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Traffic Signal Central Control: A Methodology to determine Effectiveness

By:

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American University of Beirut
Beirut, Lebanon, 1990

A thesis submitted to the
Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of

(Master of Engineering)

Department of Civil and Environmental Engineering

*Carleton University
Ottawa, Ontario
December, 1998*

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Faculty of Graduate Studies and Research
acceptance of the thesis

“Traffic Signal Central Control: A Methodology to determine Effectiveness”

submitted by
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In partial fulfillment of the requirements for the degree of
Master of Engineering

Chair
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Department of Civil and Environmental Engineering

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Carleton University
January 1999

“TO MY BELOVED FAMILY”
Father, Mother, Wife and Son

Who have encouraged me to achieve my goals, through the course of my life.

“THIS IS FOR YOU”

ABSTRACT

A well designed traffic control system has the ability to coordinate traffic signals, access traffic data, provide traveler information and the ability to manage traffic through features such as closed circuit television and variable message signs. Today's communications and computer industries can provide able and effective tools to make this possible.

This research study has developed and implemented a methodological framework for investigating the capability of such systems to reduce delay and harmful emissions. A case study was needed to help us better understand the consequential improvements. Also, at the time this research was initiated, the city of Syracuse, was planning to implement a traffic control system in an attempt to improve air quality, mobility and traffic safety, therefore it was considered beneficial to apply the developed methodology so as to check on the effectiveness of the advanced central traffic control. The models were calibrated with field data.

Specifically, the purpose of this thesis research is to provide a methodology for studying the feasibility of traffic control systems, by proving that a city can use advanced technology to improve traffic flow and safety, and reduce delay time and emissions. The methodological framework uses two transportation software packages, namely, Transyt 7F and Traf-Netsim. Traffic counts were provided by the NYDOT , and other required data were collected through field studies, in the City of Syracuse.

The results of the network simulations show that average delay time decreased by 52.5% according to the Transyt 7F software and by 35.9% according to the Traf-Netsim software. Carbon monoxide (CO) decreased by 46.4%, as reported by the Netsim model. Also other important measures of effectiveness exhibited serious improvements.

The significance of this study lies in its ability to demonstrate the effectiveness of Intelligent Transportation Systems (ITS). And to explain their capabilities and constraints. It also attempts to establish a methodology through which a traffic signal central control system's feasibility could be checked for different applications.

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I also wish to thank the University of Florida, specifically, Mr. David Hale, whose assistance in debugging the Traf-Netsim files was very valuable.

Last, but definitely not least, I would like to offer my gratitude and appreciation to the lady who stood behind me in the past two years, my beloved wife, Suha.

ACRONYMS & DEFINITIONS

CBD	=	Central Business District
CCTV	=	Closed Circuit Television
CENTRO	=	Syracuse Public Transportation
CO	=	Carbon-Monoxide
DBMS	=	Data Base Management System
DI	=	Disutility Index
DTMF	=	Dual Tone Multi-Function
EV	=	Electric Vehicle
FREFLO	=	FRE for freeway network & FLO for macroscopic simulation
HAR	=	Highway Advisory Radio
HOV	=	High Occupancy Vehicles
HC	=	Hydro-Carbon
HCM	=	Highway Capacity Manual
hr.	=	hour
I/M	=	Inspection/Maintenance
ITS	=	Intelligent Transportation System
IVHS	=	Intelligent Vehicle Highway System
LAN	=	Local Area Network
LEV	=	Low Emissions Vehicle
MATS	=	Multi-Arterial Traffic System
MBQ	=	Maximum Back of Queue
mi.	=	mile
MIST	=	Management Information System for Traffic
MOE	=	Measure Of Effectiveness
mph	=	mile per hour
MTBF	=	Mean Time Between Failures
MTTR	=	Mean Time To Repair

NETFLO	=	NET for street network and FLO for macroscopic simulation
NO _x	=	Nitrogen Oxide
NYDOT	=	New York Department Of Transportation
NYSIP	=	New York State Implementation Plan
OPAC	=	Urban Traffic Control (UTC) system (American, 1982)
pax	=	passenger
PHF	=	Peak Hour Factor
PI	=	Performance Index
PROYDYN	=	UTC system (French, 1982)
ROADSIM	=	ROAD for two lane road network & SIM for microscopic simulation
ROMANCE	=	ROad MANagement System for Europe
SCATS	=	UTC system (Australia, 1979)
SCOOT	=	Split, Cycle and Offset Optimization Technique
SQL	=	Structured Query Language
TIP	=	Transportation Improvement Plan
TRAF-NETSIM	=	TRAFfic NETwork SIMulation
TRANSYT 7F	=	TRAffic Network StudY Tool
TT	=	Travel Time
TTT	=	Total Travel Time
UTCS	=	Urban Traffic Control System
UTOPIA	=	UTC system (Italy, 1983)
veh.	=	vehicle
VMS	=	Variable Message Sign
WAN	=	Wide Area Network

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CHAPTER I

RESEARCH PROBLEM

1.1 BACKGROUND: GENERAL

Traffic congestion is a serious problem that has endless adverse effects. It started with the introduction of the passenger vehicle on a mass scale. Of course the problem only became obvious and noteworthy in the past few decades. When more affordable car prices and changing life styles led to a tremendous increase in car ownership, which in turn led to more road travel. Such increased traffic overwhelmed urban traffic corridors, sometimes beyond a foreseeable solution. As a result, a small disturbance in traffic flow would cause a disproportionately large disruption over a widespread area. It is therefore essential to use all spare capacity on the network by spreading the traffic load and hence minimize the problem. Old traffic policies and control systems revolved around increasing roadway capacities, which is becoming more and more unfeasible and sometimes perhaps impossible.

New strategies were developed which utilize the ever improving computer technologies, and systems such as MATS¹, SCOOT², MIST³ ..etc.... These have proven their capability to improve traffic flow, when applied properly. That is, a number of systems have been adapted for specific needs, which makes them most efficient for those applications.

¹Multi-Arterial Traffic System

²Split, Cycle and Offset Optimization Technique

³Managment Information System for Traffic

For a description of MIST, Management Information System for Traffic (the off-the-shelf system being implemented in Syracuse), its properties and features, see Appendix C.

1.2 BACKGROUND: THIS RESEARCH

Over the years, urban areas have implemented signalized traffic control systems with the belief that these improve traffic flow. These systems met their objectives. Most such installations took place on an incremental basis and their effectiveness was frequently not simulated prior to implementation. At present, due to the large number of networks to be upgraded and the variety of systems available, it is becoming imperative to simulate performance in order to study effectiveness. However , there is a lack of a methodological framework for undertaking such an ambitious task. In the absence of methodology, decisions tend to be made without a scientific basis.

In this research, methodological advances will be used for assessing the elements of the Management Information System for Traffic (Mist). The City of Syracuse is used as a test case for improving traffic flow and maintaining acceptable carbon-monoxide (CO) levels in the air. However this study will also show the improvement in other measures of effectiveness in the Central Business District (CBD).

The City of Syracuse, hereafter referred to as the ‘study area’, lies in the northern part of the state of New York. In a geographic area that is known as Upstate New York. Its population is 659,864 residents according to the 1990 census. What gives the city its importance is the fact that it provides essential services to an area of 100km radius. These services include referral medical centers, government services, university and colleges and other vital services. This importance comes at a price of increased demand on the city’s traffic system, especially in the CBD area. The increased traffic volume causes higher

delay times and consequently higher emissions. Also as a result, the network's productivity becomes lower. The value of the lost time is not only measured by its negative economic impact but also by its impact on commuters and the stress they are subjected to. The same applies to the pollution levels, whose effects could not be economically measured by this study.

What made this city highly relevant as a case study for this thesis, is its existing high levels of air pollutants and the need to manage its traffic congestion in order to reduce delay time and emission levels.

The study area includes 145 intersections in the CBD area, the university hill area and along several connecting arteries. This thesis will consider the core of the network consisting of 41 signals bounded by Adams St. in the south, west Genesee and James St. in the north, south State St. in the east and south Clinton St. in the west. Additionally, the study network includes one stop sign on the intersection of Harrison Pl. and Harrison St. and one pedestrian signal near an elderly complex on south Clinton St.. Refer to figure 1.1 for an area map.

1.3 INTRODUCTION TO ADVANCED TRAFFIC CONTROL

The most important measure of effectiveness of a traffic network is delay time. It reflects the effect of traffic flow and number of stops. In turn, it affects travel time, fuel consumption and emission levels. Delay time is one of the important factors that determine the level of service of an intersection. It is essential to know that delay as reported by this thesis is estimated from computer simulation software and not measured from a sample of vehicular operation (i.e. not measured in the field). Therefore, delay

DOWNTOWN INDEX

STREETS

Adams St.	B-2
Almond St.	B-1
Bank Al.	A-1
Burnet Ave.	B-1
Canal St.	B-1
Cedar St.	B-2
Clinton St.	A-1
Clinton St., S.	A-2
Dickerson St.	A-2
Erie Blvd., E.	B-1
Erie Blvd., W.	A-1
Fabius St.	A-2
Fayette St., E.	B-2
Fayette St., W.	A-2
Franklin St., N.	A-1
Franklin St., S.	A-1
Genesee St., E.	B-2
Genesee St., W.	A-1
Giifford St.	A-2
Granger St.	A-2
Harrison Pl.	B-2
Harrison St.	B-2
Herald Pl.	A-1
Hickory St.	B-1
James St.	B-1
Jefferson St., W.	A-2
Landmark Pl.	B-1
Leavenworth Pl.	A-1
Madison St.	B-2

Marcellus St.	A-2
Mc Bride St.	B-1
Mc Carthy Ave.	B-2
Mc Cormick St.	A-2
Montgomery St.	B-2
Niagara St.	A-2
Onondaga St., W.	A-2
Otisco St.	A-2
Park Ave.	A-1
Pearl St.	B-1
Plum St.	A-1
Salina St., N.	A-1
Salina St., S.	A-2
State St., N.	B-1
State St., S.	B-1, 2
Townsend St.	B-1
Tracy St.	A-1
Tully St.	A-2
Union St.	B-1
Wallace St.	A-1
Watson St.	A-2
Warren St., N.	B-1
Warren St., S.	B-2
Washington St., E.	B-1
Washington St., W.	A-1
Water St., E.	B-1
Water St., W.	A-1
West St., S.	A-2
Willow St., E.	B-1
Willow St., W.	A-1
Wyoming St.	A-2

FIGURE 1.1

time here reflects the theoretical basis of the traffic flow model and user assumptions. Simulation software packages such as Transyt 7F and Traf-Netsim have been developed to assist researchers and traffic operations engineers to simulate networks. The results of simulations cover such important information items as travel time, delay, fuel consumption and emissions.

Vehicles are a major contributor to harmful emissions. A recent United states study suggests that 43% of smog-producing emissions are generated by cars [CNN, 1997]. These emissions are produced by the internal combustion engine during various stages of its operating cycle: idle, acceleration, slow speed, high speed and deceleration. Different emissions such as Hydro-Carbons (HC), Nitrogen Oxides (NO_x) and, most significantly, Carbon Monoxide (CO) are produced .

Advanced systems or intelligent systems are being developed at a rapid rate for improving traffic control and management. The Intelligent Transportation Systems (ITS) use computers, communications, sensor and display technologies. These can offer a variety of technological solutions to the growing transportation problems. They are a set of potential new technologies designed to alleviate congestion and increase roadway capacity, primarily by rerouting and smoothing traffic flow. ITS can achieve this by communicating with signal controllers, collecting data from various detectors, analyzing the collected data, creating optimal signal timing plans, and sending commands to the signal controllers.

Perhaps to say there is one solution to traffic congestion and its related problems would be an over-statement. This is due in fact to the ever growing urban centers around the world. With this growth, traffic problems are created, because most of the time it

becomes infeasible to keep increasing the capacity of a roadway by increasing its size. As a result other solutions had to be found. The idea is to manage traffic rather than to expand transportation networks. This management could take any form, to mention a few: provide more adequate public transportation which would reduce the volume of single driver vehicles and move more people in fewer vehicles. The idea here would be to increase the average number of passengers per vehicle. Another method which leads to the same result is the High Occupancy Vehicle lanes (HOV) which provide a great incentive for people to share rides. However, most of these methods depend basically on simple ingenuity, meaning that no sophisticated technology would be needed aside from the regular equipment used in traffic regulation. The only problem with these solutions is the fluctuating degree of acceptance by the driving public.

Since the early 1980's new methods based on the advancing technologies have started to appear in more places in North America and around the modern world. All of these methods revolve around making urban transportation systems more adaptive and perhaps interactive with their changing traffic composition and volumes. Such systems will have the ability to collect and access traffic data easily, set green times for signal phases, coordinate traffic signals, provide traffic management through Closed Circuit Television (CCTV) and provide accurate and timely traveler information.

More advanced traveller information systems and traffic management systems are being demonstrated which have the ability to communicate with vehicles and direct them to their destination away from traffic jams, making sure that the network is not overloaded in some sections and underloaded in others. Such systems are referred to as ITS. The one problem with ITS is that vehicles have to be equipped with very expensive devices, so does the city. Perhaps this is the way of the future, but for the time being the advanced traffic control system (part of the ITS) remains a reasonable choice for most cities, for it

relies on detectors, closed circuit television cameras, local controllers and central computers, all of which are readily available and at reasonable costs.

The various existing urban traffic control systems can be classified into several generations that range from fixed time off-line signals to real time on-line systems.

The first category is based on predefined timing plans elaborated off-line and stored in libraries. Usually, optimal time plans are determined for a wide network of junctions, using Transyt 7F or a different version of the Transyt software [Highway Capacity Manual, 1994].

The second category includes systems that continuously modify initial time plans by little changes, to respond to fluctuations in traffic conditions, over a wide network of junctions.

The third category doesn't rely on time plans. These systems are adaptive real-time Urban Traffic Control (UTC) systems, which consist of an optimization algorithm and a traffic prediction model. The optimization algorithm generates the optimal signal timing that minimizes a junction wide objective, using predicted traffic conditions as inputs.

There exist several well known control systems that have been created for specific needs. However, most of these systems are adaptive and could be manipulated to meet certain demands or growing needs. A well known system is the Scoot model, which is a fully decentralized system. That is, control is maintained at a central computer while a common cycle promotes coordination. Thus, the system is designed to respond to changes in traffic demand by slowly varying the cycle lengths by a few seconds every cycle. Of course different systems have different approaches to traffic signal control. For instance, a

fully distributed approach is where all timing calculations are performed by the signal controllers. There are no calculations done by a central computer although one is needed to monitor and manage the system. Examples of such systems are PRODYN, OPAC, and SPORT models.

Another alternative would be the Hierarchical signal control system which includes SCATS and UTOPIA models. This approach combines both centralized and distributed control methods. In the centralized hierarchical system, the central computer is largely responsible for signal timings. It determines cycle length offset and green split for each intersection based on average traffic flow inside the predefined subsystem. The local controllers are able to make minor adjustments to the given splits under the central computer restrictions. The distributed hierarchical approach on the other hand gives control to the local controllers to override the central computer and change signal timings which are calculated by the central computer as an initial point to optimize their own timings.

In conclusion, it is important to remember that with both centralized and distributed approaches, the one chosen should reflect what the needs of a city are, and whether one would serve its purposes better than the other. For, while central control is better able to plan for efficient coordination, the distributed approach can adapt better to fluctuations in traffic.

In a nutshell Traffic Control comprises the following:

1. Network monitoring to determine traffic volumes, detect incidents and events.

2. Estimation of the impact of these events.
3. Development of an appropriate traffic management strategy.
4. Implementation of that strategy.

Urban traffic control systems could improve urban life in many ways:

- Help in the detection of traffic accidents and help improve the ability to react to them.
- Reduce traffic related emissions and their impact on air quality.
- Improve response time to emergencies by giving priority to emergency vehicles on selected routes.
- Improve data collection for better traffic flow control and monitoring.
- Provide better conditions for people with disabilities, pedestrians and cyclists.
- Improve safety.
- Improve the socio-economic conditions of the City.
- Improve transit services and perhaps help increase transit share of the travel market.
- Provide a very flexible system that is capable of reacting to congestion and other short term events more readily than ever.

As a step towards instrumentation of modern cities , traffic signal interconnect is a very important technique in making traffic flow more manageable. This network of controlled signals provide a higher level of service by being able to adjust to fluctuations in traffic demand.

1.4 CONTRIBUTION OF TRAFFIC CONTROL vs. OTHER TECHNOLOGICAL INNOVATIONS

According to the New York state Transportation Improvement Plan (TIP) Air Quality Conformity data, the TIP should provide a 28% decrease in CO emissions by 1996 and a 57% decrease in CO emissions by 2006 in the Syracuse area. These decreases are based on the implementation of all TIP projects that could be modeled including the enhanced Inspection / Maintenance Program (I/M) and the Low Emissions Vehicle program (LEV). The I/M and LEV programs, which reflect improvements due to improved vehicle emissions systems, were shown to be responsible for 97.3% of the expected 2006 emissions reductions. All other projects, including this signal interconnect project, are expected to account for the remaining 2.7% of emissions reductions.

Based on the analysis of the air quality effects resulting from the signal interconnection and coordination, it would be very reasonable to anticipate that this project will exceed its expected contribution to the 2.7% of emissions reduction for that part of the maintenance plan affected by the project. Thus making its implementation feasible and recommended.

Still, we should take into account that there are other methods to reduce delay time and emissions. These solutions focus on the heart of the problem. By that, we mean that they tend to either reduce the number of vehicles or reduce their harmful emissions, and from the above numbers we know that their impact on emissions is much more evident than the signals control system being studied. It should be noted that signal interconnect has a positive impact on delay time, whereas I/M and LEV programs only impact emissions. Other management methods address both problems, yet their effects are

difficult to determine. For instance, the vehicle occupancy rate could be increased by promoting mass transportation and providing incentives for multi-occupant vehicles such as High Occupancy Vehicle lanes. This policy has been used by many urban cities in North America, and the results have varied from one city to the other. However, it could be said that, in conjunction with other management techniques, this policy was successful to a certain degree. Addressing the issue of emissions, the best solution would be to produce less emissions to begin with, because the number of vehicles will keep on increasing with the growth in population and the economy. The best ways to reduce emissions production in vehicles would be described next.

A. Encouraging the use of cleaner vehicles such as Electric Vehicles (EV's) which are being mass produced now by several car manufacturers. EV's have the following properties:

1. Limited Range

Today's EV either uses lead acid batteries or advanced prototype batteries. Lead acid powered EVs have about 50 miles / 80 kms range between charges and are the least expensive. Advanced batteries hope to have about 100 miles / 160 kms range between charges, but are currently very expensive.

2. Clean

EVs have no tail pipe emissions. All related emissions are produced and supposedly controlled at power plants.

3. Quiet

The more advanced EV motors emit almost no sound. Unlike gasoline vehicles, there is no "combustion" requiring a muffler. Thus making the EV the environmentally conscious vehicle of our century.

4. Home Recharging

The EV can be recharged at home. This is especially convenient for those who do not like to refuel at gasoline stations. The downside to this is that it can take up to six hours to recharge a dead battery.

From the above we can see that the EV's are a convenient simple solution for a rather complex problem. And their use could be encouraged by increasing the imposed taxes on petroleum products. Thus, not only influencing the driving population towards investing in the above mentioned vehicles, but might also help increase the mass transit share of the population. Some might argue that this method is unacceptable as it tends to interfere in the individual's freedom of choice, not to mention reduce much-needed revenues from gas taxes in the long term. Yet, we should not overlook the benefits to society and its environment from such a policy. An alternative to the EV would be a hybrid vehicle, which a Japanese car company, Toyota, has recently started mass producing. This vehicle has a small highly efficient gasoline engine plus an electric drive. Test results show a reduction of 50% in emissions and a 70 miles/gal (30 km/litre) fuel consumption [Arabia Tech, 1997].

B. Encouraging new technological advances such as the new fuel cell technology is also very attractive. The demonstration vehicle was produced under a U.S government and industry program. It had a goal of making a vehicle able to travel 80 miles on one gallon (34.3 km per litre) of fuel, some three times the present rate. The only emissions are water vapor. The fuel cell principle was discovered by a British scientist Sir William Grove in 1839. His theory stated that mixing hydrogen and oxygen in the presence of a conductor produces electricity, with water vapor as its only waste product. But hydrogen is difficult to produce in large quantities and fuel cells were too large and expensive for commercial

use on this scale. However, recent developments in the proton exchange membrane (PEM) are encouraging.

Most car manufacturers have been looking at the possibility of replacing the internal combustion engine with fuel cells, which is basically composed of two thin plates on top of each other with channels separated by thin membranes. With the new technology, hydrogen can be extracted from a hydrocarbon fuel like gasoline, natural gas, methanol or ethanol. Thus utilizing the existing network of refueling stations. However, this system needs to be reduced in size, weight and cost. A leading company in this field, Ballard Power Systems of Vancouver, Canada, has already developed a prototype vehicle powered by methanol. Both Ballard Power Systems (in association with Daimler Benz and other major automobile manufacturers) and the U.S. team expect to start producing vehicles with the new technology by 2005. Whereas in Japan the same car manufacturer of the hybrid unit, Toyota, have already started marketing hybrid technology cars for the year 1999 [Arabia Tech, 1997].

C. A more readily available solution is to control emissions. A Japanese car manufacturer, Honda, has developed an exhaust system that is almost free of regulated emissions. Two catalytic converters are used, one is located under the floor and another fitted near the exhaust manifold. Between the two converters they produce one-tenth of emissions such as carbon monoxide, hydrocarbons and nitrogen oxide, than any other vehicle. However, no estimate of cost or a date for commercial production are known at this time.

These innovative vehicle technology advancements would, upon their introduction, reduce emissions. Yet, they clearly cannot reduce delay time, which will only grow worse as traffic volumes increase.

1.5 PURPOSE OF THIS RESEARCH

This thesis research has developed a methodology for estimating the benefits of ITS technologies by taking into account delay, energy and environmental impacts. However; since ITS technologies are fairly new it is almost impossible to study their social impacts. We will indeed take a quantitative approach to proving the feasibility of ITS through modeling and simulation based on collected data. The purpose of this study is to show that ITS will improve the performance of the network by improving the efficiency and operation of its traffic signals. Through optimization and interconnection of the 145 signals, it is expected that delay and stop time will be reduced and cause improvement in air quality.

The City of Syracuse is implementing several projects that include traffic management components, such as variable message signs and closed circuit television. The benefits behind these are hard to quantify, but they will help improve the management plan by offering additional options in traffic control.

This thesis will take a look at a transportation management technique aimed at reducing traffic congestion by utilizing new technologies. In fact it is hoped it would lead to many other benefits, among which it is noteworthy to mention the following:

1. Savings in travel time by re-routing traffic away from a link when its capacity is reached.
2. More consistent travel time and improved driver comfort leading to a reduction in stress levels and accidents.
3. Reduction in congestion leading to more benefits to the economy, that is lower transport cost and less environmental pollution.

4. More efficient use of the network, reducing the need for new road construction or controls over its use.

1.6 RESEARCH OBJECTIVES

This research is intended to fill a knowledge gap by developing a methodological framework for analyzing and evaluating advanced traffic control systems. Traffic movement affects everybody through congestion, safety, pollution and cost. A well defined system architecture can produce many effective solutions to improve mobility, safety and air quality. To bring realism in the demonstration of the methodology, Syracuse is used as a case study. The Syracuse traffic control system is intended to improve the interaction between driver, the vehicle and the roadway, and will help improve the quality of life for the CBD area.

The main objectives of this thesis research are to advance a methodological framework for:

1. The quantification of delay, energy consumption and emissions for a traffic network.
2. Reducing delay time, energy consumption and emissions through advanced traffic control systems.

Two categories of action were defined in order to achieve these objectives.

A. Peak Hour Emissions Analysis.

- 1- To advance a methodology for identifying the causes of traffic related pollution.
- 2- To advance a methodology for reducing delay time, energy consumption and emissions through traffic congestion management.

- 3- To calibrate a traffic model to estimate delay time and emissions.
- 4- To produce an optimal timing plan for the peak period volumes.
- 5- To determine the improved values of delay and emissions by implementing the new timing plan into the developed model, which has the capability of studying the various types of emissions.
- 6- To analyze the results produced from steps three and five to determine whether the system helps reduce emissions' levels.

B- Adaptive Control Analysis.

- 1- To develop optimal timing plans that mimic UTCS generated plans for creating an improved network of traffic signals, thus attempting to simulate a traffic responsive control system.
- 2- To study the effect of implementing these plans using different measures of effectiveness.
- 3- To produce optimal timing plans for the peak period volumes and determine their effectiveness using standard measures.
- 4- To analyze the results produced by steps two and three and determine whether or not the UTC system is beneficial.

1.7 SCOPE

This research has resulted in the following outcomes:

- 1- A methodology of general applicability and a traffic model for the case study, which produced values for emissions and delay time, plus other measures of effectiveness, for different scenarios of traffic volumes and signal timing plans.
- 2- A model that generated optimal traffic signal timing plans for different time periods and produced different measures of effectiveness.
- 3- Evaluation of the models and a proof of their efficiency in producing reliable results.
- 4- Finally this study has achieved its objective by creating a methodology to study the effectiveness of UTCS, by studying the effects of implementing UTCS on delay time, energy and emission levels, which would be applicable for different cities.

A note, worth mentioning here, is that this particular research study uses traffic counts from the evening peak hour, as it was the most critical period for studying delay time and emissions. However; the models could be very easily adapted to study any period of the day as needed.

1.8 THESIS OUTLINE

Following this introductory chapter, research methodology is described in chapter 2. Data collection is the subject of chapter 3. In chapter 4, network simulation is covered.

Chapter 5 is devoted to the analysis of simulation outputs. Chapter 6 presents conclusions. Appendix A contains one of the input and part of the output files for the Netsim model. Appendix B contains one of the input and output files of the Transyt 7F model. Appendix C includes a description of the tools and features of Management Information System for Traffic (MIST). And Appendix D contains an introduction to the computer models.

CHAPTER II

RESEARCH METODOLOGY

2.1 WORK PLAN: THE SCIENTIFIC APPROACH

The first step in producing a successful methodology was to develop a work plan or a study planning platform. Figure 2.1 shows the logic of the work plan. Drawing upon the scientific method, it starts with the requirements of problem recognition and problem definition, called here problem identification. Solutions are then generated for achieving the set objectives. This step is followed by testing (analyzing) solutions, validation of analyses and acquiring a closer understanding of the problem as well as solutions. In the assessment step, solutions are evaluated. Finally recommendations are made.

Due to the cyclic nature of planning, the process of problem solving returns to the problem identification.

WORK PLAN

FIGURE 2.1

2.2 RESEARCH METHODOLOGY

Figure 2.2 presents the methodological framework. In this chapter, a description of the major components is presented. Details are covered in the following chapters.

It should be mentioned here that the study methodology relies upon detailed simulation of the network. The calibrated simulation models and the implementation of the simulations for the study network closely match the working and the capabilities of the area-wide signal inter-connection and coordination. Furthermore, through fine tuning of the simulations, some features of the adaptive traffic control are being represented in this research.

2.3 PROBLEM IDENTIFICATION

The issue of traffic congestion is at the heart of almost every traffic study, and most traffic solutions revolve around making traffic flow smoother. Congestion is most serious in the Downtown/CBD, because excessive delays at one intersection could cause traffic backups all the way upstream (the domino effect), thus depreciating the levels of service of the entire network of intersections. Hence, a few problematic spots in the network would be enough to cause increased delay time and overall higher numbers of stops throughout the system.

In the case of this thesis research, the effects to be studied are the two main products of congestion, i.e. air pollution and delay time. The initial model of the case study showing existing conditions required a wide range of information, some of which had to be collected from the field. All the data were collected during the evening

Research Methodology

FIGURE 2.2

Research Methodology (Continued)

Figure 2.2

peak hour to be consistent with the available traffic counts. From field observation, it was obvious that there were many congested spots in the study area and many of them had high pedestrian volumes, especially near bus stations and major office buildings. and shopping centers. These delays cause a higher level of emissions during the peak periods. Idling vehicles, low speed moving vehicles and “Stop and Go” motion produce excessive amounts of emissions, including Carbon-Monoxide and Oxides of Nitrogen and Hydrocarbons.

Although the study area does not suffer from unusual smog levels, it is considered as a maintenance area by the NYDOT and the city has to reduce its emission levels to meet the set guidelines.

2.4 SOLUTION: ADVANCED TRAFFIC CONTROL

The second step after identifying the problem would be to look at possible solutions, analyze these solutions, and attempt to verify their workability and forecasted benefits. After several meetings with NYDOT officials, it was agreed to consider a new UTC system, Management Information System for Traffic ‘MIST’, as a prospective solution. This selection was deemed obvious, because the city’s traffic signals’ coordination controllers are outdated and obsolete by today’s standards.

To study the effectiveness of a UTC system, a methodology had to be developed and used for analyses. The problem identified and a solution defined, next came the processes of developing and testing a model that would represent real-time conditions. Following a study of previous models developed for a generally similar purpose over the last decade, it was decided that the best way to study emission levels and delay time would

be to utilize such software packages as Traf-Netsim. The second requirement for developing our model was to be able to create an optimal signal timing plan for our case study, similar to that created by a UTCS. After consideration of several software packages, it was determined that the Transyt software will be ideal, as it uses the same algorithms utilized by most UTC systems.

The model design required that existing conditions be studied and analyzed, using the Traf-Netsim software. However, Traf-netsim doesnot have the capability to optimize signal timing plans, that is why an improved (optimal if you may) signal timing plan was produced using the Transyt 7F traffic model. The last step, in the computer simulation, was to study the network under the newly developed plan. An attempt was made to reach a recommendation based on the performance of the new plan.

After data were collected from different sources according to the requirements of the above mentioned software packages, these had to be calibrated. Because the data were collected on different days, the volumes of traffic traveling through the system did not add up as if the data were collected at the same point in time. The Traf-Netsim software did its own calibration during its initial simulation. It should be noted that sometimes it might fail to reach equilibrium and some alterations to the input data might be considered. After equilibrium was reached, initial conditions were determined, i.e. emission levels and delay time. The Netsim software provides Measures Of Effectiveness (MOEs) which identify different parameters associated with delay and emissions within the study area.

Using the same data, a Transyt 7F model was then created to study both existing and improved conditions. Again a wide range of MOEs were produced and analyzed to help validate the efficiency of the model in recreating real-time situations.

The next step in the computer simulation was to introduce the new timing plan to the Traf-Netsim model in order to determine improved conditions. Some alterations to the timing plan might be necessary if MOEs at any intersection / junction did not depict reasonable real-time situations.

The last step in this process was to analyze and assess the outputs of all three models and compare results, to come out with recommendations.

The final stage was to attempt to simulate adaptive control by using the Transyt 7F model. By comparing the MOEs produced from this exercise, conclusions regarding the effectiveness of UTC systems may be drawn.

CHAPTER III

DATA COLLECTION

3.1 DATA REQUIREMENTS

Data are an essential and integral part of any research effort. That is why data collection should be planned well before hand. The data needed for the study to be performed should be soundly defined and the procedure for obtaining it well identified. Gathering unessential data could be costly and time consuming, and the model will not work if any data are missing.

So, the first part of this section would be to define the required data:

- 1- Traffic volumes/counts at and around the peak period/hour.
- 2- Bus statistics.
- 3- Description of the links.
- 4- Network controls, i.e. signal timings and movement restrictions.
- 5- Parking restrictions, meter parking and parking garages.
- 6- Pedestrian traffic.
- 7- Observations and notes: time and date, weather and pavement conditions.

In the second part it is fundamental to determine the sources of these data and the means to obtain them. The sources were defined to be the following:

1- The New York Department Of Transportation.

2- Centro (Bus Transportation Company).

3- City of Syracuse.

4- Field surveys.

Figure 3.1 illustrates the study area where the field measurements were taken.

3.2 ACQUIRED DATA

3.2.1 Traffic Flow Data

The New York Department Of Transportation (NYDOT) has an active program for performing traffic surveys to determine traffic volumes in the Syracuse CBD area. The study area counts were performed between January 1996 and November 1996. Figure 3.2 and Figure 3.3 show samples of collected data. Both sheets display the same information including the Peak Hour Factor (PHF), but Figure 3.2 shows the PHF for the entire intersection, whereas Figure 3.3 shows the PHF for each approach. The PHF as defined by the Highway Capacity Manual (HCM) is “used to focus the analysis on the peak 15 minutes of the hour. It is an important feature of the operational analysis method. However; for planning purposes, the appropriate value of the PHF will depend on the nature of the application.”. It is calculated as: “ The hourly volume during the maximum volume-hour of the day divided by the peak 15 minute rate of flow within the peak hour.”[Transyt., 1991].

SYRACUSE DOWNTOWN INTERCONNECT PROJECT

LEGEND

- CDD INTERSECTIONS
- UNIVERSITY HILL INTERSECTIONS
- JAMES STREET ARTERIAL INTERSECTIONS
- ⊙ CLOSED CIRCUIT TELEVISION LOCATION

COMPONENTS OF PROJECT AREA
Figure 3.1

PM PEAK RESULTS														CITY: Syracuse STATE: New York		DAY: Tuesday DATE: Oct. 29, 1996		JOB #: 13289 OBSERVER: Craig, Has	
INTERSECTION OF: AND:														Adams St. State St.					
HOUR BEGINS	NB LEFT	NB THRU	NB RIGHT	SB LEFT	SB THRU	SB RIGHT	EB LEFT	EB THRU	EB RIGHT	WB LEFT	WB THRU	WB RIGHT							
14:45	0	0	0	0	0	0	0	0	0	0	0	0							
15:00	0	0	0	0	0	0	0	0	0	0	0	0							
15:15	0	0	0	0	0	0	0	0	0	0	0	0							
15:30	0	0	0	0	0	0	0	0	0	0	0	0							
15:45	0	0	0	0	0	0	0	0	0	0	0	0							
16:00	1	20	35	34	41	14	18	307	9	0	0	0							
16:15	1	41	58	62	70	20	25	551	18	0	0	0							
16:30	2	62	94	106	112	25	41	926	27	0	0	0							
16:45	4	82	125	139	140	30	56	1267	36	0	0	0							
17:00	5	103	155	162	171	38	72	1652	43	0	0	0							
17:15	7	124	172	189	205	44	83	1967	58	0	0	0							
17:30	8	133	202	214	229	47	94	2179	67	0	0	0							
17:45	8	136	214	229	239	50	108	2380	70	0	0	0							
18:00	0	0	0	0	0	0	0	0	0	0	0	0							
18:15	0	0	0	0	0	0	0	0	0	0	0	0							
18:30	0	0	0	0	0	0	0	0	0	0	0	0							

INTERSECTION														COUNT		REDUCTION			
HOUR BEGINS	NB LEFT	NB THRU	NB RIGHT	SB LEFT	SB THRU	SB RIGHT	EB LEFT	EB THRU	EB RIGHT	WB LEFT	WB THRU	WB RIGHT	SB TOTAL	EB TOTAL	WB TOTAL	SUB TOTAL			
14:45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
15:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
15:15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
15:30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
15:45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
16:00	1	20	35	34	41	14	18	307	9	0	0	0	0	0	0	0			
16:15	0	21	23	28	29	6	7	244	9	0	0	0	0	0	0	479			
16:30	1	21	36	44	42	5	16	375	9	0	0	0	0	0	0	367			
16:45	2	20	31	33	28	5	15	341	9	0	0	0	0	0	0	549			
17:00	1	21	30	23	31	8	16	385	7	0	0	0	0	0	0	484			
17:15	2	21	17	27	34	6	11	315	15	0	0	0	0	0	0	522			
17:30	1	9	30	25	24	3	11	212	9	0	0	0	0	0	0	448			
17:45	0	3	12	15	10	3	14	201	3	0	0	0	0	0	0	324			
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	261			
18:15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
18:30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

PEAK HOUR SUMMARY																			
HOUR	NB LEFT	NB THRU	NB RIGHT	SB LEFT	SB THRU	SB RIGHT	EB LEFT	EB THRU	EB RIGHT	WB LEFT	WB THRU	WB RIGHT	SB TOTAL	EB TOTAL	WB TOTAL	SUB TOTAL			
16:30	1	21	36	44	42	5	16	375	9	0	0	0	0	0	0	0			
16:45	2	20	31	33	28	5	15	341	9	0	0	0	0	0	0	549			
17:00	1	21	30	23	31	8	16	385	7	0	0	0	0	0	0	484			
17:15	2	21	17	27	34	6	11	315	15	0	0	0	0	0	0	522			
TOTAL	6	83	114	127	135	24	58	1416	40	0	0	0	0	0	0	2003			

549	484	522	448	2003	0.91211
-----	-----	-----	-----	------	---------

FIGURE 3.2
29

SMTC

VEHICLE VOLUME GRAPHIC SUMMARY

Location: Salina St. at Genesee/James

Day: Wednesday

Date: 1/25/95

Start time: 4:00 PM

Stop time: 6:00 PM

Weather: clear

Road Surface: dry

Observer: klm

TURNING MOVEMENT SUMMARY

Street	Salina St.			Salina St.			Genesee/James			Genesee/James			TOTAL
Direction Bound	Northb			Southb			Eastb			Westb			
Time	Left	Straight	Right	Left	Straight	Right	Left	Straight	Right	Left	Straight	Right	
4:00 - 4:15 PM	7	61	22	20	92	16	10	73	5	5	91	3	405
4:15 - 4:30 PM	15	62	16	17	73	17	9	49	4	11	116	5	394
4:30 - 4:45 PM	12	70	9	8	76	18	1	64	1	10	107	2	378
4:45 - 5:00 PM	15	95	12	31	78	8	1	61	1	11	80	3	396
5:00 - 5:15 PM	7	109	7	7	114	14	3	59	4	10	102	4	440
5:15 - 5:30 PM	11	69	18	18	61	17	3	66	2	7	80	2	354
5:30 - 5:45 PM	11	70	8	11	55	13	2	48	4	9	75	1	307
5:45 - 6:00 PM	5	53	8	25	52	7	1	45	4	12	59	0	271
TOTAL	83	589	100	137	601	110	30	465	25	75	710	20	2945
PEAK HR TOTAL	49	336	44	63	341	57	14	233	10	42	405	14	1608

Peak Hr Time= 4:15 PM - 5:15 PM

TURNING MOVEMENT DIAGRAM WITH PEAK HOUR FACTORS

FIGURE 3.3

3.2.2 Bus Statistics

The required bus data include route information, number of stops, distances between bus stops and intersection stop lines, time tables, bus average occupancy rate in the study area, and bus average speeds. The mass transportation company operating in the Syracuse area, CENTRO, was very helpful in supplying most of these data by providing time tables for all their buses that are scheduled to enter and operate in the specified area, plus route maps, average bus speeds in that area and frequency of stops. Figure 3.4 shows an example of time tables and route maps, capacity of each bus stop, number of routes using the same stop, and bus headways. Note that all these data are based on a scheduled and not actual operating conditions.

3.2.3 City Information

There was some difficulty in obtaining all the required data such as geometric data and signals preset timings from the City of Syracuse . But certain questions were answered as to the nature of signal operations and they provided assistance in estimating required data and confirming the accuracy of the collected data.

3.3 FIELD DATA ACQUISITION

In order to collect data from the field, a summary form was developed where all the required data could be easily and systematically collected and accounted for. Figure 3.5 shows an example of this form.

9M GREAT NORTHERN MALL 9T OSWEGO									
ROUTE NUMBER	GREAT NORTHERN MALL	SENECA MALL	WEGMAN'S-RT. 57 PARK-N-RIDE	LIVERPOOL VILLAGE & TULIP ST. & OSWEGO RD.	OLD LIVERPOOL RD. & LAKEVIEW	CAROUSEL CENTER	DOWNTOWN FAYETTE & SALINA STS.	CIVIC CENTER STATE & MADISON STS.	GREYHOUND/RAILWAYS ERIE BLVD TERMINAL
READ ACROSS									
WEEKDAYS									
MORNING									
9M	5:35	5:41	5:45	5:55	5:58	6:05		6:43	1
9T		6:20		6:30		6:38		7:55	2
9T		7:20	EXPRESS	7:29		7:40	7:45	7:55	4
9M	7:06	7:17	7:22	7:35	7:40	7:50	7:55		3
9T	10:02			10:13	10:18	10:23		10:45	
9T	11:50	12:02		12:13	12:18	12:23	12:35	12:45	
AFTERNOON									
9T	1:50	2:02		2:13	2:18	2:23	2:35	2:45	1
9M	5:00	5:08	5:16	5:28	5:33	5:40			2
9T		5:42		5:53	5:58	6:03	6:15	6:22	1,5
9M	9:58			10:15	10:20	10:30			
SATURDAYS									
MORNING									
9M	6:40	6:47	6:53	7:06	7:10	7:20			
9T	9:30	9:42		9:53	9:58	10:03	10:15	10:25	
AFTERNOON									
9T	12:30	12:42		12:53	12:58	1:03	1:15	1:25	
9T	4:45	4:57		5:08	5:13	5:18	5:30	5:40	
9M	6:25	6:32		6:51	6:55	7:05			1,5
SUNDAYS - (NO HOLIDAY SERVICE) - SEE NOTE 6									
AFTERNOON									
9T	12:10	12:22		12:33	12:38	12:43	12:53	1:00	
9T	2:57	3:09		3:20	3:25	3:30	3:40	3:47	
9T	4:47	4:59		5:10	5:15	5:20	5:30	5:37

- NOTE 1 - DOES NOT OPERATE ON 3RD, HICKORY, OR 6TH.
NOTE 2 - THIS TRIP OPERATES ON RT. 57 BETWEEN RT. 31 AND SOULE RD. IT DOES NOT TRAVEL TO GREAT NORTHERN MALL OR SOULE RD.
NOTE 3 - THIS TRIP STOPS AT THE GREAT NORTHERN MALL PARK-N-RIDE.
NOTE 4 - EXPRESS TRIP OPERATES ON RT. 57 FROM RT. 31 TO TULIP & OSWEGO STS. AFTER RT. 57 & GASKIN RD. THIS TRIP PICKS UP ONLY AT TULIP & OSWEGO. IT WILL STOP TO DISCHARGE CUSTOMERS ALONG THE ROUTE.
NOTE 5 - THIS TRIP DOES NOT PULL INTO WEGMANS.
NOTE 6 - ON THE FOLLOWING HOLIDAYS NO LIVERPOOL SERVICE WILL OPERATE: NEW YEAR'S DAY, MEMORIAL DAY, FOURTH OF JULY, LABOR DAY, THANKSGIVING AND CHRISTMAS.

9P LIVERPOOL-RT. 57

CASUAL ESTATES

SENECA MALL

WEGMAN'S-RT. 57
PARK-N-RIDE

LIVERPOOL VILLAGE
TULIP ST & OSWEGO RD.

OLD LIVERPOOL RD.
& LAKEVIEW

DOWNTOWN
FAYETTE & SALINA STS.

CIVIC CENTER
STATE & MADISON STS.

SYRACUSE UNIV.
COLLEGE PLACE

SEE NOTES

➤ READ ACROSS ➤

WEEKDAYS

MORNING

6:42	6:46	6:59	EXP FR RT 57 STILL GLENN	7:20	7:25	2
7:01	7:05	7:18	EXP FR RT 57 STILL GLENN	7:42	7:47	2,4,5
7:30	7:35	7:47	EXP FR RT 57 STILL GLENN	8:10	8:15	2,4
7:56	8:02	8:12	8:25	8:29	8:40	8:44

AFTERNOON

12:26	1:00	SEE 90	1:24	1:40	6
2:58	3:08	SEE 90	3:30	3:48	6
5:38	5:42	5:46	5:59	6:10	1,3
6:18	6:22	6:26	6:39	6:44	1,3
8:48					7

SATURDAYS

MORNING

10:12	10:45	SEE 90	11:06	11:25	6
-------	-------	--------	-------	-------	---

AFTERNOON

1:37	1:45	SEE 90	2:06	2:25	6
3:12	3:45	SEE 90	4:06	4:25	6

FIGURE 34

INTERSECTION INFORMATION SHEET 1

FIELD SURVEY

CYCLE LENGTH = 90 SEC.

DATE: FEB. 12/97

TIME: 04:03 PM

WEATHER CONDITIONS: COLD,
CLEAR, DRY PAVEMENT.

PEDESTRIAN TRAFFIC RATE PER 5 MIN.:
 NORTH BOUND: 12
 SOUTH BOUND: 16
 EAST BOUND: 19
 WEST BOUND: 14

LEGEND

← = LEFT TURN ALLOWED

↘ = NO LEFT TURN

G= GREEN TIME

L= LEFT TIME

R= RIGHT TIME

Y= YIELD/YELLOW TIME

TH= THROUGH LANES

LL= LEFT LANES

(LL* FOR POCKET LENGTH)

RL=RIGHT LANES

(RL* FOR POCKET LENGTH)

D= DISTANCE FROM STOP LINE

DB= DISTANCE FROM
BUS STOP TO INTERSECTION

FIGURE 3.5

The collected data are described next.

3.3.1 Geometric Data

These data were collected during the off-peak periods, because it was easier to take measurements when traffic volumes were low. These data included:

1. Number of lanes on each approach/direction.
2. Lane assignments.
3. Length of the link i.e. the distance between stop lines of all approaches of an intersection.
4. Distance between bus stops and the approach stop-line, if any.
5. Turn pockets and their length, if any.

3.3.2 Network Controls

1. Signal Timings: These data were collected during the evening peak period and checked twice to eliminate any errors. These include:

- a- Green time for every approach.
- b- Red time for every approach.
- c- Amber time for every approach.
- d- All red time, if any.
- e- Left turn only green time, if any.
- f- Right turn green time, if any.
- g- Cycle length.
- h- Sequence of approach movements.

i- Signal offsets.

2. Movement Restrictions: also observed during peak periods, because some of these restrictions do not apply during other periods of the day. Especially where they were controlled by electrically operated signs. These include:

- a- No turns
- b- No left turn
- c- One/two way street
- d- Dead end streets
- e- No turns on red.

3. Parking.

- a- Meter parking
- b- Parking time restrictions, if any
- c- Parking garages: the location of a parking garage between two traffic signals might explain variation in traffic volumes at these two intersections.

3.3.3 Pedestrian Traffic

These data are required per approach on every approach, i.e. pedestrian crossing link (i,j) at node j. See Figure 3.6.

The required data are treated as a pedestrian code recorded on record type 11 of the Netsim input file.

Figure 3.6 : Roadway Link

These codes are:

- '0' No pedestrian traffic (0-100 Pedestrians/Hour)
- '1' Light pedestrian traffic (100-250 Pedestrians/Hour)
- '2' Moderate pedestrian traffic (250-500 Pedestrians/Hour)
- '3' Heavy pedestrian traffic (greater than 500 Pedestrians/Hour)

To obtain these codes, a count of pedestrians was performed at every intersection for all directions and for a duration of 5 minutes. Next, a flow rate per hour was obtained by multiplying that number by 12. This was done on and around the traffic volume peak 15 minutes for that intersection.

3.3.4 Field Observations and Notes

These data were required for the purpose of calibrating the models as required and explained in the next chapter. Also notes were taken during the collection process. These include:

1. Time and date of the collection of data.
2. Weather conditions at that time
3. Pavement conditions: slippery, dry, wet, ..etc.
4. Observed delay and congestion conditions
5. Observed bottlenecks
6. Any special occurrences.

3.4 FIELD DATA COLLECTION PROCESS

The main objective was to collect all of the above mentioned data, accurately and within a reasonable time frame. Part of the data had to be collected during the evening peak period, but most of the geometric data could be gathered anytime of the day. General background data and information were obtained from the New York Department of Transportation and the City of Syracuse to verify and elaborate on the results collected from field surveys.

The survey was subdivided into two categories to simplify the process of data collection:

- 1- Signal timings, offsets, movement restrictions, pedestrian traffic and field notes.
- 2- Roadway geometry, number of lanes and width, distances between intersections and parking restrictions, meter parking, parking garages and lots.

On February 13, 1997 between 4:00pm and 5:30pm, phase 1 started by timing traffic signals along the study area corridors. The first signal to be timed was that on S.State st. and Adams st. and then moved North bound on S.State until the intersection on Erie blvd. and S.State st. was surveyed.

The first step was to mark down all the movement restrictions and any special signal features, such as left turn only phases or right turn green ...etc.. The second step was to mark down the time and date, then start timing each approach's green, amber and red signal periods twice to confirm the observed time and reduce human error. It was made sure to record all the approaches moving during each phase.

The second step was to count all pedestrian traffic on each approach if any exists. These counts were performed for a five minutes interval and an hourly rate is later produced as discussed earlier.

The third step was to observe any unusual conditions, such as excessive congestion (spill-back of traffic), bad weather conditions, pavement conditions and pedestrian facilities (sidewalks, walk signals, crossing restrictions).

The final step was to time the offsets of any particular intersection to its adjacent intersections (where it is visually possible). This step was repeated several times to eliminate mistakes.

Over the next seven days the same procedure was repeated at different intersections until all the intersections in the study area were covered.

On February 21, 1997 the second phase of data collection started. Since this phase didn't require data to be collected during the peak hour, the process started around 10:00am and continued until 3:00pm every day until the study area was covered.

Using a measurement wheel all the distances between signal stop-lines were collected from the side walks to avoid any traffic disturbance and for safety reasons. The second step was to record the presence of a bus stop and record the distance between the bus stop and the traffic signal stop line. The third step was to observe any left or right turn pockets and measure their length. The fourth step was to record the number of lanes and lane widths of each approach.

Any parking restrictions such as 'NO Parking' signs, meter parking and meter parking restrictions, if any, were recorded during the process.

This phase was time consuming and required intensive work for a ten days period.

CHAPTER IV

NETWORK SIMULATION

4.1 INTRODUCTION

This thesis research required the use of two traffic simulation software packages. Traf-Netsim which stands for **Traffic Network Simulation**, and Transyt 7F which stands for **Traffic Network Study Tool** version 7F. Both software packages were adapted for use by the Federal Highway Administration (FHWA), USA. Transyt-7F was originally developed in the late 1960s by the Transport and Road Research Laboratory (TRRL) in the United Kingdom. The idea behind Traf-Netsim was first conceived by FHWA in the mid 1970's and was developed in 1986 under the sponsorship of the FHWA at the US Department of Transportation, Office of Safety and Traffic Operations, Research and Development. Both packages have seen several updates since their initial release [Traf., 1989, Transyt., 1991].

The Traf software package contains several traffic models which represent different sections of the transportation environment, such as freeway simulation model (FREFLO), two way rural road simulation model (ROADSIM), a microscopic simulation model for urban traffic (NETSIM)...etc.. For our purposes Netsim offers the required outputs and best analysis of the network at hand.

Netsim simulates the movement of vehicles through the network at intervals of one second each. For each interval a vehicle's speed, position and its relationship to other vehicles is reported. So, as the vehicle is moved through the network, all the information

relating to that vehicle is updated, thus conveying a very realistic set of information. Which makes this package excellent for portraying a somewhat true image of traffic movement through a network.

Transyt 7F is the most comprehensive tool for traffic signal timing and analysis. It has two major functions, one is to simulate traffic flow in a signalized network. It simulates traffic flow in small time increments (designated by the operator in the input file). The second feature of the software is that it utilizes a platoon dispersion algorithm that simulates the normal dispersion of platoons as they travel downstream. It also calculates travel delay, number of stops, fuel consumption, travel time and other measures of effectiveness.

4.2 PHASE ONE

4.2.1 Traf-Netsim

Before the start of the simulation process, we need to understand the microscopic simulation methodology adopted by the software package. As defined by the Traf User Reference Guide (1989) "Netsim applies interval-based simulation to describe traffic operations. This means that every vehicle is a distinct object which is moved every second, and that every variable control device (traffic signals) and event are updated every second.... Vehicles are moved according to car following logic, response to traffic control devices and response to other demands..... Congestion can result in queues extending throughout the length of a link and blocking the upstream intersection, thus impeding traffic flow there. Pedestrian traffic can delay turning vehicles at intersections." For these and other reasons (different vehicle types, different types of drivers, lane changing decision making...etc.), every vehicle's behavior may be simulated to reflect real life.

4.2.1.1 Car Following

A car following model developed by Gipps (1981) sets limits on the performance of both car and driver to calculate a safe speed with respect to the vehicle ahead of it [Chang et al., 1993]. The new speed of a vehicle c at time $(t+\tau)$ has two limitations on it, the first one is that the vehicle will not exceed its driver's desired velocity, the second condition is that a collision will not occur. Equations 1 and 2 display these stipulations respectively.

$$(1) \quad v_{dc}(t+\tau) = v_c(t) + 2.5A_c\tau(1 - v_c(t)/V_c) (0.025 + v_c(t)/V_c)^{1/2}$$

$$(2) \quad v_{sc}(t+\tau) = B_c\tau + (B_c^2\tau^2 - B_c[2[X_{c-1}(t) - S_{c-1} - X_c(t)]] - v_c(t)\tau - v_{c-1}(t)^2/B_{c-1})^{1/2}$$

where

A_c	=	the maximum acceleration of vehicle c ,
B_c	=	the most severe braking acceptable by the driver of vehicle c ($B_c < 0$),
S_c	=	the effective size of vehicle c (physical length + safety margin),
V_c	=	the desired speed of the driver of vehicle c ,
$X_c(t)$	=	the location of the front of vehicle c at time t ,
$v_c(t)$	=	the speed of vehicle c at time t , and
v_{dc}	=	the speed of vehicle c according to the desired speed limitation,
v_{sc}	=	the speed of vehicle c according to the safety limitation,

τ = the apparent reaction time, a constant for all vehicles.

Consequently, the speed of vehicle c at time $(t + \tau)$ is the minimum between the two speed limits, v_{dc} and v_{sc} :

$$(3) \quad v_c(t + \tau) = \min(v_{dc}(t + \tau), v_{sc}(t + \tau))$$

4.2.1.2 Lane-Changing

According to Gipps (1986) a driver will make the determination to change lanes based on the answers to the following questions:

- Is it beneficial to change lanes?
- Is it essential to change lanes?
- Is it possible to change lanes?

Figure 4.1 illustrates the lane-changing procedure [Chang et al., 1993], where car 2 needs to move into the gap between cars 1 and 3. Before changing lanes the driver must weigh the “hazard” and make a judgment call on whether the lead/lag gaps are sufficient. This differs from one driver to the other depending on the need to change lanes and on the driver’s behavior.

However, if the vehicle is too close to the intersection and needs to make a lane change the driver might take a higher risk in order to get into the desired lane. This will lead to accepting smaller gaps and perhaps harder braking. On the other hand, if the vehicle doesn’t have to change lanes (to turn right or left or park ...etc.) then the driver will refrain from taking unnecessary risks. Based on these assumptions a logic for the model is determined:

“ if current lane speed < desired speed
 if left lane speed > right lane speed and
 if left lane speed > current lane speed + speed indifference threshold and
 if lane-change to left lane is feasible
 target lane is left lane
else
 if right lane speed > current lane speed + speed indifference threshold and
 if lane-change to right lane is feasible
 target lane is the right lane
else
 stay in the current lane “

Lane-Changing Technique

Figure 4.1

4.2.2 Traf-Netsim Simulation

The next step after collecting all the required data, was to start the process of simulation in order to determine initial conditions. Both Traf-Netsim and Transyt 7F models can be generated at this point. Also, note that we could have started by simulating adaptive control using Transyt 7F, but instead chose to start with the initial and final peak hour conditions.

This section will be categorized into the following sub-sections:

4.2.2.1 Input Data

The Netsim model requires users to input accurate information which describes the actual traffic conditions in order to proceed with the simulation process. The software is equipped with a wide range of error messages which could “hopefully” guide the user to correct any discrepancies in the input data. Most of the material included in this section was derived from the Netsim User’s Guide and Books written about the software [ASCE, 1990, Labrum et al, 1981, ITE, 1990].

This software package requires detailed information about the traffic (type, volume, speed, behavior), the system (geometry), and network controls (signals type, timings, signs, etc.). These data are entered into a series of cards which are very well classified, and self explanatory.

The important requirements to be considered in the data entry are as follows:

- Traffic counts/volumes entering and exiting each node in the network (study area),
- Turning movement on each junction,
- Traffic controls i.e. signal timings and offsets, signs and movement restrictions,
- Parking information i.e. meter parking and off-the-street parking,
- Pedestrian movement on each approach, broken down into three categories as explained earlier,
- Public transit/ bus operation, which includes: bus routes, stops, mean headways and occupancy,
- Percentage of car-pools on each approach.
- Percentage of heavy vehicles/trucks on the network (each approach entered separately),
- Type, location and number of each transit stop,
- Number of lanes on each approach, lane width, turning pockets' lengths,
- Distances between intersections' stop lines,
- Driving habits / behavior i.e. acceleration and deceleration
- Fuel consumption (average per vehicle / truck / bus).

4.2.2.2 Output Information

Traf-Netsim generates many measures of effectiveness (MOEs) on every link in the network. A copy of part of the output is provided in Appendix A. The outputs we are interested in from this simulation are the levels of emissions and delay time. Table 4.1 includes a sample of the Netsim output for the initial existing conditions.

The output data from a Netsim model include:

- Netsim link characteristics,
- Changes to Netsim link characteristics,

TABLE 4.1

NETSIM SAMPLE OUTPUT

CUMULATIVE VALUES OF FUEL CONSUMPTION AND OF EMISSIONS

LINK	FUEL CONSUMPTION						VEHICLE EMISSION RATES (KG/MILE.HOUR)		
	GALLONS			M.P.G.			HC	CO	NO X
	A	T	B	A	T	B			
(185, 41)	1.7	0.2	0.2	0.7	0.3	0.9	0.364	3.175	0.502
(41, 183)	2.4	0.0	0.2	0.2	0.0	0.4	0.468	2.262	0.518
(183, 40)	2.1	0.3	0.2	0.0	0.0	0.0	0.403	1.025	0.403
(40, 181)	0.0	0.0	0.0	3.7	0.0	0.0	0.015	0.930	0.055
(181, 39)	0.0	0.0	0.0	10.8	0.0	0.0	0.007	0.340	0.015
(39, 179)	0.3	0.0	0.0	7.7	0.0	0.0	0.050	2.867	0.177
(179, 39)	4.4	0.4	0.0	0.5	0.4	0.0	0.460	4.733	0.581
(39, 181)	2.3	0.2	0.0	0.0	0.0	0.0	0.533	3.367	0.542
(181, 40)	1.9	0.5	0.0	0.0	0.0	0.0	0.426	2.263	0.426
(40, 183)	0.1	0.0	0.0	4.1	1.8	0.0	0.020	1.165	0.078
(183, 41)	0.0	0.0	0.0	8.2	6.1	0.0	0.007	0.107	0.017
(41, 185)	0.0	0.1	0.0	9.4	2.0	0.0	0.007	0.312	0.024
(177, 38)	0.6	0.2	0.1	9.2	4.7	3.3	0.111	2.478	0.343
(38, 175)	0.3	0.1	0.0	8.5	2.4	6.9	0.103	2.886	0.368
(37, 173)	0.8	0.2	0.0	2.0	0.7	0.0	0.192	1.748	0.347
(175, 37)	0.3	0.1	0.0	11.3	3.4	10.1	0.054	1.049	0.107
(173, 36)	1.7	0.1	0.0	0.6	0.2	0.0	0.370	1.882	0.396
(36, 171)	0.1	0.0	0.0	6.6	0.0	0.0	0.030	1.645	0.113
(171, 35)	0.0	0.0	0.0	19.3	0.0	0.0	0.007	0.125	0.018
(35, 169)	0.1	0.0	0.0	9.9	2.5	0.0	0.032	1.763	0.110
(169, 35)	1.6	0.5	0.0	2.9	1.1	0.0	0.303	2.615	0.613
(35, 171)	1.9	0.1	0.0	1.4	1.9	0.0	0.401	3.420	0.610
(171, 36)	2.0	0.4	0.0	0.9	0.5	0.0	0.383	2.993	0.414
(36, 173)	0.2	0.0	0.0	6.8	2.4	0.0	0.064	3.696	0.233
(173, 37)	0.1	0.0	0.0	10.2	4.4	0.0	0.028	0.485	0.062
(37, 175)	0.1	0.0	0.0	9.5	3.5	0.0	0.038	1.845	0.143
(175, 38)	0.1	0.0	0.0	21.2	3.0	0.0	0.010	0.133	0.020
(38, 177)	0.2	0.1	0.0	15.0	3.6	0.0	0.023	1.026	0.068
(168, 34)	0.1	0.0	0.0	11.4	0.0	0.0	0.021	1.041	0.054
(34, 166)	0.1	0.0	0.0	6.8	0.0	0.0	0.027	1.693	0.095
(166, 33)	0.1	0.0	0.0	7.0	0.0	0.0	0.018	0.189	0.020
(33, 164)	0.1	0.0	0.0	4.3	0.0	0.0	0.054	1.306	0.202
(164, 32)	0.4	0.0	0.0	1.9	0.0	0.0	0.077	0.852	0.089
(32, 162)	0.0	0.0	0.0	5.5	0.0	0.0	0.014	0.810	0.052
(162, 31)	0.0	0.0	0.0	17.6	0.0	0.0	0.003	0.029	0.003
(31, 160)	0.0	0.0	0.0	6.5	0.0	0.0	0.012	0.721	0.043
(160, 31)	0.1	0.0	0.0	10.6	4.6	0.0	0.023	1.246	0.062
(31, 162)	0.1	0.0	0.0	8.9	2.9	0.0	0.022	1.138	0.077
(162, 32)	0.3	0.1	0.0	2.2	1.1	0.0	0.057	0.730	0.073

LEGEND: A: AUTOMOBILE
T: TRUCK
B: BUS
HC: HYDROCARBON
CO: CARBONMONOXIDE
NO X: NITROGENOXIDES

- Turning movement and pocket data,
- Conditional turning movement data,
- Signal and sign control codes,
- Interpretation of signal control codes,
- Traffic control table for signs and fixed time signals,
- Entry link volumes,
- Source / sink volumes,
- Environmental data,
- Cumulative link and subnetwork statistics,
- Cumulative link-specific person measures of effectiveness,
- Link and turn-movement specific measures of effectiveness (optional output, controlled by record type 2),
- Fuel consumption and vehicle emissions statistics,
- Bus specific movements.

4.2.2.3 Data Calibration

After the first simulation is complete the output data are analyzed to determine any discrepancy in the measures of effectiveness produced by the studied network. These variations could be in the form of very high delay times at a node / approach which could not be justified by the volume of traffic entering that node / approach. Another type of divergence could be in the form of excessive levels of emissions at a node / approach which is again not justified by traffic volumes, delay or other factors affecting that node / approach. Several measures could be taken to correct these inconsistencies. But first it should be determined whether or not the discrepancy is due to an input error. If the fault was of a geometrical nature i.e. wrong number of lanes, movement direction / restriction, it could be mistaken by the software as a part of the network characteristic and the

simulation allowed to proceed and produce faulty results. These error types are easy to spot and correct.

Another source of error could be an input traffic volume at a node / approach that is too high or too low and cannot be justified by the upstream traffic volumes. This could occur if the data were collected at that junction during a special event. The best way to correct for this, would be to locate these junctions and perform traffic count surveys. The results would help determine a proper course of action.

Since the data were not collected simultaneously for the entire network as would be the case with the traffic control system, highly variable data such as traffic volumes and pedestrian volumes were always good candidates to be error sources.

4.2.2.4 Network Configuration

The Netsim network consisted of 130 nodes (allowed 250) and 244 links (allowed 500). The entire network was analyzed in one simulation run. In the process of developing this model, several obstacles were encountered, but were overcome with the help of the software developers and the University of Florida Transportation Engineering Department. Ultimately the output results were satisfactory.

All intersections were given numbers, according to the Netsim numbering scheme, from 1 to 799. Entry and exit nodes are where traffic enters or exits the network. These are numbered from 8000 to 8999. Sinks are where traffic ends up. These could be a parking garage, a business or government complex..etc. These are numbered 2000 to 2999. The numbering scheme helps us better understand the network assignment, Figure

4.2 displays the different nodes (1 to 42), dummy nodes (101 to 187) and links used to input the data into the Traf-Netsim software package.

4.2.2.5 Results

The results from this process simulate the actual / existing conditions during the evening peak hour. Two main data categories are required from the output of this simulation. These are the total delay time of the network (area being studied) and the emission levels produced by traffic traversing the study area.

It is worth mentioning that when congestion at a node exceeds the capacity of that node (to hold queuing cars), Netsim assumes a spill-back scenario and traffic would sometimes be backed up all the way outside the study area (in extreme cases). So an important measure of effectiveness here is the maximum number of vehicles on the system as reported by the Netsim model. This is a significant measure, because as the congestion is better managed in the improved network, this number will increase. However; since this aspect represents actual conditions, it will be allowed.

The maximum number of vehicles on the network was 1022 and occurred at 894 seconds from the start of the simulation (maximum number permitted by the software is 3500). Table 4.2 includes the initial delay and initial emissions produced.

Emissions are presented as the average per directional link to a reference node. This is achieved by dividing the total emissions (i.e. CO, NO_x or HC) for a node by the number of its directional links, see Figure 4.3. The network-wide average is determined

NETSIM NETWORK

FIGURE 4.2

by dividing the sum of emissions for all directional links in the network by 244 (the total number of links).

Delay is given for each directional link as the left, through or right average per vehicle, see Figure 4.4. So, to obtain an average delay for a reference node, these values are multiplied by the number of vehicles making left, through or right movements. Then the total delay obtained (seconds) is divided by the total number of vehicles at that node. The network-wide average is determined by dividing the total delay from all nodes by the total number of vehicles on the network.

FIGURE 4.3

Table 4.2
TRAF-NETSIM RESULTS
EMISSIONS' LEVELS AND DELAY TIME
EXISTING CONDITIONS INTIAL SIMULATION

90 SECOND CYCLE

REFERENCE NODE	CO Kg/mile.hr	NO X Kg/mile.hr	HC Kg/mile.hr	DELAY TIME sec./veh.
1	2.89	0.71	0.21	11.6
2	2.06	0.26	0.08	4.9
3	3.23	0.20	0.07	3.3
4	4.65	0.47	0.13	6.2
5	4.81	0.44	0.15	12.6
6	2.68	0.38	0.12	8.3
7	2.73	0.50	0.15	10.5
8	2.50	0.23	0.07	19.2
9	1.60	0.25	0.10	8.7
10	2.95	0.28	0.13	22.8
11	2.94	0.39	0.16	47.6
12	3.92	0.33	0.10	10.2
13	2.24	0.32	0.10	7.9
14	1.63	0.10	0.03	9.4
15	2.10	0.18	0.12	51.3
16	4.48	0.40	0.12	7.6
17	2.68	0.17	0.03	6.7
18	2.76	0.18	0.06	13.7
19	3.63	0.32	0.20	172.5
20	3.13	0.25	0.10	69.7
21	2.08	0.23	0.08	8.1
22	1.90	0.40	0.18	71.8
23	2.80	0.25	0.15	229.1
24	1.72	0.17	0.08	156.7
25	2.08	0.19	0.10	40.9
26	2.60	0.22	0.13	43.0
27	2.48	0.15	0.05	7.5
28	4.25	0.30	0.10	12.0
29	3.94	0.31	0.11	20.3
30	3.33	0.26	0.15	9.7

REFERENCE NODE	CO Kg/mile.hr	NO X Kg/mile.hr	HC Kg/mile.hr	DELAY TIME sec./veh.
31	2.05	0.13	0.03	6.7
32	2.38	0.20	0.06	7.6
33	3.15	0.22	0.07	5.7
34	2.54	0.18	0.08	5.4
35	3.67	0.42	0.12	7.1
36	3.48	0.35	0.12	5.2
37	3.56	0.44	0.16	18.9
38	4.98	0.42	0.13	5.6
39	3.98	0.72	0.22	3.8
40	3.78	0.48	0.23	19.3
41	4.52	0.60	0.30	12.0
42	3.60	0.44	0.13	8.1
Average per link	3.21 kg/mile.hr	0.34 kg/mile.hr	0.13 kg/mile.hr	-
Network Average	-	-	-	19.24 sec/veh.

NOTES:

1. See Figures 4.3 & 4.4 for explanation of "Node Reference"
2. Average per link is the Total divided by 244 links.
3. Delay time for a Node Reference is presented as the weighted average to a node.
4. Network Average is the total delay (sec.) divided by total number of vehicles.
5. All emissions are presented as the average per directional links.

DELAY TIME REFERENCE NODE

FIGURE 4.4

Note: An approach represents traffic flow direction, it could have a separate lane, no lane, pocket or multiple lanes or pockets.

Delay time is represented as the weighted average of delay time of all the vehicles approaching and leaving the Reference Node.

4.2.3 Transyt 7F

Transyt 7F simulates the flow of traffic in a signalized network. It is a macroscopic traffic model that considers platoons of vehicles versus individual vehicles (as is the case with Netsim) for small increments of time. Transyt 7F also utilizes a platoon dispersion algorithm (i.e. spreading out) of vehicle platoons as they travel through the network.

4.2.3.1 Traffic Flow Model

Transyt simulates traffic macroscopically, where the cycle is divided into small time increments called steps. The step is usually 1 to 3 seconds in length. The smaller the step the more accurate the results are.

When the phase changes to green and vehicles start dispersing through the intersection, there is usually a slight delay before vehicles start flowing at a constant speed. This is known as Start-up Lost Time (SLT). The constant rate of discharge is called the Saturation Flow Rate (SFR).

-Maximum possible flow rate (f),

$$f = 3600/h$$

where: h = minimum headway as the queue departs.

Note that f does not represent capacity, which is the maximum possible traffic volume in vph, considering red time and lost time.

Figure 4.5 illustrates one of the simpler cases of platoon dispersion as it travels down stream [M|O|S|T, 1991]. Note that as vehicles start moving, they move at different

speeds to maintain safe headways (safe headways change per drivers' habits, age, behaviour...etc.), that is why traffic spreads out.

4.2.3.2 Algorithms

a- Arrival Flow Pattern

That is traffic arriving at the stop-line as if it is not impeded by the downstream signal and is mathematically expressed as [M|O|S|T, 1991]:

$$(4) \quad I_{At} = \sum_B^x F_{AB} (P_{AB} * O_{Bt}).$$

where:

I_{At} = the arrival flow pattern on link A for time step t,

F_{AB} = smoothing process factor for flow to link A from link B,
where $F = (1 + a * \beta * T)^{-1}$
a is an empirically derived constant called
the platoon dispersion factor (PDF),
 β is an empirical factor usually = 0.8,
and T is cruise travel time on the link.

P_{AB} = the proportion of O_{AB} that feeds a link,

O_{Bt} = the outflow pattern of link B for time step t (defined below),

x = the number of links (B) that feed link A.

Simple Case of Platoon Dispersion

Figure 4.5

b- Departure Flow Pattern

It is the profile of vehicles actually leaving the stop-line. It is equal to the saturation flow pattern when there is a queue. After the queue dissipates it becomes equal to the Arrival Flow Pattern for the duration of the effective green. To determine the departure pattern, the queue must be determined first [M|O|S|T, 1991]:

$$(5) \quad Q_t = \max [(Q_{t-1} + N_t - L_t) , (0)]$$

where:

Q_t = number of vehicles in the queue at time t on a given link
(similarly for Q_{t-1}),

N_t = number of vehicles arriving during interval t given by the
Arrival Flow Pattern, and

L_t = number of vehicles allowed to leave during interval t,
given by the Departure Flow Pattern,

Since Transyt simulates traffic for a single cycle, the queue length represents only that which would occur due to traffic arriving during that cycle. Hence no build-up of queues as time goes by.

The departure pattern for a link A during time interval t is given by:

$$(6) \quad O_{At} = Q_{A, t-1} + N_{At} - Q_{At}$$

4.2.3.3 Permitted Movements Model

This is the default model used by Transyt 7F. It was developed by the Australian Road Research Board (ARRB) [M|O|S|T, 1991].

The model is subject to the following constraints:

$$(7) \quad MFR(t) = \begin{cases} 0, & \text{if the opposing flow is at its Saturation Flow Rate at time } t, \text{ or} \\ MFR_u(t), & \text{if the opposing queue has cleared at time } t. \end{cases}$$

where:

$$MFR(t) = \text{maximum flow rate at time } t, \text{ and}$$

$$MFR_u(t) = \text{MFR without an opposing queue at time } t.$$

The form of the ARRB model is:

$$(8) \quad MFR(t) = \{L * S * \exp [-(T - D) L] / 1 - \exp (-H * L)\} * 3600$$

where:

$$(9) \quad L = V_o(t) / 1 - [D * V_o(t) / N]$$

$$(10) \quad S = [1 - D * V_o(t) / N]^N$$

and

$$\begin{aligned} V_o &= \text{the opposing flow rate at time } t, \\ H &= \text{minimum departure headway in sec,} \\ D &= \text{minimum headway of opposing traffic lanes in sec,} \\ T &= \text{acceptable critical Gap in sec, and} \\ \exp &= \text{natural base of logarithms, or } e^{(\text{exponent})}. \end{aligned}$$

Transyt offers a variety of other models to choose from. However, for this research study the default model (ARRB) was utilized.

4.2.4 Transyt 7F Simulation

4.2.4.1 Input Data Requirement

A typical Transyt 7F data file structure can be categorized into four main groups as follows:

- 1- Network parameters and program control options.
- 2- Intersection specific data.
- 3- Link weighting and modification parameters.
- 4- Run control cards.

As in the case of the Traf-Netsim input structure, the data are entered into cards designed for specific data. Table 4.3 presents the different cards used in this input file and a brief description of each card. Contrary to the Traf-Netsim input, this software package doesn't require a great deal of details and most of its cards are optional cards that need not be entered if the operator is not looking for a high level of accuracy. For the purpose of this thesis, a reasonable level of accuracy is essential. But the results from this run can be modified to reach satisfactory results in the final Traf-Netsim run.

4.2.4.2 Output data

Transyt provides a summary of the input data in the same order it was entered. Then it produces a traffic performance table for the entered initial settings. This table contains measures of effectiveness, such as total delay, travel time, passenger delay, number of stops, system average speed, fuel consumption and performance index. Table

4.4 contains the initial readings for the 90 seconds cycle. All data in this table should be reviewed for its reasonableness.

Timing tables for individual intersections are then produced. These tables contain the controller settings for interval lengths and offsets. A typical table is shown in Figure 4.6. At the beginning of these tables, network wide information items are provided which are self explanatory.

The cycle length for the first run was set at 90 seconds in the run control of the input data. This was done to compare measures of effectiveness between existing 90 seconds cycle and a synchronized 90 seconds cycle. After that was done, the software was allowed (with some restrictions, mentioned below) to choose an optimum cycle length. This cycle was set by the operator at a minimum of 60 seconds and each phase length had to be long enough to allow for safe pedestrian crossing, where one exists. The output from this run was again compared with the existing 90 seconds cycle output.

Going back to the printed tables, the splits represent the total seconds, and percent of cycle for each phase, including all intervals in each phase. An 'M' next to an interval duration indicates that the phase length was constrained by the minimum phase coded. The links moving in each phase are also indicated to enable the reconstruction of the phase sequence at the node. Controller offsets or yield points are given in terms of seconds and percent of cycle. The offset is always used for a pre-timed controller.

Following is an interpretation of the given MOEs as provided by the Transyt 7F user's guide [Transyt..., 1991].

TABLE 4.3**TRANSYT 7F INPUT CARDS**

CARD NO.	NAME	COMMENT
0	Special options	Optional
1	System Controls	One required
2	Optimization node list	Required for optimization
3	Movement numbering card	Optional
4	Hill climb step sizes	Optional
5	Not currently used	Reserved for future use
6	Sensitivity parameters	Optional
7	Shared-lane groups	Optional
8	Model parameters	Optional
9	Not currently used	Reserved for future use
10	Operating parameters	Optional
1X	Interval timing	One required per node
18	Timing continuation	Optional
2Y	Signal phasing	One required per phase
2Z	Signal phasing continuation	Optional
28	Link data	One required per link
29	Link data continuation	Optional
-28	Bottleneck link data	One required per link
-29	Bottleneck link data continuation	Optional
31	Link-to link flow weighting	Optional
34	Spillover penalty parameters	Optional
35	Speed modifiers	Optional
36	Volume modifiers	Optional
37	Delay weight	Optional
38	Stop weights	Optional
39	Platoon dispersion factors	Optional
40	Flow profile diagrams	Optional
41	Bandwidth coordinates	Optional
42	Arterial definition	Optional
43	Arterial weighting factors	Optional
5X	Run parameters	Required
60	Route summary request	Optional, 5X, 60, 61 must be in this order
61	route summary link list	Same as 60
9X	termination	One required per run

TABLE 4.4

CYCLE: 90 Seconds, 20 Steps

<PERFORMANCE WITH INITIAL SETTINGS>

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	241	2167	2408
Total Travel Time	veh-hr/hr	87	195	282
Total Uniform Delay	veh-hr/hr	23	121	144
Total Random Delay	veh-hr/hr	0	2	2
Total Delay	veh-hr/hr	23	123	146
Average Delay	sec/veh	15.1	9.3	9.9
Passenger Delay	pax-hr/hr	28	147	175
Stops: Total	veh/hr	2924	17043	19967
Percentage	%	53	36	38
System Speed	mph	2.8	11.1	8.5
Fuel Consumption	gal/hr	92	275	367
Operating Cost	\$/hr	293	1778	2071
Performance Index	DI			565.1

CYCLE: 90 Seconds, 20 Steps

<PERFORMANCE WITH OPTIMAL SETTINGS>

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	241	2167	2408
Total Travel Time	veh-hr/hr	78	165	243
Total Uniform Delay	veh-hr/hr	14	90	104
Total Random Delay	veh-hr/hr	0	2	2
Total Delay	veh-hr/hr	14	92	107
Average Delay	sec/veh	9.4	7.0	7.2
Passenger Delay	pax-hr/hr	17	111	128
Stops: Total	veh/hr	2154	13232	15386
Percentage	%	39	28	29
System Speed	mph	3.1	13.1	9.9
Fuel Consumption	gal/hr	74	232	306
Operating Cost	\$/hr	253	1498	1751
Performance Index	DI			421.2

Performance Index (PI): Disutility Index (DI):
 Disutility Index Total Operating Cost

No. of Simulations =1040, Links = 52299 Elapsed Time = 10.0 sec.

 TRANSYT-7F TRAFFIC SIGNAL TIMING TABLES

 NETWORK-WIDE SIGNAL TIMING PARAMETERS

SYSTEM CYCLE LENGTH = 60 SECONDS

MASTER OFFSET REFERENCE LOCATION=INTERSECTION NO.41 START OF INTERVAL 1.

Key to Interval Types:

F : Fixed green.

V : Variable green.

Y : Yellow.

R : All-red.

An 'M' by an interval length means this is the minimum time available.

 INTERSECTION CONTROLLER SETTINGS

 INTERSECTION 1 PRETIMED - SPLITS OPTIMIZED

Interval Number :	1	2	3	4	5	6
Intvl Length(sec):	33	3	2	17	3	2
Intvl Length (%) :	56	5	3	28	5	3
Pin Settings (%) :	100/0	56	61	64	92	97
Phase Start (No.):	1			2		
Interval Type :	V	Y	R	V	Y	R
Splits (sec):	38			22		
Splits (%) :	64			36		
Links Moving :	105			103		
	106			-104		
				101		
				-102		
Offset = 16 sec 27 %.						

FIGURE 4.6

- Total Travel Time (TTT)

This is an important MOE in evaluating alternative control strategies, particularly if coded speeds change from “before” to “after”. Total travel time includes both the time spent moving and the time spent delayed for all vehicles on each link. Since the delay estimates do not account for changes in cruise speed on links, it is important to use travel time to evaluate improvements which lead to cruise speed increases.

- Average System speed

$$\text{average speed} = \text{TT}/\text{TTT}$$

where: TT is Total Travel, which is the product of link traffic volume and link length (vehicle-mile)

TTT is total vehicle-hour per hour of time (Vehicle-hour).

- Delay

Total delay is the sum of the uniform, random and saturation delay. The average delay per vehicle is the total delay on the link divided by the total flow on the link. The delay MOE values are delay due to signal timing only. Transyt delay estimates have been shown to closely match field measurements in uncongested conditions. Delay affects fuel consumption and the total operating cost of a network.

- Average travel time

It is the total time spent on the link by the average vehicle. It is calculated as:

$$T = L/1.47u + d$$

Where: T is average travel time in seconds

L is link length in feet

u is cruise speed in mph

d is average delay in sec./veh.

- Stops

All vehicles that are delayed are assumed to stop, although full stops are not assumed for vehicles encountering small delays. Stops are reported in units of vehicles per hour and also as a percentage of vehicles stopped.

- Saturation flow and degree of saturation

The saturation flow column generally reflects the saturation flow rate coded by the user. The degree of saturation is an indicator of the degree of congestion that can be expected on a link. The degree of saturation 'X', which is also the volume to capacity (v/c) ratio, expressed as a percentage, should be interpreted as follows:

1- If 'X' is less than 95%, the traffic performance on a link will probably be acceptable and the other MOE values should be reasonable (assuming the input data and model parameters are, too).

2- If 'X' is above 95%, the link may be congested if it is pre-timed. Here cycle failures (that is, failing to clear the queue on a link during the green period) are probable. On links with high degrees of saturation, random plus saturation delay will make up the largest portion of the total delay estimated. These MOE values may not represent actual conditions. This will in turn affect the values of other MOEs such as total travel time and fuel consumption. This is particularly true if 'X' is greater than about 110%.

- Maximum back of queue (MBQ)

It is the average (i.e., 50th percentile) maximum extension of the queue upstream on the link during the cycle. The MBQ value includes vehicles which arrive during the green and join the back of queue, while the front of the queue is discharging during the initial seconds of the effective green. This value should be reviewed to check for the chance of spillover into the upstream intersection.

- Disutility Index (DI)

It represents excess fuel consumption, that is, fuel consumption due to delay and stops in gallons per hour.

- Fuel consumption

The estimate of fuel consumption is based on a linear combination of total travel time, delay and stops. The fuel consumption value given includes fuel used at cruise, idle and acceleration/deceleration speeds. It is in units of gallons per hour.

4.2.3.3 Network Configuration

Figure 4.7 represents the network assignment used to portray the study area for this run. Transyt's 'standard' numbering scheme has intersection nodes numbered 1 through 42. The north bound approach on intersection 1 for example is 101, south bound is 103, west bound is 107, and east bound is 105. Left turn on approach 101 is 102, on 103 is 104, on 105 is 106 and on 107 is 108. This numbering scheme is illustrated in Figure 4.8. Card number 3 in the input file represents the movement numbering card.

4.2.4.4 Calibration

Calibrating the Transyt 7F model, as with the Netsim model, ensures that the simulation is accurately representing the flow of traffic in the study area for the studied period. This is very essential to warrant that the software will develop an appropriate timing plan for that period.

The first step in calibrating the Transyt model, as recommended by the user's guide, was to code the existing signal timing plan and traffic data, and then make a series of simulation runs. The purpose of this simulation exercise was to calibrate the Transyt model to reflect traffic flow with the existing timing plan. Then the simulation output was examined and, if necessary, the input data were modified, until the model represented the existing conditions reasonably well.

First, the performance table from the simulation run was examined. MOE values, particularly the degree of saturation and the maximum back of queue (MBQ) extension,

Transyt 7F Network

FIGURE 4.7

Transyt 7F Numbering Scheme

FIGURE 4.8

was compared with actual conditions on the street to determine how closely the software was modeling existing traffic performance.

The MBQ extension on a link is easily checked in the field. This may be larger than the maximum number of vehicles queued, since vehicles can join the back of queue while the front of the queue is discharging at the beginning of the effective green. Large discrepancies in queue length between field condition and the Transyt 7F performance table usually indicates that either the volume or the saturation flow rate coded for the link is incorrect. The MBQ was calibrated on short links and links representing turn bays, where there was a danger of queues extending into the upstream intersection or adjoining lanes.

Over-saturated links in the field, generally exhibited “cycle failures” or failure of the queue to clear during one signal cycle. In this case, several inputs were incorrect. The equation for degree of saturation ‘X’ is presented as follows:

$$X = \text{volume} * \text{cycle length} / \text{saturation flow rate} * \text{effective green}$$

a check was made to be sure that the volume and saturation flow rate for the link were correct. When a link was congested in the field and the queue did not clear, it was particularly important that demand, rather than discharge volume was entered. Also it was made sure that start-up lost time and extension of the effective green, both of which determine actual effective green time, were coded correctly and represented field conditions. Effective green was calculated as:

$$\text{Effective green} = \text{Actual green} - \text{Start-up lost time} + \text{Extension of effective green}$$

Finally, other MOEs were inspected in the performance table, such as percentage of vehicles stopped and average travel time, to see if they looked reasonable. If any input parameters were found to be incorrect, changes were made and the simulation rerun; and results were then checked to see if they accurately reflected field conditions.

4.2.4.5 Results

The output of both the initial and final runs were found to be satisfactory on completion of the above calibrations. The results were compared and the improved timing plan was adopted for use in the next phase of the methodology. Table 4.5 displays the new timing plan, and Table 4.6 shows the corresponding performance MOEs.

4.3 PHASE TWO

After the initial conditions were fully analyzed and results of initial emissions and delay determined, the final step in the computer simulation was to use the Traf-Netsim generated model to determine improved conditions.

4.3.1 Traf-Netsim Simulation

Only minor changes had to be made to the original file before it could produce the improved output required. The newly developed timing plan replaced the old timing plan, keeping in mind that the same movement of links was maintained as before. The simulation was run and the required output was determined as done in phase one.

TABLE 4.5
TRANSYT'S IMPROVED TIMING PLAN

ALL TIMINGS ARE IN SECONDS

Reference Node NO.	INTERVAL NUMBER									OFFSET
	1	2	3	4	5	6	7	8	9	
1	33	3	2	17	3	2				16
2	37	3	17M	3						59
3	32	3	22	3						55
4	37	3	17M	3						45
5	34	3	30	3						51
6	14	3	40	3						50
7	35	3	2	15	3	2				11
8	40	3	2	10	3	2				52
9	-	-	-	-		STOP SIGN				
10	25	3	2	25	3	2				52
11	11	3	27	3	13	3				8
12	18	3	36	3						8
13	27	3	27	3						19
14	9	3	45	3						33
15	12	3	2	23	3	2	10M	3	2	6
16	31	3	23	3						3
17	27M	3	27	3						60
18	30	-	24	3						27
19	27	3	27	3						54
20	28	3	26	3						50
21	27	3	27	3						53
22	-	-	-	-		PEDESTRIAN CROSSING				
23	37	3	17	3						17
24	22	3	32	3						59
25	22	3	32	3						55
26	30	3	2	20	3	2				46
27	37	3	5	12	3					8
28	25	3	1	27	3	1				53
29	17	3	1	25	3	1	6M	3	1	55
30	21	3	1	31	3	1				55
31	35	3	19	3						4
32	25M	3	29	3						59
33	7M	3	7M	3	37	3				59
34	19M	3	35	3						4
35	42	3	12	3						59
36	23	3	31	3						59
37	28	3	26	3						59
38	34	3	1	18	3	1				3
39	28	3	26	3						59
40	22	3	32	3						59
41	38	3	16	3						0
42	13M	3	2	37	3	2				24

M" INDICATES THAT THIS IS THE MINIMUM PHASE CODED
OFFSET IS IN SECONDS AND ITS REFERENCE IS NODE 41

TABLE 4.6

<PERFORMANCE WITH OPTIMAL SETTINGS>

All MOEs are in units per hour.

CYCLE: 60 Seconds, 13 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	241	2167	2408
Total Travel Time	veh-hr/hr	74	132	206
Total Uniform Delay	veh-hr/hr	10	58	68
Total Random Delay	veh-hr/hr	0	1	1
Total Delay	veh-hr/hr	10	60	69
Average Delay	sec/veh	6.3	4.5	4.7
Passenger Delay	pax-hr/hr	12	72	83
Stops: Total	veh/hr	2294	12397	14692
Percentage	%	41	26	28
System Speed	mph	3.3	16.4	11.7
Fuel Consumption	gal/hr	65	203	268
Operating Cost	\$/hr	234	1368	1602
Performance Index	DI			313.8

Performance Index (PI): Disutility Index (DI):
 Disutility Index Total Operating Cost

No. of Simulations = 893, Links = 51221 Elapsed Time = 302.9 sec.

4.3.1.1 Calibration

The initial conditions Netsim model was calibrated and checked for any mistaken entries. The remaining activity was to make sure that the newly developed plan will not produce unsatisfactory results when applied to the model.

The first step was to carefully study the MOEs produced by the new model for any unreasonably high or low results. Since the results from this run could not be compared to actual “on the ground” conditions, it was up to the operator to determine which values were acceptable or not. As for spillbacks, it was expected that they shouldn’t occur under the new plan, and their presence was detected and the reason behind it eliminated.

A study was made to determine if the high delay and/or high emissions were not related to any spill-back effect, but rather to an error in the new signal settings. This occurrence could sometimes be determined if the output values on different approaches of an intersection vary tremendously. In such cases, those settings were altered and the simulation rerun until satisfactory results were achieved. This method of calibration was based on trial and error and on the operators experience, and could not be substantiated by field surveys.

It should be clear that changing the signal timings of an intersection will almost always produce a higher overall delay and emissions, simply because the original plan produced by the Transyt 7F model is supposed to be the optimal plan for the studied network. However, given that optimal conditions do not always provide a workable

solution, deviations from that plan are allowed for a somewhat reasonable increase in output parameters.

4.3.1.2 Results

The results from this simulation run are supposed to predict various measures of effectiveness when improvements are made to the signal timing plan. But, as discussed above, it is very difficult to substantiate these results by field data. However; it should be easy to reach the desired level of accuracy by just manipulating the new timing plan in order to remove any unacceptable outputs. Table 4.8 displays Netsim's improved system delay and emissions' levels. The maximum number of vehicles allowed on the network is 1061 and occurred at 899 seconds.

With all the simulation runs successfully completed, the information attained are summarized in Table 4.7.

**COMPUTER SIMULATIONS
SUMMARY TABLE**

	EXISTING CONDITIONS	IMPROVED CONDITIONS
TRAF-NETSIM 1st RUN	YES	---
TRANSYT 7 F RUN	YES	YES
TRAF-NETSIM 2nd RUN	---	YES

Table 4.7

Table 4.8

TRAF-NETSIM RESULTS
EMISSIONS' LEVELS AND DELAY TIME
FINAL SIMULATION

60 SECOND CYCLE

REFERENCE NODE NO.	CO Kg/mile.hr	NO X Kg/mile.hr	HC Kg/mile.hr	DELAY TIME sec.
1	1.68	0.24	0.08	10.6
2	1.78	0.18	0.05	4.4
3	1.32	0.17	0.05	4.8
4	2.02	0.30	0.10	3.9
5	2.10	0.36	0.11	7.5
6	1.68	0.12	0.03	9.9
7	2.80	0.50	0.15	11.7
8	1.85	0.22	0.07	11.1
9	1.43	0.23	0.08	8.6
10	1.07	0.32	0.12	25.8
11	1.40	0.34	0.14	46.3
12	2.02	0.27	0.08	7.0
13	1.88	0.20	0.08	6.7
14	1.00	0.10	0.03	9.0
15	1.27	0.23	0.10	53.4
16	2.04	0.28	0.10	10.2
17	1.70	0.18	0.05	5.2
18	1.08	0.16	0.04	6.9
19	1.85	0.28	0.15	115.5
20	1.75	0.29	0.11	34.6
21	1.28	0.18	0.05	4.6
22	1.43	0.40	0.18	43.8
23	0.72	0.20	0.18	24.8
24	0.65	0.13	0.07	131.6
25	1.25	0.18	0.10	69.4
26	1.23	0.15	0.12	12.8
27	1.27	0.15	0.07	5.1
28	1.95	0.30	0.10	8.6
29	2.07	0.24	0.07	16.3
30	1.85	0.20	0.13	11.3

Reference NODE NO.	CO Kg/mile.hr	NO X Kg/mile.hr	HC Kg/mile.hr	DELAY TIME seconds
31	1.55	0.10	0.03	5.3
32	1.32	0.20	0.14	4.5
33	2.20	0.17	0.05	6.2
34	1.38	0.14	0.04	6.2
35	1.82	0.32	0.17	4.4
36	2.78	0.28	0.22	8.1
37	1.49	0.16	0.06	7.6
38	1.75	0.18	0.05	3.8
39	2.66	0.36	0.30	4.9
40	1.81	0.25	0.19	5.0
41	1.45	0.28	0.20	8.7
42	2.14	0.33	0.10	5.6
AVERAGE PER LINK	1.72 kg/mile.hr	0.25 kg/mile.hr	0.11 kg/mile.hr	-
Network Average	-	-	-	12.33 sec/veh.

NOTES:

1. See Figures 4.3 & 4.4 for explanation of "Node Reference"
2. Average per link is the Total divided by 244 links.
3. Delay time for a Node Reference is presented as the weighed average of all approaches to a node.
4. Network Average is the total delay (sec.) divided by total number of vehicles.
5. All emissions are presented as the average per directional links.

4.4 PHASE THREE

After the studies of the peak hour have been completed through the previous two phases, we now have a better understanding of what each software package can achieve and the accuracy of its output (done through comparing similar MOEs). The next step would be to attempt to study the effect of adaptive control in the most economical and least time consuming way. From Table 4.7 we note that the Transyt 7F software package delivers the required existing and improved conditions and their respective MOEs (except for the environmental data which have already been determined in phases one and two). Thus making Transyt 7F the logical choice for this phase of the study.

4.4.1 Adaptive Control

To be able to study adaptive control, it is important to understand how the system functions. To be brief we review the steps of the process:

- Data are collected by detector loops placed on all the approaches to an intersection.
- Controllers gather these data and send it through the interconnect network to the main control or central control.
- A central computer system will process these data and develop a timing plan that will maximize the network's usefulness, using such algorithms as the Transyt algorithm.
- The newly devised plan is then sent to the controllers to be implemented.
- The whole process is then repeated.

Several things could vary from one system to the other, but the basic idea behind adaptive control is to be able to react to traffic changes very quickly, efficiently and properly. This reaction time could be as low as few minutes depending on the size of the network and on the system utilized. And the implementation of the plan could be gradual as explained before.

However; being limited by the collected data which has volumes for fifteen minute intervals, we have to assume that the adaptive system implements a new timing plan every fifteen minutes. With this being the case, the steps in subsection 4.2.4 are then followed for each of the four periods chosen for this study.

Results are then compared and a conclusion reached based on the consistency of these outputs. Refer to Tables 4.9 to 4.16 for a list of outputs from this phase (as produced by the software package).

The next chapter contains a full analysis of all the outputs obtained from all three phases, and of how they relate to each other.

TABLE 4.9
ADAPTIVE CONTROL SIMULATION
FIRST PERIOD

<PERFORMANCE WITH INITIAL SETTINGS>

CYCLE: 90 Seconds, 20 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	254	2262	2516
Total Travel Time	veh-hr/hr	88	211	299
Total Uniform Delay	veh-hr/hr	23	130	153
Total Random Delay	veh-hr/hr	0	5	5
Total Delay	veh-hr/hr	23	135	158
Average Delay	sec/veh	14.2	9.8	10.3
Passenger Delay	pax-hr/hr	27	162	190
Stops: Total	veh/hr	2947	19790	22738
Percentage	%	51	40	41
System Speed	mph	2.9	10.7	8.4
Fuel Consumption	gal/hr	93	303	396
Operating Cost	\$/hr	298	1981	2279
Performance Index	DI			626.6

<PERFORMANCE WITH OPTIMAL SETTINGS>

CYCLE: 90 Seconds, 20 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	254	2262	2516
Total Travel Time	veh-hr/hr	81	171	252
Total Uniform Delay	veh-hr/hr	15	93	108
Total Random Delay	veh-hr/hr	0	2	2
Total Delay	veh-hr/hr	15	95	110
Average Delay	sec/veh	9.5	6.9	7.2
Passenger Delay	pax-hr/hr	18	114	133
Stops: Total	veh/hr	2331	14110	16442
Percentage	%	40	28	30
System Speed	mph	3.1	13.2	10.0
Fuel Consumption	gal/hr	78	243	321
Operating Cost	\$/hr	264	1578	1842
Performance Index	DI			440.7

Performance Index (PI): Disutility Index (DI):
Disutility Index Total Operating Cost

No. of Simulations =1039, Links = 55495 Elapsed Time = 10.3 sec.

TABLE 4.10
ADAPTIVE CONTROL SIMULATION
FIRST PERIOD
OPTIMAL CYCLE

<PERFORMANCE WITH OPTIMAL SETTINGS>

All MOEs are in units per hour.

CYCLE: 61 Seconds, 14 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	254	2261	2515
Total Travel Time	veh-hr/hr	75	139	214
Total Uniform Delay	veh-hr/hr	9	61	70
Total Random Delay	veh-hr/hr	0	2	2
Total Delay	veh-hr/hr	9	63	73
Average Delay	sec/veh	5.8	4.6	4.7
Passenger Delay	pax-hr/hr	11	76	87
Stops: Total	veh/hr	2242	13237	15480
Percentage	%	39	27	28
System Speed	mph	3.4	16.3	11.8
Fuel Consumption	gal/hr	66	215	281
Operating Cost	\$/hr	240	1447	1687
Performance Index	DI			331.3

Performance Index (PI): Disutility Index (DI):
Disutility Index Total Operating Cost

No. of Simulations = 966, Links = 53581 Elapsed Time = 311.7 sec.

TABLE 4.11
ADAPTIVE CONTROL SIMULATION
SECOND PERIOD

<PERFORMANCE WITH INITIAL SETTINGS>

CYCLE: 90 Seconds, 20 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	222	2110	2332
Total Travel Time	veh-hr/hr	80	188	268
Total Uniform Delay	veh-hr/hr	21	116	137
Total Random Delay	veh-hr/hr	0	1	1
Total Delay	veh-hr/hr	21	117	138
Average Delay	sec/veh	14.6	9.1	9.6
Passenger Delay	pax-hr/hr	25	140	165
Stops: Total	veh/hr	2611	17040	19651
Percentage	%	51	37	38
System Speed	mph	2.8	11.2	8.7
Fuel Consumption	gal/hr	83	268	352
Operating Cost	\$/hr	267	1748	2016
Performance Index	DI			543.4

<PERFORMANCE WITH OPTIMAL SETTINGS>

CYCLE: 90 Seconds, 20 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	222	2110	2332
Total Travel Time	veh-hr/hr	74	155	230
Total Uniform Delay	veh-hr/hr	15	83	99
Total Random Delay	veh-hr/hr	0	1	1
Total Delay	veh-hr/hr	15	84	100
Average Delay	sec/veh	10.7	6.6	7.0
Passenger Delay	pax-hr/hr	18	101	120
Stops: Total	veh/hr	2321	12471	14792
Percentage	%	45	27	29
System Speed	mph	3.0	13.6	10.2
Fuel Consumption	gal/hr	72	220	292
Operating Cost	\$/hr	243	1423	1667
Performance Index	DI			395.0

Performance Index (PI): Disutility Index (DI):
Disutility Index Total Operating Cost

No. of Simulations =1030, Links = 54103 Elapsed Time = 10.2 sec.

TABLE 4.12
ADAPTIVE CONTROL SIMULATION
SECOND PERIOD
OPTIMAL CYCLE

<PERFORMANCE WITH OPTIMAL SETTINGS>

All MOEs are in units per hour.

CYCLE: 63 Seconds, 14 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	222	2110	2332
Total Travel Time	veh-hr/hr	70	130	200
Total Uniform Delay	veh-hr/hr	10	58	69
Total Random Delay	veh-hr/hr	0	1	1
Total Delay	veh-hr/hr	10	60	70
Average Delay	sec/veh	7.2	4.6	4.9
Passenger Delay	pax-hr/hr	12	72	84
Stops: Total	veh/hr	2245	11719	13964
Percentage	%	44	25	27
System Speed	mph	3.2	16.2	11.7
Fuel Consumption	gal/hr	62	197	260
Operating Cost	\$/hr	222	1318	1540
Performance Index	DI			308.2

Performance Index (PI): Disutility Index (DI):
Disutility Index Total Operating Cost

No. of Simulations = 985, Links = 48751 Elapsed Time = 285.3 sec.

TABLE 4.13
ADAPTIVE CONTROL SIMULATION
THIRD PERIOD

<PERFORMANCE WITH INITIAL SETTINGS>

CYCLE: 90 Seconds, 20 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	273	2356	2628
Total Travel Time	veh-hr/hr	99	216	316
Total Uniform Delay	veh-hr/hr	26	135	161
Total Random Delay	veh-hr/hr	0	3	3
Total Delay	veh-hr/hr	26	138	164
Average Delay	sec/veh	15.2	9.5	10.1
Passenger Delay	pax-hr/hr	32	165	197
Stops: Total	veh/hr	3320	19792	23112
Percentage	%	53	38	40
System Speed	mph	2.7	10.9	8.3
Fuel Consumption	gal/hr	104	309	413
Operating Cost	\$/hr	332	2012	2344
Performance Index	DI			641.9

<PERFORMANCE WITH OPTIMAL SETTINGS>

CYCLE: 90 Seconds, 20 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	273	2356	2628
Total Travel Time	veh-hr/hr	94	176	270
Total Uniform Delay	veh-hr/hr	21	95	116
Total Random Delay	veh-hr/hr	0	2	2
Total Delay	veh-hr/hr	21	97	118
Average Delay	sec/veh	12.2	6.7	7.3
Passenger Delay	pax-hr/hr	25	116	142
Stops: Total	veh/hr	3092	13885	16977
Percentage	%	50	27	29
System Speed	mph	2.9	13.4	9.7
Fuel Consumption	gal/hr	93	247	341
Operating Cost	\$/hr	310	1596	1906
Performance Index	DI			459.3

Performance Index (PI): Disutility Index (DI):
Disutility Index Total Operating Cost

No. of Simulations =1044, Links = 59144 Elapsed Time = 11.0 sec.

TABLE 4.14
ADAPTIVE CONTROL SIMULATION
THIRD PERIOD
OPTIMAL CYCLE

<PERFORMANCE WITH OPTIMAL SETTINGS>

All MOEs are in units per hour.

CYCLE: 61 Seconds, 14 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	273	2356	2628
Total Travel Time	veh-hr/hr	85	140	225
Total Uniform Delay	veh-hr/hr	12	58	71
Total Random Delay	veh-hr/hr	0	3	3
Total Delay	veh-hr/hr	12	61	73
Average Delay	sec/veh	7.1	4.2	4.5
Passenger Delay	pax-hr/hr	15	73	88
Stops: Total	veh/hr	2636	12450	15086
Percentage	%	42	24	26
System Speed	mph	3.2	16.8	11.7
Fuel Consumption	gal/hr	75	213	288
Operating Cost	\$/hr	270	1424	1694
Performance Index	DI			324.7

Performance Index (PI): Disutility Index (DI):
Disutility Index Total Operating Cost

No. of Simulations =1008, Links = 53361 Elapsed Time = 313.6 sec.

TABLE 4.15
ADAPTIVE CONTROL SIMULATION
FOURTH PERIOD

<PERFORMANCE WITH INITIAL SETTINGS>

CYCLE: 90 Seconds, 20 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	211	1940	2151
Total Travel Time	veh-hr/hr	76	175	251
Total Uniform Delay	veh-hr/hr	20	109	129
Total Random Delay	veh-hr/hr	0	1	1
Total Delay	veh-hr/hr	20	110	130
Average Delay	sec/veh	15.1	9.3	9.9
Passenger Delay	pax-hr/hr	24	132	156
Stops: Total	veh/hr	2429	15421	17850
Percentage	%	51	36	38
System Speed	mph	2.8	11.1	8.6
Fuel Consumption	gal/hr	80	249	328
Operating Cost	\$/hr	254	1606	1861
Performance Index	DI			507.6

<PERFORMANCE WITH OPTIMAL SETTINGS>

CYCLE: 90 Seconds, 20 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	211	1940	2151
Total Travel Time	veh-hr/hr	66	142	208
Total Uniform Delay	veh-hr/hr	11	76	87
Total Random Delay	veh-hr/hr	0	1	1
Total Delay	veh-hr/hr	11	77	88
Average Delay	sec/veh	8.1	6.5	6.7
Passenger Delay	pax-hr/hr	13	93	106
Stops: Total	veh/hr	1717	11354	13071
Percentage	%	36	27	28
System Speed	mph	3.2	13.6	10.3
Fuel Consumption	gal/hr	61	202	263
Operating Cost	\$/hr	213	1305	1518
Performance Index	DI			352.4

Performance Index (PI): Disutility Index (DI):
Disutility Index Total Operating Cost

No. of Simulations =1047, Links = 58785 Elapsed Time = 10.9 sec.

TABLE 4.16
ADAPTIVE CONTROL SIMULATION
FOURTH PERIOD
OPTIMAL CYCLE

<PERFORMANCE WITH OPTIMAL SETTINGS>

All MOEs are in units per hour.

CYCLE: 63 Seconds, 14 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	211	1940	2151
Total Travel Time	veh-hr/hr	67	117	183
Total Uniform Delay	veh-hr/hr	11	51	61
Total Random Delay	veh-hr/hr	0	1	2
Total Delay	veh-hr/hr	11	52	63
Average Delay	sec/veh	8.4	4.4	4.8
Passenger Delay	pax-hr/hr	13	62	76
Stops: Total	veh/hr	2062	10422	12484
Percentage	%	43	24	26
System Speed	mph	3.2	16.6	11.7
Fuel Consumption	gal/hr	62	178	240
Operating Cost	\$/hr	215	1187	1402
Performance Index	DI			276.1

Performance Index (PI): Disutility Index (DI):
Disutility Index Total Operating Cost

No. of Simulations = 993, Links = 52539 Elapsed Time = 304.7 sec.

CHAPTER V

ANALYSIS OF SIMULATION OUTPUTS

5.1 INTRODUCTION

Control of traffic in time as well as in space adds a new dimension to traditional highway engineering solutions to traffic congestion and its related problems. The proven benefits of traffic control include: improved traffic flows, generally reduced congestion, shorter journey times, substantial fuel savings and emission reduction. In the context of this research, traffic delay reduction and lower levels of emissions are achieved. Also, the controlled systems will be able to handle more traffic volumes at a better level of service. It should be noted that this thesis research is attempting to substantiate and quantify these benefits of advanced central traffic control.

Traffic control systems can provide the basis for an expanded control philosophy incorporating features such as emergency vehicle priority, variable message signs, congestion monitoring and other intervention strategies. For future purposes it can be expanded into areas such as expert system traffic control and interaction with vehicle and driver information systems. Traffic control systems can also be used to influence the pattern of route choice to enforce policy objectives such as protecting neighborhood environments, increase safety, divert traffic from heavy pedestrian areas or give priority to public transit vehicles. Such features could constitute reason enough to adopt control systems.

5.2 HIGHLIGHTS OF SIMULATION AND EXPECTED RESULTS

Traffic control systems will not only reduce congestion but will, in the process, redistribute it between different areas or between different categories of the traffic system. This is an attempt to arrange for queuing to take place in areas where it could be best discharged or accommodated. This is an important point in helping understand the differences between the before and after results.

As described earlier, the purpose of this study is to confirm delay and air quality improvement benefits associated with the coordination of traffic signals in the Syracuse CBD area. Forty adjacent signalized intersections in the heart of the CBD were designated to model the potential air quality impact of coordinating one hundred and forty five signals in this project area. These forty signals are not part of any coordinated system at the present time (Fall 1997). Current air quality models are not applicable to the study of improvement in air quality due to the improved traffic progression by signal coordination. First, Traf-Netsim and Transyt-7F computer models were used to demonstrate improvements in air quality for the forty designated intersections, then Transyt-7F was used to study the effects of adaptive control systems. Traffic counts were provided by the New York Department of Transportation and signal timings were taken at these intersections for the evening peak period. Intersection geometrics, allowable lane movements and distances between intersections were measured. Traf-Netsim was used to model the existing system weekday afternoon peak hour and determine its initial levels of emissions. Transyt 7F was then used to synchronize and optimize the signal timings for these intersections. Transyt 7F requires that all signal timings be the same, and it does not give carbon monoxide emissions. That is why Traf-Netsim is then used to model the system with the improved timing plan, to determine the carbon monoxide as well as other

emissions. The Traf-Netsim simulation of existing conditions was calibrated to represent the observed existing conditions. Appendix A contains the Traf-Netsim input and part of the output files for the existing system. After calibration of the existing system, a Traf-Netsim model of the improved system was developed. The first step in preparing an improved system involves using Transyt 7F to model the existing system, with the requirement that all cycle lengths be set to the same value, which was no problem as they were all set at 90 seconds. These signal timings were then used to update the Traf-Netsim model to create an improved signal timing plan for the system. However the length of the cycle in the improved plan was found to be 60 seconds, which will be discussed later. Appendix B contains the input and part of the output files for the Transyt 7F model.

The second step was to use Transyt 7F to study the effect of utilizing a traffic responsive system. Four consecutive traffic counts, fifteen minute peak hour periods, were used to create four separate Transyt 7F models. For each period the existing conditions are determined, then a synchronized timing plan is developed for the existing cycle length and its MOEs are determined. In the final step an optimum timing plan is developed and its MOEs are determined. Results from these three steps are then compared.

5.3 BENEFITS OF TRAFFIC CONTROL

The improved system demonstrated that the signal timing changes will reduce the emissions level for the selected forty two intersections. As the system expands to include adjacent signalized intersections, further improvements will be realized allowing for a convergence to an optimal solution. Also, as is a normal and reasonable engineering practice, the “optimal” system determined by the computer models could be adjusted using engineering judgment. Several factors affect these adjustments. First, the models may not determine the optimal solution. In some situations it is necessary for the engineer to make

additional adjustments, based on past experience, which when modeled will further improve the system. Second, in some situations the optimal solution may cause some individual approaches to degrade below an acceptable level of service (optimal here means the highest overall improvements in system wide measures of effectiveness). For example, the optimal set of signal timings giving the lowest system wide average delay might cause specific approaches to have unacceptably high delays. In order to improve the level of service at these intersections it would be necessary to alter their signal timings. Although this might cause the overall delay and emissions levels to become higher (less than optimal), the adjustments would make the system more acceptable to the driving public.

Table 5.1 contains a comparison of system wide measures of effectiveness for both the existing system and the improved system as produced by Transyt-7F, for the peak hour period. It shows a comparison between the existing conditions for a 90 second cycle and the improved conditions after coordinating the forty signals at the same cycle length. The reduction in total delay was 39 veh-hr/hr or 26.7%; average delay improved by 2.7 sec/veh or 27.3%; fuel consumption improved by 61 gal/hr (231 litre/hr) or 16.6%; system speed increased by 1.4 mph (2.3 km/hr) or 16.5%; and the disutility (performance) index decreased by 143.9 DI or 25.5%. The DI is a measure of disadvantageous operation; that is stops, delays, fuel consumption, etc. In this case DI specifies excess fuel consumption (due to delay and stops) in gallons per hour.

The optimal cycle length, as given by Transyt 7F, was 45 seconds. However, such a short cycle raises concern about safety, as short cycles could mean less time for pedestrian crossings, and higher system speeds. Therefore, the minimum cycle length was

TABLE 5.1

TRANSYT 7F RESULTS**PEAK
HOUR**

Cycle Length

PERFORMANCE MEASURES	UNITS	90seconds	90 seconds	% CHANGE	60 seconds	% CHANGE
		EXISTING SYSTEM	IMPROVED SYSTEM		OPTIMIZED SYSTEM	
TOTAL TRAVEL	veh-mi/hr	2408	2408	0.0	2408	0
TOTAL TRAVEL TIME	veh-hr/hr	282	243	-13.8	206	-27.0
TOTAL UNIFORM DELAY	veh-hr/hr	144	104	-27.8	68	-52.8
TOTAL DELAY	veh-hr/hr	146	107	-26.7	69	-52.7
AVERAGE DELAY	sec/veh	9.9	7.2	-27.3	4.7	-52.5
PASSENGER DELAY	pax-hr/hr	175	128	-26.9	83	-52.6
STOPS:TOTAL	veh/hr	19967	15386	-22.9	14692	-26.4
PERCENTAGE		38	29	-23.7	28	-26.3
SYSTEM SPEED	mph	8.5	9.9	16.5	11.7	37.6
FUEL CONSUMPTION	gal/hr	367	306	-16.6	268	-27.0
OPERATING COST	\$/hr	2071	1751	-15.5	1602	-22.6
PERFORMANCE INDEX	DI	565.1	421.2	-25.5	313.8	-44.5

NOTES:

% Change is compared to the existing 90 sec. cycle

DI= DISUTILITY INDEX

set at 60 seconds and the individual phases set at sufficient minimums to allow for pedestrians safe crossing as needed. For an optimum reached by Transyt 7F at 60 seconds, Table 5.1 shows a comparison between the new improved cycle (60 seconds cycle) and the existing 90 seconds cycle, for the peak hour period. In this case, total delay reduced by 77 veh-hr/hr or 52.7%, Average delay improved by 5.2 sec/veh or 52.5%, fuel consumption improved by 99 gal/hr (375 litre/hr) or 27.0%, system speed increased by 3.2 mph (5.15 km/hr) or 37.6% and the disutility (performance) index decreased by 251.3 DI or 44.5%.

Comparing the results from Table 5.1: It is clear that it would be more advantageous to use the shorter cycle for its tremendous improvements. However, we have to take notice that the system speed has increased by 37.6% in the 60 second cycle improved system as compared to the 16.5% increase in the 90 second cycle improved system. Thus, although the 60 seconds cycle provides greater improvements in the remaining measures of effectiveness, it could mean some problems with safety as discussed earlier. Nevertheless, considering the fact that the implemented system would incorporate a large arsenal of safety features and equipment, it was decided, for the purpose of this study, to use the shorter cycle due to its advantages.

Table 5.2 and Figures 5.1, 5.2 and 5.3 show a comparison between the Traf-Netsim emission rates for the existing system and the new improved one. A positive number indicates that the intersection in general produced higher emissions in the improved system. Worth mentioning here is that some intersections appear to have been adversely affected under the new system. However, under closer inspection we find that these intersections by comparison to other intersections are still lower than average. Other intersections that had a considerable increase in HC emissions were intersections

Table 5.2

TRAF-NETSIM RESULTS **EMISSION RATES**

Reference NODE NO.	EXISTING SYSTEM			IMPROVED SYSTEM			% CHANGE		
	90 SEC. CYCLE			60 SEC. CYCLE			CO	NO X	HC
	CO Kg/mile. hr	NO X g/mile. hr	HC Kg/mile. hr	CO Kg/mile. hr	NO X g/mile. hr	HC Kg/mile. hr			
1	2.89	0.71	0.21	1.68	0.24	0.08	-41.9	-66.3	-62.3
2	2.06	0.26	0.08	1.78	0.18	0.05	-13.6	-30.8	-37.5
3	3.23	0.20	0.07	1.32	0.17	0.05	-59.1	-15.0	-25.4
4	4.65	0.47	0.13	2.02	0.30	0.10	-56.6	-35.8	-24.8
5	4.81	0.44	0.15	2.10	0.36	0.11	-56.3	-17.8	-24.7
6	2.68	0.38	0.12	1.68	0.12	0.03	-37.3	-68.4	-71.7
7	2.73	0.50	0.15	2.80	0.50	0.15	2.6	0.0	0.0
8	2.50	0.23	0.07	1.85	0.22	0.07	-26.0	-4.3	1.5
9	1.60	0.25	0.10	1.43	0.23	0.08	-10.6	-8.0	-20.0
10	2.95	0.28	0.13	1.07	0.32	0.12	-63.7	13.1	-12.0
11	2.94	0.39	0.16	1.40	0.34	0.14	-52.4	-11.6	-7.7
12	3.92	0.33	0.10	2.02	0.27	0.08	-48.5	-18.2	-17.0
13	2.24	0.32	0.10	1.88	0.20	0.08	-16.1	-37.5	-20.0
14	1.63	0.10	0.03	1.00	0.10	0.03	-38.5	0.0	0.0
15	2.10	0.18	0.12	1.27	0.23	0.10	-39.5	25.7	-14.3
16	4.48	0.40	0.12	2.04	0.28	0.10	-54.5	-30.0	-16.7
17	2.68	0.17	0.03	1.70	0.18	0.05	-36.6	9.6	51.5
18	2.76	0.18	0.06	1.08	0.16	0.04	-60.9	-11.1	-33.3
19	3.63	0.32	0.20	1.85	0.28	0.15	-49.0	-10.4	-25.0
20	3.13	0.25	0.10	1.75	0.29	0.11	-44.0	16.0	13.0
21	2.08	0.23	0.08	1.28	0.18	0.05	-38.3	-20.0	-33.3
22	1.90	0.40	0.18	1.43	0.40	0.18	-24.7	0.0	2.9
23	2.80	0.25	0.15	0.72	0.20	0.18	-74.3	-20.0	22.0
24	1.72	0.17	0.08	0.65	0.13	0.07	-62.1	-20.4	-19.3
25	2.08	0.19	0.10	1.25	0.18	0.10	-39.9	-4.3	0.0
26	2.60	0.22	0.13	1.23	0.15	0.12	-52.7	-31.8	-9.8
27	2.48	0.15	0.05	1.27	0.15	0.07	-48.8	0.0	34.0
28	4.25	0.30	0.10	1.95	0.30	0.10	-54.1	0.0	0.0
29	3.94	0.31	0.11	2.07	0.24	0.07	-47.5	-22.6	-35.5
30	3.33	0.26	0.15	1.85	0.20	0.13	-44.4	-23.1	-11.3

Table 5.2 (CONT.)

TRAF-NETSIM RESULTS **EMISSIONS' LEVELS**

REFERENCE NODE NO.	EXISTING SYSTEM			IMPROVED SYSTEM			% CHANGE		
	90 SEC. CYCLE			60 SEC. CYCLE			CO	NO X	HC
	CO g/mile.h r	NO X g/mile.h r	HC g/mile. hr	CO g/mile. hr	NO X g/mile.h r	HC g/mile.h r			
31	2.05	0.13	0.03	1.55	0.10	0.03	-24.4	-24.8	0.0
32	2.38	0.20	0.06	1.32	0.20	0.14	-44.5	0.0	133.3
33	3.15	0.22	0.07	2.20	0.17	0.05	-30.2	-22.7	-25.4
34	2.54	0.18	0.08	1.38	0.14	0.04	-45.7	-22.2	-50.0
35	3.67	0.42	0.12	1.82	0.32	0.17	-50.4	-23.8	43.1
36	3.48	0.35	0.12	2.78	0.28	0.22	-20.1	-20.0	85.9
37	3.56	0.44	0.16	1.49	0.16	0.06	-58.1	-63.1	-61.2
38	4.98	0.42	0.13	1.75	0.18	0.05	-64.9	-56.1	-62.4
39	3.98	0.72	0.22	2.66	0.36	0.30	-33.2	-50.0	36.4
40	3.78	0.48	0.23	1.81	0.25	0.19	-52.1	-47.4	-15.6
41	4.52	0.60	0.30	1.45	0.28	0.20	-67.9	-52.8	-33.3
42	3.60	0.44	0.13	2.14	0.33	0.10	-40.6	-25.2	-22.5
AVERAGE PER LINK	3.2	0.3	0.1	1.7	0.2	0.1	-46.4	-27.6	-14.2

Notes

1. See Figure 4.3 for an explanation of "Node Reference"
2. Average per link is the Total divided by 244 links.
3. The Existing system has 1022 vehicles and the improved System has 1061 vehicles (maximum at one time).
4. All emissions are presented as the average per directional links.

FIGURE 5.1 TRAF-NETSIM OUTPUT
CARBON MONOXIDE

FIGURE 5.2 TRAF-NETSIM OUTPUT
NITROGEN OXIDE

FIGURE 5.3 TRAF-NETSIM OUTPUT
HYDRO CARBON

23, 35 and 39, but we have to understand that these intersections were not severely affected and improvement will most definitely occur at these nodes once the entire system has been optimized. So we have to realize that the improvement under a new system doesn't mean that every intersection or approach has to improve. Rather, it is the redistribution of traffic flow what makes the system optimal. What we should look for is an overall improvement without allowing any extreme emissions or delays to occur at a particular intersection. This is most probable to happen due to the software limitations, but could always be corrected by an experienced controller.

The overall improvement in carbon monoxide for this system was 46.4% of initial emissions or 1.4 kg/mile.hr per link (0.87 kg/km.hr per link), nitrogen oxides decreased by 27.6% or 0.085 kg/mile.hr per link (0.05 kg/km.hr per link), and hydrocarbons decreased by 14.2% or 0.015 kg/mile.hr per link (0.01 kg/km.hr per link). It is noteworthy to mention that the method of calculation for these emissions differ, because at different stages of the internal combustion engine's operation, the relative proportion of various emissions produced differs.

The system demonstrated higher moving speeds and a lower number of stops and lower delay time. This means that traffic flow has improved in the form of a generally uniform speed and less stop-and-go operation.

Note that emissions are based on card type 60 input, which assumes that passenger vehicles consume 6.48 gal/hr or 0.0018gal/sec (0.007lit/sec) of gas when traveling at a normal speed of 31.68 mph or 48.4 ft/sec (14.2m/sec) and at an acceleration rate of 9 ft/sec/sec (2.7 m/sec/sec). Trucks consume 19.44 gal/hr or 0.0054gal/sec (0.02 lit/sec) when traveling at a normal speed of 25.2 mph or 37ft/sec (11.3 m/sec) and the same

acceleration rate. Finally, buses consume 16.2 gal/hr or 0.0045 gal/sec (0.017 lit/sec) when traveling at a normal speed of 20.2 mph or 29.5 ft/sec (9m/sec) and the same rate of acceleration. These numbers do vary under normal operations because different cars use different amounts of fuel and there is no way of knowing the exact fuel usage. However, it should not be an issue since we are looking at percent change here and not studying the absolute amounts of emissions.

Computer simulations, in spite of all the advancements made, are still limited to representing perfect system operation. Traffic disruptions, accidents and the fluctuations in travel speed due to different driving behaviors and different age groups are not very well accounted for in these simulations. Also, the importance of pedestrian presence and its effect on traffic movement is not always taken into account. Transyt 7F, for example, doesn't take into account any pedestrian presence, while Traf-Netsim allows for some fluctuations in traffic movement due to pedestrian volumes (no pedestrians, low pedestrian traffic= 100-250 peds/hr, moderate= 250-500 peds/hr, heavy > 500 peds/hr). We expect this would lead to having less delay time reported by Transyt 7F as compared to that reported by Traf-Netsim, especially in the down town area where pedestrian traffic is at its peak during the afternoon hours.

Total delay reported by Traf-Netsim was 35.9% lower than the old system (refer to Table 5.3 and figure 5.4 for Traf-Netsim's output). Transyt 7F reports delay-time in sec/veh for the entire network simulated, whereas Traf-Netsim's delay is reported per link. Taking that into consideration we find that the average delay decreased from 19.2 sec/veh per link in the existing network to a 12.3 sec/veh per link in the improved one, a 35.9% decrease in delay. Compared to Transyt's 52.5% decrease, we conclude that Traf-Netsim's results are higher due to previously mentioned differences.

Table 5.3

TRAF-NETSIM RESULTS
DELAY TIME

	EXISTING SYSTEM	IMPROVED SYSTEM	
	90 SEC. CYCLE	60 SEC. CYCLE	CHANGE
REFERENCE NODE NO.	DELAY (sec/veh.)	DELAY (sec/veh.)	%
1	11.6	10.6	-8.7
2	4.9	4.4	-10.2
3	3.3	4.8	45.7
4	6.2	3.9	-37.4
5	12.6	7.5	-40.0
6	8.3	9.9	20.0
7	10.5	11.7	11.7
8	19.2	11.1	-42.1
9	8.7	8.6	-1.5
10	22.8	25.8	13.2
11	47.6	46.3	-2.8
12	10.2	7.0	-30.9
13	7.9	6.7	-14.8
14	9.4	9.0	-4.4
15	51.3	53.4	4.1
16	7.6	10.2	33.5
17	6.7	5.2	-22.4
18	13.7	6.9	-49.2
19	172.5	115.5	-33.0
20	69.7	34.6	-50.4
21	8.1	4.6	-43.4
22	71.8	43.8	-39.0
23	229.1	24.8	-89.2
24	156.7	131.6	-16.0
25	40.9	69.4	69.8
26	43.0	12.8	-70.4
27	7.5	5.1	-32.8
28	12.0	8.6	-28.3
29	20.3	16.3	-19.6
30	9.7	11.3	15.7

Table 5.3 (CONT.)

TRAF-NETSIM RESULTS
DELAY TIME

	EXISTING SYSTEM 90 SEC. CYCLE	IMPROVED SYSTEM 60 SEC. CYCLE	CHANGE
NODE NO.	DELAY (sec/veh.)	DELAY (sec/veh.)	%
31	6.7	5.3	-21.6
32	7.6	4.5	-41.0
33	5.7	6.2	9.9
34	5.4	6.2	14.0
35	7.1	4.4	-37.4
36	5.2	8.1	55.4
37	18.9	7.6	-59.5
38	5.6	3.8	-32.3
39	3.8	4.9	28.7
40	19.3	5.0	-73.9
41	12.0	8.7	-27.5
42	8.1	5.6	-31.0
Network Average	19.2	12.3	-35.9

Notes

1. The Existing system has 1022 vehicles and the improved System has 1061 vehicles (maximum at one time).
2. See Figure 4.4 for an explanation of "Node Reference"
3. Delay time for a Node Reference is presented as the weighed average of all approaches to a node.
4. Network Average is the total delay (sec.) divided by total number of vehicles.

FIGURE 5.4 TRAF-NETSIM OUTPUT
DELAY TIME

When reviewing the improvements between existing signal timings and improved signal timings, there are several important points that need to be addressed. The first is that the system has been improved and not optimized as discussed before. The second issue is the character of the improved system, as the system will increase in size to include the 145 signals. The studied system has many high volume approaches where the upstream signal is not part of the coordinated system. Therefore, coordination of the system will not improve tremendously the traffic parameters for these approaches. This is demonstrated at some of the network's high volume approaches. The CO emissions at these intersections are mildly affected by the system signal coordination. Any predicted changes in CO emissions and other measures of effectiveness are due only to changes in green time, cycle length and random vehicle arrivals. This causes both positive and negative changes on these approaches, although the intersection and/or the system as a whole shows reductions in both emissions and delay. By expanding the system to include upstream signals, these approaches and overall intersection performance would be improved.

Again, when comparing system measures of effectiveness, the treatment of some of the low volume approaches needs to be reviewed. In an attempt to show the possible overall intersection improvement, measures of effectiveness were allowed to degrade on some low volume approaches. This is normal and accepted procedure when trying to improve an arterial network. Low volume approaches are typically defined as those approaches where the volumes do not exceed five to ten percent of the total intersection volume. Degradation to low volume approaches could be avoided, but it would cause an overall decrease in the intersection and system measures of effectiveness. The individual approach numbers were not tabulated for the purpose of this study. However, they could be easily obtained from the output files of Traf-Netsim in appendix A.

Traf-Netsim gives delay in sec./vehicle/approach, so it would be difficult to compare the before and after, intersection by intersection. However, delay results give us an idea of intersections with unusually high delays under the improved plan. Thus allowing the controller to make adjustments to the upcoming plans is an attempt to correct the problem. Delay is displayed as a total. Approach by approach delays could be obtained from Traf-Netsim output files in Appendix A.

It is noteworthy to mention that the delay improvement given by Transyt 7F is slightly high. However the implemented system can , under perfect operation conditions, produce even better results. The reason is that the Mist system as described in Appendix C, can change plans every few seconds, thus countering any sudden fluctuations in traffic volumes, travel speed and pedestrian volumes. Although the change will be gradual, their effect will still be noticeable. The traffic models used assume a constant traffic volume for the peak hour and develop a plan for that particular volume, whereas traffic shifts are in fact unpredictable and can cause minor changes in predicted volumes, which could cause unnecessary delays.

Finally, studying the results from the adaptive control simulation, Tables 5.4, 5.5, 5.6 and 5.7, we notice a trend of improvements that is similar to all four simulated periods. For example, average delay improved by approximately 30% in the 90 second cycle improved system versus an approximate improvement of 50% in the optimized system (cycle varies). Bar charts of some of these MOEs were produced to compare these results to each other and to the peak hour results. See Figures 5.5, 5.6, 5.7, 5.8 and 5.9, which clearly show what kind of improvements are to be expected from implementing an adaptive control system.

TABLE 5.4

TRANSYT 7F RESULTS **SIMULATING ADAPTIVE CONTROL** **FIRST** **PERIOD**

Cycle Length

PERFORMANCE MEASURES	UNITS	90seconds	90 seconds	% CHANGE	61 seconds	% CHANGE
		EXISTING SYSTEM	IMPROVED SYSTEM		OPTIMIZED SYSTEM	
TOTAL TRAVEL	veh-mi/hr	2516	2516	0	2515	-0.0
TOTAL TRAVEL TIME	veh-hr/hr	299	252	-15.7	214	-28.4
TOTAL UNIFORM DELAY	veh-hr/hr	153	108	-29.4	70	-54.2
TOTAL DELAY	veh-hr/hr	158	110	-30.4	73	-53.8
AVERAGE DELAY	sec/veh	10.3	7.2	-30.1	4.7	-54.4
PASSENGER DELAY	pax-hr/hr	190	133	-30.0	87	-54.2
STOPS: TOTAL	veh/hr	22738	16442	-27.7	15480	-31.9
PERCENTAGE		41	30	-26.8	28	-31.7
SYSTEM SPEED	mph	8.4	10	19.0	11.8	40.5
FUEL CONSUMPTION	gal/hr	396	321	-18.9	281	-29.0
OPERATING COST	\$/hr	2279	1842	-19.2	1687	-26.0
PERFORMANCE INDEX	DI	626.6	440.7	-29.7	331.3	-47.1

NOTES:

%CHANGE is compared to the existing 90 sec. cycle.

DI= DISUTILITY INDEX

TABLE 5.5

TRANSYT 7F RESULTS
SIMULATING ADAPTIVE CONTROL
SECOND
PERIOD

		Cycle Length				
		90seconds	90 seconds		63 seconds	
PERFORMANCE MEASURES	UNITS	EXISTING SYSTEM	IMPROVED SYSTEM	% CHANGE	OPTIMIZED SYSTEM	% CHANGE
TOTAL TRAVEL	veh-mi/hr	2332	2332	0.0	2332	0
TOTAL TRAVEL TIME	veh-hr/hr	268	230	-14.2	200	-25.4
TOTAL UNIFORM DELAY	veh-hr/hr	137	99	-27.7	69	-49.6
TOTAL DELAY	veh-hr/hr	138	100	-27.5	70	-49.3
AVERAGE DELAY	sec/veh	9.6	7	-27.1	4.9	-49.0
PASSENGER DELAY	pax-hr/hr	165	120	-27.3	84	-49.1
STOPS: TOTAL	veh/hr	19651	14792	-24.7	13964	-28.9
PERCENTAGE		38	29	-23.7	27	-28.9
SYSTEM SPEED	mph	8.7	10.2	17.2	11.7	34.5
FUEL CONSUMPTION	gal/hr	352	292	-17.0	260	-26.1
OPERATING COST	\$/hr	2016	1667	-17.3	1540	-23.6
PERFORMANCE INDEX	DI	543.4	395	-27.3	308.2	-43.3

NOTES:

% Change is compared to the existing 90 sec. cycle
 DI= DISUTILITY INDEX

TABLE 5.6

TRANSYT 7F RESULTS
SIMULATING ADAPTIVE CONTROL
THIRD
PERIOD

Cycle Length

		90seconds	90 seconds		61 seconds	
PERFORMANCE MEASURES	UNITS	EXISTING SYSTEM	IMPROVED SYSTEM	% CHANGE	OPTIMIZED SYSTEM	% CHANGE
TOTAL TRAVEL	veh-mi/hr	2628	2628	0.0	2628	0
TOTAL TRAVEL TIME	veh-hr/hr	316	270	-14.6	225	-28.8
TOTAL UNIFORM DELAY	veh-hr/hr	161	116	-28.0	71	-55.9
TOTAL DELAY	veh-hr/hr	164	118	-28.0	73	-55.5
AVERAGE DELAY	sec/veh	10.1	7.3	-27.7	4.5	-55.4
PASSENGER DELAY	pax-hr/hr	197	142	-27.9	88	-55.3
STOPS: TOTAL	veh/hr	23112	16977	-26.5	15086	-34.7
PERCENTAGE		40	29	-27.5	26	-35.0
SYSTEM SPEED	mph	8.3	9.7	16.9	11.7	41.0
FUEL CONSUMPTION	gal/hr	413	341	-17.4	288	-30.3
OPERATING COST	\$/hr	2344	1906	-18.7	1694	-27.7
PERFORMANCE INDEX	DI	641.9	459.3	-28.4	324.7	-49.4

NOTES:

% Change is compared to the existing 90 sec. cycle

DI= DISUTILITY INDEX

TABLE 5.7

TRANSYT 7F RESULTS
SIMULATING ADAPTIVE CONTROL
FOURTH
PERIOD

Cycle Length

PERFORMANCE MEASURES	UNITS	90seconds	90 seconds	% CHANGE	63 seconds	% CHANGE
		EXISTING SYSTEM	IMPROVED SYSTEM		OPTIMIZED SYSTEM	
TOTAL TRAVEL	veh-mi/hr	2151	2151	0.0	2151	0
TOTAL TRAVEL TIME	veh-hr/hr	251	208	-17.1	183	-27.1
TOTAL UNIFORM DELAY	veh-hr/hr	129	87	-32.6	61	-52.7
TOTAL DELAY	veh-hr/hr	130	88	-32.3	63	-51.5
AVERAGE DELAY	sec/veh	9.9	6.7	-32.3	4.8	-51.5
PASSENGER DELAY	pax-hr/hr	156	106	-32.1	76	-51.3
STOPS: TOTAL	veh/hr	17850	13071	-26.8	12484	-30.1
PERCENTAGE		38	28	-26.3	26	-31.6
SYSTEM SPEED	mph	8.6	10.3	19.8	11.7	36.0
FUEL CONSUMPTION	gal/hr	328	263	-19.8	240	-26.8
OPERATING COST	\$/hr	1861	1518	-18.4	1402	-24.7
PERFORMANCE INDEX	DI	507.6	352.4	-30.6	276.1	-45.6

NOTES:

% Change is compared to the existing 90 sec. cycle

DI= DISUTILITY INDEX

From the socio-economic point of view, any significant improvement to delay time and/or emission levels means a healthier environment for economic growth of the downtown area. This would mean attracting new traffic to the area and thus creating a new problem caused by increased traffic volumes. However, if the system can accommodate more traffic volumes at the existing levels of service, from the economic standpoint the system does what it is intended for.

From a social perspective, the disturbance caused to the downtown inhabitants would be unacceptable. Increased volumes of traffic bring with it more noise, more accidents and lower levels of safety. But, some would argue that economic growth does come at a price, and residents would be the most likely interest group to benefit from this growth. The implemented systems, whether it is the MIST system or some other system being used today, do take into consideration these factors and it is within their capabilities to redirect traffic and most of its problems from residential and heavy pedestrian volume areas. This is achieved by reducing the level of service at such intersections. Also, closed circuit cameras placed at strategic locations, would help reduce traffic related problems.

FIGURE 5.5 TRANSYT 7F
TOTAL TRAVEL TIME

FIGURE 5.6 TRANSYT 7F OUTPUT

TOTAL DELAY

FIGURE 5.7 TRANSYT 7F
AVERAGE DELAY

FIGURE 5.8 TRANSYT 7F OUTPUT

PASSENGER DELAY

FIGURE 5.9 TRANSYT 7F OUTPUT
SYSTEM SPEED

CHAPTER VI

CONCLUSIONS

6.1 GENERAL CONCLUSIONS

The overall objective of this thesis research was to assess the potential of advanced technologies for relieving urban congestion. This section details the overall conclusions from the research undertaken.

1. Advanced transportation technologies, such as the one discussed in this thesis, show excellent potential for making significant impacts on urban congestion levels, hence improving delay time and emissions levels. Signal control systems have greater potential than others for addressing congestion problems in the near term, with the option of being upgradable for long term effectiveness.
2. This technology offers other potential benefits, as well as increasing transportation system efficiency through congestion reduction. These include improvements in safety and improved driver comfort and convenience. These benefit areas should be considered alongside system and environmental efficiency improvements.
3. Traffic central control and user information systems offer good short term payoffs, with potential for significant impacts on congestion levels and traffic patterns. For example, variable message signs could benefit system users, and closed caption cameras could help reduce delay time at critical locations in the system. They could also benefit nonusers,

particularly when nonreoccurrent congestion arises because of traffic incidents. Here, these signs could help divert traffic away from the affected area.

4. Adaptive traffic control based on real time optimization could make a major contribution to relieving urban congestion through more efficient use of the existing highway system in urban areas. Real time systems have been tested and evaluated in other countries such as England, France, Finland and Malaysia. Results from these countries show that real time systems can provide very significant benefits in comparison to their implementation costs. Adaptive traffic control systems provide additional benefits over fixed time systems by responding to flow variations within the signal plan period, as well as to daily and seasonal fluctuations. Traffic control systems also adjust automatically to long term changes in traffic conditions, avoiding the “aging” disbenefits of a fixed time signal plan, which has to be updated regularly. This is very obvious in the case of this study, where in the four periods studied we notice that improvements were maintained at a consistent level in spite of the variations in traffic volumes and conditions.

The analysis indicates that the significant benefits seen in other countries with adaptive systems can also be achieved in Canadian and US transportation networks. Specific benefits of these traffic control systems will be greatest where the links are short, flows are high and significant flow variations occur within a signal plan period. Of these factors traffic flow volumes tend to be dominant in determining overall benefit levels. As urban flow levels increase in the future, benefits of such systems will become even more significant.

5. There are important issues to be resolved in implementing advanced transportation technologies. These include financing sources for the system, jurisdictional issues, the role

of public and private sectors and user issues. Alternative solutions are available for each one of these issues, and the most appropriate solution depends on the particular technology under consideration. The system described in this thesis does not require a major physical presence. Hence, its availability could go unnoticed by users and thus reduce any negative reaction due to its implementation.

6. More advanced systems such as ITS have attractive features from an implementation issues perspective. However, there are still important areas to be resolved before these systems are widely implemented on North American streets. These issues include technological development and adaptation, integration into existing infrastructure, jurisdictional and funding arrangements, public/private sector roles, and user acceptance. Therefore, the proposed traffic signal interconnect system provides the perfect 'stepping stone' until such issues are worked out.

It is easy to say that implementing an advanced control system is feasible for the above mentioned reasons and calculations; however, the author would like to stop here and take a closer look at what this system has achieved and hopes to achieve in the future. First, we know that our total delay time has been reduced, thus fulfilling the economical aspect of the study. Second, the emissions levels has been reduced tremendously and hence the environmental and social aspect has been also fulfilled. Third, we proved the system's effectiveness in adapting to changing traffic conditions and volumes, and its ability to maintain a consistent level of service under these variable conditions. What the system also promises to deliver is of importance to us. It will allow for a quick response to various emergency situations such as traffic accidents. It also promises to give priority to various emergency vehicles. Another feature of the system is that it is capable to redirect traffic away from heavily populated areas to keep safety and noise in these areas

at acceptable levels. All of these features make for a very attractive package, especially that this system allows for easy future upgrade to more intelligent systems.

The Traf-Netsim and Transyt 7F computer models confirm the potential improvements that could be attained in CO and other emissions along with improvements in other measures of effectiveness, including delays and average speeds. These findings concurred with and at times exceeded, the expected CO reductions in the Transportation Improvement Plan (TIP) for New York state [Syracuse Metropolitan., 1994]. These forty-two intersections were modeled using both Traf-Netsim and Transyt 7F computer models for the PM peak hour using existing signal timings, offsets and volumes. A signal coordination scheme was developed for the existing signal system showing improved operation by adjusting signal timings. The coordinated system demonstrated overall improvements in system-wide measures of effectiveness, with a reduction of 46.4% in CO. As a subsystem of the entire network, this emission value is a conservative estimate of the potential reductions in CO emissions. As adjacent intersections are included in the coordinated system, increased efficiency in the signal coordination will allow for further reduction in emissions along with improvements in other measures of effectiveness.

6.2 SPECIFIC CONCLUSIONS

This thesis research demonstrated air quality improvements associated with the coordination of the forty-two analyzed intersections. The Traf-Netsim and Transyt 7F computer models were used to model the existing and improved signal systems. The overall system wide improvement in CO emissions was found to be 46.4 percent. All forty two intersections and their approaches demonstrated reductions in CO emissions, except as noted. The intersections, their approaches, and the entire system also demonstrated positive improvements in other measures of effectiveness. For example, average speed

increased by 37.6 percent (Transyt 7F), and system average delay decreased by 35.9 percent (Traf-Netsim).

According to the New York State Implementation Plan (NYSIP) [NY Department of Environment., 1992] it is expected that travel time improvements should be between 8-17.5 percent as a result of implementing a traffic signal control system. From coordinating these forty two signals we notice that this expectation has been exceeded with an overall travel time reduction of 27 percent. This agrees well with the expected reduction, and by increasing the number of signals within the project area, further improvements in all measures of effectiveness will result. Based on the results of this subset of forty two intersections, it is reasonable to expect that the coordination of some 145 intersections will further decrease CO and other emissions as required by the state agency.

It is further understood that Traffic Signal Control would produce a reduction in CO emissions for a limited period of time, but that the permanent solution to air quality problem lies in eliminating vehicular emissions altogether (e.g. the rough advanced catalytic convertor and fuel cell engines). However, having an adaptive control system in place will likely ensure the least delay time and travel time for whatever traffic volumes pass through the controlled area.

It is safe to deduce that emissions will no longer be the deciding factor in determining the feasibility of ITS technologies. It is likely that such technologies will be judged on how efficiently they use all of the street network's available capacity, as well as keeping traffic flow as smooth as possible. In conclusion, it may be stated that, despite of the fact that the CO and other emissions connected to traffic growth could be short lived, adaptive control systems could still be very effective due to their potential to minimize

traffic congestion, noise, delay time and fuel consumption, even after their environmental benefits have been depleted.

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APPENDIX A

TRAF-NETSIM FILES

TRAF-NETSIM

FINAL SIMULATION

INPUT FILE

SYRACUSE TRAFFIC SIGNALS INTERCONNECT PROJECT

ABDULKADER ALKADRY

04 10 97 CARLETON UNIVERSITY

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0 1 11 11 0 1 31615 01234894114589137

900

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1 ONETSIM

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39	181	214	2	01	40		30	111	11
181	40	214	2	01	182	183	187	183	26
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41	185	244	2	01	8185		30	111	11
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155	28	232	2	01	163	153	153	26	21	30	111
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27	153	262	2	01	28				30	111	11
153	28	262	2	01	155	163	155	26	21	30	211
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155	29	232	2	01	156	157	165	157	26	21	30
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157	30	255	2	01	158	159	159	26	21	30	111
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142	23	330	2	01	143	144	144	26	21	30	111
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181	40	39	35
183	40	41	35
178	8178		35

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102	11									36
103	11									36
104	11									36
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190	11									36
125	1									36
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112	1									36
117	1									36
111	11									36
118	1									36
116	1									36
139	1									36
122	11									36
100	1									36
123	1									36
124	1									36
135	1									36
115	11									36
126	11									36
119	11									36
127	11									36
138	11									36
131	1									36
22	11									36
136	11									36
137	11									36
143	1									36
144	11									36
154	1									36
147	11									36
146	11									36
149	1									36
148	11									36
152	1									36
153	11									36
163	1									36
156	11									36
159	11									36
157	1									36
161	1									36
162	11									36
172	1									36
165	11									36
164	1									36
167	1									36
166	1									36
170	1									36
171	11									36
180	1									36
174	11									36

[illegible]

128121	121	7	117	8	9	10	118	11	22	20	147	25	156	29	165	33	174	187	
12	37	182	40	1878187														187	
138187	187	40	182	37	174	33	165	29	156	25	147	20	22	11	115	5	105	187	
13	4	104	3	103	2	102	1	1078107										187	
148120	120	12	119	11	126	15	135	19	145	24	154	28	163	32	172	36	180	187	
14	39	1798179																187	
158187	187	40	182	37	174	33	165	29	156	25	147	20	22	11	119	12	120	187	
158120																		187	
168186	186	41	184	38	176	34	167	30	158	26	148	25	147	20	22	11	115	187	
16	5	1098109																187	
178177	177	38	175	37	174	33	165	29	156	25	147	20	22	11	115	5	109	187	
178109																		187	
188187	187	40	182	37	174	33	165	29	156	25	147	20	22	11	115	5	105	187	
18	4	104	3	103	2	102	1	1078107										187	
198121	121	7	117	8	9	10	118	11	22	20	147	25	156	29	165	33	174	187	
19	37	182	40	1878187														187	
208142	142	23	144	24	146	25	148	26	1508150									187	
218150	150	26	148	25	146	24	144	23	1428142									187	
228187	187	40	182	37	174	33	165	29	156	25	147	20	22	11	115	5	105	187	
22	4	104	3	103	2	102	1	111	7	117	8	9	10	118	11	22	20	147	187
22	25	156	29	165	33	174	37	182	40	1878187								187	
238107	107	1	102	2	103	3	104	4	105	5	115	11	22	20	147	25	156	187	
23	29	165	33	174	37	182	40	1878187										187	
248107	107	1	102	2	103	3	104	4	114	10	125	15	135	19	145	24	146	187	
24	25	148	26	1508150														187	
258109	109	5	115	11	22	20	147	25	156	29	155	28	153	27	1518151			187	
268107	107	1	111	7	122	13	127	16	138	42	139	17	133	18	134	19	145	187	
26	24	144	23	1428142														187	
1	242533	9																188	
2	1032																	188	
3	33	9																188	
4	282136273732																	188	
5	2533	9262322																188	
6	17181935																	188	
7	3416	1	83029															188	
8	3029																	188	
9	113112	4	3															188	
10	5	4	3															188	
11	2	1																188	
12	113112	4	3															188	
13	2	1	83029															188	
14	181920																	188	
15	2	1																188	
16	242533	1	8															188	
17	2	1	8															188	
18	2	1	83029															188	
19	113112	4	3															188	
20	1032																	188	
21	33	9																188	
22	2	1	8302928113112	4	3													188	
23	1413	5	4	3														188	
24	14171832																	188	
25	5	41535																188	
26	2821362737	9																188	
1	300	2	60	3	60	4	360	5	300	6	360	7	300	8	120	9	300	189	
10	360	11	420	12	300	13	480	14	360	15	300	16	240	17	420	18	240	189	
19	60	20	120	21	300	22	420	23	180	24	240	25	180	26	360			189	
1		0																210

TRAF-NETSIM

INITIAL SIMULATION

EMISSIONS TABLE

CUMULATIVE VALUES OF FUEL CONSUMPTION AND OF EMISSIONS

LINK	FUEL CONSUMPTION						VEHICLE EMISSION RATES (KG/MILE.HOUR)		
	GALLONS			M.P.G.			HC	CO	NO X
	A	T	B	A	T	B			
(185, 41)	2.5	0.2	0.1	0.1	0.0	0.3	0.502	5.132	0.515
(41, 183)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(183, 40)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(40, 181)	0.1	0.0	0.0	4.1	1.8	0.0	0.029	1.778	0.105
(181, 39)	0.0	0.0	0.0	11.5	4.4	0.0	0.011	0.467	0.019
(39, 179)	1.8	0.2	0.0	6.8	2.6	0.0	0.308	4.671	1.102
(179, 39)	1.1	0.3	0.0	8.0	3.7	0.0	0.165	3.220	0.469
(39, 181)	1.0	0.2	0.0	4.0	1.8	0.0	0.332	3.645	0.918
(181, 40)	1.7	0.1	0.0	2.4	4.0	0.0	0.397	1.529	0.645
(40, 183)	1.9	0.2	0.0	2.3	1.4	0.0	0.454	4.465	1.042
(183, 41)	1.9	0.1	0.0	2.6	4.2	0.0	0.398	6.791	0.717
(41, 185)	0.5	0.1	0.0	6.9	3.3	0.0	0.178	5.920	0.677
(177, 38)	0.8	0.2	0.1	6.3	3.6	4.6	0.145	7.625	0.418
(38, 175)	0.3	0.1	0.0	7.6	4.2	5.6	0.091	5.068	0.334
(37, 173)	0.2	0.1	0.0	8.5	2.7	0.0	0.064	3.557	0.243
(175, 37)	0.6	0.1	0.0	3.6	2.3	1.5	0.140	2.720	0.251
(173, 36)	0.1	0.0	0.0	13.2	4.5	0.0	0.035	1.629	0.116
(36, 171)	0.1	0.0	0.0	16.5	5.2	0.0	0.038	1.686	0.110
(171, 35)	0.1	0.0	0.0	20.1	6.1	0.0	0.022	0.490	0.053
(35, 169)	0.4	0.1	0.0	9.9	4.4	0.0	0.098	5.698	0.346
(169, 35)	1.0	0.3	0.0	8.0	3.8	0.0	0.248	4.246	0.777
(35, 171)	0.6	0.3	0.0	9.7	3.1	0.0	0.185	3.499	0.679
(171, 36)	0.5	0.2	0.0	12.6	5.1	0.0	0.106	2.194	0.231
(36, 173)	0.7	0.2	0.0	7.2	4.4	0.0	0.215	2.828	0.635
(173, 37)	1.2	0.2	0.0	3.8	2.7	0.0	0.281	4.545	0.494
(37, 175)	0.5	0.1	0.0	8.5	4.1	0.0	0.161	1.947	0.590
(175, 38)	0.4	0.1	0.0	13.1	5.8	0.0	0.076	1.464	0.150
(38, 177)	0.6	0.2	0.0	12.5	4.3	0.0	0.095	4.583	0.319
(168, 34)	0.2	0.0	0.0	6.2	2.9	0.0	0.031	1.340	0.073
(34, 166)	0.0	0.0	0.0	9.8	2.2	0.0	0.016	0.939	0.053
(166, 33)	0.1	0.0	0.0	7.0	4.3	0.0	0.016	0.220	0.025
(33, 164)	0.1	0.0	0.0	4.6	2.8	0.0	0.056	3.452	0.209
(164, 32)	0.1	0.0	0.0	9.6	3.8	0.0	0.018	0.210	0.026
(32, 162)	0.1	0.0	0.0	7.0	3.4	0.0	0.029	1.766	0.104
(162, 31)	0.0	0.0	0.0	16.2	6.1	0.0	0.010	0.136	0.011
(31, 160)	0.1	0.0	0.0	6.5	4.5	0.0	0.031	1.827	0.115
(160, 31)	0.1	0.1	0.0	7.9	4.5	0.0	0.026	1.352	0.071
(31, 162)	0.1	0.0	0.0	6.8	5.8	0.0	0.031	1.767	0.116
(162, 32)	0.0	0.0	0.0	18.1	5.5	0.0	0.008	0.255	0.029
(34, 168)	0.0	0.0	0.0	7.1	0.0	0.0	0.006	0.342	0.021
(159, 30)	1.2	0.2	0.0	1.4	1.2	0.0	0.153	3.836	0.262
(30, 157)	0.0	0.0	0.0	14.3	3.3	0.0	0.005	0.232	0.016
(157, 29)	0.1	0.0	0.0	3.9	2.5	0.0	0.018	0.846	0.052
(29, 155)	0.2	0.0	0.0	4.0	1.9	1.6	0.073	4.674	0.270
(155, 28)	0.1	0.0	0.0	13.4	4.1	4.6	0.019	0.740	0.043
(28, 153)	0.1	0.0	0.1	7.8	3.4	1.7	0.027	1.585	0.097
(153, 27)	0.0	0.0	0.0	15.0	4.3	5.1	0.010	0.372	0.029
(27, 151)	0.1	0.0	0.1	11.5	3.6	2.0	0.019	1.055	0.061
(151, 27)	0.4	0.1	0.1	8.6	3.2	3.7	0.092	5.184	0.281
(27, 153)	0.3	0.1	0.0	8.7	4.0	3.7	0.091	5.180	0.319
(153, 28)	0.2	0.0	0.0	13.9	6.7	8.0	0.038	0.830	0.086

(28, 155)	0.2	0.0	0.1	9.5	6.8	1.8	0.081	4.496	0.290
(155, 29)	0.3	0.0	0.0	8.3	11.9	3.6	0.067	1.152	0.115
(29, 157)	0.2	0.0	0.0	7.7	4.0	0.0	0.058	3.151	0.195
(157, 30)	1.1	0.1	0.0	1.0	0.4	0.0	0.218	2.271	0.225
(30, 159)	0.1	0.0	0.0	8.4	0.0	0.0	0.024	1.454	0.084
(150, 26)	3.3	0.6	0.3	0.3	0.3	0.2	0.330	4.195	0.375
(26, 148)	0.4	0.0	0.3	0.0	0.0	0.0	0.072	0.725	0.072
(148, 25)	0.9	0.0	0.2	0.0	0.0	0.0	0.193	1.933	0.193
(25, 146)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(146, 24)	0.4	0.0	0.0	1.0	0.0	0.0	0.093	1.012	0.110
(24, 144)	0.3	0.0	0.4	1.2	0.3	2.1	0.049	0.648	0.067
(144, 23)	0.0	0.0	0.0	18.4	0.0	3.0	0.001	0.013	0.003
(23, 142)	0.1	0.0	0.0	6.8	2.6	2.6	0.014	0.777	0.051
(142, 23)	2.1	0.3	0.6	1.3	1.1	0.4	0.314	3.888	0.448
(23, 144)	0.5	0.2	0.4	2.8	1.5	1.6	0.118	4.211	0.288
(144, 24)	0.1	0.0	0.0	9.0	4.8	3.9	0.027	0.513	0.060
(24, 146)	0.1	0.0	0.1	7.7	2.2	1.9	0.031	1.666	0.117
(146, 25)	0.1	0.0	0.1	10.1	12.1	3.2	0.019	0.563	0.047
(25, 148)	0.1	0.0	0.1	5.2	1.2	4.1	0.036	1.042	0.092
(148, 26)	0.5	0.0	0.1	1.7	1.1	2.3	0.108	1.608	0.194
(26, 150)	0.2	0.1	0.1	7.9	2.9	2.5	0.042	2.514	0.144
(137, 21)	0.0	0.0	0.0	14.6	3.4	0.0	0.010	0.232	0.023
(21, 137)	0.4	0.0	0.0	3.3	0.0	0.0	0.138	2.394	0.512
(137, 20)	1.5	0.0	0.0	1.7	0.0	0.0	0.316	5.774	0.541
(20, 136)	0.3	0.0	0.0	5.1	0.0	0.0	0.096	5.622	0.352
(136, 19)	0.9	0.0	0.0	1.6	0.0	0.0	0.198	3.159	0.305
(19, 134)	0.1	0.0	0.0	8.4	2.0	0.0	0.038	2.252	0.136
(134, 18)	0.1	0.0	0.0	12.8	3.3	0.0	0.018	0.320	0.037
(18, 133)	0.1	0.0	0.0	6.6	3.0	0.0	0.073	4.003	0.273
(133, 17)	0.1	0.0	0.0	8.6	5.5	0.0	0.053	2.658	0.165
(17, 130)	0.1	0.0	0.0	7.3	4.8	0.0	0.044	2.394	0.200
(130, 16)	0.1	0.0	0.0	7.3	3.9	0.0	0.036	1.149	0.084
(17, 133)	0.2	0.0	0.0	3.1	1.7	1.8	0.116	6.161	0.483
(133, 18)	0.2	0.0	0.1	4.6	2.7	3.7	0.089	3.842	0.211
(18, 134)	0.4	0.2	0.1	5.4	1.9	2.2	0.106	5.430	0.375
(134, 19)	1.4	0.3	0.3	1.4	1.2	1.2	0.253	4.174	0.393
(19, 136)	0.2	0.0	0.0	5.4	2.7	0.0	0.084	5.464	0.305
(136, 20)	0.6	0.1	0.0	2.2	1.4	0.0	0.123	1.866	0.196
(20, 137)	0.1	0.0	0.0	5.7	2.3	0.0	0.034	1.975	0.131
(12, 119)	0.3	0.1	0.0	6.6	2.0	2.8	0.092	5.349	0.340
(119, 11)	0.2	0.0	0.0	9.1	5.8	5.0	0.048	0.970	0.090
(11, 126)	0.1	0.0	0.0	8.2	2.3	6.9	0.036	2.094	0.123
(126, 15)	0.3	0.0	0.0	4.4	7.7	2.7	0.044	0.616	0.067
(15, 124)	0.2	0.1	0.0	9.7	4.0	0.0	0.031	1.716	0.105
(124, 14)	0.1	0.0	0.0	13.9	7.1	0.0	0.015	0.187	0.025
(14, 123)	0.1	0.0	0.0	4.8	2.6	0.0	0.049	2.862	0.196
(123, 13)	0.3	0.0	0.0	5.3	4.1	0.0	0.087	2.295	0.259
(140, 42)	0.4	0.1	0.0	6.6	6.1	0.0	0.101	5.357	0.315
(42, 139)	0.5	0.1	0.1	5.2	2.7	1.6	0.161	3.037	0.594
(139, 17)	0.3	0.0	0.1	11.4	6.4	3.7	0.057	1.145	0.118
(17, 131)	0.2	0.0	0.0	10.1	2.5	0.0	0.036	1.915	0.127
(131, 15)	0.6	0.0	0.0	3.8	2.8	0.0	0.060	0.679	0.074
(15, 126)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(126, 11)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(11, 119)	0.6	0.1	0.0	5.0	2.4	2.1	0.208	3.297	0.756
(12, 120)	0.4	0.1	0.0	5.6	2.6	2.0	0.146	1.046	0.538

(120, 12)	0.3	0.0	0.0	6.8	5.8	2.5	0.084	4.191	0.244
(118, 11)	1.5	0.1	1.5	1.6	1.6	0.3	0.316	4.588	0.556
(119, 12)	0.4	0.1	0.0	8.9	4.4	2.6	0.089	2.240	0.216
(121, 7)	1.4	0.2	0.5	10.1	5.5	4.1	0.192	2.262	0.569
(7, 117)	0.7	0.1	0.2	6.9	3.7	3.1	0.290	2.980	1.039
(117, 8)	0.6	0.1	0.4	9.3	4.0	2.0	0.183	6.940	0.594
(8, 9)	1.0	0.2	0.7	10.2	3.4	2.3	0.169	7.857	0.567
(9, 10)	1.7	0.2	0.6	5.3	3.7	2.1	0.224	4.786	0.454
(10, 118)	0.9	0.2	0.3	3.0	1.3	2.0	0.219	6.795	0.578
(106, 6)	0.8	0.2	0.0	6.5	4.9	0.0	0.243	3.896	0.773
(6, 190)	0.9	0.2	0.0	6.7	3.3	0.0	0.295	5.115	1.038
(190, 5)	1.0	0.2	0.0	5.9	3.3	0.0	0.203	3.281	0.348
(5, 105)	0.4	0.1	0.1	5.2	1.7	1.8	0.306	5.668	1.249
(105, 4)	0.3	0.2	0.1	7.9	2.4	1.7	0.190	7.129	0.568
(4, 104)	0.6	0.1	0.1	6.5	3.2	2.3	0.330	6.476	1.233
(104, 3)	0.4	0.1	0.1	11.6	4.6	3.6	0.169	8.119	0.454
(3, 103)	0.5	0.2	0.0	13.8	4.7	6.3	0.144	7.011	0.458
(103, 2)	0.4	0.1	0.1	15.8	5.8	4.7	0.109	3.703	0.285
(2, 102)	0.7	0.2	0.1	11.0	5.0	2.0	0.237	2.939	0.787
(1, 101)	4.2	0.4	0.0	10.6	4.9	0.0	0.625	4.259	2.147
(1, 107)	0.6	0.1	0.1	8.1	4.1	2.8	0.087	5.291	0.301
(102, 1)	2.4	0.2	0.1	5.5	5.3	4.8	0.722	2.539	2.461
(1, 102)	0.0	0.0	0.2	3.5	0.0	1.7	0.014	0.956	0.046
(102, 2)	0.0	0.0	0.1	9.8	0.0	7.0	0.006	0.234	0.010
(2, 103)	0.1	0.0	0.2	3.8	0.0	2.0	0.033	2.041	0.122
(103, 3)	0.0	0.0	0.2	10.9	0.0	3.3	0.008	0.196	0.028
(3, 104)	0.1	0.0	0.1	4.5	0.0	2.1	0.064	3.494	0.251
(104, 4)	0.1	0.0	0.1	6.0	0.0	4.3	0.055	2.914	0.172
(4, 105)	0.1	0.0	0.1	5.6	1.8	1.4	0.059	2.670	0.230
(105, 5)	0.2	0.0	0.0	3.5	3.2	2.4	0.081	2.149	0.138
(6, 106)	0.1	0.0	0.0	7.8	6.2	0.0	0.043	2.610	0.150
(190, 6)	0.1	0.0	0.0	14.7	3.6	0.0	0.013	0.238	0.024
(5, 190)	0.1	0.0	0.0	6.1	2.3	0.0	0.051	3.347	0.172
(107, 1)	0.6	0.1	0.3	7.3	4.3	4.2	0.086	4.230	0.259
(1, 111)	0.2	0.1	0.1	7.2	2.6	2.5	0.054	3.091	0.203
(111, 7)	0.3	0.1	0.2	5.0	2.7	1.8	0.057	1.091	0.135
(7, 122)	0.2	0.0	0.1	5.2	3.1	1.6	0.095	5.892	0.342
(122, 13)	0.2	0.0	0.1	6.1	2.8	3.7	0.062	1.712	0.150
(13, 127)	0.6	0.1	0.1	6.2	3.4	2.1	0.198	1.550	0.724
(127, 16)	0.5	0.0	0.1	9.6	4.6	7.6	0.109	3.840	0.304
(42, 140)	0.2	0.1	0.0	8.4	2.9	0.0	0.037	2.238	0.121
(16, 138)	0.6	0.0	0.1	5.7	2.9	1.9	0.287	7.444	1.047
(138, 42)	0.5	0.0	0.1	7.1	4.3	3.6	0.172	5.029	0.469
(42, 141)	0.3	0.0	0.0	5.5	1.6	0.0	0.253	4.640	0.965
(141, 42)	0.4	0.0	0.0	4.1	3.6	0.0	0.252	2.405	0.813
(42, 138)	0.4	0.1	0.0	5.0	3.7	0.0	0.204	2.524	0.738
(138, 16)	0.2	0.0	0.0	12.1	6.2	0.0	0.059	1.404	0.136
(16, 127)	0.5	0.0	0.0	6.4	5.6	0.0	0.150	8.533	0.567
(127, 13)	0.2	0.0	0.0	14.1	7.0	0.0	0.045	1.219	0.130
(13, 122)	0.3	0.0	0.0	11.7	9.1	0.0	0.090	4.391	0.301
(122, 7)	0.4	0.1	0.0	7.6	3.1	0.0	0.112	2.490	0.301
(7, 111)	0.6	0.1	0.0	6.4	3.0	0.0	0.174	1.643	0.625
(111, 1)	0.7	0.1	0.0	6.0	3.6	0.0	0.132	2.730	0.292
(17, 128)	0.1	0.0	0.0	4.4	1.9	0.0	0.030	1.838	0.107
(128, 14)	0.0	0.0	0.0	13.8	6.1	0.0	0.008	0.254	0.017
(14, 100)	0.1	0.0	0.0	4.1	2.0	0.0	0.052	3.173	0.197
(100, 8)	0.1	0.0	0.0	9.4	3.9	0.0	0.017	0.435	0.033
(8, 112)	0.2	0.0	0.0	5.1	2.8	0.0	0.057	3.712	0.202

(112, 2)	0.2	0.0	0.0	6.7	5.1	0.0	0.050	1.400	0.131
(3, 113)	0.0	0.0	0.0	5.7	0.0	0.0	0.008	0.547	0.023
(113, 9)	0.0	0.0	0.0	16.3	0.0	0.0	0.002	0.068	0.005
(9, 113)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(113, 3)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(178, 35)	0.4	0.1	0.0	5.2	5.1	0.0	0.108	4.932	0.331
(35, 170)	0.1	0.0	0.0	3.8	2.2	0.0	0.070	3.134	0.313
(170, 31)	0.1	0.0	0.0	4.6	3.2	0.0	0.069	3.132	0.199
(31, 161)	0.1	0.0	0.0	5.4	4.8	0.0	0.066	4.104	0.243
(161, 27)	0.1	0.0	0.0	12.4	5.6	0.0	0.023	0.632	0.041
(27, 152)	0.1	0.0	0.0	4.4	0.6	0.0	0.060	2.478	0.198
(152, 23)	1.2	0.1	0.0	0.6	0.5	0.0	0.386	4.542	0.499
(23, 143)	0.1	0.1	0.0	5.3	2.4	0.0	0.051	3.387	0.183
(143, 18)	0.1	0.0	0.0	12.5	5.4	0.0	0.015	0.242	0.029
(108, 4)	0.6	0.3	0.0	7.1	3.0	4.1	0.114	5.890	0.360
(4, 114)	0.2	0.2	0.1	7.8	2.2	1.8	0.051	2.819	0.189
(114, 10)	0.3	0.2	0.1	4.4	2.4	3.4	0.054	0.565	0.063
(10, 125)	0.8	0.2	0.1	1.9	1.3	1.8	0.258	7.991	0.622
(125, 15)	1.2	0.1	0.1	1.4	2.3	1.3	0.295	3.868	0.411
(15, 135)	1.7	0.4	0.1	0.9	0.4	0.7	0.332	5.691	0.547
(135, 19)	2.0	0.2	0.1	0.4	0.1	0.5	0.376	4.048	0.431
(19, 145)	1.1	0.1	0.2	0.7	0.3	0.9	0.206	2.722	0.306
(145, 24)	1.2	0.1	0.2	0.7	0.6	0.9	0.215	2.741	0.305
(24, 154)	0.1	0.0	0.0	5.1	2.3	1.7	0.072	3.697	0.302
(154, 28)	0.2	0.0	0.0	4.1	1.9	3.3	0.087	2.582	0.242
(28, 163)	0.2	0.0	0.0	4.2	1.9	0.0	0.121	6.805	0.474
(163, 32)	0.2	0.0	0.0	6.2	3.1	0.0	0.076	2.914	0.193
(32, 172)	0.1	0.0	0.0	5.0	5.1	0.0	0.152	6.767	0.638
(172, 36)	0.2	0.0	0.0	4.9	2.7	0.0	0.180	5.461	0.525
(36, 180)	0.1	0.0	0.0	5.7	2.5	0.0	0.127	7.065	0.456
(180, 39)	0.5	0.0	0.0	3.4	3.2	0.0	0.327	7.876	1.059
(187, 40)	1.0	0.1	0.2	1.6	2.4	1.2	0.318	6.673	0.646
(40, 182)	0.2	0.1	0.1	2.4	1.7	1.5	0.173	4.178	0.492
(182, 37)	0.3	0.1	0.1	2.0	1.4	1.2	0.217	4.917	0.628
(37, 174)	0.2	0.1	0.3	3.6	1.9	0.7	0.189	4.021	0.799
(174, 33)	0.2	0.1	0.1	5.6	2.5	1.7	0.124	5.706	0.428
(33, 165)	0.2	0.1	0.2	8.7	3.7	1.9	0.086	4.683	0.311
(165, 29)	0.5	0.2	0.1	3.4	1.6	2.2	0.164	2.724	0.338
(29, 156)	0.7	0.3	0.3	2.4	1.2	1.6	0.248	6.497	0.641
(156, 25)	1.3	0.1	0.3	1.2	1.7	1.0	0.355	5.872	0.618
(25, 147)	0.5	0.1	0.7	4.1	4.3	0.4	0.111	4.517	0.328
(147, 20)	0.3	0.1	0.2	7.8	3.3	2.5	0.052	1.249	0.145
(20, 22)	0.2	0.1	0.1	7.8	2.8	2.2	0.081	3.104	0.295
(22, 11)	0.9	0.2	0.1	3.4	2.4	3.4	0.178	3.382	0.439
(11, 115)	0.5	0.2	0.2	5.5	2.5	2.4	0.164	6.832	0.610
(115, 5)	0.3	0.1	0.1	10.7	3.9	3.1	0.064	1.630	0.138
(5, 109)	0.2	0.1	0.0	7.1	3.1	2.5	0.087	5.520	0.305
(109, 5)	0.7	0.1	0.1	3.8	3.1	4.1	0.214	8.476	0.618
(5, 115)	0.7	0.1	0.5	3.7	1.8	3.3	0.190	8.384	0.541
(115, 11)	1.4	0.1	0.3	1.8	1.2	1.5	0.267	4.229	0.468
(11, 22)	1.1	0.1	0.1	1.9	1.0	2.0	0.231	5.687	0.504
(22, 20)	0.8	0.1	0.1	1.7	0.8	1.8	0.207	2.960	0.381
(20, 147)	0.3	0.0	0.4	4.1	2.3	0.3	0.097	5.475	0.307
(147, 25)	0.1	0.0	0.1	15.5	3.2	2.9	0.019	0.454	0.045
(25, 156)	0.1	0.0	0.1	10.6	2.6	1.7	0.042	2.179	0.157

(156, 29)	0.1	0.0	0.0	8.5	4.4	5.5	0.042	0.810	0.100
(29, 165)	0.2	0.0	0.0	4.2	2.2	2.7	0.131	7.774	0.492
(165, 33)	0.1	0.0	0.0	9.9	3.5	6.4	0.051	2.625	0.176
(33, 174)	0.1	0.0	0.0	10.1	2.1	2.1	0.052	2.215	0.193
(174, 37)	0.2	0.0	0.0	4.8	4.6	1.2	0.092	2.154	0.190
(37, 182)	0.2	0.0	0.0	2.2	0.6	1.4	0.181	4.688	0.414
(182, 40)	0.5	0.0	0.0	0.9	2.5	2.8	0.359	6.559	0.596
(40, 187)	0.1	0.0	0.0	4.6	2.6	1.7	0.075	5.024	0.268
(186, 41)	1.2	0.1	0.1	1.8	2.1	2.2	0.368	8.092	0.765
(41, 184)	0.4	0.0	0.0	2.2	2.8	1.9	0.366	1.152	0.958
(184, 38)	0.2	0.0	0.0	3.7	3.2	3.8	0.219	2.702	0.729
(38, 176)	0.2	0.0	0.1	4.0	4.9	0.8	0.179	8.472	0.572
(176, 34)	0.2	0.1	0.0	4.1	1.2	1.7	0.157	4.939	0.380
(34, 167)	0.5	0.1	0.1	2.5	1.4	1.4	0.205	5.170	0.405
(167, 30)	0.8	0.0	0.1	1.4	2.7	1.9	0.325	5.237	0.561
(30, 158)	0.5	0.1	0.2	1.5	1.1	0.2	0.213	6.991	0.467
(158, 26)	0.4	0.4	0.2	1.9	0.4	0.0	0.144	2.132	0.234
(26, 149)	0.2	0.1	0.0	5.6	2.2	0.0	0.071	4.397	0.257
(149, 21)	0.1	0.0	0.0	9.5	3.9	0.0	0.028	0.524	0.064
(21, 43)	0.2	0.0	0.0	4.7	2.0	0.0	0.084	5.148	0.315
(43, 12)	0.2	0.1	0.0	10.7	4.0	0.0	0.027	0.820	0.066
(12, 116)	0.3	0.1	0.0	3.6	2.0	0.0	0.159	9.875	0.589
(116, 6)	0.3	0.1	0.0	5.7	2.2	0.0	0.085	2.214	0.183
(6, 110)	0.2	0.1	0.0	6.6	2.7	0.0	0.032	1.991	0.110
SUBNETWORK-	111.5	18.3	18.1	4.8	2.7	1.9	0.120	4.469	0.318

THE HIGHEST NUMBER OF VEHICLES ON THE NETWORK WAS 1022 VEHICLES (MAXIMUM ALLOWED IS 3500).
THIS MAXIMUM OCCURED AT 894 SECONDS.

LEGEND: A: AUTOMOBILE
 T: TRUCK
 B: BUS
 HC: HYDROCARBON
 CO: CARBONMONOXIDE
 NO X: NITROGENOXIDES

TRAF-NETSIM

INITIAL SIMULATION

DELAY TIME TABLE

NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE III

LINK	TOTAL TIME (SECS/VEH)			DELAY TIME (SECS/VEH)		
	L	T	R	L	T	R
(185, 41)	0.0	0.0	0.0	0.0	0.0	0.0
(41, 183)	0.0	0.0	0.0	0.0	0.0	0.0
(183, 40)	0.0	0.0	0.0	0.0	0.0	0.0
(40, 181)	0.0	6.4	0.0	0.0	1.5	0.0
(181, 39)	0.0	19.8	0.0	0.0	15.0	0.0
(39, 179)	0.0	13.0	0.0	0.0	1.9	0.0
(179, 39)	0.0	22.8	0.0	0.0	11.7	0.0
(39, 181)	0.0	6.5	0.0	0.0	1.6	0.0
(181, 40)	38.0	41.6	18.0	33.1	36.7	13.1
(40, 183)	0.0	9.1	0.0	0.0	3.3	0.0
(183, 41)	0.0	27.7	0.0	0.0	21.9	0.0
(41, 185)	0.0	6.7	0.0	0.0	1.1	0.0
(177, 38)	0.0	22.7	17.3	0.0	12.4	7.1
(38, 175)	0.0	6.8	0.0	0.0	1.3	0.0
(37, 173)	0.0	6.3	0.0	0.0	1.2	0.0
(175, 37)	10.0	52.3	161.6	4.4	46.7	156.0
(173, 36)	0.0	8.2	0.0	0.0	3.1	0.0
(36, 171)	0.0	6.5	0.0	0.0	0.7	0.0
(171, 35)	0.0	7.6	13.0	0.0	1.8	7.2
(35, 169)	0.0	8.5	0.0	0.0	1.0	0.0
(169, 35)	19.8	14.7	0.0	12.3	7.2	0.0
(35, 171)	0.0	7.1	0.0	0.0	1.3	0.0
(171, 36)	0.0	17.1	14.7	0.0	11.3	8.9
(36, 173)	0.0	6.4	0.0	0.0	1.3	0.0
(173, 37)	108.2	30.3	9.0	103.1	25.1	3.9
(37, 175)	0.0	6.8	0.0	0.0	1.3	0.0
(175, 38)	20.5	16.1	0.0	14.9	10.5	0.0
(38, 177)	0.0	12.2	0.0	0.0	2.0	0.0
(168, 34)	0.0	12.1	16.5	0.0	2.6	7.0
(34, 166)	0.0	6.8	0.0	0.0	1.1	0.0
(166, 33)	46.0	43.0	0.0	40.3	37.3	0.0
(33, 164)	0.0	7.2	0.0	0.0	1.8	0.0
(164, 32)	37.7	22.6	0.0	32.4	17.2	0.0
(32, 162)	0.0	7.5	0.0	0.0	1.8	0.0
(162, 31)	0.0	17.5	11.0	0.0	11.8	5.3
(31, 160)	0.0	10.2	0.0	0.0	2.7	0.0
(160, 31)	30.0	17.6	0.0	22.5	10.1	0.0
(31, 162)	0.0	6.8	0.0	0.0	1.1	0.0
(162, 32)	0.0	6.4	0.0	0.0	0.7	0.0
(34, 168)	0.0	10.3	0.0	0.0	0.9	0.0
(159, 30)	0.0	18.0	13.5	0.0	8.3	3.8
(30, 157)	0.0	9.3	0.0	0.0	3.5	0.0
(157, 29)	47.0	46.0	0.0	41.2	40.2	0.0
(29, 155)	0.0	7.2	0.0	0.0	1.9	0.0
(155, 28)	13.2	15.8	0.0	7.9	10.5	0.0
(28, 153)	0.0	7.9	0.0	0.0	2.0	0.0
(153, 27)	0.0	19.9	9.0	0.0	13.9	3.0
(27, 151)	0.0	9.1	0.0	0.0	1.4	0.0
(151, 27)	16.3	14.8	0.0	8.6	7.1	0.0
(27, 153)	0.0	7.3	0.0	0.0	1.3	0.0
(153, 28)	0.0	18.1	12.3	0.0	12.1	6.4

(28, 155)	0.0	6.5	0.0	0.0	1.2	0.0
(155, 29)	27.2	17.1	13.1	21.9	11.8	7.8
(29, 157)	0.0	6.8	0.0	0.0	1.0	0.0
(157, 30)	7.0	24.9	0.0	1.2	19.1	0.0
(30, 159)	0.0	11.3	0.0	0.0	1.6	0.0
(150, 26)	0.0	0.0	0.0	0.0	0.0	0.0
(26, 148)	0.0	0.0	0.0	0.0	0.0	0.0
(148, 25)	0.0	0.0	0.0	0.0	0.0	0.0
(25, 146)	0.0	0.0	0.0	0.0	0.0	0.0
(146, 24)	537.2	622.0	0.0	532.0	616.8	0.0
(24, 144)	0.0	716.8	0.0	0.0	710.7	0.0
(144, 23)	0.0	9.7	9.0	0.0	3.6	3.0
(23, 142)	0.0	9.1	0.0	0.0	1.6	0.0
(142, 23)	500.4	484.3	0.0	492.9	476.8	0.0
(23, 144)	0.0	161.9	0.0	0.0	155.9	0.0
(144, 24)	0.0	25.4	37.0	0.0	19.4	31.0
(24, 146)	0.0	7.4	0.0	0.0	2.2	0.0
(146, 25)	0.0	16.7	0.0	0.0	11.4	0.0
(25, 148)	0.0	41.7	0.0	0.0	36.4	0.0
(148, 26)	174.6	175.9	0.0	169.2	170.6	0.0
(26, 150)	0.0	13.2	0.0	0.0	2.0	0.0
(137, 21)	0.0	12.5	0.0	0.0	6.8	0.0
(21, 137)	0.0	11.0	0.0	0.0	5.4	0.0
(137, 20)	127.0	178.2	195.0	121.4	172.6	189.4
(20, 136)	0.0	12.0	0.0	0.0	6.7	0.0
(136, 19)	348.7	24.2	0.0	343.4	18.9	0.0
(19, 134)	0.0	7.6	0.0	0.0	1.0	0.0
(18, 133)	0.0	4.0	0.0	0.0	1.1	0.0
(133, 17)	0.0	9.1	7.2	0.0	6.2	4.3
(17, 130)	0.0	5.5	0.0	0.0	1.0	0.0
(130, 16)	26.6	0.0	7.0	22.2	0.0	2.6
(17, 133)	0.0	4.5	0.0	0.0	1.6	0.0
(133, 18)	0.0	23.8	0.0	0.0	20.9	0.0
(18, 134)	0.0	28.1	0.0	0.0	21.5	0.0
(134, 19)	0.0	161.1	525.4	0.0	154.4	518.8
(19, 136)	0.0	7.1	0.0	0.0	1.8	0.0
(136, 20)	166.3	131.6	135.0	161.1	126.3	129.7
(20, 137)	0.0	8.0	0.0	0.0	2.2	0.0
(12, 119)	0.0	7.6	0.0	0.0	2.0	0.0
(119, 11)	39.9	21.2	13.8	34.3	15.5	8.1
(11, 126)	0.0	9.4	0.0	0.0	1.9	0.0
(126, 15)	146.4	36.6	0.0	138.9	29.1	0.0
(15, 124)	0.0	11.3	0.0	0.0	1.9	0.0
(124, 14)	0.0	36.9	21.1	0.0	27.5	11.8
(14, 123)	0.0	6.9	0.0	0.0	2.1	0.0
(123, 13)	21.1	0.0	11.2	16.3	0.0	6.5
(140, 42)	28.6	28.1	16.8	20.8	20.3	9.0
(42, 139)	0.0	7.7	0.0	0.0	1.9	0.0
(139, 17)	0.0	26.3	17.0	0.0	20.5	11.2
(17, 131)	0.0	13.4	0.0	0.0	2.0	0.0
(131, 15)	0.0	0.0	29.9	0.0	0.0	18.6
(15, 126)	0.0	0.0	0.0	0.0	0.0	0.0
(126, 11)	0.0	0.0	0.0	0.0	0.0	0.0
(11, 119)	0.0	7.4	0.0	0.0	1.8	0.0
(12, 120)	0.0	7.6	0.0	0.0	1.7	0.0
(120, 12)	0.0	21.4	12.5	0.0	15.5	6.6
(118, 11)	124.6	140.2	176.7	119.0	134.5	171.0

(119, 12)	30.7	21.4	0.0	25.0	15.7	0.0
(121, 7)	19.5	23.7	18.5	6.9	11.1	5.9
(7, 117)	0.0	6.1	0.0	0.0	1.5	0.0
(117, 8)	10.0	20.1	0.0	5.4	15.5	0.0
(8, 9)	0.0	18.2	0.0	0.0	8.9	0.0
(9, 10)	0.0	45.5	38.5	0.0	36.2	29.2
(10, 118)	0.0	40.3	0.0	0.0	34.7	0.0
(106, 6)	0.0	15.3	15.7	0.0	8.8	9.2
(6, 190)	0.0	7.2	0.0	0.0	1.6	0.0
(190, 5)	20.6	21.0	18.8	15.0	15.4	13.2
(5, 105)	0.0	6.1	0.0	0.0	3.5	0.0
(105, 4)	8.4	9.1	0.0	5.9	6.6	0.0
(4, 104)	0.0	4.2	0.0	0.0	1.0	0.0
(104, 3)	4.7	6.7	0.0	1.4	3.5	0.0
(3, 103)	0.0	6.4	0.0	0.0	0.9	0.0
(103, 2)	0.0	10.8	0.0	0.0	5.3	0.0
(2, 102)	0.0	6.1	0.0	0.0	1.0	0.0
(1, 101)	0.0	13.1	0.0	0.0	1.7	0.0
(1, 107)	0.0	14.4	0.0	0.0	1.9	0.0
(102, 1)	20.5	21.9	13.3	15.4	16.8	8.2
(1, 102)	0.0	7.8	0.0	0.0	2.7	0.0
(102, 2)	0.0	20.4	0.0	0.0	15.3	0.0
(2, 103)	0.0	9.1	0.0	0.0	3.7	0.0
(103, 3)	0.0	32.6	0.0	0.0	27.2	0.0
(3, 104)	0.0	5.1	0.0	0.0	1.9	0.0
(104, 4)	0.0	14.2	9.4	0.0	11.0	6.2
(4, 105)	0.0	9.8	0.0	0.0	7.2	0.0
(105, 5)	14.1	9.3	14.1	11.6	6.7	11.6
(6, 106)	0.0	7.7	0.0	0.0	1.2	0.0
(190, 6)	8.0	13.7	0.0	2.4	8.0	0.0
(5, 190)	0.0	6.8	0.0	0.0	1.2	0.0
(107, 1)	54.8	44.3	39.3	42.3	31.8	26.8
(1, 111)	0.0	8.6	0.0	0.0	2.2	0.0
(111, 7)	57.2	73.8	0.0	50.8	67.4	0.0
(7, 122)	0.0	6.6	0.0	0.0	1.9	0.0
(122, 13)	0.0	31.2	0.0	0.0	26.5	0.0
(13, 127)	0.0	7.9	0.0	0.0	1.9	0.0
(127, 16)	0.0	22.2	0.0	0.0	16.3	0.0
(42, 140)	0.0	12.9	0.0	0.0	1.6	0.0
(16, 138)	0.0	5.6	0.0	0.0	1.5	0.0
(138, 42)	38.2	19.6	24.5	34.1	15.5	20.4
(42, 141)	0.0	3.3	0.0	0.0	0.9	0.0
(141, 42)	6.6	14.7	8.0	4.2	12.3	5.7
(42, 138)	0.0	5.8	0.0	0.0	1.7	0.0
(138, 16)	0.0	12.4	0.0	0.0	8.3	0.0
(16, 127)	0.0	8.3	0.0	0.0	2.4	0.0
(127, 13)	0.0	10.5	0.0	0.0	4.6	0.0
(13, 122)	0.0	5.6	0.0	0.0	0.9	0.0
(122, 7)	0.0	23.4	19.1	0.0	18.7	14.4
(7, 111)	0.0	8.0	0.0	0.0	1.6	0.0
(111, 1)	50.6	51.3	59.3	44.2	45.0	52.9
(17, 128)	0.0	7.5	0.0	0.0	1.7	0.0
(128, 14)	13.3	17.0	0.0	7.5	11.2	0.0
(14, 100)	0.0	6.7	0.0	0.0	2.1	0.0
(100, 8)	0.0	28.3	18.3	0.0	23.7	13.7
(8, 112)	0.0	7.8	0.0	0.0	1.5	0.0
(112, 2)	30.1	0.0	11.4	23.8	0.0	5.1

(3, 113)	0.0	7.0	0.0	0.0	0.9	0.0
(113, 9)	0.0	6.7	0.0	0.0	0.5	0.0
(9, 113)	0.0	0.0	0.0	0.0	0.0	0.0
(113, 3)	0.0	0.0	0.0	0.0	0.0	0.0
(178, 35)	30.3	24.6	16.5	24.8	19.2	11.0
(35, 170)	0.0	3.3	0.0	0.0	1.4	0.0
(170, 31)	5.0	14.2	5.2	3.1	12.3	3.3
(31, 161)	0.0	5.7	0.0	0.0	1.4	0.0
(161, 27)	33.8	10.6	9.0	29.4	6.2	4.7
(27, 152)	0.0	30.1	0.0	0.0	26.7	0.0
(152, 23)	365.9	302.1	320.0	362.4	298.7	316.6
(23, 143)	0.0	7.5	0.0	0.0	1.5	0.0
(143, 18)	29.6	0.0	13.5	23.6	0.0	7.5
(108, 4)	20.7	32.6	24.3	11.3	23.2	14.9
(4, 114)	0.0	8.3	0.0	0.0	2.5	0.0
(114, 10)	12.0	25.1	0.0	6.2	19.3	0.0
(10, 125)	0.0	6.6	0.0	0.0	2.1	0.0
(125, 15)	0.0	47.4	54.3	0.0	42.9	49.8
(15, 135)	0.0	87.1	0.0	0.0	81.2	0.0
(135, 19)	7.0	440.0	560.0	1.1	434.1	554.1
(19, 145)	0.0	387.8	0.0	0.0	381.6	0.0
(145, 24)	219.5	492.5	378.0	213.4	486.4	371.9
(24, 154)	0.0	5.6	0.0	0.0	2.1	0.0
(154, 28)	24.0	33.3	77.0	20.5	29.8	73.5
(28, 163)	0.0	5.3	0.0	0.0	2.1	0.0
(163, 32)	0.0	19.1	5.5	0.0	15.9	2.3
(32, 172)	0.0	3.1	0.0	0.0	1.4	0.0
(172, 36)	7.8	10.2	2.8	6.1	8.6	1.1
(36, 180)	0.0	3.2	0.0	0.0	1.2	0.0
(180, 39)	19.0	0.0	6.9	17.1	0.0	4.9
(187, 40)	26.3	29.6	41.5	22.6	25.8	37.8
(40, 182)	0.0	26.4	0.0	0.0	24.9	0.0
(182, 37)	3.0	34.9	0.0	1.5	33.4	0.0
(37, 174)	0.0	24.9	0.0	0.0	22.7	0.0
(174, 33)	10.1	10.0	0.0	7.9	7.8	0.0
(33, 165)	0.0	4.9	0.0	0.0	1.7	0.0
(165, 29)	72.8	43.2	68.0	69.5	39.9	64.8
(29, 156)	0.0	37.5	0.0	0.0	33.2	0.0
(156, 25)	0.0	74.2	0.0	0.0	70.0	0.0
(25, 147)	0.0	82.8	0.0	0.0	76.7	0.0
(147, 20)	0.0	31.4	50.0	0.0	25.3	43.9
(20, 22)	0.0	10.4	0.0	0.0	6.0	0.0
(22, 11)	0.0	76.1	70.3	0.0	69.9	64.0
(11, 115)	0.0	15.4	0.0	0.0	9.2	0.0
(115, 5)	21.0	10.6	10.0	14.8	4.3	3.8
(5, 109)	0.0	6.0	0.0	0.0	1.0	0.0
(109, 5)	24.0	27.2	18.2	19.0	22.2	13.2
(5, 115)	0.0	44.6	0.0	0.0	38.3	0.0
(115, 11)	122.4	124.8	0.0	116.2	118.6	0.0
(11, 22)	0.0	99.0	0.0	0.0	92.8	0.0
(22, 20)	161.4	84.3	16.3	157.1	79.9	12.0
(20, 147)	0.0	76.8	0.0	0.0	70.6	0.0
(147, 25)	0.0	15.9	0.0	0.0	9.8	0.0
(25, 156)	0.0	5.7	0.0	0.0	1.4	0.0
(156, 29)	22.0	21.5	28.6	17.7	17.2	24.3
(29, 165)	0.0	4.5	0.0	0.0	1.3	0.0
(165, 33)	0.0	6.3	8.5	0.0	3.1	5.3

(33, 174)	0.0	6.9	0.0	0.0	4.6	0.0
(174, 37)	0.0	7.7	2.0	0.0	5.4	0.0
(37, 182)	0.0	2.9	0.0	0.0	1.3	0.0
(182, 40)	12.7	5.5	5.2	11.1	3.9	3.7
(40, 187)	0.0	4.9	0.0	0.0	1.2	0.0
(186, 41)	0.0	28.2	37.9	0.0	24.2	33.9
(41, 184)	0.0	3.0	0.0	0.0	1.5	0.0
(184, 38)	0.0	8.2	4.8	0.0	6.7	3.3
(38, 176)	0.0	2.4	0.0	0.0	0.6	0.0
(176, 34)	33.0	9.7	3.7	31.1	7.8	1.8
(34, 167)	0.0	5.3	0.0	0.0	2.3	0.0
(167, 30)	0.0	23.3	26.6	0.0	20.3	23.5
(30, 158)	0.0	5.6	0.0	0.0	2.3	0.0
(158, 26)	0.0	41.3	29.5	0.0	37.9	26.2
(26, 149)	0.0	8.1	0.0	0.0	2.3	0.0
(149, 21)	0.0	26.2	0.0	0.0	20.3	0.0
(21, 43)	0.0	6.4	0.0	0.0	2.2	0.0
(43, 12)	34.8	34.4	24.1	25.5	25.0	14.7
(12, 116)	0.0	7.2	0.0	0.0	2.8	0.0
(116, 6)	38.1	34.3	8.0	33.7	29.9	3.6
(6, 110)	0.0	12.1	0.0	0.0	1.8	0.0

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

TRAF-NETSIM

FINAL SIMULATION

EMISSIONS TABLES

CUMULATIVE VALUES OF FUEL CONSUMPTION AND OF EMISSIONS

LINK	FUEL CONSUMPTION						VEHICLE EMISSION RATES (KG/MILE.HOUR)		
	GALLONS			M.P.G.			HC	CO	NO X
	A	T	B	A	T	B			
(185, 41)	1.7	0.2	0.2	0.7	0.3	0.9	0.364	3.175	0.502
(41, 183)	2.4	0.0	0.2	0.2	0.0	0.4	0.468	2.262	0.518
(183, 40)	2.1	0.3	0.2	0.0	0.0	0.0	0.403	1.025	0.403
(40, 181)	0.0	0.0	0.0	3.7	0.0	0.0	0.015	0.930	0.055
(181, 39)	0.0	0.0	0.0	10.8	0.0	0.0	0.007	0.340	0.015
(39, 179)	0.3	0.0	0.0	7.7	0.0	0.0	0.050	2.867	0.177
(179, 39)	4.4	0.4	0.0	0.5	0.4	0.0	0.460	4.733	0.581
(39, 181)	2.3	0.2	0.0	0.0	0.0	0.0	0.533	3.367	0.542
(181, 40)	1.9	0.5	0.0	0.0	0.0	0.0	0.426	2.263	0.426
(40, 183)	0.1	0.0	0.0	4.1	1.8	0.0	0.020	1.165	0.078
(183, 41)	0.0	0.0	0.0	8.2	6.1	0.0	0.007	0.107	0.017
(41, 185)	0.0	0.1	0.0	9.4	2.0	0.0	0.007	0.312	0.024
(177, 38)	0.6	0.2	0.1	9.2	4.7	3.3	0.111	2.478	0.343
(38, 175)	0.3	0.1	0.0	8.5	2.4	6.9	0.103	2.886	0.368
(37, 173)	0.8	0.2	0.0	2.0	0.7	0.0	0.192	1.748	0.347
(175, 37)	0.3	0.1	0.0	11.3	3.4	10.1	0.054	1.049	0.107
(173, 36)	1.7	0.1	0.0	0.6	0.2	0.0	0.370	1.882	0.396
(36, 171)	0.1	0.0	0.0	6.6	0.0	0.0	0.030	1.645	0.113
(171, 35)	0.0	0.0	0.0	19.3	0.0	0.0	0.007	0.125	0.018
(35, 169)	0.1	0.0	0.0	9.9	2.5	0.0	0.032	1.763	0.110
(169, 35)	1.6	0.5	0.0	2.9	1.1	0.0	0.303	2.615	0.613
(35, 171)	1.9	0.1	0.0	1.4	1.9	0.0	0.401	3.420	0.610
(171, 36)	2.0	0.4	0.0	0.9	0.5	0.0	0.383	2.993	0.414
(36, 173)	0.2	0.0	0.0	6.8	2.4	0.0	0.064	3.696	0.233
(173, 37)	0.1	0.0	0.0	10.2	4.4	0.0	0.028	0.485	0.062
(37, 175)	0.1	0.0	0.0	9.5	3.5	0.0	0.038	1.845	0.143
(175, 38)	0.1	0.0	0.0	21.2	3.0	0.0	0.010	0.133	0.020
(38, 177)	0.2	0.1	0.0	15.0	3.6	0.0	0.023	1.026	0.068
(168, 34)	0.1	0.0	0.0	11.4	0.0	0.0	0.021	1.041	0.054
(34, 166)	0.1	0.0	0.0	6.8	0.0	0.0	0.027	1.693	0.095
(166, 33)	0.1	0.0	0.0	7.0	0.0	0.0	0.018	0.189	0.020
(33, 164)	0.1	0.0	0.0	4.3	0.0	0.0	0.054	1.306	0.202
(164, 32)	0.4	0.0	0.0	1.9	0.0	0.0	0.077	0.852	0.089
(32, 162)	0.0	0.0	0.0	5.5	0.0	0.0	0.014	0.810	0.052
(162, 31)	0.0	0.0	0.0	17.6	0.0	0.0	0.003	0.029	0.003
(31, 160)	0.0	0.0	0.0	6.5	0.0	0.0	0.012	0.721	0.043
(160, 31)	0.1	0.0	0.0	10.6	4.6	0.0	0.023	1.246	0.062
(31, 162)	0.1	0.0	0.0	8.9	2.9	0.0	0.022	1.138	0.077
(162, 32)	0.3	0.1	0.0	2.2	1.1	0.0	0.057	0.730	0.073
(34, 168)	0.0	0.0	0.0	6.9	0.0	0.0	0.004	0.236	0.015
(159, 30)	0.9	0.2	0.0	1.9	0.9	0.0	0.127	1.478	0.230
(30, 157)	0.1	0.0	0.0	8.3	0.0	0.0	0.018	0.908	0.062
(157, 29)	0.1	0.0	0.0	4.1	0.0	0.0	0.037	1.892	0.117
(29, 155)	0.2	0.0	0.0	4.2	2.0	1.4	0.066	2.299	0.234
(155, 28)	0.1	0.0	0.0	12.9	7.7	3.3	0.021	0.959	0.048
(28, 153)	0.1	0.0	0.1	6.8	3.3	1.9	0.031	1.029	0.105
(153, 27)	0.0	0.0	0.1	23.0	3.9	7.3	0.005	0.080	0.011
(27, 151)	0.1	0.0	0.1	11.4	2.7	2.2	0.019	1.074	0.060
(151, 27)	0.3	0.1	0.1	9.9	5.0	3.6	0.082	1.528	0.238
(27, 153)	0.3	0.1	0.0	8.7	4.0	6.6	0.084	1.584	0.299
(153, 28)	0.2	0.1	0.0	12.7	5.6	7.9	0.040	0.747	0.091

(28, 155)	0.3	0.1	0.1	7.2	3.7	1.9	0.115	2.726	0.419
(155, 29)	0.3	0.1	0.0	9.3	3.4	4.8	0.062	1.049	0.116
(29, 157)	0.3	0.1	0.0	5.4	2.7	0.0	0.101	2.358	0.348
(157, 30)	1.0	0.1	0.0	1.1	1.3	0.0	0.201	2.116	0.217
(30, 159)	0.1	0.0	0.0	9.0	0.0	0.0	0.019	1.023	0.068
(150, 26)	2.8	0.5	0.3	0.5	0.4	0.8	0.292	2.387	0.367
(26, 148)	0.6	0.0	0.2	0.0	0.0	0.0	0.121	1.229	0.124
(148, 25)	1.1	0.0	0.2	0.0	0.0	0.0	0.217	1.175	0.217
(25, 146)	0.0	0.0	0.0	3.1	0.0	0.0	0.005	0.316	0.015
(146, 24)	0.1	0.0	0.1	0.5	0.0	0.0	0.020	0.254	0.025
(24, 144)	0.2	0.1	0.4	1.3	0.6	6.0	0.044	0.904	0.070
(144, 23)	0.0	0.0	0.0	11.0	2.9	3.1	0.003	0.055	0.011
(23, 142)	0.0	0.0	0.1	25.3	4.2	2.2	0.001	0.011	0.002
(142, 23)	2.0	0.4	0.5	0.3	0.2	0.2	0.304	1.301	0.354
(23, 144)	0.4	0.1	0.4	0.9	2.2	1.8	0.063	0.666	0.076
(144, 24)	0.0	0.0	0.0	4.4	3.4	3.0	0.002	0.036	0.008
(24, 146)	0.0	0.0	0.1	4.0	0.0	2.2	0.004	0.230	0.015
(146, 25)	0.0	0.0	0.0	7.3	0.0	4.7	0.001	0.035	0.004
(25, 148)	0.0	0.0	0.1	4.0	0.0	2.5	0.004	0.223	0.015
(148, 26)	0.0	0.0	0.1	22.0	0.0	2.9	0.000	0.004	0.001
(26, 150)	0.0	0.0	0.1	9.7	0.0	2.7	0.006	0.368	0.022
(137, 21)	0.0	0.0	0.0	13.7	8.4	0.0	0.006	0.085	0.012
(21, 137)	0.4	0.0	0.0	3.2	0.0	0.0	0.147	3.293	0.537
(137, 20)	0.8	0.0	0.0	3.3	0.0	0.0	0.181	2.429	0.358
(20, 136)	0.3	0.0	0.0	5.5	0.0	0.0	0.105	2.458	0.388
(136, 19)	0.6	0.0	0.0	2.7	0.0	0.0	0.135	2.137	0.236
(19, 134)	0.1	0.0	0.0	10.0	0.0	0.0	0.033	1.874	0.109
(134, 18)	0.1	0.0	0.0	15.5	3.0	0.0	0.013	0.211	0.026
(18, 133)	0.1	0.0	0.0	6.7	2.7	0.0	0.058	1.122	0.216
(133, 17)	0.1	0.0	0.0	7.1	2.9	0.0	0.040	1.665	0.132
(17, 130)	0.1	0.0	0.0	6.5	4.0	0.0	0.043	2.176	0.199
(130, 16)	0.1	0.0	0.0	12.6	9.9	0.0	0.020	0.770	0.056
(17, 133)	0.2	0.0	0.0	3.1	1.6	1.5	0.118	2.460	0.477
(133, 18)	0.1	0.0	0.1	5.5	2.7	3.3	0.083	2.426	0.249
(18, 134)	0.3	0.1	0.1	6.8	2.3	1.9	0.078	1.577	0.281
(134, 19)	0.9	0.2	0.2	2.1	1.3	2.0	0.160	2.591	0.264
(19, 136)	0.2	0.0	0.0	6.5	3.8	0.0	0.072	1.362	0.265
(136, 20)	0.4	0.1	0.0	2.6	1.2	0.0	0.089	1.233	0.134
(20, 137)	0.1	0.0	0.0	6.4	2.0	0.0	0.020	1.123	0.073
(12, 119)	0.3	0.0	0.0	6.3	2.1	4.5	0.093	2.229	0.352
(119, 11)	0.4	0.0	0.0	4.5	2.3	4.4	0.087	1.329	0.168
(11, 126)	0.1	0.0	0.0	5.9	0.0	3.7	0.031	1.857	0.115
(126, 15)	0.1	0.0	0.0	5.1	0.0	4.2	0.023	0.336	0.037
(15, 124)	0.3	0.0	0.0	7.4	3.0	0.0	0.059	1.335	0.208
(124, 14)	0.2	0.0	0.0	13.5	8.5	0.0	0.021	0.264	0.034
(14, 123)	0.1	0.0	0.0	4.6	0.0	0.0	0.045	2.654	0.174
(123, 13)	0.2	0.0	0.0	5.9	0.0	0.0	0.074	2.298	0.241
(140, 42)	0.5	0.1	0.0	6.3	3.9	0.0	0.109	3.644	0.346
(42, 139)	0.4	0.1	0.1	5.2	2.4	1.7	0.161	2.634	0.555
(139, 17)	0.2	0.0	0.0	15.1	6.7	5.7	0.041	0.794	0.085
(17, 131)	0.3	0.0	0.0	9.3	2.4	0.0	0.038	2.120	0.135
(131, 15)	0.3	0.0	0.0	7.7	5.0	0.0	0.032	0.548	0.064
(15, 126)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(126, 11)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(11, 119)	0.5	0.1	0.0	5.1	2.3	1.5	0.094	1.838	0.228
(12, 120)	0.3	0.1	0.0	7.1	3.2	6.3	0.109	2.590	0.392

(120, 12)	0.3	0.0	0.0	6.9	8.8	3.9	0.081	1.952	0.232
(118, 11)	1.4	0.2	1.4	1.9	1.5	0.4	0.282	1.853	0.463
(119, 12)	0.3	0.1	0.0	11.3	4.3	2.3	0.071	1.972	0.177
(121, 7)	1.3	0.2	0.6	11.0	5.4	3.7	0.173	2.182	0.517
(7, 117)	0.7	0.1	0.1	7.1	4.8	8.7	0.293	6.092	1.037
(117, 8)	0.5	0.1	0.4	10.4	2.7	1.9	0.175	5.843	0.584
(8, 9)	0.8	0.2	0.7	12.6	3.4	2.3	0.144	6.882	0.468
(9, 10)	1.4	0.1	0.6	7.6	5.0	2.4	0.186	4.554	0.441
(10, 118)	1.0	0.2	0.4	3.1	1.6	2.0	0.249	1.059	0.679
(106, 6)	1.2	0.3	0.0	4.8	2.9	0.0	0.017	4.589	0.050
(6, 190)	1.0	0.3	0.0	5.5	2.3	0.0	0.034	0.473	0.230
(190, 5)	0.4	0.2	0.0	13.8	3.8	0.0	0.096	2.966	0.268
(5, 105)	0.3	0.1	0.0	7.9	3.3	0.9	0.236	1.845	0.923
(105, 4)	0.3	0.1	0.0	11.0	3.6	1.6	0.158	2.811	0.455
(4, 104)	0.5	0.1	0.0	7.9	4.6	2.1	0.192	1.837	0.358
(104, 3)	0.5	0.1	0.0	9.7	3.5	3.5	0.200	2.559	0.572
(3, 103)	0.7	0.2	0.0	10.4	3.9	7.9	0.021	1.776	0.073
(103, 2)	0.4	0.2	0.0	16.7	5.1	3.4	0.097	2.711	0.248
(2, 102)	0.8	0.2	0.0	9.7	4.1	1.8	0.185	2.743	0.410
(1, 101)	4.7	0.5	0.0	9.7	4.3	0.0	0.112	2.632	0.509
(1, 107)	0.5	0.1	0.1	8.1	3.6	2.6	0.076	1.547	0.263
(102, 1)	2.4	0.2	0.0	5.6	4.5	5.5	0.103	1.162	0.302
(1, 102)	0.0	0.0	0.2	3.3	0.0	1.6	0.014	0.918	0.052
(102, 2)	0.0	0.0	0.0	13.8	0.0	8.5	0.004	0.209	0.012
(2, 103)	0.1	0.0	0.2	4.7	0.0	2.3	0.029	1.849	0.099
(103, 3)	0.0	0.0	0.1	11.7	0.0	3.8	0.009	0.339	0.032
(3, 104)	0.1	0.0	0.1	4.2	0.0	1.6	0.070	2.999	0.265
(104, 4)	0.1	0.0	0.1	6.4	0.0	4.9	0.057	1.686	0.195
(4, 105)	0.1	0.0	0.1	7.4	1.8	1.9	0.045	1.356	0.167
(105, 5)	0.1	0.0	0.0	7.3	5.3	3.8	0.050	2.382	0.106
(6, 106)	0.2	0.0	0.0	5.4	2.4	0.0	0.075	1.755	0.266
(190, 6)	0.1	0.0	0.0	9.4	4.6	0.0	0.023	0.423	0.042
(5, 190)	0.1	0.0	0.0	6.9	2.3	0.0	0.045	2.763	0.163
(107, 1)	0.6	0.1	0.3	8.0	3.9	5.2	0.081	2.134	0.251
(1, 111)	0.3	0.0	0.1	6.1	2.5	2.8	0.077	2.467	0.288
(111, 7)	0.4	0.0	0.1	4.9	5.1	2.3	0.069	1.226	0.148
(7, 122)	0.3	0.1	0.1	4.9	2.0	1.7	0.110	1.515	0.411
(122, 13)	0.2	0.1	0.1	7.5	2.8	2.6	0.055	1.324	0.129
(13, 127)	0.6	0.1	0.1	6.3	2.7	2.4	0.099	1.601	0.118
(127, 16)	0.6	0.1	0.1	7.7	3.9	4.3	0.133	2.022	0.354
(42, 140)	0.2	0.1	0.0	7.6	3.0	0.0	0.033	1.890	0.123
(16, 138)	0.6	0.0	0.1	5.2	3.4	1.6	0.142	1.794	0.132
(138, 42)	0.4	0.0	0.1	8.9	4.2	4.2	0.139	2.762	0.405
(42, 141)	0.3	0.0	0.0	5.8	1.9	0.0	0.044	1.786	0.327
(141, 42)	0.3	0.0	0.0	4.5	3.5	0.0	0.103	1.639	0.349
(42, 138)	0.4	0.0	0.0	5.6	4.3	0.0	0.075	0.641	0.240
(138, 16)	0.2	0.0	0.0	10.5	4.0	0.0	0.071	1.783	0.163
(16, 127)	0.5	0.1	0.0	6.0	2.9	0.0	0.170	3.872	0.654
(127, 13)	0.3	0.1	0.0	12.5	3.5	0.0	0.053	1.422	0.156
(13, 122)	0.3	0.0	0.0	9.6	2.9	0.0	0.112	2.706	0.398
(122, 7)	0.5	0.1	0.0	6.0	2.8	0.0	0.142	2.752	0.320
(7, 111)	0.5	0.1	0.0	6.6	2.4	0.0	0.157	3.042	0.593
(111, 1)	0.6	0.1	0.0	6.5	4.1	0.0	0.115	2.519	0.284
(17, 128)	0.0	0.0	0.0	4.8	0.0	0.0	0.014	1.009	0.049
(128, 14)	0.0	0.0	0.0	24.0	0.0	0.0	0.002	0.021	0.003
(14, 100)	0.1	0.0	0.0	4.2	1.8	0.0	0.050	1.036	0.190
(100, 8)	0.1	0.0	0.0	10.2	5.0	0.0	0.017	0.414	0.028

(8, 112)	0.2	0.0	0.0	4.6	2.7	0.0	0.066	1.373	0.231
(112, 2)	0.2	0.0	0.0	6.8	5.5	0.0	0.050	1.374	0.138
(3, 113)	0.0	0.0	0.0	6.9	0.0	0.0	0.004	0.232	0.012
(113, 9)	0.0	0.0	0.0	16.7	0.0	0.0	0.001	0.012	0.002
(9, 113)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(113, 3)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(178, 35)	1.1	0.1	0.0	1.2	3.0	0.0	0.245	1.044	0.401
(35, 170)	0.0	0.0	0.0	4.2	1.7	0.0	0.040	1.953	0.163
(170, 31)	0.1	0.0	0.0	3.6	2.0	0.0	0.054	2.398	0.149
(31, 161)	0.1	0.0	0.0	4.9	2.7	0.0	0.060	3.740	0.223
(161, 27)	0.1	0.0	0.0	7.9	3.2	0.0	0.029	0.909	0.063
(27, 152)	0.4	0.1	0.0	1.2	0.2	0.0	0.144	2.379	0.237
(152, 23)	2.3	0.2	0.0	0.1	0.1	0.0	0.743	1.428	0.742
(23, 143)	0.0	0.0	0.0	4.9	1.9	0.0	0.012	0.802	0.042
(143, 18)	0.0	0.0	0.0	17.0	8.4	0.0	0.003	0.026	0.003
(108, 4)	0.6	0.2	0.1	7.6	2.9	4.0	0.109	2.677	0.352
(4, 114)	0.2	0.2	0.1	6.4	2.5	2.0	0.067	1.736	0.254
(114, 10)	0.3	0.1	0.1	5.8	3.3	5.1	0.048	0.638	0.081
(10, 125)	0.5	0.1	0.1	4.6	2.4	1.9	0.189	2.424	0.692
(125, 15)	0.9	0.1	0.1	3.0	2.4	3.8	0.229	3.825	0.442
(15, 135)	1.4	0.2	0.3	1.8	1.2	1.1	0.297	1.510	0.676
(135, 19)	1.6	0.3	0.1	1.2	0.7	2.1	0.318	1.449	0.487
(19, 145)	0.8	0.2	0.2	2.0	0.5	1.1	0.172	1.733	0.380
(145, 24)	1.3	0.2	0.1	1.2	0.8	1.5	0.233	1.092	0.378
(24, 154)	0.1	0.0	0.0	4.9	2.1	3.0	0.074	1.360	0.302
(154, 28)	0.1	0.0	0.0	5.8	3.1	2.4	0.051	1.122	0.123
(28, 163)	0.3	0.0	0.0	3.0	2.5	1.7	0.136	1.168	0.445
(163, 32)	0.4	0.1	0.0	1.6	0.5	2.2	0.148	2.533	0.218
(32, 172)	0.5	0.0	0.0	0.6	3.8	2.3	0.364	1.724	0.493
(172, 36)	0.3	0.0	0.0	0.9	2.7	1.1	0.238	3.850	0.322
(36, 180)	0.4	0.1	0.1	0.5	0.1	0.2	0.240	2.659	0.271
(180, 39)	0.8	0.0	0.0	0.3	0.0	0.0	0.454	1.955	0.528
(187, 40)	1.2	0.2	0.1	0.2	0.3	0.1	0.367	1.508	0.455
(40, 182)	0.2	0.0	0.0	1.2	0.0	0.0	0.179	2.134	0.224
(182, 37)	0.0	0.0	0.0	2.3	0.0	0.0	0.018	0.391	0.043
(37, 174)	0.1	0.0	0.1	2.6	1.5	0.5	0.052	2.314	0.216
(174, 33)	0.1	0.0	0.0	3.7	1.8	1.9	0.065	3.747	0.227
(33, 165)	0.1	0.0	0.1	5.3	2.7	1.7	0.052	3.390	0.184
(165, 29)	0.1	0.0	0.0	7.3	6.0	2.6	0.025	0.542	0.070
(29, 156)	0.3	0.1	0.1	3.0	1.6	1.8	0.099	3.744	0.278
(156, 25)	1.2	0.1	0.3	0.9	1.2	1.0	0.324	1.597	0.501
(25, 147)	0.5	0.1	0.6	2.7	2.5	0.4	0.127	2.650	0.360
(147, 20)	0.1	0.0	0.1	9.6	4.8	2.7	0.029	0.513	0.068
(20, 22)	0.3	0.0	0.1	5.6	2.2	2.0	0.116	3.554	0.454
(22, 11)	0.3	0.0	0.1	8.2	4.0	4.7	0.062	1.557	0.160
(11, 115)	0.4	0.1	0.1	5.8	2.4	1.6	0.119	2.332	0.448
(115, 5)	0.1	0.0	0.1	19.0	6.1	3.3	0.026	0.509	0.053
(5, 109)	0.2	0.0	0.0	6.2	2.4	1.6	0.087	2.439	0.306
(109, 5)	0.5	0.1	0.1	6.1	4.0	6.3	0.172	2.250	0.553
(5, 115)	0.6	0.1	0.5	5.4	2.4	3.7	0.176	1.301	0.572
(115, 11)	1.2	0.1	0.2	2.5	2.4	1.6	0.230	1.250	0.430
(11, 22)	1.2	0.1	0.1	2.0	1.0	2.5	0.250	2.764	0.574
(22, 20)	0.8	0.1	0.1	1.7	0.6	1.4	0.222	3.564	0.419
(20, 147)	0.4	0.0	0.4	4.2	3.1	0.4	0.113	2.719	0.381
(147, 25)	0.1	0.0	0.1	13.1	7.6	4.2	0.026	0.759	0.076
(25, 156)	0.1	0.0	0.1	8.1	8.2	1.8	0.058	3.233	0.213
(156, 29)	0.1	0.0	0.0	8.6	3.4	5.4	0.039	0.795	0.090
(29, 165)	0.2	0.0	0.0	4.3	1.8	2.8	0.111	2.338	0.436

(165, 33)	0.1	0.0	0.0	8.7	2.9	4.8	0.065	3.064	0.224
(33, 174)	0.1	0.0	0.0	8.6	5.2	1.5	0.045	1.551	0.147
(174, 37)	0.1	0.0	0.0	4.7	1.0	1.7	0.082	2.240	0.158
(37, 182)	0.0	0.0	0.0	8.9	4.7	1.3	0.045	1.810	0.187
(182, 40)	0.1	0.0	0.0	4.4	4.7	1.8	0.086	2.968	0.236
(40, 187)	0.1	0.0	0.0	8.0	6.9	2.6	0.040	2.474	0.141
(186, 41)	1.2	0.4	0.0	0.5	0.3	4.1	0.360	1.201	0.479
(41, 184)	0.0	0.0	0.0	4.5	1.8	1.0	0.041	1.637	0.190
(184, 38)	0.1	0.0	0.0	3.1	1.8	11.3	0.054	2.081	0.186
(38, 176)	0.0	0.0	0.0	5.4	2.1	2.0	0.038	1.855	0.157
(176, 34)	0.1	0.0	0.0	4.1	1.9	2.5	0.075	2.317	0.228
(34, 167)	0.1	0.1	0.1	3.8	1.2	1.7	0.094	1.640	0.341
(167, 30)	0.5	0.0	0.1	1.3	1.6	1.2	0.192	2.673	0.280
(30, 158)	0.8	0.2	0.2	0.4	0.5	0.6	0.272	2.864	0.341
(158, 26)	1.0	0.4	0.2	0.2	0.1	0.2	0.328	3.448	0.340
(26, 149)	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
(149, 21)	0.0	0.0	0.0	2.6	0.0	0.0	0.004	0.100	0.015
(21, 43)	0.1	0.0	0.0	4.5	1.8	0.0	0.028	1.639	0.107
(43, 12)	0.1	0.0	0.0	11.8	7.0	0.0	0.009	0.442	0.028
(12, 116)	0.2	0.0	0.0	3.7	2.0	0.0	0.109	2.895	0.412
(116, 6)	0.1	0.0	0.0	14.8	4.5	0.0	0.032	1.578	0.076
(6, 110)	0.1	0.1	0.0	8.6	2.9	0.0	0.021	1.274	0.074
SUBNETWORK-	109.0	16.8	16.4	4.0	2.1	2.1	0.113	2.857	0.277

THE HIGHEST NUMBER OF VEHICLES ON THE NETWORK WAS 1061 VEHICLES (MAXIMUM ALLOWED IS 3500).
THIS MAXIMUM OCCURED AT 899 SECONDS.

LEGEND: A: AUTOMOBILE
 T: TRUCK
 B: BUS
 HC: HYDROCARBON
 CO: CARBONMONOXIDE
 NO X: NITROGENOXIDES

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TRAF-NETSIM

FINAL SIMULATION

DELAY TIME TABLE

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NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE III

LINK	TOTAL TIME (SECS/VEH)			DELAY TIME (SECS/VEH)		
	L	T	R	L	T	R
(185, 41)	0.0	12.7	9.0	0.0	7.2	3.5
(41, 183)	0.0	0.0	0.0	0.0	0.0	0.0
(183, 40)	0.0	0.0	0.0	0.0	0.0	0.0
(40, 181)	0.0	5.8	0.0	0.0	0.9	0.0
(181, 39)	0.0	14.6	0.0	0.0	9.7	0.0
(39, 179)	0.0	13.0	0.0	0.0	1.9	0.0
(179, 39)	0.0	24.8	0.0	0.0	13.7	0.0
(39, 181)	0.0	0.0	0.0	0.0	0.0	0.0
(181, 40)	0.0	0.0	0.0	0.0	0.0	0.0
(40, 183)	0.0	8.4	0.0	0.0	2.6	0.0
(183, 41)	60.0	13.6	0.0	54.2	7.8	0.0
(41, 185)	0.0	8.1	0.0	0.0	2.6	0.0
(177, 38)	0.0	16.3	15.9	0.0	6.1	5.7
(38, 175)	0.0	6.9	0.0	0.0	1.3	0.0
(37, 173)	0.0	6.4	0.0	0.0	1.3	0.0
(175, 37)	24.5	12.9	22.9	18.9	7.3	17.3
(173, 36)	0.0	27.4	0.0	0.0	22.3	0.0
(36, 171)	0.0	7.4	0.0	0.0	1.6	0.0
(171, 35)	0.0	7.4	6.0	0.0	1.6	0.2
(35, 169)	0.0	9.1	0.0	0.0	1.6	0.0
(169, 35)	12.0	11.4	0.0	4.5	3.9	0.0
(35, 171)	0.0	7.2	0.0	0.0	1.4	0.0
(171, 36)	0.0	21.4	24.5	0.0	15.6	18.7
(36, 173)	0.0	6.8	0.0	0.0	1.6	0.0
(173, 37)	23.3	18.9	0.0	18.2	13.7	0.0
(37, 175)	0.0	7.0	0.0	0.0	1.4	0.0
(175, 38)	19.0	9.3	0.0	13.4	3.7	0.0
(38, 177)	0.0	11.8	0.0	0.0	1.6	0.0
(168, 34)	0.0	22.5	15.6	0.0	13.0	6.1
(34, 166)	0.0	7.2	0.0	0.0	1.5	0.0
(166, 33)	52.0	46.8	0.0	46.3	41.1	0.0
(33, 164)	0.0	7.7	0.0	0.0	2.3	0.0
(164, 32)	18.8	15.3	0.0	13.4	9.9	0.0
(32, 162)	0.0	7.8	0.0	0.0	2.1	0.0
(162, 31)	0.0	18.4	11.0	0.0	12.7	5.3
(31, 160)	0.0	10.4	0.0	0.0	2.9	0.0
(160, 31)	12.5	14.2	0.0	5.0	6.7	0.0
(31, 162)	0.0	7.2	0.0	0.0	1.5	0.0
(162, 32)	0.0	13.5	0.0	0.0	7.8	0.0
(34, 168)	0.0	11.5	0.0	0.0	2.0	0.0
(159, 30)	0.0	20.0	13.8	0.0	10.3	4.0
(30, 157)	0.0	9.1	0.0	0.0	3.3	0.0
(157, 29)	0.0	34.9	40.5	0.0	29.1	34.7
(29, 155)	0.0	7.4	0.0	0.0	2.1	0.0
(155, 28)	13.8	14.2	0.0	8.6	9.0	0.0
(28, 153)	0.0	7.5	0.0	0.0	1.5	0.0
(153, 27)	0.0	14.9	9.0	0.0	8.9	3.0
(27, 151)	0.0	8.9	0.0	0.0	1.2	0.0
(151, 27)	10.0	12.8	0.0	2.3	5.1	0.0
(27, 153)	0.0	7.4	0.0	0.0	1.4	0.0

(153, 28)	0.0	19.0	17.8	0.0	13.0	11.8
(28, 155)	0.0	7.0	0.0	0.0	1.8	0.0
(155, 29)	37.8	27.0	16.9	32.5	21.7	11.7
(29, 157)	0.0	7.9	0.0	0.0	2.1	0.0
(157, 30)	52.0	19.2	0.0	46.2	13.4	0.0
(30, 159)	0.0	11.9	0.0	0.0	2.2	0.0
(150, 26)	0.0	16.7	0.0	0.0	5.4	0.0
(26, 148)	0.0	0.0	0.0	0.0	0.0	0.0
(148, 25)	0.0	0.0	0.0	0.0	0.0	0.0
(25, 146)	0.0	6.0	0.0	0.0	0.8	0.0
(146, 24)	0.0	141.3	0.0	0.0	136.0	0.0
(24, 144)	0.0	163.5	0.0	0.0	157.5	0.0
(144, 23)	0.0	9.6	25.0	0.0	3.5	19.0
(23, 142)	0.0	9.3	0.0	0.0	1.8	0.0
(23, 144)	0.0	192.5	0.0	0.0	186.5	0.0
(144, 24)	0.0	13.5	34.0	0.0	7.5	28.0
(24, 146)	0.0	7.7	0.0	0.0	2.5	0.0
(146, 25)	0.0	15.5	0.0	0.0	10.3	0.0
(25, 148)	0.0	8.2	0.0	0.0	2.8	0.0
(148, 26)	0.0	39.2	0.0	0.0	33.8	0.0
(26, 150)	0.0	13.7	0.0	0.0	2.4	0.0
(137, 21)	0.0	13.6	0.0	0.0	8.0	0.0
(21, 137)	0.0	8.6	0.0	0.0	2.9	0.0
(137, 20)	33.0	75.8	53.7	27.4	70.2	48.0
(20, 136)	0.0	7.5	0.0	0.0	2.2	0.0
(136, 19)	186.1	26.8	0.0	180.9	21.5	0.0
(19, 134)	0.0	7.6	0.0	0.0	1.0	0.0
(134, 18)	0.0	15.8	0.0	0.0	9.2	0.0
(18, 133)	0.0	4.2	0.0	0.0	1.3	0.0
(133, 17)	0.0	12.6	5.6	0.0	9.7	2.7
(17, 130)	0.0	6.1	0.0	0.0	1.7	0.0
(130, 16)	9.6	0.0	23.0	5.2	0.0	18.6
(17, 133)	0.0	4.7	0.0	0.0	1.7	0.0
(133, 18)	0.0	16.4	0.0	0.0	13.5	0.0
(18, 134)	0.0	9.3	0.0	0.0	2.6	0.0
(134, 19)	0.0	135.6	83.7	0.0	129.0	77.1
(19, 136)	0.0	7.0	0.0	0.0	1.7	0.0
(136, 20)	48.7	63.0	86.5	43.5	57.7	81.2
(20, 137)	0.0	7.9	0.0	0.0	2.1	0.0
(12, 119)	0.0	8.0	0.0	0.0	2.3	0.0
(119, 11)	75.7	46.4	27.3	70.1	40.7	21.6
(11, 126)	0.0	10.2	0.0	0.0	2.7	0.0
(126, 15)	117.4	49.3	0.0	109.9	41.8	0.0
(15, 124)	0.0	11.5	0.0	0.0	2.2	0.0
(124, 14)	0.0	33.0	20.4	0.0	23.6	11.1
(14, 123)	0.0	7.2	0.0	0.0	2.4	0.0
(123, 13)	14.8	0.0	9.6	10.1	0.0	4.8
(140, 42)	29.6	29.6	19.2	21.7	21.7	11.4
(42, 139)	0.0	7.5	0.0	0.0	1.7	0.0
(139, 17)	0.0	18.1	12.6	0.0	12.3	6.9
(17, 131)	0.0	13.7	0.0	0.0	2.3	0.0
(131, 15)	0.0	0.0	51.4	0.0	0.0	40.1
(15, 126)	0.0	0.0	0.0	0.0	0.0	0.0
(126, 11)	0.0	0.0	0.0	0.0	0.0	0.0
(11, 119)	0.0	7.6	0.0	0.0	1.9	0.0
(12, 120)	0.0	7.3	0.0	0.0	1.4	0.0
(120, 12)	0.0	20.6	11.3	0.0	14.6	5.4

(118, 11)	88.8	126.3	59.9	83.1	120.6	54.2
(119, 12)	22.9	15.0	0.0	17.3	9.3	0.0
(121, 7)	22.4	18.5	20.9	9.8	5.9	8.3
(7, 117)	0.0	6.1	0.0	0.0	1.6	0.0
(117, 8)	10.3	16.7	0.0	5.7	12.1	0.0
(8, 9)	0.0	18.2	0.0	0.0	8.9	0.0
(9, 10)	0.0	37.9	41.8	0.0	28.5	32.4
(10, 118)	0.0	35.3	0.0	0.0	29.6	0.0
(106, 6)	0.0	27.8	23.5	0.0	21.3	17.0
(6, 190)	0.0	7.7	0.0	0.0	2.1	0.0
(190, 5)	12.2	12.7	10.3	6.6	7.1	4.7
(5, 105)	0.0	4.1	0.0	0.0	1.5	0.0
(105, 4)	11.1	5.4	0.0	8.6	2.9	0.0
(4, 104)	0.0	4.0	0.0	0.0	0.8	0.0
(104, 3)	5.0	10.1	0.0	1.8	6.9	0.0
(3, 103)	0.0	6.5	0.0	0.0	1.1	0.0
(103, 2)	0.0	10.5	0.0	0.0	5.0	0.0
(2, 102)	0.0	6.2	0.0	0.0	1.1	0.0
(1, 101)	0.0	13.2	0.0	0.0	1.9	0.0
(1, 107)	0.0	14.8	0.0	0.0	2.3	0.0
(102, 1)	18.9	21.4	19.2	13.8	16.3	14.1
(1, 102)	0.0	8.2	0.0	0.0	3.0	0.0
(102, 2)	0.0	10.0	0.0	0.0	4.9	0.0
(2, 103)	0.0	8.1	0.0	0.0	2.7	0.0
(103, 3)	0.0	30.6	0.0	0.0	25.1	0.0
(3, 104)	0.0	5.8	0.0	0.0	2.5	0.0
(104, 4)	0.0	5.3	8.2	0.0	2.0	5.0
(4, 105)	0.0	8.7	0.0	0.0	6.2	0.0
(105, 5)	15.3	15.0	6.9	12.7	12.5	4.3
(6, 106)	0.0	8.7	0.0	0.0	2.2	0.0
(190, 6)	23.0	26.7	0.0	17.4	21.0	0.0
(5, 190)	0.0	6.5	0.0	0.0	0.9	0.0
(107, 1)	43.0	35.9	33.0	30.5	23.4	20.5
(1, 111)	0.0	8.9	0.0	0.0	2.5	0.0
(111, 7)	65.8	73.8	0.0	59.4	67.4	0.0
(7, 122)	0.0	6.6	0.0	0.0	2.0	0.0
(122, 13)	0.0	25.5	0.0	0.0	20.8	0.0
(13, 127)	0.0	7.9	0.0	0.0	2.0	0.0
(127, 16)	0.0	31.7	0.0	0.0	25.7	0.0
(42, 140)	0.0	13.5	0.0	0.0	2.2	0.0
(16, 138)	0.0	5.9	0.0	0.0	1.9	0.0
(138, 42)	25.7	14.7	21.7	21.6	10.6	17.6
(42, 141)	0.0	3.2	0.0	0.0	0.8	0.0
(141, 42)	12.2	6.4	4.5	9.8	4.0	2.2
(42, 138)	0.0	5.4	0.0	0.0	1.3	0.0
(138, 16)	0.0	15.1	0.0	0.0	11.0	0.0
(16, 127)	0.0	8.5	0.0	0.0	2.5	0.0
(127, 13)	0.0	14.3	0.0	0.0	8.3	0.0
(13, 122)	0.0	5.7	0.0	0.0	1.1	0.0
(122, 7)	0.0	37.7	29.9	0.0	33.0	25.2
(7, 111)	0.0	8.4	0.0	0.0	2.0	0.0
(111, 1)	45.3	40.0	29.8	38.9	33.6	23.4
(17, 128)	0.0	6.6	0.0	0.0	0.8	0.0
(128, 14)	10.5	5.0	0.0	4.7	0.0	0.0
(14, 100)	0.0	6.8	0.0	0.0	2.2	0.0
(100, 8)	0.0	25.3	18.2	0.0	20.7	13.6
(8, 112)	0.0	8.3	0.0	0.0	2.0	0.0

(112, 2)	29.0	0.0	10.0	22.7	0.0	3.7
(3, 113)	0.0	7.5	0.0	0.0	1.4	0.0
(113, 9)	0.0	7.5	0.0	0.0	1.4	0.0
(9, 113)	0.0	0.0	0.0	0.0	0.0	0.0
(113, 3)	0.0	0.0	0.0	0.0	0.0	0.0
(178, 35)	33.5	20.0	13.3	28.1	14.5	7.9
(35, 170)	0.0	3.1	0.0	0.0	1.2	0.0
(170, 31)	0.0	15.4	7.0	0.0	13.6	5.1
(31, 161)	0.0	5.9	0.0	0.0	1.6	0.0
(161, 27)	43.5	21.5	14.7	39.2	17.2	10.3
(27, 152)	0.0	5.8	0.0	0.0	2.3	0.0
(152, 23)	0.0	0.0	0.0	0.0	0.0	0.0
(23, 143)	0.0	7.4	0.0	0.0	1.4	0.0
(143, 18)	19.5	0.0	12.0	13.5	0.0	6.0
(108, 4)	26.5	30.2	19.3	17.1	20.9	9.9
(4, 114)	0.0	8.3	0.0	0.0	2.5	0.0
(114, 10)	55.3	39.4	0.0	49.5	33.6	0.0
(10, 125)	0.0	13.2	0.0	0.0	8.7	0.0
(125, 15)	0.0	60.5	85.3	0.0	56.0	80.8
(15, 135)	0.0	121.3	0.0	0.0	115.4	0.0
(135, 19)	300.0	291.8	292.5	294.1	285.9	286.6
(19, 145)	0.0	159.2	0.0	0.0	153.0	0.0
(145, 24)	188.8	294.5	228.5	182.6	288.4	222.4
(24, 154)	0.0	5.3	0.0	0.0	1.8	0.0
(154, 28)	21.4	24.9	44.4	17.9	21.4	40.9
(28, 163)	0.0	5.2	0.0	0.0	1.9	0.0
(163, 32)	0.0	8.3	12.0	0.0	5.0	8.8
(32, 172)	0.0	2.9	0.0	0.0	1.2	0.0
(172, 36)	14.0	9.8	11.3	12.3	8.1	9.7
(36, 180)	0.0	2.7	0.0	0.0	0.7	0.0
(180, 39)	0.0	0.0	7.2	0.0	0.0	5.2
(187, 40)	0.0	20.8	17.0	0.0	17.0	13.3
(40, 182)	0.0	3.5	0.0	0.0	2.0	0.0
(182, 37)	0.0	24.8	0.0	0.0	23.3	0.0
(37, 174)	0.0	27.3	0.0	0.0	25.0	0.0
(174, 33)	5.0	8.6	0.0	2.8	6.3	0.0
(33, 165)	0.0	4.7	0.0	0.0	1.4	0.0
(165, 29)	18.5	13.7	16.7	15.3	10.5	13.4
(29, 156)	0.0	52.2	0.0	0.0	47.9	0.0
(156, 25)	0.0	185.5	0.0	0.0	181.3	0.0
(25, 147)	0.0	119.4	0.0	0.0	113.3	0.0
(20, 22)	0.0	6.5	0.0	0.0	2.2	0.0
(22, 11)	0.0	27.2	25.9	0.0	20.9	19.7
(11, 115)	0.0	15.1	0.0	0.0	8.8	0.0
(115, 5)	13.6	11.1	13.0	7.3	4.8	6.8
(5, 109)	0.0	6.3	0.0	0.0	1.2	0.0
(109, 5)	11.6	16.2	13.4	6.6	11.2	8.4
(5, 115)	0.0	31.0	0.0	0.0	24.8	0.0
(115, 11)	42.5	90.4	0.0	36.2	84.2	0.0
(11, 22)	0.0	101.9	0.0	0.0	95.6	0.0
(22, 20)	112.0	123.3	36.7	107.7	119.0	32.3
(20, 147)	0.0	73.4	0.0	0.0	67.3	0.0
(147, 25)	0.0	12.9	12.0	0.0	6.8	5.9
(25, 156)	0.0	5.8	0.0	0.0	1.6	0.0
(156, 29)	30.0	19.5	19.0	25.7	15.2	14.7
(29, 165)	0.0	4.6	0.0	0.0	1.4	0.0
(165, 33)	0.0	4.3	7.0	0.0	1.1	3.8

(33, 174)	0.0	7.4	0.0	0.0	5.2	0.0
(174, 37)	0.0	5.4	8.0	0.0	3.2	5.8
(37, 182)	0.0	2.3	0.0	0.0	0.7	0.0
(182, 40)	49.0	3.3	10.6	47.5	1.7	9.1
(40, 187)	0.0	4.2	0.0	0.0	0.5	0.0
(186, 41)	0.0	21.3	38.0	0.0	17.3	34.0
(41, 184)	0.0	3.3	0.0	0.0	1.8	0.0
(184, 38)	0.0	15.4	11.0	0.0	14.0	9.5
(38, 176)	0.0	2.4	0.0	0.0	0.5	0.0
(176, 34)	2.0	12.9	5.0	0.1	11.1	3.1
(34, 167)	0.0	5.1	0.0	0.0	2.0	0.0
(167, 30)	29.0	23.2	9.3	25.9	20.1	6.2
(30, 158)	0.0	5.6	0.0	0.0	2.3	0.0
(158, 26)	0.0	0.0	21.0	0.0	0.0	17.7
(26, 149)	0.0	0.0	0.0	0.0	0.0	0.0
(149, 21)	0.0	19.8	0.0	0.0	13.9	0.0
(21, 43)	0.0	6.3	0.0	0.0	2.2	0.0
(43, 12)	16.0	12.7	16.5	6.6	3.3	7.1
(12, 116)	0.0	6.4	0.0	0.0	2.0	0.0
(116, 6)	7.7	6.4	8.8	3.4	2.0	4.4
(6, 110)	0.0	11.4	0.0	0.0	1.2	0.0

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

APPENDIX B

TRANSYT 7F FILES

TRANSYT 7F

INPUT FILE

INITIAL CONDITIONS

THESIS															
-1	90	90	1	2	45	0	4	-1	2	1	60	0	0	0	0
2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	16	17	18	19	20	21	23	24	25	26	27	28	29	30	31
2	32	33	34	35	36	37	38	39	40	41	42				
3	2	1	13	4	3	14	6	5	15	8	7	16			
7	2407	0	0	0	0	2607	0	0	0	0	2705	0	0	0	0
7	1303	0	0	0	0	1805	0	0	0	0	1907	0	0	0	0
7	2907	0	0	0	0	2805	0	0	0	0	3301	0	0	0	0
7	503	0	0	0	0	807	0	0	0	0	1101	0	0	0	0
10	1	4	1	1700	30	35	100	30	0	85	25	40	100	125	120
12	1	4	1	50	3	2	30	3	2	0	0	0	0	0	0
21	1	1	1	2	3	25	105	106	0	0	0	0	0	0	0
22	1	4	4	5	6	18	103	-104	101	-102	0	0	0	0	0
28	102	550	0	10	0	0	0	30	0	0	0	0	0	0	0
29	102	0	0	0	15	0	0	0	103	0	0	0	0	0	0
28	101	550	3400	203	0	0	0	30	0	0	0	0	0	0	0
28	104	281	0	127	0	703	105	30	0	0	0	0	0	0	0
29	104	0	0	0	15	0	0	0	101	0	0	0	0	0	0
28	103	281	3400	286	0	708	54	30	703	231	30	0	0	0	0
28	106	225	1600	58	0	205	46	30	0	0	0	0	0	0	0
29	106	0	0	0	15	0	0	0	0	0	0	0	0	0	0
28	105	225	3400	384	0	205	353	30	204	57	30	0	0	0	0
12	2	0	1	57	3	27	3	0	0	0	0	0	0	0	0
21	2	1	1	2	0	10	205	207	-208	0	0	0	0	0	0
22	2	3	3	4	0	20	203	204	0	0	0	0	0	0	0
28	204	278	1600	201	0	803	184	30	0	0	0	0	0	0	0
29	204	0	0	0	15	0	0	0	0	0	0	0	0	0	0
28	203	278	3400	233	0	803	104	30	808	40	30	0	0	0	0
28	205	240	3400	1341	0	305	1101	30	304	281	30	0	0	0	0
28	208	225	0	10	0	0	0	0	0	0	0	0	0	0	0
29	208	0	0	0	15	0	0	0	205	0	0	0	0	0	0
28	207	225	3400	27	0	0	0	30	0	0	0	0	0	0	0
12	3	0	1	57	3	27	3	0	0	0	0	0	0	0	0
21	3	1	1	2	0	10	305	-306	307	-308	0	0	0	0	0
22	3	3	3	4	0	20	303	-304	301	-302	0	0	0	0	0
28	302	500	0	10	0	0	0	30	0	0	0	0	0	0	0
29	302	0	0	0	15	0	0	0	303	0	0	0	0	0	0
28	301	500	3400	10	0	0	0	30	0	0	0	0	0	0	0
28	304	270	0	281	0	0	0	30	0	0	0	0	0	0	0
29	304	0	0	0	15	0	0	0	301	0	0	0	0	0	0
28	303	270	3400	142	23	908	102	30	0	0	0	0	0	0	0
28	306	142	0	10	0	405	10	30	0	0	0	0	0	0	0
29	306	0	0	0	15	0	0	0	307	0	0	0	0	0	0
28	305	142	3400	1109	0	405	674	30	401	19	30	0	0	0	0
28	308	240	0	10	0	207	10	30	0	0	0	0	0	0	0
29	308	0	0	0	15	0	0	0	305	0	0	0	0	0	0
28	307	240	3400	72	0	207	27	30	203	19	30	0	0	0	0
12	4	0	1	50	3	34	3	0	0	0	0	0	0	0	0
21	4	1	1	2	0	10	405	-406	407	0	0	0	0	0	0
22	4	3	3	4	0	20	401	402	0	0	0	0	0	0	0
28	402	500	1600	10	0	0	0	30	0	0	0	0	0	0	0
28	401	500	3400	270	0	0	0	30	0	0	0	0	0	0	0
28	406	112	0	61	0	505	58	30	0	0	0	0	0	0	0
29	406	0	0	0	2	0	0	0	407	0	0	0	0	0	0
28	405	112	3400	914	0	505	674	30	504	227	30	501	19	30	0
28	407	142	3400	155	0	307	38	30	302	10	30	303	61	30	0

12	5	0	1	50	3	34	3	0	0	0	0	0	0	0
21	5	1	1	2	0	10	505	-506	507	-508	0	0	0	0
22	5	3	3	4	0	20	503	-504	501	-502	0	0	0	0
28	502	221	0	58	0	0	0	30	0	0	0	0	0	0
29	502	0	0	0	15	0	0	0	503	0	0	0	0	0
28	501	221	3400	333	0	0	0	30	0	0	0	0	0	0
28	504	275	0	127	35	1104	87	30	0	0	0	0	0	0
29	504	0	0	0	15	0	0	0	501	0	0	0	0	0
28	503	275	3400	490	0	1103	250	2530	1112	60	30	1108	43	2530
28	506	248	0	28	0	605	28	30	0	0	0	0	0	0
29	506	0	0	0	15	0	0	0	507	0	0	0	0	0
28	505	248	3400	782	0	605	476	30	604	402	30	0	0	0
28	508	112	0	23	0	407	16	30	0	0	0	0	0	0
29	508	0	0	0	15	0	0	0	505	0	0	0	0	0
28	507	112	3400	141	0	407	139	30	402	10	30	0	0	0
12	6	0	1	50	3	29	3	0	0	0	0	0	0	0
21	6	1	1	2	0	10	605	607	-608	0	0	0	0	0
22	6	3	3	4	0	20	603	604	0	0	0	0	0	0
28	604	192	1600	402	0	1203	244	30	0	0	0	0	0	0
28	603	192	3400	556	0	1203	478	30	1212	24	30	1209	156	30
28	605	285	3400	503	0	0	0	0	0	0	0	0	0	0
28	608	248	0	10	0	507	10	30	0	0	0	0	0	0
29	608	0	0	0	2	0	0	0	605	0	0	0	0	0
28	607	248	3400	193	0	507	106	30	502	58	30	503	10	30
12	7	0	1	53	3	2	29	3	2	0	0	0	0	0
21	7	1	1	2	3	20	707	708	0	0	0	0	0	0
22	7	4	4	5	6	12	703	701	-702	0	0	0	0	0
28	702	281	0	28	0	101	26	30	0	0	0	0	0	0
29	702	0	0	0	2	0	0	0	703	0	0	0	0	0
28	701	281	3400	170	0	101	83	30	106	58	30	0	0	0
28	703	206	3400	308	0	1303	294	30	1305	10	30	0	0	0
28	708	555	1600	54	0	0	0	0	0	0	0	0	0	0
28	707	555	3400	677	0	0	0	0	0	0	0	0	0	0
12	8	0	1	55	3	2	25	3	2	0	0	0	0	0
21	8	1	1	2	3	12	807	808	0	0	0	0	0	0
22	8	4	4	5	6	11	803	0	0	0	0	0	0	0
28	803	200	3400	205	0	1403	127	30	1405	98	30	0	0	0
28	808	202	1600	40	0	707	36	30	0	0	0	0	0	0
28	807	202	3400	651	0	707	540	2530	702	28	30	703	77	30
11	9	0	0	0	0	0	0	0	0	0	0	0	0	0
21	9	0	0	0	0	0	907	908	901	902	0	0	0	0
28	902	270	1700	22	6	301	10	30	0	0	0	0	0	0
28	901	270	3400	106	0	301	10	30	306	10	30	307	62	30
28	908	412	1700	110	0	807	105	30	0	0	0	0	0	0
28	907	412	3400	711	0	807	611	30	803	101	30	0	0	0
12	10	0	1	35	3	2	45	3	2	0	0	0	0	0
21	10	1	1	2	3	20	1007	0	0	0	0	0	0	0
22	10	4	4	5	6	25	1001	1002	0	0	0	0	0	0
28	1002	255	1600	152	0	401	92	30	0	0	0	0	0	0
28	1001	255	3400	406	0	401	261	30	406	61	30	407	116	30
28	1007	412	3400	711	0	907	611	30	902	22	30	0	0	0
13	11	0	1	32	3	29	3	20	3	0	0	0	0	0
21	11	1	1	2	0	10	1111-1112	1109-1110	0	0	0	0	0	0
22	11	3	3	4	0	20	1101-1102	1103-1104	0	0	0	0	0	0
23	11	5	5	6	0	15	1107	1108	0	0	0	0	0	0
28	1102	275	0	68	0	501	58	2525	0	0	0	0	0	0
29	1102	0	0	0	2	0	0	0	1103	0	0	0	0	0

28	1101	275	3400	312	0	501	256	30	506	28	30	507	12	30	0
28	1109	248	3400	324	0	1209	156	30	1204	10	30	0	0	0	0
28	1104	274	0	91	3	2003	75	30	0	0	0	0	0	0	0
29	1104	0	0	0	12	0	0	0	1101	0	0	0	0	0	0
28	1103	274	3400	417	38	2003	299	30	2008	24	30	2005	46	30	0
28	1110	248	0	165	0	1209	154	30	0	0	0	0	0	0	0
29	1110	0	0	0	2	0	0	0	1111	0	0	0	0	0	0
28	1111	330	3400	300	0	1511	275	30	1502	10	30	0	0	0	0
28	1108	248	1600	64	0	1007	63	30	0	0	0	0	0	0	0
28	1107	248	3400	605	0	1007	509	30	1002	88	30	0	0	0	0
28	1112	330	0	60	11	1511	46	30	0	0	0	0	0	0	0
29	1112	0	0	0	2	0	0	0	1109	0	0	0	0	0	0
12	12	0	1	40	3	44	3	0	0	0	0	0	0	0	0
21	12	1	1	2	0	10	1209	1211-1212	0	0	0	0	0	0	0
22	12	3	3	4	0	11	1203	1204	0	0	0	0	0	0	0
28	1209	262	3400	172	0	0	0	0	0	0	0	0	0	0	0
28	1204	412	1600	180	0	2103	135	30	0	0	0	0	0	0	0
28	1203	412	3400	902	0	2103	331	30	2108	130	30	2105	121	30	0
28	1211	248	3400	657	0	1111	417	30	1102	68	30	1107	64	30	0
28	1212	248	0	24	0	1111	21	30	0	0	0	0	0	0	0
29	1212	0	0	0	2	0	0	0	1209	0	0	0	0	0	0
12	13	0	1	40	3	44	3	0	0	0	0	0	0	0	0
21	13	1	1	2	0	20	1305	1306	0	0	0	0	0	0	0
22	13	3	3	4	0	22	1303-1304	1301	0	0	0	0	0	0	0
28	1301	206	3400	245	0	701	142	30	707	83	30	0	0	0	0
28	1304	262	0	10	0	1603	10	30	0	0	0	0	0	0	0
29	1304	0	0	0	15	0	0	0	1301	0	0	0	0	0	0
28	1303	262	3400	294	0	1603	219	2520	1605	55	30	0	0	0	0
28	1306	210	1600	147	0	1405	120	30	0	0	0	0	0	0	0
28	1305	210	3400	192	0	1405	128	30	1404	52	30	0	0	0	0
12	14	0	1	30	3	54	3	0	0	0	0	0	0	0	0
21	14	1	1	2	0	10	1405	0	0	0	0	0	0	0	0
22	14	3	3	4	0	30	1403	1404	0	0	0	0	0	0	0
28	1404	255	1600	152	0	1712	56	30	1705	81	30	0	0	0	0
28	1403	255	3400	179	0	1712	56	30	1705	121	30	0	0	0	0
28	1405	412	3400	226	0	1509	78	30	1501	140	30	0	0	0	0
13	15	0	1	30	3	2	30	3	2	15	3	2	0	0	0
21	15	1	1	2	3	15	1509-1510	1511	0	0	0	0	0	0	0
22	15	4	4	5	6	15	1501	1502	0	0	0	0	0	0	0
23	15	7	7	8	9	15	1510	0	0	0	0	0	0	0	0
28	1502	199	1600	10	0	1001	10	30	0	0	0	0	0	0	0
28	1501	199	3400	497	0	1001	254	30	1007	202	30	0	0	0	0
28	1509	330	3400	169	0	1109	31	30	1107	64	30	1102	68	30	0
28	1510	330	1600	91	0	1109	82	30	0	0	0	0	0	0	0
29	1510	0	0	0	2	0	0	0	1511	0	0	0	0	0	0
28	1511	500	3400	285	0	1711	130	30	1705	121	30	0	0	0	0
12	16	0	1	35	3	49	3	0	0	0	0	0	0	0	0
21	16	1	1	2	0	20	1605	1606	0	0	0	0	0	0	0
22	16	3	3	4	0	25	1601	1603-1604	0	0	0	0	0	0	0
28	1601	262	3400	392	0	1301	245	2505	1306	147	30	0	0	0	0
28	1604	180	0	10	0	4203	10	30	0	0	0	0	0	0	0
29	1604	0	0	0	15	0	0	0	1601	0	0	0	0	0	0
28	1603	180	3400	219	0	4203	219	30	4208	25	30	0	0	0	0
28	1606	195	1600	176	0	1705	108	30	0	0	0	0	0	0	0
28	1605	195	3400	231	0	1705	154	30	1712	56	30	0	0	0	0
12	17	0	1	57	3	27	3	0	0	0	0	0	0	0	0
21	17	1	1	2	0	30	1705	0	0	0	0	0	0	0	0
22	17	3	3	4	0	12	1711	1712	0	0	0	0	0	0	0

28	1705	128	3400	275	0	1805	149	30	1804	124	30	0	0	0	0
28	1711	255	3400	346	0	4207	115	30	4202	55	30	4203	104	30	0
28	1712	255	3400	56	0	4207	51	30	0	0	0	0	0	0	0
12	18	0	1	39	3	45	3	0	0	0	0	0	0	0	0
21	18	1	1	2	0	20	1805	1807-1808	0	0	0	0	0	0	0
22	18	3	3	4	0	25	1803	1804	0	0	0	0	0	0	0
28	1804	264	1600	124	0	2303	120	30	0	0	0	0	0	0	0
28	1803	264	3400	214	0	2303	120	30	2308	59	30	2305	35	30	0
28	1805	292	3400	179	0	1905	108	2525	1901	76	30	0	0	0	0
28	1808	128	0	10	0	0	0	0	0	0	0	0	0	0	0
29	1808	0	0	0	15	0	0	0	1805	0	0	0	0	0	0
28	1807	128	3400	137	0	1711	130	30	0	0	0	0	0	0	0
12	19	0	1	35	3	49	3	0	0	0	0	0	0	0	0
21	19	1	1	2	0	20	1905-1906	1907	0	0	0	0	0	0	0
22	19	3	3	4	0	25	1901	1902	0	0	0	0	0	0	0
28	1902	260	1600	95	0	1501	89	30	0	0	0	0	0	0	0
28	1901	260	3400	541	0	1501	357	30	1510	91	30	1511	85	30	0
28	1906	232	0	70	0	2005	70	30	0	0	0	0	0	0	0
29	1906	0	0	0	15	0	0	0	1907	0	0	0	0	0	0
28	1905	232	3400	178	0	2005	110	30	2004	10	30	2001	31	30	0
28	1907	292	3400	261	0	1807	37	2520	1803	190	30	0	0	0	0
12	20	0	1	41	3	43	3	0	0	0	0	0	0	0	0
21	20	1	1	2	0	12	2005	2007-2008	2006	0	0	0	0	0	0
22	20	3	3	4	0	28	2001-2002	2003-2004	0	0	0	0	0	0	0
28	2002	191	0	65	0	1101	61	30	0	0	0	0	0	0	0
29	2002	0	0	0	15	0	0	0	2003	0	0	0	0	0	0
28	2001	191	3400	500	0	1101	224	30	1110	165	30	1107	64	30	0
28	2004	270	0	10	0	2503	10	30	0	0	0	0	0	0	0
29	2004	0	0	0	15	0	0	0	2001	0	0	0	0	0	0
28	2003	270	3400	385	0	2503	400	30	2508	10	30	2505	10	30	0
28	2006	255	1600	247	0	2605	205	30	0	0	0	0	0	0	0
28	2005	255	3400	240	0	2105	115	30	2104	91	30	0	0	0	0
28	2008	232	0	24	0	1907	24	30	0	0	0	0	0	0	0
29	2008	0	0	0	15	0	0	0	2005	0	0	0	0	0	0
28	2007	232	3400	238	0	1907	138	30	1902	95	30	0	0	0	0
12	21	0	1	36	3	48	3	0	0	0	0	0	0	0	0
21	21	1	1	2	0	20	2105	2107-2108	0	0	0	0	0	0	0
22	21	3	3	4	0	25	2103	2104	0	0	0	0	0	0	0
28	2104	259	1600	91	0	2603	82	30	0	0	0	0	0	0	0
28	2103	259	3400	469	0	2603	301	30	2608	67	30	2605	51	30	0
28	2105	500	3400	236	0	0	0	0	0	0	0	0	0	0	0
28	2108	255	0	130	0	2007	98	30	0	0	0	0	0	0	0
29	2108	0	0	0	15	0	0	0	2105	0	0	0	0	0	0
28	2107	255	3400	243	0	2007	106	30	2003	39	30	2002	65	30	0
12	23	0	1	47	3	37	3	0	0	0	0	0	0	0	0
21	23	1	1	2	0	28	2305	2307-2308	0	0	0	0	0	0	0
22	23	3	3	4	0	17	2303	2304	0	0	0	0	0	0	0
28	2304	150	1600	35	0	2703	22	30	0	0	0	0	0	0	0
28	2303	150	3400	220	0	2703	90	30	2708	18	30	2705	60	30	0
28	2305	266	3400	247	0	2405	183	2540	2401	42	30	0	0	0	0
28	2308	330	0	59	0	0	0	0	0	0	0	0	0	0	0
29	2308	0	0	0	15	0	0	0	2305	0	0	0	0	0	0
28	2307	330	3400	306	0	0	0	0	0	0	0	0	0	0	0
12	24	0	1	37	3	47	3	0	0	0	0	0	0	0	0
21	24	1	1	2	0	20	2405-2406	2407	0	0	0	0	0	0	0
22	24	3	3	4	0	25	2401	2402	0	0	0	0	0	0	0

28	2402	270	1600	19	0	1901	18	30	0	0	0	0	0	0
28	2401	270	3400	844	0	1901	360	30	1906	70	30	1907	99	30
28	2406	229	0	56	0	2505	50	30	0	0	0	0	0	0
29	2406	0	0	0	15	0	0	0	2407	0	0	0	0	0
28	2407	266	3400	315	0	2307	247	2530	2303	65	30	0	0	0
28	2405	229	3400	239	0	2505	188	30	2504	10	30	2501	10	30
12	25	0	1	30	3	54	3	0	0	0	0	0	0	0
21	25	1	1	2	0	16	2505-2506	2507-2508		0	0	0	0	0
22	25	3	3	4	0	29	2501-2502	2503-2504		0	0	0	0	0
28	2505	236	3400	244	0	2605	202	2520	2604	50	30	0	0	0
28	2506	236	0	10	0	2605	10	30	0	0	0	0	0	0
29	2506	0	0	0	15	0	0	0	2507	0	0	0	0	0
28	2507	229	3400	343	0	2407	259	30	2402	19	30	0	0	0
28	2508	229	0	10	0	2407	10	30	0	0	0	0	0	0
29	2508	0	0	0	15	0	0	0	2505	0	0	0	0	0
28	2501	270	3400	616	0	2001	402	30	2006	47	30	2007	38	30
28	2502	270	0	10	0	2001	10	30	0	0	0	0	0	0
29	2502	0	0	0	15	0	0	0	2503	0	0	0	0	0
28	2503	188	3400	418	0	2903	341	30	2908	68	30	2905	16	30
28	2504	188	0	10	0	2903	10	30	0	0	0	0	0	0
29	2504	0	0	0	15	0	0	0	2501	0	0	0	0	0
12	26	0	1	40	3	2	40	3	2	0	0	0	0	0
21	26	1	1	2	3	20	2605	2607-2608		0	0	0	0	0
22	26	4	4	5	6	20	2603	2604	0	0	0	0	0	0
28	2605	495	3400	256	0	0	0	0	0	0	0	0	0	0
28	2607	236	3400	330	0	2507	271	2550	2502	10	30	2503	10	30
28	2608	236	0	67	0	2507	59	30	0	0	0	0	0	0
29	2608	0	0	0	15	0	0	0	2605	0	0	0	0	0
28	2603	146	3400	465	0	3003	392	30	3008	83	30	3005	34	30
28	2604	146	1600	50	0	3003	50	30	0	0	0	0	0	0
12	27	0	1	57	3	5	22	3	0	0	0	0	0	0
21	27	1	1	2	3	33	2705	2707-2708		0	0	0	0	0
22	27	4	4	5	0	12	2703	2704	0	0	0	0	0	0
28	2705	262	3400	337	0	2805	205	2520	2801	115	30	0	0	0
28	2707	338	3400	234	0	0	0	0	0	0	0	0	0	0
28	2708	338	0	18	0	0	0	0	0	0	0	0	0	0
29	2708	0	0	0	15	0	0	0	2705	0	0	0	0	0
28	2703	191	3400	141	0	3103	96	30	3108	28	30	3105	40	30
28	2704	191	1600	12	0	3103	12	30	0	0	0	0	0	0
12	28	0	1	46	3	1	36	3	1	0	0	0	0	0
21	28	1	1	2	3	26	2805	2806	2807	0	0	0	0	0
22	28	4	4	5	6	18	2801	2802	0	0	0	0	0	0
28	2805	232	3400	259	0	2905	70	2525	2904	59	30	2901	37	30
28	2806	232	1600	54	7	2905	45	30	0	0	0	0	0	0
29	2806	0	0	0	15	0	0	0	2807	0	0	0	0	0
28	2807	262	3400	242	0	2707	216	30	2703	39	30	0	0	0
28	2801	154	3400	862	0	2401	701	30	2406	56	30	2407	53	30
28	2802	154	1600	149	0	2401	82	30	0	0	0	0	0	0
13	29	0	1	36	3	1	31	3	1	12	3	1	0	0
21	29	1	1	2	3	18	2905-2906	2907-2908		0	0	0	0	0
22	29	4	4	5	6	16	2901-2902	2903-2904		0	0	0	0	0
23	29	7	7	8	9	10	2902	2904	0	0	0	0	0	0
28	2905	255	3400	146	0	3005	65	30	3004	40	30	0	0	0
28	2906	255	0	35	0	3005	20	30	0	0	0	0	0	0
29	2906	0	0	0	2	0	0	0	2907	0	0	0	0	0
28	2907	232	3400	449	0	2807	156	2530	2802	149	30	0	0	0
28	2908	232	0	68	0	2807	51	30	0	0	0	0	0	0
29	2908	0	0	0	2	0	0	0	2905	0	0	0	0	0

28	2901	188	3400	455	0	2501	464	30	2506	10	30	2507	10	30	0
28	2902	188	1600	48	0	2501	48	30	0	0	0	0	0	0	0
29	2902	0	0	0	2	0	0	0	2903	0	0	0	0	0	0
28	2903	142	3400	425	0	3303	300	30	3305	13	30	0	0	0	0
28	2904	142	1600	59	0	3303	46	30	0	0	0	0	0	0	0
29	2904	0	0	0	2	0	0	0	2901	0	0	0	0	0	0
12	30	0	1	41	3	1	46	3	1	0	0	0	0	0	0
21	30	1	1	2	3	20	3005	3007-3008	0	0	0	0	0	0	0
22	30	4	4	5	6	25	3003	3004	0	0	0	0	0	0	0
28	3005	428	3400	119	0	0	0	0	0	0	0	0	0	0	0
28	3007	255	3400	370	0	2907	219	30	2902	48	30	2903	24	30	0
28	3008	255	0	83	0	2907	70	30	0	0	0	0	0	0	0
29	3008	0	0	0	15	0	0	0	3005	0	0	0	0	0	0
28	3003	135	3400	507	0	3403	321	2530	3405	17	30	0	0	0	0
28	3004	135	1600	40	0	3403	30	30	0	0	0	0	0	0	0
12	31	0	1	45	3	39	3	0	0	0	0	0	0	0	0
21	31	1	1	2	0	28	3105	3107-3108	0	0	0	0	0	0	0
22	31	3	3	4	0	17	3103	3104	0	0	0	0	0	0	0
28	3105	251	3400	137	0	3205	73	30	3201	42	30	0	0	0	0
28	3107	330	3400	84	0	0	0	0	0	0	0	0	0	0	0
28	3108	330	0	28	0	0	0	0	0	0	0	0	0	0	0
29	3108	0	0	0	15	0	0	0	3105	0	0	0	0	0	0
28	3103	82	3400	133	0	3503	64	30	3508	19	30	3505	28	30	0
28	3104	82	1600	11	0	3503	11	30	0	0	0	0	0	0	0
12	32	0	1	52	3	32	3	0	0	0	0	0	0	0	0
21	32	1	1	2	0	28	3207	0	0	0	0	0	0	0	0
22	32	3	3	4	0	16	3201	3205-3206	0	0	0	0	0	0	0
28	3207	251	1600	86	0	3107	56	30	3103	16	30	0	0	0	0
28	3201	142	3400	752	0	2801	598	30	2806	54	30	2807	35	30	0
28	3205	236	3400	101	0	3305	45	30	3304	18	30	3301	20	30	0
28	3206	236	0	28	0	3305	18	30	0	0	0	0	0	0	0
29	3206	0	0	0	15	0	0	0	3207	0	0	0	0	0	0
13	33	0	1	17	3	12	3	52	3	0	0	0	0	0	0
21	33	1	1	2	0	10	3305	3306	0	0	0	0	0	0	0
22	33	3	3	4	0	10	3304	0	0	0	0	0	0	0	0
23	33	5	5	6	0	25	3301	3303-3304	0	0	0	0	0	0	0
28	3305	251	3400	103	0	3405	36	30	3404	37	30	0	0	0	0
28	3306	251	1600	27	0	3405	14	30	0	0	0	0	0	0	0
28	3301	142	3400	512	0	2901	370	2540	2906	35	30	2907	92	30	0
28	3303	98	3400	364	0	3703	319	30	3708	31	30	3705	20	30	0
28	3304	98	1600	18	0	3703	18	30	0	0	0	0	0	0	0
29	3304	0	0	0	15	0	0	0	3301	0	0	0	0	0	0
12	34	0	1	42	3	42	3	0	0	0	0	0	0	0	0
21	34	1	1	2	0	22	3405	0	0	0	0	0	0	0	0
22	34	3	3	4	0	22	3403	3404	0	0	0	0	0	0	0
28	3405	417	3400	67	0	0	0	0	0	0	0	0	0	0	0
28	3404	82	1600	37	0	3803	28	30	0	0	0	0	0	0	0
28	3403	82	3400	396	0	3803	298	30	3808	47	30	3805	40	30	0
12	35	0	1	57	3	27	3	0	0	0	0	0	0	0	0
21	35	1	1	2	0	28	3505	3507-3508	0	0	0	0	0	0	0
22	35	3	3	4	0	13	3503	3504	0	0	0	0	0	0	0
28	3505	255	3400	444	0	3605	308	30	3601	88	30	0	0	0	0
28	3507	330	3400	611	0	0	0	0	0	0	0	0	0	0	0
28	3508	330	0	19	0	0	0	0	0	0	0	0	0	0	0
29	3508	0	0	0	15	0	0	0	3505	0	0	0	0	0	0
28	3503	240	3400	202	0	0	0	0	0	0	0	0	0	0	0
28	3504	240	1600	99	0	0	0	0	0	0	0	0	0	0	0
12	36	0	1	47	3	37	3	0	0	0	0	0	0	0	0

21	36	1	1	2	0	25	3605-3606	3607	0	0	0	0	0	0
22	36	3	3	4	0	20	3601	3602	0	0	0	0	0	0
28	3605	225	3400	309	0	3705	281	30	3704	10	30	3701	48	30
28	3606	225	0	10	0	3705	10	30	0	0	0	0	0	0
29	3606	0	0	0	15	0	0	0	3607	0	0	0	0	0
28	3607	255	3400	643	0	3507	578	30	3503	28	30	0	0	0
28	3601	74	3400	827	0	3201	618	30	3206	28	30	3207	86	30
28	3602	74	1600	125	0	3201	92	30	0	0	0	0	0	0
12	37	0	1	47	3	37	3	0	0	0	0	0	0	0
21	37	1	1	2	0	27	3705-3706	3707-3708	0	0	0	0	0	0
22	37	3	3	4	0	18	3701-3702	3703-3704	0	0	0	0	0	0
28	3705	245	3400	307	0	3805	267	30	3804	30	30	0	0	0
28	3706	245	0	10	0	3805	10	30	0	0	0	0	0	0
29	3706	0	0	0	15	0	0	0	3707	0	0	0	0	0
28	3707	225	3400	774	0	3607	598	30	3602	125	30	0	0	0
28	3708	225	0	31	0	3607	26	30	0	0	0	0	0	0
29	3708	0	0	0	15	0	0	0	3705	0	0	0	0	0
28	3701	98	3400	510	0	3301	488	30	3306	27	30	0	0	0
28	3702	98	0	10	0	3301	10	30	0	0	0	0	0	0
29	3702	0	0	0	15	0	0	0	3703	0	0	0	0	0
28	3703	68	3400	381	0	0	0	0	0	0	0	0	0	0
28	3704	68	0	10	0	0	0	0	0	0	0	0	0	0
29	3704	0	0	0	15	0	0	0	3701	0	0	0	0	0
12	38	0	1	45	3	1	37	3	1	0	0	0	0	0
21	38	1	1	2	3	26	3805	3807-3808	0	0	0	0	0	0
22	38	4	4	5	6	18	3803	3804	0	0	0	0	0	0
28	3805	450	3400	312	0	0	0	0	0	0	0	0	0	0
28	3807	245	3400	652	0	3707	675	30	3702	10	30	3703	35	30
28	3808	245	0	47	0	3707	47	30	0	0	0	0	0	0
29	3808	0	0	0	2	0	0	0	3805	0	0	0	0	0
28	3803	56	3400	422	0	0	0	30	0	0	0	0	0	0
28	3804	56	1600	30	0	0	0	0	0	0	0	0	0	0
12	39	0	1	47	3	37	3	0	0	0	0	0	0	0
21	39	1	1	2	0	25	3905-3906	3907	0	0	0	0	0	0
22	39	3	3	4	0	20	3901	3902	0	0	0	0	0	0
28	3905	214	3400	614	0	0	0	30	0	0	0	0	0	0
28	3906	214	0	13	0	0	0	0	0	0	0	0	0	0
29	3906	0	0	0	15	0	0	0	3907	0	0	0	0	0
28	3907	488	3400	442	0	0	0	0	0	0	0	0	0	0
28	3901	86	3400	585	0	3601	579	30	3606	10	30	3607	19	30
28	3902	86	1600	35	0	3601	35	30	0	0	0	0	0	0
12	40	0	1	37	3	47	3	0	0	0	0	0	0	0
21	40	1	1	2	0	18	4005-4006	4007-4008	0	0	0	0	0	0
22	40	3	3	4	0	28	4001-4002	4003-4004	0	0	0	0	0	0
28	4005	255	3400	257	0	4105	348	30	4104	33	30	0	0	0
28	4006	255	0	14	0	4105	14	30	0	0	0	0	0	0
29	4006	0	0	0	15	0	0	0	3907	0	0	0	0	0
28	4007	214	3400	461	0	3907	387	30	3902	35	30	0	0	0
28	4008	214	0	42	0	3907	38	30	0	0	0	0	0	0
29	4008	0	0	0	15	0	0	0	4005	0	0	0	0	0
28	4001	68	3400	429	0	3701	409	30	3706	10	30	3707	21	30
28	4002	68	0	49	0	3701	49	30	0	0	0	0	0	0
29	4002	0	0	0	15	0	0	0	4003	0	0	0	0	0
28	4003	165	3400	461	0	0	0	0	0	0	0	0	0	0
28	4004	165	0	63	0	0	0	0	0	0	0	0	0	0
29	4004	0	0	0	15	0	0	0	4001	0	0	0	0	0
12	41	0	1	47	3	37	3	0	0	0	0	0	0	0

21	41	1	1	2	0	28	4105	4107-4108	0	0	0	0	0	0
22	41	3	3	4	0	18	4103	4104	0	0	0	0	0	0
28	4105	244	3400	410	0	0	0	0	0	0	0	0	0	0
28	4107	255	3400	555	0	4007	342	30	4002	49	30	4003	57	30
28	4108	255	0	89	0	4007	63	30	4002	11	30	0	0	0
29	4108	0	0	0	15	0	0	0	4105	0	0	0	0	0
28	4103	56	3400	341	0	0	0	0	0	0	0	0	0	0
28	4104	56	1700	33	0	0	0	0	0	0	0	0	0	0
12	42	0	1	35	3	2	45	3	2	0	0	0	0	0
21	42	1	1	2	3	18	4207	4208	0	0	0	0	0	0
22	42	4	4	5	6	27	4201-4202	4203-4204	0	0	0	0	0	0
28	4207	345	3400	210	0	0	0	0	0	0	0	0	0	0
28	4208	345	1600	25	0	0	0	0	0	0	0	0	0	0
28	4201	180	3400	530	0	1601	342	30	1606	176	30	0	0	0
28	4202	180	0	55	0	1601	50	30	0	0	0	0	0	0
29	4202	0	0	0	2	0	0	0	4203	0	0	0	0	0
28	4203	105	3400	371	0	0	0	0	0	0	0	0	0	0
28	4204	105	0	48	0	0	0	0	0	0	0	0	0	0
29	4204	0	0	0	2	0	0	0	4201	0	0	0	0	0
39	75	503	807	1102	1303	1805	1907	2407	2607	2705	2805	2907	3301	0
52	2	0	0											1
90														1

TRANSYT 7F

OUTPUT FILE

OPTIMAL CONDITIONS

<PERFORMANCE WITH OPTIMAL SETTINGS>

All MOEs are in units per hour.

THESIS

CYCLE: 60 Seconds, 13 Steps

SYSTEM-WIDE PERFORMANCE: ALL NODES

PERFORMANCE MEASURES	UNITS	BUSES	OTHER	SYSTEM TOTALS
Total Travel	veh-mi/hr	241	2167	2408
Total Travel Time	veh-hr/hr	74	132	206
Total Uniform Delay	veh-hr/hr	10	58	68
Total Random Delay	veh-hr/hr	0	1	1
Total Delay	veh-hr/hr	10	60	69
Average Delay	sec/veh	6.3	4.5	4.7
Passenger Delay	pax-hr/hr	12	72	83
Stops: Total	veh/hr	2294	12397	14692
Percentage	%	41	26	28
System Speed	mph	3.3	16.4	11.7
Fuel Consumption	gal/hr	65	203	268
Operating Cost	\$/hr	234	1368	1602
Performance Index	DI			313.8

Performance Index (PI): Disutility Index (DI):
Disutility Index Total Operating Cost

No. of Simulations = 893, Links = 51221 Elapsed Time = 302.9 sec.

TRANSYT-7F TRAFFIC SIGNAL TIMING TABLES

NETWORK-WIDE SIGNAL TIMING PARAMETERS

SYSTEM CYCLE LENGTH = 60 SECONDS

MASTER OFFSET REFERENCE LOCATION = INTERSECTION NO. 41 START OF INTERVAL 1.

Key to Interval Types:

F : Fixed green.

V : Variable green.

Y : Yellow.

R : All-red.

An 'M' by an interval length means this is the minimum time available.

INTERSECTION CONTROLLER SETTINGS

INTERSECTION 1 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6
Intvl Length(sec): 33 3 2 17 3 2
Intvl Length (%) : 56 5 3 28 5 3
Pin Settings (%) : 100/0 56 61 64 92 97
Phase Start (No.): 1 2
Interval Type : V Y R V Y R
Splits (sec): 38 22
Splits (%): 64 36
Links Moving : 105 103
 106 -104
 101
 -102
Offset = 16 sec 27 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 2 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4
Intvl Length(sec): 37 3 17M 3
Intvl Length (%) : 62 5 28 5
Pin Settings (%) : 100/0 62 67 95
Phase Start (No.): 1 2
Interval Type : V Y V Y
Splits (sec): 40 20
Splits (%): 67 33
Links Moving : 205 203
 207 204
 -208
Offset = 59 sec 98 %.

INTERSECTION 3 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4
Intvl Length(sec): 32 3 22 3
Intvl Length (%): 53 5 37 5
Pin Settings (%): 100/0 53 58 95
Phase Start (No.): 1 2
Interval Type : V Y V Y
Splits (sec): 35 25
Splits (%): 58 42

Links Moving : 305 303
 -306 -304
 307 301
 -308 -302

Offset = 55 sec 92 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 4 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4
Intvl Length(sec): 37 3 17M 3
Intvl Length (%): 62 5 28 5
Pin Settings (%): 100/0 62 67 95
Phase Start (No.): 1 2
Interval Type : V Y V Y
Splits (sec): 40 20
Splits (%): 67 33

Links Moving : 405 401
 -406 402
 407

Offset = 45 sec 75 %.

INTERSECTION 5 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 24 3 30 3

Intvl Length (%) : 40 5 50 5

Pin Settings (%) : 100/0 40 45 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 27 33

Splits (%): 45 55

Links Moving : 505 503

 -506 -504

 507 501

 -508 -502

Offset = 51 sec 85 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 6 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 14 3 40 3

Intvl Length (%) : 23 5 67 5

Pin Settings (%) : 100/0 23 28 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 17 43

Splits (%): 28 72

Links Moving : 605 603

 607 604

 -608

Offset = 50 sec 83 %.

INTERSECTION 7 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6

Intvl Length(sec) : 35 3 2 15 3 2

Intvl Length (%) : 59 5 3 25 5 3

Pin Settings (%) : 100/0 59 64 67 92 97

Phase Start (No.) : 1 2

Interval Type : V Y R V Y R

Splits (sec) : 40 20

Splits (%) : 67 33

Links Moving : 707 703
 708 701
 -702

Offset = 11 sec 18 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 8 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6

Intvl Length(sec) : 40 3 2 10 3 2

Intvl Length (%) : 67 5 3 17 5 3

Pin Settings (%) : 100/0 67 72 75 92 97

Phase Start (No.) : 1 2

Interval Type : V Y R V Y R

Splits (sec) : 45 15

Splits (%) : 75 25

Links Moving : 807 803
 808

Offset = 52 sec 87 %.

INTERSECTION 9 PRETIMED - SPLITS OPTIMIZED

This node has only one phase, no signal timing.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 10 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6

Intvl Length(sec): 25 3 2 25 3 2

Intvl Length (%): 42 5 3 42 5 3

Pin Settings (%): 100/0 42 47 50 92 97

Phase Start (No.): 1 2

Interval Type : V Y R V Y R

Splits (sec): 30 30

Splits (%): 50 50

Links Moving : 1007 1001
1002

Offset = 52 sec 87 %.

INTERSECTION 11 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6

Intvl Length(sec): 11 3 27 3 13 3

Intvl Length (%): 18 5 45 5 22 5

Pin Settings (%): 100/0 18 23 68 73 95

Phase Start (No.): 1 2 3

Interval Type : V Y V Y V Y

Splits (sec): 14 30 16

Splits (%): 23 50 27

Links Moving : 1111 1101 1107
-1112 -1102 1108
1109 1103
-1110 -1104

Offset = 8 sec 13 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 12 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec) : 18 3 36 3

Intvl Length (%) : 30 5 60 5

Pin Settings (%) : 100/0 30 35 95

Phase Start (No.) : 1 2

Interval Type : V Y V Y

Splits (sec) : 21 39

Splits (%) : 35 65

Links Moving : 1209 1203
 1211 1204
 -1212

Offset = 8 sec 13 %.

INTERSECTION 13 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec) : 27 3 27 3

Intvl Length (%) : 45 5 45 5

Pin Settings (%) : 100/0 45 50 95

Phase Start (No.) : 1 2

Interval Type : V Y V Y

Splits (sec) : 30 30

Splits (%) : 50 50

Links Moving : 1305 1303
 1306 -1304
 1301

Offset = 19 sec 32 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 14 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 9 3 45 3

Intvl Length (%): 15 5 75 5

Pin Settings (%): 100/0 15 20 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 12 48

Splits (%): 20 80

Links Moving : 1405 1403
1404

Offset = 33 sec 55 %.

INTERSECTION 15 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6 7 8 9

Intvl Length(sec): 12 3 2 23 3 2 10M 3 2

Intvl Length (%): 20 5 3 39 5 3 17 5 3

Pin Settings (%): 100/0 20 25 28 67 72 75 92 97

Phase Start (No.): 1 2 3

Interval Type : V Y R V Y R V Y R

Splits (sec): 17 28 15

Splits (%): 28 47 25

Links Moving : 1509 1501 1510
-1510 1502
1511

Offset = 6 sec 10 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 16 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4
Intvl Length(sec): 31 3 23 3
Intvl Length (%): 52 5 38 5
Pin Settings (%): 100/0 52 57 95
Phase Start (No.): 1 2
Interval Type : V Y V Y
Splits (sec): 34 26
Splits (%): 57 43
Links Moving : 1605 1601
1606 1603
-1604

Offset = 3 sec 5 %.

INTERSECTION 17 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4
Intvl Length(sec): 27M 3 27 3
Intvl Length (%): 45 5 45 5
Pin Settings (%): 100/0 45 50 95
Phase Start (No.): 1 2
Interval Type : V Y V Y
Splits (sec): 30 30
Splits (%): 50 50
Links Moving : 1705 1711
1712

Offset = 59 sec 98 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 18 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4
Intvl Length(sec): 30 3 24 3
Intvl Length (%): 50 5 40 5
Pin Settings (%): 100/0 50 55 95
Phase Start (No.): 1 2
Interval Type : V Y V Y
Splits (sec): 33 27
Splits (%): 55 45
Links Moving : 1805 1803
1807 1804
-1808

Offset = 27 sec 45 %.

INTERSECTION 19 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4
Intvl Length(sec): 27 3 27 3
Intvl Length (%): 45 5 45 5
Pin Settings (%): 100/0 45 50 95
Phase Start (No.): 1 2
Interval Type : V Y V Y
Splits (sec): 30 30
Splits (%): 50 50
Links Moving : 1905 1901
-1906 1902
1907

Offset = 54 sec 90 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 20 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4
Intvl Length(sec) : 28 3 26 3
Intvl Length (%) : 47 5 43 5
Pin Settings (%) : 100/0 47 52 95
Phase Start (No.) : 1 2
Interval Type : V Y V Y
Splits (sec) : 31 29
Splits (%) : 52 48

Links Moving : 2005 2001
 2007 -2002
 -2008 2003
 2006 -2004

Offset = 50 sec 83 %.

INTERSECTION 21 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4
Intvl Length(sec) : 27 3 27 3
Intvl Length (%) : 45 5 45 5
Pin Settings (%) : 100/0 45 50 95
Phase Start (No.) : 1 2
Interval Type : V Y V Y
Splits (sec) : 30 30
Splits (%) : 50 50

Links Moving : 2105 2103
 2107 2104
 -2108

Offset = 53 sec 88 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 23 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 37 3 17 3

Intvl Length (%): 62 5 28 5

Pin Settings (%): 100/0 62 67 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 40 20

Splits (%): 67 33

Links Moving : 2305 2303
2307 2304
-2308

Offset = 17 sec 28 %.

INTERSECTION 24 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 22 3 32 3

Intvl Length (%): 37 5 53 5

Pin Settings (%): 100/0 37 42 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 25 35

Splits (%): 42 58

Links Moving : 2405 2401
-2406 2402
2407

Offset = 59 sec 98 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 25 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 22 3 32 3

Intvl Length (%) : 37 5 53 5

Pin Settings (%) : 100/0 37 42 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 25 35

Splits (%): 42 58

Links Moving : 2505 2501

 -2506 -2502

 2507 2503

 -2508 -2504

Offset = 55 sec 92 %.

INTERSECTION 26 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6

Intvl Length(sec): 30 3 2 20 3 2

Intvl Length (%) : 51 5 3 33 5 3

Pin Settings (%) : 100/0 51 56 59 92 97

Phase Start (No.): 1 2

Interval Type : V Y R V Y R

Splits (sec): 35 25

Splits (%): 59 41

Links Moving : 2605 2603

 2607 2604

 -2608

Offset = 46 sec 77 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 27 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5
Intvl Length(sec) : 37 3 5 12 3
Intvl Length (%) : 62 5 8 20 5

Pin Settings (%) : 100/0 62 67 75 95

Phase Start (No.) : 1 2

Interval Type : V Y R V Y

Splits (sec) : 45 15
Splits (%) : 75 25

Links Moving : 2705 2703
 2707 2704
 -2708

Offset = 8 sec 13 %.

INTERSECTION 28 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6
Intvl Length(sec) : 25 3 1 27 3 1
Intvl Length (%) : 42 5 2 44 5 2

Pin Settings (%) : 100/0 42 47 49 93 98

Phase Start (No.) : 1 2

Interval Type : V Y R V Y R

Splits (sec) : 29 31
Splits (%) : 49 51

Links Moving : 2805 2801
 2806 2802
 2807

Offset = 53 sec 88 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 29 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6 7 8 9
Intvl Length(sec): 17 3 1 25 3 1 6M 3 1
Intvl Length (%): 28 5 2 41 5 2 10 5 2
Pin Settings (%): 100/0 28 33 35 76 81 83 93 98
Phase Start (No.): 1 2 3
Interval Type : V Y R V Y R V Y R
Splits (sec): 21 29 10
Splits (%): 35 48 17
Links Moving : 2905 2901 2902
-2906 -2902 2904
2907 2903
-2908 -2904

Offset = 55 sec 92 %.

INTERSECTION 30 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6
Intvl Length(sec): 21 3 1 31 3 1
Intvl Length (%): 35 5 2 51 5 2
Pin Settings (%): 100/0 35 40 42 93 98
Phase Start (No.): 1 2
Interval Type : V Y R V Y R
Splits (sec): 25 35
Splits (%): 42 58
Links Moving : 3005 3003
3007 3004
-3008

Offset = 55 sec 92 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 31 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 35 3 19 3

Intvl Length (%): 58 5 32 5

Pin Settings (%): 100/0 58 63 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 38 22

Splits (%): 63 37

Links Moving : 3105 3103
3107 3104
-3108

Offset = 4 sec 7 %.

INTERSECTION 32 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 25M 3 29 3

Intvl Length (%): 42 5 48 5

Pin Settings (%): 100/0 42 47 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 28 32

Splits (%): 47 53

Links Moving : 3207 3201
3205
-3206

Offset = 59 sec 98 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 33 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6
Intvl Length(sec): 7M 3 7M 3 37 3
Intvl Length (%): 12 5 12 5 61 5
Pin Settings (%): 100/0 12 17 29 34 95
Phase Start (No.): 1 2 3
Interval Type : V Y V Y V Y
Splits (sec): 10 10 40
Splits (%): 17 17 66

Links Moving : 3305 3304 3301
3306 3303
-3304

Offset = 59 sec 98 %.

INTERSECTION 34 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4
Intvl Length(sec): 19M 3 35 3
Intvl Length (%): 32 5 58 5
Pin Settings (%): 100/0 32 37 95
Phase Start (No.): 1 2
Interval Type : V Y V Y
Splits (sec): 22 38
Splits (%): 37 63

Links Moving : 3405 3403
3404

Offset = 4 sec 7 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 35 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec) : 42 3 12 3

Intvl Length (%) : 70 5 20 5

Pin Settings (%) : 100/0 70 75 95

Phase Start (No.) : 1 2

Interval Type : V Y V Y

Splits (sec) : 45 15

Splits (%) : 75 25

Links Moving : 3505 3503
 3507 3504
 -3508

Offset = 59 sec 98 %.

INTERSECTION 36 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec) : 23 3 31 3

Intvl Length (%) : 38 5 52 5

Pin Settings (%) : 100/0 38 43 95

Phase Start (No.) : 1 2

Interval Type : V Y V Y

Splits (sec) : 26 34

Splits (%) : 43 57

Links Moving : 3605 3601
 -3606 3602
 3607

Offset = 59 sec 98 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 37 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 28 3 26 3

Intvl Length (%) : 47 5 43 5

Pin Settings (%) : 100/0 47 52 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 31 29

Splits (%): 52 48

Links Moving : 3705 3701
 -3706 -3702
 3707 3703
 -3708 -3704

Offset = 59 sec 98 %.

INTERSECTION 38 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6

Intvl Length(sec): 34 3 1 18 3 1

Intvl Length (%) : 56 5 2 30 5 2

Pin Settings (%) : 100/0 56 61 63 93 98

Phase Start (No.): 1 2

Interval Type : V Y R V Y R

Splits (sec): 38 22

Splits (%): 63 37

Links Moving : 3805 3803
 3807 3804
 -3808

Offset = 3 sec 5 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 39 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 28 3 26 3

Intvl Length (%) : 47 5 43 5

Pin Settings (%) : 100/0 47 52 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 31 29

Splits (%): 52 48

Links Moving : 3905 3901
 -3906 3902
 3907

Offset = 59 sec 98 %.

INTERSECTION 40 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec): 22 3 32 3

Intvl Length (%) : 37 5 53 5

Pin Settings (%) : 100/0 37 42 95

Phase Start (No.): 1 2

Interval Type : V Y V Y

Splits (sec): 25 35

Splits (%): 42 58

Links Moving : 4005 4001
 -4006 -4002
 4007 4003
 -4008 -4004

Offset = 59 sec 98 %.

CYCLE: 60 Seconds, 13 Steps

INTERSECTION 41 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4

Intvl Length(sec) : 38 3 16 3

Intvl Length (%) : 63 5 27 5

Pin Settings (%) : 100/0 63 68 95

Phase Start (No.) : 1 2

Interval Type : V Y V Y

Splits (sec) : 41 19

Splits (%) : 68 32

Links Moving : 4105 4103
 4107 4104
 -4108

Offset = 0 sec 0 %.

This is the master controller.

INTERSECTION 42 PRETIMED - SPLITS OPTIMIZED

Interval Number : 1 2 3 4 5 6

Intvl Length(sec) : 13M 3 2 37 3 2

Intvl Length (%) : 22 5 3 62 5 3

Pin Settings (%) : 100/0 22 27 30 92 97

Phase Start (No.) : 1 2

Interval Type : V Y R V Y R

Splits (sec) : 18 42

Splits (%) : 30 70

Links Moving : 4207 4201
 4208 -4202
 4203
 -4204

Offset = 24 sec 40 %.

CYCLE: 60 Seconds, 13 Steps

--- 92 --- NOTE -

 END OF JOB!

APPENDIX C

Management Information System for Traffic

This Appendix is intended to show that there are certain features in UTC systems which, at this point in time, cannot be quantitatively accounted for through the use of traffic simulation models, it also shows the upgradability potential of the system . Management Information System for Traffic (referred to as ‘MIST’ hereafter) was chosen because it was the suggested system for use in the study area.

C.1 BACKGROUND

The Management Information System for Traffic (MIST) was developed by a U.S. firm, Farradyne Systems Inc. This system is based on modern software architecture called the Client-Server model. It provides either distributed or once-per second control. Meaning this system can process data from both central computers and local controllers. “It offers a broad range of control capabilities that can be manually commanded, or scheduled up to a year in advance.... The traffic responsive mode includes time-of-day detector weighing, section locking and time-of-day definitions of plan eligibility.”¹ Its traffic control modes could be manual, time-of-day, traffic responsive and flash, as well as local control modes.

MIST’s central computer plays the role of managing the system and performing special functions, such as network optimization, communications and data base management. Where its powerful controllers assume the role of signal timing optimization for the intersections. MIST is applicable for use as signal systems and freeway systems as well as traveler information systems. It can control 240 intersections on a single processor and up to 2000 intersections on a network configuration, running various versions of local

¹Management Information System For Traffic. Farradyne Systems, Inc.

controller softwares. It can also control variable message signs (VMS), Highway Advisory Radio (HAR), ramp metering equipment, count stations, and closed circuit television (CCTV) cameras. It can provide traffic information to remote work stations and in vehicle displays. The system also has the capability to detect incidents and optimize signal timing.

C.2 SYSTEM FEATURES

MIST has a variety of system features, some of which are briefly discussed in the following section.

C.2.1 Open System Architecture

MIST is capable of monitoring and controlling field devices which are integrated into the system. These devices could be signal controllers, variable message signs, or any electronic device that could be controlled and monitored by a computerized system.

MIST system architecture design includes the definition of a generic software kernel for both client and server components of a traffic application system. Thus strategies can be readily implemented in future projects. The well planned kernel design is capable of providing minimal constraints and remain flexible enough to meet the processing requirements of current and perhaps future IVHS systems. Each component within this architecture model provides a specific function. This modularity allows individual modules to be included or deleted from the architecture when a system is built for a specific traffic application. The modular structure of this architecture facilitates modular software programming techniques, thus allowing the traffic application software to be easily customized or reconfigured by developers. This modularity also allows the

architecture to support an entire line of traffic applications ranging from a simple count station processing system to a fully integrated IVHS system.

C.2.2 Multiple Configurations

MIST supports multiple configurations which would otherwise be dependent upon specific requirements of a system. These configurations can provide information interchange among several traffic management modules integrated into the MIST system. This flexibility allows an agency to purchase system components that are cost effective for its unique transportation requirements. It also allows for future expansions should it be deemed necessary.

The open system architecture of MIST allows the system software to be implemented in many different hardware configurations. For instance, the various modules of MIST can be implemented in a standalone configuration where one computer is used to process all of the tasks of the system. However, MIST is more commonly installed in a Local Area Network (LAN) configuration where each computer on the network is responsible for performing a specific task in the system, see Figure C.1. Finally, it could also be installed in a Wide Area Network (WAN) configuration, where multiple independent computer systems share vital transportation-related information with one another.

The WAN configuration is extremely useful for providing coordinated control among various independent traffic control systems. For instance, personnel from State, City and Local agencies could monitor the traffic conditions within the same geographic area, in order to see how to better serve the traffic needs for which they are responsible

LAN Architecture for MIST

Typical MIST Configuration

Figure C.1

(MIST Function, July 1996)

for. This configuration allows the various agencies to work together in order to provide more coordinated traffic flow along major arterials that pass through multiple jurisdictions. In addition, this configuration also allows agencies in different areas of a region to share vital traffic-related data, such as characteristics of major incidents along an interstate highway.

C.2.3 Database

SQL (Structured Query Language), is rapidly emerging as the standard database language for all platforms. MIST integrates a database management system (DBMS) that supports the SQL database command language. All system configuration data and user-defined system parameters are stored in the system database. Also status data and data obtained from the specific field devices integrated into the system are stored in the system database.

C.2.4 Equipment Monitoring

One of the features of this system is that it is capable of monitoring all field equipment interfaced with the system and can provide user-defined alarm reports. MIST can monitor communications equipment, detectors, controllers and other hardware devices in order to detect and report malfunctions.

C.2.5 Surveillance

The feature of most interest to us would be the system's ability to receive, process and store all traffic data measured by the surveillance system detectors. The system

receives detector count, occupancy, and/or speed data at least once per minute from all detectors defined in the system. The surveillance system then processes these data elements and derives the measures of effectiveness (MOEs). Detector's MOEs are used to gather traffic flow data and to develop traffic control timing plans, to select traffic responsive timing patterns and to store historical MOE values.

C.2.6 Reports

These reports contain valuable information such as the system status, traffic flows, equipment repair histories and database configuration. The following categories of reports are available in the MIST system.

Standard Reports: The purpose of these reports is to provide an informative summary of information.

User-Defined Reports: Mist allows the user to select the database table and the specific columns containing the desired information.

123 Reports: MIST provides MOEs for all detectors and links. These data consists of summary data written to the SQL database. Third-part programs running as separate applications, such as Lotus 123 or Microsoft Excel, enable users to view and print data both graphically and in a spreadsheet form.

Rotary File Reports: MIST stores all row data received by the system. The information is stored in files that are labeled by date and time. The data is only kept in the system for a user-defined period. This information can be imported and analyzed by

numerous software packages. This process allows the user to save raw data during special situations so that the information can be analyzed at a later date.

C.2.7 Event Scheduler

This scheduling capability includes time-of-day, day-of-week, day-of-year schedules with a one minute resolution. It is possible to schedule up to 1000 functions per 24 hour period. It is also possible to schedule and execute 30 functions during any single one minute period assuming that the thirty commands, collectively, do not take more than one minute to execute.

The commands to be performed by the system are displayed to the user where they can be stored in a specific day program. The user can either delete specific commands, record additional commands, or save the existing schedule as another day program.

MIST scheduling capability includes two types of schedules: permanent schedules and temporary schedules. Permanent schedules contain the schedule of events for each day of the week and generic holidays. Functions stored in the permanent schedule remain unchanged after they have been executed. The system automatically assigns the schedule for each day to its corresponding day of week. In addition, a calendar scheduler is used to define which day of week or generic holiday schedule would be used in lieu of the normal day of week schedule for a particular day of the year.

The temporary schedule provides the capability of scheduling one-time events in addition to events normally scheduled for the current day. The temporary schedule is used to program special activities in advance. Commands stored in the temporary schedule are deleted following their execution. Typical activities might include scheduling the

generation of reports during periods of unattended operation or the implementation of unique timing plans during sporting events.

C.2.8 Maintenance/Inventory

Another important feature provided with MIST is the tracking of inventory and maintenance activities. Failure summary displays provide statistical reports including the period of operation, the number of failures, the Mean Time Between Failures (MTBF), and the Mean Time To Repair (MTTR) for specific equipment components. Bar graph displays are used by the system to show MTBF values graphically. This allows users to easily compare the performance of each equipment component in order to determine preventive maintenance needs and to determine which types of equipment have operated the most effectively within the system. These comparison reports assist the traffic engineer in making future purchase decisions by evaluating the past performance of existing equipment.

C.3 SIGNAL SYSTEM FEATURES

The MIST system was originally developed to provide signal system features, but has since been expanded to include freeway system features. Some of the signal system features of the MIST system are discussed in the following sections.

C.3.1 Traffic Control Modes

1- Time of day (default mode): When in this mode the timing plan commands are implemented in accordance with the time-of-day schedule that is stored locally in the controller's data base.

2- Manual: When the operator wishes to change the timing plan on one of the intersections or a group of intersections, the system places them in the manual mode.

3- Traffic Responsive: When a section of intersections is placed in the traffic responsive mode, section timing plan changes are implemented as a result of UTCS algorithm. During traffic responsive operation, multiple sections can be made to operate as one system by using the master/slave section locking feature. It allows for efficient coordination across section boundaries as it eliminates the possibility of each section selecting a different timing plan.

4- Free and Flush traffic control modes: This mode relies on the capabilities to handle special functions sent by MIST.

C.3.2 Traffic Signal Controllers

MIST controls the system through supervising individual traffic controllers. The system typically communicated directly with the local traffic signal controllers; however, it can also communicate directly with on-street area masters. With this system the user can download or upload any data element or set of data to and from a local controller data base. When data elements have been edited, the system automatically displays the current value of the data element in the controller's database.

C.3.3 Traffic Control Functions

Mist is capable of automatically generating necessary inputs to the algorithm from the historical volume and occupancy data stored in the system database. This helps in

reducing the time needed for data entry that is required for traffic responsive timing plans. The system also maintains a permanent record of all significant system activities, including user access, intersection operation, detector and link MOEs, trouble calls, and equipment repairs.

Mist provides editing of controller parameters and allows comparison of the field database with central database to find any discrepancies. This procedure should be scheduled to be done at off peak times. It also offers freeway system features, but we will not discuss this aspect of the system as it doesn't impact the study at hand. We will indicate however, that Mist could gather count data from unique locations within the signal system such as within a tunnel or near a bridge. The types of displays and reports with count station data are similar to those available with system detector data gathered from traffic signal controllers.

C.4 FREEWAY SYSTEM FEATURES

It is important to discuss the system's freeway features, as a reminder of its future expansion capabilities. So some of its freeway system features are briefly discussed in the following sections.

C.4.1 Data Fusion Software

Data fusion software accumulates, organizes and disseminates data from different sources within the system. Such sources could be electronically equipped vehicles, System operators and modeling techniques. The volume of data received by most Intelligent Vehicle Highway Systems (IVHS) is in excess of an individual operator's capacity to process, make judgments and decide what data to transmit. This feature allows mist to

ascribe a value of quality and age to each of the data sources. A score is assigned to it and is then linearly decremented each minute using the age factor. Then the most appropriate data is transmitted.

C.4.2 Incident Detection

The MIST system is capable of integrating various incident detection algorithms. One incident detection algorithm uses the current speed data compared to a minimum speed threshold value stored in the data base to identify when an incident alarm should be issued. Thresholds can be set by time-of-day, type of day, weather conditions and location.

C.4.3 Environmental Sensors

Perhaps by far the most important feature of this system is its ability to gather various types of environmental data from sensors located along a roadway. Some of the weather conditions that could be monitored include air quality, fog, dust, rain and ice.

The system performs various algorithms on the data collected to determine the optimum actions to take, in lieu of the current traffic conditions and weather conditions.

C.4.4 Closed Circuit Television

The Closed Circuit Television (CCTV) camera control features of MIST were designed to fully implement all features of each camera controller in the system and to support multiple camera controller type. The camera control feature in the MIST system is software based, with both the camera video and controls displayed on the computer console. Operator use of the camera controls are implemented as part of the graphical user

interface, using dialog box controls and the computer mouse. The camera control software allows users to control the cameras via pan, tilt and zoom.

The MIST system can display the map locations of all cameras in the system. During program startup, the database is read in order to determine the number and locations of the cameras integrated in the system. One camera symbol is dynamically created for each camera listed in the database and the camera symbols are placed on the map at their specified location. The color of a camera's symbol denotes its status.

C.4.5 Count Stations

MIST is capable of gathering Measures Of Effectiveness (MOEs) collected from count stations located throughout the roadway system. While count stations are typically located along a freeway, MIST could also gather count data from unique locations within the signal system, such as a tunnel or near a bridge. The types of displays and reports available with the count station data are similar to those with the system detector data gathered from traffic signal controllers.

All MOEs generated by count station equipment can be gathered by MIST and stored in the system's database. This data consists of traffic volume, occupancy, speed, vehicle classification, delay, etc.. This data could be generated by loop inductance detectors, radar detectors, video detectors, or any electronic device that can be polled by the MIST system.

C.4.6 Variable Message Signs

The Variable Message Sign (VMS) feature in MIST is designed to fully implement all features of each sign in the system and to support multiple sign types. Advantages of using multiple sign types may consist of: sign requirements could be different for various locations, being able to obtain your signs from multiple sources and be able to keep up with new technological innovations. MIST maintains a list of programmed messages for each sign in the system. Most signs have the capability to maintain a list of messages in their controller, and a description of these messages is kept within the database for operator reference. Each sign is limited by its controller as to how many programmed messages it can support. The system also maintains a list of stored messages for each sign in the system which, upon selection, can be downloaded to the sign's controller for display.

As with cameras, the system is capable of displaying the location of all signs on the system map. MIST supports different type of symbol for each sign, to make easier for the controller/operator to visually identify the sign type from the graphic symbol.

C.4.7 Ramp Metering

To aid in regulating the flow of traffic entering and leaving a freeway system, the MIST system offers capabilities for both the control and monitoring of ramp metering equipment. The MIST system offers monitoring and control features designed to meet both strategic and local traffic flow objectives. Since MIST also offers full control capabilities of traffic signal controllers and variable message signs, strategic monitoring and control of a fully integrated roadway system is greatly enhanced.

The MIST system is capable of uploading and/or downloading all relevant controller parameters stored in the local ramp meter controllers. Therefore, specific ramp metering plans can be developed and implemented through the MIST system. Finally, MIST can also integrate ramp metering algorithms which automatically implement the most appropriate ramp metering plan depending upon the real-time traffic conditions on the ramp as well as on the freeway system.

C.4.8 Highway Advisory Radio

MIST can be used to control the broadcast of voice messages from highway advisory radio (HAR) Transmitters. Communications with HAR transmitter sites is most economically conducted through the use of a dial-up telephone service. Where dial-up telephone communications are used, MIST is capable of storing the phone numbers of all HAR transmitter sites in a large traffic management system. In addition to transmitter site phone numbers, MIST can also store access and function codes associated with the operation of transmitter field equipment.

When a system operator initiates communication with a HAR transmitter site, MIST takes care of generating the appropriate Dual Tone Multi-Function (DTMF) touch-tone codes required to exercise control over the site's field equipment. Additionally, the system is capable of transmitting any selected voice message to the transmitter site for eventual broadcast. Message transmissions may be monitored and verified by system operators prior to instructing the site to transmit a message over the airwaves. A log of all calls made to the highway advisory radio transmission sites is kept by MIST.

C.4.9 Remote Terminals

MIST supports access to the system from remote terminals. There are three types of users that can remotely access the system: Terminal Users, Graphics Workstation Users, and Phone Users. Terminal users are to log into the system via a terminal program. This access technique allows users with any type of operating system to access the data. Graphics workstation users have a graphics workstation that is the same as that of the operator of the system. These users will be able to make the same types of inquiries as terminal users, but will also be able to view graphical data, such as a map of the system. Phone users merely use a phone to transmit data to the system operators. They can also retrieve system data from the operators. The level of functionality that a remote user will have depends to a large degree on the hardware/software available at the remote site and the type of communications between the remote site and the central system.

APPENDIX D

Introduction To The Computer Models

D.1 TRAF-NETSIM

D.1.1 Background

Netsim (**Network simulation**) was developed to evaluate and test the operation of Urban Traffic Control Systems (UTCS). The microcomputer version of the software was released in June 1986 by the Federal Highway Administration (FHWA). The program is currently available from (and supported by) the University of Florida and Mctrans Center (**Microcomputers in transportation**). Netsim is a microscopic simulation model for urban networks, where every vehicle is considered as an individual entity and is moved once every second. Its location with respect to other vehicles and the network are determined, as well as its speed, acceleration and status are remeasured.

Netsim employs the “car following” algorithm (see chapter 4 section 4.2.1.1).

D.1.2 Input Data

-Run Control (cards 0 to 5): The input file starts with the run control cards. Table D.1 describes these cards [Traf-Netsim., 1989]. The run control data provides optional information (operator, institution...etc.), crucial information on which model to run

Record or Card	Description
00	Title
01	Identification
02	Run Control
03	Time Period
04	Time Step Control

Table D.1

(Netsim, Netflo, Roadsim...etc.), how many time intervals are to be run and type of output data desired.

-Network Description (cards 10, 11, 21, 22, 35 and 36): These provide link names, characteristics, turning movements, type of signal or intersection control, lengths of links, ...etc.

-Bus Operation (cards 150, 185, 186, 187, 188 and 189): These cards describe bus routes, stops, dwelling time at bus stops, buses' operation frequency, bus stops' location and percent of buses that don't stop at each location...etc.

-Traffic Volumes and Vehicle Occupancy (cards 50, 51 and 52): These cards describe traffic volumes entering the network through entrance nodes and volumes leaving the network through exit or sink nodes. Also vehicle occupancy or loading factors are entered on card type 52.

-Vehicle Characteristics (cards 58, 141, 142, 143 and 149): These cards are optional for the Netsim model, they define the type, corresponding percentages and characteristics of vehicles (length, acceleration, speed, discharge headways,...etc.).

-Fuel and Pollution (card 60): These may be optionally specified for fuel consumption and pollution emissions. Note that only one rate for CO, NOx and HC is specified for all types of vehicles.

-Pedestrian Volumes (card 11): These volumes are specified for every link in either one of these forms:

- “0” No pedestrian traffic,
- “1” Light pedestrian traffic,
- “2” Average pedestrian traffic,
- “3” Heavy pedestrian traffic,

-Incidents, Events and Parking (cards 56 and 148): Netsim has short term and long term events. Where short term events represent short term interruptions to traffic taking place in the curb line, and long term events are longer interruptions to traffic.

-Graphics (card 195): This feature is intended to portray the network more realistically.

D.1.3 Output Data

Note that emissions for trucks and buses are not available from this particular package, because such data was not attainable at the time this software was developed. The output from Netsim may be in either English or Metric units as specified by the user on record type 02. The output files of a Traf-Netsim model will include the following [Traf-Netsim., 1989].

“....Netsim link characteristics...Changes to Netsim link characteristics (subsequent time period)...Turning and conditional turning movements and pocket data...Signal and sign control codes...Interpretation of signal control codes...Traffic control table for signs and fixed time signals...Traffic control table for actuated signals...Entry link volumes...Source/sink volumes...Vehicle occupancy...Short term events...Long term events...Parking activity specifications...Vehicle type specifications...Environmental data...Cumulative link and subnetwork statistics...Cumulative link-specific person measures of effectiveness...Link and turn movement-specific measures of effectiveness

(optional output controlled by record type 02)...Fuel consumption and vehicle emission statistics (optional output controlled by record type 02)..."

Other outputs include bus-station specific measures, bus-route specific measures, turn movement specific measures by link, section specific link aggregation output and intermediate link-specific measures.

D.2 Transyt 7F

D.2.1 Background

Transyt is a signal timing and analysis tool for two dimensional networks. It is used to optimize coordinated traffic signal systems to reduce delay time, stops and fuel consumption. Also to perform detailed operational studies. The model was developed in Great Britain by Mr. Dennis I. Robertson in 1967. Since then, many improvements were made to the model and newer versions released both in Great Britain and in the USA. Release 7 (June 1992) added a number of new modeling capabilities that include: Clear optimization of progression opportunities (PROS), new split algorithm (based on degrees of saturation), replaced the random delay estimate with the one in the HCM (Highway Capacity Manual), changed the default model to the ARRB (Australian Road Research Board) model (described in chapter 4), revised stops algorithm (for better accuracy at or near saturation), permit coding of initial offsets while requesting the calculation of initial splits...etc.

D.2.2 Input Data

Refer to Table 4.3 for the different types of cards. In the following narrative, the different cards are briefly explained (Transyt., 1991). Note that this section defines only those cards that were used in this research.

- Run title card is used to provide an identification label for each Transyt 7F run.
- Card “0” (special options) is provided to allow for certain options and change others.
- Card “1” (run controls) is intended to provide network-wide parameters and to establish input/output options.
- Card “2” (optimization node list card) is used to list the nodes for which the signal timing is to be optimized.
- Card “3” (movement numbering card) is used to identify the numbering scheme for the links. The software has two link numbering schemes identified and could be used.
- Card “7” (shared-lane groups card) is used to identify the groups of links that share lanes in the network. These are the links that will end at a single downstream node and will share the same stopline and signal timing.
- Card “10” (network master card) is used to code information that applies to all nodes and/or links. The source node that all offsets are referenced to, may be coded on this card.

-Card "1X" (controller timing card) is used to code offset values and interval duration. The "X" stands for the number of signal phases that exist at a node.

-Card "2Y" (phase sequence card) defines the signal phases for the signalized intersection listed on card "1X". It outlines the intervals that comprise each phase and the links receiving the green during each phase. The "Y" stands for the phase number being described.

-Card "28" (link data card) provides information on all of the links existing in the network (length, saturation flow rate, total flow rate and link numbers of upstream links that are sources of traffic on the subject link).

-Card "29" (link data continuation card) is used to provide additional information on any link in the network. It provides information about permitted movements and a fourth upstream input link.

-Card "39" (platoon dispersion modification card) is utilized to change the platoon dispersion factor (PDF) for specific links.

-Card "5X" (run card) is used to define what type of Transyt 7F run is desired (optimization run, simulation run or cycle length evaluation only run).

-Card "90" (termination card) marks the end of a Transyt 7F run.

D.2.2 Output Data

This section lists and describes the outputs produced by Transyt 7F.

-Input data report: provides a list of the input data.

-Traffic performance table: it reports various measures of effectiveness (MOEs) of traffic performance. These include, total traffic volumes, saturation flow rates, total delay, average delay per vehicle, average travel time, uniform stops, maximum back of queue, queue capacity, fuel consumption and effective green time. See Table 4.4 for an example.

-Signal timing tables: see Appendix B (Transyt 7F output file) for an illustration. These tables give the length of each signal interval in seconds and percent of cycle length. Also, controller pin settings are given (which is the cumulative percentage of cycle length at the start of each interval). The type of each interval (variable, fixed, yellow or all red) and the splits (the total seconds and percent of cycle including all intervals in each cycle) are indicated. The links moving during each phase are given to allow for reconstruction of the phase sequence at each intersection. Finally, the offset (in seconds) from the master controller is printed.

In addition, Transyt 7F is capable of producing a series of diagrams such as flow-profile, time-space, time-location and platoon progression. These diagrams are optional outputs.

IMAGE EVALUATION TEST TARGET (QA-3)

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