2	21.1	A	1.5	26.3	B	0.2	21.7	A	0.1	<.0001	0.0006
B3	33.0	A	2.1	41.3	B	0.3	33.8	A	0.2	<.0001	0.0008
B4	40.9	A	0.8	59.7	B	1.4	52.2	C	6.3	<.0001	0.0004
C1	19.2	A	1.0	23.4	B	0.1	19.8	A	0.1	<.0001	0.001
C2	21.1	A	3.8	26.7	B	0.1	21.8	A	0.2	<.0003	0.0059
C3	31.2	A	5.7	39.8	B	0.2	32.4	A	0.2	<.0002	0.006
C4	64.7	A	1.1	72.3	B	3.0	65.9	A	1.8	<.0001	0.0009
D1	43.1	A	3.0	52.4	B	0.3	43.9	A	0.2	<.0001	0.0008
D2	30.2	A	1.8	37.4	B	0.3	30.6	A	0.3	<.0001	0.0012
D3	29.9	A	0.4	32.4	B	2.4	29.6	A	1.5	0.0086	0.0235

Sunday May 11, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	36.6	A	1.3	39.7	B	0.3	36.9	A	0.2	<.0001	0.0011
A2	37.4	A	1.1	45.5	B	0.2	37.0	A	0.2	<.0001	0.0007
A3	51.8	A	1.8	56.9	B	0.9	53.0	A	0.6	<.0001	0.0011
B1	21.8	A	1.7	24.5	B	0.1	20.9	A	0.1	<.0001	0.0004
B2	20.4	A	1.3	26.3	B	0.2	21.7	C	0.1	<.0001	0.0004
B3	33.9	A	1.9	41.2	B	0.2	33.8	A	0.1	<.0001	0.0012
B4	48.2	A	2.9	58.2	B	1.7	48.4	A	5.6	<.0001	0.0011
C1	20.1	A	0.8	23.4	B	0.1	19.9	A	0.1	<.0001	0.0008
C2	21.8	A	0.2	26.7	B	0.1	21.8	A	0.2	<.0001	0.0011
C3	32.2	A	0.3	39.6	B	0.1	32.2	A	0.3	<.0001	0.0012
C4	63.7	A	2.7	69.4	B	1.2	65.9	A	1.8	<.0002	0.0011
D1	42.6	A	2.3	52.2	B	0.3	43.9	A	0.2	<.0001	0.0008
D2	29.2	A	1.6	37.5	B	0.3	30.7	C	0.3	<.0001	0.0004
D3	30.2	A	0.4	32.1	B	0.9	30.0	A	1.4	0.0015	0.0044

Monday May 12, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	36.1	A	1.9	39.9	B	0.3	37.1	A	0.2	<.0001	0.0008
A2	36.0	A	2.7	45.5	B	0.2	37.0	A	0.2	<.0001	0.0011
A3	53.9	A	2.8	57.3	B	0.8	55.7	A,B	1.5	0.0129	0.0344
B1	19.9	A	2.1	24.8	B	0.2	21.0	A	0.2	<.0001	0.0009
B2	22.8	A	5.0	28.3	A,B	0.2	21.7	B	0.2	0.0198	0.007
B3	32.2	A	3.0	41.1	B	0.2	33.9	A	0.2	<.0001	0.0008
B4	55.6	A	1.4	61.4	B	2.1	53.2	A	6.6	0.0039	0.0027
C1	20.7	A	3.2	23.3	B	0.1	19.8	A	0.1	0.0065	0.0214
C2	21.7	A	2.1	28.7	B	0.2	21.9	A	0.1	<.0001	0.0012
C3	29.6	A	2.9	39.7	B	0.2	32.3	C	0.2	<.0001	0.0004
C4	68.0	A,B	1.1	70.0	B	1.5	67.1	A	1.7	0.0062	0.0201
D1	44.7	A	2.0	52.9	B	0.4	44.1	A	0.4	<.0001	0.0011
D2	29.2	A	1.9	37.9	B	0.4	30.7	C	0.3	<.0001	0.0007
D3	29.4	A	2.9	32.7	B	1.1	30.7	A,B	1.6	0.0208	0.0235

Tuesday May 13, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	34.6	A	3.4	39.5	B	0.3	36.5	A	0.3	0.0007	0.0054
A2	35.6	A	2.1	45.4	B	0.2	36.8	A	0.1	<.0001	0.0008
A3	52.0	A	0.8	54.9	B	1.0	52.5	A	1.1	<.0001	0.0016
B1	22.1	A,B	3.1	24.5	B	0.1	20.8	A	0.1	0.0039	0.0034
B2	20.2	A	2.5	26.3	B	0.1	21.6	A	0.2	<.0001	0.0007
B3	33.2	A	1.1	41.1	B	0.1	33.8	A	0.1	<.0001	0.0008
B4	50.3	A	1.5	59.7	B	2.2	49.6	A	7.5	0.0009	0.001
C1	19.9	A	3.4	23.3	B	0.1	19.8	A	0.1	0.0042	0.0011
C2	21.3	A	2.6	26.6	B	0.2	21.8	A	0.2	<.0001	0.0012
C3	32.8	A	2.7	39.6	B	0.3	32.1	A	0.1	<.0001	0.0008
C4	63.4	A	1.4	71.6	B	2.2	63.8	A	1.8	<.0001	0.0011
D1	43.5	A	3.1	52.6	B	0.3	44.0	A	0.2	<.0001	0.0012
D2	30.0	A	1.8	37.5	B	0.3	30.6	A	0.2	<.0001	0.0012
D3	31.4	A	1.4	31.3	A	0.9	29.8	A	1.2	0.0371	0.0526

Note: Tukey's Studentized Range Test (TK) = Means with the same letter are not significant at the 0.05 level

Table 4-4 (continued)
Statistical Analysis of Travel Time on Test Network "First Hour"
First hour of observation (12:30 - 13:30)

Wednesday May 14, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	TK	Stand. Dev.	Default Mean	TK	Stand. Dev.	Calibrated Mean	TK	Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	35.9	A	1.6	39.7	B	0.2	36.8	A	0.1	<.0001	0.0008
A2	37.6	A	4.5	45.6	B	0.2	37.0	A	0.2	<.0001	0.0043
A3	52.7	A	0.8	56.0	B	1.6	53.3	A	0.7	<.0001	0.0053
B1	20.3	A	1.4	24.5	B	0.1	20.9	A	0.1	<.0001	0.0007
B2	20.8	A	2.4	26.3	B	0.2	21.7	A	0.1	<.0001	0.0008
B3	34.1	A	3.3	41.2	B	0.2	33.8	A	0.1	<.0001	0.0019
B4	54.2	A	1.4	60.4	B	1.5	50.5	A	7.1	0.0015	0.0012
C1	20.1	A	3.2	23.3	B	0.2	19.7	A	0.1	0.0032	0.0004
C2	20.9	A	2.3	26.6	B	0.1	21.8	A	0.1	<.0001	0.0007
C3	31.9	A	2.0	39.7	B	0.1	32.2	A	0.1	<.0001	0.0011
C4	65.4	A	2.3	71.9	B	2.2	66.3	A	1.5	<.0001	0.0011
D1	43.2	A	2.8	52.7	B	0.2	44.1	A	0.2	<.0001	0.0012
D2	30.3	A	1.5	37.7	B	0.3	30.7	A	0.3	<.0001	0.0012
D3	29.9	A	1.4	32.7	B	0.9	30.4	A	0.7	0.0002	0.0012

Thursday May 15, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	TK	Stand. Dev.	Default Mean	TK	Stand. Dev.	Calibrated Mean	TK	Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	36.3	A	2.3	40.4	B	0.3	37.8	A	0.4	<.0001	0.0006
A2	31.2	A	12.0	45.7	B	0.3	37.1	A,B	0.2	0.0036	0.0006
A3	55.4	A,B	6.6	58.0	B	1.4	53.5	A,B	1.0	0.0529	0.0047
B1	20.4	A	1.7	24.7	B	0.2	21.0	A	0.1	<.0001	0.0009
B2	20.0	A	2.2	26.5	B	0.2	21.7	C	0.1	<.0001	0.0004
B3	33.0	A	2.0	41.3	B	0.2	33.8	A	0.2	<.0001	0.0008
B4	45.7	A	2.1	59.3	B	1.1	47.3	A	7.3	<.0001	0.0012
C1	19.2	A	1.4	23.4	B	0.1	19.8	A	0.2	<.0001	0.0008
C2	21.6	A	2.3	26.8	B	0.1	21.9	A	0.2	<.0001	0.0012
C3	32.7	A	3.3	39.9	B	0.2	32.3	A	0.3	<.0001	0.0012
C4	62.1	A	1.9	69.8	B	2.3	64.5	A	1.6	<.0001	0.0005
D1	43.4	A	2.1	52.8	B	0.3	44.4	A	0.4	<.0001	0.0011
D2	30.5	A	2.6	37.8	B	0.1	30.9	A	0.3	<.0001	0.0012
D3	28.7	A	1.6	32.8	B	1.0	30.3	A	1.2	<.0001	0.0007

Friday May 16, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	TK	Stand. Dev.	Default Mean	TK	Stand. Dev.	Calibrated Mean	TK	Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	30.3	A	3.7	36.9	B	0.2	33.5	C	0.2	<.0001	0.0004
A2	34.9	A	2.7	44.6	B	0.2	36.1	A	0.3	<.0001	0.0011
A3	38.5	A	4.1	47.4	B	2.2	42.1	A	1.4	<.0001	0.0009
B1	18.8	A	3.1	24.5	B	0.2	21.0	A	0.1	<.0001	0.0007
B2	18.9	A	1.2	25.7	B	0.2	21.0	C	0.2	<.0001	0.0001
B3	32.5	A	2.0	40.7	B	0.3	33.2	A	0.2	<.0001	0.0008
B4	44.0	A	2.3	51.5	B	1.8	43.2	A	3.2	<.0001	0.0012
C1	20.7	A	1.8	23.3	B	0.1	19.9	A	0.1	<.0001	0.0035
C2	20.1	A	1.4	26.5	B	0.1	21.7	C	0.2	<.0001	0.0004
C3	30.7	A	3.9	39.4	B	0.2	32.0	A	0.3	<.0001	0.0012
C4	47.5	A	2.8	55.9	B	2.0	49.0	A	1.2	<.0001	0.0011
D1	40.5	A	3.5	51.4	B	0.4	42.9	A	0.2	<.0001	0.0009
D2	26.7	A	2.3	36.5	B	0.4	29.6	C	0.1	<.0001	0.0001
D3	23.6	A	2.2	27.0	B	1.3	24.4	A	0.6	0.0017	0.0039

Note: Tukey's Studentized Range Test (TK) = Means with the same letter are not significant at the 0.05 level

Second, the column labeled Kruskal Wallis Pr > chi-square, which is a non-parametric analog to ANOVA, gives the p-value for comparing the three groups. The numbers in this column are all well below 0.05 with the exception of Tuesday in which link D3 had a p-value of .0526, slightly greater than 0.05. Therefore similar conclusion can be drawn based on the non-parametric test.

Third, to determine which mean is different from the other, the Tukey's Studentized Range Test was used. Since there are three groups, Tukey's test will perform all pair wise comparisons. Observed vs. default, observed vs. calibrated, and default vs. calibrated.

The first comparison (observed vs. default): Looking at the columns labeled TK, abbreviation for tukey, one can see that the majority of the observed travel times and the default travel times through out the week have different letters beside their means. This is true along all road segments through out the week, with the exception of road segments B2 and C4 on Monday, B1 and D3 on Tuesday, and A3 on Thursday. In other words, from the possible 98 comparisons (14 segments * 7 day) only 5 had similar means. Therefore, given the above one can conclude that there is a statistical significance at the 0.05 level between most of the observed travel times and the simulated travel times derived from the default model.

The second comparison (observed vs. calibrated): From table 4-4 it appears that the majority of road segments have similar letters beside their means. The observed travel times and the calibrated travel times are similar with the exception of road segments B4 on Saturday, B2 and D2 on Sunday, B2, C3 and D2 on Monday, B2 on Thursday, and A1, B2, C2 and D2 on Friday. Therefore, from the 98 possible comparisons 11 comparisons had different means. In summary, the tukey's test indicates that 87 (98-11) comparisons of travel times have no significant differences between the observed and calibrated travel times at the 0.05 significant level. This is a positive indication of how well the calibrated model performs in the test network. However, since a total of 4 road segments were significantly different on Friday (weak-end and low volume) it appears that the calibrated model doesn't predict as well under low traffic volumes.

The third comparison (default vs. calibrated): Looking at table 4-4 it can be seen that there are only 7 out of 98 comparisons which indicates that the means are similar. Therefore it can be said that there is a significant difference at the 0.05 level between the simulated travel times from both the default and calibrated Netsim model.

Delay Time on Test Network "First Hour":

Looking at the statistical analysis of Delay Time on the Test Network during the first hour of observation (Table 4-5) the following comments and interpretations are drawn:

First, the column titled ANOVA Pr> F gives the p-values for comparing the three group means for route delay time. The majority of numbers in this column are above the reference probability of 0.05 set by this research for comparison purposes. From the 98 comparisons (14 * 7), 37 comparisons have a p-value less than 0.05. This means that 37 comparisons suggests that the average groups are statistically significant while the reminder 61 comparisons suggests that there is no difference among the groups. The two days that showed the most differences among the groups are Sunday and Friday with 9 road segments and 8 road segments respectively.

Table 4-5
Statistical Analysis of Delay Time on Test Network "First Hour"
First hour of observation (12:30 - 13:30)

Saturday May 10, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	11.5	A,B	2.3	10.4	B	0.3	13.1	A	0.3	0.0052	0.0165
A2	2.0	A	2.8	3.3	A	0.2	2.5	A	0.2	0.3151	0.0305
A3	40.1	A	4.5	42.6	A	1.9	41.4	A	2.3	0.3656	0.2998
B1	2.3	A	1.7	3.4	A,B	0.1	3.7	B	0.1	0.0389	0.0074
B2	1.9	A	1.6	2.5	A	0.2	2.3	A	0.1	0.477	0.0846
B3	2.5	A	2.1	3.2	A	0.3	2.9	A	0.1	0.5352	0.0432
B4	26.9	A	0.8	42.3	B	1.5	38.1	B	6.2	<.0001	0.001
C1	3.1	A	1.0	3.4	A	0.1	3.6	A	0.1	0.3714	0.1149
C2	1.9	A	3.8	2.8	A	0.1	2.4	A	0.2	0.7199	0.0311
C3	2.4	A	5.7	4.0	A	0.1	3.2	A	0.2	0.6656	0.0308
C4	47.0	A	5.4	52.7	B	3.0	49.9	A,B	1.7	0.0334	0.0342
D1	6.8	A	3.0	7.3	A	0.3	7.1	A	0.2	0.8888	0.2569
D2	3.7	A	1.9	4.5	A	0.3	3.8	A	0.3	0.3578	0.0568
D3	22.0	A	0.4	22.6	A	2.4	21.6	A	1.5	0.5279	0.7227

Sunday May 11, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	12.7	A	1.3	10.0	B	0.2	12.7	A	0.2	<.0001	0.0012
A2	3.5	A	1.1	3.3	A	0.2	2.6	A	0.2	0.0547	0.0091
A3	39.8	A	1.8	42.0	B	0.9	40.8	A,B	1.5	0.0375	0.0465
B1	3.9	A	1.7	3.3	A	0.1	3.7	A	0.1	0.56	0.0343
B2	1.2	A	1.3	2.5	B	0.1	2.3	B	0.1	0.0096	0.0138
B3	3.3	A	1.9	3.2	A	0.2	2.9	A	0.2	0.7275	0.1651
B4	34.9	A	2.9	40.9	B	1.7	34.3	A	5.6	0.0049	0.0024
C1	4.0	A	0.8	3.4	B	0.1	3.6	A,B	0.1	0.0479	0.0081
C2	2.6	A,B	0.2	2.8	B	0.1	2.4	A	0.2	0.0035	0.0056
C3	3.3	A	0.3	3.8	B	0.1	2.9	A	0.3	<.0001	0.0014
C4	46.1	A	3.7	49.8	B	1.2	50.0	B	1.8	0.0123	0.0178
D1	6.3	A	2.3	7.2	A	0.3	7.2	A	0.2	0.398	0.584
D2	2.7	A	1.5	4.5	B	0.4	3.9	A,B	0.2	0.0055	0.0079
D3	22.3	A	0.4	22.2	A	1.0	22.0	A	1.4	0.8195	0.865

Monday May 12, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	12.3	A	1.9	10.1	B	0.2	12.9	A	0.3	0.0006	0.0014
A2	2.0	A	2.7	3.3	A	0.1	2.6	A	0.2	0.2957	0.0439
A3	41.9	A	2.8	42.4	A	0.9	43.5	A	1.5	0.2862	0.301
B1	2.0	A	2.1	3.4	A,B	0.1	3.7	B	0.2	0.0428	0.055
B2	3.6	A	5.0	2.5	A	0.2	2.4	A	0.2	0.6781	0.4161
B3	1.7	A	3.0	3.2	A	0.2	2.9	A	0.1	0.26	0.0678
B4	41.7	A	1.4	44.1	A	2.1	39.1	A	6.6	0.0946	0.0526
C1	4.6	A	3.2	3.3	A	0.1	3.5	A	0.1	0.3978	0.154
C2	2.5	A	2.0	2.8	A	0.2	2.5	A	0.1	0.8368	0.102
C3	0.7	A	2.9	3.8	B	0.2	3.1	B	0.2	0.0068	0.0035
C4	50.4	A	5.4	50.4	A	1.5	51.1	A	1.7	0.8873	0.2247
D1	8.4	A	2.0	7.7	A	0.4	7.4	A	0.3	0.2795	0.1464
D2	2.6	A	1.9	5.0	B	0.3	4.0	A,B	0.3	0.0038	0.0074
D3	21.4	A	2.9	22.8	A	1.1	22.7	A	1.6	0.3796	0.5327

Tuesday May 13, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	10.7	A	3.4	9.8	A	0.3	12.3	A	0.3	0.0986	0.0264
A2	1.6	A	2.1	3.2	A	0.2	2.5	A	0.2	0.0682	0.0099
A3	40.0	A	0.8	40.0	A	1.0	40.4	A	1.1	0.6988	0.7948
B1	4.2	A	3.1	3.3	A	0.1	3.5	A	0.1	0.6043	0.0504
B2	1.1	A	2.5	2.5	A	0.1	2.2	A	0.2	0.1866	0.0918
B3	2.6	A	1.1	3.2	A	0.1	2.9	A	0.1	0.3143	0.0375
B4	36.4	A,B	1.5	42.3	B	2.2	35.4	A	7.5	0.0247	0.0046
C1	3.8	A	3.4	3.3	A	0.1	3.5	A	0.1	0.9058	0.1633
C2	2.1	A	2.6	2.8	A	0.2	2.3	A	0.2	0.718	0.1685
C3	3.9	A	2.7	3.8	A	0.3	2.9	A	0.2	0.4342	0.0314
C4	45.8	A	5.7	51.9	B	2.2	47.9	A,B	1.8	0.0181	0.0038
D1	7.2	A	3.1	7.5	A	0.3	7.2	A	0.2	0.9436	0.4596
D2	3.5	A	1.8	4.5	A	0.3	3.7	A	0.3	0.1573	0.049
D3	23.4	A	1.4	21.5	B	0.9	21.8	B	1.2	0.0153	0.0292

Note: Tukey's Studentized Range Test (TK) = Means with the same letter are not significant at the 0.05 level

Table 4-5 (continued)
Statistical Analysis of Delay Time on Test Network "First Hour"
First hour of observation (12:30 - 13:30)

Wednesday May 14, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	12.0	A	1.6	10.0	B	0.1	12.6	A	0.2	<.0001	0.0048
A2	3.6	A	4.5	3.4	A	0.2	2.7	A	0.1	0.7833	0.0408
A3	40.7	A	0.8	41.1	A	1.6	41.2	A	0.7	0.6671	0.382
B1	2.4	A	1.4	3.3	A,B	0.1	3.7	B	0.1	0.0285	0.0035
B2	1.6	A	2.4	2.5	A	0.2	2.3	A	0.1	0.4999	0.1272
B3	3.6	A	3.3	3.2	A	0.2	2.9	A	0.1	0.781	0.0422
B4	40.2	A,B	1.4	43.0	B	1.5	36.4	A	7.1	0.0297	0.0084
C1	4.0	A	3.1	3.3	A	0.2	3.5	A	0.1	0.7287	0.008
C2	1.7	A	2.3	2.7	A	0.1	2.4	A	0.2	0.3092	0.0309
C3	3.0	A	2.0	3.8	A	0.1	3.0	A	0.2	0.3801	0.0438
C4	47.7	A	4.3	52.3	B	2.2	50.3	A,B	1.4	0.028	0.0465
D1	6.9	A	2.8	7.6	A	0.3	7.4	A	0.2	0.7462	0.6024
D2	3.8	A	1.5	4.8	A	0.3	3.9	A	0.3	0.0979	0.0466
D3	21.9	A	1.4	22.8	A	0.9	22.4	A	0.7	0.2918	0.2727

Thursday May 15, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	12.4	A,B	2.3	10.6	B	0.2	13.6	A	0.4	0.0021	0.0042
A2	-2.8	A	12.0	3.5	A	0.3	2.8	A	0.2	0.2034	0.0078
A3	43.4	A	6.6	43.2	A	1.4	40.4	A	1.0	0.3072	0.0478
B1	2.5	A	1.7	3.5	A	0.1	3.8	A	0.1	0.0631	0.0058
B2	0.9	A	2.2	2.7	B	0.2	2.4	A,B	0.1	0.0343	0.0185
B3	2.4	A	2.0	3.4	A	0.2	2.9	A	0.1	0.3288	0.0312
B4	31.8	A	2.1	42.0	B	1.2	33.2	A	7.3	0.0008	0.0028
C1	3.2	A	1.4	3.4	A	0.1	3.5	A	0.2	0.7068	0.3691
C2	2.4	A	2.3	2.9	A	0.2	2.5	A	0.2	0.7311	0.1017
C3	3.9	A	3.3	4.0	A	0.2	3.1	A	0.3	0.6593	0.0997
C4	44.5	A	3.7	50.1	B	2.3	48.5	B	1.6	0.0027	0.002
D1	7.1	A	2.1	7.7	A	0.3	7.5	A	0.4	0.6252	0.7266
D2	4.0	A	2.6	4.9	A	0.1	4.0	A	0.3	0.4458	0.0314
D3	20.7	A	1.6	22.9	B	1.1	22.2	A,B	1.2	0.0198	0.0192

Friday May 16, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	6.4	A	3.7	7.2	A,B	0.1	9.3	B	0.2	0.0506	0.0253
A2	1.0	A	2.7	2.4	A	0.2	1.8	A	0.2	0.2561	0.0504
A3	26.5	A	4.1	32.5	B	2.2	30.0	A,B	1.4	0.0031	0.0085
B1	0.9	A	3.1	3.3	A,B	0.2	3.7	B	0.1	0.021	0.0049
B2	-0.3	A	1.1	2.0	B	0.2	1.6	B	0.2	<.0001	0.0005
B3	1.9	A	2.0	2.7	A	0.2	2.2	A	0.2	0.5286	0.0671
B4	30.0	A	2.3	34.2	B	1.8	29.1	A	3.2	0.0027	0.0024
C1	4.6	A	1.8	3.4	A	0.1	3.6	A	0.2	0.089	0.067
C2	0.9	A	1.4	2.7	B	0.1	2.2	B	0.2	0.0028	0.0048
C3	1.9	A	3.9	3.6	A	0.2	2.8	A	0.3	0.3808	0.00687
C4	29.9	A	4.7	36.2	B	1.9	33.0	A,B	1.2	0.0035	0.0025
D1	4.2	A	3.5	6.3	A	0.4	6.2	A	0.2	0.1217	0.6182
D2	0.2	A	2.4	3.6	B	0.3	2.8	B	0.2	0.0006	0.0004
D3	15.7	A	2.2	17.1	A	1.3	16.3	A	0.6	0.2448	0.2344

Note: Tukey's Studentized Range Test (TK) = Means with the same letter are not significant at the 0.05 level

Second, the column labeled Kruskal Wallis Pr > chi-square, which is a non-parametric analog to ANOVA, gives the p-value for comparing the three groups. The numbers in this column gives a different prospective. Here 61 comparisons have a p-value less than 0.05 while the reminder 37 have a p-value greater than 0.05. Looking closely at the delay times presented in the table, it can be seen that the values are different. It appears that a 10% to 18% change between default and calibrated means (i.e. Saturday, Monday, and Wednesday on link B4) showed no statistical significance according to ANOVA. On the other hand, the Kruskal Wallis test on the same values showed statistical significance. To conclude that the means are significantly different based on the Kruskal-Wallis test can increase the probability of committing a type I error. This means rejecting the Null Hypothesis when it is true. Based on the above, for the data presented on delay time this research does not enough evidence to conclude that the means are significantly different.

However, from a practical point of view, it should be mentioned that the simulated delay values derived from the calibrated model seems closer to the observed values in comparison with the simulated values produced by the default model.

Travel Time on Test Network "Second Hour":

Referring to the summary of statistical analysis of Travel Time on the Test Network during the second hour (Table 4-6) the following comments and interpretations are presented:

First, the column labeled ANOVA Pr > F gives the p-value for comparing the groups. The numbers in this column are all below the alpha value of 0.05 with the exception of road segment D3 on Mondays, and Thursdays in which the level of

Table 4-6
Statistical analysis of Travel Time on Test Network "Second Hour"
Second hour observation (13:30 - 14:30)

Saturday May 10, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	37.0	A	3.1	40.2	B	0.4	37.5	A	0.2	0.0086	0.0064
A2	36.4	A	2.2	46.0	B	0.6	37.2	A	0.2	<.0001	0.0011
A3	54.4	A	3.3	60.9	B	2.6	55.2	A	1.3	0.0003	0.0029
B1	19.8	A	2.0	24.6	B	0.1	21.0	A	0.1	<.0001	0.0008
B2	20.9	A	3.0	26.5	B	0.2	21.8	A	0.2	<.0001	0.0008
B3	32.2	A	2.2	41.3	B	0.2	33.9	A	0.2	<.0001	0.0008
B4	55.6	A	1.9	64.9	B	1.5	55.2	A	4.7	<.0001	0.0011
C1	20.3	A	1.3	23.5	B	0.2	19.9	A	0.1	<.0001	0.0006
C2	22.0	A	2.1	27.1	B	0.1	22.2	A	0.1	<.0001	0.0009
C3	31.8	A	1.1	40.5	B	0.2	32.8	C	0.3	<.0001	0.0004
C4	68.9	A	3.7	74.8	B	5.1	66.4	A	1.9	0.0008	0.0019
D1	42.3	A	3.5	52.7	B	0.2	44.2	A	0.2	<.0001	0.0011
D2	31.4	A	1.4	38.2	B	0.2	31.1	A	0.2	<.0001	0.0012
D3	31.8	A	2.5	35.2	B	1.8	31.8	A	0.8	0.0031	0.0069

Sunday May 11, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	37.1	A	0.2	37.1	B	1.5	40.1	A	0.2	<.0001	0.0012
A2	37.1	A	0.1	45.8	B	0.6	37.1	A	0.2	<.0001	0.0012
A3	56.7	A	0.1	61.2	B	3.5	55.8	A	1.6	0.0006	0.001
B1	20.3	A	1.6	24.6	B	0.2	21.0	A	0.1	<.0001	0.001
B2	21.1	A	1.2	26.5	B	0.9	21.6	A	0.1	<.0001	0.0008
B3	32.7	A	1.7	41.2	B	0.2	33.7	A	0.1	<.0001	0.0012
B4	49.0	A	1.0	61.8	B	1.9	51.4	A	6.4	<.0001	0.0008
C1	19.5	A	1.1	23.3	B	0.1	19.8	A	0.1	<.0001	0.0012
C2	21.4	A	0.2	26.9	B	0.2	21.9	C	0.2	<.0001	0.0002
C3	32.3	A	0.4	40.0	B	0.2	32.5	A	0.2	<.0001	0.0007
C4	70.8	A	2.8	79.4	B	3.4	71.6	A	5.1	0.0009	0.0065
D1	44.0	A	2.4	52.9	B	0.2	44.6	A	0.4	<.0001	0.001
D2	29.8	A	2.1	38.3	B	0.3	31.4	A	0.3	<.0001	0.0007
D3	30.9	A	3.0	34.7	B	1.4	31.8	A	1.4	0.009	0.0113

Monday May 12, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	36.7	A	2.0	40.2	B	0.3	37.5	A	0.4	<.0001	0.0012
A2	37.5	A	0.8	46.1	B	1.0	37.2	A	0.2	<.0001	0.0009
A3	56.1	A	1.8	60.8	B	5.0	56.1	A	1.3	0.0161	0.0194
B1	21.8	A	1.6	24.6	B	0.1	21.1	A	0.1	<.0001	0.0011
B2	22.4	A	2.3	26.4	B	0.1	21.8	A	0.2	<.0001	0.0011
B3	31.7	A	2.0	41.3	B	0.1	33.8	C	0.2	<.0001	0.0004
B4	55.2	A	1.7	62.0	B	1.6	56.6	A	1.6	<.0001	0.0008
C1	21.0	A	1.2	23.6	B	0.1	19.9	C	0.1	<.0001	0.0003
C2	21.7	A	2.8	27.1	B	0.1	22.3	A	0.1	<.0001	0.0011
C3	31.1	A	3.4	40.5	B	0.2	33.0	A	0.2	<.0001	0.0005
C4	68.1	A	1.2	74.5	B	1.7	69.9	A	1.6	<.0001	0.0004
D1	42.9	A	2.6	52.9	B	0.2	44.3	A	0.3	<.0001	0.001
D2	30.7	A	2.2	38.2	B	0.3	31.4	A	0.2	<.0001	0.0008
D3	32.7	A	2.2	33.6	A	2.2	32.3	A	1.1	0.4201	0.3823

Tuesday May 13, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	37.0	A	0.7	40.2	B	0.2	37.7	C	0.2	<.0001	0.0005
A2	36.4	A	1.6	46.0	B	0.4	37.1	A	0.1	<.0001	0.0008
A3	55.0	A	3.9	61.5	B	3.5	56.2	A	2.3	0.0037	0.0121
B1	20.0	A	2.8	24.7	B	0.1	21.1	A	0.1	0.0001	0.0015
B2	20.6	A	1.3	26.5	B	0.2	21.9	C	0.1	<.0001	0.0007
B3	32.9	A	2.5	41.3	B	0.1	34.0	A	0.2	<.0001	0.0011
B4	55.5	A	3.5	62.8	B	1.2	56.3	A	5.5	0.0042	0.0009
C1	21.2	A,B	3.2	23.6	B	0.2	19.9	A	0.2	0.0046	0.0251
C2	23.7	A	2.2	27.2	B	0.2	22.3	A	0.2	<.0001	0.0016
C3	32.2	A	2.5	40.7	B	0.2	33.1	A	0.4	<.0001	0.001
C4	69.1	A	1.5	80.2	B	8.8	69.4	A	2.7	0.0014	0.0014
D1	43.3	A	2.6	53.0	B	0.4	44.6	A	0.3	<.0001	0.0012
D2	30.5	A	2.2	38.4	B	0.3	31.4	A	0.3	<.0001	0.0011
D3	32.2	A	2.3	34.8	B	1.2	32.8	A,B	1.2	0.0218	0.0111

Note: Tukey's Studentized Range Test (TK) = Means with the same letter are not significant at the 0.05 level

Table 4-6 (continued)
Statistical analysis of Travel Time on Test Network "Second Hour"
Second hour observation (13:30 - 14:30)

Wednesday May 14, 1997 ; 7 Observations in each cell

Road Segment	Observed Mean	TK	Stand. Dev.	Default Mean	TK	Stand. Dev.	Calibrated Mean	TK	Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	36.2	A	2.4	40.1	B	0.3	37.2	A	0.2	0.0002	0.0064
A2	37.0	A	1.7	45.6	B	0.2	37.1	A	0.2	<.0001	0.0012
A3	52.7	A	1.2	60.0	B	1.8	56.4	C	1.8	<.0001	0.0004
B1	20.6	A	2.4	24.6	B	0.2	21.0	A	0.1	<.0001	0.0012
B2	20.6	A	3.6	26.5	B	0.3	21.7	A	0.1	<.0001	0.0061
B3	32.9	A	2.8	41.3	B	0.3	33.8	A	0.2	<.0001	0.0008
B4	58.1	A,B	3.2	62.9	B	3.1	54.9	A	4.8	0.0034	0.0047
C1	21.0	A	3.2	23.6	B	0.1	19.9	A	0.2	0.0047	0.0217
C2	21.5	A	2.8	27.2	B	0.2	22.2	A	0.2	<.0001	0.0012
C3	33.3	A	1.1	40.5	B	0.3	33.1	A	0.4	<.0001	0.0012
C4	75.8	A,B	2.4	82.5	B	9.2	73.4	A	6.2	0.0482	0.0197
D1	45.3	A	1.5	53.4	B	0.4	44.7	A	0.1	<.0001	0.0012
D2	30.2	A	0.2	38.7	B	0.4	31.5	C	0.2	<.0001	0.0001
D3	31.3	A	1.6	35.6	B	1.3	33.3	A	1.7	0.002	0.0018

Thursday May 15, 1997 ; 7 Observations in each cell

Road Segment	Observed Mean	TK	Stand. Dev.	Default Mean	TK	Stand. Dev.	Calibrated Mean	TK	Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	36.9	A	1.9	40.5	B	0.2	37.6	A	0.3	<.0001	0.0011
A2	34.4	A	1.4	52.1	B	8.9	37.3	A	0.2	<.0001	0.0001
A3	56.3	A	0.8	73.1	B	9.8	57.1	A	1.7	<.0001	0.0012
B1	22.1	A	2.5	24.8	B	0.2	21.1	A	0.2	0.0004	0.006
B2	20.8	A	2.0	26.6	B	0.2	21.9	A	0.2	<.0001	0.0007
B3	32.9	A	3.8	41.3	B	0.2	33.9	A	0.2	<.0001	0.0008
B4	56.6	A	3.2	66.3	B	3.2	58.0	A	2.4	<.0001	0.0013
C1	20.2	A	1.7	23.6	B	0.2	19.9	A	0.1	<.0001	0.0011
C2	21.7	A	1.5	27.0	B	0.1	22.2	A	0.1	<.0001	0.001
C3	31.4	A	2.4	40.3	B	0.3	32.9	A	0.1	<.0001	0.0004
C4	69.5	A	2.2	79.8	B	9.2	70.7	A	2.3	0.0055	0.0024
D1	42.2	A	2.9	52.8	B	0.3	44.6	C	0.3	<.0001	0.0004
D2	30.8	A	3.0	38.1	B	0.3	31.4	A	0.3	<.0001	0.0008
D3	33.2	A	2.5	33.9	A	1.4	32.4	A	1.5	0.3497	0.1954

Friday May 16, 1997 ; 7 Observations in each cell

Road Segment	Observed Mean	TK	Stand. Dev.	Default Mean	TK	Stand. Dev.	Calibrated Mean	TK	Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	31.2	A	3.0	37.4	B	0.2	34.1	C	0.1	<.0001	0.0003
A2	34.1	A	2.4	44.8	B	0.2	36.2	C	0.2	<.0001	0.0004
A3	42.5	A	3.4	52.1	B	1.7	45.1	A	1.1	<.0001	0.0007
B1	19.5	A	3.7	24.5	B	0.2	20.9	A	0.2	0.0011	0.006
B2	22.9	A	2.0	26.0	B	0.2	21.2	C	0.1	<.0001	0.0031
B3	32.5	A	2.3	40.9	B	0.2	33.4	A	0.2	<.0001	0.0006
B4	35.5	A	3.7	49.1	B	0.7	39.7	A	5.2	<.0001	0.0008
C1	19.1	A	0.2	23.1	B	0.2	19.7	A	0.1	0.0003	0.0059
C2	20.2	A	2.6	25.9	B	0.2	21.2	A	0.1	<.0001	0.0008
C3	30.9	A	3.4	38.8	B	0.3	31.5	A	0.3	<.0001	0.0011
C4	53.0	A	3.7	63.8	B	1.5	55.1	A	1.2	<.0001	0.0008
D1	41.4	A	4.2	51.7	B	0.3	43.4	A	0.3	<.0001	0.0012
D2	28.8	A	1.2	36.8	B	0.1	30.0	C	0.3	<.0001	0.0003
D3	26.0	A	1.8	29.0	B	0.8	26.2	A	1.8	0.0032	0.0114

Note: Tukey's Studentized Range Test (TK) = Means with the same letter are not significant at the 0.05 level

significance (p-value) are 0.4201 and 0.3497 respectively. Therefore, since most of the p-values are less than the level set for rejection of the null hypothesis. This translates that based on the data presented there is a large evidence for rejecting the null hypothesis in favor of the alternative hypothesis. In conclusion, there is evidence that the Travel Times will be different among the three study groups (observed, default, and calibrated). This finding is similar to the Travel Time study during the first hour of data collection.

Second, the values under the Kruskal Wallis Pr > chi-square, gives the p-values for comparing the three mean groups for Travel Time. The values are all below the 0.05 significance level with the exception of road segment D3 on Mondays and Thursdays in which the p-values where .3823 and .1954 respectively. For this comparison it seems that both the parametric and non-parametric tests produces the same statistical conclusion. That is, since the p-values are less than the reference probability, the null hypothesis is rejected and one concludes' that the averages for the groups are significantly different.

Third, since the above conclusion only states that at least two means are different. The next step would be to use the Tukey's Studentized Range test, a multiple comparison procedure, to further investigate differences between groups. The outcome of this test is presented in the table under the heading TK. Tukey's test will perform all pair-wise comparisons among the groups. That is, it will compare observed vs. default, observed vs. calibrated, and default vs. calibrated.

In comparing the observed travel times vs. the travel times produced by the default model, it is clearly seen that most of the observed travel time means have the letter A and most of the default travel times have the letter B next to them. This implies that the majority of the simulated travel times produced by the default model are statistically significant from those observed in the field at the 0.05 confidence level. This conclusion is true for most of the road segments through out the week with the exception of road segments D3 on Monday and Thursday, and C1 on Tuesday. In other words, from the possible 98 comparisons only 3 had similar means.

The second comparison (observed vs. calibrated) the following remarks are drawn: Looking at the travel times under observed and calibrated columns it is clear that the majority of the means have similar letters next to them. This means that the observed travel times and the simulated travel times from the calibrated model are not significantly different at the 0.05 level. This is true for all the road segments with the exception of C3 on Saturday, C2 on Sunday, B3 and C1 on Monday, A1 and B2 on Tuesday, A3 and D2 on Wednesday, D1 on Thursday, and A1, A2, B2, and D2 on Friday. Therefore, from the 98 possible comparisons only 13 road segments showed statistically significant differences among their mean travel times.

In summary, the default model for the second hour correctly predicted only 3 travel times where the calibrated model for the same hour correctly predicted 85 travel times out of a possible 98. This indicates that the calibrated Netsim model is able to correctly predict travel times in mush more instances than the default Netsim model.

The third and final comparison is comparing the default travel times and the calibrated travel times. Looking at both columns it is obvious that most of the values have different letters. This is a good indication that based on the second hour of data collection, the simulated travel times produced by both default and calibrated models are statistically significant at the 0.05 level. This fact was observed in all the road links with the exception of road segment D3 on Monday, Tuesday, and Thursday.

Delay Time on Test Network "Second Hour":

In reference to Table 4-7, titled summary of statistical analysis of Delay Time on the Test Network during the second hour of observation, the following is presented:

First, the column under the heading ANOVA Pr > F gives the p-values for comparing delay time for the three group. It appears that some of the numbers are below 0.05 and some are above the 0.05 level set by this research. From the 98 possible values only 36 had a p-value less than 0.05. This says that only 36 road segments through out the week had mean delay times significantly different, and that the reminder 62 road segments showed no statistical differences. The two days that showed the most differences among the groups are Sunday and Friday each with 7 road segments having p-values less than 0.05. It showed be mentioned that similar conclusion was drawn for delay time during the first hour of observation.

Second, the column labeled Kruskal Wallis Pr > chi-square, a non-parametric statistical procedure, gives the p-values for comparing the three groups. According to this test 55 out of the possible 98 had a p-value less than 0.05. Therefore, according to the results of a non-parametric test more than half of the links had group means that are statistically different.

To summarize the findings on delay time based on both parametric and non-parametric tests, it appears that about 63% (62 road segments) and 44% (43 road segments) of the road segments had a p-value > 0.05 for both ANOVA and Kruskal-Wallis tests respectively. These percentages are pretty high, therefore this study

Table 4-7
Statistical analysis of Delay Time on Test Network "Second Hour"
Second hour observation (13:30 - 14:30)

Saturday May 10, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	13.2	A	3.1	10.8	B	0.3	13.4	A	0.2	0.0109	0.0081
A2	2.4	A	2.2	3.8	A	0.6	2.9	A	0.1	0.1572	0.0313
A3	42.4	A	3.3	45.9	B	2.6	43.1	A,B	1.4	0.0438	0.0283
B1	1.9	A	2.1	3.5	A,B	0.1	3.7	B	0.2	0.0217	0.036
B2	1.8	A	3.0	2.7	A	0.2	2.4	A	0.1	0.6292	0.0993
B3	1.7	A	2.2	3.3	A	0.2	3.0	A	0.2	0.0692	0.0926
B4	41.7	A	1.9	47.6	B	1.4	41.1	A	4.7	0.0012	0.0012
C1	4.2	A	1.3	3.5	A	0.2	3.6	A	0.1	0.2195	0.0252
C2	2.8	A	2.1	3.3	A	0.1	2.8	A	0.1	0.6844	0.0236
C3	3.0	A	1.1	4.6	B	0.2	3.6	A	0.3	0.0006	0.0039
C4	49.2	A	6.1	55.1	A	5.1	50.4	A	2.0	0.0699	0.0677
D1	6.0	A	3.5	7.6	A	0.1	7.5	A	0.3	0.2983	0.7695
D2	4.9	A	1.4	5.2	A	0.2	4.2	A	0.2	0.0912	0.0173
D3	23.9	A	2.5	25.3	A	1.8	23.8	A	0.8	0.229	0.1098

Sunday May 11, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	13.3	A	1.5	10.4	B	0.2	13.5	A	0.3	<.0001	0.0012
A2	3.1	A,B	1.0	3.6	B	0.5	2.7	A	0.1	0.0483	0.0149
A3	44.7	A	0.9	46.3	A	3.5	43.6	A	1.6	0.1133	0.1224
B1	2.4	A	1.6	3.4	A,B	0.2	3.7	B	0.1	0.0437	0.0195
B2	2.0	A	1.2	2.7	A	0.1	2.2	A	0.1	0.1633	0.0304
B3	2.1	A	1.7	3.2	A	0.2	2.8	A	0.1	0.14	0.075
B4	35.1	A	0.1	44.5	B	1.9	37.3	A	6.4	0.0007	0.0018
C1	3.5	A	1.1	3.4	A	0.1	3.5	A	0.1	0.9426	0.5715
C2	2.2	A	0.2	3.0	B	0.2	2.5	A	0.2	<.0001	0.0009
C3	3.4	A	0.4	4.1	B	0.2	3.3	A	0.2	<.0001	0.0016
C4	53.2	A	3.5	59.8	B	3.4	55.6	A,B	5.1	0.0218	0.0158
D1	7.7	A	2.4	7.7	A	0.3	7.8	A	0.4	0.9768	0.637
D2	3.3	A	2.1	5.3	B	0.3	4.6	A,B	0.3	0.0186	0.0116
D3	23.0	A	3.0	24.8	A	1.4	23.8	A	1.4	0.2964	0.2244

Monday May 12, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	12.8	A	2.0	10.5	B	0.3	13.4	A	0.4	0.0006	0.0064
A2	3.5	A,B	0.8	3.9	B	1.0	2.8	A	0.1	0.0411	0.018
A3	44.1	A,B	1.8	45.9	A	5.0	44.0	A	1.3	0.4532	0.8218
B1	3.9	A	1.5	3.5	A	0.1	3.8	A	0.1	0.6324	0.1094
B2	3.3	A	2.3	2.6	A	0.1	2.4	A	0.2	0.4566	0.2551
B3	1.2	A	2.0	3.3	B	0.1	2.9	B	0.1	0.01	0.0035
B4	41.3	A	1.7	44.7	B	1.6	42.5	A,B	1.6	0.0035	0.0097
C1	5.0	A	1.2	3.6	B	0.1	3.7	B	0.1	0.0026	0.0009
C2	2.5	A	2.8	3.3	A	0.1	2.8	A	0.1	0.7066	0.0932
C3	2.2	A	3.4	4.6	A	0.3	3.8	A	0.2	0.0889	0.0058
C4	50.4	A	5.3	54.9	A	1.7	53.9	A	1.9	0.0495	0.0178
D1	4.5	A	0.3	6.6	A	2.5	7.8	A	0.2	0.293	0.4652
D2	4.2	A	2.3	5.3	A	0.3	4.5	A	0.3	0.3101	0.0318
D3	24.8	A	2.2	23.7	A	2.1	24.2	A	1.1	0.6061	0.3763

Tuesday May 13, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	13.1	A	0.8	10.5	B	0.3	13.6	A	0.2	<.0001	0.0011
A2	2.4	A	1.6	3.8	B	0.4	2.8	A,B	0.2	0.0393	0.0114
A3	43.0	A	3.9	46.6	A	3.5	44.0	A	2.3	0.1439	0.1719
B1	2.2	A	2.9	3.5	A	0.1	3.8	A	0.1	0.1621	0.0049
B2	1.4	A	1.3	2.7	B	0.2	2.5	B	0.1	0.0138	0.099
B3	0.4	A	2.5	3.3	A	0.2	3.0	A	0.2	0.495	0.1516
B4	41.6	A	3.5	45.5	A	1.2	42.2	A	5.5	0.1509	0.0276
C1	5.2	A	3.2	3.6	A	0.2	3.7	A	0.2	0.2287	0.2839
C2	4.4	A	2.2	3.3	A	0.2	2.8	A	0.2	0.0833	0.03
C3	3.3	A	2.5	4.7	A	0.2	3.8	A	0.3	0.2121	0.0294
C4	51.4	A	5.0	60.6	B	8.8	53.4	A,B	2.7	0.0274	0.0092
D1	7.0	A	2.6	7.9	A	0.3	7.9	A	0.3	0.4623	0.8515
D2	4.0	A	2.2	5.4	A	0.3	4.6	A	0.3	0.1615	0.0259
D3	24.3	A	2.3	24.9	A	1.2	24.8	A	1.2	0.7158	0.9188

Note: Tukey's Studentized Range Test (TK) = Means with the same letter are not significant at the 0.05 level

Table 4-7 (continued)
Statistical analysis of Delay Time on Test Network "Second Hour"
Second hour observation (13:30 - 14:30)

Wednesday May 14, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	12.3	A	2.4	10.4	B	0.3	12.9	A	0.3	0.0087	0.0088
A2	3.1	A	1.7	3.4	A	0.2	2.7	A	0.2	0.453	0.0258
A3	40.7	A	1.1	45.1	B	1.8	44.3	B	1.8	0.0001	0.0025
B1	2.8	A	2.4	3.5	A	0.2	3.8	A	0.1	0.3961	0.2602
B2	1.5	A	3.6	2.7	A	0.3	2.3	A	0.1	0.5418	0.0807
B3	2.4	A	2.9	3.3	A	0.2	2.9	A	0.2	0.5757	0.053
B4	44.2	A	3.2	45.6	A	3.1	40.8	A	4.8	0.0745	0.116
C1	4.9	A	3.2	3.6	A	0.2	3.6	A	0.2	0.2974	0.5008
C2	2.3	A	2.8	3.3	A	0.2	2.8	A	0.2	0.5346	0.0937
C3	4.4	A	1.1	4.7	A	0.3	3.8	A	0.3	0.1013	0.0223
C4	58.2	A	5.2	62.9	A	9.2	57.4	A	6.3	0.3171	0.4289
D1	9.0	A	1.5	8.3	A	0.4	7.9	A	0.2	0.0839	0.0585
D2	3.6	A	0.2	5.7	B	0.5	4.7	C	0.2	<.0001	0.0001
D3	23.4	A	1.7	26.0	B	1.2	25.2	A,B	1.7	0.0184	0.0413

Thursday May 15, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	13.0	A	1.9	10.8	B	0.3	13.4	A	0.3	0.0004	0.006
A2	0.4	A	1.4	9.9	B	8.8	2.9	A,B	0.2	0.008	0.0001
A3	44.8	A	0.8	58.2	B	9.8	45.0	A	1.7	0.0004	0.0012
B1	4.2	A	2.5	3.6	A	0.2	3.9	A	0.2	0.758	0.2623
B2	1.6	A	2.0	2.8	A	0.2	2.6	A	0.2	0.174	0.0697
B3	2.3	A	3.8	3.3	A	0.2	2.9	A	0.2	0.7016	0.0511
B4	42.7	A	3.2	49.0	B	3.3	43.8	A	2.4	0.0019	0.0047
C1	4.1	A	1.7	3.6	A	0.2	3.6	A	0.1	0.6464	0.93
C2	2.4	A	1.5	3.2	A	0.2	2.8	A	0.1	0.3306	0.0387
C3	2.5	A	2.4	4.4	B	0.3	3.6	A,B	0.1	0.0566	0.0034
C4	51.8	A	5.0	60.2	A	9.2	54.8	A	2.3	0.0598	0.0245
D1	5.9	A	2.9	7.7	A	0.3	7.8	A	0.2	0.0787	0.0266
D2	4.2	A	3.0	5.1	A	0.3	4.6	A	0.2	0.6529	0.0698
D3	25.3	A	2.5	24.1	A	1.4	24.4	A	1.5	0.4749	0.6289

Friday May 16, 1997 : 7 Observations in each cell

Road Segment	Observed Mean	Observed TK	Observed Stand. Dev.	Default Mean	Default TK	Default Stand. Dev.	Calibrated Mean	Calibrated TK	Calibrated Stand. Dev.	ANOVA Pr > F	Kruskal Wallis Pr > chi-square
A1	7.3	A	2.9	7.7	A,B	0.3	9.9	B	0.1	0.0243	0.0067
A2	0.1	A	2.4	2.6	B	0.3	1.9	A,B	0.2	0.0132	0.0042
A3	30.6	A	3.4	37.2	B	1.7	32.9	A,B	1.1	0.0001	0.0011
B1	1.6	A	3.7	3.4	A	0.1	3.7	A	0.1	0.1874	0.0514
B2	3.7	A	2.0	2.2	A,B	0.2	1.8	B	0.1	0.0152	0.0125
B3	2.0	A	2.3	3.0	A	0.2	2.4	A	0.2	0.3909	0.0101
B4	21.6	A	3.7	31.8	B	0.7	25.6	A	5.2	0.0003	0.0008
C1	3.2	A	2.6	3.1	A	0.2	3.4	A	0.1	0.9317	0.0719
C2	1.0	A	2.6	2.1	A	0.2	1.8	A	0.1	0.4144	0.0852
C3	2.0	A	3.4	3.0	A	0.3	2.3	A	0.3	0.6647	0.0682
C4	35.4	A	7.8	44.2	B	1.6	39.2	A,B	1.1	0.008	0.001
D1	5.1	A	4.2	6.6	A	0.3	6.5	A	0.4	0.4299	0.843
D2	2.3	A	1.2	3.9	B	0.2	3.2	A,B	0.3	0.0027	0.0032
D3	18.1	A	1.8	19.1	A	0.8	18.2	A	1.8	0.4063	0.1754

Note: Tukey's Studentized Range Test (TK) = Means with the same letter are not significant at the 0.05 level

concludes that for the second hour of observation, there was not enough evidence to reject the Null hypothesis and concludes that the averages of delay time among the three groups are not significantly different at the 0.05 level. However, from a practical point of view, and looking back at delay values it appears that the simulated delay values from the calibrated model are closer to the delay values observed in the field in comparison with the simulated delay values generated by the default model.

The same conclusion was drawn with respect to delay time during the first hour of data collection.

Summary of Findings on the Test Network

This research observed and recorded traffic volumes, signal timings, traffic composition and other related factors on the Test Network (Mecca Street) for a period of two hours on seven consecutive days in Amman-Jordan. The study performed a total of 98 traffic simulation runs using the Traf-Netsim model with both the default and calibrated parameters. The main objective of this phase was to determine if Traf-Netsim model can or can't accurately predict Travel Times and Delay Times along the arterial street. This was accomplished by the following:

First, the Traf-Netsim model was executed 49 times using the default parameters embedded in to the model (default model)

Second, the model was modified using the observed values for mean free flow speed, start-up lost time and queue discharge headway along with their respective distributions (calibrated model).

Third, the simulated Travel Times and route Delay Times derived from both the default and calibrated models were compared with the observed values in the field.

To compare the three group means several statistical hypotheses were setup. The null hypothesis for Travel Time states that the population means for all groups are the same and the alternative hypothesis says that at least two means are different. Similar hypotheses were used for Delay Time along the route.

The summary of statistical analysis of Travel Time and Delay Time were presented for the Test Network (Mecca Street) in Tables 4-4, 4-5, 4-6 and 4-7. For Travel Time the null hypothesis was rejected in favor of the alternative hypothesis. Further investigation revealed that the simulated Travel Times from the calibrated model produced values similar to the observed values. On the other hand, for Delay Time there was not enough evidence to reject the null hypothesis. However, differences between the simulated Delay Times from the calibrated model and observed values were less in comparison with the differences between the simulated delay values from the default model and those observed in the field.

Validation Network

The second site, referred to as the Validation Network, is a stretch of Al Shareef Nasser bin Jameel Street (or Safeway Street), which is approximately 1.5 kilometers long (or 0.94 miles). The second site was used to answer the following question:

- Can the Traf-Netsim model using the calibrated parameters adequately simulate both Time and Delay time along a second arterial street? This was also accomplished by comparing the simulated values produced by the calibrated model with observed values collected in the field for the validation Network.

Defining the Hypotheses

To test if the simulated Travel Times and Delay Times derived from the calibrated model are statistically significant from the observed values obtained from the floating car study, the following hypotheses were constructed:

Travel Time along the Arterial:

- The Null Hypothesis states that the Travel Time means are the same.

The two groups are:

1. Simulated model with calibrated parameters.
2. Observed values form the field.

In terms of a mathematical expression the Null Hypotheses is:

$$\mathbf{H_o} : u_{\text{calibrated}} = u_{\text{observed}}$$

- The Alternative Hypotheses states that the Travel Time means are significantly different.

In terms of a mathematical expression the Alternative Hypotheses is:

$$\mathbf{H_a} : u_{\text{calibrated}} \neq u_{\text{observed}}$$

Delay Time along the Arterial:

Similar null and alternative hypotheses for the mean Delay Time were also constructed.

$$\mathbf{H_o} : u_{\text{calibrated}} = u_{\text{observed}}$$

$\mathbf{H_a} : u_{\text{calibrated}} \neq u_{\text{observed}}$

To test and evaluate if the two group means for both travel time and delay time presented in the above hypotheses are statistically significant a Two-Sample t-test will be used and is presented below:

Two sample t-test:

The t-test is a parametric procedure that compares two samples. However, before performing the Two-Sample t-tests the following assumptions should be checked.

1- Observations are independent random samples.
2- Observations for each group are a sample from a population with a normal distribution.
3- The two groups have equal variances.

The first assumption of independent observations is met, since in this research every Travel Time or Delay Time whether simulated or measured in the field is unrelated to every other measurement. For the simulated measurements this was accomplished by using a different random number seed for each simulation run which generates internally a different pattern of driver types and vehicle paths along the network.

The second assumption of normality is hard to meet since there are only 8 to 10 observations in each group. Conclusively, this assumption was not met.

The third and final assumption is concerned whether the variances for the two groups are equal. This assumption is tested using the PROC TTEST procedure in *SAS*. The output produced by *SAS* contains two values for the t-test one based on equal variances the other on unequal variances. For this research some of the means had equal variances and others had unequal variances. The probability value in the table reflects the appropriate t-test.

In summary, since the data in each group was small, the assumption of normality could not be checked. Thus, both the Two-Sample t-test and the Wilcoxon Rank Sum Test for comparing two independent groups were used. The Wilcoxon Rank Sum Test is a non-parametric analogue to the two-sample t-test and is sometimes referred to as the Mann-Whitney U test. The only assumption required for this non-parametric test is that the observations are independent and this assumption was met.

Statistical Interpretation

The following section will present the summaries of the statistical tests and will evaluate the null and alternative hypotheses for travel time and delay time on the validation network. Prior to presenting the statistical results, it should be mentioned that the naming of the links in the validation network were also modified for added clarity and simplicity when viewing the statistical analysis. Figure 4-2 shows the aggregated links and nodes for the validation network.

Travel Time on Validation Network "First Hour":

Looking at the statistical analysis of Travel Time on the Validation Network for the first hour (Table 4-8) the following comments and interpretations are made:

First, the column labeled T-Test Pr >| t | gives the p-values for comparing the two groups. In looking at the values it seems that most of the p-values are well above the rejection criteria of 0.05 set by this research. This is true for all the road segments through out the week, with the exception of road segment D1 on Friday, B1 on Saturday,

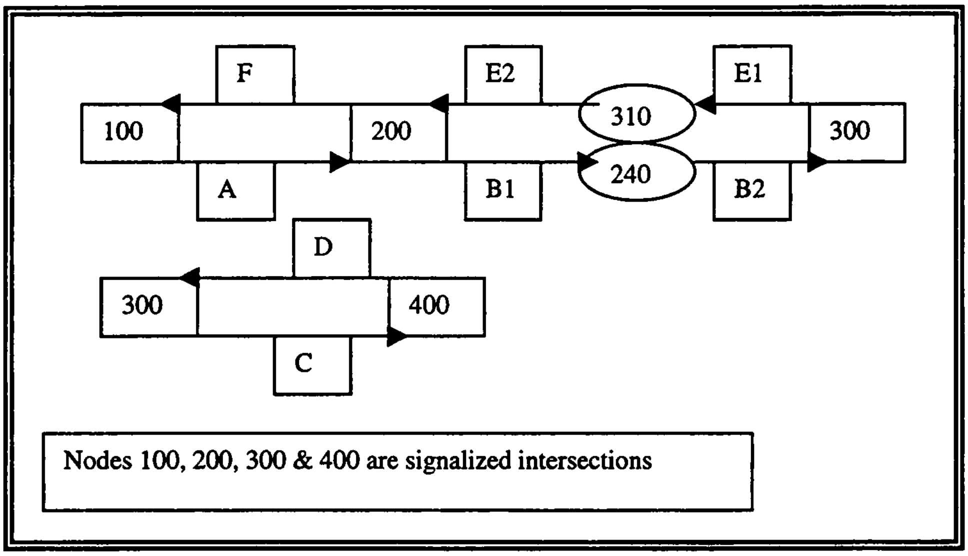


Figure 4-2
Validation Network

Table 4-8
Statistical analysis of Travel Time on Validation Network "First Hour"
First hour of observation (12:30 - 13:30)

Saterday June 27, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	18.2	3.9	17.1	0.2	0.4572	0.958
B1	25.0	0.9	26.0	0.2	0.0195	0.1025
B2	41.1	3.6	39.2	1.3	0.1905	0.1556
C	26.8	2.0	28.2	2.1	0.206	0.2268
D	35.4	1.9	37.8	2.6	0.0584	0.0659
E1	22.5	1.9	23.8	1.5	0.1265	0.1563
E2	30.6	2.7	30.8	0.4	0.81	0.4945
F	19.8	3.6	21.5	0.8	0.2121	0.3717

Sunday June 28, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	16.4	4.1	16.8	0.2	0.8038	1
B1	21.6	2.2	25.5	0.2	0.0014	0.0133
B2	42.7	3.9	40.0	1.6	0.1041	0.1559
C	27.2	4.1	28.1	2.7	0.6056	0.4733
D	43.5	3.2	43.4	4.9	0.9915	0.7965
E1	21.6	1.9	24.0	0.9	0.0071	0.018
E2	31.8	3.2	31.0	0.4	0.5164	0.958
F	19.6	5.4	21.5	0.7	0.3481	0.1036

Monday June 29, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	18.9	4.0	17.1	0.2	0.243	0.5789
B1	25.6	1.5	26.6	0.2	0.1266	0.1028
B2	37.8	5.6	39.3	0.7	0.4562	0.8766
C	28.9	3.2	29.0	1.5	0.1062	0.1275
D	39.9	2.0	42.1	3.5	0.1376	0.1278
E1	24.5	1.9	26.1	1.9	0.1252	0.1275
E2	33.3	3.8	31.8	0.7	0.2804	0.5635
F	20.6	4.0	23.3	1.0	0.0955	0.0659

Tuesday June 30, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	18.2	4.8	16.8	0.2	0.4654	1
B1	24.8	2.0	26.0	0.1	0.1416	0.1824
B2	38.9	5.7	39.7	2.0	0.7185	0.958
C	33.1	3.0	33.4	3.0	0.8082	0.9581
D	38.1	4.6	42.1	4.5	0.1021	0.0831
E1	21.4	1.4	24.6	0.9	<.0001	0.0009
E2	32.8	3.8	31.1	0.5	0.229	0.4932
F	23.2	3.7	21.9	0.6	0.3653	0.5629

Table 4-8 (continued)
Statistical analysis of Travel Time on Validation Network "First Hour"
First hour of observation (12:30 - 13:30)

Wednesday July 1, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	15.9	1.2	16.8	0.4	0.084	0.0653
B1	25.3	1.7	25.9	0.2	0.3236	0.2265
B2	39.2	2.4	37.6	2.6	0.2152	0.0831
C	24.8	1.5	26.2	1.4	0.0765	0.0831
D	33.7	2.7	34.9	1.4	0.2856	0.2271
E1	18.7	1.5	22.2	0.4	0.0002	0.0009
E2	31.2	3.6	30.6	0.7	0.6221	0.9581
F	20.0	2.2	21.4	0.5	0.1262	0.3717

Thursday July 2, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	20.0	4.6	17.2	0.3	0.1361	0.2698
B1	25.7	2.1	26.8	0.2	0.1598	0.0813
B2	37.3	2.3	39.0	1.9	0.1419	0.0831
C	33.3	3.1	36.1	5.6	0.2359	0.3181
D	43.0	6.6	47.0	4.6	0.1747	0.1563
E1	23.8	3.1	25.5	1.3	0.1832	0.1563
E2	33.6	2.7	32.0	0.6	0.1376	0.317
F	21.7	4.0	23.8	0.8	0.1838	0.0404

Friday July 3, 1998: 10 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	14.0	4.0	15.8	0.5	0.1971	0.0885
B1	20.9	2.1	23.1	0.3	0.0083	0.0072
B2	28.4	3.9	30.6	0.7	0.107	0.3845
C	16.7	2.0	19.2	0.3	0.0037	0.0013
D	21.3	2.3	23.3	0.7	0.0274	0.0311
E1	16.0	2.0	19.6	0.2	0.0002	0.0027
E2	26.5	4.8	27.5	0.7	0.5198	0.578
F	14.1	2.4	16.6	0.3	0.0077	0.0028

Sunday, and Friday, E1 on Sunday, Tuesday, Wednesday, and Friday. Thus from the possible 56 comparisons only 8 had a p-value less than 0.05. With Friday and Sunday having 3 and 2 road segments respectively.

Second, in looking at the column labeled Wilcoxon Pr > | Z | which gives the p-values for the non-parametric procedure. In this column the majority of the p-values are also greater than 0.05 with the exception of Sunday links B1 and E1, Tuesday link E1, Wednesday link E1, Thursday link F, and Friday links B1, C, D, and E1. Of the possible 56 comparisons only 9 had a p-value less than 0.05, again with Friday and Sunday having 4 and 2 links respectively.

In conclusion, since the majority of the p-values are greater than the reference probability of 0.05, this means failure to reject the null hypothesis. And since we are comparing independent groups, this research will conclude that the mean travel time for the two groups are not significantly different. In other words, it appears that the calibrated Netsim model can accurately predict the Travel Times in Amman-Jordan.

<u>Delay Time on Validation Network "First Hour"</u>:

Looking at the statistical analysis of Delay Time on the Validation Network during the first hour (Table 4-9) the following conclusions are drawn:

First, the column under the heading T-Test Pr > | t | gives the p-values for comparing delay time for the two groups. The numbers in most cases are larger than the reference probability value of 0.05. Looking at the six weekdays (Saturday, Sunday, Monday, Tuesday, Wednesday, and Thursday) it appears that only 5 out of possible 48 (8*6) links had a p-value greater than 0.05. However it seems that on the weekend (Friday) there were 5 road segments with a p-value greater than 0.05.

Table 4-9
Statistical analysis of Delay Time on Validation Network "First Hour"
First hour of observation (12:30 - 13:30)

Saturday June 27, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	9.8	3.9	8.6	0.2	0.4188	0.958
B1	12.2	0.9	13.0	0.2	0.0442	0.1031
B2	21.6	3.6	19.4	1.3	0.1433	0.1556
C	14.2	2.0	15.4	2.1	0.2552	0.2268
D	22.8	1.9	25.0	2.6	0.0772	0.0659
E1	8.8	1.9	10.0	1.1	0.1756	0.1893
E2	12.0	2.7	12.0	0.4	0.997	0.5629
F	11.0	3.6	12.6	0.8	0.2416	0.5629

Sunday June 28, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	8.0	4.1	8.3	0.2	0.8558	1
B1	8.8	2.2	12.5	0.2	0.0018	0.0133
B2	23.1	3.9	20.2	1.6	0.0781	0.1559
C	14.5	4.1	15.3	2.7	0.6747	0.5635
D	30.9	3.2	30.7	4.9	0.9396	0.7929
E1	7.9	1.9	10.1	0.9	0.0107	0.0353
E2	13.2	3.3	12.2	0.4	0.421	0.958
F	10.7	5.4	12.6	0.7	0.3704	0.1036

Monday June 29, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	10.5	4.0	8.6	0.2	0.2203	0.4299
B1	12.8	1.5	13.6	0.2	0.2006	0.1876
B2	18.2	5.6	19.5	0.7	0.5292	0.958
C	14.2	3.2	16.2	1.5	0.129	0.1275
D	27.3	2.0	29.4	3.5	0.1717	0.1278
E1	10.8	1.9	12.2	1.9	0.1614	0.2701
E2	14.7	3.6	13.0	0.7	0.22	0.4309
F	11.7	4.0	14.4	1.0	0.1052	0.0659

Tuesday June 30, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	9.8	4.8	8.3	0.2	0.4336	1
B1	12.0	2.0	13.0	0.1	0.2003	0.3703
B2	19.3	5.7	19.9	2.0	0.8099	0.958
C	20.4	3.0	20.6	3.0	0.88	0.9581
D	25.5	4.6	29.3	4.4	0.1159	0.1036
E1	7.7	1.4	10.7	0.9	0.0002	0.0009
E2	14.2	3.8	12.3	0.5	0.1984	0.4939
F	14.4	3.7	13.0	0.6	0.3297	0.4306

Table 4-9 (continued)
Statistical analysis of Delay Time on Validation Network "First Hour"
First hour of observation (12:30 - 13:30)

Wednesday July 1, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	7.5	1.2	8.3	0.4	0.1179	0.188
B1	12.4	1.7	12.9	0.2	0.4416	0.4942
B2	19.7	2.4	17.8	2.6	0.1563	0.0406
C	12.1	1.5	13.4	1.4	0.1093	0.1033
D	21.1	2.7	22.2	1.4	0.3435	0.2694
E1	5.0	1.5	8.3	0.4	0.0003	0.0009
E2	12.6	3.6	11.7	0.7	0.5068	0.9581
F	11.2	2.2	12.4	0.5	0.1532	0.713

Thursday July 2, 1998: 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	11.6	4.6	8.7	0.3	0.1245	0.2698
B1	12.8	2.1	13.8	0.2	0.2174	0.1023
B2	17.8	2.3	19.2	1.8	0.2101	0.1278
C	20.6	3.1	23.2	5.6	0.2639	0.3181
D	30.4	6.6	34.3	4.6	0.1919	0.1893
E1	10.1	3.1	11.7	1.3	0.2266	0.1889
E2	15.0	2.7	13.2	0.6	0.0975	0.2694
F	12.8	4.0	14.9	0.8	0.2012	0.04

Friday July 3, 1998: 10 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	5.6	4.0	7.3	0.5	0.2212	0.1036
B1	8.1	2.1	10.1	0.3	0.012	0.0088
B2	8.8	3.9	10.6	0.8	0.1502	0.4267
C	4.0	2.0	6.3	0.3	0.0055	0.0028
D	8.7	2.3	10.5	0.7	0.0395	0.0311
E1	2.4	2.0	5.8	0.2	0.0003	0.0028
E2	7.9	4.8	8.7	0.7	0.6154	0.4272
F	5.3	2.4	7.7	0.3	0.0098	0.0028

Second, the column labeled Wilcoxon Pr > | Z |, a non-parametric test, also gives the p-values for comparing the two group means. According to the data presented, there are 6 road segments with a p-value greater than 0.05 during the six week days (Saturday through Thursday). And on Friday the weekend there are 5 road segments with a p-value greater than 0.05.

In summary, based on the results presented by both parametric and non-parametric procedures the p-values for most links are much greater than 0.05. This means that this study would fail to reject the null hypothesis and conclude that the average Delay Times simulated from the calibrated Netsim model and those observed in the field are not significantly different based on the data presented during the first hour of observation. This is a positive indication of how well the calibrated Traf-Netsim simulation model performs in Amman-Jordan. However, on Friday's there is a statistical significance between the calibrated Netsim model and the observed values in the field.

<u>Travel Time on Validation Network "Second Hour"</u>:

In reference to the summary of statistical analysis of Travel Time on the Validation Network for the second hour (Table 4-10) the following is presented:

First, the column under the heading T-Test Pr > | t | gives the p-values for comparing the means derived from the calibrated model and those observed in the validation network. The majority of the values are greater than the 5% significance level. From the possible 48 links (8 segments * 6 weekdays) only 6 showed differences that are significant at the 5% level. However, on Friday the weekend, 5 out of 8 links showed significant differences between the calibrated and observed Travel Times.

Table 4-10
Statistical analysis of Travel Time on Validation Network "Second Hour"
Second hour of observation (13:30 - 14:30)

Saterday June 27, 1998; 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	18.0	3.4	17.4	1.7	0.654	0.8744
B1	23.4	3.3	25.4	0.1	0.121	0.013
B2	38.6	3.8	39.8	0.8	0.409	0.6365
C	23.5	3.7	26.6	1.4	0.0553	0.0659
D	34.6	3.0	36.8	3.2	0.1614	0.1559
E1	20.0	2.5	23.0	0.7	0.0107	0.0136
E2	29.4	4.5	31.8	4.5	0.3105	0.713
F	19.9	5.4	22.0	4.4	0.4145	0.0657

Sunday June 28, 1998; 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	20.1	4.4	17.1	0.3	0.0797	0.4302
B1	23.5	2.1	25.6	0.2	0.0226	0.0649
B2	36.3	4.2	37.4	1.7	0.5138	0.7927
C	22.4	4.8	24.6	1.0	0.2287	0.3717
D	32.4	3.5	34.9	2.6	0.1276	0.2271
E1	20.9	2.4	22.3	0.5	0.154	0.3184
E2	31.2	3.4	30.3	0.6	0.4986	0.9581
F	19.4	1.8	20.0	0.6	0.3583	0.2268

Monday June 29, 1998; 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	20.7	3.9	17.1	0.3	0.0324	0.1028
B1	26.6	4.3	25.6	0.1	0.5525	1
B2	40.3	3.7	38.6	1.4	0.2555	0.5632
C	26.3	4.1	27.4	1.4	0.494	0.7128
D	42.0	2.0	38.9	3.1	0.0317	0.0681
E1	21.2	2.1	23.2	0.8	0.0325	0.0659
E2	32.4	3.9	31.3	0.5	0.4348	1
F	20.2	2.2	21.5	0.6	0.1269	0.0404

Tuesday June 30, 1998; 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	19.6	3.7	17.7	0.3	0.1762	0.1141
B1	22.4	2.5	25.7	0.2	0.0065	0.0134
B2	37.6	3.2	38.8	1.8	0.3339	0.372
C	27.1	3.8	28.3	1.7	0.4221	0.4948
D	41.0	3.8	41.1	4.2	0.9547	1
E1	24.1	1.2	25.2	1.4	0.1112	0.1893
E2	30.1	2.5	31.8	0.8	0.0823	0.2268
F	19.7	3.6	21.7	0.5	0.1398	0.1036

Table 4-10 (continued)
Statistical analysis of Travel Time on Validation Network "Second Hour"
Second hour of observation (13:30 - 14:30)

Wednesday July 1, 1998; 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	16.6	3.0	17.2	0.3	0.5916	0.4302
B1	23.8	2.5	25.7	0.3	0.0682	0.1889
B2	37.7	3.3	39.6	1.5	0.1695	0.3184
C	28.9	2.3	30.6	3.2	0.2508	0.3181
D	38.9	4.0	41.5	4.6	0.254	0.372
E1	21.2	4.0	23.6	0.6	0.1347	0.0829
E2	30.1	2.6	30.8	0.7	0.5214	0.7923
F	20.4	3.4	21.3	0.6	0.4787	0.4306

Thursday July 2, 1998; 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	15.7	3.9	17.0	0.1	0.3575	0.1015
B1	26.9	1.7	26.1	0.2	0.1669	0.4289
B2	36.6	4.3	39.4	1.4	0.1191	0.2271
C	27.3	2.1	29.8	3.3	0.0881	0.1033
D	36.8	3.4	38.8	3.1	0.2488	0.7927
E1	21.4	4.4	23.3	0.6	0.2442	0.8767
E2	28.7	3.5	30.7	0.6	0.1413	0.1033
F	20.8	1.9	21.7	0.6	0.2059	0.5277

Friday July 3, 1998; 9 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	14.9	2.7	15.7	0.4	0.3925	0.9296
B1	19.9	1.3	23.3	0.2	< 0001	0.0004
B2	28.0	5.3	31.0	0.6	0.1282	0.2327
C	15.9	2.8	19.1	0.3	0.0098	0.0061
D	21.6	1.9	23.7	0.8	0.0101	0.0092
E1	16.5	1.6	19.9	0.1	0.0003	0.0004
E2	29.3	3.9	27.6	0.3	0.2383	0.1327
F	13.2	2.7	15.9	0.7	0.0162	0.0061

Second, Looking at the column labeled Wilcoxon Pr > | Z | which gives the p-values for the non-parametric procedure. In this column the majority of the p-values are also greater than 0.05 with the exception of links B1 and E1 on Saturday, F on Monday, B1 on Tuesday, and B1, C, D, E1, and F on Friday.

In closure, since the majority of the p-values during the weekday (i.e. Saturday, Sunday, Monday, Tuesday, Wednesday, and Thursday) are greater than the reference probability of 0.05. This means that I would fail to reject the null hypothesis and conclude that it appears that the simulated Travel Times from the calibrated Traf-Netsim model are not significantly different from the observed Travel Times in the field. This supports the finding of Travel Times during the first hour and further supports the idea that the calibrated Netsim model is transposable and can accurately predict the traffic performance in Amman-Jordan. However, Looking at Friday, which is the weak end in Jordan, It appears that the calibrated model doesn't predict the traffic performance in Jordan. The values derived from the model are larger than those observed in the field. This could mean that drivers are more aggressive on Fridays and don't follow the speed limit signs. An important fact to state is that on Friday's the traffic volumes are down by 50% in comparison with the weekday traffic volumes during the same hour.

<u>Delay Time on Validation Network "Second Hour":</u>

Looking at the statistical inquiry of Delay Time on the Validation Network during the second hours of data collection (Table 4-11) the following remarks and interpretations are presented:

First, the column under the heading T-Test Pr > | t | gives the p-values for comparing delay times during the second hour for the two groups. The numbers in most

Table 4-11
Statistical analysis of Delay Time on Validation Network "Second Hour"
Second hour of observation (13:30 - 14:30)

Saterday June 27, 1998; 8 Observations in each cell						
Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	9.6	3.4	8.9	1.7	0.6022	0.8744
B1	10.5	3.3	12.4	0.1	0.1474	0.013
B2	19.1	3.8	20.0	0.9	0.5241	0.713
C	10.8	3.7	13.8	1.4	0.065	0.0829
D	22.0	3.0	24.1	3.2	0.1902	0.1889
E1	6.3	2.5	9.2	0.8	0.0145	0.0239
E2	10.8	4.5	12.9	4.5	0.3608	0.7927
F	11.1	5.4	13.1	4.4	0.4367	0.0659

Sunday June 28, 1998; 8 Observations in each cell						
Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	11.7	4.4	8.6	0.3	0.0913	0.3713
B1	10.7	2.1	12.6	0.2	0.0311	0.1008
B2	16.8	4.2	17.6	1.7	0.6099	0.9581
C	9.7	4.8	11.8	1.0	0.2619	0.3717
D	19.8	3.4	22.1	2.6	0.1515	0.2701
E1	7.3	2.4	8.4	0.5	0.214	0.4306
E2	12.6	3.4	11.5	0.6	0.3882	0.7132
F	10.6	1.8	11.1	0.6	0.447	0.2271

Monday June 29, 1998; 8 Observations in each cell						
Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	12.3	3.9	8.6	0.3	0.0291	0.1028
B1	13.8	4.3	12.7	0.2	0.4994	1
B2	20.8	3.7	18.8	1.4	0.1942	0.3181
C	13.6	4.0	14.6	1.4	0.5542	0.7963
D	29.4	2.0	26.1	3.1	0.027	0.0661
E1	7.5	2.0	9.3	0.8	0.0491	0.1036
E2	13.8	3.9	12.4	0.5	0.343	1
F	11.3	2.2	12.6	0.7	0.159	0.0406

Tuesday June 30, 1998; 8 Observations in each cell						
Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	11.2	3.7	9.2	0.3	0.158	0.1028
B1	9.5	2.5	12.7	0.2	0.0083	0.0134
B2	18.0	3.2	19.0	1.8	0.4399	0.4945
C	14.4	3.8	15.5	1.7	0.4802	0.5283
D	28.4	3.6	28.4	0.2	0.982	0.7929
E1	10.4	1.2	11.3	1.4	0.1884	0.2701
E2	11.5	2.6	13.0	0.8	0.1435	0.3177
F	10.9	3.6	12.8	0.6	0.1797	0.1036

Table 4-11 (continued)
Statistical analysis of Delay Time on Validation Network "Second Hour"
Second hour of observation (13:30 - 14:30)

Wednesday July 1, 1998; 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	8.2	3.0	8.7	0.3	0.6546	0.4302
B1	10.9	2.5	12.7	0.3	0.0765	0.2268
B2	18.2	3.3	19.8	1.5	0.2426	0.4309
C	16.3	2.3	17.8	3.2	0.2996	0.4306
D	26.3	4.0	28.7	4.5	0.2869	0.372
E1	7.5	4.0	9.7	0.6	0.1588	0.1031
E2	11.5	2.6	12.0	0.7	0.6579	0.8745
F	11.5	3.4	12.3	0.6	0.5362	0.4306

Thursday July 2, 1998; 8 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	7.3	3.9	8.5	0.1	0.392	0.1015
B1	14.1	1.7	13.1	0.2	0.1308	0.2698
B2	17.1	4.3	19.6	1.4	0.1558	0.2698
C	14.6	2.1	17.0	3.3	0.1079	0.1033
D	24.2	3.4	26.0	3.1	0.2948	0.7926
E1	7.7	4.4	9.5	0.6	0.3066	0.8748
E2	10.1	3.5	11.9	0.6	0.2016	0.1033
F	11.9	1.9	12.8	0.7	0.2565	0.6363

Friday July 3, 1998; 9 Observations in each cell

Road Segment	Observed Mean (sec.)	Observed Stand. Dev.	Calibrated Mean (sec.)	Calibrated Stand. Dev.	T-Test Pr > |t|	Wilcoxon Pr > |Z|
A	6.5	2.7	7.2	0.4	0.4508	0.8598
B1	7.1	1.3	10.3	0.2	<.0001	0.0004
B2	8.4	5.3	11.1	0.6	0.1605	0.4263
C	3.2	2.8	6.3	0.3	0.0122	0.0061
D	9.0	1.9	10.9	0.8	0.0166	0.0216
E1	2.8	1.6	6.0	0.1	0.0004	0.0004
E2	10.7	3.9	8.8	0.3	0.1841	0.0766
F	4.3	2.7	7.0	0.7	0.0193	0.0061

cases are larger than the reference probability value of 0.05. This is true of all the weekdays with the exception of road segment E1 on Saturday, B1 on Sunday, D and E1 on Monday, and B1 on Tuesday. Therefore from the total 48 road segments during the weekday only 5 showed statistical differences at the 5% significant level. On Friday, the following 5 road segments showed statistical differences at the 5% level. The five segments are B1, C, D, E1, and F.

Second, the column under the heading Wilcoxon Pr > | Z | gives the associated p values based on a non-parametric test. The majority of the p-values during the weekdays are larger than the 5% significant level. This is true for all road segments in the validation network with the exception of road segment B1 on Saturday, Sunday, and Tuesday. Therefore only 3 out of possible 48 links showed statistical differences at the 5% significant level. On Friday, the values say a different story. As can be seen from the table, there are 5 road segments having a p-value less than 0.05. This indicates that for Friday the results are significantly different. The five road segments are B1, C, D, E1, and F, which are the same according to the two-sample t-test.

In summary, the statistical tests for Delay Time during the second hour produces large p-values on the majority of the road segments during the weekdays. This means that this research would fail to reject the null hypothesis and concludes that the average Delay Times simulated from the calibrated Traf-Netsim model are not significantly different from those observed in the field during the validation study. This is a good indication of how well the calibrated model performed in the validation network.

Nonetheless, since the p-values for Friday are less than the reference probability of 0.05, this implies that there is a statistical difference between the calibrated and observed delay times, thus the null hypothesis is rejected.

Summary of Findings on the Validation Network

This research recorded and observed traffic volumes on the Validation Network (Safeway Street) for a period of two hours on seven consecutive days in Amman-Jordan. This phase of the study performed a total of 57 simulation runs using the calibrated Traf-Netsim model with the following parameters reflecting the Jordanian driving environment.

- The mean Start-up Lost Time was modified from 2.0 seconds to 1.8 seconds.
- The distribution of Start-up Lost Time was modified as shown below

Driver Characteristic K	1	2	3	4	5	6	7	8	9	10
Default	218	140	125	118	102	86	78	63	47	23
Calibrated	211	169	141	121	101	83	64	48	37	25

- The mean Queue Discharge headway was modifies from 1.8 seconds to 1.5 seconds.
- The distribution of Queue Discharge Headway was modified as shown below:

Driver Characteristic K	1	2	3	4	5	6	7	8	9	10
Default	170	120	120	110	100	100	90	70	70	50
Calibrated	180	134	118	105	95	88	81	75	67	57

- The mean Free Flow Speed was modified from 30 mph (48 Km/h) to 38 mph (60 Km/h) the posted speed limit.

The main objective of this phase is to test if the calibrated Traf-Netsim model is transportable. That is, to test if the model can simulate traffic conditions at a second site without changes to any of the calibrated parameters measured in the Test Network. The only change would be the input data directly related to the characteristics of the validation network. This was accomplished by the following:

First, the validation network had to be coded into Netsim in the form of nodes and links as specified by Traf-Netsim format.

Second, the calibrated model was executed several times and the simulated Travel Times and Delay Times were compared with the observed values derived from the floating car method.

To compare the two group means the following hypotheses were used. The null hypothesis for Travel Time states that the population means are the same. And the alternative hypothesis states that the population means are different. For Delay Time similar hypotheses where setup. The summary of statistical analysis of Travel Time and Delay Time for the Validation Network was presented in Tables 4-8, 4-9, 4-10, and 4-11.

The statistical tests for Travel Time indicated that there are no differences between the calibrated values and the observed values for all weekdays. Thus, the null hypothesis could not be rejected and this study concluded that the calibrated Netsim model could accurately predict Travel Times during the weekdays. An exception was found for Friday, which is a public holiday, thus the null hypothesis was rejected in favor of the alternative hypothesis and this research concluded that the calibrated model couldn't accurately predict the Travel Times under low traffic volumes.

The statistical tests for Delay Time also indicated that there are no differences between the calibrated and the observed values for all the weekdays. As before, the calibrated model failed to predict, within a given accuracy, the observed Delay Times on

Friday's. Although from a practical point of view it appears that the calibrated values were higher than the observed values. This would mean that under low traffic conditions drivers do act quicker than under heavy traffic conditions.

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

Discussion

As urban traffic congestion continues to increase in many metropolitan cities around the globe, traffic engineers are constantly applying the latest technology to help manage traffic problems. The traffic engineer's responsibility goes beyond optimization of movement on a limited network to a complete and comprehensive evaluation of different transportation strategies on a systemwide basis. TRAF-NETSIM, which is a microscopic computer simulation program developed in the United States of America, is one of the most accepted and respected traffic network simulation models among the profession. In addition it is probably one of the most extensively tested and validated traffic simulation model in America. However, to use TRAF-NETSIM in other regions around the world, the model's ability to simulate the traffic performance within an acceptable tolerance should be properly tested and validated.

Amman, the capital of Jordan is a major commercial, economic, and cultural center of almost two million inhabitants. The city of Amman, like many other cities in the region, has its share of traffic congestion on its main streets. However, the traffic department in Amman – Jordan does not employ this computer software technology to assist municipal engineers and policy makers in making decisions, as to which design schemes should be implemented on the road network. The main objective of this research is to test whether or not TRAF-NETSIM can accurately simulate the driving conditions in Amman - Jordan. This was accomplished through actual field observations of traffic flow on two selected high-volume urban arterial roads in Amman. To capture all of the traffic activities along the arterial road, several high-tech video cameras, positioned in strategic locations on top of high buildings were used to record traffic counts. This procedure required more equipment than manual traffic counts, but it had the advantage of requiring fewer personnel in the field, thus minimizing possible error in data collection. Nonetheless, additional time was required to summarize traffic data from the videos.

Based on the data collected and gathered through out this study and the statistical analysis on the various measures of performance, the following conclusions were reached:

- The TRAF-NETSIM model can be used to simulate the traffic conditions in Amman-Jordan provided that the following values of various traffic parameters are used.
    - A mean Start-Up Lost Time of 1.8 seconds should be specified instead of the default value of 2.0 seconds in the model.
    - The distribution of Start-up Lost Time should be modified as shown below:

Driver Characteristic K	1	2	3	4	5	6	7	8	9	10
Default	218	140	125	118	102	86	78	63	47	23
Calibrated	211	169	141	121	101	83	64	48	37	25

    - A mean Queue Discharge Headway of 1.5 seconds should be specified instead of the default value of 1.8 seconds embedded in the model.
    - The distribution of Queue Discharge Headway should be modified as shown below:

Driver Characteristic K	1	2	3	4	5	6	7	8	9	10
Default	170	120	120	110	100	100	90	70	70	50
Calibrated	180	134	118	105	95	88	81	75	67	57

- The Calibrated TRAF-NETSIM was able to predict Travel Time within a 5% confidence level for Saturday, Sunday, Monday, Tuesday, Wednesday, and Thursday on both the Test and Validation networks. As can be seen from Tables 5-1 and 5-2, the majority of the road segments showed no significant differences between the simulated travel times from the calibrated model and the observed travel times in the field.
- The Calibrated TRAF-NETSIM was able to predict Delay Time within a 5% confidence level for Saturday, Sunday, Monday, Tuesday, Wednesday, and Thursday on both the Test and Validation networks Tables 5-3, and 5-4. The majority of the links showed no statistical significance between the simulated delay times and those observed in the field.
- The Calibrated TRAF-NETSIM model was not able to simulate the observed Travel Time and Delay Time during a Friday. It should be mentioned that Jordan has a six-day workweek with Fridays off and that Friday traffic is similar to Sunday traffic encountered in the United States.
- The simulated Travel Time's using the default values were significantly different from the observed Travel Times. Table 5-5 shows a summary of travel times between the observed and simulated values on the test network.
- The simulated Delay Time's using the default values were significantly different from the observed delay time. Table 5-6 shows delay times between the simulated values and those observed in the field.

TABLE 5-1

Summary of Travel Time on Test Network (Observed vs. Calibrated)

OBSERVED VS. CALIBRATED		SATURDAY			SUNDAY			MONDAY			TUESDAY			WEDNESDAY			THURSDAY			FRIDAY		
		OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N
A1	1st Hr	35.4	37.2	N	36.6	36.9	N	36.1	37.1	N	34.6	36.5	N	35.9	36.8	N	36.3	37.8	N	30.3	33.5	Y
	2nd Hr	37.0	37.5	N	37.1	40.1	N	36.7	37.5	N	37.0	37.7	Y	36.2	37.2	N	36.9	37.6	N	31.2	34.1	Y
A2	1st Hr	35.9	36.9	N	37.4	37.0	N	36.0	37.0	N	35.6	36.8	N	37.6	37.0	N	31.2	37.1	N	34.9	36.1	N
	2nd Hr	36.4	37.2	N	37.1	37.1	N	37.5	37.2	N	36.4	37.1	N	37.0	37.1	N	34.4	37.3	N	34.1	36.2	Y
A3	1st Hr	52.1	53.6	N	51.8	53.0	N	53.9	55.7	N	52.0	52.5	N	52.7	53.3	N	55.4	53.5	N	38.5	42.1	N
	2nd Hr	54.4	55.2	N	56.7	55.8	N	56.1	56.1	N	55.0	56.2	N	52.7	56.4	Y	56.3	57.1	N	42.5	45.1	N
B1	1st Hr	20.2	20.9	N	21.8	20.9	N	19.9	21.0	N	22.1	20.8	N	20.3	20.9	N	20.4	21.0	N	18.8	21.0	N
	2nd Hr	19.8	21.0	N	20.3	21.0	N	21.8	21.1	N	20.0	21.1	N	20.6	21.0	N	22.1	21.1	N	19.5	20.9	N
B2	1st Hr	21.1	21.7	N	20.4	21.7	Y	22.8	21.7	Y	20.2	21.6	N	20.8	21.7	N	20.0	21.7	Y	18.9	21.0	Y
	2nd Hr	20.9	21.8	N	21.1	21.6	N	22.4	21.8	N	20.6	21.9	Y	20.6	21.7	N	20.8	21.9	N	22.9	21.2	Y
B3	1st Hr	33.0	33.8	Y	33.9	33.8	N	32.2	33.9	N	33.2	33.8	N	34.1	33.8	N	33.0	33.8	N	32.5	33.2	N
	2nd Hr	32.2	33.9	N	32.7	33.7	N	31.7	33.8	Y	32.9	34.0	N	32.9	33.8	N	32.9	33.9	N	32.5	33.4	N
B4	1st Hr	40.9	52.2	N	48.2	48.4	N	55.6	53.2	N	50.3	49.6	N	54.2	50.5	N	45.7	47.3	N	44.0	43.2	N
	2nd Hr	55.6	55.2	N	49.0	51.4	N	55.2	56.6	N	55.5	56.3	N	58.1	54.9	N	56.6	58.0	N	35.5	39.7	N
C1	1st Hr	19.2	19.8	N	20.1	19.9	N	20.7	19.8	N	19.9	19.8	N	20.1	19.7	N	19.2	19.8	N	20.7	19.9	N
	2nd Hr	20.3	19.9	N	19.5	19.8	N	21.0	19.9	Y	21.2	19.9	N	21.0	19.9	N	20.2	19.9	N	19.1	19.7	N
C2	1st Hr	21.1	21.8	N	21.8	21.8	N	21.7	21.9	N	21.3	21.8	N	20.9	21.8	N	21.6	21.9	N	20.1	21.7	Y
	2nd Hr	22.0	22.2	N	21.4	21.9	Y	21.7	22.3	N	23.7	22.3	N	21.5	22.2	N	21.7	22.2	N	20.2	21.2	N
C3	1st Hr	31.2	32.4	N	32.2	32.2	N	29.6	32.3	Y	32.8	32.1	N	31.9	32.2	N	32.7	32.3	N	30.7	32.0	N
	2nd Hr	31.8	32.8	Y	32.3	32.5	N	31.1	33.0	N	32.2	33.1	N	33.3	33.1	N	31.4	32.9	N	30.9	31.5	N
C4	1st Hr	64.7	65.9	N	63.7	65.9	N	68.0	67.1	N	63.4	63.8	N	65.4	66.3	N	62.1	64.5	N	47.5	49.0	N
	2nd Hr	66.9	66.4	N	70.8	71.6	N	68.1	69.9	N	69.1	69.4	N	75.8	73.4	N	69.5	70.7	N	53.0	56.1	N
D1	1st Hr	43.1	43.9	N	42.6	43.9	N	44.7	44.1	N	43.5	44.0	N	43.2	44.1	N	43.4	44.4	N	40.5	42.9	N
	2nd Hr	42.3	44.2	N	44.0	44.6	N	42.9	44.3	N	43.3	44.6	N	45.3	44.7	N	42.2	44.6	Y	41.4	43.4	N
D2	1st Hr	30.2	30.6	N	29.2	30.7	Y	29.2	30.7	Y	30.0	30.6	N	30.3	30.7	N	30.5	30.9	N	26.7	29.6	Y
	2nd Hr	31.4	31.1	N	29.8	31.4	N	30.7	31.4	N	30.5	31.4	N	30.2	31.5	Y	30.8	31.4	N	28.8	30.0	Y
D3	1st Hr	29.9	29.6	N	30.2	30.0	N	29.4	30.7	N	31.4	29.8	N	29.9	30.4	N	28.7	30.3	N	23.6	24.4	N
	2nd Hr	31.8	31.8	N	30.9	31.8	N	32.7	32.3	N	32.2	32.8	N	31.3	33.3	N	33.2	32.4	N	26.0	26.2	N
SUMMARY		2 YES 26 NO			3 YES 25 NO			5 YES 23 NO			2 YES 26 NO			2 YES 26 NO			2 YES 26 NO			8 YES 20 NO		

Y = YES = MEANS ARE SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL

N = NO = MEANS ARE NOT SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL

1st Hr = 12:30 - 13:30

2nd Hr = 13:30 - 14:30

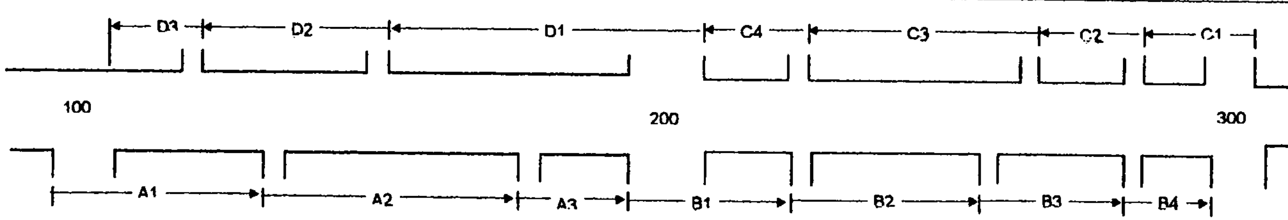


TABLE 5-2

Summary of Travel Time on Validation Network (Observed vs. Calibrated)

OBSERVED VS. CALIBRATED		SATURDAY			SUNDAY			MONDAY			TUESDAY			WEDNESDAY			THURSDAY			FRIDAY		
		OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N
A	1st Hr	18.2	17.1	N	16.4	16.8	N	18.9	17.1	N	18.2	16.8	N	15.9	16.8	N	20.0	17.2	N	14.0	15.8	N
	2nd Hr	18.0	17.4	N	20.1	17.1	N	20.7	17.1	N	19.6	17.7	N	16.6	17.2	N	15.7	17.0	N	14.9	15.7	N
B1	1st Hr	25.0	26.0	N	21.6	25.5	Y	25.6	26.6	N	24.8	26.0	N	25.3	25.9	N	25.7	26.8	N	20.9	23.1	Y
	2nd Hr	23.4	25.4	N	23.5	25.6	N	26.6	25.6	N	22.4	25.7	Y	23.8	25.7	N	26.9	26.1	N	19.9	23.3	Y
B2	1st Hr	41.1	39.2	N	42.7	40.0	N	37.8	39.3	N	38.9	39.7	N	39.2	37.6	N	37.3	39.0	N	28.4	30.6	N
	2nd Hr	38.6	39.8	N	36.3	37.4	N	40.3	38.6	N	37.5	38.8	N	37.7	39.6	N	36.6	39.4	N	28.0	31.0	N
C	1st Hr	26.8	28.2	N	27.2	28.1	N	26.9	29.0	N	33.1	33.4	N	24.8	26.2	N	33.3	36.1	N	16.7	19.2	Y
	2nd Hr	23.5	26.6	N	22.4	24.6	N	26.3	27.4	N	27.1	28.3	N	28.9	30.6	N	27.3	29.8	N	15.9	19.1	Y
D	1st Hr	35.4	37.8	N	43.5	43.4	N	39.9	42.1	N	38.1	42.1	N	33.7	34.9	N	43.0	47.0	N	21.3	23.3	Y
	2nd Hr	34.6	36.8	N	32.4	34.9	N	42.0	38.9	N	41.0	41.1	N	38.9	41.5	N	36.8	38.8	N	21.6	23.7	Y
E1	1st Hr	22.5	23.8	N	21.6	24.0	Y	24.5	26.1	N	21.4	24.6	Y	18.7	22.2	Y	23.8	25.5	N	16.0	19.6	Y
	2nd Hr	20.0	23.0	Y	20.9	22.3	N	21.2	23.2	N	24.1	25.2	N	21.2	23.6	N	21.4	23.3	N	16.5	19.9	Y
E2	1st Hr	30.6	30.8	N	31.8	31.0	N	33.3	31.8	N	32.8	31.1	N	31.2	30.6	N	33.6	32.0	N	26.5	27.5	N
	2nd Hr	29.4	31.8	N	31.2	30.3	N	32.4	31.3	N	30.1	31.6	N	30.1	30.8	N	28.7	30.7	N	29.3	27.6	N
F	1st Hr	19.8	21.5	N	19.6	21.5	N	20.6	23.3	N	23.2	21.9	N	20.0	21.4	N	21.7	23.8	N	14.1	16.6	Y
	2nd Hr	19.9	22.0	N	19.4	20.0	N	20.2	21.5	N	19.7	21.7	N	20.4	21.3	N	20.8	21.7	N	13.2	15.9	Y
SUMMARY		1 YES 15 NO			2 YES 14 NO			0 YES 16 NO			2 YES 14 NO			1 YES 15 NO			0 YES 16 NO			1 0 YES 6 NO		

Y = YES = MEANS ARE SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL

N = NO = MEANS ARE NOT SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL

1st Hr = 12:30 - 13:30

2nd Hr = 13:30 - 14:30

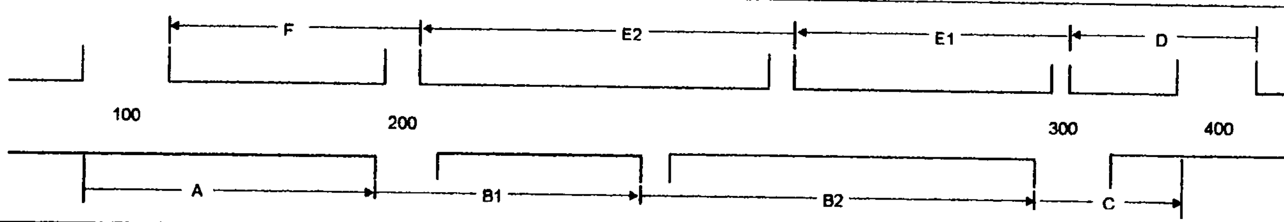


TABLE 5-3

Summary of Delay Time on Test Network (Observed vs. Calibrated)

OBSERVED VS. CALIBRATED		SATURDAY			SUNDAY			MONDAY			TUESDAY			WEDNESDAY			THURSDAY			FRIDAY		
		OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N
A1	1st Hr	11.5	13.1	N	12.7	12.7	N	12.3	12.9	N	10.7	12.3	N	12.0	12.6	N	12.4	13.6	N	6.4	9.3	Y
	2nd Hr	13.2	13.4	N	13.3	13.5	N	12.8	13.4	N	13.1	13.6	N	12.3	12.9	N	13.0	13.4	N	7.3	9.9	Y
A2	1st Hr	2.0	2.5	N	3.5	2.6	N	2.0	2.6	N	1.6	2.5	N	3.6	2.7	N	-2.8	2.8	N	1.0	1.8	N
	2nd Hr	2.4	2.9	N	3.1	2.7	N	3.5	2.8	N	2.4	2.8	N	3.1	2.7	N	0.4	2.9	N	0.1	1.9	N
A3	1st Hr	40.1	41.4	N	39.8	40.8	N	41.9	43.5	N	40.0	40.4	N	40.7	41.2	N	43.4	40.4	N	26.5	30.0	N
	2nd Hr	42.4	43.1	N	44.7	43.6	N	44.1	44.0	N	43.0	44.0	N	40.7	44.3	Y	44.8	45.0	N	30.6	32.9	N
B1	1st Hr	2.3	3.7	Y	3.9	3.7	N	2.0	3.7	Y	4.2	3.5	N	2.4	3.7	Y	2.5	3.8	N	0.9	3.7	Y
	2nd Hr	1.9	3.7	Y	2.4	3.7	Y	3.9	3.8	N	2.2	3.8	N	2.8	3.8	N	4.2	3.9	N	1.6	3.7	N
B2	1st Hr	1.9	2.3	N	1.2	2.3	Y	3.6	2.4	N	1.1	2.2	N	1.6	2.3	N	0.9	2.4	Y	-0.3	1.6	Y
	2nd Hr	1.8	2.4	N	2.0	2.2	N	3.3	2.4	N	1.4	2.5	Y	1.5	2.3	N	1.6	2.6	N	3.7	1.8	Y
B3	1st Hr	2.5	2.9	N	3.3	2.9	N	1.7	2.9	N	2.6	2.9	N	3.6	2.9	N	2.4	2.9	N	1.9	2.2	N
	2nd Hr	1.7	3.0	N	2.1	2.8	N	1.2	2.9	Y	0.4	3.0	N	2.4	2.9	N	2.3	2.9	N	2.0	2.4	N
B4	1st Hr	28.9	38.1	Y	34.9	34.3	N	41.7	39.1	N	36.4	35.4	N	40.2	36.4	N	31.8	33.2	N	30.0	29.1	N
	2nd Hr	41.7	41.1	N	35.1	37.3	N	41.3	42.5	N	41.6	42.2	N	44.2	40.8	N	42.7	43.8	N	21.6	25.6	N
C1	1st Hr	3.1	3.6	N	4.0	3.6	N	4.6	3.5	N	3.8	3.5	N	4.0	3.5	N	3.2	3.5	N	4.6	3.6	N
	2nd Hr	4.2	3.6	N	3.5	3.5	N	5.0	3.7	Y	5.2	3.7	N	4.9	3.6	N	4.1	3.6	N	3.2	3.4	N
C2	1st Hr	1.9	2.4	N	2.6	2.4	N	2.5	2.5	N	2.1	2.3	N	1.7	2.4	N	2.4	2.5	N	0.9	2.2	Y
	2nd Hr	2.8	2.8	N	2.2	2.5	N	2.5	2.8	N	4.4	2.8	N	2.3	2.8	N	2.4	2.8	N	1.0	1.8	N
C3	1st Hr	2.4	3.2	N	3.3	2.9	N	0.7	3.1	Y	3.9	2.9	N	3.0	3.0	N	3.9	3.1	N	1.9	2.8	N
	2nd Hr	3.0	3.6	N	3.4	3.3	N	2.2	3.8	N	3.3	3.8	N	4.4	3.8	N	2.5	3.6	N	2.0	2.3	N
C4	1st Hr	47.0	49.9	N	46.1	50.0	Y	50.4	51.1	N	45.8	47.9	Y	47.7	50.3	N	44.5	48.5	Y	29.9	33.0	N
	2nd Hr	49.2	50.4	N	53.2	55.8	N	50.4	53.9	N	51.4	53.4	Y	58.2	57.4	N	51.8	54.8	N	35.4	39.2	N
D1	1st Hr	6.8	7.1	N	6.3	7.2	N	8.4	7.4	N	7.2	7.2	N	6.9	7.4	N	7.1	7.5	N	4.2	6.2	N
	2nd Hr	6.0	7.5	N	7.7	7.8	N	4.5	7.8	N	7.0	7.9	N	9.0	7.9	N	5.9	7.8	N	5.1	6.5	N
D2	1st Hr	3.7	3.8	N	2.7	3.9	N	2.6	4.0	N	3.5	3.7	N	3.8	3.9	N	4.0	4.0	N	0.2	2.8	Y
	2nd Hr	4.9	4.2	N	3.3	4.6	N	4.2	4.5	N	4.0	4.6	N	3.6	4.7	Y	4.2	4.6	N	2.3	3.2	N
D3	1st Hr	22.0	21.6	N	22.3	22.0	N	21.4	22.7	N	23.4	21.8	Y	21.9	22.4	N	20.7	22.2	N	15.7	16.3	N
	2nd Hr	23.9	23.8	N	23.0	23.8	N	24.8	24.2	N	24.3	24.8	N	23.4	25.2	N	25.3	24.4	N	18.1	18.2	N
SUMMARY		3 YES 25 NO			3 YES 25 NO			4 YES 24 NO			4 YES 24 NO			3 YES 25 NO			2 YES 26 NO			7 YES 21 NO		

Y = YES = MEANS ARE SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL
N = NO = MEANS ARE NOT SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL

1st Hr = 12:30 - 13:30
2nd Hr = 13:30 - 14:30

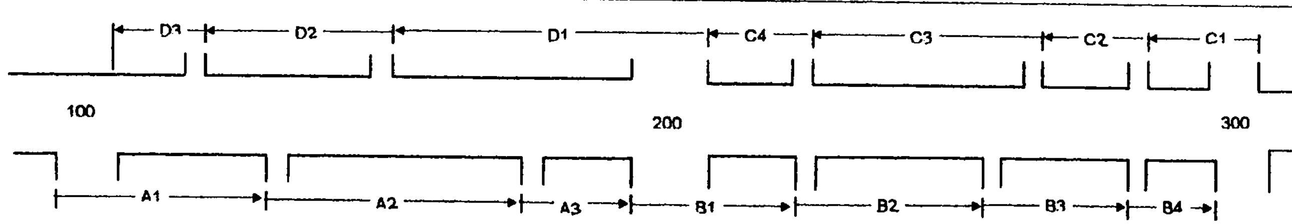


TABLE 5-4
Summary of Delay Time on Validation Network (Observed vs. Calibrated)

OBSERVED VS. CALIBRATED		SATURDAY			SUNDAY			MONDAY			TUESDAY			WEDNESDAY			THURSDAY			FRIDAY		
		OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N	OBS	CAL	Y / N
A	1st Hr	9.8	8.6	N	8.0	8.3	N	10.5	8.6	N	9.8	8.3	N	7.6	8.3	N	11.6	8.7	N	5.6	7.3	N
	2nd Hr	9.6	8.9	N	11.7	8.6	N	12.3	8.6	N	11.2	9.2	N	8.2	8.7	N	7.3	8.5	N	6.5	7.2	N
B1	1st Hr	12.2	13.0	N	8.8	12.5	Y	12.8	13.6	N	12.0	13.0	N	12.4	12.9	N	12.8	13.8	N	8.1	10.1	Y
	2nd Hr	10.5	12.4	N	10.7	12.6	N	13.8	12.7	N	9.5	12.7	Y	10.9	12.7	N	14.1	13.1	N	7.1	10.3	Y
B2	1st Hr	21.6	19.4	N	23.1	20.2	N	18.2	19.5	N	19.3	19.9	N	18.7	17.8	N	17.8	19.2	N	8.8	10.8	N
	2nd Hr	19.1	20.0	N	16.8	17.6	N	20.8	18.8	N	18.0	19.0	N	18.2	19.8	N	17.1	19.6	N	8.4	11.1	N
C	1st Hr	14.2	15.4	N	14.5	15.3	N	14.2	16.2	N	20.4	20.6	N	12.1	13.4	N	20.6	23.2	N	4.0	6.3	Y
	2nd Hr	10.8	13.8	N	9.7	11.8	N	13.6	14.6	N	14.4	15.5	N	16.3	17.8	N	14.6	17.0	N	3.2	6.3	Y
D	1st Hr	22.8	25.0	N	30.9	30.7	N	27.3	29.4	N	25.5	29.3	N	21.1	22.2	N	30.4	34.3	N	8.7	10.5	Y
	2nd Hr	22.0	24.1	N	19.8	22.1	N	29.4	26.1	N	28.4	28.4	N	26.3	28.7	N	24.2	26.0	N	9.0	10.9	Y
E1	1st Hr	8.8	10.0	N	7.9	10.1	Y	10.8	12.2	N	7.7	10.7	Y	5.0	8.3	Y	10.1	11.7	N	2.4	5.8	Y
	2nd Hr	6.3	9.2	Y	7.3	8.4	N	7.5	9.3	N	10.4	11.3	N	7.5	9.7	N	7.7	9.5	N	2.8	6.0	Y
E2	1st Hr	12.0	12.0	N	13.2	12.2	N	14.7	13.0	N	14.2	12.3	N	12.6	11.7	N	15.0	13.2	N	7.9	8.7	N
	2nd Hr	10.8	12.9	N	12.6	11.5	N	13.8	12.4	N	11.5	13.0	N	11.5	12.0	N	10.1	11.9	N	10.7	8.8	N
F	1st Hr	11.0	12.6	N	10.7	12.6	N	11.7	14.4	N	14.4	13.0	N	11.2	12.4	N	12.8	14.9	N	5.3	7.7	Y
	2nd Hr	11.1	13.1	N	10.6	11.1	N	11.3	12.6	N	10.9	12.8	N	11.5	12.3	N	11.9	12.8	N	4.3	7.0	Y
SUMMARY		1 YES 15 NO			2 YES 14 NO			0 YES 16 NO			2 YES 14 NO			1 YES 15 NO			0 YES 16 NO			1 0 YES 6 NO		

Y = YES = MEANS ARE SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL
N = NO = MEANS ARE NOT SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL

1st Hr = 12:30 - 13:30
2nd Hr = 13:30 - 14:30

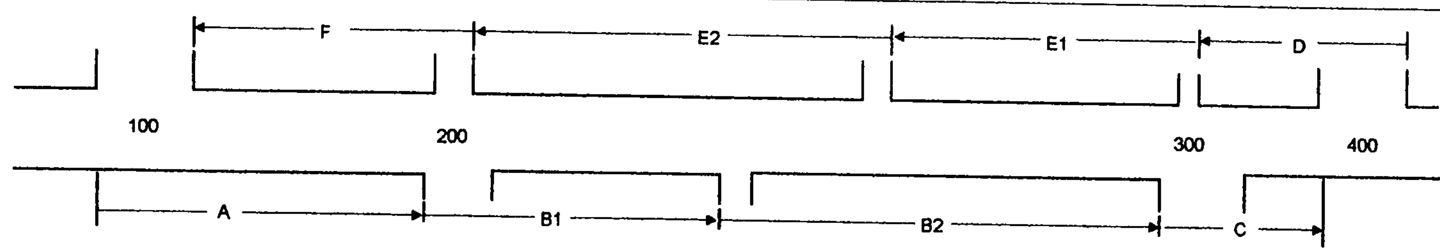


TABLE 5-5

Summary of Travel Time on Test Network (Observed vs. Default)

OBSERVED VS. DEFAULT		SATURDAY			SUNDAY			MONDAY			TUESDAY			WEDNESDAY			THURSDAY			FRIDAY		
		OBS	DEF	Y / N	OBS	DEF	Y / N	OBS	DEF	Y / N	OBS	DEF	Y / N	OBS	DEF	Y / N	OBS	DEF	Y / N	OBS	DEF	Y / N
A1	1st Hr	35.4	40.1	Y	36.6	39.7	Y	36.1	39.9	Y	34.6	39.5	Y	35.9	39.7	Y	36.3	40.4	Y	30.3	36.9	Y
	2nd Hr	37.0	40.2	Y	37.1	37.1	Y	36.7	40.2	Y	37.0	40.2	Y	36.2	40.1	Y	36.9	40.5	Y	31.2	37.4	Y
A2	1st Hr	35.9	45.5	Y	37.4	45.5	Y	36.0	45.5	Y	35.6	45.4	Y	37.6	45.6	Y	31.2	45.7	Y	34.9	44.6	Y
	2nd Hr	36.4	46.0	Y	37.1	45.8	Y	37.5	46.1	Y	36.4	46.0	Y	37.0	45.6	Y	34.4	52.1	Y	34.1	44.8	Y
A3	1st Hr	52.1	57.4	Y	51.8	56.9	Y	53.9	57.3	Y	52.0	54.9	Y	52.7	56.0	Y	55.4	58.0	N	38.5	47.4	Y
	2nd Hr	54.4	60.9	Y	56.7	61.2	Y	56.1	60.8	Y	55.0	61.5	Y	52.7	60.0	Y	56.3	73.1	Y	42.5	52.1	Y
B1	1st Hr	20.2	24.6	Y	21.8	24.5	Y	19.9	24.6	Y	22.1	24.5	N	20.3	24.5	Y	20.4	24.7	Y	18.8	24.5	Y
	2nd Hr	19.8	24.6	Y	20.3	24.6	Y	21.8	24.6	Y	20.0	24.7	Y	20.6	24.6	Y	22.1	24.8	Y	19.5	24.5	Y
B2	1st Hr	21.1	26.3	Y	20.4	26.3	Y	22.8	26.3	N	20.2	26.3	Y	20.8	26.3	Y	20.0	26.5	Y	18.9	25.7	Y
	2nd Hr	20.9	26.5	Y	21.1	26.5	Y	22.4	26.4	Y	20.6	26.5	Y	20.6	26.5	Y	20.8	26.6	Y	22.9	26.0	Y
B3	1st Hr	33.0	41.3	Y	33.9	41.2	Y	32.2	41.1	Y	33.2	41.1	Y	34.1	41.2	Y	33.0	41.3	Y	32.5	40.7	Y
	2nd Hr	32.2	41.3	Y	32.7	41.2	Y	31.7	41.3	Y	32.9	41.3	Y	32.9	41.3	Y	32.9	41.3	Y	32.5	40.9	Y
B4	1st Hr	40.9	59.7	Y	48.2	58.2	Y	55.6	61.4	Y	50.3	59.7	Y	54.2	60.4	Y	45.7	59.3	Y	44.0	51.5	Y
	2nd Hr	55.6	64.9	Y	49.0	61.8	Y	55.2	62.0	Y	55.5	62.8	Y	58.1	62.9	N	58.6	66.3	Y	35.5	49.1	Y
C1	1st Hr	19.2	23.4	Y	20.1	23.4	Y	20.7	23.3	Y	19.9	23.3	Y	20.1	23.3	Y	19.2	23.4	Y	20.7	23.3	Y
	2nd Hr	20.3	23.5	Y	19.5	23.3	Y	21.0	23.6	Y	21.2	23.6	N	21.0	23.6	Y	20.2	23.6	Y	19.1	23.1	Y
C2	1st Hr	21.1	26.7	Y	21.8	26.7	Y	21.7	26.7	Y	21.3	26.6	Y	20.9	26.6	Y	21.6	26.8	Y	20.1	26.5	Y
	2nd Hr	22.0	27.1	Y	21.4	26.9	Y	21.7	27.1	Y	23.7	27.2	Y	21.5	27.2	Y	21.7	27.0	Y	20.2	25.9	Y
C3	1st Hr	31.2	39.8	Y	32.2	39.6	Y	29.6	39.7	Y	32.8	39.6	Y	31.9	39.7	Y	32.7	39.9	Y	30.7	39.4	Y
	2nd Hr	31.6	40.5	Y	32.3	40.0	Y	31.1	40.5	Y	32.2	40.7	Y	33.3	40.5	Y	31.4	40.3	Y	30.9	38.8	Y
C4	1st Hr	64.7	72.3	Y	63.7	69.4	Y	68.0	70.0	N	63.4	71.6	Y	65.4	71.9	Y	62.1	69.8	Y	47.5	55.9	Y
	2nd Hr	66.9	74.8	Y	70.8	79.4	Y	68.1	74.5	Y	69.1	80.2	Y	75.6	82.5	N	69.5	79.8	Y	53.0	63.8	Y
D1	1st Hr	43.1	52.4	Y	42.6	52.2	Y	44.7	52.9	Y	43.5	52.6	Y	43.2	52.7	Y	43.4	52.8	Y	40.5	51.4	Y
	2nd Hr	42.3	52.7	Y	44.0	52.9	Y	42.9	52.9	Y	43.3	53.0	Y	45.3	53.4	Y	42.2	52.8	Y	41.4	51.7	Y
D2	1st Hr	30.2	37.4	Y	29.2	37.5	Y	29.2	37.9	Y	30.0	37.5	Y	30.3	37.7	Y	30.5	37.8	Y	26.7	36.5	Y
	2nd Hr	31.4	38.2	Y	29.8	38.3	Y	30.7	38.2	Y	30.5	38.4	Y	30.2	38.7	Y	30.8	38.1	Y	28.8	36.8	Y
D3	1st Hr	29.9	32.4	Y	30.2	32.1	Y	29.4	32.7	Y	31.4	31.3	N	29.9	32.7	Y	28.7	32.8	Y	23.6	27.0	Y
	2nd Hr	31.8	35.2	Y	30.9	34.7	Y	32.7	33.6	N	32.2	34.8	Y	31.3	35.8	Y	33.2	33.9	N	26.0	29.0	Y
SUMMARY		28 YES 0 NO			28 YES 0 NO			25 YES 3 NO			25 YES 3 NO			26 YES 2 NO			26 YES 2 NO			28 YES 0 NO		

Y = YES = MEANS ARE SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL

N = NO = MEANS ARE NOT SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL

1st Hr = 12:30 - 13:30

2nd Hr = 13:30 - 14:30

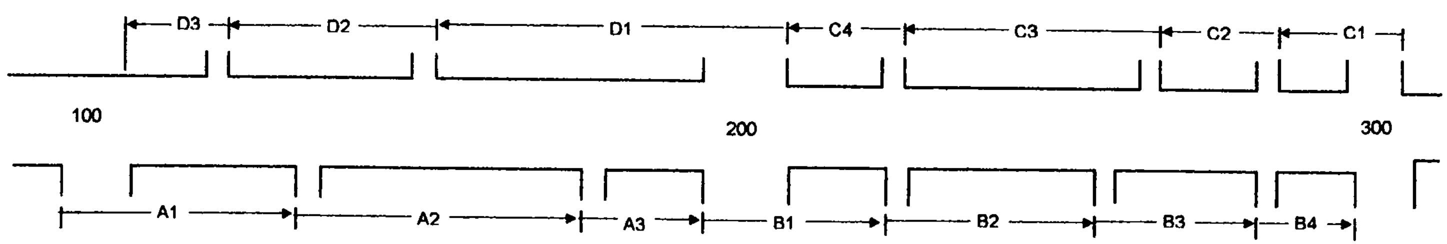


TABLE 5-6

Summary of Delay Time on Test Network (Observed vs. Default)

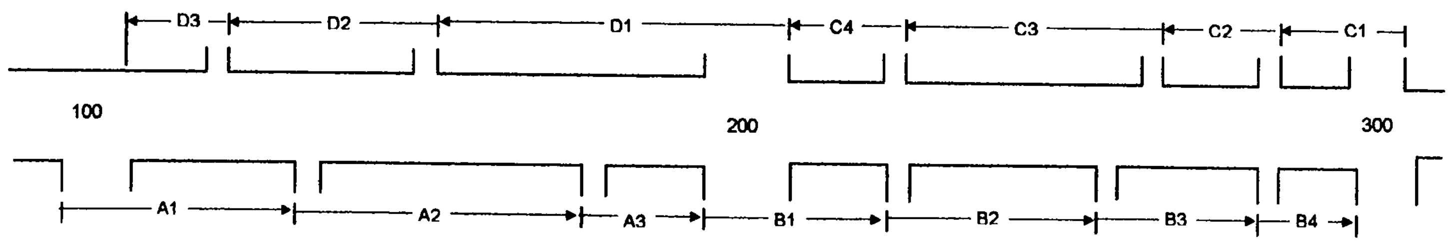
OBSERVED VS. DEFAULT		SATURDAY			SUNDAY			MONDAY			TUESDAY			WEDNESDAY			THURSDAY			FRIDAY		
		OBS	DEF	Y / N	OBS	DEF	Y / N	OBS	DEF	Y / N	OBS	DEF	Y / N	OBS	DEF	Y / N	OBS	DEF	Y / N	OBS	DEF	Y / N
A1	1st Hr	11.6	10.4	N	12.7	10.0	Y	12.3	10.1	Y	10.7	9.8	N	12.0	10.0	Y	12.4	10.6	N	6.4	7.2	N
	2nd Hr	13.2	10.6	Y	13.3	10.4	Y	12.8	10.5	Y	13.1	10.5	Y	12.3	10.4	Y	13.0	10.8	Y	7.3	7.7	N
A2	1st Hr	2.0	3.3	N	3.6	3.3	N	2.0	3.3	N	1.6	3.2	N	3.6	3.4	N	-2.8	3.6	N	1.0	2.4	N
	2nd Hr	2.4	3.8	N	3.1	3.6	N	3.5	3.9	N	2.4	3.8	Y	3.1	3.4	N	0.4	9.9	Y	0.1	2.6	Y
A3	1st Hr	40.1	42.6	N	39.8	42.0	Y	41.9	42.4	N	40.0	40.0	N	40.7	41.1	N	43.4	43.2	N	26.5	32.5	Y
	2nd Hr	42.4	45.9	Y	44.7	46.3	N	44.1	45.9	N	43.0	46.6	N	40.7	45.1	Y	44.8	58.2	Y	30.6	37.2	Y
B1	1st Hr	2.3	3.4	N	3.9	3.3	N	2.0	3.4	N	4.2	3.3	N	2.4	3.3	N	2.6	3.6	N	0.9	3.3	N
	2nd Hr	1.9	3.5	N	2.4	3.4	N	3.9	3.5	N	2.2	3.5	N	2.8	3.5	N	4.2	3.6	N	1.6	3.4	N
B2	1st Hr	1.9	2.6	N	1.2	2.6	Y	3.6	2.6	N	1.1	2.6	N	1.6	2.6	N	0.9	2.7	Y	-0.3	2.0	Y
	2nd Hr	1.8	2.7	N	2.0	2.7	N	3.3	2.6	N	1.4	2.7	Y	1.5	2.7	N	1.6	2.8	N	3.7	2.2	N
B3	1st Hr	2.6	3.2	N	3.3	3.2	N	1.7	3.2	N	2.6	3.2	N	3.6	3.2	N	2.4	3.4	N	1.9	2.7	N
	2nd Hr	1.7	3.3	N	2.1	3.2	N	1.2	3.3	Y	0.4	3.3	N	2.4	3.3	N	2.3	3.3	N	2.0	3.0	N
B4	1st Hr	26.9	42.3	Y	34.9	40.9	Y	41.7	44.1	N	36.4	42.3	N	40.2	43.0	N	31.8	42.0	Y	30.0	34.2	Y
	2nd Hr	41.7	47.6	Y	35.1	44.5	Y	41.3	44.7	Y	41.6	45.5	N	44.2	45.6	N	42.7	49.0	Y	21.6	31.8	Y
C1	1st Hr	3.1	3.4	N	4.0	3.4	Y	4.6	3.3	N	3.8	3.3	N	4.0	3.3	N	3.2	3.4	N	4.6	3.4	N
	2nd Hr	4.2	3.5	N	3.5	3.4	N	5.0	3.6	Y	5.2	3.6	N	4.9	3.6	N	4.1	3.6	N	3.2	3.1	N
C2	1st Hr	1.9	2.8	N	2.6	2.8	N	2.6	2.8	N	2.1	2.8	N	1.7	2.7	N	2.4	2.9	N	0.9	2.7	Y
	2nd Hr	2.8	3.3	N	2.2	3.0	Y	2.5	3.3	N	4.4	3.3	N	2.3	3.3	N	2.4	3.2	N	1.0	2.1	N
C3	1st Hr	2.4	4.0	N	3.3	3.8	Y	0.7	3.8	Y	3.9	3.8	N	3.0	3.8	N	3.9	4.0	N	1.9	3.6	N
	2nd Hr	3.0	4.6	Y	3.4	4.1	Y	2.2	4.6	N	3.3	4.7	N	4.4	4.7	N	2.5	4.4	Y	2.0	3.0	N
C4	1st Hr	47.0	52.7	Y	46.1	49.8	Y	50.4	50.4	N	45.8	51.9	Y	47.7	62.3	Y	44.6	60.1	Y	29.9	36.2	Y
	2nd Hr	49.2	55.1	N	53.2	59.8	Y	50.4	54.9	N	51.4	60.6	Y	58.2	62.9	N	51.8	60.2	N	35.4	44.2	Y
D1	1st Hr	6.8	7.3	N	6.3	7.2	N	8.4	7.7	N	7.2	7.6	N	6.9	7.6	N	7.1	7.7	N	4.2	6.3	N
	2nd Hr	6.0	7.6	N	7.7	7.7	N	4.5	6.6	N	7.0	7.9	N	9.0	8.3	N	5.9	7.7	N	5.1	6.6	N
D2	1st Hr	3.7	4.6	N	2.7	4.6	Y	2.6	6.0	Y	3.6	4.6	N	3.8	4.8	N	4.0	4.9	N	0.2	3.6	Y
	2nd Hr	4.9	5.2	N	3.3	5.3	Y	4.2	5.3	N	4.0	5.4	N	3.6	5.7	Y	4.2	5.1	N	2.3	3.9	Y
D3	1st Hr	22.0	22.6	N	22.3	22.2	N	21.4	22.8	N	23.4	21.6	Y	21.9	22.8	N	20.7	22.9	Y	16.7	17.1	N
	2nd Hr	23.9	25.3	N	23.0	24.8	N	24.8	23.7	N	24.3	24.9	N	23.4	26.0	Y	25.3	24.1	N	18.1	19.1	N
SUMMARY		5 YES 23 NO			13 YES 15 NO			7 YES 21 NO			6 YES 22 NO			6 YES 22 NO			9 YES 19 NO			11 YES 17 NO		

Y = YES = MEANS ARE SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL

N = NO = MEANS ARE NOT SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL

1st Hr = 12:30 - 13:30

2nd Hr = 13:30 - 14:30



Recommendations for Future Research

This research study illustrated the high degree of conformity and reliability of the TRAF-NETSIM model's ability to simulate actual traffic conditions in Amman-Jordan provided that some of the model's default values are modified to reflect the local driving conditions. However, due to the limited resources available for this research the following recommendations are appropriate:

- The model should be tested and validated on additional street networks in Amman, such as an urban grid network.
- The model should be tested with the presence of high pedestrian activities.
- The TRAF-NETSIM model should be tested and calibrated on low to moderate traffic volumes in Amman-Jordan.
- The model's credibility in simulating other measures of performance such as Stopped Delay Time and Phase Failure should be investigated.
- The simulated MOE's produced by the model should be compared with other network simulation models such as Transyt-7F.

Possible Applications

The TRAF-NETSIM model is a very useful tool for Traffic Engineers. The applications of the simulation model covers most of the traffic situations encountered in most urban areas. The following is a brief list of possible applications.

- Signal timing plan evaluation
- Left-turn and right –turn pocket length evaluation
- Near-side bus stop versus far-side bus stop

- Effects of lane closure due to construction
- Effects of introducing a new overpass or underpass
- Evaluating the effects of enforcing different parking regulations
- HOV lane evaluations

Traf-Netsim Model Limitations

Despite the modifications and new enhancements made to NETSIM over the past several years, there are some specific scenarios in which the model is not applicable. However, the model can be "tricked" into representing some of the desired operations.

- TRAF-NETSIM does not simulate four-way stop sign.
- The model does not simulate the behavior of traffic travelling around a traffic circle.
- Railroad Crossing simulation can not be modeled.
- Two-way left-turn lanes are not explicitly simulated in the model.
- Currently, the model uses the Uniform Headway distribution logic to generate all vehicles into the network. However, in the interest of providing more valid output especially under low traffic volume conditions, the model should allow the engineer to specify the type of distribution to be used to generate vehicle arrivals.

Contributions

TRAF-NETSIM model is designed as a tool to aid engineers in testing a variety of complex traffic related problems. It was originally developed to simulate traffic performance in the United States. Yet, this study demonstrated that TRAF-NETSIM is capable of simulating the traffic performance in Amman, provided that some of the model's default parameters be modified to reflect the local driving behavior. This will substantially help traffic engineers in Jordan to test different traffic control and traffic management strategies, on a network wide basis, which under normal circumstances can not be analyzed due to the highly variable nature of traffic operations. In addition, this study was able to ascertain the identity of some of the driver's characteristics at signalized intersections like Queue Discharge Headway's and Start-Up Lost Times. This, of course, would be beneficial information for local traffic engineers to use when timing traffic signals or estimating intersection capacity, especially since there are a lack of technical reports addressing driver's characteristics at signalized intersections in Amman Jordan.

Disclaimer

This study was able to determine that the calibrated TRAF-NETSIM model can accurately simulate travel time and delay time in Amman-Jordan. Further studies should be performed to test the applicability of other measures of effectiveness, fuel consumption, and vehicle emission values produced by the simulation model.

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Appendices

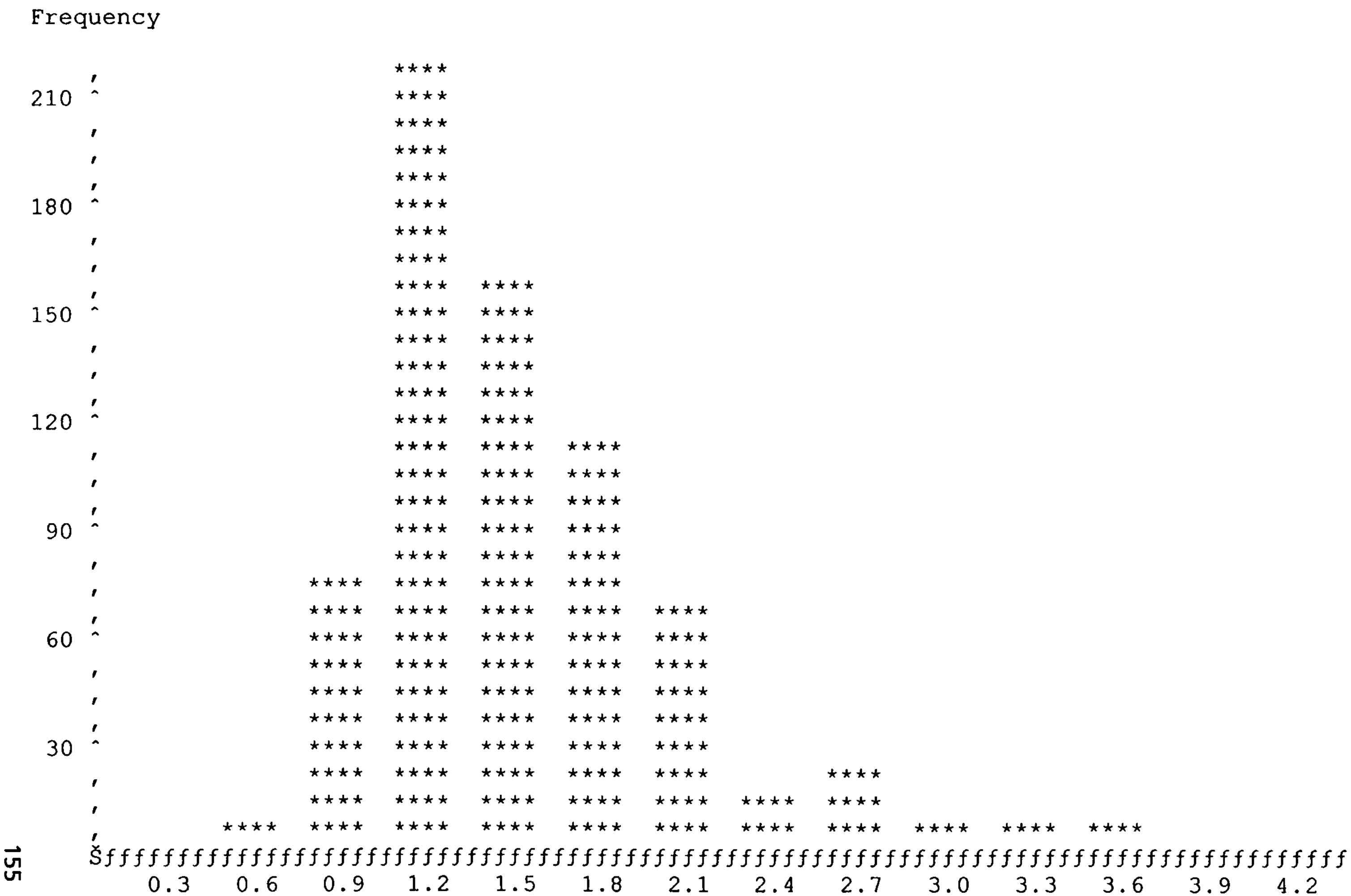
Appendix A

SAS output Start-Up Lost Time and Queue Discharge Headway

BAR CHART

Vehicle Departure Headways at a Signalized Intersection

From End of 3 rd Vehicle in Queue



Queue Discharge Headways
Normality Test

The UNIVARIATE Procedure
Variable: headway (Queue Discharge Headways)

Moments

N	780	Sum Weights	780
Mean	1.5064359	Sum Observations	1175.02
Std Deviation	0.54827503	Variance	0.30060551
Skewness	1.71755977	Kurtosis	4.09012076
Uncorrected SS	2004.264	Corrected SS	234.171692
Coeff Variation	36.3955102	Std Error Mean	0.0196314

Basic Statistical Measures

Location		Variability	
Mean	1.506436	Std Deviation	0.54828
Median	1.350000	Variance	0.30061
Mode	1.130000	Range	3.90000
		Interquartile Range	0.62000

Tests for Location: Mu0=0

<table>
<tr><th>Test</th><th colspan="2">-Statistic-</th><th colspan="2">-----p Value------</th></tr>
<tr><td>Student's t</td><td>t</td><td>76.73606</td><td>Pr > |t|</td><td><.0001</td></tr>
<tr><td>Sign</td><td>M</td><td>390</td><td>Pr >= |M|</td><td><.0001</td></tr>
<tr><td>Signed Rank</td><td>S</td><td>152295</td><td>Pr >= |S|</td><td><.0001</td></tr>
</table>

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.858921	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.12771	Pr > D	<0.0100
Cramer-von Mises	W-Sq	4.974149	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	29.33061	Pr > A-Sq	<0.0050

Quantiles (Definition 5)

Quantile	Estimate
100% Max	4.250
99%	3.540
95%	2.665

Normality Test

The UNIVARIATE Procedure

Variable: headway (Queue Discharge Headways)

Quantiles (Definition 5)

Quantile	Estimate
90%	2.125
75% Q3	1.760
50% Median	1.350
25% Q1	1.140
10%	1.035
5%	0.940
1%	0.660
0% Min	0.350

Extreme Observations

----Lowest----		----Highest---	
Value	Obs	Value	Obs
0.35	2	3.77	776
0.35	1	3.84	777
0.37	3	4.00	778
0.52	4	4.06	779
0.56	5	4.25	780

The UNIVARIATE Procedure

Variable: dh (Difference between Observed and Default Headways)

Moments

N	780	Sum Weights	780
Mean	-0.2935641	Sum Observations	-228.98
Std Deviation	0.54827503	Variance	0.30060551
Skewness	1.71755977	Kurtosis	4.09012076
Uncorrected SS	301.392	Corrected SS	234.171692
Coeff Variation	-186.76501	Std Error Mean	0.0196314

Basic Statistical Measures

Location		Variability	
Mean	-0.29356	Std Deviation	0.54828
Median	-0.45000	Variance	0.30061
Mode	-0.67000	Range	3.90000
		Interquartile Range	0.62000

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	-14.9538	Pr > |t|	<.0001
Sign	M	-217.5	Pr >= |M|	<.0001
Signed Rank	S	-95480.5	Pr >= |S|	<.0001

Quantiles (Definition 5)

Quantile	Estimate
100% Max	2.450
99%	1.740
95%	0.865
90%	0.325
75% Q3	-0.040
50% Median	-0.450
25% Q1	-0.660
10%	-0.765
5%	-0.860
1%	-1.140
0% Min	-1.450

The UNIVARIATE Procedure

Variable: dh (Difference between Observed and Default Headways)

Extreme Observations

----Lowest----		----Highest---	
Value	Obs	Value	Obs
-1.45	2	1.97	776
-1.45	1	2.04	777
-1.43	3	2.20	778
-1.28	4	2.26	779
-1.24	5	2.45	780

Summary of Headway data

The MEANS Procedure

Analysis Variable : dh Difference between Observed and Default Headways

N	Mean	Std Dev	Range	Variance	t Value	Pr > |t|
780	-0.2935641	0.5482750	3.9000000	0.3006055	-14.95	<.0001

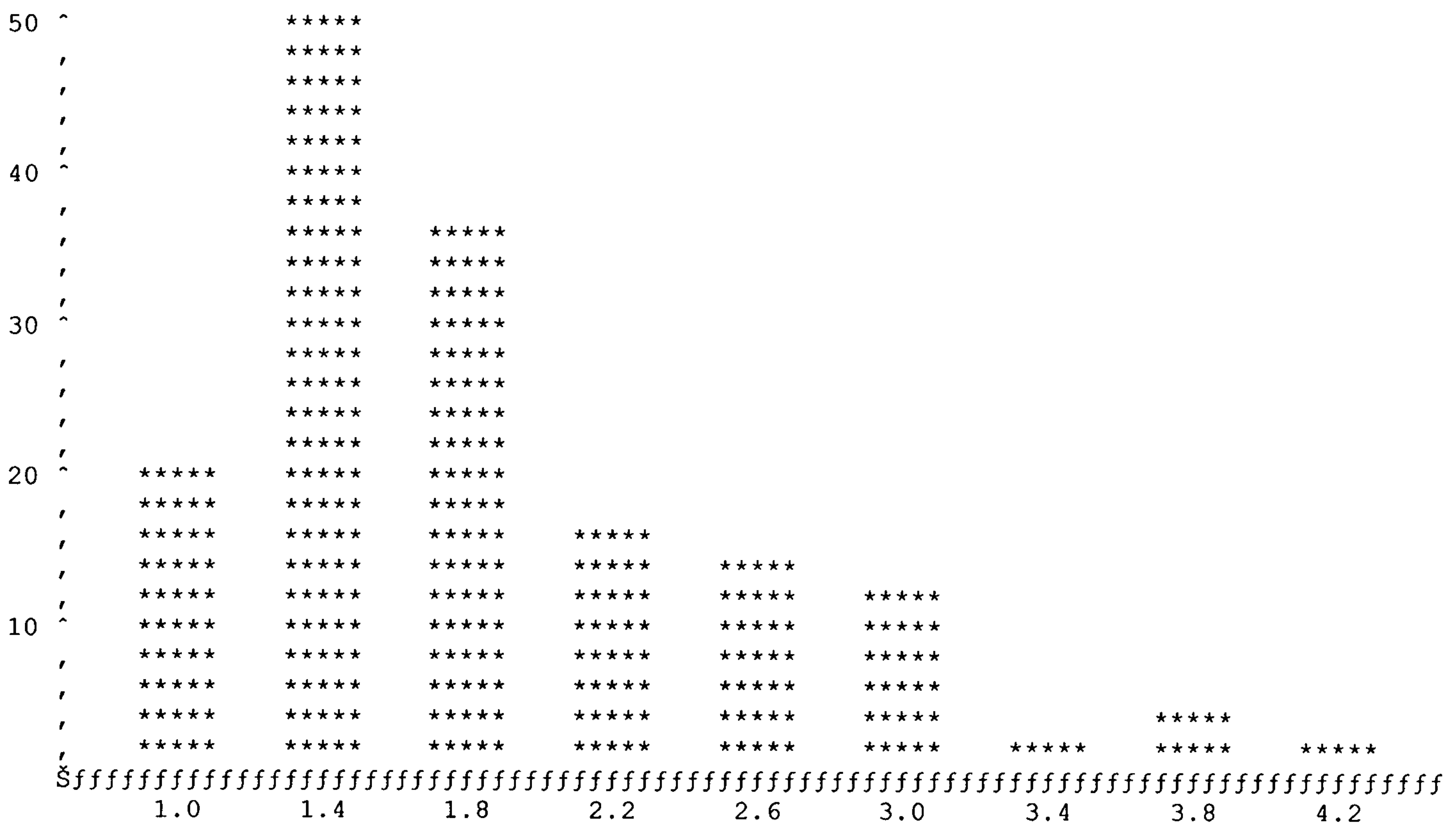
value of T-statistic for 95% CI with 780 DF

Obs	tvalue
1	1.96301

BAR CHART

Sart-Up Lost Time for First Vehicle at a Signalized Intersection

Frequency



Start Up Lost Time for the first Vehcile in Queue

Normality Test

The UNIVARIATE Procedure

Variable: losttime (Start Up Lost Time for the first Vehcile in Queue)

Moments

N	163	Sum Weights	163
Mean	1.82453988	Sum Observations	297.4
Std Deviation	0.69201192	Variance	0.4788805
Skewness	1.27689477	Kurtosis	1.24934208
Uncorrected SS	620.1968	Corrected SS	77.5786405
Coeff Variation	37.9280238	Std Error Mean	0.05420256

Basic Statistical Measures

Location		Variability	
Mean	1.824540	Std Deviation	0.69201
Median	1.600000	Variance	0.47888
Mode	1.240000	Range	3.41000
		Interquartile Range	0.88000

NOTE: The mode displayed is the smallest of 5 modes with a count of 4.

Tests for Location: Mu0=0

```
Test           -Statistic-    -----p Value------

Student's t    t  33.66151    Pr > |t|    <.0001
Sign           M      81.5    Pr >= |M|   <.0001
Signed Rank    S      6683    Pr >= |S|   <.0001
```

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.876143	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.160368	Pr > D	<0.0100
Cramer-von Mises	W-Sq	1.19402	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	6.629633	Pr > A-Sq	<0.0050

Normality Test

The UNIVARIATE Procedure

Variable: losttime (Start Up Lost Time for the first Vehcile in Queue)

Quantiles (Definition 5)

Quantile	Estimate
100% Max	4.31
99%	4.15
95%	3.16
90%	2.88
75% Q3	2.18
50% Median	1.60
25% Q1	1.30
10%	1.18
5%	1.10
1%	0.97
0% Min	0.90

Extreme Observations

----Lowest----		----Highest---	
Value	Obs	Value	Obs
0.90	1	3.66	159
0.97	2	3.67	160
1.00	3	3.79	161
1.04	4	4.15	162
1.06	6	4.31	163

The UNIVARIATE Procedure
Variable: dlt (Difference between Observed and Default Start-Up Lost Times)

Moments

N	163	Sum Weights	163
Mean	-0.1754601	Sum Observations	-28.6
Std Deviation	0.69201192	Variance	0.4788805
Skewness	1.27689477	Kurtosis	1.24934208
Uncorrected SS	82.5968	Corrected SS	77.5786405
Coeff Variation	-394.3984	Std Error Mean	0.05420256

Basic Statistical Measures

Location		Variability	
Mean	-0.17546	Std Deviation	0.69201
Median	-0.40000	Variance	0.47888
Mode	-0.76000	Range	3.41000
		Interquartile Range	0.88000

NOTE: The mode displayed is the smallest of 5 modes with a count of 4.

Tests for Location: Mu0=0

<table>
<tr><th>Test</th><th colspan="2">-Statistic-</th><th colspan="2">-----p Value------</th></tr>
<tr><td>Student's t</td><td>t</td><td>-3.23712</td><td>Pr > |t|</td><td>0.0015</td></tr>
<tr><td>Sign</td><td>M</td><td>-35.5</td><td>Pr >= |M|</td><td><.0001</td></tr>
<tr><td>Signed Rank</td><td>S</td><td>-2365.5</td><td>Pr >= |S|</td><td><.0001</td></tr>
</table>

Quantiles (Definition 5)

Quantile	Estimate
100% Max	2.31
99%	2.15
95%	1.16
90%	0.88
75% Q3	0.18
50% Median	-0.40
25% Q1	-0.70
10%	-0.82
5%	-0.90
1%	-1.03
0% Min	-1.10

The UNIVARIATE Procedure

Variable: dlt (Difference between Observed and Default Start-Up Lost Times)

Extreme Observations

----Lowest----		----Highest---	
Value	Obs	Value	Obs
-1.10	1	1.66	159
-1.03	2	1.67	160
-1.00	3	1.79	161
-0.96	4	2.15	162
-0.94	6	2.31	163

Summary of Start-Up Lost Time data

The MEANS Procedure

Analysis Variable : dlt Difference between Observed and Default Start-Up Lost Times

N	Mean	Std Dev	Range	Variance	t Value	Pr > |t|
163	-0.1754601	0.6920119	3.4100000	0.4788805	-3.24	0.0015

value of T-statistic for 95% CI with 162 DF

Obs	tvalue
1	1.97472

1

156

Appendix B

Analysis of Variance

Analysis of Variance

To compare the mean of the three Travel Times and Delay Times obtained from the three different study types Default, Calibrated, and Observed. Independent random samples of both Travel Times and Delay Times were selected from each of the three study types (Populations). Most likely the three sample means would be different. However, this doesn't necessarily imply a difference among the population means for the three study types used in this research. To decide whether the differences among the sample means are large enough to suggest that the corresponding population means are significantly different, the Analysis of Variance procedure was utilized.

The Logic Underlying Analysis of Variance:

A first point to remember in looking back at the Null and Alternative hypotheses for travel time and delay time is that the hypotheses to be tested are considered as an overall statement. In other words, analysis of variance will tell us only if there are significant variations among the means in the total hypothesis statement. ANOVA will not tell us about the comparison of individual means. That is, ANOVA will not tell us if the mean travel time produced by the default model is significantly different from the mean travel time produced by the calibrated model, and so on and so forth. If the analysis of variance indicates that the means among the three study types differ, then an appropriate multiple comparison procedure such as Tukey's method will be used to determine which means are and are not significantly different form one another.

Before preceding any further, some of the terminology used by analysis of variance will be introduced now.

Factor:

A factor in analysis of variance is an independent variable being analyzed. In this research, I am measuring Travel Time and Delay Time under three different types of study. Therefore, the factor under investigation is the variable study type as defined by this research.

Factor Level:

A factor level is a specific entity of the factor under study. In the study of the effect of different study type on Travel Time, study type is the factor under study and the three study types, observed, calibrated, and default are levels of that factor. Hence, you conclude that the study type factor has three levels in this study.

Single Factor Study:

A single-factor study as opposed to a multi-factor study is an investigation in which the effect of only one factor is of concern. Since this research is concerned with what are the effects of different study types on travel time and delay time, this research is conducting a single-factor analysis of variance study. An example of a multi-factor study could be the effects on study types and traffic volumes on travel time and delay time. Here, the two factors, study type and traffic volume would be investigated simultaneously to gain further insight on their effects on the variable or variables being observed.
Table B-1 shows the symbolic notation used by a single factor analysis of variance, for Travel Time in the Test Network:

Table B-1
Notation used by ANOVA

FACTOR LEVEL	1	2	3	
STUDY TYPE	DEFAULT	CALIBRATED	OBSERVED	
OBSERVATIONS	$Y_{11}...Y_{17}$	$Y_{21}...Y_{27}$	$Y_{31}...Y_{37}$	
SAMPLE SIZE	n1	n2	N3	N_{TOTAL}
TOTAL	Y_{T1}	Y_{T2}	Y_{T3}	Y_{TOTAL}
VARIANCE	$S1^2$	$S2^2$	$S3^2$	
MEAN	Y1	Y2	Y3	Y_{GRAND}

Where:

- Y_{11}: Travel Time for the first simulation run obtained from the default model.
- Y_{17}: Travel Time for the seventh simulation run obtained from the default model.
- n_1: Number of simulation runs for default model.
- Y_{T1}: Total Travel Time from default model.
- Y1: Mean Travel Time from default model.
- N_{TOTAL}: Total number of observations across all groups.
- $S1^2$: Variance of Travel Time from default model.
- Y_{GRAND}: The average of all sample observations; $Y_{GRAND} = (Y_{TOTAL} / N_{TOTAL})$

etc.

Appendix C

TRAF-NETSIM Simulation output

Test Network Default Model

1

```
INPUT FILE NAME: MWED1.TRF
RUN DATE       : 08/05/99

TTTTTTTTTTT  RRRRRRRRR      AAAAAAA    FFFFFFFFFFF
TTTTTTTTTTT  RRRRRRRRRR    AAAAAAAAA   FFFFFFFFFFF
TTTTTTTTTTT  RRRRRRRRRRR  AAAAAAAAAAA  FFFFFFFFFFF
    TTT      RRR     RRR  AAA     AAA  FFF
    TTT      RRR     RRR  AAA     AAA  FFF
    TTT      RRRRRRRRRRR  AAAAAAAAAAA  FFFFFFF
    TTT      RRRRRRRRRR   AAAAAAAAAAA  FFFFFFF
    TTT      RRR RRR      AAA     AAA  FFF
    TTT      RRR  RRR     AAA     AAA  FFF
    TTT      RRR   RRR    AAA     AAA  FFF
    TTT      RRR    RRR   AAA     AAA  FFF
    TTT      RRR     RRR  AAA     AAA  FFF

    MICRO-COMPUTER PROTECTED-MODE VERSION
     (REQUIRES 80386 AND 80387 OR ABOVE)

                   VERSION 5.00
              RELEASE DATE MAR 1995
              TRAF SIMULATION MODEL

                   DEVELOPED FOR

         U. S. DEPARTMENT OF TRANSPORTATION
           FEDERAL HIGHWAY ADMINISTRATION
INTELLIGENT VEHICLE HIGHWAY SYSTEM RESEARCH DIVISION
```

```
1                                       CARD FILE LIST
0SEQ.# :----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

     1 :TEST NETWORT :    MECCA STREET                                                 0
     2 :                  WEDNESDAY MAY 14, 1997                                       0
     3 :                  DEFAULT , EVERY 60 MINUTES                                   0
     4 :                  12:30  --  13:30                                             0
     5 :                                                                               0
     6 :SAMI SAID GHEZAWI                     05  16  97                           1   1
     7 :   0   1          30                         1 0   31230      132841           2
     8 :3600                                                                           3
     9 :                                                                               4
    10 :                                               1                               5
    11 :8102 102             3                   100                          0       11
    12 :8103 103             3                   100                                  11
    13 : 102 100 150     100 2   1 0 81      103 101 104                     0021     11
    14 : 100 102 150         3     0            8102                                  11
    15 : 103 100 128         4    -2 4TT1    101 104 102                       21     11
    16 : 100 103 128         3     2            8103                                  11
    17 : 100 101 100         2     0            8101                                  11
    18 : 108 106 100         1     0            8106                                  11
    19 :8106 106             1     0             108                                  11
    20 : 106 108 100         1     0                 110                              11
    21 : 114 112 100         1     0            8112                                  11
    22 :8112 112             1     0             114                                  11
    23 : 112 114 100         1     0                 116                              11
    24 : 122 120 100         1     0            8120                                  11
    25 :8120 120             1     0             122                                  11
    26 : 120 122 100         1     0                 125                              11
    27 : 125 126 131         1     1                    +204                          11
    28 : 126 204  70         1     0                    +202                          11
    29 : 200 204  43         4     0             202                                  11
    30 : 204 202 137         3     0            8202                                  11
    31 :8202 202             3     0             206                                  11
    32 : 202 206 100         3     0             200    +208                          11
    33 : 206 200  75         4     0 TT81   207  205                                  11
```

34 :	206	208	88	1	0					+212	11
35 :	212	210	100	1	0			8210			11
36 :	8210	210		1	0			212			11
37 :	210	212	100	1	0				216		11
38 :	216	214	100	1	0			8214			11
39 :	8214	214		1	0			216			11
40 :	214	216	100	1	0				218		11
41 :	222	220	100	1	0			8220			11
42 :	8220	220		1	0			222			11
43 :	220	222	100	1	0				226		11
44 :	226	224	100	1	0			8224			11
45 :	8224	224		1	0			226			11
46 :	224	226	100	1	0				228		11
47 :	228	310	77	1	0					+302	11
48 :	300	310	47	3	0			302			11
49 :	310	302	100	3	0			8302			11
50 :	8302	302		3	0			304			11
51 :	302	304	100	3	0			300		+306	11
52 :	304	300	41	3	0		227	305			11
53 :	304	306	60	1	-3					+308	11
54 :	300	306	48	3	-4			308			11
55 :	306	308	200	3	-4			8300			11
56 :	8300	308		3	+4			300		+307	11
57 :	308	307	190	1	+4					+305	11
58 :	308	300	243	3	+4	T81	310	227			11
59 :	307	305	58	1	+3					+303	11
60 :	305	303	100	3	0			8301			11
61 :	8301	303		3	0			301			11
62 :	303	301	100	3	0			300		+227	11
63 :	301	300	37	3	0		306	310			11
64 :	300	305	25	3	0			303			11
65 :	301	227	40	1	+3					+311	11
66 :	311	309	78	1	0			8309			11
67 :	8309	309		1	0			311			11
68 :	309	311	78	1	0				315		11
69 :	315	313	100	1	0			8313			11
70 :	8313	313		1	0			315			11

71 :	313	315	100		1		0				218			11
72 :	218	317	100		1		0			8317				11
73 :	8317	317			1		0			218				11
74 :	317	218	100		1		0				323			11
75 :	323	321	100		1		0			8321				11
76 :	8321	321			1		0			323				11
77 :	321	323	100		1		0				327			11
78 :	327	325	100		1		0			8325				11
79 :	8325	325			1		0			327				11
80 :	325	327	100		1		0				331			11
81 :	331	329	100		1		0			8329				11
82 :	8329	329			1		0			331				11
83 :	329	331	100		1		0				335			11
84 :	335	333	100		1		0			8333				11
85 :	8333	333			1		0			335				11
86 :	333	335	100		1		0				337			11
87 :	337	205	108		1		0					+201		11
88 :	200	205	54		3		3			201				11
89 :	205	201	50		3		+5			8201				11
90 :	8201	203			2		-5			275				11
91 :	203	275	50		3		-5			200		+207		11
92 :	275	200	35	30	3	1	-3	8	208	204				11
93 :	275	207	49		1		0					+209		11
94 :	217	215	100		1		0			8215				11
95 :	8215	215			1		0			217				11
96 :	215	217	100		1		0				219			11
97 :	225	223	100		1		0			8223				11
98 :	8223	223			1		0			225				11
99 :	223	225	100		1		0				100			11
100 :	100	104	160		4		0			108			21	11
101 :	104	108	98		3		-4			110	106			11
102 :	108	110	70		3		-4			114				11
103 :	110	114	70		3		-4			116	112			11
104 :	114	116	112		3		-5			118				11
105 :	116	118	200		3		-4			122				11
106 :	118	122	254		3		-4			125	120			11
107 :	122	125	40		3		1			200		+126		11

108	:	125	200	160	150	4	1	1	TTT1	205	208					11
109	:	200	208	68		3		0			212					11
110	:	208	212	216		3		+5			216	210				11
111	:	212	216	319		3		+6			218	214				11
112	:	216	218	155		3		+4			222					11
113	:	218	222	124		3		+4			226	220				11
114	:	222	226	230		3		-1			228	224				11
115	:	226	228	187		3		-4			300		+310			11
116	:	228	300	45		3		-6	TT8	305	306					11
117	:	300	227	28		3		+4			311					11
118	:	227	311	240		3		+4			315	309				11
119	:	311	315	187		3		+1			218	313				11
120	:	315	218	133		3		-4			323	317				11
121	:	218	323	134		3		-4			327	321				11
122	:	323	327	126		3		-6			331	325				11
123	:	327	331	125		3		-6			335	329				11
124	:	331	335	96		3		-6			337	333				11
125	:	335	337	173		3		-4			200		+205			11
126	:	337	200	90	70	3	1	-2	TT8	204	207					11
127	:	200	207	40		3		-2			209					11
128	:	207	209	131		3		-1			211					11
129	:	209	211	99		3		+1			213					11
130	:	211	213	200		3		+5			217					11
131	:	213	217	135		3		+4			219	215				11
132	:	217	219	65		3		+4			221					11
133	:	219	221	200		3		+5			225					11
134	:	221	225	177		3		+4			100	223				11
135	:	225	100	132		4		+3	7T81	102	103	101		103		11
136	:	308	300	512	825						8300	308		85	15	21
137	:	308	307			100					8302	302		100		21
138	:	304	300	217	314						8301	303		100		21
139	:	302	304		531	148					8202	202		100		21
140	:	228	300	208	814						8201	203		100		21
141	:	226	228		1022	123					8102	102		100		21
142	:	301	300	202	398						8103	103		100		21
143	:	303	301		600	44					8215	215		100		21
144	:	337	200	458	858						8120	120		100		21

145	:	335	337		1316		290	8210	210	100	21
146	:	206	200	239	515			8214	214	100	21
147	:	202	206		754		83	8333	333	100	21
148	:	125	200	1261	715			8329	329	100	21
149	:	125	126				100				21
150	:	126	204				100	8224	224	100	21
151	:	275	200	624	405			8309	309	100	21
152	:	203	275		1029		476	8223	223	100	21
153	:	102	100	600	25	888		8112	112	100	21
154	:	103	100	259	929	33		8220	220	100	21
155	:	225	100	971	725	43		8313	313	100	21
156	:	100	102		100			8317	317	100	21
157	:	100	103		100			8321	321	100	21
158	:	100	101		100			8325	325	100	21
159	:	104	108		99	1		8106	106	100	21
160	:	108	106		100						21
161	:	106	108			100					21
162	:	100	104		100						21
163	:	108	110		100						21
164	:	110	114		98	2					21
165	:	114	112		100						21
166	:	112	114			100					21
167	:	114	116		100						21
168	:	116	118		100						21
169	:	118	122		99	1					21
170	:	122	125		90		10				21
171	:	122	120		100						21
172	:	120	122			100					21
173	:	275	207				100				21
174	:	228	310				100				21
175	:	206	208				100				21
176	:	208	212		90	10					21
177	:	212	210		100						21
178	:	210	212			100					21
179	:	212	216		73	27					21
180	:	216	214		100						21
181	:	214	216			100					21

182	:	216	218	100			21
183	:	218	222	97	3		21
184	:	222	220	100			21
185	:	220	222		100		21
186	:	222	226	99	1		21
187	:	226	224	100			21
188	:	224	226		100		21
189	:	227	311	99	1		21
190	:	205	201	100			21
191	:	200	204	100			21
192	:	200	205	100			21
193	:	200	208	100			21
194	:	200	207	100			21
195	:	218	317	100			21
196	:	218	323	99	1		21
197	:	204	202	100			21
198	:	207	209	100			21
199	:	209	211	100			21
200	:	211	213	100			21
201	:	213	217	94	6		21
202	:	217	215	100			21
203	:	215	217		100		21
204	:	217	219	100			21
205	:	219	221	100			21
206	:	221	225	91	9		21
207	:	225	223	100			21
208	:	223	225		100		21
209	:	300	305	100			21
210	:	300	310	100			21
211	:	300	306	100			21
212	:	305	303	100			21
213	:	310	302	100			21
214	:	306	308	100			21
215	:	304	306			100	21
216	:	307	305			100	21
217	:	301	227			100	21
218	:	337	205			100	21

219	:	311	309		100		21
220	:	311	315		98	2	21
221	:	309	311			100	21
222	:	300	227		100		21
223	:	315	313		100		21
224	:	313	315			100	21
225	:	315	218		98	2	21
226	:	317	218			100	21
227	:	323	321		100		21
228	:	321	323			100	21
229	:	323	327		98	2	21
230	:	327	325		100		21
231	:	325	327			100	21
232	:	327	331		98	2	21
233	:	331	329		100		21
234	:	329	331			100	21
235	:	331	335		97	3	21
236	:	335	333		100		21
237	:	333	335			100	21
238	:	204		126	200		35
239	:	126		125			35
240	:	125		122			35
241	:	227		301	300		35
242	:	305		307	300		35
243	:	306		304	300		35
244	:	310		228	300		35
245	:	311		309	227		35
246	:	226		224	222		35
247	:	315		313	311		35
248	:	222		220	218		35
249	:	218		317	315	216	35
250	:	323		321	218		35
251	:	216		214	212		35
252	:	327		325	323		35
253	:	331		329	327		35
254	:	335		333	331		35
255	:	212		210	208		35

256	:	208	206	200	35
257	:	205	337	200	35
258	:	207	275	200	35
259	:	122	120	118	35
260	:	217	215	213	35
261	:	114	112	110	35
262	:	108	106	104	35
263	:	225	223	221	35
264	:	102	8102	100	35
265	:	103	8103	100	35
266	:	101	100		35
267	:	104	100		35
268	:	110	108		35
269	:	106	8106	108	35
270	:	116	114		35
271	:	112	8112	114	35
272	:	118	116		35
273	:	120	8120	122	35
274	:	337	335		35
275	:	202	8202	204	35
276	:	206	202		35
277	:	210	8210	212	35
278	:	214	8214	216	35
279	:	220	8220	222	35
280	:	224	8224	226	35
281	:	302	8302	310	35
282	:	308	8300	306	35
283	:	303	8301	305	35
284	:	309	8309	311	35
285	:	313	8313	315	35
286	:	317	8317	218	35
287	:	321	8321	323	35
288	:	325	8325	327	35
289	:	329	8329	331	35
290	:	333	8333	335	35
291	:	201	205		35
292	:	203	8201		35

```
293 : 209      207                    35
294 : 211      209                    35
295 : 213      211                    35
296 : 215     8215 217                35
297 : 221      219                    35
298 : 223     8223 225                35
299 : 228      226                    35
300 : 304      302                    35

301 : 307      308                    35
302 : 301      303                    35
303 : 275      203                    35
304 : 219      217                    35
305 : 102 1                           36
306 : 101 1                           36
307 : 103 1                           36
308 : 104 1                           36
309 : 225 51                          36
310 : 106 1                           36
311 : 221 1                           36
312 : 114 51                          36
313 : 112 1                           36
314 : 116 1                           36
315 : 217 51                          36
316 : 215 1                           36
317 : 118 1                           36
318 : 213 1                           36
319 : 122 51                          36
320 : 126 1                           36
321 : 125 1                           36
322 : 219 1                           36
323 : 211 1                           36
324 : 120 1                           36
325 : 207 01                          36
326 : 206 1                           36
327 : 202 1                           36
328 : 205 01                          36
```

329	:	275	1	36
330	:	201	1	36
331	:	203	1	36
332	:	208	01	36
333	:	337	1	36
334	:	212	51	36
335	:	335	51	36
336	:	210	1	36
337	:	333	1	36
338	:	331	51	36
339	:	329	1	36
340	:	327	51	36
341	:	325	1	36
342	:	216	51	36
343	:	214	1	36
344	:	323	51	36
345	:	321	1	36
346	:	218	511	36
347	:	317	1	36
348	:	222	51	36
349	:	108	1	36
350	:	110	1	36
351	:	204	01	36
352	:	315	51	36
353	:	220	1	36
354	:	313	1	36
355	:	226	51	36
356	:	311	51	36
357	:	224	1	36
358	:	309	1	36
359	:	228	1	36
360	:	227	01	36
361	:	310	01	36
362	:	304	1	36
363	:	302	1	36
364	:	306	01	36
365	:	307	1	36

```
366 : 308 1                                                                      36
367 : 305 01                                                                     36
368 : 301 1                                                                      36
369 : 303 1                                                                      36
370 : 223 1                                                                      36
371 : 209 1                                                                      36
372 : 100 103 100 225 100 102 100                  0                 27  287 0 43
373 : 200 275 200 337 200 206 200 125 200         0               1181  380 0 43
374 : 300 228 300 301 300 308 300 304 300         0               2469  140 0 43
375 : 100   3 211         211       221                                          45
376 : 100   1 121         121       221                                          45
377 : 100   2 221         111       221                                          45
378 : 100   4 221         221       111                                          45
379 : 200   1 112         222       222       222                                45
380 : 200   2 222         112       222       222                                45
381 : 200   3 222         222       112       222                                45
382 : 200   4 222         222       222       112                                45
383 : 300   1 112         222       222       222                                45
384 : 300   2 222         112       222       222                                45
385 : 300   3 222         222       112       222                                45
386 : 300   4 222         222       222       112                                45
387 : 100 3 2  113  61  0  0 18  1                                               46
388 : 100 3 2  213  61  0  0 18  1                                               46
389 : 100 1 2  14   52  0  0 40  0                                               46
390 : 100 1 2  24   52  0  0 40  0                                               46
391 : 100 2 2  213  61  0  0 40  1                                               46
392 : 100 2 2  24   52  0  0 40  1                                               46
393 : 100 4 2  39   61  0  0 18  1                                               46
394 : 200 1 2  19   61  0  0 16  1                                               46
395 : 200 2 2  29  110  0  0 19  1                                               46
396 : 200 3 2  39   61  0  0 16  1                                               46
397 : 200 4 2  49  121  0  0 18  1                                               46
398 : 300 1 2  19   96  0  0 15  1                                               46
399 : 300 2 2  29   40  0  0 15  1                                               46
400 : 300 3 2  39   70  0  0 15  1                                               46
401 : 300 4 2  49   30  0  0 15  1                                               46
402 : 200 1  25  640            6          400 400 30 10010100000000             47
```

```
403 : 200 2  30  640          6          400 400 30 10010100010000          47
404 : 200 3  20  640          6          400 400 30 10010100000000          47
405 : 200 4  35  660          6          600 600 30 10010100010000          47
406 : 300 1  30  740          7          400 400 30 10010100000000          47
407 : 300 2  20  740          7          400 400 30 10010100010000          47
408 : 300 3  30  740          7          400 400 30 10010100000000          47
409 : 300 4  20  740          7          400 400 30 10010100010000          47
410 : 100 3  25  760          7          600 600 30 10010100000000          47
411 : 100 1  20  740          7          400 400  0  0010100000000          47
412 : 100 2  10  640          6          400 400  0  0011100010000          47
413 : 100 4  17  740          7          400 400 30 10010100010000          47
414 :8300 3081578  1   8215 215  38        8120 120 126                     50
415 :8302 302 680  1   8210 210  24        8214 214 156                     50
416 :8301 303 644  1   8333 333 371        8329 329   4                     50
417 :8202 202 837  1   8224 224  43        8309 309 106                     50
418 :8201 2031505  1   8321 321  15        8325 325  15                     50
419 :8102 1021513  1   8106 106  15        8313 313  15                     50
420 :8103 1031188  1   8112 112  15        8317 317  15                     50
421 :8223 223 315  1   8220 220  15                                         50
422 :    0                                                                 170
423 : 108      358     374                                                 195
424 : 110      428     380                                                 195
425 : 204     1280     337                                                 195
426 : 216     1884     392                                                 195
427 : 218     2038     378                                                 195
428 : 323     1905     393                                                 195
429 : 311     2342     282                                                 195
430 : 315     2167     345                                                 195
431 : 228     2530     161                                                 195
432 : 310     2554      90                                                 195
433 : 307     2620     120                                                 195
434 : 305     2577     163                                                 195
435 : 301     2579     177                                                 195
436 : 102      127     127                                                 195
437 : 101      127     387                                                 195
438 : 103       01     280                                                 195
439 : 104      265     345                                                 195
```

440	:	100	127	287	195
441	:	200	1281	380	195
442	:	300	2569	140	195
443	:	225	255	344	195
444	:	223	255	444	195
445	:	106	358	262	195
446	:	221	428	382	195
447	:	114	498	379	195
448	:	112	498	279	195
449	:	116	610	379	195
450	:	217	675	382	195
451	:	215	675	482	195
452	:	118	810	378	195
453	:	213	810	382	195
454	:	125	1104	378	195
455	:	122	1064	378	195
456	:	211	1010	381	195
457	:	120	1064	278	195
458	:	126	1214	363	195
459	:	209	1110	381	195
460	:	207	1241	380	195
461	:	206	1282	304	195
462	:	202	1281	212	195
463	:	205	1277	434	195
464	:	275	1276	420	195
465	:	201	1273	480	195
466	:	203	1270	480	195
467	:	208	1350	380	195
468	:	337	1385	383	195
469	:	212	1566	385	195
470	:	335	1558	387	195
471	:	210	1566	285	195
472	:	333	1558	487	195
473	:	331	1654	389	195
474	:	329	1654	489	195
475	:	327	1779	392	195
476	:	325	1779	492	195

```
477 : 214     1884      292                                                                195
478 : 321     1905      493                                                                195
479 : 317     2038      493                                                                195
480 : 222     2157      345                                                                195
481 : 220     2157      245                                                                195
482 : 313     2167      445                                                                195
483 : 226     2371      262                                                                195
484 : 224     2371      162                                                                195
485 : 309     2390      345                                                                195
486 : 304     2556       90                                                                195
487 : 302     2545       01                                                                195
488 : 306     2610      112                                                                195
489 : 308     2776        6                                                                195
490 : 303     2588      270                                                                195
491 : 219      610      382                                                                195
492 : 227     2545      155                                                                195
493 : 104 108    1                                                                         196
494 : 221 225    2                                                                         196
495 : 216 218    1                                                                         196
496 : 218 323    2                                                                         196
497 : 222 226    1                                                                         196
498 : 228 310    1                                                                         196
499 : 304 306    1                                                                         196
500 : 311 315    2                                                                         196
```

1

TRAF SIMULATION MODEL

DEVELOPED FOR

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
INTELLIGENT VEHICLE HIGHWAY SYSTEM RESEARCH DIVISION

0

START OF CASE 1

```
0                      TEST NETWORT :    MECCA STREET
0                                        WEDNESDAY MAY 14, 1997
0                                        DEFAULT , EVERY 60 MINUTES
0                                        12:30  --  13:30
0
0

                                                DATE =  05/  16/  97
0                                               USER = SAMI SAID GHEZAWI
0                                             AGENCY =
1                                                    RUN CONTROL DATA

                    VALUE                          RUN PARAMETERS AND OPTIONS

0                       1     RUN IDENTIFICATION NUMBER
0                       0     NEXT CASE CODE = (0,1) IF ANOTHER CASE (DOES NOT, DOES) FOLLOW
0                       1     RUN TYPE CODE = ( 1, 2, 3) TO RUN (SIMULATION, ASSIGNMENT, BOTH)
                                              (-1,-2,-3) TO CHECK (SIMULATION, ASSIGNMENT, BOTH) ONLY

0                             NETSIM ENVIRONMENTAL OPTIONS
                              ----------------------------
                        0     FUEL/EMISSION RATE TABLES ARE NOT PRINTED
                        0     SIMULATION:  PERFORMED                             ENVIRONMENTAL MEASURES:
CALCULATED
                              RATE TABLES: EMBEDDED                              TRAJECTORY FILE:
NOT WRITTEN
0                       1     INPUT  UNITS CODE = (0,1) IF INPUT IS IN (ENGLISH, METRIC) UNITS
                        0     OUTPUT UNITS CODE = (0,1,2,3) IF OUTPUT IS IN (SAME AS INPUT, ENGLISH,
METRIC, BOTH) UNITS
0                    1230     CLOCK TIME AT START OF SIMULATION (HHMM)
0                       0     SIGNAL TRANSITION CODE = (0,1,2,3) IF (NO, IMMEDIATE, 2-CYCLE, 3-CYCLE)
TRANSITION WAS REQUESTED
0                    7581     RANDOM NUMBER SEED
                   132841     RANDOM NUMBER SEED TO GENERATE TRAFFIC STREAM FOR NETSIM OR LEVEL I
SIMULATION
```

```
                       3600    DURATION (SEC) OF TIME PERIOD NO.  1
0                        60*   LENGTH OF A TIME INTERVAL, SECONDS
0                        30    MAXIMUM INITIALIZATION TIME, NUMBER OF TIME INTERVALS
0                         0    NUMBER OF TIME INTERVALS BETWEEN SUCCESSIVE STANDARD OUTPUTS
0                         0    TIME INTERMEDIATE OUTPUT WILL BEGIN AT INTERVALS OF     0 SECS. FOR    0
SECS. FOR MICROSCOPIC MODELS
0                         1    NETSIM MOVEMENT-SPECIFIC OUTPUT CODE = (0,1) (IF NOT, IF) REQUESTED FOR
NETSIM SUBNETWORK
0                         0    NETSIM GRAPHICS OUTPUT CODE = (0,1) IF GRAPHICS OUTPUT (IS NOT, IS)
REQUESTED
0                          *  VALUE ASSERTED BY THE MODEL FOR THE FOLLOWING REASON -
0                             TIME INTERVAL DURATION OMITTED. DEFAULT VALUE OF 60 SECONDS ASSUMED.
```

1 INITIALIZATION STATISTICS

TIME INTERVAL NUMBER	SUBNETWORK TYPE	PRIOR CONTENT (VEHICLES)	CURRENT CONTENT (VEHICLES)	PERCENT DIFFERENCE
1	NETSIM	0	147	10000
2	NETSIM	147	232	57
3	NETSIM	232	272	17
4	NETSIM	272	312	14
5	NETSIM	312	343	9
6	NETSIM	343	333	2

EQUILIBRIUM ATTAINED

ALL EXISTING SUBNETWORKS REACHED EQUILIBRIUM

```
1                                    CUMULATIVE NETSIM STATISTICS AT TIME 13:30: 0

                      ELAPSED TIME IS  1: 0: 0 ( 3600 SECONDS),    TIME PERIOD  1 ELAPSED TIME IS 3600
SECONDS


                             VEHICLE MINUTES      RATIO   MINUTES / KM      ----- SECONDS / VEHICLE  ---
-  -- AVERAGE VALUES --
                  VEHICLE      MOVE    DELAY   TOTAL   MOVE/   TOTAL   DELAY     TOTAL   DELAY   QUEUE
STOP  STOPS VOLUME   SPEED
    LINK          KM   TRIPS   TIME    TIME    TIME    TOTAL    TIME    TIME      TIME    TIME    TIME
TIME   (%)    VPH    KMPH
    ----      -----------   --------------------   -----   -------------    ----------------------------
-   -------------------

 (8102, 102)          1519
1519
 (8103, 103)          1188
1188
```

(102, 100)	228.24	1522	283.6	597.1	880.8	0.32	3.86	2.62	34.7	23.5	17.6
16.9	59	1522	15.5								
(100, 102)	139.08	930	172.8	51.3	224.1	0.77	1.61	0.37	14.5	3.3	0.0
0.0	0	930	37.2								
(103, 100)	150.68	1177	187.3	598.1	785.4	0.24	5.21	3.97	40.0	30.5	25.1
24.5	75	1177	11.5								
(100, 103)	165.53	1293	205.7	77.2	282.9	0.73	1.71	0.47	13.1	3.6	0.0
0.0	0	1293	35.1								
(100, 101)	32.22	327	40.0	4.2	44.2	0.91	1.37	0.13	8.1	0.8	0.0
0.0	0	327	43.7								
(108, 106)	1.48	15	1.8	0.7	2.6	0.72	1.74	0.50	10.3	2.9	0.5
0.0	0	15	34.5								
(8106, 106)		15									
15											
(106, 108)	1.50	15	1.9	2.5	4.3	0.43	2.89	1.65	17.3	9.9	7.2
7.2	73	15	20.8								
(114, 112)	3.94	40	4.9	1.6	6.5	0.75	1.65	0.41	9.8	2.4	0.0
0.0	0	40	36.3								
(8112, 112)		15									
15											
(112, 114)	1.50	15	1.9	5.2	7.1	0.26	4.71	3.47	28.3	20.8	19.2
18.9	100	15	12.7								
(122, 120)	1.18	12	1.5	0.4	1.8	0.80	1.55	0.31	9.2	1.8	0.0
0.0	0	12	38.7								
(8120, 120)		126									
126											
(120, 122)	12.70	127	15.8	27.4	43.2	0.37	3.40	2.16	20.4	12.9	10.8
10.6	100	127	17.6								
(125, 126)	22.54	172	28.0	2.1	30.1	0.93	1.33	0.09	10.5	0.7	0.0
0.0	0	172	45.0								
(126, 204)	12.06	172	15.0	10.9	25.9	0.58	2.14	0.90	9.0	3.8	1.8
1.8	22	172	28.0								
(200, 204)	31.89	742	39.6	22.3	61.9	0.64	1.94	0.70	5.0	1.8	0.4
0.2	4	742	30.9								
(204, 202)	124.40	909	154.6	50.3	204.9	0.75	1.65	0.40	13.5	3.3	0.0
0.0	0	909	36.4								

(8202, 202)		837									
837											
(202, 206)	83.78	838	104.1	2.1	106.2	0.98	1.27	0.03	7.6	0.2	0.0
0.0	0	838	47.3								
(206, 200)	56.91	759	70.7	693.3	764.1	0.09	13.43	12.18	60.4	54.8	49.6
48.8	86	759	4.5								
(206, 208)	6.25	71	7.8	7.9	15.7	0.50	2.51	1.27	13.3	6.7	4.8
4.7	43	71	23.9								
(212, 210)	12.70	129	15.8	5.3	21.1	0.75	1.66	0.42	9.8	2.5	0.0
0.0	0	129	36.1								
(8210, 210)		24									
24											
(210, 212)	2.40	24	3.0	2.5	5.5	0.55	2.28	1.04	13.7	6.2	3.8
3.7	100	24	26.3								
(216, 214)	32.09	326	39.9	14.4	54.3	0.73	1.69	0.45	10.0	2.7	0.0
0.0	0	326	35.5								
(8214, 214)		156									
156											
(214, 216)	15.50	155	19.3	14.0	33.2	0.58	2.14	0.90	12.9	5.4	3.2
3.1	100	155	28.0								
(222, 220)	3.15	32	3.9	1.4	5.3	0.74	1.67	0.43	9.9	2.5	0.0
0.0	0	32	35.9								
(8220, 220)		15									
15											
(220, 222)	1.50	15	1.9	1.5	3.4	0.55	2.27	1.02	13.6	6.1	3.5
3.5	100	15	26.5								
(226, 224)	1.08	11	1.3	0.4	1.8	0.76	1.63	0.39	9.6	2.3	0.0
0.0	0	11	36.8								
(8224, 224)		43									
43											
(224, 226)	4.30	43	5.3	5.1	10.4	0.51	2.43	1.19	14.6	7.1	5.3
5.2	100	43	24.7								
(228, 310)	11.26	146	14.0	12.3	26.3	0.53	2.34	1.09	10.8	5.1	2.4
2.3	26	146	25.7								
(300, 310)	40.04	853	49.8	15.3	65.0	0.77	1.62	0.38	4.6	1.1	0.0
0.0	0	853	36.9								

```
 ( 310, 302)   99.77    998   124.0    49.7   173.7   0.71   1.74   0.50    10.4    3.0    0.0
0.0      0   998    34.5
 (8302, 302)            681
681
 ( 302, 304)   67.98    680    84.5     9.6    94.1   0.90   1.38   0.14     8.3    0.8    0.3
0.3      3   680    43.4
 ( 304, 300)   21.85    531    27.2   379.9   407.1   0.07  18.63  17.39    46.0   42.9   38.5
37.9    81   531     3.2
 ( 304, 306)    9.19    153    11.4    10.2    21.6   0.53   2.35   1.11     8.5    4.0    2.0
2.0     26   153    25.5
 ( 300, 306)   43.45    908    54.0    19.2    73.2   0.74   1.68   0.44     4.8    1.3    0.0
0.0      0   908    35.6
 ( 306, 308)  211.35   1057   262.6    72.5   335.2   0.78   1.59   0.34    19.0    4.1    0.0
0.0      0  1057    37.8

            * AVERAGE QUEUE AND STOP TIME ARE COMPUTED AS TOTAL QUEUE TIME OR TOTAL STOP TIME DIVIDED BY
              TOTAL NUMBER OF VEHICLES DISCHARGED FROM LINK PLUS NUMBER OF VEHICLES CURRENTLY ON THE LINK.


1                                           CUMULATIVE NETSIM STATISTICS AT TIME 13:30: 0

                        ELAPSED TIME IS  1: 0: 0 ( 3600 SECONDS),    TIME PERIOD  1 ELAPSED TIME IS 3600
SECONDS

                                   VEHICLE MINUTES      RATIO   MINUTES / KM      ----- SECONDS / VEHICLE  ---
-  -- AVERAGE VALUES --
                    VEHICLE      MOVE   DELAY   TOTAL   MOVE/   TOTAL   DELAY      TOTAL   DELAY   QUEUE
STOP  STOPS VOLUME   SPEED
    LINK        KM   TRIPS       TIME    TIME    TIME   TOTAL    TIME    TIME       TIME    TIME    TIME
TIME   (%)     VPH    KMPH
    ----      -----------     --------------------  -----   -------------      ----------------------------
-   -------------------
```

(8300, 308)		1581										1581			
(308, 307)	45.00	237	55.9	4.4	60.3	0.93	1.34	0.10	15.3	1.1	0.0	0.0	0	237	44.8
(308, 300)	322.36	1327	400.6	867.3	1267.9	0.32	3.93	2.69	57.3	39.2	31.9	31.3	79	1327	15.3
(307, 305)	13.73	237	17.1	8.9	25.9	0.66	1.89	0.65	6.6	2.2	0.7	0.7	16	237	31.8
(305, 303)	73.48	735	91.3	38.4	129.8	0.70	1.77	0.52	10.6	3.1	0.0	0.0	0	735	34.0
(8301, 303)		644										644			
(303, 301)	64.38	644	80.0	29.6	109.6	0.73	1.70	0.46	10.2	2.8	1.9	1.8	10	644	35.2
(301, 300)	22.13	600	27.5	409.4	436.9	0.06	19.74	18.50	43.7	40.9	37.4	36.8	72	600	3.0
(300, 305)	12.45	498	15.5	8.1	23.6	0.65	1.90	0.65	2.8	1.0	0.0	0.0	0	498	31.6
(301, 227)	1.88	47	2.3	3.4	5.8	0.40	3.07	1.83	7.4	4.4	2.8	2.8	25	47	19.5
(311, 309)	0.61	8	0.8	0.2	0.9	0.80	1.55	0.31	7.1	1.4	0.0	0.0	0	8	38.7
(8309, 309)		106										106			
(309, 311)	8.27	106	10.3	14.9	25.2	0.41	3.04	1.80	14.3	8.4	6.5	6.5	100	106	19.7
(315, 313)	2.56	26	3.2	1.0	4.2	0.76	1.63	0.39	9.7	2.3	0.0	0.0	0	26	36.7
(8313, 313)		15										15			
(313, 315)	1.50	15	1.9	1.6	3.4	0.54	2.29	1.05	13.7	6.3	4.3	4.3	100	15	26.2
(218, 317)	2.76	28	3.4	1.1	4.6	0.75	1.65	0.41	9.8	2.4	0.0	0.0	0	28	36.4
(8317, 317)		15										15			

(317, 218)	1.50	15	1.9	2.4	4.3	0.44	2.83	1.59	17.0	9.5	7.4
7.3	100	15	21.2								
(323, 321)	0.59	6	0.7	0.2	0.9	0.79	1.58	0.34	9.3	2.0	0.0
0.0	0	6	38.0								
(8321, 321)		15									
15											
(321, 323)	1.50	15	1.9	1.9	3.7	0.50	2.49	1.25	14.9	7.5	5.9
5.9	100	15	24.1								
(327, 325)	2.07	21	2.6	0.9	3.5	0.74	1.68	0.43	9.9	2.6	0.0
0.0	0	21	35.8								
(8325, 325)		15									
15											
(325, 327)	1.50	15	1.9	2.4	4.3	0.44	2.85	1.60	17.1	9.6	7.9
7.7	100	15	21.1								
(331, 329)	2.85	29	3.5	1.1	4.6	0.77	1.62	0.38	9.6	2.2	0.0
0.0	0	29	37.0								
(8329, 329)		4									
4											
(329, 331)	0.40	4	0.5	0.3	0.8	0.60	2.08	0.84	12.5	5.0	3.3
3.0	100	4	28.8								
(335, 333)	3.05	31	3.8	1.2	5.0	0.75	1.65	0.41	9.7	2.4	0.0
0.0	0	31	36.4								
(8333, 333)		371									
371											
(333, 335)	36.99	370	46.0	68.8	114.8	0.40	3.10	1.86	18.6	11.2	7.0
6.5	100	370	19.3								
(337, 205)	29.35	272	36.5	39.7	76.2	0.48	2.59	1.35	16.8	8.8	5.6
5.3	38	272	23.1								
(200, 205)	83.46	1547	103.7	15.8	119.5	0.87	1.43	0.19	4.6	0.6	0.0
0.0	0	1547	41.9								
(205, 201)	91.03	1821	113.1	22.9	136.0	0.83	1.49	0.25	4.5	0.8	0.0
0.0	0	1821	40.1								
(8201, 203)		1317									
1317											
(203, 275)	65.48	1310	81.4	835.0	916.4	0.09	13.99	12.75	42.0	38.2	31.7
29.9	56	1310	4.3								

(275, 200)	31.16	889	38.7	794.4	833.2	0.05	26.74	25.49	56.2	53.6	48.6	48.0	54	889	2.2
(275, 207)	20.51	418	25.5	128.5	154.0	0.17	7.51	6.27	22.1	18.4	12.9	11.7	66	418	8.0
(217, 215)	9.16	93	11.4	3.9	15.2	0.75	1.66	0.42	9.8	2.5	0.0	0.0	0	93	36.1
(8215, 215)		38										38			
(215, 217)	3.80	38	4.7	5.6	10.3	0.46	2.71	1.47	16.3	8.8	6.7	6.6	100	38	22.1
(225, 223)	11.12	113	13.8	4.4	18.2	0.76	1.64	0.40	9.7	2.3	0.0	0.0	0	113	36.6
(8223, 223)		315										315			
(223, 225)	31.49	315	39.1	46.1	85.3	0.46	2.71	1.47	16.2	8.8	4.6	4.4	100	315	22.2
(100, 104)	274.77	1776	341.5	101.6	443.0	0.77	1.61	0.37	15.0	3.4	0.3	0.2	1	1776	37.2

* AVERAGE QUEUE AND STOP TIME ARE COMPUTED AS TOTAL QUEUE TIME OR TOTAL STOP TIME DIVIDED BY TOTAL NUMBER OF VEHICLES DISCHARGED FROM LINK PLUS NUMBER OF VEHICLES CURRENTLY ON THE LINK.

1 CUMULATIVE NETSIM STATISTICS AT TIME 13:30: 0

ELAPSED TIME IS 1: 0: 0 (3600 SECONDS), TIME PERIOD 1 ELAPSED TIME IS 3600 SECONDS

```
                              VEHICLE MINUTES       RATIO   MINUTES / KM      ----- SECONDS / VEHICLE  ---
-  -- AVERAGE VALUES --
                    VEHICLE       MOVE    DELAY    TOTAL    MOVE/   TOTAL    DELAY      TOTAL    DELAY    QUEUE
STOP   STOPS VOLUME   SPEED
```

LINK	KM	TRIPS	TIME	TIME	TIME	TOTAL	TIME	TIME	TIME	TIME	TIME	TIME	(%)	VPH	KMPH
(104, 108)	174.21	1775	216.5	131.2	347.7	0.62	2.00	0.75	11.8	4.4	0.3	0.0	0	1775	30.1
(108, 110)	124.44	1775	154.6	65.9	220.6	0.70	1.77	0.53	7.5	2.2	0.2	0.0	0	1775	33.8
(110, 114)	124.65	1778	154.9	10.8	165.7	0.93	1.33	0.09	5.6	0.4	0.0	0.0	0	1778	45.1
(114, 116)	195.53	1748	243.0	16.3	259.3	0.94	1.33	0.08	8.9	0.6	0.0	0.0	0	1748	45.2
(116, 118)	347.91	1740	432.4	30.4	462.8	0.93	1.33	0.09	16.0	1.0	0.0	0.0	0	1740	45.1
(118, 122)	442.04	1741	549.3	47.9	597.3	0.92	1.35	0.11	20.6	1.7	0.0	0.0	0	1741	44.4
(122, 125)	74.23	1859	92.2	73.2	165.4	0.56	2.23	0.99	5.3	2.4	0.6	0.4	4	1859	26.9
(125, 200)	264.99	1656	329.3	1271.9	1601.2	0.21	6.04	4.80	58.0	46.1	38.5	37.9	80	1656	9.9
(200, 208)	80.68	1187	100.3	21.8	122.1	0.82	1.51	0.27	6.2	1.1	0.0	0.0	0	1187	39.7
(208, 212)	272.94	1263	339.2	50.6	389.8	0.87	1.43	0.19	18.5	2.4	0.0	0.0	0	1263	42.0
(212, 216)	372.10	1166	462.4	70.1	532.5	0.87	1.43	0.19	27.4	3.6	0.1	0.1	0	1166	41.9
(216, 218)	152.35	982	189.3	20.5	209.8	0.90	1.38	0.13	12.8	1.3	0.1	0.0	0	982	43.6
(218, 222)	121.32	978	150.8	12.7	163.5	0.92	1.35	0.10	10.0	0.8	0.0	0.0	0	978	44.5
(222, 226)	220.69	959	274.3	23.2	297.4	0.92	1.35	0.10	18.6	1.4	0.0	0.0	0	959	44.5
(226, 228)	185.28	990	230.3	67.9	298.2	0.77	1.61	0.37	18.1	4.1	1.8	1.6	10	990	37.3
(228, 300)	38.57	855	47.9	539.7	587.6	0.08	15.23	13.99	41.2	37.9	33.3	32.7	70	855	3.9

(300, 227)	29.42	1049	36.6	15.5	52.1	0.70	1.77	0.53	3.0	0.9	0.0
0.0	0	1049	33.9								
(227, 311)	266.03	1109	330.6	44.7	375.3	0.88	1.41	0.17	20.3	2.4	0.0
0.0	0	1109	42.5								
(311, 315)	226.07	1208	281.0	36.9	317.8	0.88	1.41	0.16	15.8	1.8	0.1
0.0	0	1208	42.7								
(315, 218)	159.07	1197	197.7	22.6	220.3	0.90	1.38	0.14	11.0	1.1	0.0
0.0	0	1197	43.3								
(218, 323)	158.66	1183	197.2	19.2	216.4	0.91	1.36	0.12	11.0	1.0	0.0
0.0	0	1183	44.0								
(323, 327)	150.05	1192	186.5	21.0	207.5	0.90	1.38	0.14	10.4	1.1	0.0
0.0	0	1192	43.4								
(327, 331)	148.21	1186	184.2	18.9	203.1	0.91	1.37	0.13	10.3	1.0	0.0
0.0	0	1186	43.8								
(331, 335)	111.28	1159	138.3	17.0	155.3	0.89	1.40	0.15	8.0	0.9	0.0
0.0	0	1159	43.0								
(335, 337)	257.79	1489	320.4	55.9	376.2	0.85	1.46	0.22	15.2	2.3	0.3
0.1	1	1489	41.1								
(337, 200)	111.23	1237	138.2	1038.5	1176.7	0.12	10.58	9.34	57.1	50.4	43.5
42.8	82	1237	5.7								
(200, 207)	42.28	1059	52.5	22.6	75.1	0.70	1.78	0.53	4.3	1.3	0.0
0.0	0	1059	33.8								
(207, 209)	193.19	1474	240.1	43.7	283.8	0.85	1.47	0.23	11.6	1.8	0.0
0.0	0	1474	40.8								
(209, 211)	144.63	1460	179.7	23.2	202.9	0.89	1.40	0.16	8.3	1.0	0.0
0.0	0	1460	42.8								
(211, 213)	288.73	1444	358.8	46.7	405.5	0.88	1.40	0.16	16.8	1.9	0.0
0.0	0	1444	42.7								
(213, 217)	195.11	1445	242.5	37.2	279.7	0.87	1.43	0.19	11.6	1.5	0.0
0.0	0	1445	41.9								
(217, 219)	90.37	1392	112.3	16.3	128.6	0.87	1.42	0.18	5.5	0.7	0.0
0.0	0	1392	42.2								
(219, 221)	280.93	1405	349.1	41.3	390.5	0.89	1.39	0.15	16.7	1.8	0.0
0.0	0	1405	43.2								
(221, 225)	251.82	1422	312.9	50.8	363.8	0.86	1.44	0.20	15.3	2.1	0.1
0.1	0	1422	41.5								

```
 ( 225, 100)  214.47  1625   266.5   740.7  1007.2    0.26    4.70    3.45      37.2    27.3    21.3
20.3     68   1625    12.8
0SUBNETWORK= 9437.64  8990  195.48  183.34  378.81    0.52    2.41    1.17      2.53    1.22    0.84
0.82  132.7           24.9
                            -- VEHICLE - HOURS --                              --- MINUTES / VEHICLE-TRIP ---
PER

TRIP

1
                                            CUMULATIVE NETSIM STATISTICS AT TIME 13:30: 0

                         ELAPSED TIME IS  1: 0: 0 ( 3600 SECONDS),    TIME PERIOD  1 ELAPSED TIME IS 3600
SECONDS
```

DISCHARGE BY LANE

LINK	LANE 1 VEH	LANE 1 VPH	LANE 2 VEH	LANE 2 VPH	LANE 3 VEH	LANE 3 VPH	LANE 4 VEH	LANE 4 VPH	LANE 5 VEH	LANE 5 VPH	LANE 6 VEH	LANE 6 VPH	LANE 7 VEH	LANE 7 VPH
(102, 100)	254	254	384	384	0	0	0	0	0	0	0	0	884	884
(100, 102)	118	118	341	341	471	471	0	0	0	0	0	0	0	0
(103, 100)	23	23	464	464	416	416	274	274	0	0	0	0	0	0
(100, 103)	397	397	473	473	423	423	0	0	0	0	0	0	0	0
(100, 101)	101	101	226	226	0	0	0	0	0	0	0	0	0	0
(108, 106)	15	15	0	0	0	0	0	0	0	0	0	0	0	0
(106, 108)	15	15	0	0	0	0	0	0	0	0	0	0	0	0
(114, 112)	40	40	0	0	0	0	0	0	0	0	0	0	0	0
(112, 114)	15	15	0	0	0	0	0	0	0	0	0	0	0	0
(122, 120)	12	12	0	0	0	0	0	0	0	0	0	0	0	0
(120, 122)	127	127	0	0	0	0	0	0	0	0	0	0	0	0
(125, 126)	172	172	0	0	0	0	0	0	0	0	0	0	0	0
(126, 204)	172	172	0	0	0	0	0	0	0	0	0	0	0	0
(200, 204)	88	88	192	192	462	462	0	0	0	0	0	0	0	0

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( 204, 202)          264   264        309   309        336   336        0     0          0     0
0     0          0     0
( 202, 206)           29    29        386   386        423   423        0     0          0     0
0     0          0     0
( 206, 200)          162   162        216   216        205   205      176   176          0     0
0     0          0     0
( 206, 208)           71    71          0     0          0     0        0     0          0     0
0     0          0     0
( 212, 210)          129   129          0     0          0     0        0     0          0     0
0     0          0     0
( 210, 212)           24    24          0     0          0     0        0     0          0     0
0     0          0     0
( 216, 214)          326   326          0     0          0     0        0     0          0     0
0     0          0     0
( 214, 216)          155   155          0     0          0     0        0     0          0     0
0     0          0     0
( 222, 220)           32    32          0     0          0     0        0     0          0     0
0     0          0     0
( 220, 222)           15    15          0     0          0     0        0     0          0     0
0     0          0     0
( 226, 224)           11    11          0     0          0     0        0     0          0     0
0     0          0     0
( 224, 226)           43    43          0     0          0     0        0     0          0     0
0     0          0     0
( 228, 310)          146   146          0     0          0     0        0     0          0     0
0     0          0     0
( 300, 310)          114   114        273   273        466   466        0     0          0     0
0     0          0     0
( 310, 302)          270   270        343   343        385   385        0     0          0     0
0     0          0     0
( 302, 304)           39    39        347   347        294   294        0     0          0     0
0     0          0     0
( 304, 300)          109   109        180   180        242   242        0     0          0     0
0     0          0     0
( 304, 306)          153   153          0     0          0     0        0     0          0     0
0     0          0     0
```

(300, 306)	198	198	301	301	409	409	0	0	0	0	0	0	0	0
(306, 308)	349	349	353	353	355	355	0	0	0	0	0	0	0	0
(308, 307)	237	237	0	0	0	0	0	0	0	0	0	0	0	0
(308, 300)	466	466	446	446	415	415	0	0	0	0	0	0	0	0
(307, 305)	237	237	0	0	0	0	0	0	0	0	0	0	0	0
(305, 303)	344	344	186	186	205	205	0	0	0	0	0	0	0	0
(303, 301)	20	20	305	305	319	319	0	0	0	0	0	0	0	0
(301, 300)	113	113	210	210	277	277	0	0	0	0	0	0	0	0
(300, 305)	109	109	180	180	209	209	0	0	0	0	0	0	0	0
(301, 227)	47	47	0	0	0	0	0	0	0	0	0	0	0	0
(311, 309)	8	8	0	0	0	0	0	0	0	0	0	0	0	0
(309, 311)	106	106	0	0	0	0	0	0	0	0	0	0	0	0
(315, 313)	26	26	0	0	0	0	0	0	0	0	0	0	0	0
(313, 315)	15	15	0	0	0	0	0	0	0	0	0	0	0	0
(218, 317)	28	28	0	0	0	0	0	0	0	0	0	0	0	0
(317, 218)	15	15	0	0	0	0	0	0	0	0	0	0	0	0
(323, 321)	6	6	0	0	0	0	0	0	0	0	0	0	0	0
(321, 323)	15	15	0	0	0	0	0	0	0	0	0	0	0	0

```
( 327, 325)        21    21       0     0       0     0       0     0       0     0
0     0        0     0
( 325, 327)        15    15       0     0       0     0       0     0       0     0
0     0        0     0
( 331, 329)        29    29       0     0       0     0       0     0       0     0
0     0        0     0
( 329, 331)         4     4       0     0       0     0       0     0       0     0
0     0        0     0
( 335, 333)        31    31       0     0       0     0       0     0       0     0
0     0        0     0
( 333, 335)       370   370       0     0       0     0       0     0       0     0
0     0        0     0
( 337, 205)       272   272       0     0       0     0       0     0       0     0
0     0        0     0
( 200, 205)       166   166     715   715     666   666       0     0       0     0
0     0        0     0
( 205, 201)       451   451     705   705     665   665       0     0       0     0
0     0        0     0
( 203, 275)       235   235     450   450     625   625       0     0       0     0
0     0        0     0
( 275, 200)        88    88     192   192     244   244       0     0       0     0
0     0      365   365
( 275, 207)       418   418       0     0       0     0       0     0       0     0
0     0        0     0
( 217, 215)        93    93       0     0       0     0       0     0       0     0
0     0        0     0
( 215, 217)        38    38       0     0       0     0       0     0       0     0
0     0        0     0
( 225, 223)       113   113       0     0       0     0       0     0       0     0
0     0        0     0
( 223, 225)       315   315       0     0       0     0       0     0       0     0
0     0        0     0
( 100, 104)         0     0    1163  1163     563   563      50    50       0     0
0     0        0     0
( 104, 108)       897   897     668   668     210   210       0     0       0     0
0     0        0     0
```

(108, 110)	900	900	665	665	210	210	0	0	0	0		
0	0	0	0									
(110, 114)	876	876	690	690	212	212	0	0	0	0		
0	0	0	0									
(114, 116)	791	791	725	725	232	232	0	0	0	0		
0	0	0	0									
(116, 118)	711	711	740	740	289	289	0	0	0	0		
0	0	0	0									
(118, 122)	656	656	746	746	339	339	0	0	0	0		
0	0	0	0									
(122, 125)	85	85	575	575	1199	1199	0	0	0	0		
0	0	0	0									
(125, 200)	115	115	323	323	182	182	509	509	0	0		
0	0	527	527									
(200, 208)	139	139	514	514	534	534	0	0	0	0		
0	0	0	0									
(208, 212)	338	338	462	462	463	463	0	0	0	0		
0	0	0	0									
(212, 216)	473	473	345	345	348	348	0	0	0	0		
0	0	0	0									
(216, 218)	311	311	349	349	322	322	0	0	0	0		
0	0	0	0									
(218, 222)	324	324	332	332	322	322	0	0	0	0		
0	0	0	0									
(222, 226)	318	318	339	339	302	302	0	0	0	0		
0	0	0	0									
(226, 228)	81	81	494	494	415	415	0	0	0	0		
0	0	0	0									
(228, 300)	196	196	309	309	350	350	0	0	0	0		
0	0	0	0									
(300, 227)	465	465	378	378	206	206	0	0	0	0		
0	0	0	0									
(227, 311)	459	459	353	353	297	297	0	0	0	0		
0	0	0	0									
(311, 315)	523	523	368	368	317	317	0	0	0	0		
0	0	0	0									

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( 315, 218)        493   493       372   372       332   332        0     0       0     0
0     0        0     0
( 218, 323)        461   461       382   382       340   340        0     0       0     0
0     0        0     0
( 323, 327)        468   468       382   382       342   342        0     0       0     0
0     0        0     0
( 327, 331)        472   472       383   383       331   331        0     0       0     0
0     0        0     0
( 331, 335)        429   429       397   397       333   333        0     0       0     0
0     0        0     0
( 335, 337)        169   169       670   670       650   650        0     0       0     0
0     0        0     0
( 337, 200)        254   254       330   330       307   307        0     0       0     0
0     0      346   346
( 200, 207)        254   254       396   396       409   409        0     0       0     0
0     0        0     0
( 207, 209)        606   606       470   470       398   398        0     0       0     0
0     0        0     0
( 209, 211)        586   586       480   480       394   394        0     0       0     0
0     0        0     0
( 211, 213)        553   553       517   517       374   374        0     0       0     0
0     0        0     0
( 213, 217)        553   553       506   506       386   386        0     0       0     0
0     0        0     0
( 217, 219)        491   491       517   517       384   384        0     0       0     0
0     0        0     0
( 219, 221)        497   497       519   519       389   389        0     0       0     0
0     0        0     0
( 221, 225)        301   301       645   645       476   476        0     0       0     0
0     0        0     0
( 225, 100)        373   373       256   256       438   438      558   558       0     0
0     0        0     0
```

1

NETSIM PERSON MEASURES OF EFFECTIVENESS

LINK	PERSON KM	PERSON TRIPS	DELAY PERSON-MIN	TRAVEL TIME PERSON-MIN
(102, 100)	296.4	1976.4	775.4	1143.7
(100, 102)	180.8	1208.9	66.7	291.3
(103, 100)	195.7	1528.9	776.9	1020.2
(100, 103)	215.0	1679.7	100.3	367.6
(100, 101)	41.8	424.6	5.4	57.4
(108, 106)	1.9	19.5	1.0	3.3
(106, 108)	1.9	19.5	3.2	5.6
(114, 112)	5.1	52.0	2.1	8.5
(112, 114)	1.9	19.5	6.8	9.2
(122, 120)	1.5	15.6	0.5	2.4
(120, 122)	16.5	165.1	35.6	56.1
(125, 126)	29.3	223.6	2.7	39.1

33.6	(126, 204)	15.7	223.6	14.1
80.4	(200, 204)	41.4	963.5	29.0
266.2	(204, 202)	161.6	1180.6	65.4
138.0	(202, 206)	108.9	1088.8	2.8
992.8	(206, 200)	73.9	986.2	900.9
20.4	(206, 208)	8.1	92.2	10.3
27.4	(212, 210)	16.5	167.7	6.9
7.1	(210, 212)	3.1	31.2	3.2
70.5	(216, 214)	41.7	423.2	18.7
43.2	(214, 216)	20.1	201.5	18.2
6.8	(222, 220)	4.1	41.6	1.8
4.4	(220, 222)	1.9	19.5	2.0
2.3	(226, 224)	1.4	14.3	0.5
13.6	(224, 226)	5.6	55.9	6.6
34.2	(228, 310)	14.6	189.6	16.0
84.5	(300, 310)	52.0	1108.3	19.8
225.7	(310, 302)	129.6	1296.6	64.6
122.2	(302, 304)	88.3	883.3	12.5

LINK	PERSON KM	PERSON TRIPS	DELAY PERSON-MIN	TRAVEL TIME PERSON-MIN
(304, 300)	28.4	689.9	493.6	528.9
(304, 306)	11.9	198.6	13.3	28.1
(300, 306)	56.4	1179.2	24.9	95.0

1

NETSIM PERSON MEASURES OF EFFECTIVENESS

LINK	PERSON KM	PERSON TRIPS	DELAY PERSON-MIN	TRAVEL TIME PERSON-MIN
(306, 308)	274.5	1372.6	94.2	435.3
(308, 307)	58.5	308.0	5.7	78.4
(308, 300)	418.9	1724.4	1127.0	1647.6
(307, 305)	17.8	308.0	11.5	33.7
(305, 303)	95.5	954.8	49.9	168.6
(303, 301)	83.6	836.4	38.5	142.4
(301, 300)	28.7	779.3	531.7	567.5
(300, 305)	16.2	646.8	10.6	30.7
(301, 227)	2.4	61.0	4.5	7.5
(311, 309)	0.8	10.4	0.2	1.2

32.7	(309, 311)	10.8	137.8	19.4
5.4	(315, 313)	3.3	33.8	1.3
4.5	(313, 315)	1.9	19.5	2.0
5.9	(218, 317)	3.6	36.4	1.5
5.5	(317, 218)	1.9	19.5	3.1
1.2	(323, 321)	0.8	7.8	0.3
4.9	(321, 323)	1.9	19.5	2.4
4.5	(327, 325)	2.7	27.2	1.2
5.5	(325, 327)	1.9	19.5	3.1
6.0	(331, 329)	3.7	37.7	1.4
1.1	(329, 331)	0.5	5.2	0.4
6.5	(335, 333)	4.0	40.2	1.6
149.2	(333, 335)	48.1	481.0	89.4
99.0	(337, 205)	38.2	353.6	51.6
155.2	(200, 205)	108.4	2009.6	20.5
176.7	(205, 201)	118.3	2365.8	29.8
1190.2	(203, 275)	85.0	1701.4	1084.5
1081.7	(275, 200)	40.5	1154.2	1031.4

(275, 207)	26.7	543.1	167.0	200.1
(217, 215)	11.9	120.8	5.0	19.8
(215, 217)	4.9	49.4	7.3	13.4
(225, 223)	14.5	146.8	5.7	23.7

1 NETSIM PERSON MEASURES OF EFFECTIVENESS

LINK	PERSON KM	PERSON TRIPS	DELAY PERSON-MIN	TRAVEL TIME PERSON-MIN
(223, 225)	40.9	409.3	60.0	110.8
(100, 104)	356.9	2306.6	131.9	575.4
(104, 108)	226.3	2305.3	170.4	451.6
(108, 110)	161.6	2305.4	85.6	286.5
(110, 114)	161.9	2309.3	14.1	215.3
(114, 116)	254.0	2270.3	21.2	336.8
(116, 118)	451.9	2259.9	39.5	601.1
(118, 122)	574.1	2261.1	62.3	775.7

214.9	(122, 125)	96.4	2414.5	95.1
2079.4	(125, 200)	344.1	2150.6	1651.7
158.5	(200, 208)	104.8	1541.2	28.3
506.1	(208, 212)	354.4	1639.9	65.7
691.3	(212, 216)	483.1	1513.7	91.0
272.4	(216, 218)	197.8	1275.1	26.6
212.3	(218, 222)	157.5	1269.9	16.5
386.2	(222, 226)	286.6	1245.3	30.1
387.2	(226, 228)	240.6	1285.6	88.2
763.0	(228, 300)	50.1	1110.3	700.8
67.7	(300, 227)	38.2	1363.1	20.2
487.7	(227, 311)	345.7	1441.0	58.1
413.0	(311, 315)	293.8	1569.7	47.9
286.2	(315, 218)	206.7	1555.4	29.3
281.2	(218, 323)	206.2	1537.2	25.0
269.6	(323, 327)	195.0	1548.9	27.3
263.9	(327, 331)	192.6	1541.2	24.5
201.9	(331, 335)	144.6	1506.1	22.1

(335, 337)	335.0	1935.2	72.6	489.0
(337, 200)	144.5	1607.6	1349.6	1529.2
(200, 207)	55.0	1376.5	29.4	97.7
(207, 209)	251.1	1915.7	56.8	368.8
(209, 211)	188.0	1897.5	30.2	263.8
(211, 213)	375.2	1876.7	60.7	527.0
(213, 217)	253.6	1878.0	48.4	363.5
(217, 219)	117.5	1809.2	21.2	167.1
(219, 221)	365.1	1826.1	53.7	507.5
(221, 225)	327.3	1848.2	66.0	472.8
(225, 100)	278.7	2111.9	962.6	1309.0

1 *** NOTE *** TIME PERIOD 1 SPECIFIC NETSIM STATISTICS ARE THE SAME AS CUMULATIVE OUTPUT AT THE END OF TIME PERIOD 1.

1 NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE I

0 LINK VEHICLE-KM VEHICLE-TRIPS SPEED (KMPH) STOPS (PCT)

	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT
(8102, 102)				0	1519	0						
(8103, 103)				0	1188	0						
(102, 100)	92.08	3.60	132.57	614	24	884	10.1	10.3	25.4	85.8	83.3	41.2
(100, 102)	0.00	139.08	0.00	0	930	0	0.0	37.2	0.0	0.0	0.0	0.0
(103, 100)	35.08	112.65	2.94	274	880	23	10.9	11.5	30.1	77.0	76.6	30.4
(100, 103)	0.00	165.53	0.00	0	1293	0	0.0	35.1	0.0	0.0	0.0	0.0
(100, 101)	0.00	32.22	0.00	0	327	0	0.0	43.7	0.0	0.0	0.0	0.0
(108, 106)	0.00	1.48	0.00	0	15	0	0.0	34.5	0.0	0.0	0.0	0.0
(8106, 106)				0	15	0						
(106, 108)	0.00	0.00	1.50	0	0	15	0.0	0.0	20.8	0.0	0.0	73.3
(114, 112)	0.00	3.94	0.00	0	40	0	0.0	36.3	0.0	0.0	0.0	0.0
(8112, 112)				0	15	0						
(112, 114)	0.00	0.00	1.50	0	0	15	0.0	0.0	12.7	0.0	0.0	100.0
(122, 120)	0.00	1.18	0.00	0	12	0	0.0	38.7	0.0	0.0	0.0	0.0
(8120, 120)				0	126	0						
(120, 122)	0.00	0.00	12.70	0	0	127	0.0	0.0	17.6	0.0	0.0	100.0
(125, 126)	0.00	22.54	0.00	0	172	0	0.0	45.0	0.0	0.0	0.0	0.0
(126, 204)	0.00	12.06	0.00	0	172	0	0.0	28.0	0.0	0.0	22.1	0.0
(200, 204)	0.00	31.89	0.00	0	742	0	0.0	30.9	0.0	0.0	4.2	0.0

(204, 202)	0.00	124.40	0.00	0	909	0	0.0	36.4	0.0	0.0	0.0	0.0
(8202, 202)				0	837	0						
(202, 206)	0.00	83.78	0.00	0	838	0	0.0	47.3	0.0	0.0	0.0	0.0
(206, 200)	18.22	38.69	0.00	243	516	0	4.5	4.5	0.0	88.1	85.7	0.0
(206, 208)	0.00	6.25	0.00	0	71	0	0.0	23.9	0.0	0.0	43.7	0.0
(212, 210)	0.00	12.70	0.00	0	129	0	0.0	36.1	0.0	0.0	0.0	0.0
(8210, 210)				0	24	0						
(210, 212)	0.00	0.00	2.40	0	0	24	0.0	0.0	26.3	0.0	0.0	100.0
(216, 214)	0.00	32.09	0.00	0	326	0	0.0	35.5	0.0	0.0	0.0	0.0
(8214, 214)				0	156	0						
(214, 216)	0.00	0.00	15.50	0	0	155	0.0	0.0	28.0	0.0	0.0	100.0
(222, 220)	0.00	3.15	0.00	0	32	0	0.0	35.9	0.0	0.0	0.0	0.0
(8220, 220)				0	15	0						
(220, 222)	0.00	0.00	1.50	0	0	15	0.0	0.0	26.5	0.0	0.0	100.0
(226, 224)	0.00	1.08	0.00	0	11	0	0.0	36.8	0.0	0.0	0.0	0.0
(8224, 224)				0	43	0						
(224, 226)	0.00	0.00	4.30	0	0	43	0.0	0.0	24.7	0.0	0.0	100.0
(228, 310)	0.00	11.26	0.00	0	146	0	0.0	25.7	0.0	0.0	26.0	0.0
(300, 310)	0.00	40.04	0.00	0	853	0	0.0	36.9	0.0	0.0	0.0	0.0
(310, 302)	0.00	99.77	0.00	0	998	0	0.0	34.5	0.0	0.0	0.0	0.0
(8302, 302)				0	681	0						

LINK	VEHICLE-KM LEFT	VEHICLE-KM THRU	VEHICLE-KM RIGHT	VEHICLE-TRIPS LEFT	VEHICLE-TRIPS THRU	VEHICLE-TRIPS RIGHT	SPEED (KMPH) LEFT	SPEED (KMPH) THRU	SPEED (KMPH) RIGHT	STOPS (PCT) LEFT	STOPS (PCT) THRU	STOPS (PCT) RIGHT
(302, 304)	0.00	67.98	0.00	0	680	0	0.0	43.4	0.0	0.0	3.2	0.0
(304, 300)	8.48	13.37	0.00	206	325	0	2.9	3.4	0.0	79.6	83.4	0.0
(304, 306)	0.00	9.19	0.00	0	153	0	0.0	25.5	0.0	0.0	26.1	0.0
(300, 306)	0.00	43.45	0.00	0	908	0	0.0	35.6	0.0	0.0	0.0	0.0
(306, 308)	0.00	211.35	0.00	0	1057	0	0.0	37.8	0.0	0.0	0.0	0.0

0 EACH VEHICLE WHICH CROSSES THE STOPLINE IS CONSIDERED AS 1 VEH-TRIP FOR THESE STATISTICS

1

NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE I (CONT.)

0 LINK	VEHICLE-KM			VEHICLE-TRIPS			SPEED (KMPH)			STOPS (PCT)		
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT
(8300, 308)				0	1581	0						
(308, 307)	0.00	45.00	0.00	0	237	0	0.0	44.8	0.0	0.0	0.0	0.0
(308, 300)	116.85	205.52	0.00	481	846	0	15.8	15.0	0.0	77.1	80.3	0.0

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        ( 307, 305)    0.00   13.73     0.00        0    237      0      0.0   31.8    0.0
0.0       16.0       0.0
        ( 305, 303)    0.00   73.48     0.00        0    735      0      0.0   34.0    0.0
0.0        0.0       0.0
        (8301, 303)                                 0    644      0
        ( 303, 301)    0.00   64.38     0.00        0    644      0      0.0   35.2    0.0
0.0       10.4       0.0
        ( 301, 300)    8.34   13.79     0.00      226    374      0      3.0    3.1    0.0
66.4      76.5        0.0
        ( 300, 305)    0.00   12.45     0.00        0    498      0      0.0   31.6    0.0
0.0        0.0       0.0
        ( 301, 227)    0.00    1.88     0.00        0     47      0      0.0   19.5    0.0
0.0       25.5       0.0
        ( 311, 309)    0.00    0.61     0.00        0      8      0      0.0   38.7    0.0
0.0        0.0       0.0
        (8309, 309)                                 0    106      0
        ( 309, 311)    0.00    0.00     8.27        0      0    106      0.0    0.0   19.7
0.0        0.0     100.0
        ( 315, 313)    0.00    2.56     0.00        0     26      0      0.0   36.7    0.0
0.0        0.0       0.0
        (8313, 313)                                 0     15      0
        ( 313, 315)    0.00    0.00     1.50        0      0     15      0.0    0.0   26.2
0.0        0.0     100.0
        ( 218, 317)    0.00    2.76     0.00        0     28      0      0.0   36.4    0.0
0.0        0.0       0.0
        (8317, 317)                                 0     15      0
        ( 317, 218)    0.00    0.00     1.50        0      0     15      0.0    0.0   21.2
0.0        0.0     100.0
        ( 323, 321)    0.00    0.59     0.00        0      6      0      0.0   38.0    0.0
0.0        0.0       0.0
        (8321, 321)                                 0     15      0
        ( 321, 323)    0.00    0.00     1.50        0      0     15      0.0    0.0   24.1
0.0        0.0     100.0
        ( 327, 325)    0.00    2.07     0.00        0     21      0      0.0   35.8    0.0
0.0        0.0       0.0
        (8325, 325)                                 0     15      0
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(325, 327)	0.00	0.00	1.50	0	0	15	0.0	0.0	21.1	0.0	0.0	100.0
(331, 329)	0.00	2.85	0.00	0	29	0	0.0	37.0	0.0	0.0	0.0	0.0
(8329, 329)				0	4	0						
(329, 331)	0.00	0.00	0.40	0	0	4	0.0	0.0	28.8	0.0	0.0	100.0
(335, 333)	0.00	3.05	0.00	0	31	0	0.0	36.4	0.0	0.0	0.0	0.0
(8333, 333)				0	371	0						
(333, 335)	0.00	0.00	36.99	0	0	370	0.0	0.0	19.3	0.0	0.0	100.0
(337, 205)	0.00	29.35	0.00	0	272	0	0.0	23.1	0.0	0.0	38.2	0.0
(200, 205)	0.00	83.46	0.00	0	1547	0	0.0	41.9	0.0	0.0	0.0	0.0
(205, 201)	0.00	91.03	0.00	0	1821	0	0.0	40.1	0.0	0.0	0.0	0.0
(8201, 203)				0	1317	0						
(203, 275)	0.00	65.48	0.00	0	1310	0	0.0	4.3	0.0	0.0	56.6	0.0
(275, 200)	19.80	11.36	0.00	565	324	0	2.4	2.1	0.0	49.0	64.2	0.0
(275, 207)	0.00	20.51	0.00	0	418	0	0.0	8.0	0.0	0.0	66.3	0.0
(217, 215)	0.00	9.16	0.00	0	93	0	0.0	36.1	0.0	0.0	0.0	0.0
(8215, 215)				0	38	0						
(215, 217)	0.00	0.00	3.80	0	0	38	0.0	0.0	22.1	0.0	0.0	100.0
(225, 223)	0.00	11.12	0.00	0	113	0	0.0	36.6	0.0	0.0	0.0	0.0
(8223, 223)				0	315	0						
(223, 225)	0.00	0.00	31.49	0	0	315	0.0	0.0	22.2	0.0	0.0	100.0
(100, 104)	0.00	274.77	0.00	0	1776	0	0.0	37.2	0.0	0.0	1.7	0.0

LINK	VEHICLE-KM LEFT	VEHICLE-KM THRU	VEHICLE-KM RIGHT	VEHICLE-TRIPS LEFT	VEHICLE-TRIPS THRU	VEHICLE-TRIPS RIGHT	SPEED (KMPH) LEFT	SPEED (KMPH) THRU	SPEED (KMPH) RIGHT	STOPS (PCT) LEFT	STOPS (PCT) THRU	STOPS (PCT) RIGHT
(104, 108)	0.00	172.74	1.47	0	1760	15	0.0	30.1	23.2	0.0	0.1	0.0

0 EACH VEHICLE WHICH CROSSES THE STOPLINE IS CONSIDERED AS 1 VEH-TRIP FOR THESE STATISTICS

1 NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE I (CONT.)

0 LINK	VEHICLE-KM			VEHICLE-TRIPS			SPEED (KMPH)			STOPS (PCT)		
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT
(108, 110)	0.00	124.44	0.00	0	1775	0	0.0	33.8	0.0	0.0	0.0	0.0
(110, 114)	0.00	121.84	2.80	0	1738	40	0.0	45.5	33.8	0.0	0.0	0.0
(114, 116)	0.00	195.53	0.00	0	1748	0	0.0	45.2	0.0	0.0	0.0	0.0
(116, 118)	0.00	347.91	0.00	0	1740	0	0.0	45.1	0.0	0.0	0.0	0.0
(118, 122)	0.00	439.25	2.79	0	1730	11	0.0	44.4	42.1	0.0	0.2	0.0
(122, 125)	0.00	74.23	0.00	0	1859	0	0.0	26.9	0.0	0.0	4.0	0.0
(125, 200)	165.78	99.21	0.00	1036	620	0	9.3	11.2	0.0	86.7	70.6	0.0
(200, 208)	0.00	80.68	0.00	0	1187	0	0.0	39.7	0.0	0.0	0.0	0.0
(208, 212)	0.00	245.28	27.66	0	1135	128	0.0	42.5	38.3	0.0	0.2	0.0
(212, 216)	0.00	267.75	104.35	0	839	327	0.0	43.2	38.9	0.0	0.4	0.3

(216, 218)	0.00	152.35	0.00	0	982	0	0.0	43.6	0.0	0.0	0.0	0.0
(218, 222)	0.00	117.36	3.97	0	946	32	0.0	44.9	34.9	0.0	0.0	0.0
(222, 226)	0.00	218.16	2.53	0	948	11	0.0	44.6	41.2	0.0	0.0	0.0
(226, 228)	0.00	185.28	0.00	0	990	0	0.0	37.3	0.0	0.0	10.5	0.0
(228, 300)	7.80	30.77	0.00	173	682	0	3.9	4.0	0.0	69.4	71.3	0.0
(300, 227)	0.00	29.42	0.00	0	1049	0	0.0	33.9	0.0	0.0	0.0	0.0
(227, 311)	0.00	264.11	1.92	0	1101	8	0.0	42.5	41.4	0.0	0.0	0.0
(311, 315)	0.00	221.21	4.87	0	1182	26	0.0	42.9	35.2	0.0	0.3	0.0
(315, 218)	0.00	155.35	3.72	0	1169	28	0.0	43.6	35.1	0.0	0.0	0.0
(218, 323)	0.00	157.85	0.80	0	1177	6	0.0	44.0	38.1	0.0	0.1	0.0
(323, 327)	0.00	147.41	2.64	0	1171	21	0.0	43.6	35.4	0.0	0.0	0.0
(327, 331)	0.00	144.46	3.75	0	1156	30	0.0	44.1	35.2	0.0	0.2	0.0
(331, 335)	0.00	108.21	3.07	0	1127	32	0.0	43.2	36.0	0.0	0.0	0.0
(335, 337)	0.00	257.79	0.00	0	1489	0	0.0	41.1	0.0	0.0	1.2	0.0
(337, 200)	37.59	73.64	0.00	418	819	0	5.4	5.8	0.0	83.5	81.7	0.0
(200, 207)	0.00	42.28	0.00	0	1059	0	0.0	33.8	0.0	0.0	0.0	0.0
(207, 209)	0.00	193.19	0.00	0	1474	0	0.0	40.8	0.0	0.0	0.0	0.0
(209, 211)	0.00	144.63	0.00	0	1460	0	0.0	42.8	0.0	0.0	0.0	0.0

LINK	MOVING TIME (VEH-MINS) LEFT	THRU	RIGHT	DELAY TIME (VEH-MINS) LEFT	THRU	RIGHT	TOTAL TIME (VEH-MINS) LEFT	THRU	RIGHT	RATIO MOVE/TOTAL (VEH-MINS) LEFT	THRU	RIGHT
(211, 213)	0.00	288.73	0.00	0	1444	0	0.0	42.7	0.0	0.0	0.3	0.0
(213, 217)	0.00	182.56	12.56	0	1352	93	0.0	42.4	35.1	0.0	0.1	0.0
(217, 219)	0.00	90.37	0.00	0	1392	0	0.0	42.2	0.0	0.0	0.0	0.0
(219, 221)	0.00	280.93	0.00	0	1405	0	0.0	43.2	0.0	0.0	0.1	0.0
(221, 225)	0.00	231.81	20.01	0	1309	113	0.0	42.0	37.2	0.0	0.5	1.8
(225, 100)	121.68	89.09	3.70	922	675	28	11.7	14.5	17.1	73.8	63.0	46.4

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NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE II

LINK	MOVING TIME (VEH-MINS) LEFT	THRU	RIGHT	DELAY TIME (VEH-MINS) LEFT	THRU	RIGHT	TOTAL TIME (VEH-MINS) LEFT	THRU	RIGHT	RATIO MOVE/TOTAL (VEH-MINS) LEFT	THRU	RIGHT
(8102, 102)												

(8103, 103)												
(102, 100)	114.43	4.47	164.75	432.41	16.41	148.30	546.83	20.88	313.05	0.21	0.21	0.53
(100, 102)	0.00	173.32	0.00	0.00	50.80	0.00	0.00	224.12	0.00	0.00	0.77	0.00
(103, 100)	43.59	140.00	3.66	148.78	447.13	2.21	192.37	587.13	5.87	0.23	0.24	0.62
(100, 103)	0.00	205.70	0.00	0.00	77.23	0.00	0.00	282.93	0.00	0.00	0.73	0.00
(100, 101)	0.00	40.63	0.00	0.00	3.57	0.00	0.00	44.20	0.00	0.00	0.92	0.00
(108, 106)	0.00	1.86	0.00	0.00	0.70	0.00	0.00	2.57	0.00	0.00	0.73	0.00
(8106, 106)												
(106, 108)	0.00	0.00	1.86	0.00	0.00	2.47	0.00	0.00	4.33	0.00	0.00	0.43
(114, 112)	0.00	4.97	0.00	0.00	1.55	0.00	0.00	6.52	0.00	0.00	0.76	0.00
(8112, 112)												
(112, 114)	0.00	0.00	1.86	0.00	0.00	5.20	0.00	0.00	7.07	0.00	0.00	0.26
(122, 120)	0.00	1.49	0.00	0.00	0.34	0.00	0.00	1.83	0.00	0.00	0.81	0.00
(8120, 120)												
(120, 122)	0.00	0.00	15.78	0.00	0.00	27.40	0.00	0.00	43.18	0.00	0.00	0.37
(125, 126)	0.00	28.02	0.00	0.00	2.05	0.00	0.00	30.07	0.00	0.00	0.93	0.00
(126, 204)	0.00	14.98	0.00	0.00	10.87	0.00	0.00	25.85	0.00	0.00	0.58	0.00
(200, 204)	0.00	39.63	0.00	0.00	22.30	0.00	0.00	61.93	0.00	0.00	0.64	0.00
(204, 202)	0.00	154.60	0.00	0.00	50.33	0.00	0.00	204.93	0.00	0.00	0.75	0.00
(8202, 202)												
(202, 206)	0.00	104.12	0.00	0.00	2.12	0.00	0.00	106.23	0.00	0.00	0.98	0.00

(206, 200)	22.64	48.08	0.00	222.49	470.85	0.00	245.13	518.93	0.00	0.09	0.09	0.00
(206, 208)	0.00	7.77	0.00	0.00	7.93	0.00	0.00	15.70	0.00	0.00	0.50	0.00
(212, 210)	0.00	16.03	0.00	0.00	5.06	0.00	0.00	21.08	0.00	0.00	0.76	0.00
(8210, 210)												
(210, 212)	0.00	0.00	2.98	0.00	0.00	2.48	0.00	0.00	5.47	0.00	0.00	0.55
(216, 214)	0.00	40.50	0.00	0.00	13.78	0.00	0.00	54.28	0.00	0.00	0.75	0.00
(8214, 214)												
(214, 216)	0.00	0.00	19.26	0.00	0.00	13.98	0.00	0.00	33.23	0.00	0.00	0.58
(222, 220)	0.00	3.98	0.00	0.00	1.29	0.00	0.00	5.27	0.00	0.00	0.75	0.00
(8220, 220)												
(220, 222)	0.00	0.00	1.86	0.00	0.00	1.54	0.00	0.00	3.40	0.00	0.00	0.55
(226, 224)	0.00	1.37	0.00	0.00	0.40	0.00	0.00	1.77	0.00	0.00	0.77	0.00
(8224, 224)												
(224, 226)	0.00	0.00	5.34	0.00	0.00	5.11	0.00	0.00	10.45	0.00	0.00	0.51
(228, 310)	0.00	13.99	0.00	0.00	12.31	0.00	0.00	26.30	0.00	0.00	0.53	0.00
(300, 310)	0.00	49.76	0.00	0.00	15.27	0.00	0.00	65.03	0.00	0.00	0.77	0.00
(310, 302)	0.00	123.99	0.00	0.00	49.74	0.00	0.00	173.73	0.00	0.00	0.71	0.00
(8302, 302)												
(302, 304)	0.00	84.48	0.00	0.00	9.60	0.00	0.00	94.08	0.00	0.00	0.90	0.00
(304, 300)	10.53	16.62	0.00	162.10	217.81	0.00	172.63	234.43	0.00	0.06	0.07	0.00
(304, 306)	0.00	11.42	0.00	0.00	10.22	0.00	0.00	21.63	0.00	0.00	0.53	0.00

Link	Moving Left	Moving Thru	Moving Right	Delay Left	Delay Thru	Delay Right	Total Left	Total Thru	Total Right	Ratio Left	Ratio Thru	Ratio Right
(300, 306)	0.00	54.00	0.00	0.00	19.17	0.00	0.00	73.17	0.00	0.00	0.74	0.00
(306, 308)	0.00	262.65	0.00	0.00	72.53	0.00	0.00	335.18	0.00	0.00	0.78	0.00

1 NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE II

LINK	MOVING TIME (VEH-MINS) LEFT	THRU	RIGHT	DELAY TIME (VEH-MINS) LEFT	THRU	RIGHT	TOTAL TIME (VEH-MINS) LEFT	THRU	RIGHT	RATIO MOVE/TOTAL (VEH-MINS) LEFT	THRU	RIGHT
(8300, 308)												
(308, 307)	0.00	55.93	0.00	0.00	4.40	0.00	0.00	60.33	0.00	0.00	0.93	0.00
(308, 300)	145.21	255.40	0.00	299.09	568.20	0.00	444.30	823.60	0.00	0.33	0.31	0.00
(307, 305)	0.00	17.06	0.00	0.00	8.88	0.00	0.00	25.93	0.00	0.00	0.66	0.00
(305, 303)	0.00	91.32	0.00	0.00	38.43	0.00	0.00	129.75	0.00	0.00	0.70	0.00
(8301, 303)												
(303, 301)	0.00	80.01	0.00	0.00	29.62	0.00	0.00	109.63	0.00	0.00	0.73	0.00
(301, 300)	10.36	17.14	0.00	158.82	250.58	0.00	169.18	267.72	0.00	0.06	0.06	0.00
(300, 305)	0.00	15.47	0.00	0.00	8.15	0.00	0.00	23.62	0.00	0.00	0.65	0.00
(301, 227)	0.00	2.33	0.00	0.00	3.43	0.00	0.00	5.77	0.00	0.00	0.40	0.00
(311, 309)	0.00	0.78	0.00	0.00	0.17	0.00	0.00	0.95	0.00	0.00	0.82	0.00
(8309, 309)												

(309, 311)	0.00	0.00	10.28	0.00	0.00	14.90	0.00	0.00	25.18	0.00	0.00	0.41
(315, 313)	0.00	3.23	0.00	0.00	0.95	0.00	0.00	4.18	0.00	0.00	0.77	0.00
(8313, 313)												
(313, 315)	0.00	0.00	1.86	0.00	0.00	1.57	0.00	0.00	3.43	0.00	0.00	0.54
(218, 317)	0.00	3.48	0.00	0.00	1.07	0.00	0.00	4.55	0.00	0.00	0.76	0.00
(8317, 317)												
(317, 218)	0.00	0.00	1.86	0.00	0.00	2.39	0.00	0.00	4.25	0.00	0.00	0.44
(323, 321)	0.00	0.75	0.00	0.00	0.19	0.00	0.00	0.93	0.00	0.00	0.80	0.00
(8321, 321)												
(321, 323)	0.00	0.00	1.86	0.00	0.00	1.87	0.00	0.00	3.73	0.00	0.00	0.50
(327, 325)	0.00	2.61	0.00	0.00	0.86	0.00	0.00	3.47	0.00	0.00	0.75	0.00
(8325, 325)												
(325, 327)	0.00	0.00	1.86	0.00	0.00	2.40	0.00	0.00	4.27	0.00	0.00	0.44
(331, 329)	0.00	3.60	0.00	0.00	1.03	0.00	0.00	4.63	0.00	0.00	0.78	0.00
(8329, 329)												
(329, 331)	0.00	0.00	0.50	0.00	0.00	0.34	0.00	0.00	0.83	0.00	0.00	0.60
(335, 333)	0.00	3.85	0.00	0.00	1.18	0.00	0.00	5.03	0.00	0.00	0.77	0.00
(8333, 333)												
(333, 335)	0.00	0.00	45.97	0.00	0.00	68.78	0.00	0.00	114.75	0.00	0.00	0.40
(337, 205)	0.00	36.47	0.00	0.00	39.68	0.00	0.00	76.15	0.00	0.00	0.48	0.00
(200, 205)	0.00	103.72	0.00	0.00	15.78	0.00	0.00	119.50	0.00	0.00	0.87	0.00

LINK	MOVING TIME			DELAY TIME			TOTAL TIME			RATIO MOVE/TOTAL		
(205, 201)	0.00	113.12	0.00	0.00	22.91	0.00	0.00	136.03	0.00	0.00	0.83	0.00
(8201, 203)												
(203, 275)	0.00	81.38	0.00	0.00	835.00	0.00	0.00	916.38	0.00	0.00	0.09	0.00
(275, 200)	24.61	14.11	0.00	476.54	317.89	0.00	501.15	332.00	0.00	0.05	0.04	0.00
(275, 207)	0.00	25.49	0.00	0.00	128.52	0.00	0.00	154.02	0.00	0.00	0.17	0.00
(217, 215)	0.00	11.55	0.00	0.00	3.68	0.00	0.00	15.23	0.00	0.00	0.76	0.00
(8215, 215)												
(215, 217)	0.00	0.00	4.72	0.00	0.00	5.58	0.00	0.00	10.30	0.00	0.00	0.46
(225, 223)	0.00	14.04	0.00	0.00	4.19	0.00	0.00	18.23	0.00	0.00	0.77	0.00
(8223, 223)												
(223, 225)	0.00	0.00	39.14	0.00	0.00	46.15	0.00	0.00	85.28	0.00	0.00	0.46
(100, 104)	0.00	353.18	0.00	0.00	89.83	0.00	0.00	443.02	0.00	0.00	0.80	0.00
(104, 108)	0.00	214.67	1.83	0.00	129.22	1.97	0.00	343.88	3.80	0.00	0.62	0.48
(108, 110)	0.00	154.64	0.00	0.00	65.93	0.00	0.00	220.57	0.00	0.00	0.70	0.00
(110, 114)	0.00	151.42	3.48	0.00	9.33	1.50	0.00	160.75	4.98	0.00	0.94	0.70
(114, 116)	0.00	243.00	0.00	0.00	16.30	0.00	0.00	259.30	0.00	0.00	0.94	0.00

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NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE II

LINK MOVING TIME DELAY TIME TOTAL TIME
RATIO MOVE/TOTAL

Link	(VEH-MINS) LEFT	THRU	RIGHT	(VEH-MINS) LEFT	THRU	RIGHT	(VEH-MINS) LEFT	THRU	RIGHT	(VEH-MINS) LEFT	THRU	RIGHT
(116, 118)	0.00	432.36	0.00	0.00	30.44	0.00	0.00	462.80	0.00	0.00	0.93	0.00
(118, 122)	0.00	545.87	3.47	0.00	47.43	0.51	0.00	593.30	3.98	0.00	0.92	0.87
(122, 125)	0.00	92.25	0.00	0.00	73.19	0.00	0.00	165.43	0.00	0.00	0.56	0.00
(125, 200)	206.02	123.30	0.00	865.93	405.94	0.00	1071.95	529.23	0.00	0.19	0.23	0.00
(200, 208)	0.00	100.27	0.00	0.00	21.82	0.00	0.00	122.08	0.00	0.00	0.82	0.00
(208, 212)	0.00	304.82	34.38	0.00	41.62	8.97	0.00	346.43	43.35	0.00	0.88	0.79
(212, 216)	0.00	332.74	129.69	0.00	38.98	31.13	0.00	371.72	160.82	0.00	0.90	0.81
(216, 218)	0.00	189.33	0.00	0.00	20.47	0.00	0.00	209.80	0.00	0.00	0.90	0.00
(218, 222)	0.00	145.84	4.93	0.00	10.84	1.88	0.00	156.68	6.82	0.00	0.93	0.72
(222, 226)	0.00	271.11	3.15	0.00	22.62	0.54	0.00	293.73	3.68	0.00	0.92	0.85
(226, 228)	0.00	230.25	0.00	0.00	67.93	0.00	0.00	298.18	0.00	0.00	0.77	0.00
(228, 300)	9.70	38.23	0.00	110.60	429.05	0.00	120.30	467.28	0.00	0.08	0.08	0.00
(300, 227)	0.00	36.56	0.00	0.00	15.54	0.00	0.00	52.10	0.00	0.00	0.70	0.00
(227, 311)	0.00	328.21	2.38	0.00	44.32	0.40	0.00	372.53	2.78	0.00	0.88	0.86
(311, 315)	0.00	274.90	6.05	0.00	34.65	2.24	0.00	309.55	8.28	0.00	0.89	0.73
(315, 218)	0.00	193.06	4.62	0.00	20.82	1.74	0.00	213.88	6.37	0.00	0.90	0.73

(218, 323)	0.00	196.17	1.00	0.00	18.95	0.27	0.00	215.12	1.27	0.00	0.91	0.79
(323, 327)	0.00	183.19	3.29	0.00	19.84	1.20	0.00	203.03	4.48	0.00	0.90	0.73
(327, 331)	0.00	179.53	4.66	0.00	17.15	1.72	0.00	196.68	6.38	0.00	0.91	0.73
(331, 335)	0.00	134.47	3.82	0.00	15.75	1.30	0.00	150.22	5.12	0.00	0.90	0.75
(335, 337)	0.00	320.36	0.00	0.00	55.86	0.00	0.00	376.22	0.00	0.00	0.85	0.00
(337, 200)	46.71	91.52	0.00	372.27	666.20	0.00	418.98	757.72	0.00	0.11	0.12	0.00
(200, 207)	0.00	52.55	0.00	0.00	22.58	0.00	0.00	75.13	0.00	0.00	0.70	0.00
(207, 209)	0.00	240.08	0.00	0.00	43.68	0.00	0.00	283.77	0.00	0.00	0.85	0.00
(209, 211)	0.00	179.73	0.00	0.00	23.22	0.00	0.00	202.95	0.00	0.00	0.89	0.00
(211, 213)	0.00	358.81	0.00	0.00	46.67	0.00	0.00	405.48	0.00	0.00	0.88	0.00
(213, 217)	0.00	226.87	15.61	0.00	31.36	5.86	0.00	258.23	21.47	0.00	0.88	0.73
(217, 219)	0.00	112.31	0.00	0.00	16.27	0.00	0.00	128.58	0.00	0.00	0.87	0.00
(219, 221)	0.00	349.12	0.00	0.00	41.35	0.00	0.00	390.47	0.00	0.00	0.89	0.00
(221, 225)	0.00	288.08	24.87	0.00	43.39	7.41	0.00	331.47	32.28	0.00	0.87	0.77
(225, 100)	151.22	110.71	4.59	474.28	258.07	8.34	625.50	368.78	12.93	0.24	0.30	0.36

1 NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE III

LINK TOTAL TIME DELAY TIME QUEUE TIME**
STOP TIME**

Link	(SECS/VEH) LEFT	(SECS/VEH) THRU	(SECS/VEH) RIGHT	(SECS/VEH) LEFT	(SECS/VEH) THRU	(SECS/VEH) RIGHT	(VEH-MINS) LEFT	(VEH-MINS) THRU	(VEH-MINS) RIGHT	(VEH-MINS) LEFT	(VEH-MINS) THRU	(VEH-MINS) RIGHT
(8102, 102)												
(8103, 103)												
(102, 100)	53.4	52.2	21.2	42.3	41.0	10.1	370.3	14.2	64.8	362.8	14.0	55.4
(100, 102)	0.0	14.5	0.0	0.0	3.3	0.0	0.0	0.2	0.0	0.0	0.0	0.0
(103, 100)	42.1	40.0	15.3	32.6	30.5	5.8	127.2	371.9	0.9	124.6	362.4	0.9
(100, 103)	0.0	13.1	0.0	0.0	3.6	0.0	0.0	0.4	0.0	0.0	0.0	0.0
(100, 101)	0.0	8.1	0.0	0.0	0.7	0.0	0.0	0.1	0.0	0.0	0.0	0.0
(108, 106)	0.0	10.3	0.0	0.0	2.8	0.0	0.0	0.1	0.0	0.0	0.0	0.0
(8106, 106)												
(106, 108)	0.0	0.0	17.3	0.0	0.0	9.9	0.0	0.0	1.8	0.0	0.0	1.8
(114, 112)	0.0	9.8	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8112, 112)												
(112, 114)	0.0	0.0	28.3	0.0	0.0	20.8	0.0	0.0	4.8	0.0	0.0	4.7
(122, 120)	0.0	9.2	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8120, 120)												
(120, 122)	0.0	0.0	20.4	0.0	0.0	12.9	0.0	0.0	23.0	0.0	0.0	22.5
(125, 126)	0.0	10.5	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(126, 204)	0.0	9.0	0.0	0.0	3.8	0.0	0.0	5.3	0.0	0.0	5.2	0.0
(200, 204)	0.0	5.0	0.0	0.0	1.8	0.0	0.0	4.8	0.0	0.0	2.7	0.0

(204, 202)	0.0	13.5	0.0	0.0	3.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0
(8202, 202)												
(202, 206)	0.0	7.6	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(206, 200)	60.5	60.3	0.0	54.9	54.8	0.0	204.4	437.7	0.0	201.7	430.6	0.0
(206, 208)	0.0	13.3	0.0	0.0	6.7	0.0	0.0	5.7	0.0	0.0	5.6	0.0
(212, 210)	0.0	9.8	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8210, 210)												
(210, 212)	0.0	0.0	13.7	0.0	0.0	6.2	0.0	0.0	1.5	0.0	0.0	1.5
(216, 214)	0.0	10.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8214, 214)												
(214, 216)	0.0	0.0	12.9	0.0	0.0	5.4	0.0	0.0	8.4	0.0	0.0	8.1
(222, 220)	0.0	9.9	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8220, 220)												
(220, 222)	0.0	0.0	13.6	0.0	0.0	6.1	0.0	0.0	0.9	0.0	0.0	0.9
(226, 224)	0.0	9.6	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8224, 224)												
(224, 226)	0.0	0.0	14.6	0.0	0.0	7.1	0.0	0.0	3.8	0.0	0.0	3.7
(228, 310)	0.0	10.8	0.0	0.0	5.1	0.0	0.0	5.8	0.0	0.0	5.6	0.0
(300, 310)	0.0	4.6	0.0	0.0	1.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0
(310, 302)	0.0	10.4	0.0	0.0	3.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
(8302, 302)												

(302, 304)	0.0	8.3	0.0	0.0	0.8	0.0	0.0	3.9	0.0	0.0	3.8	0.0
(304, 300)	50.3	43.3	0.0	47.2	40.2	0.0	146.5	199.8	0.0	144.0	196.4	0.0
(304, 306)	0.0	8.5	0.0	0.0	4.0	0.0	0.0	5.3	0.0	0.0	5.1	0.0
(300, 306)	0.0	4.8	0.0	0.0	1.3	0.0	0.0	0.4	0.0	0.0	0.0	0.0
(306, 308)	0.0	19.0	0.0	0.0	4.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0

1

NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE III

LINK	TOTAL TIME (SECS/VEH)			DELAY TIME (SECS/VEH)			QUEUE TIME** (VEH-MINS)			STOP TIME** (VEH-MINS)		
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT
(8300, 308)												
(308, 307)	0.0	15.3	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(308, 300)	55.4	58.4	0.0	37.3	40.3	0.0	247.3	471.9	0.0	242.4	462.1	0.0
(307, 305)	0.0	6.6	0.0	0.0	2.2	0.0	0.0	2.8	0.0	0.0	2.8	0.0
(305, 303)	0.0	10.6	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8301, 303)												
(303, 301)	0.0	10.2	0.0	0.0	2.8	0.0	0.0	20.1	0.0	0.0	19.3	0.0
(301, 300)	44.9	42.9	0.0	42.2	40.2	0.0	144.5	230.3	0.0	142.3	226.8	0.0
(300, 305)	0.0	2.8	0.0	0.0	1.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0

(301, 227)	0.0	7.4	0.0	0.0	4.4	0.0	0.0	2.2	0.0	0.0	2.2	0.0
(311, 309)	0.0	7.1	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8309, 309)												
(309, 311)	0.0	0.0	14.3	0.0	0.0	8.4	0.0	0.0	11.6	0.0	0.0	11.5
(315, 313)	0.0	9.7	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8313, 313)												
(313, 315)	0.0	0.0	13.7	0.0	0.0	6.3	0.0	0.0	1.1	0.0	0.0	1.1
(218, 317)	0.0	9.8	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8317, 317)												
(317, 218)	0.0	0.0	17.0	0.0	0.0	9.5	0.0	0.0	1.9	0.0	0.0	1.8
(323, 321)	0.0	9.3	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8321, 321)												
(321, 323)	0.0	0.0	14.9	0.0	0.0	7.5	0.0	0.0	1.5	0.0	0.0	1.5
(327, 325)	0.0	9.9	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8325, 325)												
(325, 327)	0.0	0.0	17.1	0.0	0.0	9.6	0.0	0.0	2.0	0.0	0.0	1.9
(331, 329)	0.0	9.6	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8329, 329)												
(329, 331)	0.0	0.0	12.5	0.0	0.0	5.0	0.0	0.0	0.2	0.0	0.0	0.2
(335, 333)	0.0	9.7	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8333, 333)												
(333, 335)	0.0	0.0	18.6	0.0	0.0	11.2	0.0	0.0	43.7	0.0	0.0	40.8

(337, 205)	0.0	16.8	0.0	0.0	8.8	0.0	0.0	25.6	0.0	0.0	24.4	0.0
(200, 205)	0.0	4.6	0.0	0.0	0.6	0.0	0.0	0.5	0.0	0.0	0.0	0.0
(205, 201)	0.0	4.5	0.0	0.0	0.8	0.0	0.0	0.3	0.0	0.0	0.0	0.0
(8201, 203)												
(203, 275)	0.0	42.0	0.0	0.0	38.2	0.0	0.0	702.3	0.0	0.0	663.6	0.0
(275, 200)	53.2	61.5	0.0	50.6	58.9	0.0	436.5	294.8	0.0	431.2	291.7	0.0
(275, 207)	0.0	22.1	0.0	0.0	18.4	0.0	0.0	91.0	0.0	0.0	82.9	0.0
(217, 215)	0.0	9.8	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8215, 215)												
(215, 217)	0.0	0.0	16.3	0.0	0.0	8.8	0.0	0.0	4.3	0.0	0.0	4.2
(225, 223)	0.0	9.7	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8223, 223)												
(223, 225)	0.0	0.0	16.2	0.0	0.0	8.8	0.0	0.0	24.0	0.0	0.0	23.1
(100, 104)	0.0	15.0	0.0	0.0	3.0	0.0	0.0	8.6	0.0	0.0	4.5	0.0
(104, 108)	0.0	11.7	15.2	0.0	4.4	7.9	0.0	8.8	0.3	0.0	0.6	0.1
(108, 110)	0.0	7.5	0.0	0.0	2.2	0.0	0.0	6.7	0.0	0.0	0.0	0.0
(110, 114)	0.0	5.5	7.5	0.0	0.3	2.2	0.0	0.0	0.0	0.0	0.0	0.0
(114, 116)	0.0	8.9	0.0	0.0	0.6	0.0	0.0	0.1	0.0	0.0	0.0	0.0

NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE III

LINK	TOTAL TIME (SECS/VEH)			DELAY TIME (SECS/VEH)			QUEUE TIME** (VEH-MINS)			STOP TIME** (VEH-MINS)		
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT
(116, 118)	0.0	16.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(118, 122)	0.0	20.6	21.7	0.0	1.6	2.8	0.0	0.3	0.0	0.0	0.1	0.0
(122, 125)	0.0	5.3	0.0	0.0	2.4	0.0	0.0	19.3	0.0	0.0	11.7	0.0
(125, 200)	62.1	51.2	0.0	50.2	39.3	0.0	730.4	358.8	0.0	720.5	349.5	0.0
(200, 208)	0.0	6.2	0.0	0.0	1.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0
(208, 212)	0.0	18.3	20.3	0.0	2.2	4.2	0.0	0.2	0.4	0.0	0.1	0.3
(212, 216)	0.0	26.6	29.5	0.0	2.8	5.7	0.0	0.8	1.3	0.0	0.2	0.8
(216, 218)	0.0	12.8	0.0	0.0	1.3	0.0	0.0	1.7	0.0	0.0	0.0	0.0
(218, 222)	0.0	9.9	12.8	0.0	0.7	3.5	0.0	0.0	0.0	0.0	0.0	0.0
(222, 226)	0.0	18.6	20.1	0.0	1.4	2.9	0.0	0.2	0.0	0.0	0.0	0.0
(226, 228)	0.0	18.1	0.0	0.0	4.1	0.0	0.0	29.6	0.0	0.0	26.5	0.0
(228, 300)	41.7	41.1	0.0	38.4	37.7	0.0	96.2	381.2	0.0	94.7	374.2	0.0
(300, 227)	0.0	3.0	0.0	0.0	0.9	0.0	0.0	0.4	0.0	0.0	0.0	0.0
(227, 311)	0.0	20.3	20.9	0.0	2.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0

(311, 315)	0.0	15.7	19.1	0.0	1.8	5.2	0.0	1.3	0.3	0.0	0.2	0.2
(315, 218)	0.0	11.0	13.6	0.0	1.1	3.7	0.0	0.2	0.1	0.0	0.0	0.0
(218, 323)	0.0	11.0	12.7	0.0	1.0	2.7	0.0	0.2	0.0	0.0	0.1	0.0
(323, 327)	0.0	10.4	12.8	0.0	1.0	3.4	0.0	0.2	0.0	0.0	0.0	0.0
(327, 331)	0.0	10.2	12.8	0.0	0.9	3.4	0.0	0.4	0.1	0.0	0.2	0.1
(331, 335)	0.0	8.0	9.6	0.0	0.8	2.4	0.0	0.1	0.0	0.0	0.0	0.0
(335, 337)	0.0	15.2	0.0	0.0	2.3	0.0	0.0	7.7	0.0	0.0	3.6	0.0
(337, 200)	60.1	55.5	0.0	53.4	48.8	0.0	330.5	571.9	0.0	326.7	560.5	0.0
(200, 207)	0.0	4.3	0.0	0.0	1.3	0.0	0.0	0.5	0.0	0.0	0.0	0.0
(207, 209)	0.0	11.6	0.0	0.0	1.8	0.0	0.0	0.4	0.0	0.0	0.0	0.0
(209, 211)	0.0	8.3	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(211, 213)	0.0	16.8	0.0	0.0	1.9	0.0	0.0	0.7	0.0	0.0	0.5	0.0
(213, 217)	0.0	11.5	13.8	0.0	1.4	3.8	0.0	0.5	0.2	0.0	0.1	0.2
(217, 219)	0.0	5.5	0.0	0.0	0.7	0.0	0.0	0.4	0.0	0.0	0.0	0.0
(219, 221)	0.0	16.7	0.0	0.0	1.8	0.0	0.0	0.1	0.0	0.0	0.0	0.0
(221, 225)	0.0	15.2	17.1	0.0	2.0	3.9	0.0	1.4	0.2	0.0	1.1	0.1
(225, 100)	40.7	32.8	27.7	30.9	22.9	17.9	373.3	201.4	6.0	357.8	189.8	5.7

** TIME FOR VEHICLES CURRENTLY ON THE LINK ARE INCLUDED IN THESE VALUES.

```
 THE HIGHEST NUMBER OF VEHICLES ON THE NETWORK WAS   429 VEHICLES (MAXIMUM ALLOWED IS  3500).
 THIS MAXIMUM OCCURED AT  3321 SECONDS.

0***** THERE WERE   1 WARNING MESSAGES IN DATA FOR CASE  1.
1

  MESSAGE    DESCRIPTION

-  500  Specified oncoming link (P1,P2) may not have been specified correctly. Its
        traffic opposes traffic on link (P3,P2) but no receiving link (P2,P3) was
        input.  Check Record Type 11.

 TOTAL CPU TIME FOR SIMULATION =    192.40 SECONDS
 TOTAL CPU TIME FOR THIS RUN =    192.46 SECONDS
0LAST CASE PROCESSED
```

Appendix D

TRAF-NETSIM Simulation output

Validation Network Calibrated Model

1

```
INPUT FILE NAME: SMOC1.TRF
RUN DATE       : 08/15/99
```

```
TTTTTTTTTTT  RRRRRRRRR     AAAAAAA    FFFFFFFFFFF
TTTTTTTTTTT  RRRRRRRRRR   AAAAAAAAA   FFFFFFFFFFF
TTTTTTTTTTT  RRRRRRRRRRR  AAAAAAAAAAA FFFFFFFFFFF
    TTT      RRR     RRR  AAA     AAA FFF
    TTT      RRR     RRR  AAA     AAA FFF
    TTT      RRRRRRRRRRR  AAAAAAAAAAA FFFFFFF
    TTT      RRRRRRRRRR   AAAAAAAAAAA FFFFFFF
    TTT      RRR RRR      AAA     AAA FFF
    TTT      RRR  RRR     AAA     AAA FFF
    TTT      RRR   RRR    AAA     AAA FFF
    TTT      RRR    RRR   AAA     AAA FFF
    TTT      RRR     RRR  AAA     AAA FFF
```

MICRO-COMPUTER PROTECTED-MODE VERSION
(REQUIRES 80386 AND 80387 OR ABOVE)

```
                                                     VERSION 5.00
                                                RELEASE DATE MAR 1995
1                                               TRAF SIMULATION MODEL

                                                     DEVELOPED FOR

                                          U. S. DEPARTMENT OF TRANSPORTATION
                                            FEDERAL HIGHWAY ADMINISTRATION
                                      INTELLIGENT VEHICLE HIGHWAY SYSTEM RESEARCH DIVISION
0*****************************************************************************************************

                                                     START OF CASE   1


1                                     CARD FILE LIST
0SEQ.# :----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

     1 :Validation Network  : Safeway Street                                          0
     2 :                      MONDAY, JUNE 29 , 1998                                  0
     3 :                      13:00 14:00                                             0
     4 :                                                                              0
     5 :Sami Said Ghezawi                      11  03  98                         10  1
     6 :   0   1           10                         1 0   31300      132841    7581  2
     7 :3600                                                                          3
     8 :                                                                              4
     9 :                                                1                             5
    10 :8101 101              2      02            100              18  15           11
    11 :8104 104              3      02            100              18  15           11
    12 :8202 202              2      02            200              18  15           11
    13 :8222 222              2      02            220              18  15           11
    14 :8242 242              2      02            240              18  15           11
    15 :8302 302              2      02            300              18  15           11
    16 :8301 301              1      02            300              18  15           11
```

```
17 :8311 311             1    -32            310                 18  15            11
18 :8403 403             3     02            400    +401         18  15            11
19 :8401 401             3     02            400                 18  15            11
20 : 101 100 400         3     02411    200      104             18  15  60        11
21 : 100 101 400         2     02         8101                   18  15  60        11
22 : 104 100 400         3    +42 81    101 200                  18  15  60        11
23 : 100 104 400         3    -42         8104                   18  15  60        11
24 : 300 302 400         3     02         8302                   18  15  60        11
25 : 302 300 400      40 2   1 0281     310 301 400              18  15  60        11
26 : 400 403 400         3    -32         8403                   18  15  60        11
27 : 403 400 400         3    +32          300                   18  15  60        11
28 : 400 401 400         3     02         8401                   18  15  60        11
29 : 401 400 400         4     024      403 402 300              18  15  60        11
30 : 202 200 400         3     02481    100 201 220              18  15  60        11
31 : 200 202 400         2     02         8202                   18  15  60        11
32 : 200 201 100         2    +22         8201                   18  15  60        11
33 : 220 222 100         2     02         8222                   18  15  60        11
34 : 222 220 100         1     02                240             18  15  60        11
35 : 240 242 100         2     02         8242                   18  15  60        11
36 : 242 240 100         1     02                300             18  15  60        11
37 : 300 301 100         1     02         8301                   18  15  60        11
38 : 301 300 100         1     02                310             18  15  60        11
39 : 310 311 100         1    +32         8311                   18  15  60        11
40 : 311 310 100         1    -32                200             18  15  60        11
41 : 403 401 285         1     02                   8401         18  15  60        11
42 : 400 402  50         1     02         8402                   18  15  60        11
43 : 100 200 140  30     3 1  +12       201 220 202              18  15  60        11
44 : 200 220 122         3     02            240 222             18  15  60        11
45 : 220 240  92         3    -32            300 242             18  15  60        11
46 : 240 300 326  50  40 3 1 1-72       301 400 302              18  15  60        11
47 : 300 400 211 100     3 1  -32   8   401 403                  18  15  60        11
48 : 400 300 210 100     3 1  +32   8   302 310 301              18  15  60        11
49 : 300 310 228         3    +72            200 311             18  15  60        11
50 : 310 200 310  40     3 1  +52       202 100 201              18  15  60        11
51 : 200 100 147      35 3   1-12            104 101             18  15  60        11
52 :8401 401     100                                                               21
53 :8101 101     100                                                               21
54 :8104 104     100                                                               21
55 :8202 202     100                                                               21
56 :8222 222     100                                                               21
57 :8242 242     100                                                               21
```

```
58 :8302 302      100                                                        21
59 :8301 301      100                                                        21
60 :8311 311      100                                                        21
61 :8403 403       95       5                                                21
62 : 401 400  24   10   66                                                   21
63 : 300 40010451311                                                         21
64 : 302 300 283  321056                                                     21
65 : 301 300           100                                                   21
66 : 400 300 6821620   55                                                    21
67 : 240 300  481549 204                                                     21
68 : 300 310       90  10                                                    21
69 : 202 200 367   32  38                                                    21
70 : 310 200 1721871   40                                                    21
71 : 100 200  351619   53                                                    21
72 : 104 100 5231078                                                         21
73 : 101 100 826       112                                                   21
74 : 200 100    1273 952                                                     21
75 : 200 220    1657  52                                                     21
76 : 220 240    1661  19                                                     21
77 : 222 220           100                                                   21
78 : 242 240           100                                                   21
79 : 311 310           100                                                   21
80 : 403 400      100                                                        21
81 : 403 401              +100                                               21
82 : 100 104      100                                                        21
83 : 200 202      100                                                        21
84 : 240 242      100                                                        21
85 : 300 301      100                                                        21
86 : 400 401      100                                                        21
87 : 400 403      100                                                        21
88 : 100 101      100                                                        21
89 : 200 201      100                                                        21
90 : 220 222      100                                                        21
91 : 300 302      100                                                        21
92 : 310 311      100                                                        21
93 : 400 402      100                                                        21
94 : 220      222 200                                                        35
95 : 240      242 220                                                        35
96 : 401     8401 403 400                                                    35
97 : 310      311 300                                                        35
98 : 101     8101 100                                                        35
```

```
 99 : 104     8104 100                                                       35
100 : 202     8202 200                                                       35
101 : 201      200                                                           35
102 : 222     8222 220                                                       35
103 : 242     8242 240                                                       35
104 : 301     8301 300                                                       35
105 : 302     8302 300                                                       35
106 : 403     8403 400                                                       35
107 : 402      400                                                           35
108 : 311     8311 310                                                       35
109 : 220 5                                                                  36
110 : 240 5                                                                  36
111 : 401 0                                                                  36
112 : 310 5                                                                  36
113 : 101 1                                                                  36
114 : 104 1                                                                  36
115 : 202 1                                                                  36
116 : 201 1                                                                  36
117 : 222 1                                                                  36
118 : 242 1                                                                  36
119 : 301 1                                                                  36
120 : 302 1                                                                  36
121 : 311 1                                                                  36
122 : 402 1                                                                  36
123 : 403 1                                                                  36
124 : 100 101 100 200 100 104 100                                            43
125 : 200 310 200 202 200 100 200                                            43
126 : 300 301 300 400 300 302 300 240 300                                    43
127 : 400 401 400 403 400 300 400                                            43
128 : 100 75 30 25 45  0 25      25    45             10     01              44
129 : 200 75 30 25 45  0 25      25    45             10     01              44
130 : 100   2 2 2       11       21                                          45
131 : 100   3 1 1       21       22                                          45
132 : 100   1 2 2       22       11                                          45
133 : 200   2 211      222       211                                         45
134 : 200   3 221      111       221                                         45
135 : 200   1 121      222       121                                         45
136 : 300   1 221      221       221       111                               45
137 : 300   2 221      211       221       211                               45
138 : 300   3 221      111       221       221                               45
139 : 300   4 221      221       111       221                               45
```

```
140 : 400    1 221        2         11                                                  45
141 : 400    2 221        1         21                                                  45
142 : 400    3 111        2         22                                                  45
143 : 100 2 2  29   50  0  0 10  1                                                      46
144 : 100 3 2  19   50  0  0 10  1                                                      46
145 : 100 1 2  39   50  0  0 10  1                                                      46
146 : 200 2 2  113  50  0  0 10  1                                                      46
147 : 200 2 2  313  50  0  0 10  1                                                      46
148 : 200 3 2  212  50  0  0 10  1                                                      46
149 : 200 1 2  17   50  0  0 50  1                                                      46
150 : 200 1 2  37   50  0  0 50  1                                                      46
151 : 300 1 2  413  50  0  0 10  1                                                      46
152 : 300 1 2  47   50  0  0 50  1                                                      46
153 : 300 2 2  212  50  0  0 10  1                                                      46
154 : 300 2 2  413  50  0  0 10  1                                                      46
155 : 300 3 2  212  50  0  0 10  1                                                      46
156 : 300 3 2  23   50  0  0 10  1                                                      46
157 : 300 4 2  39   50  0  0 10  1                                                      46
158 : 400 1 2  313  50  0  0 10  1                                                      46
159 : 400 1 2  37   50  0  0 50  1                                                      46
160 : 400 2 2  29   50  0  0 10  1                                                      46
161 : 400 2 2  313  50  0  0 10  1                                                      46
162 : 400 3 2  19   50  0  0 10  1                                                      46
163 : 100 2     2030           20         300 300 30 10 1111  1                         47
164 : 100 3  25  730            7         300 300 30 10 1 1   0                         47
165 : 100 1  20  730            7         300 300 30    1 1   0                         47
166 : 200 2     2030           20         300 300 30 10 1111  1                         47
167 : 200 3  25  730            7         300 300 30 10 1 1   0                         47
168 : 200 1  20  530            5         300 300 30 10 1 1   0                         47
169 : 300 1  10  530            5         300 300 30    1 1   0                         47
170 : 300 2  80  530            5         300 300 30    1 1   1                         47
171 : 300 3  30  530            5         300 300 30 10 1 1   0                         47
172 : 300 4  15  530            5         300 300 30 10 1 1   1                         47
173 : 400 1  40  530            5         300 300 30 10 1 1   0                         47
174 : 400 2  50  530            5         300 300 30 10 1 1   1                         47
175 : 400 3  45  530            5         300 300 30 10 1 1                             47
176 :8401 4011268   2                                                                   50
177 :8403 4031885   2                                                                   50
178 :8302 3021371   1                                                                   50
179 :8301 301 177                                                                       50
180 :8311 311 142                                                                       50
```

```
 181 :8202 202 437                                                                           50
 182 :8101 101 938   1                                                                       50
 183 :8104 1041601   2                                                                       50
 184 :8222 222   4                                                                           50
 185 :8242 242 144                                                                           50
 186 :2300 300 400-422                                                                       51
 187 :2400 400 300  -8                                                                       51
 188 :2200 240 300  -6                                                                       51
 189 :2500 310 200  45                                                                       51
 190 :2100 100 200-197                                                                       51
 191 :   2   0 211 169 141 121 101  83  64  48  37  25                                      149
 192 :   2   1 180 134 118 105  95  88  81  75  67  57                                      149
 193 :   0                                                                                  170
 194 : 101    1019    1502                                                                  195
 195 : 104     819    1285                                                                  195
 196 : 100    1019    1302                                                                  195
 197 : 201    1159    1384                                                                  195
 198 : 202    1159    1284                                                                  195
 199 : 200    1159    1334                                                                  195
 200 : 220    1267    1347                                                                  195
 201 : 222    1267    1297                                                                  195
 202 : 240    1358    1351                                                                  195
 203 : 242    1358    1301                                                                  195
 204 : 310    1484    1353                                                                  195
 205 : 311    1484    1403                                                                  195
 206 : 301    1699    1398                                                                  195
 207 : 302    1699    1148                                                                  195
 208 : 300    1699    1348                                                                  195
 209 : 401    1910    1543                                                                  195
 210 : 403    2110    1343                                                                  195
 211 : 400    1910    1343                                                                  195
 212 : 402    1910    1293                                                                  195
 213 :   1                                                                                  210
OSEQ.# :----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8
```

```
1                                    TRAF SIMULATION MODEL

                                        DEVELOPED FOR

                              U. S. DEPARTMENT OF TRANSPORTATION
                                FEDERAL HIGHWAY ADMINISTRATION
                     INTELLIGENT VEHICLE HIGHWAY SYSTEM RESEARCH DIVISION
0****************************************************************************************************
******************************

                                        START OF CASE   1


****************************************************************************************************
******************************
0                          Validation Network  : Safeway Street
0                                                MONDAY, JUNE 29 , 1998
0                                                13:00 14:00
0
0


                                                   DATE =  11/  03/  98
0                                                  USER = Sami Said Ghezawi
0                                                AGENCY =
1                                                       RUN CONTROL DATA


                    VALUE                          RUN PARAMETERS AND OPTIONS

0                      10     RUN IDENTIFICATION NUMBER
0                       0     NEXT CASE CODE = (0,1) IF ANOTHER CASE (DOES NOT, DOES) FOLLOW
0                       1     RUN TYPE CODE = ( 1, 2, 3) TO RUN (SIMULATION, ASSIGNMENT, BOTH)
                                              (-1,-2,-3) TO CHECK (SIMULATION, ASSIGNMENT, BOTH)
ONLY

0                             NETSIM ENVIRONMENTAL OPTIONS
                              ----------------------------
                        0     FUEL/EMISSION RATE TABLES ARE NOT PRINTED
```

```
                           0     SIMULATION:  PERFORMED                                 ENVIRONMENTAL
MEASURES:  CALCULATED
                                 RATE TABLES: EMBEDDED                                  TRAJECTORY FILE:
NOT WRITTEN
0                          1     INPUT  UNITS CODE = (0,1) IF INPUT IS IN (ENGLISH, METRIC) UNITS
                           0     OUTPUT UNITS CODE = (0,1,2,3) IF OUTPUT IS IN (SAME AS INPUT,
ENGLISH, METRIC, BOTH) UNITS
0                       1300     CLOCK TIME AT START OF SIMULATION (HHMM)
0                          0     SIGNAL TRANSITION CODE = (0,1,2,3) IF (NO, IMMEDIATE, 2-CYCLE, 3-
CYCLE) TRANSITION WAS REQUESTED
0                       7581     RANDOM NUMBER SEED
                      132841     RANDOM NUMBER SEED TO GENERATE TRAFFIC STREAM FOR NETSIM OR LEVEL I
SIMULATION

                        3600     DURATION (SEC) OF TIME PERIOD NO.  1
0                         60*    LENGTH OF A TIME INTERVAL, SECONDS
0                         10     MAXIMUM INITIALIZATION TIME, NUMBER OF TIME INTERVALS
0                          0     NUMBER OF TIME INTERVALS BETWEEN SUCCESSIVE STANDARD OUTPUTS
0                          0     TIME INTERMEDIATE OUTPUT WILL BEGIN AT INTERVALS OF    0 SECS. FOR
0 SECS. FOR MICROSCOPIC MODELS
0                          1     NETSIM MOVEMENT-SPECIFIC OUTPUT CODE = (0,1) (IF NOT, IF) REQUESTED
FOR NETSIM SUBNETWORK
0                          0     NETSIM GRAPHICS OUTPUT CODE = (0,1) IF GRAPHICS OUTPUT (IS NOT, IS)
REQUESTED
0                          *  VALUE ASSERTED BY THE MODEL FOR THE FOLLOWING REASON -
0                             TIME INTERVAL DURATION OMITTED. DEFAULT VALUE OF 60 SECONDS ASSUMED.
1
1                                          INITIALIZATION STATISTICS
```

TIME INTERVAL NUMBER	SUBNETWORK TYPE	PRIOR CONTENT (VEHICLES)	CURRENT CONTENT (VEHICLES)	PERCENT DIFFERENCE
1	NETSIM	0	128	10000
2	NETSIM	128	217	69
3	NETSIM	217	281	29
4	NETSIM	281	308	9
5	NETSIM	308	288	6

EQUILIBRIUM ATTAINED

ALL EXISTING SUBNETWORKS REACHED EQUILIBRIUM

1 CUMULATIVE NETSIM STATISTICS AT TIME 14: 0: 0

ELAPSED TIME IS 1: 0: 0 (3600 SECONDS), TIME PERIOD 1 ELAPSED TIME IS 3600 SECONDS

LINK	VEHICLE KM	VEHICLE TRIPS	VEHICLE MINUTES MOVE TIME	VEHICLE MINUTES DELAY TIME	VEHICLE MINUTES TOTAL TIME	RATIO MOVE/ TOTAL	MINUTES / KM TOTAL TIME	MINUTES / KM DELAY TIME	SECONDS / VEHICLE TOTAL TIME	SECONDS / VEHICLE DELAY TIME	SECONDS / VEHICLE QUEUE TIME	STOP TIME	STOPS (%)	AVERAGE VALUES VOLUME VPH	AVERAGE VALUES SPEED KMPH
(8101, 101)		940										940			
(8104, 104)		1607										1607			
(8202, 202)		437										437			
(8222, 222)		4										4			
(8242, 242)		144										144			
(8302, 302)		1374										1374			
(8301, 301)		177										177			
(8311, 311)		142										142			
(8403, 403)		1886										1886			
(8401, 401)		1272										1272			
(101, 100)	376.70	942	381.5	413.4	794.8	0.48	2.11	1.10	50.6	26.3	20.1	19.6	78	942	28.4
(100, 101)	611.16	1563	618.9	175.7	794.6	0.78	1.30	0.29	30.5	6.7	0.0	0.0	0	1563	46.1
(104, 100)	644.64	1612	652.8	661.7	1314.5	0.50	2.04	1.03	48.9	24.6	18.5	18.0	66	1612	29.4

(100, 104)	584.19	1463	591.6	178.5	770.0	0.77	1.32	0.31	31.6	7.3	0.0
0.0 0	1463	45.5									
(300, 302)	382.18	964	387.0	105.5	492.5	0.79	1.29	0.28	30.7	6.6	0.0
0.0 0	964	46.6									
(302, 300)	552.26	1381	559.2	691.1	1250.3	0.45	2.26	1.25	54.3	30.0	18.7
17.1 79	1381	26.5									
(400, 403)	558.26	1396	565.3	133.1	698.4	0.81	1.25	0.24	30.0	5.7	0.0
0.0 0	1396	48.0									
(403, 400)	709.42	1774	718.4	1026.8	1745.2	0.41	2.46	1.45	59.0	34.7	26.7
26.2 71	1774	24.4									
(400, 401)	407.50	1019	412.6	114.3	526.9	0.78	1.29	0.28	31.0	6.7	0.0
0.0 0	1019	46.4									
(401, 400)	508.67	1272	515.1	683.9	1199.0	0.43	2.36	1.34	56.6	32.3	23.8
23.2 62	1272	25.5									
(202, 200)	174.76	437	177.0	261.0	438.0	0.40	2.51	1.49	60.1	35.8	30.8
30.2 87	437	23.9									
(200, 202)	88.52	223	89.6	18.3	108.0	0.83	1.22	0.21	29.0	4.9	0.1
0.0 0	223	49.2									
(200, 201)	10.06	106	10.2	3.6	13.8	0.74	1.37	0.35	7.8	2.0	0.1
0.0 0	106	43.9									
(220, 222)	4.63	47	4.7	3.2	7.9	0.59	1.71	0.70	10.1	4.1	0.3
0.0 0	47	35.1									
(222, 220)	0.40	4	0.4	2.2	2.6	0.16	6.46	5.45	38.8	32.7	30.8
30.8 100	4	9.3									
(240, 242)	1.77	18	1.8	1.2	3.0	0.59	1.71	0.70	10.1	4.1	0.2
0.0 0	18	35.1									
(242, 240)	14.40	144	14.6	33.7	48.3	0.30	3.36	2.34	20.1	14.1	11.1
11.0 100	144	17.9									
(300, 301)	10.89	117	11.0	7.8	18.8	0.59	1.73	0.71	9.6	4.0	0.1
0.0 0	117	34.8									
(301, 300)	17.70	177	17.9	35.2	53.1	0.34	3.00	1.99	18.0	11.9	7.5
7.3 59	177	20.0									
(310, 311)	21.85	222	22.1	16.0	38.1	0.58	1.74	0.73	10.3	4.3	0.3
0.0 0	222	34.4									
(311, 310)	14.10	141	14.3	63.8	78.1	0.18	5.54	4.53	33.2	27.1	23.0
22.5 100	141	10.8									
(403, 401)	26.79	94	27.1	11.1	38.2	0.71	1.43	0.41	24.4	7.1	2.8
2.8 21	94	42.1									
(400, 402)	7.15	143	7.2	7.6	14.9	0.49	2.08	1.06	6.2	3.2	0.4
0.0 0	143	28.9									

```
 ( 100, 200)  251.13  1795    254.3    279.4    533.7     0.48    2.13    1.11      17.8     9.3     4.5
4.2      36   1795    28.2
 ( 200, 220)  201.90  1658    204.4    192.2    396.6     0.52    1.96    0.95      14.4     7.0     0.2
0.1       0   1658    30.5
 ( 220, 240)  148.29  1611    150.2    172.9    323.0     0.46    2.18    1.17      12.0     6.4     0.4
0.0       0   1611    27.5
 ( 240, 300)  557.80  1711    564.8    542.4   1107.2     0.51    1.98    0.97      38.8    19.0    11.9
11.3     49   1711    30.2
 ( 300, 400)  483.23  2345    489.3   1122.7   1612.0     0.30    3.34    2.32      41.2    28.7    20.9
20.2     51   2345    18.0
 ( 400, 300)  546.26  2619    553.1   1899.2   2452.4     0.23    4.49    3.48      56.2    43.5    30.0
28.1     74   2619    13.4
 ( 300, 310)  510.80  2244    517.2    396.4    913.7     0.57    1.79    0.78      24.4    10.6     1.5
0.5       4   2244    33.5
 ( 310, 200)  676.69  2183    685.2    555.7   1240.9     0.55    1.83    0.82      34.1    15.3     8.4
7.8      41   2183    32.7
 ( 200, 100)  347.45  2365    351.8    541.4    893.2     0.39    2.57    1.56      22.7    13.7     6.1
5.6      43   2365    23.3
0SUBNETWORK= 9451.55  8005  159.51   172.52   332.03     0.48    2.11    1.10      2.49    1.29    0.74
0.70  156.1           28.5
                              -- VEHICLE - HOURS --                               --- MINUTES / VEHICLE-
TRIP ---      PER

TRIP

1                                          CUMULATIVE NETSIM STATISTICS AT TIME 14: 0: 0

                       ELAPSED TIME IS  1: 0: 0 ( 3600 SECONDS),    TIME PERIOD  1 ELAPSED TIME IS
3600 SECONDS


                  VEH-MINS *    AVERAGE   -- CONGESTION --    ------------     Q U E U E   L E N G T
H  (VEHICLE)      ------------     NUMBER
                QUEUE     STOP  OCCUPANCY   STORAGE    PHASE           AVERAGE QUEUE BY LANE **
MAXIMUM QUEUE BY LANE      OF LANE
    LINK        TIME     TIME  (VEHICLE)     (%)     FAILURE     1     2     3     4     5     6     7
1   2   3   4   5   6   7  CHANGES
    ----        -------------  ---------  ----------------     -     -     -     -     -     -     -
-   -   -   -   -   -   -
```

(101, 100)	318.3	310.9	13.6	7.6	1	0	3	3	0	0	0	0
3	10	11	0	0	0	0	892				
(100, 101)	1.0	0.0	13.6	11.4	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	436				
(104, 100)	502.9	490.7	22.1	12.3	18	2	3	4	0	0	0	0
10	10	11	0	0	0	0	1258				
(100, 104)	0.8	0.0	13.2	7.4	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	275				
(300, 302)	0.4	0.0	8.7	4.9	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	367				
(302, 300)	433.0	396.1	21.0	16.8	4	2	4	0	0	0	0	3
18	13	0	0	0	0	7	641				
(400, 403)	1.0	0.0	12.1	6.8	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	546				
(403, 400)	803.9	788.5	29.6	16.5	0	4	5	7	0	0	0	0
15	18	21	0	0	0	0	875				
(400, 401)	0.4	0.0	9.1	5.1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	479				
(401, 400)	514.6	502.6	20.3	8.5	9	2	1	1	6	0	0	0
13	5	4	23	0	0	0	1522				
(202, 200)	227.1	223.2	7.7	4.3	1	0	2	2	0	0	0	0
2	10	10	0	0	0	0	426				
(200, 202)	0.2	0.0	2.1	1.8	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	76				
(200, 201)	0.2	0.0	0.4	1.3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	3				
(220, 222)	0.2	0.0	0.3	0.8	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0				
(222, 220)	2.0	2.0	0.1	0.5	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0				
(240, 242)	0.1	0.0	0.1	0.3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	3				
(242, 240)	26.7	26.3	1.4	9.4	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0				
(300, 301)	0.1	0.0	0.5	3.3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0				
(301, 300)	22.0	21.6	1.4	9.6	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0				
(310, 311)	1.3	0.0	0.9	6.3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0				

```
 ( 311, 310)    54.5    53.2      1.8      12.3        0       1     0     0     0     0     0     0
4   0   0   0   0   0   0       0
 ( 403, 401)     4.5     4.5      1.2       2.9        0       0     0     0     0     0     0     0
2   0   0   0   0   0   0       0
 ( 400, 402)     0.9     0.0      0.3       4.2        0       0     0     0     0     0     0     0
0   0   0   0   0   0   0       0
 ( 100, 200)   135.8   125.1      9.3      13.9        0       0     1     1     0     0     0     0
6   8  10   0   0   0   3     462
 ( 200, 220)     5.9     2.3      6.9      12.6        0       0     0     0     0     0     0     0
0   0   0   0   0   0   0     250
 ( 220, 240)    11.2     0.0      5.7      13.9        0       0     0     0     0     0     0     0
0   0   0   0   0   0   0      79
 ( 240, 300)   344.4   328.7     19.3      12.1        2       2     2     2     0     0     0     1
16  14  14   0   0   4   6     419
 ( 300, 400)   817.0   790.7     27.3      24.9        0       1     0     4     0     0     0     8
15  11  21   0   0   0  17    1931
 ( 400, 300)  1323.6  1238.6     41.2      37.8       14       3     3     7     0     0     0     9
21  26  34   0   0   0  17    1771
 ( 300, 310)    58.3    20.7     15.6      15.3        0       0     0     0     0     0     0     0
5   1   0   0   0   0   0     889
 ( 310, 200)   306.7   285.6     21.2      14.7        4       2     1     1     0     0     0     2
11  13   7   0   0   0   7     759
 ( 200, 100)   243.1   220.8     15.3      21.6        0       1     1     1     0     0     0     1
8   7   9   0   0   0   6    1066
0SUBNETWORK=  6162.2  5832.1    343.3      11.0       53
15425

                  *  THESE VALUES INCLUDE THE TIME FOR VEHICLES CURRENTLY ON THE LINK.
                  ** AVERAGE QUEUE CALCULATED BASED ON TIME SINCE BEGINNING OF SIMULATION
```

1

CUMULATIVE NETSIM STATISTICS AT TIME 14: 0: 0

ELAPSED TIME IS 1: 0: 0 (3600 SECONDS), TIME PERIOD 1 ELAPSED TIME IS 3600 SECONDS

DISCHARGE BY LANE

LINK	LANE 1 VEH	LANE 1 VPH	LANE 2 VEH	LANE 2 VPH	LANE 3 VEH	LANE 3 VPH	LANE 4 VEH	LANE 4 VPH	LANE 5 VEH	LANE 5 VPH	LANE 6 VEH	LANE 6 VPH	LANE 7 VEH	LANE 7 VPH
(101, 100)	113	113	390	390	439	439	0	0	0	0	0	0	0	0
(100, 101)	872	872	691	691	0	0	0	0	0	0	0	0	0	0
(104, 100)	863	863	388	388	361	361	0	0	0	0	0	0	0	0
(100, 104)	468	468	514	514	481	481	0	0	0	0	0	0	0	0
(300, 302)	319	319	323	323	322	322	0	0	0	0	0	0	0	0
(302, 300)	102	102	212	212	0	0	0	0	0	0	0	0	1067	1067
(400, 403)	483	483	497	497	416	416	0	0	0	0	0	0	0	0
(403, 400)	543	543	592	592	639	639	0	0	0	0	0	0	0	0
(400, 401)	265	265	345	345	409	409	0	0	0	0	0	0	0	0
(401, 400)	820	820	72	72	70	70	310	310	0	0	0	0	0	0
(202, 200)	32	32	202	202	203	203	0	0	0	0	0	0	0	0
(200, 202)	108	108	115	115	0	0	0	0	0	0	0	0	0	0

(200, 201)	42	42	64	64	0	0	0	0	0	0	0	0	0	0
(220, 222)	47	47	0	0	0	0	0	0	0	0	0	0	0	0
(222, 220)	4	4	0	0	0	0	0	0	0	0	0	0	0	0
(240, 242)	15	15	3	3	0	0	0	0	0	0	0	0	0	0
(242, 240)	144	144	0	0	0	0	0	0	0	0	0	0	0	0
(300, 301)	117	117	0	0	0	0	0	0	0	0	0	0	0	0
(301, 300)	177	177	0	0	0	0	0	0	0	0	0	0	0	0
(310, 311)	222	222	0	0	0	0	0	0	0	0	0	0	0	0
(311, 310)	141	141	0	0	0	0	0	0	0	0	0	0	0	0
(403, 401)	94	94	0	0	0	0	0	0	0	0	0	0	0	0
(400, 402)	143	143	0	0	0	0	0	0	0	0	0	0	0	0
(100, 200)	719	719	550	550	391	391	0	0	0	0	0	0	37	37
(200, 220)	676	676	523	523	459	459	0	0	0	0	0	0	0	0
(220, 240)	591	591	549	549	471	471	0	0	0	0	0	0	0	0
(240, 300)	527	527	490	490	452	452	0	0	0	0	198	198	41	41
(300, 400)	641	641	296	296	580	580	0	0	0	0	0	0	617	617
(400, 300)	1036	1036	564	564	546	546	0	0	0	0	0	0	469	469
(300, 310)	931	931	683	683	630	630	0	0	0	0	0	0	0	0
(310, 200)	786	786	819	819	419	419	0	0	0	0	0	0	181	181
(200, 100)	337	337	457	457	559	559	0	0	0	0	0	0	1012	1012

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NETSIM PERSON MEASURES OF EFFECTIVENESS

LINK	PERSON KM	PERSON TRIPS	DELAY PERSON-MIN	TRAVEL TIME PERSON-MIN
(101, 100)	489.0	1222.8	536.6	1031.8
(100, 101)	793.6	2029.5	228.2	1031.7
(104, 100)	836.3	2091.4	858.5	1705.4
(100, 104)	758.7	1899.9	231.8	1000.0
(300, 302)	496.0	1251.0	136.9	639.1
(302, 300)	717.6	1794.5	898.0	1624.7
(400, 403)	724.6	1812.0	172.8	906.5
(403, 400)	920.8	2302.7	1332.8	2265.3
(400, 401)	529.2	1323.4	148.4	684.3
(401, 400)	660.4	1651.3	887.9	1556.6
(202, 200)	227.2	568.1	339.4	569.4
(200, 202)	115.0	289.6	23.8	140.2
(200, 201)	13.1	137.6	4.6	17.8
(220, 222)	6.0	61.0	4.2	10.3
(222, 220)	0.5	5.2	2.8	3.4

(240, 242)	2.3	23.2	1.6	3.9
(242, 240)	18.7	187.2	43.8	62.8
(300, 301)	14.2	152.0	10.1	24.4
(301, 300)	23.0	230.1	45.7	69.0
(310, 311)	28.4	288.2	20.7	49.5
(311, 310)	18.3	183.3	82.9	101.5
(403, 401)	34.7	121.8	14.4	49.5
(400, 402)	9.3	185.8	9.9	19.3
(100, 200)	325.9	2329.5	362.6	692.6
(200, 220)	262.0	2151.8	249.4	514.8
(220, 240)	192.5	2090.8	224.4	419.2
(240, 300)	724.1	2221.0	704.1	1437.2
(300, 400)	627.5	3045.0	1457.8	2093.2
(400, 300)	709.0	3399.3	2465.1	3183.0
(300, 310)	663.3	2913.8	514.8	1186.4
(310, 200)	878.8	2835.0	721.7	1611.6
(200, 100)	451.3	3071.9	703.2	1160.2

1 *** NOTE *** TIME PERIOD 1 SPECIFIC NETSIM STATISTICS ARE THE SAME AS CUMULATIVE OUTPUT AT THE END OF TIME PERIOD 1.

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NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE I

LINK	VEHICLE-KM LEFT	VEHICLE-KM THRU	VEHICLE-KM RIGHT	VEHICLE-TRIPS LEFT	VEHICLE-TRIPS THRU	VEHICLE-TRIPS RIGHT	SPEED (KMPH) LEFT	SPEED (KMPH) THRU	SPEED (KMPH) RIGHT	STOPS (PCT) LEFT	STOPS (PCT) THRU	STOPS (PCT) RIGHT
(8101, 101)				0	940	0						
(8104, 104)				0	1607	0						
(8202, 202)				0	437	0						
(8222, 222)				0	4	0						
(8242, 242)				0	144	0						
(8302, 302)				0	1374	0						
(8301, 301)				0	177	0						
(8311, 311)				0	142	0						
(8403, 403)				0	1886	0						
(8401, 401)				0	1272	0						
(101, 100)	331.52	0.00	45.19	829	0	113	27.1	0.0	43.8	77.9	0.0	78.8
(100, 101)	0.00	611.16	0.00	0	1563	0	0.0	46.1	0.0	0.0	0.0	0.0
(104, 100)	218.74	425.89	0.00	547	1065	0	20.3	38.3	0.0	97.1	51.5	0.0
(100, 104)	0.00	584.19	0.00	0	1463	0	0.0	45.5	0.0	0.0	0.0	0.0
(300, 302)	0.00	382.18	0.00	0	964	0	0.0	46.6	0.0	0.0	0.0	0.0
(302, 300)	113.97	11.60	426.69	285	29	1067	17.0	18.3	31.6	88.4	82.8	76.8
(400, 403)	0.00	558.26	0.00	0	1396	0	0.0	48.0	0.0	0.0	0.0	0.0
(403, 400)	0.00	709.42	0.00	0	1774	0	0.0	24.4	0.0	0.0	71.2	0.0
(400, 401)	0.00	407.50	0.00	0	1019	0	0.0	46.4	0.0	0.0	0.0	0.0
(401, 400)	123.57	57.19	327.92	309	143	820	15.8	21.5	34.5	88.0	76.2	51.0

(202, 200)	149.96	12.00	12.80	375	30	32	23.3	22.9	36.6	88.3	90.0	81.3
(200, 202)	0.00	88.52	0.00	0	223	0	0.0	49.2	0.0	0.0	0.0	0.0
(200, 201)	0.00	10.06	0.00	0	106	0	0.0	43.9	0.0	0.0	0.0	0.0
(220, 222)	0.00	4.63	0.00	0	47	0	0.0	35.1	0.0	0.0	0.0	0.0
(222, 220)	0.00	0.00	0.40	0	0	4	0.0	0.0	9.3	0.0	0.0	100.0
(240, 242)	0.00	1.77	0.00	0	18	0	0.0	35.1	0.0	0.0	0.0	0.0
(242, 240)	0.00	0.00	14.40	0	0	144	0.0	0.0	17.9	0.0	0.0	100.0
(300, 301)	0.00	10.89	0.00	0	117	0	0.0	34.8	0.0	0.0	0.0	0.0
(301, 300)	0.00	0.00	17.70	0	0	177	0.0	0.0	20.0	0.0	0.0	59.9
(310, 311)	0.00	21.85	0.00	0	222	0	0.0	34.4	0.0	0.0	0.0	0.0
(311, 310)	0.00	0.00	14.10	0	0	141	0.0	0.0	10.8	0.0	0.0	100.0
(403, 401)	0.00	26.79	0.00	0	94	0	0.0	42.1	0.0	0.0	21.3	0.0
(400, 402)	0.00	7.15	0.00	0	143	0	0.0	28.9	0.0	0.0	0.0	0.0
(100, 200)	5.88	238.54	6.72	42	1705	48	9.5	29.7	28.7	78.6	35.1	41.7
(200, 220)	0.00	196.18	5.72	0	1611	47	0.0	30.7	26.9	0.0	0.8	0.0
(220, 240)	0.00	146.63	1.66	0	1593	18	0.0	27.5	28.3	0.0	0.0	0.0
(240, 300)	13.37	479.89	64.55	41	1472	198	14.8	30.3	37.8	85.4	51.7	29.8
(300, 400)	238.42	244.81	0.00	1157	1188	0	14.3	24.1	0.0	71.2	36.0	0.0
(400, 300)	161.02	375.23	10.01	772	1799	48	8.8	17.1	18.6	89.4	67.6	68.8
(300, 310)	0.00	460.04	50.76	0	2021	223	0.0	34.1	29.4	0.0	4.0	12.1

(310, 200)	56.11	608.50	12.09	181	1963	39	16.9	35.8	33.2	94.5	37.1	41.0
(200, 100)	0.00	198.77	148.68	0	1353	1012	0.0	22.6	24.4	0.0	39.1	49.7

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NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE II

LINK	MOVING TIME (VEH-MINS)			DELAY TIME (VEH-MINS)			TOTAL TIME (VEH-MINS)			RATIO MOVE/TOTAL (VEH-MINS)		
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT
(8101, 101)												
(8104, 104)												
(8202, 202)												
(8222, 222)												
(8242, 242)												
(8302, 302)												
(8301, 301)												
(8311, 311)												
(8403, 403)												
(8401, 401)												
(101, 100)	335.69	0.00	45.76	397.17	0.00	16.21	732.87	0.00	61.97	0.46	0.00	0.74
(100, 101)	0.00	632.92	0.00	0.00	161.66	0.00	0.00	794.58	0.00	0.00	0.80	0.00
(104, 100)	221.50	431.26	0.00	425.38	236.34	0.00	646.88	667.60	0.00	0.34	0.65	0.00
(100, 104)	0.00	592.42	0.00	0.00	177.61	0.00	0.00	770.03	0.00	0.00	0.77	0.00
(300, 302)	0.00	390.36	0.00	0.00	102.14	0.00	0.00	492.50	0.00	0.00	0.79	0.00
(302, 300)	115.41	11.74	432.07	285.68	26.27	379.15	401.08	38.02	811.22	0.29	0.31	0.53
(400, 403)	0.00	565.29	0.00	0.00	133.11	0.00	0.00	698.40	0.00	0.00	0.81	0.00

(403, 400)	0.00	718.36	0.00	0.00	1026.79	0.00	0.00	1745.15	0.00	0.00	0.41	0.00
(400, 401)	0.00	412.63	0.00	0.00	114.30	0.00	0.00	526.93	0.00	0.00	0.78	0.00
(401, 400)	125.13	57.91	332.05	344.42	101.81	237.70	469.55	159.72	569.75	0.27	0.36	0.58
(202, 200)	151.85	12.15	12.96	233.70	19.35	7.99	385.55	31.50	20.95	0.39	0.39	0.62
(200, 202)	0.00	90.30	0.00	0.00	17.67	0.00	0.00	107.97	0.00	0.00	0.84	0.00
(200, 201)	0.00	10.73	0.00	0.00	3.02	0.00	0.00	13.75	0.00	0.00	0.78	0.00
(220, 222)	0.00	4.76	0.00	0.00	3.16	0.00	0.00	7.92	0.00	0.00	0.60	0.00
(222, 220)	0.00	0.00	0.40	0.00	0.00	2.18	0.00	0.00	2.58	0.00	0.00	0.16
(240, 242)	0.00	1.82	0.00	0.00	1.21	0.00	0.00	3.03	0.00	0.00	0.60	0.00
(242, 240)	0.00	0.00	14.58	0.00	0.00	33.72	0.00	0.00	48.30	0.00	0.00	0.30
(300, 301)	0.00	11.84	0.00	0.00	6.96	0.00	0.00	18.80	0.00	0.00	0.63	0.00
(301, 300)	0.00	0.00	17.92	0.00	0.00	35.16	0.00	0.00	53.08	0.00	0.00	0.34
(310, 311)	0.00	22.47	0.00	0.00	15.63	0.00	0.00	38.10	0.00	0.00	0.59	0.00
(311, 310)	0.00	0.00	14.27	0.00	0.00	63.79	0.00	0.00	78.07	0.00	0.00	0.18
(403, 401)	0.00	27.13	0.00	0.00	11.09	0.00	0.00	38.22	0.00	0.00	0.71	0.00
(400, 402)	0.00	7.24	0.00	0.00	7.61	0.00	0.00	14.85	0.00	0.00	0.49	0.00
(100, 200)	5.95	241.54	6.80	31.10	241.07	7.23	37.05	482.62	14.03	0.16	0.50	0.48
(200, 220)	0.00	198.89	5.80	0.00	184.98	6.98	0.00	383.87	12.78	0.00	0.52	0.45
(220, 240)	0.00	148.48	1.68	0.00	171.03	1.84	0.00	319.52	3.52	0.00	0.46	0.48
(240, 300)	13.54	486.12	65.39	40.54	464.46	37.16	54.08	950.58	102.55	0.25	0.51	0.64

(300, 400)	247.11	253.73	0.00	755.42	355.73	0.00	1002.53	609.47	0.00	0.25	0.42	0.00
(400, 300)	164.17	382.57	10.21	938.48	934.87	22.09	1102.65	1317.43	32.30	0.15	0.29	0.32
(300, 310)	0.00	466.58	51.48	0.00	343.46	52.15	0.00	810.03	103.63	0.00	0.58	0.50
(310, 200)	56.81	616.16	12.24	142.04	404.07	9.59	198.85	1020.23	21.83	0.29	0.60	0.56
(200, 100)	0.00	201.28	150.55	0.00	326.54	214.82	0.00	527.82	365.37	0.00	0.38	0.41

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NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE III

LINK	TOTAL TIME (SECS/VEH)			DELAY TIME (SECS/VEH)			QUEUE TIME** (VEH-MINS)			STOP TIME** (VEH-MINS)		
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT
(8101, 101)												
(8104, 104)												
(8202, 202)												
(8222, 222)												
(8242, 242)												
(8302, 302)												
(8301, 301)												
(8311, 311)												
(8403, 403)												
(8401, 401)												
(101, 100)	53.0	0.0	32.9	28.7	0.0	8.6	309.6	0.0	8.6	302.5	0.0	8.3
(100, 101)	0.0	30.5	0.0	0.0	6.2	0.0	0.0	1.0	0.0	0.0	0.0	0.0
(104, 100)	71.0	37.6	0.0	46.7	13.3	0.0	361.8	141.1	0.0	356.2	134.4	0.0
(100, 104)	0.0	31.6	0.0	0.0	7.3	0.0	0.0	0.8	0.0	0.0	0.0	0.0
(300, 302)	0.0	30.7	0.0	0.0	6.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0

(302, 300)	84.4	78.7	45.6	60.1	54.4	21.3	250.9	21.3	160.8	247.9	20.5	127.8
(400, 403)	0.0	30.0	0.0	0.0	5.7	0.0	0.0	1.0	0.0	0.0	0.0	0.0
(403, 400)	0.0	59.0	0.0	0.0	34.7	0.0	0.0	803.9	0.0	0.0	788.5	0.0
(400, 401)	0.0	31.0	0.0	0.0	6.7	0.0	0.0	0.4	0.0	0.0	0.0	0.0
(401, 400)	91.2	67.0	41.7	66.9	42.7	17.4	313.1	91.5	109.9	310.0	90.6	102.0
(202, 200)	61.7	63.0	39.3	37.4	38.7	15.0	204.3	16.5	6.3	200.9	16.1	6.2
(200, 202)	0.0	29.0	0.0	0.0	4.8	0.0	0.0	0.2	0.0	0.0	0.0	0.0
(200, 201)	0.0	7.8	0.0	0.0	1.7	0.0	0.0	0.2	0.0	0.0	0.0	0.0
(220, 222)	0.0	10.1	0.0	0.0	4.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
(222, 220)	0.0	0.0	38.8	0.0	0.0	32.7	0.0	0.0	2.0	0.0	0.0	2.0
(240, 242)	0.0	10.1	0.0	0.0	4.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
(242, 240)	0.0	0.0	20.1	0.0	0.0	14.1	0.0	0.0	26.7	0.0	0.0	26.3
(300, 301)	0.0	9.6	0.0	0.0	3.6	0.0	0.0	0.1	0.0	0.0	0.0	0.0
(301, 300)	0.0	0.0	18.0	0.0	0.0	11.9	0.0	0.0	22.0	0.0	0.0	21.6
(310, 311)	0.0	10.3	0.0	0.0	4.2	0.0	0.0	1.3	0.0	0.0	0.0	0.0
(311, 310)	0.0	0.0	33.2	0.0	0.0	27.1	0.0	0.0	54.5	0.0	0.0	53.2
(403, 401)	0.0	24.4	0.0	0.0	7.1	0.0	0.0	4.5	0.0	0.0	4.5	0.0
(400, 402)	0.0	6.2	0.0	0.0	3.2	0.0	0.0	0.9	0.0	0.0	0.0	0.0
(100, 200)	52.9	17.0	17.5	44.4	8.5	9.0	27.6	104.3	3.9	27.5	94.0	3.6
(200, 220)	0.0	14.3	16.3	0.0	6.9	8.9	0.0	4.5	1.4	0.0	1.1	1.1

(220, 240)	0.0	12.0	11.7	0.0	6.4	6.1	0.0	11.1	0.1	0.0	0.0	0.0
(240, 300)	79.1	38.7	31.1	59.3	18.9	11.3	36.4	300.0	8.1	35.9	285.8	6.9
(300, 400)	52.0	30.8	0.0	39.2	18.0	0.0	608.3	208.7	0.0	595.2	195.6	0.0
(400, 300)	85.7	43.9	40.4	72.9	31.2	27.6	753.9	557.7	12.0	729.2	498.4	11.0
(300, 310)	0.0	24.0	27.9	0.0	10.2	14.0	0.0	45.8	12.4	0.0	13.9	6.8
(310, 200)	65.9	31.2	33.6	47.1	12.4	14.8	121.3	181.1	4.3	119.0	162.9	3.8
(200, 100)	0.0	23.4	21.7	0.0	14.5	12.7	0.0	196.2	46.9	0.0	186.1	34.7

** TIME FOR VEHICLES CURRENTLY ON THE LINK ARE INCLUDED IN THESE VALUES.

THE HIGHEST NUMBER OF VEHICLES ON THE NETWORK WAS 399 VEHICLES (MAXIMUM ALLOWED IS 3500).
THIS MAXIMUM OCCURED AT 3209 SECONDS.

TOTAL CPU TIME FOR SIMULATION = 215.47 SECONDS
TOTAL CPU TIME FOR THIS RUN = 215.47 SECONDS
0LAST CASE PROCESSED

VITA

Sami Said Ghezawi, a Jordanian-American citizen, was born in Jordan on April 16, 1960. He attended public school in Knoxville, Tennessee and graduated from Holston High School in June 1978. He then attended the University of Tennessee at Knoxville and received a Bachelor of Science in Civil Engineering on March 18, 1983. During his military service in the Jordanian Armed Forces, he was an instructor in algebra from 1984 to 1986. Upon his return to the United States, he entered the Master's Program at the University of Tennessee, Knoxville and obtained his Master of Science Degree in Civil Engineering (Transportation) on June 1, 1988. His thesis work involved observing both deceleration rates for vehicles and driver reactions while approaching a Traffic Signal on Chapman Hwy. , entitled " An Evaluation of a Traffic Signal with a White Bar Strobe Light". He employed his education in the engineering sciences at the Greater City of Amman Municipality as a City Traffic Engineer from 1988 to 1991. As a Traffic Engineer he designed and evaluated traffic signal plans, traffic signs and roadway markings, and was involved in several transportation management studies. In the spring of 1992 he reentered the Graduate School at the University of Tennessee, Knoxville to acquire his Doctorate in Transportation. He held a position as a graduate teacher associate at the University in the Civil and Environmental Engineering Department while completing his courses. The Doctor of Philosophy Degree with a major in Civil Engineering was earned and received in December 1999. Sami Said Ghezawi plans to follow a career in higher education in Amman, Jordan.