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ANALYSIS OF THE APPLICABILITY OF A NETWORK SIMULATION MODEL TO TRAFFIC PERFORMANCE IN THE CITY OF JEDDAH, SAUDI ARABIA

By

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ABSTRACT

ANALYSIS OF THE APPLICABILITY OF A NETWORK SIMULATION MODEL TO TRAFFIC PERFORMANCE IN THE CITY OF JEDDAH, SAUDI ARABIA

By

Hamed O. Albar

The practicing traffic engineer has long needed a problem-solving aid to deal with the increasingly sophisticated and complex urban traffic flow problem. To understand the behavior of an urban street system and to evaluate various corrective strategies implemented on such a system, one has to construct a model that best represents the internal relationship among components and accurately predicts the system performance. Due to the size of the urban street network and the random nature among vehicles and drivers, it is impossible to use an analytical approach to model such a system. On the other hand, a simulation model becomes appealing in modeling the large urban network. Furthermore, with the aid of modern digital computer technology, it is economical and practical to apply digital computer simulation modeling in solving vehicular movement problems on a large urban street network.

Among all network simulation models, NETSIM is the most widely used and among the most extensively validated models. This research was conducted to calibrate the NETSIM model to be used in analyzing the traffic performance in Saudi Arabia. A calibration network was selected in the city of Jeddah, and all the required input data were collected from the field. Data on four selected measures of performance were collected, and the program was modified until the model output matched these data. A validation network was then selected in the same city, and the model performance was tested. It was found that the traffic performance in Saudi Arabia can be simulated and analyzed using a modified NETSIM model.

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

In the name of Allah the most merciful and the most beneficient

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CHAPTER 1

INTRODUCTION TO THE STUDY

1.1 Introduction

In the early 1970s, as the price of oil started to increase rapidly, oil revenue began to grow and Saudi Arabia became one of the rich states in the Middle East. Therefore, the government initiated an ambitious five-year development plan whose objective was to change the country from a pre-industrial society to a modern industrialized country. This rapid development exerted pressure on all public utilities and facilities including the transportation system in the country as a whole, and in major cities such as Jeddah in particular.

Jeddah, the second major city in Saudi Arabia, after the capital, Rijadh, lies in the West province by the Red Sea. It is midway between Aden and Suez, at the hub of a major highway system. It serves a dual function. It is the main commercial port for the western part of the country and also a chief point of entry for pilgrims to Makkah from throughout the Moslem World. It also has the biggest and busiest airport in the country. It is a major commercial and economic activity center. A substantial majority of all bank offices in the Western Region are in Jeddah. There are several small and medium-sized factories located in the industrial zone in the city. Jeddah is also the diplomatic center of the kingdom where all the embassies and consulates except the Ministry of Foreign Affairs are located. The city has one of the major universities in the country. In the last seven years the city has experienced a remarkable growth rate. Its population has increased from about 600,000 in 1974 to approximately one million persons in 1981. The metropolitan area is about 100 square miles (35).

This expansion in area and population has influenced the traffic performance in the city. While there is considerable traffic between Jeddah and other cities and rural areas, like most cities, the road system is most congested during peak periods. Table 1.1 shows that the number of vehicles registered increased 52 times between 1971 and 1981 to reach 690,073 vehicles (34). By 1991, the number of registered vehicles in Jeddah is anticipated to increase nearly fourfold for the low population forecast and nearly ninefold for the high population forecast (base year is 1974) (39).

The study of motor vehicle accidents in Jeddah between 1971 and 1981 shows that the number of accidents increased from 347 in 1971 to 2,530 in 1981, an increase of about 730 percent. In 1981, there were slightly less than four accidents per thousand vehicles and 2,997 injuries, a rate of 1.18 injuries per accident.

The number of persons killed in traffic accidents, as shown in Table 1.1, increased from 75 in 1971 to 323 in 1981. The fatality rates (number of fatalities per 1,000 vehicles) in 1980 and 1981 in Jeddah were 0.56 and 0.50, respectively. Table 1.2 shows that these rates in the United States were 0.31 and 0.30, respectively. The table

Table 1.1.--Vehicle and accident statistics in Jeddah.

Year	No. of Vehicles	No. of Fatalities	Fatalities per 1,000 Vehicles	Number Injured	Injured per 1,000 Vehicles	No. of Acci- dents
1971	13,217	75	5.7	394	30	347
1972	25,096	65	2.6	543	22	576
1973	40,950	159	3.9	1,282	31	1,081
1974	72,269	142	2.0	1,959	27	1,531
1975	113,224	206	1.8	2,790	25	2,160
1976	185,545	287	1.5	3,340	18	2,779
1977	264,266	285	1.1	2,410	9	2,341
1978	383,108	295	0.77	3,270	9	2,607
1979	475,425	341	0.72	3,439	7	2,809
1980	602,639	342	0.56	3,387	6	2,732
1981	690,073	323	0.50	2,997	4	2,530

Table 1.2.--Vehicle and accident statistics in Kuwait and the United States.

Year	No. of Vehicles	No. of Fatalities	Fatalities per 1,000 Vehicles	Number Injured	Injured per 1,000 Vehicles
1971	158,446	233	1.5	2,718	17
1972	175,526	253	1.4	2,869	16
1973	197,777	231	1.2	2,902	15
1974	223,788	304	1.4	2,944	13
1975	272,232	367	1.3	3,168	12
1976	320,656	307	0.96	3,545	11
1977	379,101	321	0.85	3.702	10
1978	439,553	361	0.82	3,588	8
1980	164,852,000	51,077	0.31	...	..
1981	165,732,000	49,268	0.30	...	..

shows that the fatality and injury rates in Jeddah are also higher than those in Kuwait (41), a developing country close to Saudi Arabia.

In another comparison, the number of traffic fatalities per 1,000 population in the United States was 0.23 in 1980 (36), in Jeddah it was 0.43, and in Saudi Arabia it was 0.48. Table 1.3 shows that most of the accidents occur in the city, and Table 1.4 shows that most of the accidents are either run into vehicles (multiple vehicle) or run on humans (pedestrian accidents). The high rate of these types of accidents may be due to inefficient signal timing and a lack of coordination between signals.

There are approximately 120 traffic signals in the City of Jeddah, and there is an average of 20 accidents per month at these signalized intersections (49). All the signals are fixed time (no actuated), and there are no progressive systems in the city. There are no published studies on delay and congestion at intersections, but experience indicates that many major intersections are congested and oversaturated. Appendix A shows more detailed statistics on driver and traffic characteristics in Jeddah.

1.2 The Problem

The expansion of many cities in the world has made the daily movement of people and goods an increasingly complex problem. Since cities depend largely on their street systems for transportation services, the traffic engineer has the responsibility of optimizing traffic flow and safety for the benefit of the population.

Table 1.3.--Number of traffic accidents in Jeddah (1976-1981) by time and place of accident.

Year	Day	%	Evening	%	In City	%	Out of City	%
1976	1,494	54	1,285	46	2,375	85	404	15
1977	1,512	65	829	35	1,864	80	477	20
1978	1,740	67	867	33	2,140	82	467	18
1979	1,943	69	866	31	2,274	81	535	19
1980	1,813	66	919	34	2,411	88	321	12
1981	1,447	57	1,083	43	1,956	77	574	23

Table 1.4.--Number of accidents by type in Jeddah (1978-1981).

Year	Run Into		Run On		Fire	Run Down	Go Off Road	Other
	Vehicle	Other	Human	Animal				
1978	1,169	142	849	5	2	344	5	91
1979	1,297	90	914	4	3	417	13	71
1980	1,169	133	987	..	1	331	16	95
1981	1,077	125	843	6	17	335	8	119

The evaluation of comprehensive street system improvements is complicated by the large number of alternatives available, the interrelationships among the design variables, and the infeasibility of conducting large-scale experiments to test design options. In most cases, limitations of time and cost, together with the need to avoid undue disturbance of existing traffic movements, make extensive field experimentation impossible. In addition, the consequences of experimentation can include accidents, injuries, and even human life.

The introduction of computer-based mathematical simulation models has enabled traffic engineers to determine the effectiveness of proposed changes in the transportation system without actually implementing and testing them. The digital computer is particularly effective in providing the medium for exercising traffic simulation models and their interaction with external management and control measures. Thus it provides the analyst with a very convenient laboratory for experimentation, evaluation, and design.

These simulation models are designed to represent the behavior of the physical system if all the variables affecting the traffic system are identified within the model. Such variables include: road and intersection geometrics, traffic flow and volume, speed and turning movements, type of control, timing plans, and traffic composition.

In developed countries, such as the United States, these variables are generally easy to measure. In fact, there are numerous studies that have used the most sophisticated equipment and methods to collect and gather data to be used in the models. In addition, computerized filing systems are available to recall detailed historical traffic data. In contrast, in developing countries such as Saudi Arabia, the data-collection system is undeveloped and very few traffic studies have been conducted. Most of the data collection is done manually.

Since driver performance characteristics differ from one society to another, depending upon their experience with modern technology, traffic variables such as headway distributions, gap acceptance, turning speeds, and signal phase response will also be different. The pedestrian behavior also differs between Saudi Arabia and the United States, as people are not accustomed to crossing the streets at intersections only or when the signal permits. Pedestrian conflicts are more prevalent, and greater delay in moving in the network is expected.

Therefore, to use existing simulation models for analyzing and improving traffic performance, at least calibration of the data is needed, if not further modification and variation in the simulation program.

1.3 Objectives of the Study

This research is designed to achieve the following objectives:

1. To explore similarities and differences in traffic performance on urban networks between the United States and Saudi Arabia.

2. To assess the applicability of the NETSIM model to Saudi Arabia.

3. To adapt NETSIM or another network simulation model for use in the analysis of the traffic performance in Jeddah.

4. To collect data on a limited street network in Jeddah to use as input data for a computer simulation of the network and to collect additional data on a different network to test the accuracy of the simulation model.

5. To conduct a parametric analysis on the simulation model to determine which internal relationships (if any) need to be modified to calibrate the model for Saudi Arabian conditions.

CHAPTER 2

LITERATURE REVIEW

The use of traffic simulation models in analyzing traffic performance has been the subject of extensive research, in spite of the relatively short age of these models. As the models have evolved and become more reliable and sophisticated, their use in more complex traffic situations has also increased. Among all traffic simulation models, network simulation models are the most widely used. This literature review was conducted to determine the reliability and applicability of the network simulation models in general and the NETSIM model in particular in analyzing traffic performance in the United States, and developing the hypotheses to be tested in this study.

2.1 Why Simulation?

Since the beginning of traffic engineering, one of the most demanding problems has been predicting, in quantitative terms, the effects of various traffic control strategies on real traffic. This problem has not been easy to solve because traffic is a complex phenomenon, difficult to characterize numerically. Mathematical models adequately describing highly idealized and simplified conditions were developed, but these early models could not portray real-world traffic accurately.

Attention soon turned to discrete event simulation, a promising technique that uses logic and analytical and empirical relationships to analyze the behavior of complex traffic systems. The advantages of simulation techniques are:

1. They provide the analyst with a means of addressing complex "systems" problems made up of many interrelated parts, each of which is subject to considerable variability.

2. They permit the engineer to focus on specific portions of an overall problem, under conditions of at least partial "experimental control."

3. They allow the user to experiment freely with new ideas before committing the financial resources necessary to implement them in the field.

4. They are generally considerably quicker, more flexible, and less expensive than other forms of complex, analytical evaluation.

The main shortcoming of the simulation technique was the overwhelming number of computations required to represent the many interrelated events that take place in traffic. Therefore, traffic could not be simulated in a practical manner until the digital computer with its unprecedented computational speed was developed. Shortly after the introduction of early computers in the mid-1950s, traffic simulation models, in the form of elaborate computer programs, began to be created to represent single intersections, short sections of freeways, urban arterials, and even urban networks.

2.2 Classification of Models

The network simulation models can be classified as either microscopic or macroscopic in design. Macroscopic models represent the traffic stream in some aggregate form (e.g., employing a fluid flow analogy or a statistical representation). Daniel Gerlough (11) developed one of the first macroscopic network simulation models in 1960. He used many approximations which made the model rather rough and the evaluation of the effectiveness of various changes imprecise. James Kell (12) in the 1960s developed several specific intersection simulations models. These models dealt only with two-lane roadways and thus had limited applicability. W. B. Cronje (22) developed a model for the optimization of fixed-time signalized intersections in 1981 which was applicable to undersaturated as well as oversaturated conditions.

Microscopic models describe the detailed, time-varying trajectories of individual vehicles in the traffic stream. They represent the ultimate in detailed treatment. Each vehicle is identified and its position, speed, and acceleration are kept in memory.

Some authors (18) have identified a third class of models, the platoon models. These models are a half-step toward detailed realism and simulate the behavior of vehicles grouped into platoons whose location, speed, and acceleration are tracked by the program. Platoon speed is usually a function only of the general density of vehicles in the platoon, thus avoiding complicated car-following calculations.

The macroscopic models offer the advantage of lower computational cost, while the microscopic models are, in general, more accurate because they make fewer assumptions. However, their requirements for computer resources retarded their development in times when these resources were very limited. The advent of the third-generation computers in the mid-1960s made possible the development of microscopic models such as UTCS-1, which later became NETSIM (15).

2.3 Traffic Simulation Models

Currently, there are three classes of traffic simulation models: single road, single intersection, and network models. Among the single road models, freeway models used to study merging, ramp metering, the effect of traffic composition, and incident detection phenomena are becoming common. Hsu and Munjal (42) have prepared a review of single road freeway models, and May (50) provides a comprehensive survey of models for freeway corridor analysis, including their historical development and applications.

Single intersection models have generally been built for a specific purpose and are not widely applicable. Perhaps Webster's is the best-known example of a single intersection model. This model was used to study the effects of isolated traffic control signals on intersection delay (18).

Network models are more complex. Some represent surface streets only; others can include freeway networks. These models are very useful in testing signal control strategies, traffic diversion strategies, proposals to add or delete streets from a network, and similar network modifications (40).

Gibson and Ross (8, 18, 40) reviewed 19 network simulation models. They reported that ten of them are obsolete and three are limited-application signal optimization programs. Their conclusion was that the other six traffic simulation models have been a success and their users were generally pleased with the results obtained.

Gibson (44) provided a catalog of 104 documented computer models for traffic operations analysis. The models were classified according to the geometrics of the application (intersections, arterials, networks, freeways, and corridors). Only ten of these models were considered practical in the sense that they produce useful results. The models are:

1. SOAP . . . . intersection optimization
2. TEXAS . . . . detailed intersection simulation
3. PASSER II . . . . arterial optimization
4. PASSER III . . . . diamond interchange optimization
5. SUB . . . . arterial bus simulation
6. TRANSYT-7F . . . . network optimization
7. SIGPO III . . . . network optimization
8. NETSIM . . . . network simulation
9. PRIFRE . . . . freeway optimization
10. FREQ3CP . . . . freeway simulation

MacGowan and Fullerton (10) have traced the evolution and accomplishments of the Urban Traffic Control System (UTCS). The

initial objective of UTCS was to develop advanced operational control programs. The project objective was later expanded to include development and testing of control strategies using simulation techniques; testing of the strategies in a real-life environment test facility in Washington, D.C.; and improvement of performance evaluation techniques for measuring the efficiency of the new strategies. To test and evaluate these alternative network strategies, an analytical model was needed. FHWA sponsored the development of such a model, which was originally designated UTCS-1 because of its relation to the UTCS project but was renamed NETSIM.

UTCS-1/NETSIM was developed by Peat, Marwick, Mitchell, and Company and GASL. It is based on the DYNET model and is fully microscopic. The NETSIM model has been validated against field data collected in Washington, D.C., Utah, California, and New Jersey. Among all the network simulation models, NETSIM is the most widely used. It has been used successfully in numerous applications throughout the country.

Hagerty and Maleck with the Michigan DOT (3) have used NETSIM in analyzing geometric and signal system alternatives. It has also been used to evaluate corridors at the transportation planning level and to evaluate signal installation requests.

Labrum (4) described the experience with NETSIM studies at the Utah DOT. They have used it extensively to evaluate traffic control strategies for single intersections, arterials, and grid networks, as well as to analyze pedestrian control problems, bus system plans, and fuel consumption and emission rates. They have found that "the NETSIM model is a very useful tool in solving a wide variety of traffic control problems."

Hurley and Radwan (5) have used NETSIM for research in a university environment. Most of the research described analyzes the effects of traffic signal timing on fuel consumption and vehicle delay. They concluded that to use this model as a research tool, improvements in these components of the program logic and program documentation are needed.

Nemeth and Mekemson (13, 37) compared NETSIM and SOAP in analyzing pretimed and actuated signal controls at intersections. The results of their studies indicated that both methods are reliable.

Although the UTCS-1 model was originally developed to simulate an urban network, its detailed treatment of intersection behavior in addition to its great flexibility makes it an appropriate candidate for a single intersection simulation model. Cohen (17) has modified and validated the UTCS-1S model for use in the analysis of traffic performance of single urban intersections. The modified model has been successfully tested and compared to two other single intersection simulation models.

Bruce Schafer (51) has used NETSIM in a comparison of alternative traffic control strategies at a T-intersection. His opinion was that "the NETSIM computer simulation model further expands the traffic engineer's ability to analyze and evaluate alternatives in a cost-effective manner."

Davis and Ryan (38) have compared NETSIM results with field observations and Webster predictions for isolated intersections. They found "no significant difference between NETSIM results and field observations or the Webster technique for the condition simulated."

Berg and others (32) have used NETSIM to evaluate signal timing plans for an oversaturated street network. After calibration of the model, they reported that they were able to select the best plan, saving a considerable amount of manpower and several months of field observations.

Hani Mahmassani and others (52) used NETSIM in an exploratory study of network-level relationships arising in an isolated network with a fixed number of vehicles. The results were analyzed with respect to the study objectives, yielding useful insights into network-level traffic phenomena and suggesting some modifications in order to use the NETSIM model in analyzing such problems. Their suggestions were:

> The introduction of short and long term rare events and blockages, in addition to heavy vehicles, pedestrian interference, driveways and parking maneuvers is likely to improve the realism of this representation. However more fundamental modifications in the car-following and lane-switching procedures embedded in NETSIM may be required.

To enhance the NETSIM program, Hurley, Radwan, and Benenelli (24) modified an existing fuel-consumption model in a form that is suitable for insertion into the NETSIM program.

To reduce some of the difficulties associated with the NETSIM model, such as extensive data preparation, tedious debugging, and voluminous printouts, Chin and Eiger (31) developed a network simulation interactive computer graphics program (NETSIM/ICG).

Current development in network simulation modelling is being done by the Office of Research of FHWA (25). They are developing a system of traffic simulation models named TRAF. This system is designed to represent traffic flow on any existing highway facility. It will consist of both microscopic and macroscopic model components for urban networks and freeways and a microscopic component only for two-lane rural roads. NETSIM is among the components that are being integrated into TRAF.

Regarding the application and use of NETSIM in locations other than the United States, the investigator found only one paper, by Yagar and Case (47), that summarizes the evaluation of NETSIM in Toronto. The version of UTCS-1 used did not have provision for changing splits, offsets, or cycle length from one subinterval to the next, in order to study different signal control plans between subintervals. To accomplish this, another subroutine similar to PRSIG (where signal codes are primed initially) was added to the program, and changes were performed on routine UPSIG. They concluded that:

> The above modifications performed by a person who had not developed the original UTCS-1 model demonstrated that the model can be made to perform the types of operations required of it with some intimate knowledge of the program and its routines.

Although traffic conditions and driver characteristics in the United States and Canada are similar, modifications in the program were needed.

2.4 Conclusions

The conclusions from the above background review are the following:

1. Traffic simulation is an important, reliable tool for traffic engineers and transportation planners.

2. Among all network simulation models, NETSIM is the most widely used and among the most extensively validated models.

3. Due to the relatively recent development of NETSIM, it has not been used widely other than in the United States. The application and use of the model in different societies and locations may enhance the program.

CHAPTER 3

THE NETSIM MODEL

One of the major objectives of this project is to assess the applicability of the NETSIM model to Saudi Arabia. Since the NETSIM model utilizes certain embedded values in simulating a network, it is important that the effect of these values be understood. Therefore, a brief description of the model has been summarized from the NETSIM User Guide (FHWA, 1980)(1).

3.1 Model Structure

The NETSIM model was designed primarily to assist in the development and evaluation of relatively complex network control strategies under conditions of heavy traffic flow. It is particularly appropriate to the analysis of dynamically controlled traffic signal systems based on real-time surveillance of traffic movements. The model may also be used, however, to address a variety of other simpler problems, including the effectiveness of conventional traffic engineering measures, bus priority systems, and a full range of standard fixed-time and vehicle-actuated signal control strategies.

It is set in a flexible, modular format which permits its efficient application to a wide variety of design problems. It includes a set of "default" values for most input parameters, thereby avoiding the need for detailed calibration in a particular area.

The model is based on a microscopic simulation of individual vehicle trajectories as they move through a street network. Each vehicle in the system is treated separately during the simulation. An array of performance characteristics is stochastically assigned to each vehicle as it enters the network, and its behavior is governed by a set of microscopic car-following, queue discharge, and lane-switching rules. All vehicles are processed once every second and their time-space trajectory recorded to a resolution of 0.1 second.

The NETSIM model is based, in part, on two earlier network simulation models: the "DYNET" model developed by E. Lieberman and an earlier predecessor model, "TRANS" developed by D. Gerlough and F. Wagner. All three formulations describe a street network in terms of a series of interconnected links and nodes, along which traffic is processed in a series of short time-steps subject to the imposition of varying forms of traffic control. The major differences among the models are in their level of detail, the sophistication of their internal logic, and their capacity to respond accurately to widely varying traffic conditions and increasingly complex control schemes.

NETSIM is the most detailed and complex of the three. The model is divided into three major components or "modules" (see Figure 3.1):

Module #1--"NETSIM Pre-Processor"
Module #2--"NETSIM Simulator"
Module #3--"NETSIM Post-processor"

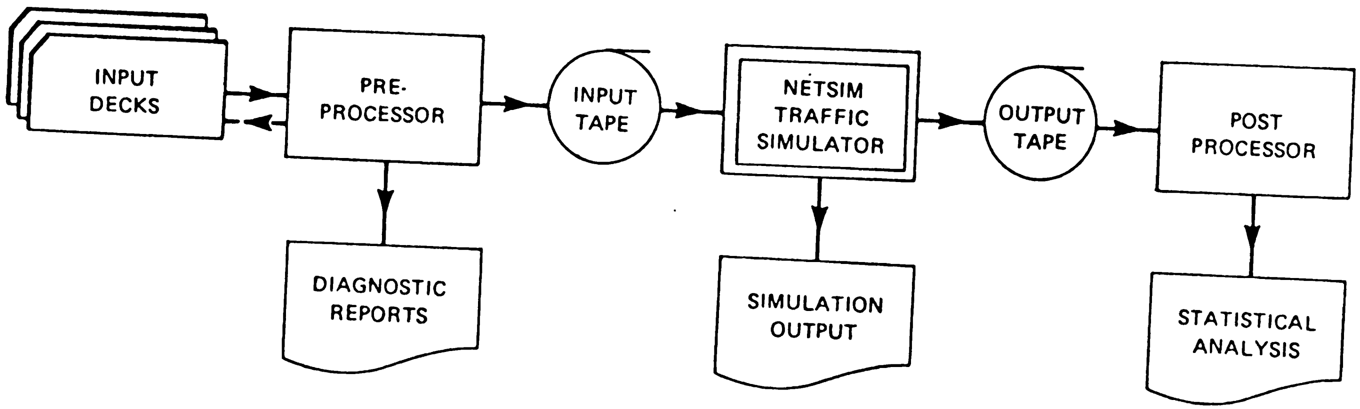

Figure 3.1.--The NETSIM model system.

The "NETSIM Pre-Processor" is designed to simplify the process of preparing and checking data inputs. It includes a comprehensive set of automatic "diagnostic checks" which are performed on all data inputs. It may be operated independently, or it may be integrated directly with the main program.

The "NETSIM Simulator" contains the main simulation program. It consists of 74 separate routines, which may be linked together in a variety of optional configurations depending on the requirements of the user. The simulator requires as input a coded description of a street network, together with a pre-specified control plan and a set of input volumes. Its output includes a set of standard measures of traffic performance, expressed as both link-specific and network-wide values.

The "NETSIM Post-Processor" consists of a set of standard data manipulation and evaluation routines designed to operate on the outputs of the main simulation program to compare the results of two or more simulation runs, construct a "historical" data file summarizing their results, and subject the resultant data set to a set of standard statistical analyses. Figure 2 illustrates the logical flow for the main executive routine within the "NETSIM Simulator." Figure 3 shows the major features of the NETSIM model.

3.2 Input Requirements

The input data required to operate the model may be grouped under two separate headings: location-specific parameters, reflecting the particular characteristics of a given network link or intersection, and phenomenological measures, which are assumed to remain constant

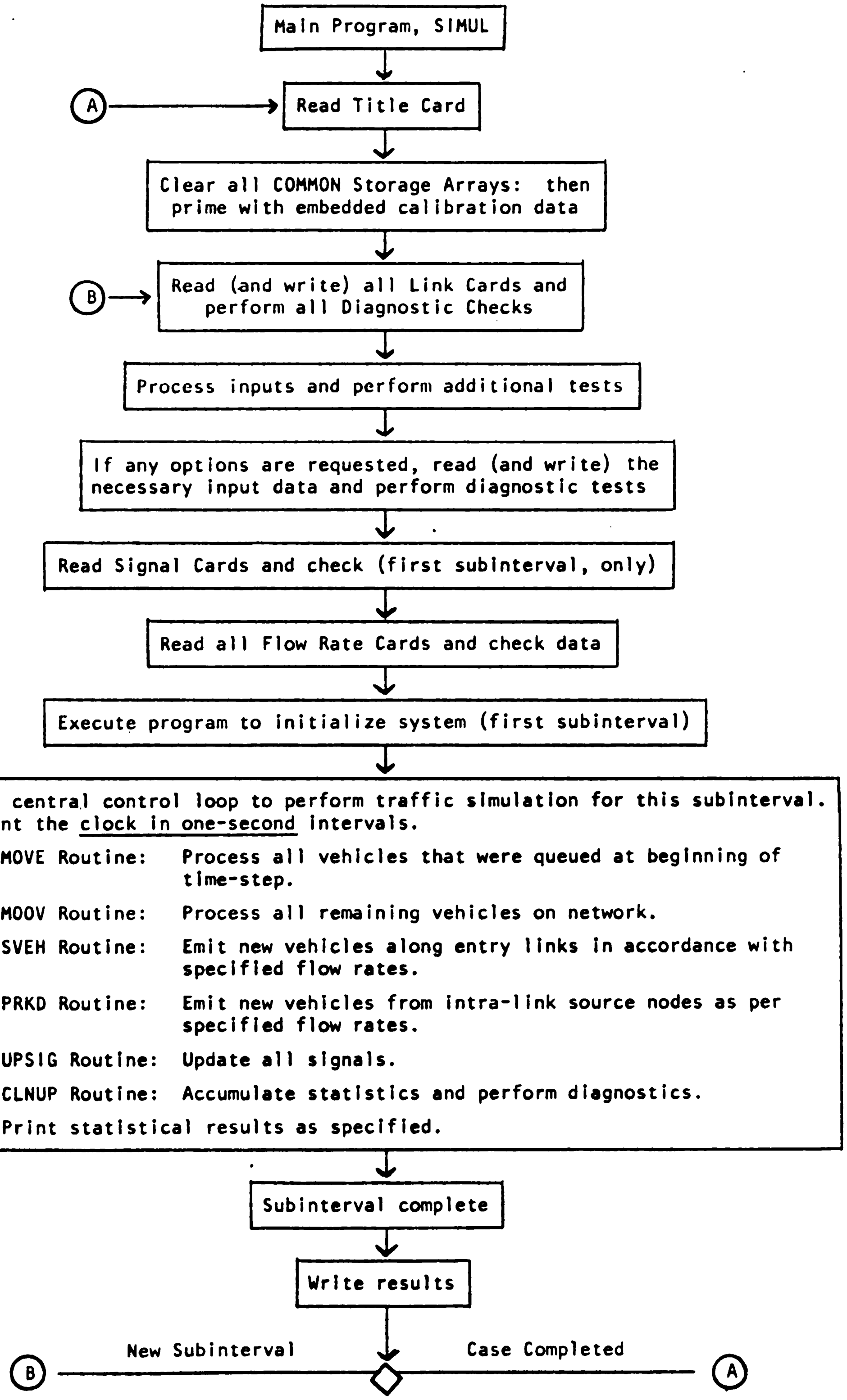

Figure 3.2.--Logic flow for NETSIM executive routine.

- MICROSCOPIC, STOCHASTIC SIMULATION OF INDIVIDUAL VEHICLE MOVEMENTS

- SIMULATION OF FULL RANGE OF CONTROL FEATURES, INCLUDING:
  - "Stop" and "yield" signs
  - Turn controls
  - Parking controls
  - Fixed-time signals
  - Vehicle-actuated signals
  - Real-time traffic control and surveillance systems

- MODULAR STRUCTURE INCORPORATING DETAILED TREATMENT OF:
  - Car following behavior
  - Network geometry
  - Grades
  - Bus traffic
  - Queue formation
  - Intersection discharge
  - Intra-link friction and mid-block blockages
  - Pedestrian-vehicular conflicts

- PROVISION FOR FLEXIBLE MIX OF STANDARD OUTPUT MEASURES

Figure 3.3.--Major features of NETSIM model.

across the entire network to be simulated, regardless of the location of a specific link or intersection. Specifically, the following input data are required:

1. For each network link: number of moving lanes, length, capacity of left-turn pocket, desired free-flow speed, mean queue discharge rate, turning movements at downstream node, identification of receiving links, pedestrian volume, and lane channelization.

2. At each intersection: complete specification of signal (or sign) control, including sequence and duration of each phase and identification of signal facing each approach.

3. Traffic demand: specified as flow rate (VPH), percentage of trucks admitted onto the network along input (entry) links and from internal source nodes, and rate of extraction of vehicles at sink nodes.

4. Duration of simulation subintervals and specification of output options.

5. As an option, specification of bus system (routes, stations, mean headways, and mean dwell times) and frequency and duration of events.

3.3 Output Characteristics

The NETSIM model provides a comprehensive range of output to describe the input data set, the status of the simulation exercise, and results of the simulation. The input data set for each subinterval is printed out in tabular form. The card listing of the input data is also optionally printed out at the beginning of the simulation. All input data are checked for completeness and consistency by the preprocessor component of the model. When errors are found, execution is aborted, and appropriate error messages are printed.

A comprehensive set of traffic performance measures (MOP) is generated either as standard output at the end of each subinterval or as intermediate output at the option of the user. Most of the MOP are produced for each individual link and for the network as a whole. The intermediate output option provides additional detailed information for individual links. These data are useful in the analysis of microscopic traffic behavior over time.

The postprocessor component of the model provides detailed comparisons of the traffic performance measures generated during two separate model runs. These comparisons are made for each individual link and the network as a whole, for each time period (subinterval), and for the entire duration of the simulation. The individual link and network-wide measures are statistically analyzed with the paired-comparison t-test, the Wilcoxin signed-rank test, the Mann-Whitney u-test, and the one-way analysis of variance to determine the level of significance of the difference.

3.4 User Options

A number of major user options are included in the phase II model. These options are:

1. Diagnostic checking of multiple input files with optional execution.

2. Storing and revision of input data sets on tape for future recall and update.

3. Modification of embedded input parameters, using study format data cards. (This is one of the options used in this study.)

4. Storing of model output on tape for future statistical module.

5. Simulation of traffic actuated signal control.

6. Simulation of a surveillance system comprising various types of detectors.

7. Simulation of bus traffic.

8. Simulation of transient blockages within the traffic stream.

9. A variety of standard output options, including tabulation of origin-destination volumes.

10. Automatic system initialization.

11. Statistical analysis of model outputs.

12. Peripheral data activities.

3.5 Limitations of the Model

The present form of the model has certain limitations. Some of these limitations are as follows:

1. Not all of the currently available real time control algorithms can be modeled.

2. Capacity constraints include a maximum of 160 links, 99 nodes, 60 entry links, and 1,600 vehicles tracked within the system.

3. Extensive checking of input data validity and careful review of output results for reasonableness are required. Erroneous conclusions can be reached due to undetected errors in input coding or careless construction of the link-node diagram.

4. Nonstandard traffic situations require the user to transform the conditions into acceptable input. Unusual driver performance, road geometrics, or pedestrian crossings require appropriate transformation.

3.6 Computer Requirements

Computer requirements for running the model are a function of several factors: the size of the test network, the level of traffic flow, the type and frequency of output reports, and the desired number and length of simulation runs. The entire model is programmed in FORTRAN IV, and it is fully operational on either IBM 05/360/370 or CDC 6600 series computers.

3.7 The Model and Traffic Performance in Jeddah

To use the NETSIM model in traffic engineering, it is not enough to know the model structure and features. In addition, the traffic conditions and circumstances of the site that would be analyzed by the model should be well understood. There are several major differences in traffic performance between the United States, where the model was developed, and Saudi Arabia. These differences are in driver characteristics as well as in the traffic systems. They can be summarized as follows:

I. Driver Characteristics

a. Due to social security, and safety factors, the law in Saudi Arabia prohibits females from driving any vehicle.

b. The law also prohibits drinking alcohol. Therefore, few accidents and traffic violations are caused by this factor.

c. More than one-third of the drivers don't have a drivers license (34), and they are not aware of most traffic regulations.

d. More than one-third of the drivers are illiterate or uneducated (34).

e. Experience shows that violation of traffic regulations (such as signals, stop signs, and high speed) is common and expected.

f. There are more pedestrian conflicts and delays due to multiple pedestrian crossings in all streets.

g. Experience also shows that many drivers are accepting smaller gaps for turning at intersections, and they have a different response to the amber phase than drivers in the United States.

h. It is common to see vehicles cluster at major intersections instead of having a regular queue.

i. It is very common in Saudi Arabia for drivers to use the horn to accelerate traffic at intersections when the light turns green. This habit may affect queue discharge headways and lost time of first-queued vehicles.

II. Traffic Systems

a. At all signalized intersections, each approach has a separate green phase. Thus, there are no conflicts with opposing traffic, and the consideration of left-turn jumpers and acceptable gaps in opposing traffic is negated.

b. All signals are controlled by a fixed time system.

c. Published data on specific traffic parameters such as headways, acceptable gaps, and distributions are missing.

d. Police enforcement is weak.

e. The cycle length of many signals exceeds 100 seconds.

All of these differences may affect in one way or another the program output. Therefore, a modification of the program may be needed, which can be done through the embedded data cards, as will be explained in the following chapters.

CHAPTER 4

METHODOLOGY

The methodology used in this research utilized the NETSIM model to analyze the traffic performance in Jeddah. This required the collection of input data, a comparison of model output with comparable field measurements, model calibration, and validation of the modified model in a second network.

4.1 Adaptation of the Model

Simulation is essentially a simplification of a real-world situation. The results obtained from any simulation model are only as good as the model reflects the particular real-world characteristics of interest to the analyst. The treatment of nonstandard traffic conditions may require the analyst to represent the essential operational characteristics of the network by an appropriate set of quantified, coded inputs.

Most of the embedded values used in the original NETSIM model reflect drivers' performance and traffic conditions as observed in Washington, D.C. These were expected to be different in Jeddah. Therefore, to facilitate the application of the NETSIM program to the analysis of traffic performance in Jeddah, calibration and/or modification was considered for the following program imbedded driver-related parameters:

1. Left-turn jumpers
2. Amber-phase response
3. Acceptable gaps at a STOP sign
4. Intersection turning speeds
5. Lane-switching acceptable lag
6. Acceptable gaps for left-turning vehicles at intersections
7. Distribution of spillback probabilities
8. Delay due to pedestrian conflict
9. Vehicle desired free-flow speed
10. Vehicle queue discharge headways
11. Lost time of first queued vehicle

These parameters are treated in the program as embedded data inputs. They represent default conditions that may be used to represent driving behavior either in the absence of adequate data or to reduce the preparation of data inputs. These values embedded within the standard load module reflect driver performance as observed in Washington, D.C. Updating of these data is provided in the program by means of "embedded data change cards."

The determination of appropriate values for each of these imbedded variables and the determination of the sensitivity of model performance to differences in these values is not an objective of this study. Instead, a systematic variation in the value of selected embedded values was conducted, and the model output compared to field observations for selected measures of performance. When the deviation between the model results and the field observations was within the specified tolerance, the parameter was fixed. After calibration of the model, its reliability and applicability to Saudi Arabia was tested on another network in Jeddah. The parametric analysis of the model is presented in the next chapter.

4.2 Network Selection and Coding

The task of selecting a suitable network site in Jeddah was not an easy one. There were many construction and development projects in the city, and the geometric design, signal control, and markings on the streets in these areas were not normal. It was also difficult to define boundaries of a chosen network due to the planning of the city and the zigzagging of many streets.

After studying a city map and touring the city for several days, a network that includes two major arterials and several signalized and unsignalized intersections was selected to serve as the study area and data-collection site. It is located in an intermediate site between the CBD and the suburbs. To assure that site is a fair representative of the traffic conditions of the city, the following criteria were used in selecting the site:

1. The site should contain traffic signals, STOP signs, one- and two-way streets, etc.

2. The site should not contain major abnormal or atypical network geometry that would cause major problems of data collection or model formulation.

3. The area should be traversed by trucks as well as private automobiles.

4. The site should include a representative range of typical link and intersection geometrics.

Figure 4.1 shows the physical network with the names of streets and signals at intersections. This network was coded according to the NETSIM program, and a link-node diagram was constructed to represent the actual street network in the computer. Figure 4.2 shows the coded network. Links may be either entry/exit type or internal to the network. Nodes are points at which vehicles enter, exit, or are controlled, such as a signalized intersection. The diagram shows also the direction of movement in the network.

4.3 Measures of Performance

The NETSIM program is capable of reporting detailed data on 16 separate performance measures for each individual link and 12 separate measures for the network as a whole. Among these performance measures, only the following were selected as MOP for this study:

1. Travel time: average travel time per vehicle per link per simulation interval, in veh. seconds (total duration, running and stopped time).

2. Delay: average delay time per vehicle, by link, per simulation interval, in veh. seconds (route delay not intersection delay, difference between total travel time and "idealized" travel time).

3. Speed: average traffic speed per link per simulation interval, in mph.

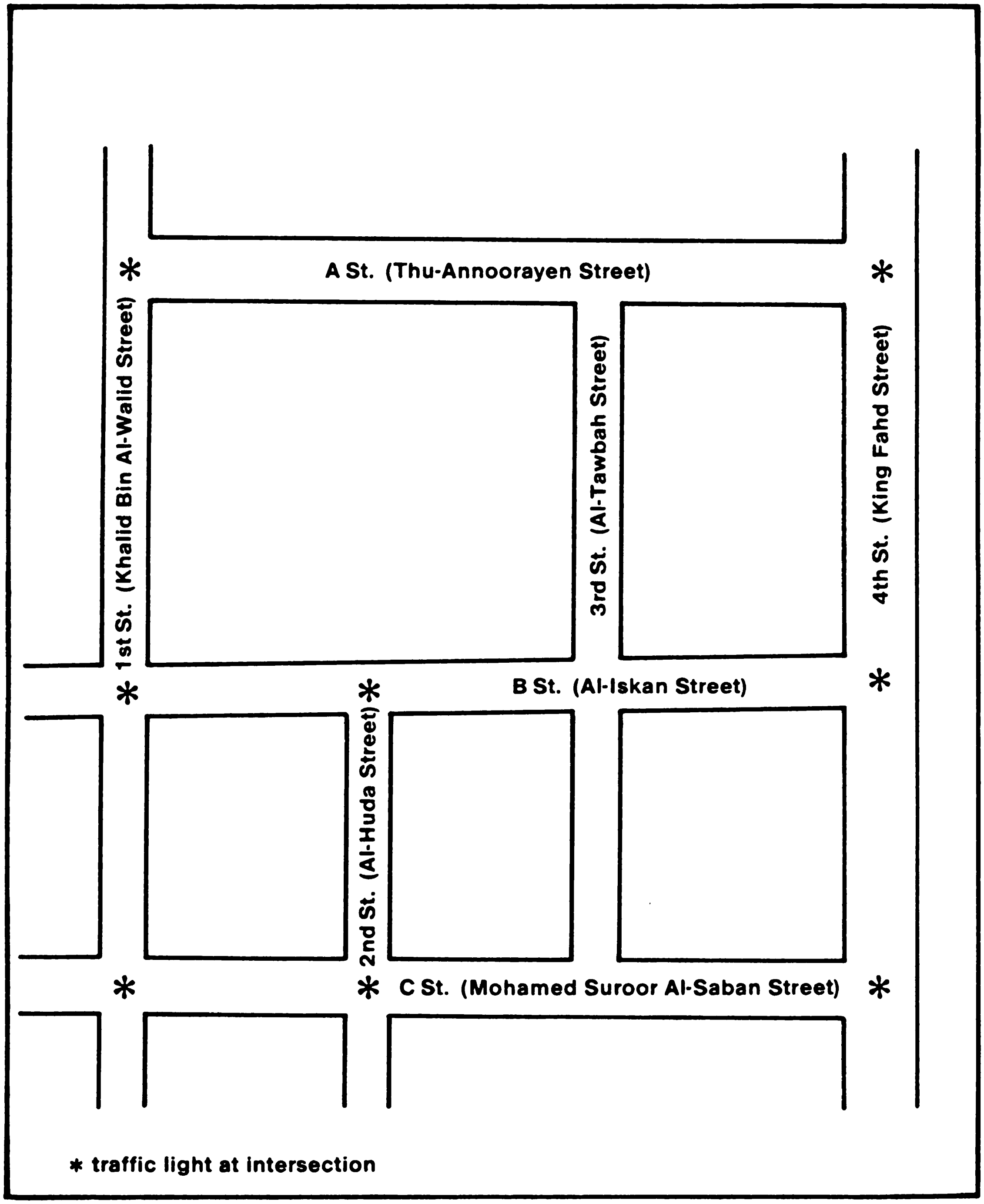

Figure 4.1.--Physical network #1.

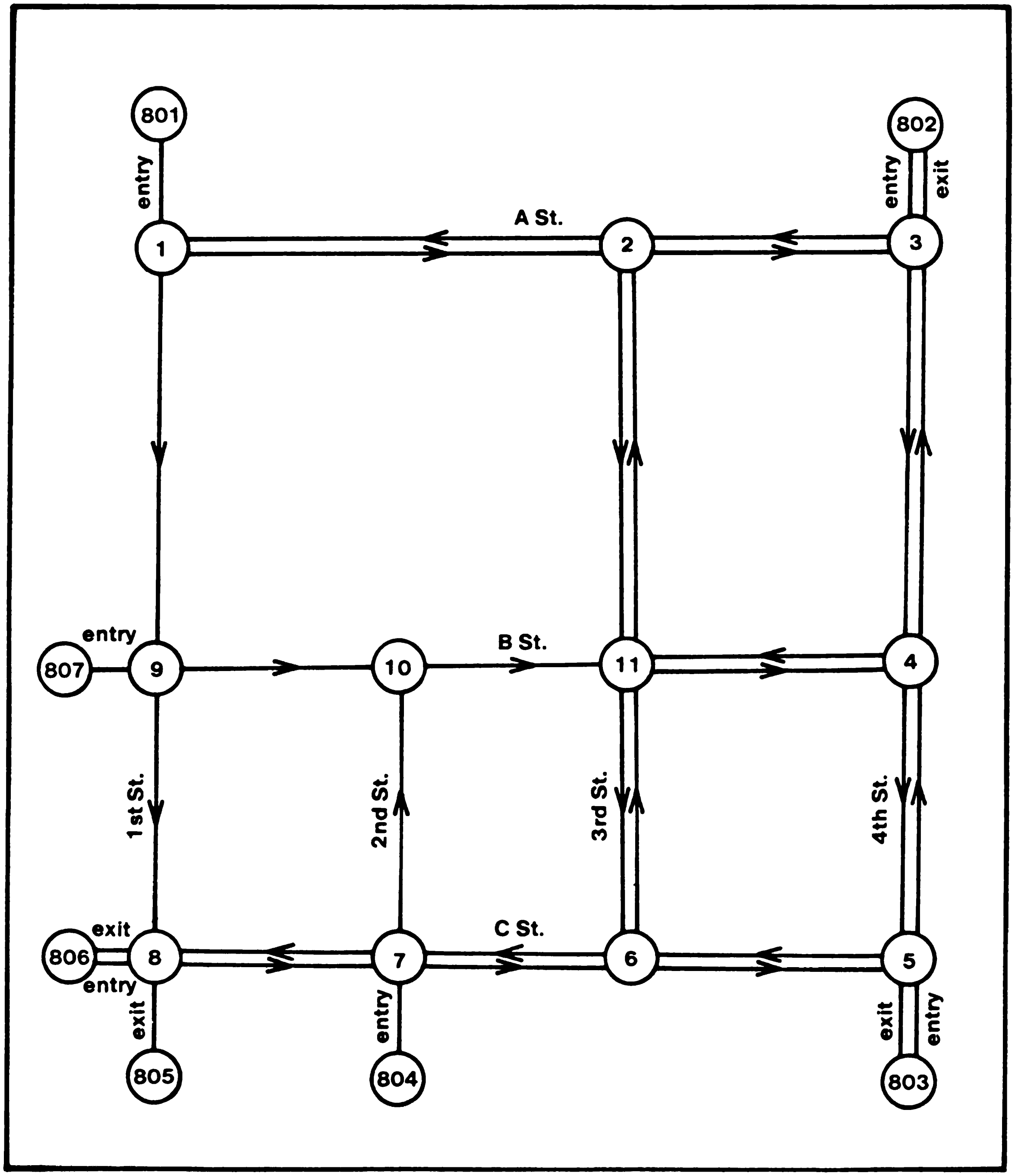

Figure 4.2.--Coded network #1.

4. Cycle failure: Total number of cycle failures, by link, during simulation interval, defined as the number of times a queue fails to clear from the discharge end of the link during a green period.

4.4 Data Collection

The data-collection phase was a major step in this project. The NETSIM program requires extensive data collection to be used as a full set of exogenous inputs. There are not enough historical traffic data from the city of Jeddah, and it was almost impossible to obtain all the necessary data from the files. Therefore, a series of manual field counts, signal checks, and network inventories was done. Ten students majoring in civil engineering at King Abdulaziz University in Jeddah assisted in the data-collection phase. Training sessions for those students were offered and designed to provide them with an over-all understanding of the traffic parameters needed to be collected and the collection methods. They were provided with field sheets and stop watches.

The data collected from the field can be grouped as follows:

1. For each link: length, number of moving lanes, length of left- and right-turn pockets, pedestrian volume, turning movements at the downstream mode, and lane channelization.

2. For each intersection: type of control (STOP, YIELD, or signal), sequence and duration of each phase, and identification of signal facing each approach.

3. Flow rates (vph), and percentage of trucks admitted onto the network along input (entry) links.

4. For comparison of MOP, the data were gathered on: travel time, delay, speed, and cycle failure at the specified intersections and links.

The computer output, in Appendix B, shows a summary of all the input data specified for each link and each intersection approach in the network.

4.5 Procedure and Schedule of Activities

The data-collection phase of this project started in the middle of April 1983 and lasted until the first week of June 1983. During this period, the weather was normal and school vacations had not yet started, and there were no abnormal conditions that might have affected traffic volume or other traffic parameters.

Due to the different social circumstances in Jeddah, there are three rush-hour count periods on weekdays as follows: from 7:30-8:30 a.m., from 1:30-2:30 p.m., and from 5:30-6:30 p.m. A 15-minute count interval was used at intersections.

The first week was devoted to selecting and coding the network. The second week was a training period on field data collection for the ten participants. Four participants were assigned at major intersections to collect data on traffic volume, turning movements, traffic composition, and pedestrian movements. Two participants were assigned to collect data on network geometrics, and two were assigned to collect the required data at nonsignalized intersections. Two persons with a stop watch determined the cycle lengths and phasing of signals. The values of the MOP at the selected locations were determined by the researcher and two students.

All the counts and readings were repeated at least three times, and their averages were used in the program. Link lengths were determined from aerial photographs obtained from the municipality of Jeddah. The same procedure was repeated for selecting, coding, and collecting data for the second network.

CHAPTER 5

DATA ANALYSIS

The 1982 version of the NETSIM computer program was used in this research. Before using the program, its performance was checked by running the program with input from the sample problem stored on the program tape. The output was compared with the stored output and found to be exactly the same except for some insignificant round-off errors.

5.1 Data Reliability

Data reliability is essential to this experiment, since the modifications in the program to suit Saudi Arabian conditions will be based on these data. Data collected from the field for this project are of two types:

1. Input data. These data include link length, number of moving lanes, length and capacity of left-turn pockets, lane channelization, signal phases and cycle length, pedestrian volume, turning movements, flow rates, and percentage of trucks.

2. Output data. These data were collected for the test networks to be used in calibrating and validating the model changes. These measures of performance (MOP) include average travel time per vehicle per link, average traffic speed per link, average delay time per vehicle per link, and cycle failure by link.

The eight most heavily congested links of the 25 links in the calibration network were selected for use in this study. For the first two MOP, the moving-car technique was used to obtain the data. A total of eight runs were made on each link, and the means and standard deviations were calculated using the formulas:

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \qquad S = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \overline{X})^2}{n-1}}$$

where $\overline{X}$ = sample mean

X_i = "i" th measurement

n = number of runs

S = standard deviation

Tables 5.1 and 5.2 show the individual data and the computed means and standard deviations of the travel time and average speed of the selected links in the calibration network.

To calculate the average delay time per vehicle, by link, the following equation is used:

$$\text{average delay time per vehicle} = \text{average travel time} - \text{"idealized" travel time}$$

$$= \text{average travel time} - \frac{\text{link length}}{\text{desired speed}}$$

Table 5.3 shows the average delay time per vehicle for these same links.

Table 5.1.--Travel time (V-sec) in the calibration network.

Run #	Link							
	1,2	2,1	1,9	2,11	11,2	3,4	4,3	9,8
1	23	36	56	65	59	59	51	29
2	19	31	61	61	62	54	42	33
3	17	25	65	55	67	58	44	26
4	22	39	54	62	60	51	49	30
5	21	33	59	57	65	57	55	25
6	16	40	66	66	58	52	45	33
7	15	36	60	64	68	61	54	35
8	21	27	53	58	63	51	41	27
ΣX_i	154	267	473	488	502	443	381	238
$\overline{X}$	19.3	33.4	59.1	61.0	62.8	55.4	47.6	29.7
S	2.96	5.42	4.78	4.00	3.69	3.89	5.40	3.66

Table 5.2.--Average speed (mph) in the calibration network.

Run #	Link							
	1,2	2,1	1,9	2,11	11,2	3,4	4,3	9,8
1	15	10	20	14	19	17	19	18
2	20	13	16	18	17	20	25	13
3	22	15	14	21	13	18	24	21
4	16	7	21	16	18	22	20	15
5	17	12	18	20	14	19	16	22
6	22	7	13	13	21	21	23	13
7	23	9	19	15	12	14	17	12
8	17	14	22	19	16	22	26	20
ΣX_i	152	87	143	136	130	153	170	134
$\overline{X}$	19.0	10.9	17.8	17.0	16.3	19.1	21.3	16.7
S	3.12	3.09	3.27	2.93	3.11	2.75	3.77	3.99

Table 5.3.--Average delay time per vehicle in the calibration network.

Link #	Link Length in ft.	Desired Speed in MPH	Average Travel Time in sec	Link Length / (Desired Speed X 1.47)	Delay in sec/veh
1,2	540	25	19.3	14.7	4.6
2,1	520	25	33.4	14.1	19.3
1,9	1620	25	59.1	44.1	15.0
2,11	1600	25	61.0	43.5	17.5
11,2	1580	25	62.8	43.0	19.8
3,4	1520	35	55.4	29.5	25.9
4,3	1520	35	47.6	29.5	18.1
9,8	620	35	29.7	12.1	17.6

Cycle failure is defined as the number of times a queue of vehicles fails to clear from the discharge end of the link during a green phase. This measure was obtained by counting this failure at signalized intersections for a period of 30 minutes. Table 5.4 shows the total number of cycle failures for the test links.

Table 5.4.--Observed cycle failures per one-half hour in the calibration network.

Link	Total Number of Cycle Failures
2,1	2
1,9	1
3,4	4
4,3	5
9,8	2

5.2. Performance of the Current NETSIM Model

The initial step used to determine the required modifications to make the NETSIM program fit Saudi traffic conditions was to simulate the given network by the model as used in the United States. By comparing simulated and measured values of the measures of performance, it was anticipated that specific modifications could be determined. Therefore, a simulation run was conducted for the calibration network. The run simulated a 30-minute time period. Equilibrium was attained for this stimulation period, and the average values for the MOP's were recorded.

To compare the measured and simulated output of travel time and average speed, the t-test was used:

$$t = \frac{(\overline{X} - \mu)}{S/\sqrt{n}} \qquad df = n-1$$

where t = student's t-test

$\overline{X}$ = mean of measurements

μ = simulated value

S = standard deviation of measurements

n = number of runs

For a 90 percent confidence interval and seven degrees of freedom, the table value of t is 1.895. If the computed $t < 1.895$, the hypothesis that there is no difference between the measured value and the simulated value will be accepted; otherwise, this hypothesis will be rejected.

Table 5.5 shows the results for the selected links. The simulation values on three links are within acceptable limits, while the other five are not, indicating that a modification in the program is needed. It does not appear that a change in a single parameter will be sufficient, since the simulation results are not uniformly high or low for the network. Thus, there are probably differences in more than one factor causing the differences in the measured and simulated values of the MOP's.

5.3 Discussion of Program Subroutines

The 1982 NETSIM model software contains a total of 11 programs, 90 subroutines, and 4 block data for fuel consumption and vehicle-emissions computations. There is a specific function for each program or subroutine, and they are related to each other according to their functions in the simulation process, as shown in Figure 5.1. The main executive program is UTCS-1. This program reads the link cards, sets up the initial data storage for further processing, tests whether cumulative and intermediate outputs are requested, activates those subroutines that initialize the contents of the COMMON storage arrays, and reads the remaining input data. All traffic characteristics and relationships assumed in the model are stored in these programs and subroutines.

The TRVL subroutine, for example, calculates the acceleration or deceleration of a vehicle; distance traveled; new speed; whether it will enter a left-turn pocket, join a queue, or switch lanes; come to a halt before a signal or travel through an intersection; whether it will

Table 5.5.--T-test of selected links using the current model.

Network #1	Travel Time sec			Average Speed MPH			Delay sec/veh		Cycle Failure	
Link	Simulated	Measured	$t_c(.05,7) = 1.895$	Simulated	Measured	$t_c(.05,7) = 1.895$	Simulated	Calculated	Simulated	Counted
1,2	18.6	19.3	.669	19.8	19.0	.726	3.3	4.6	-	-
2,1	45.0	33.4	6.056	7.9	10.9	2.747	30.9	19.3	1	2
1,9	58.7	59.1	.237	18.8	17.8	.865	14.2	15.0	0	1
2,11	47.3	61.0	9.693	23.0	17.0	4.799	3.9	17.5	-	-
11,2	62.3	62.8	.383	17.1	16.3	.729	18.3	19.8	-	-
3,4	58.2	55.4	2.038	16.8	19.1	2.369	28.3	25.9	1	4
4,3	52.3	47.6	2.465	16.5	21.3	3.602	11.8	18.1	0	5
9,8	27.1	29.7	2.013	13.9	16.7	1.985	17.8	17.6	0	2

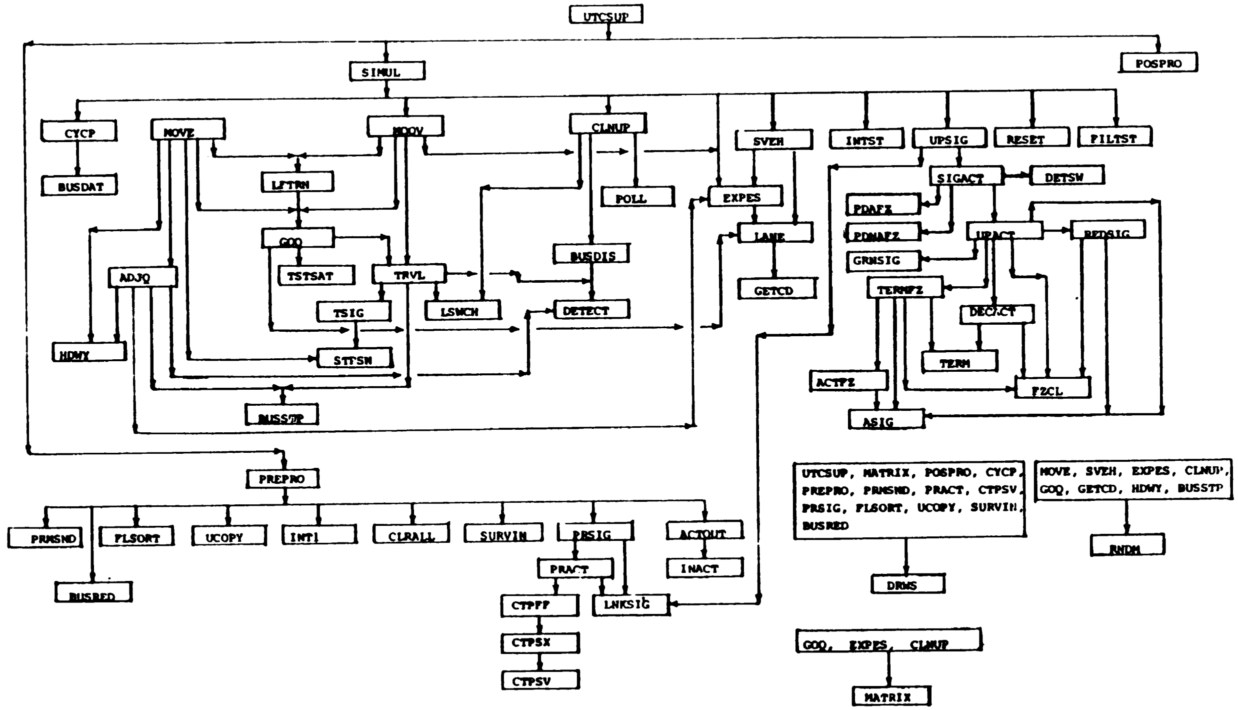

Figure 5.1.--Logical structure of NETSIM network simulation model.

be stopped by a bus at a station, or by a blocked vehicle; and applies delay due to short-term events. A user-specified speed profile and a stochastically determined desired speed provide the bases for the vehicle's trajectory. Figure 5.2 shows the overlay structure for the NETSIM program.

5.4 Embedded Data

The set of embedded data used in NETSIM includes a total of 20 separate parameters. They reflect both a series of microscopic performance characteristics and a lesser number of simple network characteristics. These data may be revised through the use of specified card types. Values and applicability of these parameters to the case study are as follows:

1. Left-turn jumpers: A left-turn jumper is a vehicle that is first in queue when the signal changes to green, and executes the left-turn maneuver (immediately) before the oncoming queues can discharge. The program includes an embedded value of .38 as the mean probability of a lead left-turn jumping (JMPG).

The traffic signal phasing used in Saudi Arabia prevents left-turn jumpers by assigning a separate signal timing for each approach, thus eliminating conflicts with on-coming traffic. To verify that this variable was being used appropriately, a run was done using a value of JMPG(I)=0. As expected, there was no change in the model output, indicating that the program is not using this parameter due to the characteristics of the described network.

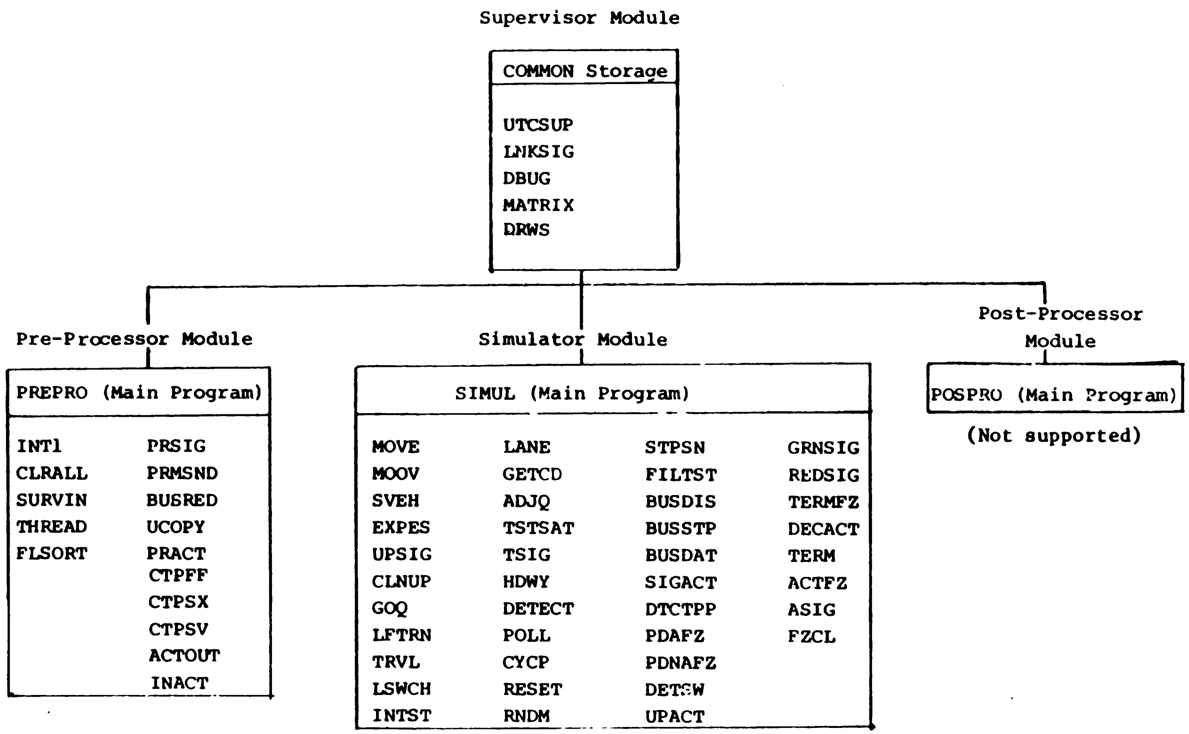

Figure 5.2.--Overlay structure for NETSIM preprocessor, simulator, and post-processor.

2. Amber phase response: The response of the lead moving vehicle in a lane that has no queue at the instant the signal turns amber, to the onset of the amber signal, is expressed in terms of an acceptable deceleration rate as follows:

I	1	2	3	4	5	6	7	8	9	10
d	4	4	5	6	7	9	12	15	18	21

where: I is the decile index of individual driver characteristics and d is the assigned acceptable deceleration in ft/sec^2.

Changes in this parameter would have a minor (and uniform) effect on the travel time MOP. Since the differences between observed and simulated results are not uniform, no change was made to this variable.

3. Acceptable gaps at a STOP sign: The stored decile distribution of acceptable gaps for near side (or one-way) cross-street traffic is:

I	1	2	3	4	5	6	7	8	9	10
g	56	50	46	42	39	37	34	30	29	20

Where: I is the decile index of individual driver characteristics and g is the acceptable gaps in sec x 10.

To account for the time required for the entering vehicle to find an acceptable gap in the traffic stream on the far side, the following additional time is applied:

I	1	2	3	4	5	6	7	8	9	10
g	12	21	26	31	35	39	42	46	49	51

where: I is the decile index of individual driver characteristics and g is the assigned acceptable gaps in sec x 10.

The selected network at Jeddah has only two STOP signs, and they are located on relatively uncongested links. These links were not used in the comparison of MOP's; thus no changes were made to this variable.

4. Turning speeds: Moving vehicles unimpeded by others must slow as they approach an intersection if they are to negotiate a turning maneuver. These speeds, applied deterministically, are:

Left-turn speed, ILT = 22 ft/sec

Right-turn speed, IRT = 13 ft/sec

Since the effect of changing this parameter would be a function of the left- and right-turning volume at each intersection it would not be uniform. Thus it is a candidate as a parameter to be changed in the calibration of the model. The number of left-turning and right-turning vehicles on each of the links used in the calibration was recorded to determine if there was a relationship between these volumes and the travel time deviations. Table 5.6 contains these data. There does not appear to be any relationship between the travel-time differences and the turning volumes. Thus, no changes were made to this variable.

5. Lane-switching acceptable lag: A vehicle cannot switch lanes unless an acceptable lag is available in the target lane. This value, deterministically applied, is IALAG = 31 tenths of a second.

This value has also not been modified since the effect of any change would be uniform across all links.

Table 5.6.--Left-turning and right-turning vehicles in the calibration network.

Link	Simulated	Measured	% Difference	% Left Turns	% Right Turns
1,2	18.6	19.3	4%	0%	15%
2,1	45.0	33.4	-25%	100%	0%
1,9	58.7	59.1	2%	14%	0%
2,11	47.3	61.0	30%	0%	0%
11,2	62.3	62.8	1%	52%	48%
3,4	58.2	55.4	- 6%	0%	5%
4,3	52.3	47.6	-10%	11%	0%
9,8	27.1	29.7	10%	6%	3%

6. Acceptable gaps for left-turning vehicles: A decile distribution of acceptable gaps in the on-coming traffic facing left-turning vehicles is stored in the IGAP array. These values, in tenths of a second, are:

I	1	2	3	4	5	6	7	8	9	10
g	78	66	60	54	48	45	42	39	36	27

As explained in "Left-Turn Jumpers," this parameter is not applicable in Saudi Arabia because there is no on-coming traffic at signalized intersections.

7. Mean effective vehicle lengths:

Autos: VLNGTH (1) = 20 (feet)

Trucks: VLNGTH (2) = 37

Buses: VLNGTH (3) = 50

These values are appropriate for Saudi Arabia, and thus the default values remained constant through the study.

8. Probability of a vehicle joining (or causing) spillback: The probability, in percentage, of a vehicle joining a spillback comprised of I vehicles is defined in the SPLPCT array:

I	1	2	3	4
SPLPCT	100	81	69	40

These probabilities are reasonable for Saudi conditions, and no change was made to this variable.

9. Delay due to pedestrian conflict: The program defined two types of conflict: strong (or heavy) interaction at the beginning of the green phase, and weak (or light) interaction for the remaining duration of the green phase. The duration of vehicular delay, in seconds, for each kind of conflict is defined by a statistical decile distribution stored in the PDLY array:

I	1	2	3	4	5	6	7	8	9	10
d_1	0	0	0	0	0	0	0	1	2	6
d_2	0	0	0	1	2	3	4	5	8	15

where I is the decile index of individual driver characteristics and d_1 is the duration of vehicular delay for weak interaction and d_2 is the duration of vehicular delay for strong interaction in seconds.

Light pedestrian flow: PPER (1) = 0

Moderate pedestrian flow: PPER (2) = 10

Heavy pedestrian flow: PPER (3) = 25

Since the ability to choose the combination of pedestrian flow (PPEN) permits the analyst to vary the pedestrian-delay component, no changes were made in the (PDLY) array.

10. Vehicle desired free-flow speed: As each vehicle enters a link, it is assigned a free-flow speed. This assignment is obtained by applying a percentage factor to the free-flow speed specified for that link. The embedded percentage values are:

I	1	2	3	4	5	6	7	8	9	10
F	75	81	91	94	97	100	107	111	117	127

where I is the decile index of individual driver characteristics and F is the assigned percentage for free-flow speed.

These values were used without any changes because the analyst can vary the specified free-flow speed to change the travel time and average speed on any link. This is one of the variables used in the calibration process.

11. Vehicle queue discharge headways: As each queued vehicle moves up to the stop-line, it is assigned a delay until discharge, reflecting the queue discharge headway. This headway is obtained by multiplying the mean queue discharge headway specified for the link by the following percentage according to the decile distribution:

K	1	2	3	4	5	6	7	8	9	10
F	170	120	120	110	100	100	90	70	70	50

where K is the decile index of individual driver characteristics and F is the assigned percentage for discharge headway.

For the second and third vehicle in queue at the time the signal turns green, additional delays of 0.5 seconds and 0.2 seconds, respectively, are added to the headway.

If the vehicle is not an automobile, the value is multiplied by a factor of 1.6 to reflect the more sluggish operating characteristics of trucks and buses.

Two runs were conducted assuming mean headway values of 2.2 and 2.0 seconds for all links. Table 5.7 shows a comparison of these two runs with the observed values for the calibration network. For a mean headway of 2.2 sec, the simulated travel time of four links and the average speed of three links were within acceptable limits, while for a mean headway of 2.0 sec, the simulated travel time and average speed of only two links were within these limits. Therefore, a mean headway of 2.2 seconds was used for the remainder of the runs.

Table 5.7.--A comparison of two mean queue departure headways.

Link #	Mean Headway sec	Travel Time sec			Average Speed MPH			Delay sec/veh		Cycle Failure	
		Simu-lated	Meas-ured	t(.05,7)= 1.895	Simu-lated	Meas-ured	t(.05,7)= 1.895	Simu-lated	Calcu-lated	Simu-lated	Counted
1,2	2.2	18.7	19.3	.573	19.7	19.0	.636	3.3	4.6	-	-
	2.0	19.1		.191	19.3		.272	3.6		-	
2,1	2.2	42.9	33.4	4.959	8.3	10.9	2.380	29.2	19.3	0	2
	2.0	40.4		3.654	8.8		1.923	28.1		0	
1,9	2.2	58.2	59.1	.533	18.9	17.8	.952	14.0	15.0	0	1
	2.0	57.3		1.066	20.1		1.990	13.8		0	
2,11	2.2	42.1	61.0	12.375	25.8	17.0	8.505	3.5	17.5	-	-
	2.0	47.2		9.764	23.0		5.799	3.9		-	

Table 5.7.--Continued.

Link #	Mean Headway sec	Travel Time sec			Average Speed MPH			Delay sec/veh		Cycle Failure	
		Simu-lated	Meas-ured	t(.05,7)= 1.895	Simu-lated	Meas-ured	t(.05,7)= 1.895	Simu-lated	Calcu-lated	Simu-lated	Counted
11,2	2.2	62.0	62.8	.613	17.2	16.3	.820	18.1	19.8	-	-
	2.0	59.9		2.222	17.8		1.367	17.9		-	
3,4	2.2	59.2	55.4	2.765	16.3	19.1	2.884	28.9	25.9	1	4
	2.0	58.7		2.401	17.0		2.163	28.4		0	
4,3	2.2	57.8	47.6	5.349	14.4	21.3	5.178	13.4	18.1	1	5
	2.0	51.7		2.150	16.9		3.302	11.6		0	
9,8	2.2	30.2	29.7	.387	13.1	16.7	2.553	18.2	17.6	0	2
	2.0	33.1		2.633	12.0		3.332	19.4		1	

12. Lost time of first queued vehicle: The first vehicle in queue when the signal turns green suffers a (start-up) lost time. This lost time can be applied deterministically by specifying its value on the link card, or it can be extracted from a decile distribution stored in the program. The mean of the stored values is 2.6 seconds. To test the sensitivity of the model results to the parameter, deterministic values of 2.4 and 2.2 sec were used in consecutive runs. Table 5.8 shows a comparison of these two runs. Using a value for lost time of 2.4 sec, simulated travel time of five links and average speed of four links were within acceptable limits, while for a value of lost time of 2.2 sec, the simulated travel time of four links and average speed of three links were within these limits. Therefore, a lost-time delay of 2.4 sec would appear to be the most appropriate value for first-queued vehicles in Jeddah. This value is lower than the 2.6 average found in the United States and reflects the aggressive nature of drivers in Saudi Arabia.

These tests of variations in the embedded parameters used in the NETSIM model calibrated for the United States accomplished two things. First, the best estimates of mean queue headway and lost-time delay to be used in Saudi Arabia were determined. Changing these parameters resulted in an increase in the number of links with acceptable travel-time deviation from three to five and the number of links with acceptable average speeds from three to four. Second, it demonstrated that other changes in the program are required, as there remain large differences between simulated and calculated delay time for

Table 5.8.--A comparison of lost-time delay of first queued vehicles.

Link #	Lost Time sec	Travel Time sec			Average Speed MPH			Delay sec/veh		Cycle Failure	
		Simulated	Measured	t(.05,7)= 1.895	Simulated	Measured	t(.05,7)= 1.895	Simulated	Calculated	Simulated	Counted
1,2	2.4	18.8	19.3	.477	19.6	19.0	.548	3.4	4.6	-	-
	2.2	18.7		.573	19.4		.363	3.3		-	
2,1	2.4	36.6	33.4	1.671	9.1	10.9	1.648	21.4	19.3	0	2
	2.2	37.9		2.349	8.6		2.106	22.1		0	
1,9	2.4	59.8	59.1	.415	18.5	17.8	.606	14.3	15.0	0	1
	2.2	58.3		.474	18.9		.952	14.0		0	
2,11	2.4	47.0	61.0	9.905	23.1	17.0	5.896	3.8	17.5	-	-
	2.2	45.4		11.320	24.2		6.960	3.6		-	

Table 5.8.--Continued.

Link #	Lost Time sec	Travel Time sec			Average Speed MPH			Delay sec/veh		Cycle Failure	
		Simu-lated	Meas-ured	t(.05,7)= 1.895	Simu-lated	Meas-ured	t(.05,7)= 1.895	Simu-lated	Calcu-lated	Simu-lated	Counted
11,2	2.4	64.7	62.8	1.456	16.5	16.3	.182	19.1	19.8	-	-
	2.2	65.1		1.762	16.0		.273	21.2		-	
3,4	2.4	59.0	55.4	2.620	16.5	19.1	2.678	28.8	25.9	1	4
	2.2	58.3		2.110	16.6		2.575	28.5		0	
4,3	2.4	56.2	47.6	4.510	14.7	21.3	4.953	13.1	18.1	1	5
	2.2	54.5		3.618	15.2		4.578	11.2		0	
9,8	2.4	28.7	29.7	.774	13.7	16.7	2.127	17.8	17.6	0	2
	2.2	28.2		1.161	13.5		2.269	17.7		1	

several links. Also, these parameter changes did not improve the comparison of simulated and counted-cycle failures.

Both Tables 5.7 and 5.8 show that the simulated average speed is slower than the measured speed for each of the links that is outside the acceptable limits. These links are also the most congested ones in the network. This suggested that a modification in the speed-volume relationship embedded in the program might be needed.

To determine the lead vehicle speed, the program uses the following relationship:

VL = MOD (JVACC [ML]/100,000, 100)

This equation represents, in FORTRAN IV, the speed-volume relationship shown in Figure 5.3. In the stable-flow region, as volume increases, the space-mean speed of traffic decreases until the critical density is reached (Point C). Thereafter, the flow becomes unstable, and both volume and speed decrease.

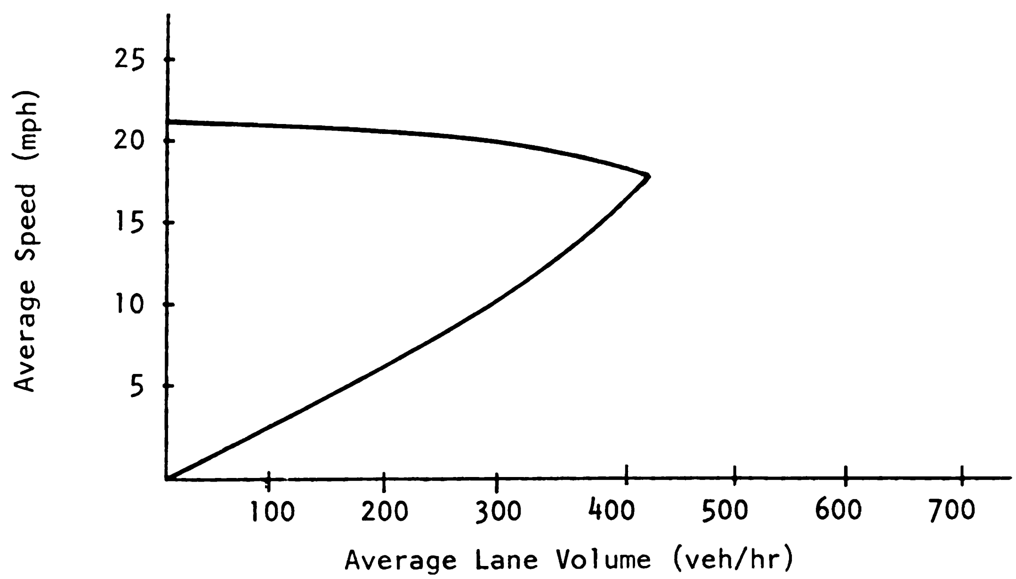

Figure 5.3.--Speed-volume relationship for the original model.

Because both the mean queue headways and the lost-time-delay parameter changes reflect more aggressive driving in Saudi Arabia, it was hypothesized that this relationship between speed and volume might also be different. The use of speed limits is not widely practiced, there is little traffic enforcement, and most drivers are aggressive. Therefore, a relationship that produces a higher speed for a given volume was indicated. Several modifications to the relationship shown in Figure 5.3 were tested; the best results were obtained when the relationship was modified to read:

VL = MOD (JVACC [ML]/100,000, 100) *1.5

Figure 5.4 illustrates this modified relationship. Table 5.9 shows a comparison of the simulated and measured MOP using the modified model. All the simulated travel times and average speeds are now within acceptable limits except the travel time on link (4,3). The simulated number of cycle failures also matches the observed data more closely than the previous runs. The complete output of the program is contained in Appendix B.

This change in the model has affected the performance of some of the network links. The average speed of link (2,1), which is a heavily traveled link, has increased from 7.9 mph to 9.8 mph. The same thing happened to links (3,4) and 4,3), which are also heavily traveled links and are among the longest links in the network. Link (1,9) has the same length as (3,4) and (4,3) but is less congested. Its average speed has decreased from 18.8 mph to 18.3 mph. There is no significant change in the performance of the low-volume, short links (9,10),

Table 5.9.--The simulated MOP using the modified model.

Network #1	Travel Time sec			Average Speed MPH			Delay sec/veh		Cycle Failure	
Link	Simulated	Measured	t(.05,7)= 1.895	Simulated	Measured	t(.05,7)= 1.895	Simulated	Calculated	Simulated	Counted
1,2	18.5	19.3	.764	19.9	19.0	.817	3.4	4.6	-	-
2,1	36.3	33.4	1.514	9.8	10.9	1.007	22.2	19.3	0	2
1,9	60.4	59.1	.770	18.3	17.8	.433	15.3	15.0	0	1
2,11	61.4	61.0	.283	17.7	17.0	.677	16.6	17.5	-	-
11,2	61.1	62.8	1.302	17.4	16.3	1.003	17.7	19.8	-	-
3,4	57.7	55.4	1.674	17.9	19.1	1.236	27.3	25.9	1	4
4,3	43.5	47.6	2.149	23.8	21.3	1.876	12.9	18.1	5	5
9,8	27.9	29.7	1.394	15.0	16.7	1.205	15.7	17.6	0	2

(10,11), or (6,7). The unsignalized links (1,2) and (11,2) show little change in their performance. The average speed for link (1,2) has increased from 19.8 mph to 19.9 mph, while the average speed for link (11,2) has increased from 17.1 mph to 17.4 mph. Most of the signalized links show some improvement. The average speed of link (9,8), connecting two signalized intersections, has increased from 13.9 mph to 15.0 mph. The same thing has happened to link (7,8). No change occurred to link (7,10), while the average speed of link (1,9) has decreased from 18.8 mph to 18.3 mph. The travel time of all these links is inversely proportional to the average speed.

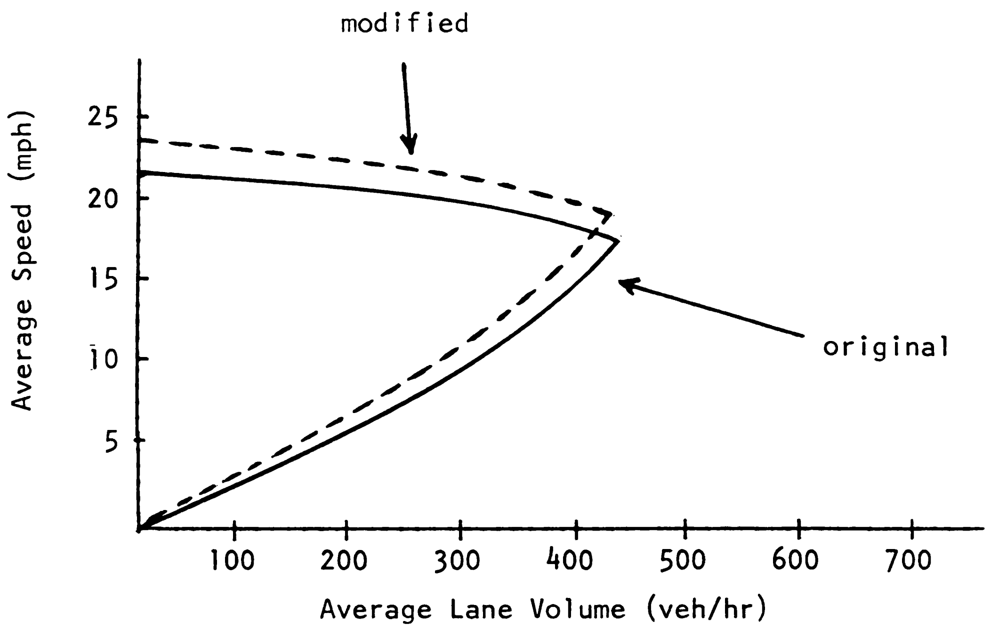

Figure 5.4.--Speed-volume relationship for the original and modified models.

The comparison of the network statistics using the original and modified models shows significant improvement. The average speed increased from 15.32 mph to 16.39 mph. STOPS/vehicle decreased from 1.47 to 1.45. Average delay/vehicle decreased from 54.70 sec to 47.52 sec. Travel time/veh-mile decreased from 3.92 min/v-mile to 3.66 min/v-mile. Stopped delay as a percentage of total delay decreased from 67.1 to 60.6.

5.5 The Model

The analysis of data collected in Jeddah shows that the NETSIM model can be applied successfully in simulating traffic performance in Saudi Arabia with the following traffic and program characteristics:

1. Queue discharge rate: A mean time-gap (headway) between vehicles discharging from a standing queue of 2.2 sec.

2. Lost time of first queued vehicle. A lost-time or queue start-up delay of 2.4 sec.

3. A modified speed-volume relationship. The formula used in the TRVL subroutine to determine lead-vehicle speed should be multiplied by 1.5.

5.6 Model Validation

Since each network of streets has its own unique set of characteristics (volumes, street lengths, signal settings, etc.), the fact that the NETSIM model could be modified to reproduce the MOP from one network is not conclusive evidence that these modifications are

suitable for other networks in Jeddah. The more critical validation test is whether the model can reproduce MOP from another network.

To validate the modified model, data for the input parameters and the MOP for a second network in Jeddah were collected. The network was similar in size to the first one, with 24 internal links and 16 nodes. Figures 5.5 and 5.6 show the physical and coded representations of the network. The eight most congested links were selected to obtain the measures of performance. Tables 5.10, 5.11, 5.12, and 5.13 contain the mean travel time, average speed, average delay time, and cycle failure for each link.

Table 5.10.--Travel time (sec) in the validation network.

Run #	Link							
	14,15	15,14	15,16	16,15	16,17	17,16	18,19	19,18
1	47	32	49	55	26	48	21	41
2	41	39	43	48	21	52	26	37
3	37	36	48	46	23	57	31	40
4	44	40	41	50	18	50	25	43
5	48	42	47	55	24	46	20	38
6	43	34	51	52	27	55	28	35
7	38	33	45	47	22	47	29	45
8	40	41	40	53	17	56	22	46
ΣX_i	338	297	364	406	178	411	202	325
$\bar{X}$	4.23	37.1	45.5	50.8	22.3	51.4	25.3	40.6
S	3.99	3.87	3.93	3.54	3.54	4.27	3.99	3.89

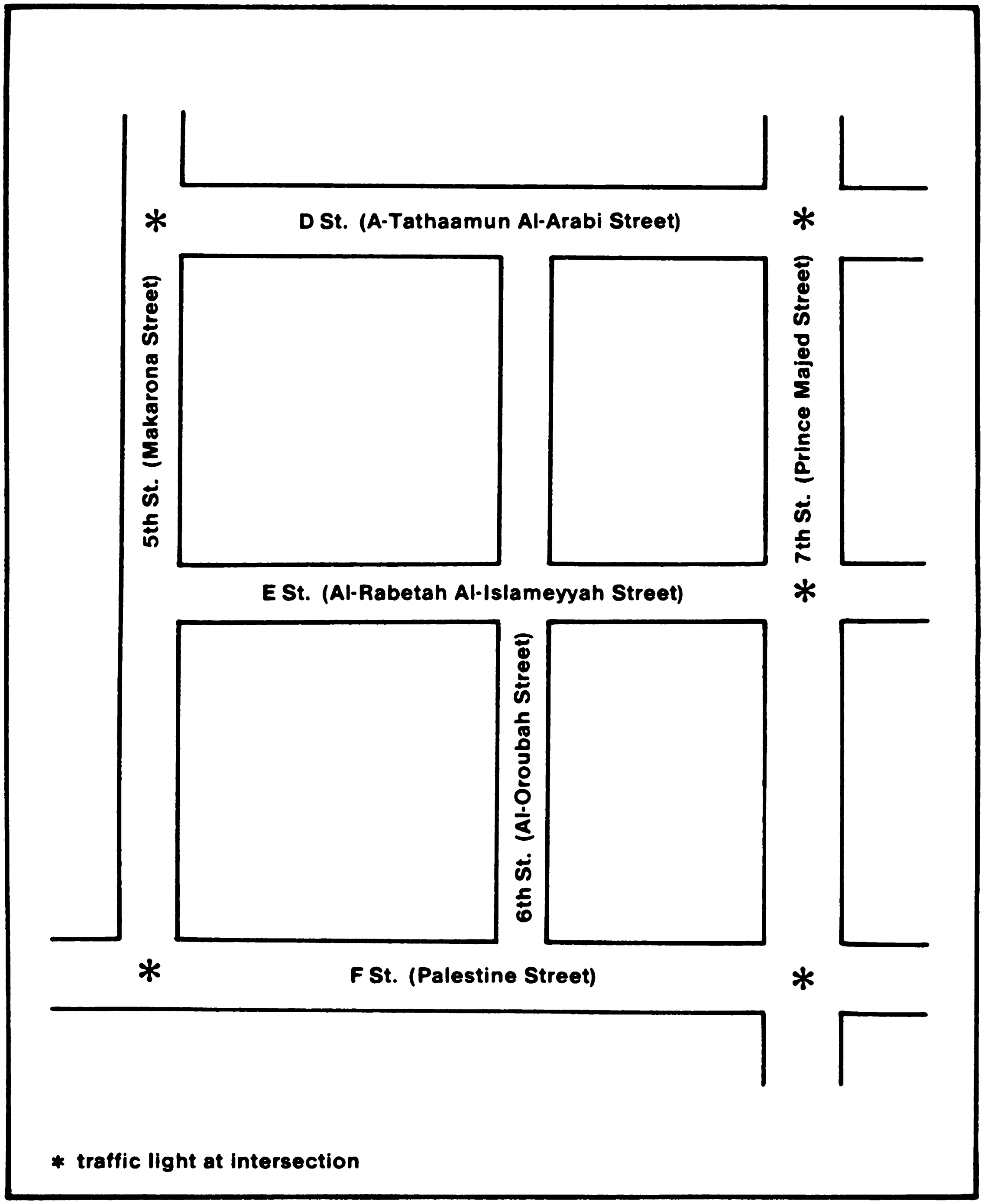

Figure 5.5.--Physical Network #2.

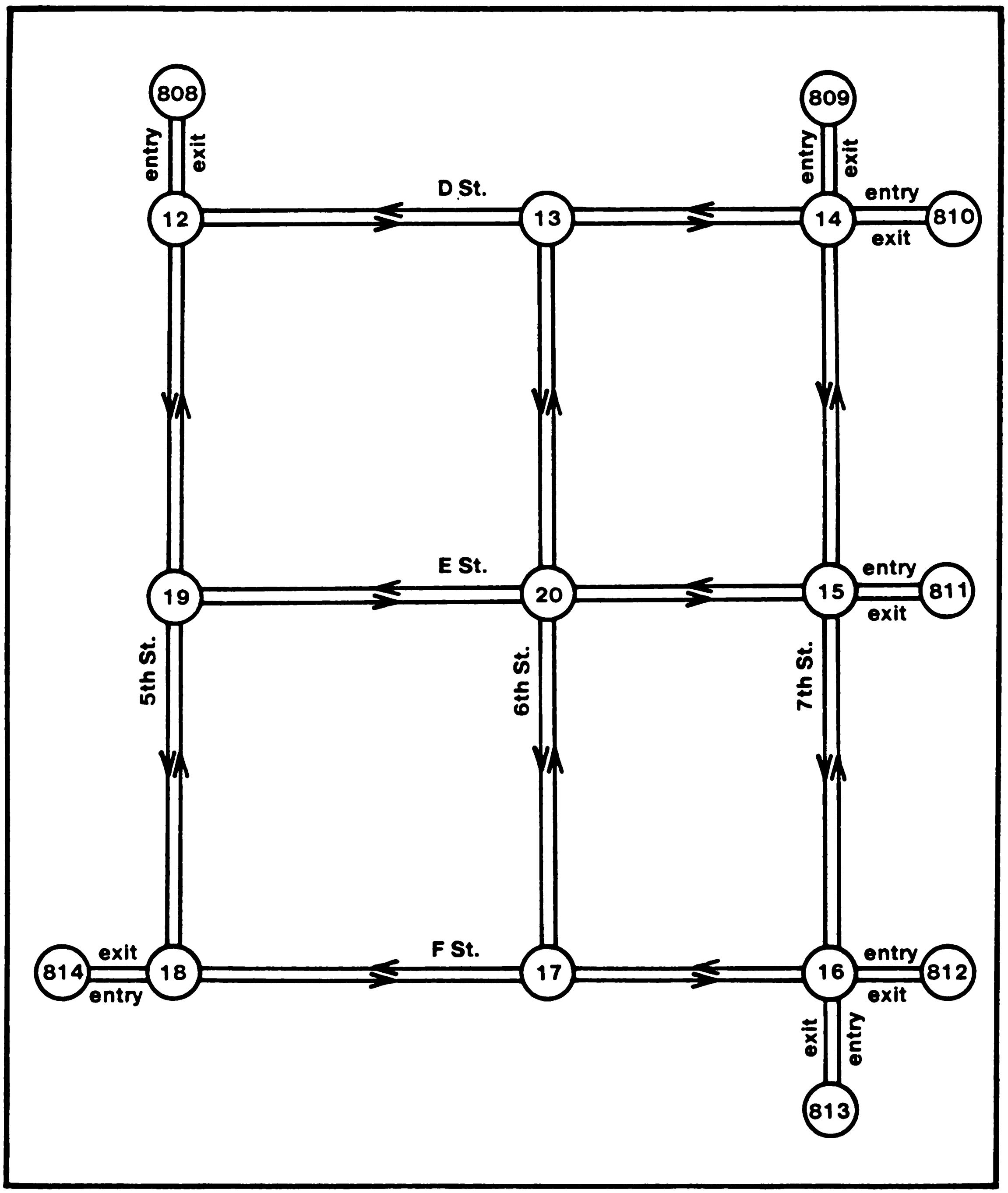

Figure 5.6.--Coded Network #2.

Table 5.11.--Average speed (mph) in the validation network.

Run #	Link							
	14,15	15,14	15,16	16,15	16,17	17,16	18,19	19,18
1	7	20	9	6	20	14	25	12
3	14	14	14	14	27	11	22	16
3	18	15	11	16	26	7	16	14
4	9	12	15	12	29	13	23	11
5	6	11	12	6	21	17	27	15
6	13	17	8	11	19	8	19	17
7	17	18	13	15	26	15	18	10
8	15	12	16	9	30	7	24	9
X_i	99	119	98	89	198	92	174	104
X	12.4	14.9	12.3	11.1	24.8	11.5	21.7	13.0
S	4.53	3.22	2.82	3.87	4.20	3.85	3.77	2.93

Table 5.12.--Average delay time per vehicle in the validation network.

Link #	Link Length in ft.	Desired Speed in MPH	Average Travel Time in sec	Link Length / Desired Speed X 1.47	Delay in sec/veh
14,15	800	40	42.3	13.6	28.7
15,14	800	40	37.1	13.6	23.5
15,16	780	40	45.5	13.3	32.2
16,15	800	40	50.8	13.6	37.2
16,17	800	40	22.3	13.6	8.7
17,16	760	40	51.4	12.9	38.5
18,19	820	35	25.3	15.9	9.4
19,18	800	35	40.6	15.5	25.1

Table 5.13.--Cycle failure of second network.

Link	Total Number of Cycle Failures
14,15	8
15,14	0
15,16	0
16,15	11
16,17	3
17,16	4
18,19	2
19,18	5

A run using the modified model was conducted for this validation network. Table 5.14 shows the simulated values and the observed values for the MOP. The t-test for all links indicates that none of the simulated values are significantly different from the observed values. This validation test confirms that the model can accurately simulate Saudi Arabian traffic flow. The complete output of the program is in Appendix C.

Comparing the simulated values of the original and modified models for this validation network, the following variations in links performance can be observed. The performance of the high-volume links has been slightly improved. The average speed of link (14,15) has increased from 13.5 mph to 14.3 mph. The average speed for link (17,16) has increased from 8.5 mph to 9.8 mph, and the average speed for link (19,18) has increased from 14.2 mph to 15.4 mph. This network is located in a recently developed area where all links have almost the same length; therefore, the model does not show any variation in links

Table 5.14.--The simulated MOP of the second network.

Network #2	Travel Time sec			Average Speed MPH			Delay sec/veh		Cycle Failure	
Link	Simu-lated	Meas-ured	t(.05,7)= 1.895	Simu-lated	Meas-ured	t(.05,7)= 1.895	Simu-lated	Calcu-lated	Simu-lated	Counted
14,15	40.3	42.3	1.417	13.5	12.4	.686	26.6	28.7	6	8
15,14	38.9	37.1	1.320	14.0	14.9	.789	25.7	23.5	1	0
15,16	47.5	45.5	1.440	11.2	12.3	1.105	33.7	32.2	0	0
16,15	52.9	50.8	1.681	10.3	11.1	.585	39.3	37.2	13	11
16,17	20.7	22.3	1.281	26.3	24.8	1.010	6.8	8.7	0	3
17,16	53.1	51.4	1.126	9.8	11.5	1.248	40.2	38.5	6	4
18,19	23.9	25.3	.993	23.2	21.7	1.126	7.9	9.4	0	2
19,18	38.4	40.6	1.560	14.2	13.0	1.159	22.6	25.1	3	5

performance due to variations in links length. There is no significant change in the performance of unsignalized links, while the simulated cycle failure of signalized links has generally improved. The cycle failure of link (13,12) has decreased from 7 to 3, the cycle failure of link (17,16) has decreased from 14 to 6, while the cycle failure of link (19,18) has increased from 0 to 3.

The comparison of network statistics using the original and modified models shows some improvements. The average speed has increased from 15.13 to 15.74 mph. The stops/vehicle has decreased from 1.32 to 1.30. The average delay per vehicle has decreased from 52.65 sec to 50.37 sec, and travel time/veh-mile has decreased from 3.94 to 3.74 min/v-mile.

5.7 Application of the Model

One of the important features of the NETSIM model is its capability to be used to analyze and evaluate traffic signal timing plans and strategies. A modification in signal timing parameters, such as offsets and the duration and sequence of the signal phases, can result in fewer stops, less delay, reduced travel time, less fuel consumption, and reduced accidents.

To demonstrate the use of the modified NETSIM model in Saudi Arabia, the model was used to simulate the effects of a modification in the existing signal timings of a major street in the calibration network in Jeddah. Figure 5.7 shows a representation of Khalid Bin Al-Walid street, which is a one-way street with three traffic lights. The

objective of the proposed timing plan is to coordinate the three signals to produce a better progressive system. This change should reduce delay and travel time and increase the average speed on the street. The offset at each intersection was set so that the first vehicle of the platoon will receive the green indication just as it reaches the intersection. Signal (1) was considered a base signal for the system. The offset of the other signals was determined using the following formula:

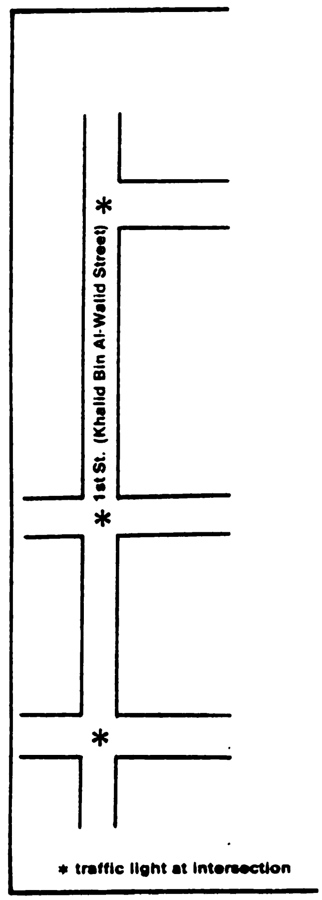

Figure 5.7.--Khalid Bin Al-Walid Street in Jeddah.

$$\text{offset} = \frac{\text{Distance between signals, in ft}}{\text{Desired speed in ft/sec}}$$

$$\text{offset for signal 9} = \frac{1{,}620}{18.3 \times 1.47} = 60.0 \text{ sec}$$

$$\text{offset for signal 8} = \frac{2{,}240}{18.3 \times 1.47} = 83.1 \text{ sec}$$

The desired speed for the system was considered to be 18.3 mph, which is the average speed on link (1,9). The highest cycle length in the system is 84 seconds at signal 1. Figures 5.8 and 5.9 show the time-space diagrams for the selected street for the modified and existing timing plans. There is an increase in the desired speed for the system from 15.5 mph to 18.3 mph, and an increase in the bandwidth (minimum green time) from 30 sec to 35 sec.

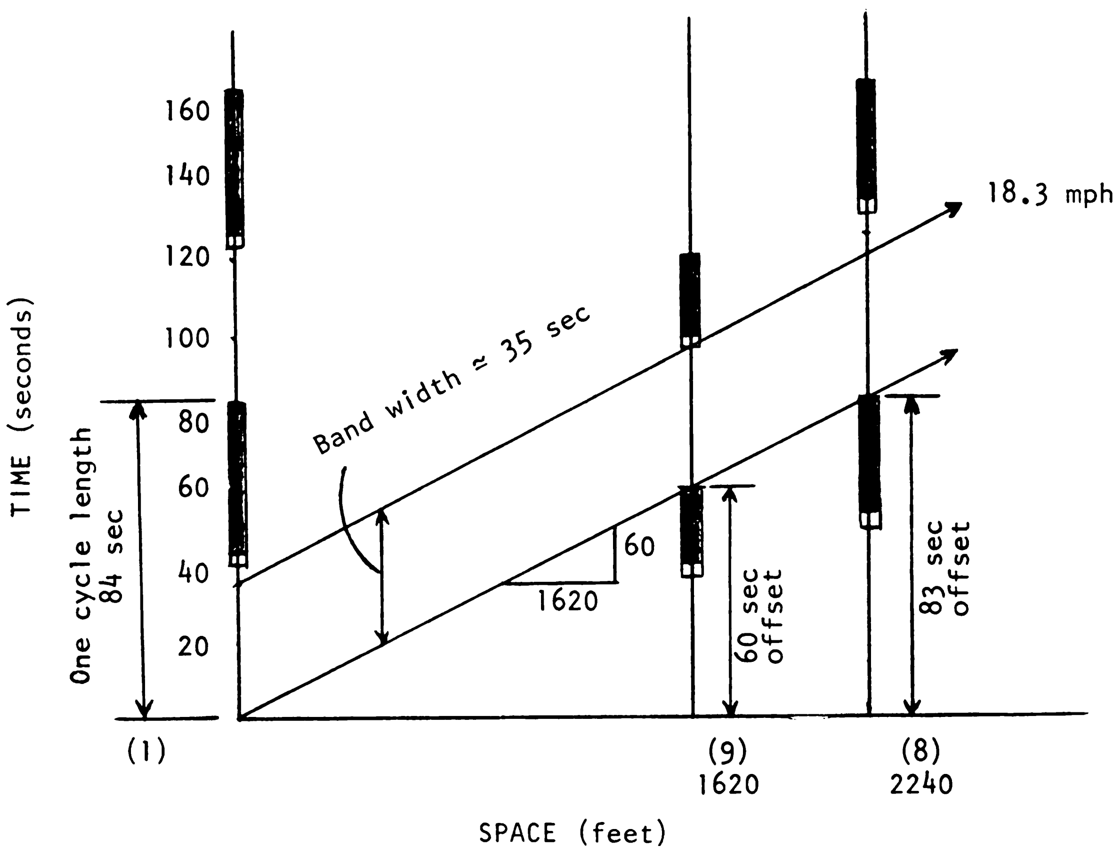

Figure 5.8.--Time-space diagram for Khalid Bin Al-Walid Street using the modified plan.

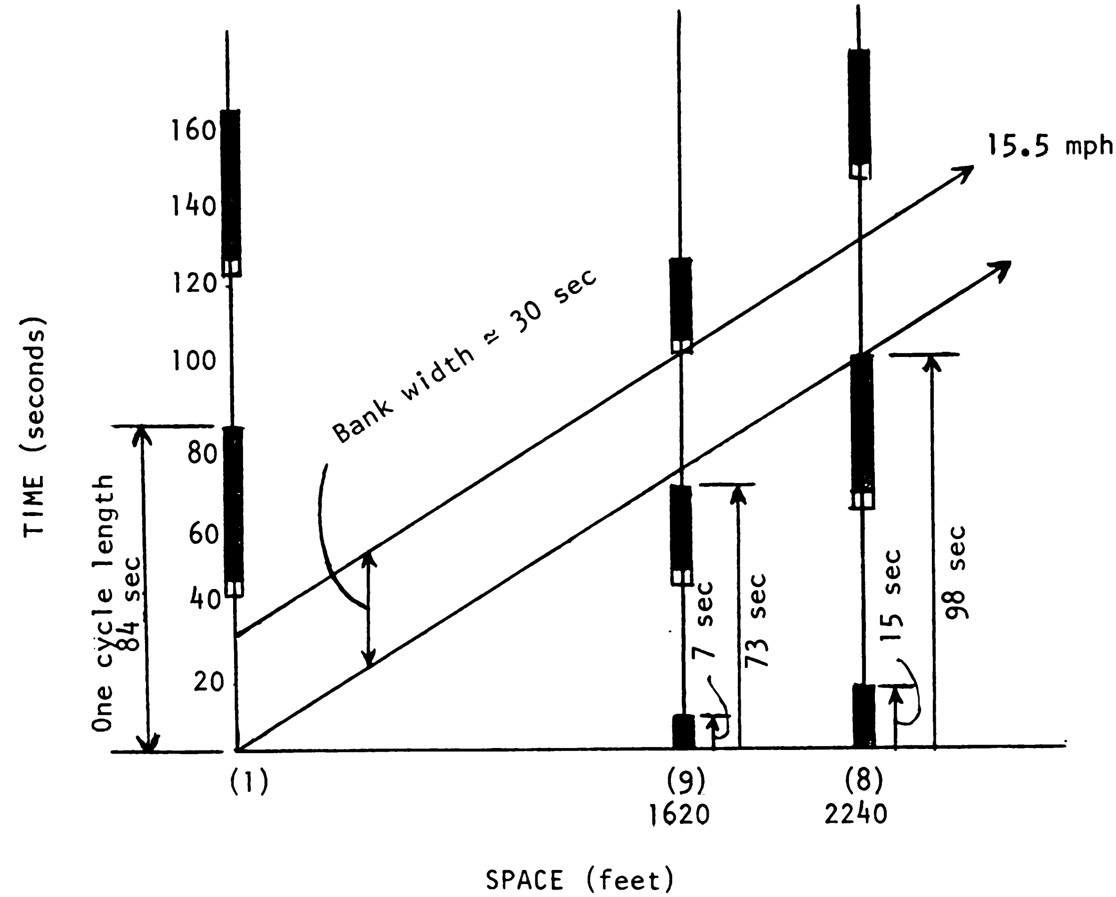

Figure 5.9.--Time-space diagram for Khalid Bin Al-Walid Street using the existing timing plan.

Table 5.15 shows a comparison between the simulated values of the measures of performance of Khalid Bin Al-Walid Street using the two timing plans. The table shows an improvement in all measures of performance due to the improvement in selecting the offset time between the signals.

This experiment demonstrates the potential benefits of using the modified NETSIM model in Saudi Arabia.

Table 5.15.--A comparison between simulated values of MOP using two different timing plans.

Link	Travel Time sec			Average Speed MPH			Delay Time sec/veh.		
	Existing Timing Plan	Modified Timing Plan	% Change	Existing Timing Plan	Modified Timing Plan	% Change	Existing Timing Plan	Modified Timing Plan	% Change
1,9	60.4	56.0	-7.3	18.3	19.7	+7.7	15.3	11.5	-24.8
9,8	27.9	26.7	-4.3	15.0	15.8	+5.3	15.7	14.7	- 6.4

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Although the NETSIM model was originally designed to simulate traffic performance in the United States, this study has demonstrated that it can be applied in different traffic conditions. The model is not difficult to understand; it can be used properly with little modeling experience. The model requires more extensive data than some other models. The payoff, however, is that the output is more representative of real conditions.

The model is relatively expensive to operate. However, it is more economical than collecting actual field data to determine the change in system performance resulting from modifications in traffic control. The availability and ease of use will continue to expand the application and acceptance of NETSIM.

The model calibration and validation was conducted by comparing the results of the model simulation with a sample of field data. Since the sampling error is unknown, the true accuracy of the modified model is also unknown. The t-test used in the analysis assumes that both the field-collected sample and the simulated results are from normal distributions. An extension of this study to include a larger sample should be conducted to verify this assumption.

Based on the data collected and analyzed in this study, the following conclusions were reached:

1. Traffic performance in Saudi Arabia can be simulated and analyzed using a modified NETSIM model.

2. A modification in the speed-volume relationship embedded in the model is needed to suit the Saudi traffic conditions. The formula used in the TRVL subroutine to determine lead vehicle speed must be multiplied by 1.5 to accurately simulate Saudi driver acceleration characteristics.

3. A mean time-gap (headway) between vehicles discharging from a standing queue of 2.2 sec and lost time for queue start-up delay of 2.4 sec are most suitable for traffic in Jeddah.

6.2 Recommendations

While this study demonstrated that the NETSIM model can be modified to simulate traffic on the street network in Jeddah, the limited application to the two networks does not answer all the questions. Additional studies and analysis should be performed, including:

1. The model should be tested and validated in different cities in Saudi Arabia such as Riyadh and Dammam.

2. Measures of performance of all links and/or nodes of both the calibration and validation networks should be obtained to establish the validity of the simulation over a broad range of link characteristics.

3. The use of automated techniques in data collection should be developed to reduce the effort required for data collection. These

techniques could include: volume counts from detectors, photologging for both traffic operational characteristics and the physical characteristics of the network, aerial photography for a multiplicity of data, street-level photography for parking characteristics and network data, and a portable event recorder for gathering information about vehicle speeds, journey times, and fuel consumed.

4. To provide a more streamlined version of the model, the options of simulation of bus traffic and transient blockages within the traffic stream were suppressed in this study. However, it is recommended that simulation of these options should be tested in Saudi Arabia because of the increased use of public bus transit and the frequent occurrence of temporary blockages due to accidents, emergency vehicles, or unusual congestion.

5. A developed data-information system is needed to collect extensive data on major traffic parameters in Saudi Arabia and to establish statistical distributions of these parameters to update the embedded input data of the model.

6. Traffic performance in Saudi Arabia should be simulated using other models (such as TRANSYT or TEXAS) and the results compared with the modified NETSIM.

7. The NETSIM User Guide needs improvement. It would be more helpful to the user if it included the program logic, the major assumptions, and the traffic modeling used in the program.

8. Among the recommended applications of the model in Jeddah and other cities in Saudi Arabia are the following:

a. Traffic-flow improvement on major streets. Travel time, delay and average speed and other traffic parameters can be improved by evaluating different timing plans for the selected street or network. This improvement will reduce congestion and increase the street capacity.

b. Control methods and operational timing at single isolated intersections to select from either traffic-actuated volume-density signal control, two- and four-way stop signs, or fixed-time signal control.

c. Effects of adding bus lanes to the CBD network or other sites.

d. Effects of parking lot or shopping center development on the surrounding area in the city.

e. Effects of geometric changes such as additions of left-turn bays or right-turn pockets.

f. Installation of future signal systems and the effects on surrounding systems.

g. Simulating the effects of the predicted future changes in traffic volume on the existing network. This would help the city in selecting and prioritizing street-improvement projects.

9. Introductory courses on modeling and the NETSIM program are recommended for the traffic engineers who are working in the traffic departments in Saudi Arabia.

APPENDICES

APPENDIX A

STATISTICS ON DRIVER AND TRAFFIC CHARACTERISTICS

IN JEDDAH

Table A1.--Vehicles and licenses in Jeddah (1971-1981).

Year	No. of Transport Vehicle Plates	No. of Private Vehicle Plates	No. of Taxi Vehic. Plates	No. of Buses Vehic. Plates	Total No. of Vehic. Plates	Index	No. of Private Driving Licenses	No. of Public Driving Licenses	Total No. of Driving Licenses	Index
1971	645	1,055	248	135	2,083	100	4,954	971	5,925	100
1972	6,711	4,185	333	650	11,879	570	5,624	662	6,286	106
1973	1,386	1,092	220	215	15,854	761	4,732	344	5,076	86
1974	12,634	14,457	1,942	1,286	31,319	1,504	10,649	461	11,110	188
1975	21,187	16,704	2,781	383	40,955	1,966	12,606	726	13,332	225
1976	36,799	29,684	5,536	302	72,321	3,472	13,172	1,292	14,465	244
1977	37,591	34,746	5,704	680	78,721	3,779	28,508	3,832	32,344	546
1978	72,475	42,080	3,979	308	118,842	5,705	27,989	7,637	35,626	601
1979	34,525	54,142	3,166	484	92,317	4,432	26,443	4,249	30,692	518
1980	52,050	71,400	...	3,050	127,214	6,107	30,030	2,073	32,309	545
1981	32,500	52,250	...	2,000	87,454	4,198	32,556	9,271	41,827	706

Table A2.--Some characteristics of drivers involved in accidents in Jeddah (1978-1981).

Year	Age <18	Age 18-30	Age 30-40	Age 40-50	Age >50	Married	Single	Educated	Unedu-cated	Has a License	Does not Have a License	% Does Not Have License
1978	121	2,459	1,011	244	51	1,974	1,912	2,192	1,694	1,674	2,212	57%
1979	106	2,708	999	267	39	1,712	2,407	2,459	1,660	1,782	2,337	57%
1980	195	1,884	967	271	47	1,534	1,830	2,072	1,292	2,051	1,313	39%
1981	309	1,892	1,132	534	123	2,031	1,959	2,525	1,465	2,417	1,573	39%

Table A3.--Number and causes of accidents in Jeddah (1978-1981).

Year	STOP	Circu-lation	Outreach	Traffic Violation	High Speed	Alcohol of Drugs	Other
1978	43	197	285	66	2,040	19	322
1979	42	309	296	100	2,702	11	289
1980	68	404	274	114	2,560	17	369
1981	32	113	91	284	2,375	13	401

Table A4.--Number and type of vehicles involved in accidents in Jeddah (1978-1981).

Year	Sedan	Jeep	Bus	Pick-up	Truck	Tank-Truck	Other
1978	1,765	78	126	862	313	63	679
1979	1,906	73	130	807	296	99	808
1980	1,507	103	145	519	281	79	730
1981	2,154	93	155	469	441	76	602

Table A5.--Number and type of accidents in Jeddah (1971-1981).

Year	No. of Vehicles Registered	Index	No. of Acci-dents	Accidents Per 1000 Vehicles	No. of Injured	Injured Per 1000 Vehicles	Injured Per 100 Acc.	No. of Fatali-ties	Fatal. Per 1000 Vehicles	Fatal. Per 100 Accid.
1971	13,217	100	347	26	394	30	114	75	6	22
1972	25,096	190	576	23	543	22	94	65	3	11
1973	40,950	310	1,081	26	1,282	31	119	159	4	15
1974	72,269	547	1,531	21	1,959	27	128	142	2	9
1975	113,224	857	2,160	19	2,790	25	129	206	2	10
1976	185,545	1,404	2,779	15	3,340	18	120	287	2	10
1977	264,266	1,999	2,341	9	2,410	9	103	285	1	12
1978	383,108	2,899	2,607	7	3,270	9	125	295	1	11
1979	475,425	3,597	2,809	6	3,439	7	122	341	1	12
1980	602,639	4,560	2,732	5	3,387	6	124	342	1	13
1981	690,073	5,221	2,530	4	2,997	4	118	323	1	13

APPENDIX B

PROGRAM OUTPUT OF CALIBRATION NETWORK

```
                 START OF CASE    1
HAMED ALBAR   JAN 1984   SIMULATION  OF  TRAFFIC
   KING FAHAD STREET,               JEDDAH,SAUDI ARABIA    0 05/20/83
            SEED FOR RANDOM NUMBER GENERATOR IS          7581
```

SIMULATION OF TRAFFIC

THE NETSIM MODEL

HAMED ALBAR JAN 1984 SIMULATION OF TRAFFIC

KING FAHAD STREET, JEDDAH, SAUDI ARABIA 0 05/20/93

SEED FOR RANDOM NUMBER GENERATOR IS 7581

LINK	LANE	SPAN	POCK L	POCK R	MEAN U-F	H	TURNING MOVEMENTS LEFT	THRU	RT	DIAG	DESTINATION NODES LEFT	THRU	RT	DIAG	LOST	PED DFN	LANE CHAN 1	2	3	4	5	TYPE	G	L	IDENTIF
(1, 2)	2	540	0	0	25	22	0	85	15	0	0	3	11	0	24	0	0	0	0	0	0	1	2	1	
(2, 1)	2	520	0	0	25	22	100	0	0	0	9	0	0	0	24	3	0	0	0	0	0	1	2	2	
(1, 9)	3	1620	0	0	25	22	14	86	0	0	10	8	0	0	24	1	0	0	0	0	0	1	2	3	
(2, 3)	2	560	0	0	25	22	52	0	48	0	802	0	4	0	24	0	0	0	0	0	0	1	2	4	
(3, 2)	2	580	0	0	25	22	90	10	0	0	11	1	0	0	24	0	0	0	0	0	0	1	2	5	
(2, 11)	2	1600	0	0	25	22	0	100	0	0	0	6	0	0	24	2	0	0	0	0	0	1	2	6	
(11, 2)	2	1560	0	0	25	22	52	0	48	0	1	0	3	0	24	0	0	0	0	0	0	1	2	7	
(3, 4)	4	1520	0	0	35	22	0	95	5	0	0	5	11	0	24	0	0	0	0	0	0	1	2	8	
(4, 3)	4	1520	12	0	35	22	11	89	0	0	2	802	0	0	24	1	0	0	0	0	0	1	2	9	
(4, 5)	4	720	0	0	35	22	0	97	3	0	0	503	6	0	24	1	0	0	0	0	0	1	2	10	
(5, 4)	4	700	12	0	35	22	9	91	0	0	11	3	0	0	24	1	0	0	0	0	0	1	2	11	
(4, 11)	2	580	0	0	20	22	0	0	100	0	0	0	2	0	24	1	0	0	0	0	0	1	2	12	
(11, 4)	2	540	0	0	20	22	40	0	60	0	3	0	5	0	24	1	0	0	0	0	0	1	2	13	
(5, 6)	2	600	0	0	20	22	0	65	35	0	0	7	11	0	24	3	0	0	0	0	0	1	2	14	
(6, 5)	2	580	0	0	20	22	45	0	55	0	4	0	803	0	24	3	0	0	0	0	0	1	2	15	
(6, 7)	2	260	0	0	20	22	0	92	8	0	0	8	10	0	24	3	0	0	0	0	0	1	2	16	
(7, 6)	2	280	0	0	20	22	55	45	0	0	11	5	0	0	24	3	0	0	0	0	0	1	2	17	
(6, 11)	2	680	0	0	25	22	0	69	31	0	0	2	4	0	24	3	0	0	0	0	0	1	2	18	
(11, 6)	2	700	0	0	25	22	54	0	46	0	5	0	7	0	24	3	0	0	0	0	0	1	2	19	
(7, 8)	3	120	0	0	20	22	20	80	0	0	805	806	0	0	24	3	0	0	0	0	0	1	2	20	
(8, 7)	2	120	0	0	20	22	12	88	0	0	10	6	0	0	24	3	0	0	0	0	0	1	2	21	
(7, 10)	2	660	0	0	20	22	0	0	100	0	0	0	11	0	24	0	0	0	0	0	0	1	2	22	
(9, 8)	3	620	0	0	35	22	6	91	3	0	7	805	806	0	24	3	0	0	0	0	0	1	2	23	
(9, 10)	2	120	0	0	20	22	0	100	0	0	0	11	0	0	24	1	0	0	0	0	0	1	2	24	
(10, 11)	2	400	0	0	20	22	0	0	100	0	0	0	6	0	24	1	0	0	0	0	0	1	2	25	
(801, 1)	3	360	0	0	ENTRY	22	21	79	0	0	2	9	0	0	24		0	0	0	0	0	1	2	26	
(802, 3)	4	480	0	0	ENTRY	22	0	97	3	0	0	4	2	0	24		0	0	0	0	0	1	2	27	
(803, 5)	4	1540	0	0	ENTRY	22	6	92	0	0	6	4	0	0	24		0	0	0	0	0	1	2	28	
(804, 7)	2	320	0	0	ENTRY	22	26	52	22	0	8	10	6	0	24		0	0	0	0	0	1	2	29	
(806, 8)	2	320	0	0	ENTRY	22	0	43	57	0	0	7	805	0	24		0	0	0	0	0	1	2	30	
(807, 9)	2	300	0	0	ENTRY	22	0	20	80	0	0	10	8	0	24		0	0	0	0	0	1	2	31	

TOPOLOGICAL FEATURES OF NETWORK

LINKS WITH LEFT-TURN MOVEMENT

LINK	OPPOSING	LINK	OPPOSING	LINK	OPPOSING	LINK	OPPOSING
(3, 2)	(1, 2)	(4, 3)	(802, 3)	(5, 4)	(3, 4)	(7, 6)	(5, 6)
(7, 8)	(806, 8)	(9, 7)	(6, 7)	(903, 5)	(4, 5)	(	

LEFT-TURNS FROM THE FOLLOWING LINKS HAVE UNOPPOSED MOVEMENT

(2, 1)	(1, 9)	(2, 3)	(11, 2)	(11, 4)	(6, 5)	(11, 6)	(9, 8)
(801, 1)	(804, 7)	(					

PLEASE VERIFY AND PREPARE TYPE 8 INPUT CARD IF NECESSARY

PEDESTRIAN DENSITY CATEGORIES

CODE	VOLUME (PEDS/HR)
0	100 TO 250
1	250 TO 500
2	ABOVE 500
3	NO PEDESTRIANS

TRAFFIC SIGNAL DATA

* INDICATES RTOR IN EFFECT FOR THIS APPROACH

NODE	INTVL	DURATION	OFFSET	(801, 1)*	(2, 1)*	(
1	1	40 (48P)	0 (0P)	1	2	
1	2	3 (4P)	40 (48P)	0	2	
1	3	37 (45P)	43 (52P)	2	1	
1	4	3 (4P)	80 (96P)	2	0	

NODE 2 IS UNDER SIGN CONTROL

NODE	INTVL	DURATION	OFFSET	(1, 2)*	(3, 2)*	(11, 2)*	(
2	1	80 (100P)	0 (0P)	1	1	5	

NODE	INTVL	DURATION	OFFSET	(802, 3)*	(2, 3)*	(4, 3)*	(
3	1	38 (54P)	24 (34P)	1	3	7	
3	2	4 (6P)	62 (89P)	0	3	7	
3	3	12 (17P)	66 (94P)	2	3	1	
3	4	3 (4P)	8 (11P)	2	3	0	
3	5	10 (14P)	11 (16P)	2	8	2	
3	6	3 (4P)	21 (30P)	2	0	2	

NODE	INTVL	DURATION	OFFSET	(3, 4)*	(11, 4)*	(5, 4)*	(
4	1	41 (59P)	34 (49P)	1	3	7	
4	2	4 (6P)	5 (7P)	0	3	7	
4	3	10 (14P)	9 (13P)	2	3	1	
4	4	3 (4P)	19 (27P)	2	3	0	
4	5	9 (13P)	22 (31P)	2	8	2	
4	6	3 (4P)	31 (44P)	2	0	2	

NODE	INTVL	DURATION	OFFSET	(4, 5)*	(6, 5)*	(803, 5)*	(
5	1	40 (57P)	49 (70P)	1	3	7	
5	2	4 (6P)	19 (27P)	0	3	7	
5	3	10 (14P)	23 (33P)	2	3	1	
5	4	3 (4P)	33 (47P)	2	3	0	
5	5	10 (14P)	36 (51P)	2	8	2	
5	6	3 (4P)	46 (56P)	2	0	2	

NODE 6 IS UNDER SIGN CONTROL

NODE	INTVL	DURATION	OFFSET	(5, 6)*	(11, 6)*	(7, 6)*	(
5	1	80 (100P)	0 (0P)	1	5	1	

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (6, 7)	(8, 7)	(804, 7)	(
7	1	22 (42P)	10 (19P)	1	7	2	
7	2	3 (6P)	32 (62P)	0	7	2	
7	3	8 (15P)	35 (57P)	2	1	2	
7	4	3 (6P)	43 (83P)	2	0	2	
7	5	13 (25P)	46 (88P)	2	2	1	
7	6	3 (6P)	7 (13P)	2	2	0	

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (7, 8)	(9, 8)	(806, 8)	(
8	1	12 (16P)	15 (19P)	1	2	2	
8	2	3 (4P)	27 (35P)	0	2	2	
8	3	42 (55P)	30 (39P)	2	1	2	
8	4	4 (5P)	72 (94P)	2	0	2	
8	5	13 (17P)	76 (99P)	7	2	1	
8	6	3 (4P)	12 (16P)	7	2	0	

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (1, 9)	(807, 9)	(
9	1	37 (63P)	7 (12P)	1	2	
9	2	4 (7P)	44 (75P)	0	2	
9	3	15 (25P)	48 (81P)	2	1	
9	4	3 (5P)	4 (7P)	2	0	

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (7, 10)	(9, 10)	(
10	1	20 (38P)	16 (30P)	1	2	
10	2	3 (6P)	36 (58P)	0	2	
10	3	27 (51P)	39 (74P)	2	1	
10	4	3 (6P)	13 (25P)	2	0	

NODE 11 IS UNDER SIGN CONTROL

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (10, 11)	(2, 11)	(4, 11)	(6, 11)
11	1	80 (100P)	0 (0P)	5	1	5	9

INTERPRETATION OF SIGNAL CODES

0	YIELD OR AMBER
1	GREEN
2	RED
3	RED WITH GREEN RIGHT ARROW
4	RED WITH GREEN LEFT ARROW
5	STOP OR RED WITH RIGHT TURN PERMITTED
6	RED WITH GREEN DIAGONAL ARROW
7	NO TURNS-GREEN THRU ARROW
8	RED WITH LEFT AND RIGHT GREEN ARROWS
9	NO LEFT TURN-GREEN THRU AND RIGHT

MAXIMUM NODE NUMBER IS 11

NUMBER OF ENTRY LINKS IS 6

```
                 SIMULATION TIME INTERVAL =1800 SECONDS.
                     SCANNING INTERVAL=1 SECOND
     INTERMEDIATE OUTPUT COMMENCES 600 SECONDS AFTER BEGINNING OF SUB-INTERVAL
 FOR A PERIOD OF 800 SECONDS, PRINT-OUT WILL APPEAR AT INTERVALS OF 200 SECONDS
    CUMULATIVE OUTPUT WILL APPEAR EVERY  0 MINUTES DURING SUB-INTERVAL
                          CLOCK TIME NOW
                            7  30 A.M.
              FUEL CONSUMPTION AND EMISSIONS WILL BE PROCESSED
             VEHICLE TRAJECTORY DATA WILL BE WRITTEN TO UNIT 23

                       EQUILIBRIUM ATTAINED
        PERIOD                   OCCUPANCY                   CHANGE

          1                         221                        -17
          2                         238                         28
          3                         210                          5
DURING PAST CYCLE, 238 VEHICLES OCCUPIED THE NETWORK.  NET CHANGE IN OCCUPANCY WAS  28 AT TIME=498
DURING PAST CYCLE, 210 VEHICLES OCCUPIED THE NETWORK.  NET CHANGE IN OCCUPANCY WAS   5 AT TIME=415

               INITIALIZATION PERIOD COMPLETED AFTER 498 SECONDS

               COMMENCE SIMULATION AND GATHER STATISTICAL DATA
   SPILLBACK HAS PREVAILED ON LINK (  7,  8) FOR  28 SECONDS FROM TIME= 101 TO TIME= 129
   SPILLBACK HAS PREVAILED ON LINK (  7,  8) FOR  20 SECONDS FROM TIME= 413 TO TIME= 433
```

LINK STATISTICS AT TIME 7 40 0

LINK	OCC.	VEH DIS	TURN LEFT	MOVEMENT THRU	RT.	QUEUE LENGTH BY LANE 1	2	3	4	5	DELAY/ VEH.	STOP DLY(P)	CYC FLR	EVNT	CURRENT CHANNELIZATION					AVG. SPEED	NO. STOP
(1, 2)	3	62	0	54	11	0	0	0	0	0	4.1	16	0	0	0	0	0	0	0	19.6	25
(2, 1)	4	54	59	0	0	0	2	0	0	0	21.7	77	0	0	0	1	0	0	0	5.6	40
(1, 9)	25	294	44	277	0	1	0	0	0	0	16.1	47	0	0	0	0	0	0	0	18.3	191
(2, 3)	11	92	59	0	44	1	8	0	0	0	31.8	84	0	0	4	0	0	0	0	8.2	70
(3, 2)	0	64	59	5	0	0	0	0	0	0	9.4	49	0	0	0	1	0	0	0	16.0	33
(2, 11)	6	66	0	74	0	0	0	0	0	0	5.4	20	0	0	0	0	0	0	0	22.1	27
(11, 2)	10	92	55	0	47	0	2	0	0	0	20.6	62	0	0	4	0	0	0	0	16.4	53
(3, 4)	55	508	0	532	29	4	4	6	7	0	31.1	60	1	0	0	0	0	0	0	16.9	424
(4, 3)	21	445	49	415	0	0	0	0	0	0	11.3	46	0	0	0	0	0	0	0	25.2	134
(4, 5)	18	490	0	495	19	1	1	1	1	0	7.4	27	0	0	0	0	0	0	0	22.1	55
(5, 4)	22	468	48	440	0	0	0	0	0	7	15.0	55	5	0	0	0	0	0	0	16.5	122
(4, 11)	3	60	0	0	62	1	0	0	0	0	8.9	45	0	0	4	0	0	0	0	13.7	84
(11, 4)	0	11	2	0	9	0	0	0	0	0	12.2	78	0	0	4	0	0	0	0	11.6	9
(5, 6)	5	58	0	36	25	0	0	0	0	0	1.4	0	0	0	0	0	0	0	0	18.3	0
(6, 5)	10	105	51	0	63	0	3	0	0	0	16.5	82	0	0	4	0	0	0	0	10.6	49
(6, 7)	2	109	0	103	9	1	1	0	0	0	11.7	73	0	0	0	0	0	0	0	8.7	71
(7, 6)	0	45	21	24	0	0	0	0	0	0	1.1	24	0	0	0	1	0	0	0	17.0	5
(6, 11)	0	45	0	35	11	0	0	0	0	0	2.1	6	0	0	0	0	0	0	0	21.3	5
(11, 6)	23	160	100	0	83	1	14	0	0	0	52.0	88	0	0	4	0	0	0	0	6.8	168
(7, 8)	8	123	29	99	0	0	2	2	0	0	21.4	88	0	0	0	0	0	0	0	3.2	56
(8, 7)	3	32	3	32	0	2	1	0	0	0	6.2	68	0	0	0	0	0	0	0	7.5	13
(7, 10)	4	54	0	0	57	0	0	0	0	0	6.5	30	0	0	4	0	0	0	0	15.3	42
(9, 8)	26	282	17	281	12	4	2	2	0	0	13.9	52	0	0	0	0	0	0	0	15.8	121
(9, 10)	2	49	0	51	0	1	1	0	0	0	9.7	75	0	0	0	0	0	0	0	5.9	38
(10, 11)	2	103	0	0	105	1	0	0	0	0	9.8	46	0	0	4	0	0	0	0	11.4	109
(801, 1)	13	311	68	254	0	2	4	5	0	0	0.0	0	0	0	0	0	0	0	0	0.0	0
(802, 3)	38	490	0	513	14	8	8	10	11	0	0.0	0	6	0	0	0	0	0	0	0.0	0
(803, 5)	11	458	47	425	0	1	1	6	6	0	0.0	0	4	0	0	0	0	0	0	0.0	0
(804, 7)	0	84	25	43	16	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0	0
(806, 8)	0	51	0	20	31	0	0	0	0	0	0.0	0	0	0	4	0	0	0	0	0.0	0
(807, 9)	2	49	0	11	40	2	0	0	0	0	0.0	0	0	0	4	0	0	0	0	0.0	0

SPILLBACK HAS PREVAILED ON LINK (7, 8) FOR 16 SECONDS FROM TIME= 729 TO TIME= 745

LINK STATISTICS AT TIME 7 43 20

LINK	OCC.	VEH DIS	TURN LEFT	MOVEMENT THRU	RT.	QUEUE LENGTH BY LANE 1	2	3	4	5	DELAY/ VEH.	STOP DLY(P)	CYC FLP	EVNT	CURRENT CHANNELIZATION					AVG. SPEED	NO. STOP
1, 2)	4	83	0	74	13	0	0	0	0	0	4.0	15	0	0	0	0	0	0	0	19.6	34
2, 1)	8	70	77	0	0	0	6	0	0	0	25.0	80	0	0	0	1	0	0	0	5.9	56
1, 9)	32	385	58	360	0	0	1	0	0	0	15.2	45	0	0	0	0	0	0	0	18.3	239
2, 3)	11	124	73	0	61	0	5	0	0	0	35.8	86	0	0	4	0	0	0	0	7.5	92
3, 2)	4	75	72	7	0	0	2	0	0	0	9.8	48	0	0	0	1	0	0	0	15.5	42
2, 11)	4	84	0	88	0	0	0	0	0	0	4.9	19	0	0	0	0	0	0	0	22.8	27
11, 2)	15	123	72	0	66	2	1	0	0	0	20.1	60	0	0	4	0	0	0	0	16.5	125
3, 4)	57	676	0	696	38	11	11	8	8	0	30.6	59	1	0	0	0	0	0	0	16.8	561
4, 3)	30	569	70	531	0	0	0	0	0	7	11.8	46	0	0	0	0	0	0	0	24.5	182
4, 5)	8	664	0	650	26	4	3	1	0	0	7.2	26	0	0	0	0	0	0	0	22.4	77
5, 4)	40	619	61	594	0	0	0	3	7	6	18.4	62	8	0	0	0	0	0	0	14.7	180
4, 11)	6	83	0	0	89	0	0	0	0	0	9.3	46	0	0	4	0	0	0	0	13.6	117
11, 4)	0	18	4	0	14	0	0	0	0	0	12.4	78	0	0	4	0	0	0	0	11.6	13
5, 6)	2	77	0	50	30	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	18.0	0
6, 5)	11	137	70	0	79	0	7	0	0	0	19.0	83	0	0	4	0	0	0	0	9.9	68
6, 7)	2	150	0	139	13	1	0	0	0	0	11.8	74	0	0	0	0	0	0	0	8.6	96
7, 6)	3	65	37	31	0	0	2	0	0	0	1.9	43	0	0	0	1	0	0	0	15.7	12
6, 11)	0	65	0	47	18	0	0	0	0	0	2.3	4	0	0	0	0	0	0	0	21.5	5
11, 6)	19	215	129	0	105	1	14	0	0	0	54.4	88	0	0	4	0	0	0	0	6.5	223
7, 8)	7	164	35	136	0	3	2	2	0	0	22.2	88	0	0	0	0	0	0	0	3.1	132
8, 7)	0	48	3	45	0	0	0	0	0	0	5.6	71	0	0	0	0	0	0	0	8.1	17
7, 10)	1	72	0	0	74	0	0	0	0	0	6.3	32	0	0	4	0	0	0	0	15.3	57
9, 6)	1	401	22	365	15	0	0	0	0	0	14.9	56	0	0	0	0	0	0	0	15.3	184
9, 10)	1	67	0	68	0	1	0	0	0	0	8.7	75	0	0	0	0	0	0	0	6.3	49
10, 11)	5	136	0	0	141	1	0	0	0	0	9.1	44	0	0	4	0	0	0	0	11.5	144
801, 1)	6	414	89	333	0	0	4	4	0	0	0.0	0	0	0	0	0	0	0	0	0.0	0
802, 3)	44	651	0	676	18	9	9	12	13	0	0.0	0	0	0	0	0	0	0	0	0.0	0
803, 5)	2	622	53	572	0	0	0	1	2	0	0.0	0	5	0	0	0	0	0	0	0.0	0
804, 7)	3	110	32	57	23	1	1	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0	0
806, 8)	3	64	0	28	39	1	2	0	0	0	0.0	0	0	0	4	0	0	0	0	0.0	0
807, 9)	0	67	0	14	53	0	0	0	0	0	0.0	0	0	0	4	0	0	0	0	0.0	0

LINK STATISTICS AT TIME 7 46 40

LINK	OCC.	VEH DIS	TURN LEFT	MOVEMENT THRU	RT.	QUEUE LENGTH BY LANE 1	2	3	4	5	DELAY/ VEH.	STOP DLY(P)	CYC FLR	EVNT	CURRENT CHANNELIZATION					AVG. SPEED	NO. STOP	STG CODE
[illegible], 2)	0	103	0	88	15	0	0	0	0	0	3.9	17	0	0	0	0	0	0	0	19.7	40	1
[illegible], 1)	1	97	98	0	0	0	0	0	0	0	23.0	79	0	0	0	1	0	0	0	5.5	68	[illegible]
1, 9)	27	488	70	446	0	5	5	3	0	0	15.5	45	0	0	0	0	0	0	0	18.1	319	1
[illegible], 3)	10	161	91	0	79	0	9	0	0	0	42.2	88	0	0	4	0	0	0	0	6.7	121	3
3, 2)	4	98	92	9	0	0	0	0	0	0	10.3	51	0	0	0	1	0	0	0	15.4	57	1
2, 11)	4	105	0	110	0	0	0	0	0	0	5.1	21	0	0	0	0	0	0	0	22.6	40	1
1, 2)	11	159	91	0	79	0	1	0	0	0	19.3	59	0	0	4	0	0	0	0	16.6	159	5
3, 4)	41	866	0	867	44	5	5	4	7	0	29.6	58	1	0	0	0	0	0	0	17.2	697	[illegible]
4, 3)	43	721	83	677	0	4	4	0	0	4	12.9	52	3	0	0	0	0	0	0	23.8	237	7
4, 5)	8	853	0	829	31	1	0	1	1	0	7.5	27	0	0	0	0	0	0	0	22.1	95	[illegible]
5, 4)	19	789	74	736	0	1	0	0	0	6	18.3	63	11	0	0	0	0	0	0	14.8	220	2
4, 11)	6	105	0	0	111	0	0	0	0	0	9.5	48	0	0	4	0	0	0	0	13.5	148	5
1, 4)	0	23	7	0	16	0	0	0	0	0	11.2	77	0	0	4	0	0	0	0	12.0	14	8
5, 6)	1	91	0	58	36	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	18.4	0	1
6, 5)	7	174	83	0	97	0	5	0	0	0	19.7	84	0	0	4	0	0	0	0	9.8	83	[illegible]
6, 7)	3	185	0	174	14	0	0	0	0	0	11.9	74	0	0	0	0	0	0	0	8.6	119	2
7, 6)	0	84	48	36	0	0	0	0	0	0	2.2	50	0	0	0	1	0	0	0	15.4	14	1
6, 11)	3	80	0	59	24	0	0	0	0	0	2.2	3	0	0	0	0	0	0	0	21.2	6	[illegible]
1, 6)	26	267	162	0	133	1	24	0	0	0	57.0	89	0	0	4	0	0	0	0	6.3	285	[illegible]
7, 8)	1	210	40	171	0	0	0	1	0	0	20.9	88	0	0	0	0	0	0	0	3.3	155	2
8, 7)	1	65	9	56	0	0	0	0	0	0	6.2	74	0	0	0	0	0	0	0	7.6	25	1
7, 10)	[illegible]	93	0	0	95	0	0	0	0	0	6.4	27	0	0	4	0	0	0	0	15.2	79	2
9, 8)	19	485	30	454	17	0	0	2	0	0	15.6	57	0	0	0	0	0	0	0	15.1	240	1
9, 10)	1	86	0	87	0	0	0	0	0	0	8.4	74	0	0	0	0	0	0	0	6.4	59	[illegible]
0, 11)	5	176	0	0	181	1	0	0	0	0	9.7	46	0	0	4	0	0	0	0	11.4	184	[illegible]
1, 1)	22	501	108	414	0	4	8	9	0	0	0.0	0	0	0	0	0	0	0	0	0.0	0	1
2, 3)	50	812	0	835	25	10	10	14	14	0	0.0	0	11	0	0	0	0	0	0	0.0	0	1
3, 5)	12	769	71	708	0	1	0	0	9	0	0.0	0	6	0	0	0	0	0	0	0.0	0	[illegible]
4, 7)	4	135	37	74	28	2	2	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0	0	[illegible]
6, 8)	2	83	0	38	46	0	1	0	0	0	0.0	0	0	0	4	0	0	0	0	0.0	0	[illegible]
7, 9)	2	82	0	18	66	2	0	0	0	0	0.0	0	0	0	4	0	0	0	0	0.0	0	2

LINK STATISTICS AT TIME 7 50 0

LINK	OCC.	VEH DIS	TURN LEFT	MOVEMENT THRU	RT.	QUEUE LENGTH BY LANE 1	2	3	4	5	DELAY/ VEH.	STOP DLY(P)	CYC FLP	EVNT	CURRENT CHANNELIZATION					AVG. SPEED	NO. STOP
(1, 2)	4	126	0	110	19	0	0	0	0	0	3.6	16	0	0	0	0	0	0	0	19.9	46
(2, 1)	5	109	114	0	0	0	5	0	0	0	23.4	78	0	0	0	1	0	0	0	9.7	81
(1, 9)	29	588	86	533	0	0	0	0	0	0	15.6	45	0	0	0	0	0	0	0	18.4	761
(2, 3)	16	189	109	0	95	0	12	0	0	0	48.0	90	0	0	4	0	0	0	0	6.1	145
(3, 2)	5	121	116	10	0	0	0	0	0	0	9.7	48	0	0	0	1	0	0	0	15.9	73
(2, 11)	6	130	0	136	0	0	1	0	0	0	7.4	38	0	0	0	0	0	0	0	21.1	51
(11, 2)	12	189	107	0	95	0	1	0	0	0	18.8	58	0	0	4	0	0	0	0	16.9	189
(3, 4)	35	1055	0	1034	56	2	2	1	2	0	28.4	57	1	0	0	0	0	0	0	17.6	412
(4, 3)	32	865	100	798	0	1	0	1	0	4	12.9	52	3	0	0	0	0	0	0	23.9	276
(4, 5)	16	1035	0	1011	35	0	0	0	0	0	7.5	27	0	0	0	0	0	0	0	22.2	113
(5, 4)	29	937	91	876	0	0	0	0	4	9	19.0	65	13	0	0	0	0	0	0	14.5	266
(4, 11)	5	128	0	0	132	0	0	0	0	0	9.6	49	0	0	4	0	0	0	0	13.7	180
(11, 4)	0	31	10	0	21	0	0	0	0	0	10.4	74	0	0	4	0	0	0	0	12.4	18
(5, 6)	1	111	0	71	41	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	18.3	0
(6, 5)	8	207	98	0	118	0	3	0	0	0	18.6	83	0	0	4	0	0	0	0	10.2	56
(6, 7)	1	225	0	208	18	1	0	0	0	0	12.0	74	0	0	0	0	0	0	0	8.6	150
(7, 6)	0	101	55	46	0	0	0	0	0	0	2.1	47	0	0	0	1	0	0	0	15.8	16
(6, 11)	0	97	0	66	31	0	0	0	0	0	2.2	3	0	0	0	0	0	0	0	21.3	6
(11, 6)	32	318	192	0	158	0	28	0	0	0	64.2	91	0	0	4	0	0	0	0	5.8	339
(7, 8)	15	241	48	205	0	4	4	4	0	0	20.7	87	0	0	0	0	0	0	0	3.3	189
(8, 7)	1	76	12	67	0	0	0	0	0	0	6.4	74	0	0	0	0	0	0	0	7.5	32
(7, 10)	3	113	0	0	116	0	0	0	0	0	6.5	28	0	0	4	0	0	0	0	14.9	55
(9, 8)	13	590	37	547	19	0	0	1	0	0	14.8	54	0	0	0	0	0	0	0	15.5	271
(9, 10)	0	103	0	103	0	0	0	0	0	0	9.1	75	0	0	0	0	0	0	0	6.1	71
(10, 11)	13	206	0	0	218	1	3	0	0	0	12.5	58	0	0	4	0	0	0	0	10.2	219
(801, 1)	4	618	131	491	0	0	1	3	0	0	0.0	0	0	0	0	0	0	0	0	0.0	0
(802, 3)	40	984	0	995	32	9	8	13	13	0	0.0	0	12	0	0	0	0	0	0	0.0	0
(803, 5)	8	925	82	851	0	1	1	0	6	0	0.0	0	9	0	0	0	0	0	0	0.0	0
(804, 7)	2	164	43	89	35	1	2	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0	0
(806, 8)	3	99	0	45	55	0	1	0	0	0	0.0	0	0	0	4	0	0	0	0	0.0	0
(807, 9)	0	100	0	20	80	0	0	0	0	0	0.0	0	0	0	4	0	0	0	0	0.0	0

SPILLBACK HAS PREVAILED ON LINK (7, 8) FOR 8 SECONDS FROM TIME=1197 TO TIME=1205
SPILLBACK HAS PREVAILED ON LINK (7, 8) FOR 8 SECONDS FROM TIME=1273 TO TIME=1281

CUMULATIVE STATISTICS SINCE BEGINNING OF SIMULATION

PRESENT TIME IS 8 0 0, ELAPSED SIMULATED TIME IS 30 MINUTES, 0 SECONDS

LINK STATISTICS

INK	VEH-MILES	VEH TRP	MOV. TIME V-MIN	DELAY TIME V-MIN	M/T	TOTAL TIME V-MIN	T-TIME / VEH. SEC	T-TIME/ VEH-MILE SEC/MILE	D-TIME / VEH SEC	D-TIME/ VEH-MILE SEC/MILE	PCT STOP DELAY	AVG. SPEED MPH	AVG. OCC.	STOPS /VEH	AVG SAT PCT	CYC FA
1, 2)	19.5	191	48.0	11.0	.81	59.0	18.5	181.1	3.4	33.7	15	19.9	2.0	.36	4	[illegible]
2, 1)	16.9	172	40.5	63.7	.39	104.2	36.3	368.9	22.2	225.5	77	9.8	3.4	.71	7	[illegible]
1, 9)	268.8	876	659.0	222.8	.75	881.8	60.4	196.6	15.3	49.7	44	18.3	29.4	.66	13	[illegible]
2, 3)	31.1	299	75.2	277.2	.21	352.4	70.7	680.9	55.6	535.5	91	5.3	11.7	.74	22	[illegible]
3, 2)	20.2	186	48.0	31.2	.61	79.3	25.6	235.1	10.1	92.6	53	15.3	2.7	.65	6	[illegible]
2, 11)	58.1	192	143.4	53.1	.73	196.5	61.4	203.1	16.6	54.9	69	17.7	6.5	.47	5	[illegible]
1, 2)	87.1	294	212.7	86.8	.71	299.5	61.1	206.4	17.7	59.6	56	17.4	10.0	.95	7	[illegible]
3, 4)	456.2	1587	804.8	721.5	.53	1526.3	57.7	200.7	27.3	94.5	56	17.9	50.9	.75	17	[illegible]
4, 3)	376.8	1309	666.8	282.4	.70	949.2	43.5	151.1	12.5	45.0	51	23.8	31.6	.32	11	[illegible]
4, 5)	208.1	1527	371.3	192.2	.66	563.5	22.1	162.5	7.6	55.4	29	22.2	18.8	.11	14	[illegible]
5, 4)	186.7	1408	329.9	459.4	.42	789.3	33.6	253.7	19.6	147.7	66	14.2	26.1	.29	18	[illegible]
4, 11)	21.3	197	64.1	32.8	.66	96.9	29.5	273.4	10.0	92.7	50	17.2	3.3	1.42	7	[illegible]
1, 4)	4.2	43	13.8	10.0	.58	23.8	33.2	340.4	13.5	142.5	81	10.6	.8	.65	2	[illegible]
5, 6)	18.0	160	55.2	4.2	.93	59.5	22.3	199.5	1.6	14.1	0	18.1	2.0	.01	4	[illegible]
6, 5)	35.0	319	107.8	93.8	.53	201.5	37.9	345.2	17.7	160.7	83	10.4	6.7	.44	12	[illegible]
6, 7)	14.9	324	47.4	68.0	.41	115.4	21.4	464.5	12.6	273.8	74	7.8	3.8	.66	17	[illegible]
7, 6)	7.9	154	25.7	4.8	.84	30.5	11.9	231.4	1.9	36.5	44	15.6	1.0	.16	4	[illegible]
6, 11)	17.9	141	44.7	5.3	.89	50.0	21.3	167.4	2.2	17.7	2	21.5	1.6	.04	3	[illegible]
1, 6)	61.4	474	148.4	640.1	.19	788.6	99.8	770.8	81.0	625.7	94	4.7	26.3	1.05	39	[illegible]
7, 8)	8.2	362	23.8	119.7	.17	143.5	23.9	1045.5	19.8	873.2	87	3.4	4.7	.72	33	[illegible]
8, 7)	2.6	115	8.5	11.0	.43	19.5	10.1	446.6	5.7	252.4	69	8.1	.7	.35	8	[illegible]
7, 10)	20.8	167	65.2	21.0	.76	86.2	31.0	249.2	7.5	60.6	37	14.4	2.9	.82	5	[illegible]
9, 8)	103.6	887	181.3	231.8	.44	413.1	27.9	239.2	15.7	134.3	56	15.0	13.7	.49	16	[illegible]
9, 10)	3.5	152	10.7	24.4	.30	35.1	13.8	609.1	9.6	423.8	75	5.9	1.2	.78	14	[illegible]
.0, 11)	22.1	302	72.2	174.5	.29	246.7	49.0	670.1	34.7	474.0	84	5.4	8.2	1.10	22	[illegible]

NETWORK STATISTICS

VEHICLE-MILES=2070.80 VEHICLE-MINUTES= 8111.2 VEHICLE-TRIPS (EST.)= 4215 STOPS/VEHICLE= 1.47

MOVING/TOTAL TRIP TIME= .526 AVG. SPEED (MPH)=15.32 MEAN OCCUPANCY= 270.0 VEH. AVG DELAY/VEHICLE= 54.70 SEC

TOTAL DELAY= 3842.8 MIN. DELAY/VEH-MILE= 1.86 MIN/V-MILE TRAVEL TIME/VEH-MILE= 3.92 MIN/V-MILE

STOPPED DELAY AS A PERCENTAGE OF TOTAL DELAY=67.1

SEED FOR RANDOM NUMBER GENERATOR IS 59161383

CUMULATIVE VALUES OF FUEL CONSUMPTION AND OF EMISSIONS

LINK		FUEL CONSUMPTION						VEHICLE EMISSIONS (GRAMS/MILE)								
		GALLONS			M.P.G.			HC			CO			NO X		
ICLE	TYPE-	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1,	2)	1.7	.2	0.0	10.9	4.0	0.0	3.2	0.0	0.0	48.3	0.0	0.0	5.8	0.0	0.0
2,	1)	2.1	.4	0.0	7.3	4.0	0.0	5.2	0.0	0.0	96.6	0.0	0.0	6.3	0.0	0.0
1,	9)	18.2	4.6	0.0	13.2	6.2	0.0	2.6	0.0	0.0	40.2	0.0	0.0	3.4	0.0	0.0
2,	3)	5.9	.6	0.0	5.0	3.4	0.0	8.2	0.0	0.0	163.7	0.0	0.0	6.5	0.0	0.0
3,	2)	1.8	.4	0.0	10.0	4.3	0.0	3.7	0.0	0.0	62.7	0.0	0.0	5.4	0.0	0.0
2,	11)	4.2	.9	0.0	12.7	5.9	0.0	2.6	0.0	0.0	42.0	0.0	0.0	3.6	0.0	0.0
11,	2)	6.0	1.5	0.0	13.2	6.0	0.0	2.6	0.0	0.0	42.5	0.0	0.0	3.0	0.0	0.0
3,	4)	35.6	7.1	0.0	11.7	5.2	0.0	3.1	0.0	0.0	47.7	0.0	0.0	5.1	0.0	0.0
4,	3)	22.8	4.7	0.0	15.1	6.7	0.0	2.4	0.0	0.0	34.0	0.0	0.0	4.3	0.0	0.0
4,	5)	17.1	3.5	0.0	11.1	4.5	0.0	3.3	0.0	0.0	48.8	0.0	0.0	7.0	0.0	0.0
5,	4)	19.6	4.6	0.0	8.4	3.5	0.0	4.4	0.0	0.0	71.6	0.0	0.0	8.0	0.0	0.0
4,	11)	1.9	.5	0.0	9.7	4.9	0.0	3.7	0.0	0.0	65.5	0.0	0.0	3.6	0.0	0.0
11,	4)	.5	.0	0.0	8.8	4.5	0.0	4.1	0.0	0.0	73.9	0.0	0.0	3.8	0.0	0.0
5,	6)	1.3	.2	0.0	12.3	5.4	0.0	2.8	0.0	0.0	43.5	0.0	0.0	3.2	0.0	0.0
6,	5)	3.8	.4	0.0	8.7	4.8	0.0	4.2	0.0	0.0	78.2	0.0	0.0	3.6	0.0	0.0
6,	7)	2.2	.4	0.0	6.3	3.4	0.0	6.1	0.0	0.0	119.9	0.0	0.0	5.7	0.0	0.0
7,	6)	.7	.0	0.0	10.8	5.3	0.0	3.2	0.0	0.0	53.6	0.0	0.0	3.8	0.0	0.0
6,	11)	1.3	.2	0.0	12.9	5.1	0.0	2.6	0.0	0.0	38.3	0.0	0.0	4.4	0.0	0.0
11,	6)	12.9	1.6	0.0	4.6	3.3	0.0	11.0	0.0	0.0	210.2	0.0	0.0	6.5	0.0	0.0
7,	8)	2.5	.3	0.0	3.0	2.5	0.0	13.5	0.0	0.0	284.8	0.0	0.0	10.4	0.0	0.0
8,	7)	.4	.0	0.0	5.9	3.3	0.0	6.6	0.0	0.0	120.7	0.0	0.0	7.4	0.0	0.0
7,	10)	1.8	.1	0.0	11.0	5.2	0.0	3.2	0.0	0.0	54.3	0.0	0.0	3.1	0.0	0.0
9,	8)	10.2	2.3	0.0	9.0	4.2	0.0	4.3	0.0	0.0	69.8	0.0	0.0	7.2	0.0	0.0
9,	10)	.7	.1	0.0	4.6	2.8	0.0	8.4	0.0	0.0	169.2	0.0	0.0	8.8	0.0	0.0
10,	11)	4.3	.5	0.0	5.1	3.0	0.0	7.6	0.0	0.0	153.4	0.0	0.0	5.6	0.0	0.0
NETWORK-WIDE STATISTICS		179.23	35.44	0.00	10.50	4.99	0.00	3.57	0.00	0.00	58.32	0.00	0.00	5.20	0.00	0.0

VEHICLE TYPE 1 = COMPOSITE AUTO, TYPE 2 = TRUCK, TYPE 3 = BUS

APPENDIX C

PROGRAM OUTPUT OF VALIDATION NETWORK

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                    START OF CASE   1
SIMULATION OF TRAFFIC CF SECOND NETWORK IN JEDDA
PRINCE MAJID SREET  ,JEDDAH             ,SAUDI ARABIA   C 05/20/83
          SEED FOR RANDOM NUMBER GENERATOR IS        7581
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SIMULATION OF TRAFFIC

THE NETSIM MODEL

SIMULATION OF TRAFFIC OF SECOND NETWORK IN JEDDA

PRINCE MAJID SREET , JEDDAH , SAUDI ARABIA 05/20/83

SEED FOR RANDOM NUMBER GENERATOR IS 7581

LINK	LANE	SPAN	POCK L	POCK R	MEAN U-F	H	TURNING MOVEMENTS LEFT	THRU	RT	DIAG	DESTINATION NODES LEFT	THRU	RT	DIAG	LOST	PED DEN	LANE CHAN 1	2	3	4	5	TYPE	G	L	IDENTIFICATI
12, 13)	2	820	0	0	30	22	0	96	14	0	0	14	20	0	24	0	0	0	0	0	0	1	2	1	
13, 12)	2	820	0	0	30	22	68	0	32	0	19	0	808	0	24	0	0	0	0	0	0	1	2	2	
12, 19)	2	840	0	0	35	22	0	100	0	0	0	18	0	0	24	1	0	0	0	0	0	1	2	3	
19, 12)	2	820	0	0	35	22	0	82	18	0	0	808	13	0	24	1	0	0	0	0	0	1	2	4	
13, 14)	2	730	0	0	30	22	20	60	20	0	809	810	15	0	24	0	0	0	0	0	0	1	2	5	
14, 13)	2	810	0	0	30	22	0	100	0	0	0	12	0	0	24	0	0	0	0	0	0	1	2	6	
13, 20)	2	760	0	0	25	22	36	36	28	0	15	17	19	0	24	3	0	0	0	0	0	1	2	7	
20, 13)	2	800	0	0	25	22	0	0	100	0	0	0	14	0	24	3	0	0	0	0	0	1	2	8	
14, 15)	4	800	0	0	40	22	7	84	9	0	811	16	20	0	24	3	0	0	0	0	0	1	2	9	
15, 14)	4	800	12	0	40	22	23	70	7	0	13	809	810	0	24	3	0	0	0	0	0	1	2	10	
15, 16)	4	750	12	0	40	22	18	72	10	0	812	813	17	0	24	0	0	0	0	0	0	1	2	11	
16, 15)	4	800	0	0	40	22	15	79	6	0	20	14	811	0	24	0	0	0	0	0	0	1	2	12	
15, 20)	2	800	0	0	25	22	4	61	35	0	17	19	13	0	24	3	0	0	0	0	0	1	2	13	
20, 15)	2	760	0	0	25	22	38	9	53	0	14	811	16	0	24	3	0	0	0	0	0	1	2	14	
16, 17)	4	800	0	0	40	22	0	93	7	0	0	18	20	0	24	0	0	0	0	0	0	1	2	15	
17, 16)	4	760	12	0	40	22	12	50	38	0	15	812	913	0	24	0	0	0	0	0	0	1	2	16	
17, 13)	4	780	0	0	40	22	0	90	10	0	0	814	19	0	24	0	0	0	0	0	0	1	2	17	
18, 17)	4	800	0	0	40	22	0	100	0	0	0	16	0	0	24	0	0	0	0	0	0	1	2	18	
17, 20)	2	760	0	0	25	22	9	64	27	0	19	13	15	0	24	3	0	0	0	0	0	1	2	19	
20, 17)	2	840	0	0	25	22	0	0	100	0	0	0	18	0	24	3	0	0	0	0	0	1	2	20	
18, 19)	2	820	0	0	35	22	0	84	16	0	0	12	20	0	24	1	0	0	0	0	0	1	2	21	
19, 18)	2	800	0	0	35	22	35	0	65	0	17	0	814	0	24	1	0	0	0	0	0	1	2	22	
19, 20)	2	760	0	0	25	22	2	93	5	0	13	15	17	0	24	0	0	0	0	0	0	1	2	23	
20, 19)	2	840	0	0	25	22	0	0	100	0	0	0	12	0	24	0	0	0	0	0	0	1	2	24	
8, 12)	2	740	0	0	ENTRY	22	27	73	0	0	13	19	0	0	24		0	0	0	0	0	1	2	25	
9, 14)	4	720	0	0	ENTRY	22	13	83	4	0	810	15	13	0	24		0	0	0	0	0	1	2	26	
10, 14)	2	680	0	0	ENTRY	22	24	48	28	0	15	13	809	0	24		0	0	0	0	0	1	2	27	
11, 15)	2	680	0	0	ENTRY	22	47	24	29	0	15	20	14	0	24		0	0	0	0	0	1	2	28	
12, 16)	4	780	10	0	ENTRY	22	17	80	3	0	813	17	15	0	24		0	0	0	0	0	1	2	29	
13, 16)	2	720	0	0	ENTRY	22	30	60	10	0	17	15	812	0	24		0	0	0	0	0	1	2	30	
14, 18)	4	780	12	0	ENTRY	22	21	79	0	0	19	17	0	0	24		0	0	0	0	0	1	2	31	

TOPOLOGICAL FEATURES OF NETWORK

LINKS WITH LEFT-TURN MOVEMENT

LINK	OPPOSING	LINK	OPPOSING	LINK	OPPOSING	LINK	OPPOSING
(13, 14)	(810, 14)	(13, 20)	(17, 20)	(14, 15)	(16, 15)	(15, 14)	(809, 14)
(15, 16)	(813, 16)	(16, 15)	(14, 15)	(15, 20)	(19, 20)	(20, 15)	(811, 15)
(17, 16)	(812, 16)	(17, 20)	(13, 20)	(19, 20)	(15, 20)	(808, 12)	(19, 12)
(809, 14)	(15, 14)	(810, 14)	(13, 14)	(811, 15)	(20, 15)	(812, 16)	(17, 16)
(813, 16)	(15, 16)	(814, 13)	(17, 13)	(			

LEFT-TURNS FROM THE FOLLOWING LINKS HAVE UNOPPOSED MOVEMENT

(13, 12) (19, 16) (

PLEASE VERIFY AND PREPARE TYPE 8 INPUT CARD IF NECESSARY

PEDESTRIAN DENSITY CATEGORIES

CODE	VOLUME (PEDS/HR)
0	100 TO 250
1	250 TO 500
2	ABOVE 500
3	NO PEDESTRIANS

TRAFFIC SIGNAL DATA

* INDICATES RTOR IN EFFECT FOR THIS APPROACH

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (808, 12)*	(17, 12)*	(19, 12)*	(
12	1	15 (19P)	16 (20P)	1	2	2	
12	2	3 (4P)	31 (39P)	1	2	2	
12	3	25 (31P)	34 (43P)	2	1	2	
12	4	3 (4P)	59 (74P)	2	0	2	
12	5	30 (38P)	62 (78P)	7	2	1	
12	6	4 (5P)	12 (15P)	7	2	0	

NODE 13 IS UNDER SIGN CONTROL

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (12, 13)*	(14, 13)*	(20, 13)*	(
13	1	80 (100P)	0 (0P)	1	1	5	

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (809, 14)*	(810, 14)*	(15, 14)*	(13, 14)*
14	1	10 (14P)	28 (38P)	2	8	2	8
14	2	3 (4P)	38 (51P)	2	8	2	8
14	3	18 (24P)	41 (55P)	2	9	2	9
14	4	3 (4P)	59 (80P)	2	9	2	9
14	5	10 (14P)	62 (84P)	8	2	8	2
14	6	4 (5P)	72 (97P)	8	2	8	2
14	7	22 (30P)	2 (3P)	9	2	9	2
14	8	4 (5P)	24 (32P)	9	2	9	2

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (14, 15)*	(811, 15)*	(16, 15)*	(20, 15)*
15	1	10 (13P)	20 (26P)	2	8	2	8
15	2	3 (4P)	30 (39P)	2	8	2	8
15	3	18 (24P)	33 (43P)	2	9	2	9
15	4	3 (4P)	51 (67P)	2	9	2	9
15	5	12 (16P)	54 (71P)	8	2	8	2
15	6	4 (5P)	66 (87P)	8	2	8	2
15	7	22 (29P)	70 (92P)	9	2	9	2
15	8	4 (5P)	16 (21P)	9	2	9	2

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (15, 16)*	(512, 16)*	(813, 16)*	(17, 16)*
16	1	20 (22P)	7 (8P)	2	8	2	8
16	2	4 (4P)	27 (29P)	2	8	2	8
16	3	25 (27P)	31 (33P)	2	9	2	9
16	4	4 (4P)	56 (60P)	2	9	2	9
16	5	10 (11P)	60 (65P)	8	2	8	2
16	6	4 (4P)	70 (75P)	8	2	8	2
16	7	22 (24P)	74 (80P)	9	2	9	2
16	8	4 (4P)	3 (3P)	9	2	9	2

NODE 17 IS UNDER SIGN CONTROL

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (16, 17)*	(18, 17)*	(20, 17)*	(
17	1	80 (100P)	0 (0P)	1	1	5	

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (14, 18)*	(19, 18)*	(17, 18)*	(
18	1	35 (43P)	0 (0P)	7	2	1	
18	2	4 (5P)	35 (43P)	7	2	0	
18	3	15 (19P)	39 (48P)	1	2	2	
18	4	4 (5P)	54 (67P)	2	2	2	
18	5	20 (25P)	56 (72P)	2	1	2	
18	6	3 (4P)	78 (96P)	2	1	2	

NODE 19 IS UNDER SIGN CONTROL

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (12, 19)*	(20, 19)*	(18, 19)*	(
19	1	80 (100P)	0 (0P)	1	5	1	

NODE 20 IS UNDER SIGN CONTROL

NODE	INTVL	DURATION	OFFSET	SIGNAL CODES FACING INDICATED APPROACHES (13, 20)*	(15, 20)*	(17, 20)*	(19, 20)*
20	1	80 (100P)	0 (0P)	5	1	5	1

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INTERPRETATION OF SIGNAL CODES

0          YIELD OR AMBER
1          GREEN
2          RED
3          RED WITH GREEN RIGHT ARROW
4          RED WITH GREEN LEFT ARROW
5          STOP OR RED WITH RIGHT TURN PERMITTED
6          RED WITH GREEN DIAGONAL ARROW
7          NO TURNS-GREEN THRU ARROW
8          RED WITH LEFT AND RIGHT GREEN ARROWS
9          NO LEFT TURN-GREEN THRU AND RIGHT

           MAXIMUM NODE NUMBER IS  20

          NUMBER OF ENTRY LINKS IS  7
```

SUB-INTERVAL 1

ENTRY LINK STATISTICS

LINK	FLOW RATE (VEH/HR)	PCT. TRUCKS
(808, 12)	817	8
(809, 14)	753	7
(810, 14)	521	4
(811, 15)	235	2
(812, 16)	1821	10
(813, 16)	627	8
(814, 18)	2012	9

SIMULATION TIME INTERVAL =1800 SECONDS.

SCANNING INTERVAL=1 SECOND

INTERMEDIATE OUTPUT COMMENCES 600 SECONDS AFTER BEGINNING OF SUB-INTERVAL

FOR A PERIOD OF 8 0 SECONDS, PRINT-OUT WILL APPEAR AT INTERVALS OF 200 SECONDS

CUMULATIVE OUTPUT WILL APPEAR EVERY 0 MINUTES DURING SUB-INTERVAL

CLOCK TIME NOW

7 30 A.M.

FUEL CONSUMPTION AND EMISSIONS WILL BE PROCESSED

VEHICLE TRAJECTORY DATA WILL BE WRITTEN TO UNIT 23

EQUILIBRIUM ATTAINED

PERIOD	OCCUPANCY	CHANGE
1	152	-13
2	165	1
3	164	30

DURING PAST CYCLE, 165 VEHICLES OCCUPIED THE NETWORK. NET CHANGE IN OCCUPANCY WAS   1 AT TIME=651

DURING PAST CYCLE, 164 VEHICLES OCCUPIED THE NETWORK. NET CHANGE IN OCCUPANCY WAS 30 AT TIME=558

INITIALIZATION PERIOD COMPLETED AFTER 651 SECONDS

COMMENCE SIMULATION AND GATHER STATISTICAL DATA

LINK STATISTICS AT TIME 7 40

LINK	OCC.	VEH DIS	TURN LEFT	MOVEMENT THRU	RT.	QUEUE 1	LENGTH 2	3	BY 4	LANE 5	DELAY/ VEH.	STOP DLY(P)	CYC FLP	EVNT	CURRENT CHANNELIZATION					AVG. SPEED	NO STOPS
(12, 13)	2	56	0	52	3	0	1	0	0	0	5.3	11	0	0	0	0	0	0	0	23.6	14
(13, 12)	3	73	55	[illegible]	23	0	3	0	0	0	22.2	76	1	0	0	1	0	0	0	13.6	57
(12, 19)	4	152	0	155		0	0	0	0	0	5.6	13	0	0	0	0	0	0	0	26.0	[illegible]
(19, 12)	6	89	0	75	2	2	2	0	0	0	24.5	73	0	0	0	0	0	0	0	13.6	55
(13, 14)	6	72	21	44	13	0	0	0	0	0	31.5	33	2	0	0	0	0	0	0	10.5	54
(14, 13)	4	76	0	79		0	0	0	0	0	4.0	11	0	0	0	0	0	0	0	24.8	11
(13, 20)	0	6	2	2	2	0	0	0	0	0	6.2	17	0	0	0	0	0	0	0	19.7	4
(20, 13)	2	24	0	0	23	0	0	0	0	0	10.0	22	0	0	4	0	0	0	0	19.1	24
(14, 15)	7	143	13	126	11	0	1	1	5	0	20.9	42	2	0	0	0	0	0	0	13.7	63
(15, 14)	15	113	33	57	5	3	2	2	1	3	38.3	75	1	0	0	0	0	0	0	19.5	[illegible]
(15, 16)	21	130	25	111	15	4	4	4	1	3	32.9	72	0	0	4	0	0	0	0	11.3	127
(16, 15)	5	115	20	97	4	0	0	1	4	0	40.3	74	5	0	0	0	0	0	0	10.1	34
(15, 20)	0	44	4	28	12	0	0	0	0	0	2.8	2	0	0	0	0	0	0	0	22.3	
(20, 15)	4	18	8	1	12	0	0	0	0	0	13.7	74	0	0	4	0	0	0	0	15.0	11
(16, 17)	10	274	0	269	12	0	0	0	0	0	6.8	2	0	0	0	0	0	0	0	26.5	34
(17, 16)	36	318	42	277	31	0	5	3	3	0	39.0	47	3	0	0	0	0	0	0	10.0	257
(17, 18)	2	293	0	267	22	0	0	0	0	0	19.3	72	0	0	0	0	0	0	0	15.6	143
(18, 17)	15	317	0	331		0	0	0	0	0	5.9	2	0	0	0	0	0	0	0	27.5	14
(17, 20)	1	20	0	14	5	0	0	0	0	0	6.1	28	0	0	0	0	0	0	0	19.7	2[illegible]
(20, 17)	0	7	0	0	7	0	0	0	0	0	9.8	41	0	0	4	0	0	0	0	17.4	7
(16, 19)	5	70	0	61	11	0	0	0	0	0	8.2	30	0	0	0	0	0	0	0	23.1	27
(19, 18)	12	146	56	0	103	0	0	0	0	0	20.9	69	0	0	4	0	0	0	0	14.7	125
(19, 20)	0	14	0	13	1	0	0	0	0	0	2.7	21	0	0	0	0	0	0	0	22.4	4
(20, 19)	1	31	0	0	32	0	0	0	0	0	7.4	42	0	0	4	0	0	0	0	18.8	31
(808, 12)	4	136	38	102	0	2	2	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0	
(809, 14)	12	125	21	109	7	2	1	5	4	0	0.0	0	5	0	0	0	0	0	0	0.0	
(810, 14)	4	87	30	40	21	1	3	0	0	0	0.0	0	7	0	0	0	0	0	0	0.0	
(811, 15)	0	40	17	13	1[illegible]	0	0	0	0	0	0.0	0	0	0	0	1	0	0	0	0.0	
(812, 16)	21	306	55	257	12	3	2	6	7	0	0.0	0	2	0	0	0	0	0	0	0.0	
(813, 15)	25	96	45	56	11	1[illegible]	15	0	0	0	0.0	0	7	0	0	0	0	0	0	0.0	
(814, 18)	36	323	83	277	0	1	0	0	22	12	0.0	0	7	0	0	0	0	0	0	0.0	

LINK STATISTICS AT TIME 7 43 2

LINK	OCC.	VEH DIS	TURN MOVEMENT LEFT	THRU	RT.	QUEUE LENGTH BY LANE 1	2	3	4	5	DELAY/ VEH.	STOP DLY(P)	CYC FLR	EVNT	CURRENT CHANNELIZATION					AVG. SPEED	NO. STOPS
12, 13)	1	76	0	68	9	0	2	0	0	0	5.1	11	0	0	0	0	0	0	0	23.8	21
13, 12)	9	95	76	0	39	0	5	0	0	0	22.1	78	1	0	0	1	0	0	0	13.5	77
12, 19)	6	197	0	202	0	0	0	0	0	0	5.6	12	0	0	0	0	0	0	0	25.8	43
19, 12)	2	124	0	99	27	0	0	0	0	0	22.9	73	0	0	0	0	0	0	0	14.3	64
13, 14)	14	93	22	64	12	6	5	0	0	0	36.1	83	3	0	0	0	0	0	0	9.5	84
14, 13)	0	102	0	104	0	0	0	0	0	0	4.1	10	0	0	0	0	0	0	0	24.2	15
13, 20)	0	9	4	3	2	0	0	0	0	0	7.0	18	0	0	0	0	0	0	0	19.3	7
20, 13)	0	32	0	0	32	0	0	0	0	0	9.6	20	0	0	4	0	0	0	0	18.1	32
14, 15)	7	194	18	167	13	0	0	0	1	0	21.3	62	2	0	0	0	0	0	0	15.5	87
15, 14)	9	153	42	114	7	0	0	0	0	0	34.3	72	1	0	0	0	0	0	0	11.5	13[illegible]
15, 16)	20	184	35	146	25	3	2	1	1	5	45.6	76	0	0	0	0	0	0	0	10.8	16[illegible]
16, 15)	9	151	24	129	5	0	0	0	5	0	39.6	74	5	0	0	0	0	0	0	10.2	12[illegible]
15, 20)	1	52	4	34	15	0	0	0	0	0	3.1	1	0	0	0	0	0	0	0	22.6	[illegible]
20, 15)	1	31	12	1	19	0	0	0	0	0	13.8	72	0	0	4	0	0	0	0	14.4	19
16, 17)	29	367	0	371	25	0	0	0	0	0	6.7	1	0	0	0	0	0	0	0	25.6	35
17, 16)	23	441	56	365	37	6	4	0	0	1	39.4	67	3	0	0	0	0	0	0	10.0	36[illegible]
17, 18)	7	373	0	347	35	1	1	1	1	0	18.5	70	0	0	0	0	0	0	0	16.8	194
18, 17)	6	426	0	433		0	0	0	0	0	5.9	0	0	0	0	0	0	0	0	27.7	24
17, 20)	0	26	1	17	9	0	0	0	0	0	8.1	27	0	0	0	0	0	0	0	18.8	25
20, 17)	0	8	0	0	8	0	0	0	0	0	9.6	37	0	0	4	0	0	0	0	17.7	8
18, 19)	6	104	0	90	22	0	0	0	0	0	8.3	26	0	0	0	0	0	0	0	22.6	47
19, 18)	7	196	75	0	129	0	1	0	0	0	21.7	71	1	0	4	0	0	0	0	14.6	164
19, 20)	1	21	0	21	1	0	0	0	0	0	3.3	23	0	0	0	0	0	0	0	21.6	7
20, 19)	2	36	0	0	39	0	0	0	0	0	7.2	39	0	0	4	0	0	0	0	19.8	36
308, 12)	4	162	52	134	0	0	4	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0	0
309, 14)	7	171	24	145	0	0	0	3	4	0	0.0	0	9	0	0	0	0	0	0	0.0	0
310, 14)	9	113	36	54	3	4	3	0	0	0	0.0	0	9	0	0	0	0	0	0	0.0	0
311, 15)	2	51	23	17	13	1	1	0	0	0	0.0	0	0	0	0	1	0	0	0	0.0	0
312, 16)	9	418	71	337	15	0	0	2	2	2	0.0	0	2	0	0	0	0	0	0	0.0	0
313, 16)	29	127	57	98	12	12	16	0	0	0	0.0	0	9	0	0	0	0	0	0	0.0	0
314, 18)	39	430	108	363		4	4	0	12	11	0.0	0	10	0	0	0	0	0	0	0.0	0

LINK STATISTICS AT TIME 7 46 4

LINK	OCC.	VEH DIS	TURN LEFT	MOVEMENT THRU	RT.	QUEUE LENGTH BY LANE 1	2	3	4	5	DELAY/ VEH.	STOP DLY(F)	CYC FLR	EVNT	CURRENT CHANNELIZATION					AVG. SPEED	NO. STOP
(12, 13)	4	93	0	85	12	0	0	0	0	0	5.1	10	0	0	0	0	0	0	0	23.6	25
(13, 12)	7	124	89		4[illegible]	0	0	0	0	0	25.1	11	2	0	0	1	0	0	0	12.7	1[illegible]
(12, 19)	6	243	0	25[illegible]		0	0	0	0	0	5.7	12	0	0	0	0	0	0	0	25.6	5[illegible]
(19, 12)	10	154	0	133	31	4	3	0	0	0	23.9	73	0	0	0	0	0	0	0	13.8	11[illegible]
(13, 14)	10	115	24	74	27	3	3	0	0	0	33.9	42	4	0	0	0	0	0	0	1[illegible]	9[illegible]
(14, 13)	1	128	0	129		0	0	0	0	0	4.0	9	0	0	0	0	0	0	0	24.3	1[illegible]
(13, 20)	0	12	5	3	3	0	0	0	0	0	6.8	17	0	0	0	0	0	0	0	18.2	1[illegible]
(20, 13)	1	39	0	[illegible]	4[illegible]	0	0	0	0	0	9.6	39	0	0	4	0	0	0	0	17.9	39
(14, 15)	13	232	21	20[illegible]	2[illegible]	1	0	1	0	0	20.6	39	2	0	0	0	0	0	0	15.8	107
(15, 14)	1	199	49	13[illegible]	1[illegible]	0	0	0	0	0	31.2	39	1	0	0	0	0	0	0	12.2	16[illegible]
(15, 16)	13	234	44	173	2[illegible]	3	2	2	3	0	35.4	74	0	0	0	0	0	0	0	10.8	203
(16, 15)	3	189	29	153	1[illegible]	0	0	1	1	0	39.4	73	7	0	0	0	0	0	0	16.3	147
(15, 20)	0	68	5	42	21	0	0	0	0	0	3.2	1	0	0	0	0	0	0	0	22.4	[illegible]
(20, 15)	1	40	18	3	2[illegible]	0	0	0	0	0	15.7	73	0	0	4	0	0	0	0	13.8	24
(16, 17)	23	476	0	462	33	0	0	0	0	0	6.6	1	0	0	0	0	0	0	0	26.3	55
(17, 16)	13	544	72	443	43	0	1	1	0	2	39.7	97	3	0	0	0	0	0	0	9.9	45[illegible]
(17, 18)	16	467	0	429	55	0	0	0	0	0	16.6	[illegible]8	0	0	0	0	0	0	0	17.9	21[illegible]
(18, 17)	13	526	0	54[illegible]	[illegible]	0	0	0	0	0	5.9	2	0	0	0	0	0	0	0	27.[illegible]	2[illegible]
(17, 20)	2	31	1	21	11	0	0	0	0	0	7.8	24	0	0	0	0	0	0	0	19.4	3[illegible]
(20, 17)	1	8	0	0	[illegible]	1	0	0	0	0	11.4	40	0	0	4	0	0	0	0	15.7	[illegible]
(18, 19)	2	133	0	112	24	0	0	0	0	0	8.2	26	0	0	0	0	0	0	0	22.[illegible]	5[illegible]
(19, 18)	10	241	68	[illegible]	163	2	4	0	0	0	21.9	70	1	0	4	0	0	0	0	14.5	20[illegible]
(19, 20)	0	25	0	24	1	0	0	0	0	0	3.0	21	0	0	0	0	0	0	0	22.0	7
(20, 19)	0	48	0	[illegible]	45	0	0	0	0	0	7.6	38	0	0	4	0	0	0	0	15.8	4[illegible]
(808, 12)	4	227	67	164		2	2	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0	[illegible]
(809, 14)	6	215	29	163	11	0	0	0	5	0	0.0	0	10	0	0	0	0	0	0	0.0	[illegible]
(810, 14)	9	140	42	56	37	4	5	0	0	0	0.0	0	12	0	0	0	0	0	0	0.0	[illegible]
(811, 15)	1	65	30	19	17	0	1	0	0	0	0.0	0	0	0	0	1	0	0	0	0.0	[illegible]
(812, 16)	6	517	98	410	1[illegible]	0	0	3	0	2	0.0	0	2	0	0	0	0	0	0	0.0	[illegible]
(813, 16)	32	160	64	111	17	16	16	0	0	0	0.0	0	11	0	0	0	0	0	0	0.0	[illegible]
(814, 18)	49	534	132	45[illegible]		0	0	0	32	12	0.0	0	12	0	0	0	0	0	0	0.0	[illegible]

LINK STATISTICS AT TIME 7 50 [illegible]

LINK	OCC.	VEH DIS	TURN LEFT	MOVEMENT THRU	RT.	QUEUE LENGTH BY LANE 1	2	3	4	5	DELAY/ VEH.	STOP DLY(P)	CYC. FLR	EVNT	CURRENT CHANNELIZATION					AVG. SPEED	NO. STOP
(12, 13)	1	112	0	98	15	0	0	0	0	0	4.9	11	0	0	0	0	0	0	0	23.7	33
(13, 12)	4	150	105	[illegible]	5	0	0	0	0	0	22.5	79	2	0	0	1	0	0	0	13.6	112
(12, 19)	9	297	0	304		0	0	0	0	0	5.9	13	0	0	0	0	0	0	0	25.4	[illegible]
(19, 12)	0	191	0	155	35	0	0	0	0	0	23.3	74	0	0	0	0	0	0	0	14.2	12-
(13, 14)	7	143	31	69	31	0	6	0	0	0	34.9	53	6	0	0	0	0	0	0	9.7	11-
(14, 13)	4	153	0	156		0	0	0	0	0	4.0	9	0	0	0	0	0	0	0	24.7	23
(13, 20)	0	15	7	4	4	0	0	0	0	0	6.9	19	0	0	0	0	0	0	0	18.1	15
(20, 13)	0	48	0	0	42	0	0	0	0	0	9.5	22	0	0	4	0	0	0	0	18.1	[illegible]
(14, 15)	0	288	23	239	25	0	0	0	0	0	21.2	59	2	0	0	0	0	0	0	15.6	145
(15, 14)	9	222	58	159	11	1	1	0	0	1	29.6	67	1	0	0	0	0	0	0	12.6	177
(15, 16)	8	296	54	22[illegible]	31	1	0	0	0	0	34.5	74	0	0	0	0	0	0	0	11.0	234
(16, 15)	5	220	35	177	11	0	0	0	2	0	40.1	74	9	0	0	0	0	0	0	10.2	173
(15, 20)	1	79	5	49	25	0	0	0	0	0	3.1	1	0	0	0	0	0	0	0	22.7	
(20, 15)	3	49	19	3	23	0	0	0	0	0	13.9	70	0	0	4	0	0	0	0	14.7	3
(16, 17)	2	576	0	539	35	0	0	0	0	0	6.7	1	0	0	0	0	0	0	0	26.5	61
(17, 16)	21	640	80	528	53	4	5	1	2	3	38.5	67	3	0	0	0	0	0	0	10.1	337
(17, 18)	33	546	0	517	63	4	3	5	3	0	19.3	70	0	0	0	0	0	0	0	16.3	29[illegible]
(18, 17)	5	629	0	635	[illegible]	0	0	0	0	0	5.8	2	0	0	0	0	0	0	0	27.7	31
(17, 20)	3	37	1	27	12	1	0	0	0	0	8.0	16	0	0	0	0	0	0	0	16.3	3-
(20, 17)	0	10	0	1	13	0	0	0	0	0	11.6	44	0	0	4	0	0	0	0	16.9	1
(18, 19)	8	164	0	141	31	0	0	0	0	0	8.0	25	0	0	0	0	0	0	0	23.3	[illegible]
(19, 18)	10	294	105	[illegible]	193	0	4	0	0	0	22.4	70	1	0	4	0	0	0	0	14.3	24-
(19, 20)	0	33	0	32	1	0	0	0	0	0	3.3	15	0	0	0	0	0	0	0	21.7	1[illegible]
(20, 19)	4	52	0	0	55	0	0	0	0	0	7.3	37	0	0	4	0	0	0	0	18.8	52
(808, 12)	3	273	80	197		0	4	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0	
(809, 14)	10	251	35	213	13	0	0	5	6	0	0.0	0	13	0	0	0	0	0	0	0.0	
(810, 14)	4	174	48	93	47	2	2	0	0	0	0.0	0	14	0	0	0	0	0	0	0.0	
(811, 15)	2	78	36	21	22	1	0	0	0	0	0.0	0	0	0	0	1	0	0	0	0.0	
(812, 16)	16	607	106	497	21	3	2	3	5	4	0.0	0	2	0	0	0	0	0	0	0.0	
(813, 16)	34	193	77	130	2[illegible]	14	20	0	0	0	0.0	0	13	0	0	0	0	0	0	0.0	
(814, 18)	53	639	159	534		2	3	0	34	11	0.0	0	15	0	0	0	0	0	0	0.0	

CUMULATIVE STATISTICS SINCE BEGINNING OF SIMULATION

PRESENT TIME IS = 0 0, ELAPSED SIMULATED TIME IS 30 MINUTES, 0 SECONDS

LINK STATISTICS

LINK	VEH-MILES	VEH TRP	MOV. TIME V-MIN	DELAY TIME V-MIN	M/T	TOTAL TIME V-MIN	T-TIME / VEH. SEC	T-TIME/ VEH-MILE SEC/MILE	D-TIME / VEH SEC	D-TIME/ VEH-MILE SEC/MILE	PCT STOP DELAY	AVG. SPEED MPH	AVG. OCC.	STOPS /VEH	AVG SAT PCT	CY FA
12, 13)	25.1	163	51.4	12.9	.83	64.3	23.7	154.0	4.8	31.0	10	23.4	2.1	.26	3	0
13, 12)	33.2	214	66.3	82.5	.45	148.8	41.7	268.5	23.1	148.9	79	13.4	5.0	.77	6	3
12, 19)	70.3	442	123.1	43.0	.74	166.1	22.5	141.7	5.8	36.7	12	25.4	5.5	.21	7	0
19, 12)	44.5	289	78.9	121.3	.39	200.2	41.6	269.9	25.2	163.5	73	13.3	6.7	.76	5	0
13, 14)	29.4	215	58.2	129.8	.31	188.0	52.5	384.0	36.2	265.1	84	9.4	6.3	.79	9	10
14, 13)	32.9	215	66.3	14.0	.83	80.2	22.4	146.3	3.9	25.4	7	24.6	2.7	.13	4	0
13, 20)	3.1	22	8.0	2.6	.75	10.6	28.9	207.5	7.1	50.8	20	17.3	.3	1.00	1	0
20, 13)	11.5	77	27.3	12.0	.69	39.3	30.6	205.2	9.3	62.6	21	17.5	1.3	1.03	2	0
14, 15)	63.1	418	95.5	185.2	.34	280.7	40.3	266.7	26.6	176.0	65	13.5	9.4	.65	7	6
15, 14)	49.2	326	72.1	139.4	.34	211.5	38.9	257.8	25.7	169.9	63	14.0	7.0	.67	5	1
15, 16)	62.9	427	97.9	239.8	.29	337.7	47.5	322.0	33.7	228.7	71	11.2	11.2	.77	7	0
16, 15)	49.9	330	74.7	216.4	.25	291.1	52.9	350.2	39.3	260.4	73	10.3	9.8	.89	7	13
15, 20)	17.1	114	40.5	5.9	.87	46.4	24.4	163.0	3.1	20.9	1	22.1	1.6	0.00	3	0
20, 15)	8.6	60	22.2	14.8	.60	37.0	37.0	259.1	14.8	103.5	71	13.9	1.2	.69	2	0
16, 17)	127.1	840	194.6	95.2	.67	289.8	20.7	136.9	6.8	45.0	1	26.3	9.6	.10	7	0
17, 16)	134.0	931	200.5	623.4	.24	823.9	53.1	368.9	40.2	279.1	87	9.8	27.5	.37	17	6
17, 18)	120.3	815	179.0	263.3	.40	442.3	32.6	220.6	19.4	131.3	71	16.3	14.7	.53	10	0
18, 17)	142.3	939	218.0	93.4	.70	311.5	19.9	131.4	6.0	39.4	2	27.4	10.3	.06	7	0
17, 20)	8.5	61	19.4	7.9	.71	27.2	26.8	192.1	7.7	55.5	24	18.7	.9	1.00	2	0
20, 17)	2.4	15	5.7	2.6	.69	8.3	33.1	208.9	10.4	65.4	38	17.2	.3	1.00	1	0
18, 19)	38.1	248	66.0	32.7	.67	98.7	23.9	155.2	7.9	51.4	23	23.2	3.2	.42	5	0
19, 18)	66.7	440	116.3	165.6	.41	281.9	38.4	253.7	22.6	149.1	71	14.2	9.4	.82	12	3
19, 20)	5.7	41	14.0	2.3	.86	16.3	23.9	171.2	3.3	23.9	22	21.0	.6	.32	1	0
20, 19)	13.0	82	31.7	12.4	.72	44.2	32.3	203.5	9.1	57.2	44	17.7	1.5	1.01	2	0

NETWORK STATISTICS

VEHICLE-MILES=1158.91 VEHICLE-MINUTES= 4446.1 VEHICLE-TRIPS (EST.)= 3000 STOPS/VEHICLE= 1.32

MOVING/TOTAL TRIP TIME= .434 AVG. SPEED (MPH)=15.64 MEAN OCCUPANCY= 148.0 VEH. AVG DELAY/VEHICLE= 50.37 SEC

TOTAL DELAY= 2518.3 MIN. DELAY/VEH-MILE= 2.17 MIN/V-MILE TRAVEL TIME/VEH-MILE= 3.84 MIN/V-MILE

STOPPED DELAY AS A PERCENTAGE OF TOTAL DELAY=67.0

SEED FOR RANDOM NUMBER GENERATOR IS 95989589

CUMULATIVE VALUES OF FUEL CONSUMPTION AND OF EMISSIONS

LINK	FUEL CONSUMPTION						VEHICLE EMISSIONS (GRAMS/MILE)								
	GALLONS			M.P.G.			HC			CO			NO X		
VEHICLE TYPE-	1	2	3	1	2	3	1	2	3	1	2	3	1	2	
(12, 13)	1.9	.5	0.0	11.6	4.5	0.0	2.9	0.0	0.0	42.0	0.0	0.0	6.2	0.0	[illegible]
(13, 12)	2.7	.3	0.0	11.8	9.1	0.0	3.5	0.0	0.0	59.0	0.0	0.0	3.7	0.0	[illegible]
(12, 19)	5.9	1.2	0.0	10.7	4.0	0.0	3.1	0.0	0.0	44.8	0.0	0.0	7.6	0.0	[illegible]
(19, 12)	4.1	.5	0.0	10.1	6.1	0.0	4.1	0.0	0.0	70.2	0.0	0.0	5.3	0.0	[illegible]
(13, 14)	3.4	.5	0.0	7.9	4.6	0.0	5.1	0.0	0.0	93.5	0.0	0.0	5.6	0.0	[illegible]
(14, 13)	2.6	.4	0.0	11.7	4.5	0.0	2.8	0.0	0.0	40.5	0.0	0.0	4.3	0.0	[illegible]
(13, 20)	.2	.1	0.0	12.0	5.5	0.0	3.1	0.0	0.0	46.3	0.0	0.0	4.3	0.0	[illegible]
(20, 13)	.9	.2	0.0	11.5	5.0	0.0	3.2	0.0	0.0	49.4	0.0	0.0	4.7	0.0	[illegible]
(14, 15)	7.2	1.2	0.0	8.0	3.9	0.0	5.1	0.0	0.0	85.1	0.0	0.0	6.9	0.0	[illegible]
(15, 14)	5.1	.8	0.0	8.6	4.1	0.0	4.8	0.0	0.0	81.1	0.0	0.0	7.7	0.0	[illegible]
(15, 16)	7.8	1.1	0.0	7.7	3.9	0.0	5.4	0.0	0.0	94.7	0.0	0.0	8.1	0.0	[illegible]
(16, 15)	6.7	1.0	0.0	6.7	3.7	0.0	6.1	0.0	0.0	108.2	0.0	0.0	9.4	0.0	[illegible]
(15, 20)	1.2	.2	0.0	13.0	5.0	0.0	2.6	0.0	0.0	36.4	0.0	0.0	4.4	0.0	[illegible]
(20, 15)	.7	.1	0.0	11.6	6.6	0.0	3.1	0.0	0.0	52.9	0.0	0.0	3.3	0.0	[illegible]
(16, 17)	11.0	3.7	0.0	10.1	3.4	0.0	3.4	0.0	0.0	48.7	0.0	0.0	6.3	0.0	[illegible]
(17, 16)	15.0	1.3	0.0	8.5	5.4	0.0	5.6	0.0	0.0	126.3	0.0	0.0	5.9	0.0	[illegible]
(17, 18)	9.1	2.1	0.0	11.7	5.3	0.0	3.8	0.0	0.0	64.9	0.0	0.0	5.1	0.0	[illegible]
(18, 17)	13.3	2.9	0.0	9.7	3.3	0.0	3.4	0.0	0.0	49.5	0.0	0.0	9.7	0.0	[illegible]
(17, 20)	.6	.1	0.0	11.9	5.1	0.0	3.2	0.0	0.0	46.9	0.0	0.0	4.7	0.0	[illegible]
(20, 17)	.2	.0	0.0	11.8	5.4	0.0	3.1	0.0	0.0	47.5	0.0	0.0	4.4	0.0	[illegible]
(18, 19)	3.2	.9	0.0	10.3	3.9	0.0	3.3	0.0	0.0	49.7	0.0	0.0	7.5	0.0	[illegible]
(19, 18)	5.3	.7	0.0	11.9	7.6	0.0	3.7	0.0	0.0	63.8	0.0	0.0	4.1	0.0	[illegible]
(19, 20)	.4	.1	0.0	12.2	4.8	0.0	2.7	0.0	0.0	41.5	0.0	0.0	4.7	0.0	[illegible]
(20, 19)	.9	.1	0.0	14.2	7.1	0.0	2.6	0.0	0.0	40.1	0.0	0.0	2.5	0.0	[illegible]
NETWORK-WIDE STATISTICS	109.58	20.76	0.00	9.66	4.41	0.00	4.09	0.00	0.00	68.26	0.00	0.00	5.69	0.00	[illegible]

VEHICLE TYPE 1 = COMPOSITE AUTO, TYPE 2 = TRUCK, TYPE 3 = BUS

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