Southwest Region University Transportation Center

Framework for Evaluating Transportation Control Measures: Energy, Air Quality, and Mobility Tradeoffs

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16. Abstract

Transportation planners, engineers, and air quality analysts are increasingly understanding the need for coordinated efforts in providing efficient and effective transportation systems while addressing serious energy and environmental concerns. Policies must be issued based on broad, coordinated efforts in transportation, air quality, and energy consumption so that optimal strategies for all three components can be implemented. At present, however, transportation planning and air quality analysis models are rather incompatible. Emissions models require detailed inputs which are not generally provided by transportation planning and analysis tools. Traditionally, transportation planning is comprised of four stages: trip generation, trip distribution, mode choice, and network assignment. In general, a forecast population, auto ownership, employment, and land use are inputs into the stages sequentially. This planning process does not adequately account for the manner in which individuals make travel decisions. The only travel-related decision that can be predicted using this traditional planning method is the mode of travel, while transportation control measures (TCMs), affect trip generation and trip distribution as well as route and mode choice.

Variables required for emissions estimation have not routinely been components of transportation planning models. What is needed is a methodology for combining transportation planning and analysis models with emissions factor models for predicting the effectiveness of various TCMs. A matrix of strategies that produce the greatest savings in air emissions and energy consumption can then be developed. The project first reviews different types of emissions and TCMs, and then develops a macro-analysis model--a unified framework--that links the transportation planning and air quality analysis models. The framework can then be used to evaluate, comparatively, the impact of various transportation control measures, which influence either travel time or travel cost, on transportation-related emissions and energy consumption.

The application of the macro-framework is demonstrated through analyses of two sample networks. The results show that the effectiveness of a TCM depends on the characteristics of the urban environment in which it is implemented. Failure to analyze the implication of a TCM prior to its implementation may yield results inconsistent with environmental and energy policy objectives. In addition, the results show that the choice of an emissions model is very critical in air quality analysis. The inclusion of an inferior emissions estimation model may result in biased conclusions.

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by

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SUMMARY

Transportation planners, engineers, and air quality analysts are increasingly understanding the need for coordinated efforts in providing efficient and effective transportation systems while addressing serious energy and environmental concerns. Policy-makers in the present and, particularly, in the near future, must issue policies based on broad, coordinated efforts in transportation, air quality, and energy consumption so that optimal strategies for all three components can be implemented. At present, however, transportation planning and air quality analysis models are rather incompatible. Emissions models require detailed inputs which are not generally provided by transportation planning and analysis tools. Traditionally, transportation planning is comprised of four stages: trip generation, trip distribution, mode choice, and network assignment. In general, a forecast population, auto ownership, employment, and land use are inputs into the stages sequentially. This planning process does not adequately account for the manner in which individuals make travel decisions. The only travel-related decision that can be predicted using this traditional planning method is the mode of travel, while transportation control measures (TCMs) affect trip generation and trip distribution as well as route and mode choice.

Traffic flow improvement, an intended product of TCMs, may cause changes in travel patterns, e.g., travel time and/or route changes. Equilibration procedures are normally used in determining flows on each link in a roadway network. However, these procedures are quite limited in estimating emissions. First, the equilibration procedures give information only about average flow conditions, while the emissions estimation models usually require different values of speed, acceleration, and deceleration for different classes of vehicle. Likewise, for fuel consumption estimation, the values of speed, stop time, and number of stops are essential but are not provided by the equilibration procedures. Second, it is very difficult to include all dimensions of travel demand, and the ones that consider frequency, destination, or mode choice in addition to route choice require the use of aggregate demand models, which do not adequately capture travel behavior. Finally, the equilibration models may make large errors in estimating traffic volumes and speeds on network links. A 30 percent error is not unusual [Horowitz, 1982].

Traffic simulation models that are generally used in optimizing traffic signals and predicting delays can be used to simulate TCMs for some roadway links in a network. Most traffic simulation models track the positions of vehicles as they move in the network and produce information such as speed and stop time on a link, which can be used in emissions models. However, these models require traffic volume as input, except a few models that are demand-responsive and, thus, are unable to forecast changes in traffic volume caused by a TCM.

A key in the estimation of air pollution is the conversion of traffic data into an amount of pollutants. This is accomplished through the use of an emissions factor model such as the Environmental Protection Agency's (EPA) MOBILE model. The model requires very detailed inputs, which often do not correspond to what is commonly available from transportation planning models, as stated previously. These include various speeds and vehicle miles of travel (VMT) for different classes of vehicle, vehicle types, ages of vehicles, accumulated miles of vehicle travel, maintenance program, analysis year, fuel volatility, daily ambient temperature, altitude and humidity.

These variables, required for emissions estimation, have not been a component of transportation planning models. What is needed is a methodology for combining transportation planning and analysis models with emissions factor models for predicting the effectiveness of various TCMs. A matrix of strategies that produce the greatest saving in air emissions and energy consumption can then be developed. This project first reviews different types of emissions and TCMs, and then develops a macro-analysis model -- a unified framework -- that links the transportation planning and air quality analysis models. The framework can then be used to evaluate, comparatively, the impact of various transportation control measures, which influence either travel time or travel cost, on transportation–related emissions and energy consumption.

The application of the macro-framework is demonstrated through analyses of two sample networks. The results show that the effectiveness of a TCM depends on the characteristics of the urban environments in which it is implemented. Failure to analyze the implications of a TCM prior to its implementation may yield results inconsistent with environmental and energy policy objectives. In addition, the results show that the choice of an emissions model is very critical in air quality analysis. The inclusion of an inferior emissions estimation model may result in biased conclusions.

CHAPTER 1. INTRODUCTION

BACKGROUND

Transportation mobility strategies may be defined as any government intervention which attempts to alter (improve) existing transportation systems. These strategies have long been confined to road construction and reconstruction. This has been, and occasionally still is, one of the most traditional methods of meeting transportation needs on a local or regional level. The additional capacity of these new roads may provide improved access to outlying areas, relieve congestion on existing roads, and meet current and future travel demand. These types of actions are very supply-oriented in that increased demand is matched by increasing the supply of the system. Although this technique has been popular in the past, air quality and energy conservation issues have become more and more important, as have financial constraints. Federal legislation designating attainment standards for urban areas and the energy crisis of the 1970's have altered ideas pertaining to transportation and mobility. As a result, an increasing number of transportation professionals are understanding the need to provide efficient and effective transportation systems while addressing serious environmental and energy concerns. The relationship between transportation and air quality has been researched extensively in recent years, as well as the transportation-energy consumption link. Policy-makers in the present and, particularly, in the future, must issue policy based on broad, coordinated efforts in transportation, air quality, and energy consumption so that optimal strategies for all three components may be implemented.

CLEAN AIR LEGISLATION

Over the past thirty years, the Clean Air Act Amendments have charged the Environmental Protection Agency (EPA) with achieving air quality standards to protect public health and welfare. The Act authorizes the EPA to promulgate emission standards for mobile and stationary emission sources. The Act also delegates responsibility for enforcing emission control regulations to the states.

During the early 1960's, the federal role on air pollution issues was limited to providing funds and supporting research. The Clean Air Act in 1963 and subsequent amendments have set a new standard for air quality in the United States. The federal government has expanded its role in addressing air quality issues and, particularly, the associated transportation impacts. The need for coordinated efforts in air quality and transportation is being understood and is supported by the recent Clean Air Act amendments.

In 1977, the President enacted the Clean Air Act Amendments of 1977. The amendments required states to develop State Implementation Plans (SIPs) for areas not meeting EPA's National Ambient Air Quality Standards (NAAQS). These SIPs were to demonstrate how the NAAQS for ozone and carbon monoxide (CO) would be achieved in all areas by the end of 1987. Unfortunately, some regions of the country could not attain the NAAQS for ozone and CO by December 31, 1987.

The amendments of 1990 establish a new perspective in addressing today's significant air quality problem. One of the key features of the 1990 Clean Air Act Amendments is the classification of non-attainment areas in an attempt to match pollution control requirements and attainment deadlines with the severity of an area's air quality problem. The purpose of this system is to give the states ultimate responsibility and flexibility to solve the non-attainment problems in their regions by imposing a combination of prescribed measures dependent on the severity of the problem. In addition, there are certain contingency measures that will be invoked if the states fail to reach the goal by the prescribed attainment date.

States with non-attainment areas classified as moderate or greater must develop adequate plans to reduce hydrocarbon (HC) emissions and oxides of nitrogen (NO_X) emissions as necessary to reach the NAAQS by the prescribed attainment deadline. All other non-attainment areas must achieve a 24 percent reduction from their 1990 HC emissions by 1999, and must continue to reduce volatile organic compounds emissions by 3 percent each year until the NAAQS are attained.

The 1990 Clean Air Act Amendments require states to submit SIP revisions. One of these sets due in November 1992 was the 1990 State Emission Inventory, which will be the baseline for the amendment-required reduction. Other SIP revisions include the plans proposed by the states with non-attainment areas to achieve the NAAQS by the prescribed date.

The emission inventories prepared in 1987 indicated that the mobile sources component is over 60 percent of the total inventory, while area sources and stationary sources occupy only 15 percent and 25 percent, respectively. It is clear that substantial reductions in the mobile source component of the emission inventory are necessary in order to meet the minimum reduction requirements as well as to provide for attainment by the prescribed dates. The changes in the new law reflect an explicit recognition by Congress that transportation sources are a major and growing impediment to achieving clean air goals. The problems addressed in the Act include a recognition of the existing gap between the transportation and air planners, and rapid growth in vehicle ownership and use in many metropolitan areas. For example, recent surveys have shown that individuals believe they have less time for leisure activities and that the pace of life seems to be speeding up. As such, time appears to be a more valuable commodity. The effect of the above forces has been to dramatically decrease the use of modes of transportation other than the single-occupant vehicle (see Table 1). These changes have led to a dramatic increase in vehicle miles of travel (VMT) -- a standard measure for motor vehicle activity. Although the requirement for coordination between transportation and air quality plans has been in the Act since the 1970's, transportation improvements were never required to conform to air quality plans. The 1990 Amendments directly confront this issue.

Table 1

Change in National Travel Modes

Travel Mode	1975	1985
Drive Alone	65.6%	72.6%
Carpool	19.3%	14.0%
Transit 6.0%	5.2%	
Other	9.1%	8.2%

Source: American Housing Survey, U.S. Census Bureau

Mobile source emissions have been identified as a major impediment to better air quality. Congress recognized this, and the new amendments expand the Department of Transportation's and EPA's responsibilities in ensuring that transportation plans, programs, and projects respond to the goals of SIPs. In addition to setting attainment levels of various pollutants for urbanized areas, transportation control measures have been outlined in the legislation to reduce the amount of vehicle travel, thereby reducing harmful emissions and possibly improving air quality. (Note: More efficient and effective use of existing transportation facilities is commonly referred to as transportation systems management (TSM), whereas the reduction of travel demand is considered by some to be different; the latter is often called transportation demand management (TDM). The expression "Transportation Control Measure" encompasses both TSM and TDM.

CHAPTER 2. MOBILE SOURCE EMISSIONS

There are two basic types of mobile emission reduction measures, namely, 1) new emission control technologies, including "high technology" inspection and maintenance, and 2) measures that reduce vehicle modes of travel (VMT). The first approach includes the application of new emission control systems installed on new vehicles and the inspection of in-use vehicles to ensure that adequate maintenance is being performed. It imposes another round of technology changes on the auto and fuel industries. The second approach includes efforts to encourage more extensive use of public transportation systems primarily through changes in travel behavior. It is worth noting that the former has seen more advances in the last decade, whereas the future will require great emphasis on the latter.

Through clear language about transportation control measures (TCMs), the 1990 Clean Air Act Amendments recognized that vehicle technology could not carry the entire load. Further reductions in vehicular emissions must rely on VMT-reduction through the development of transportation control plans. The major objective of this research is to provide a methodology and framework for evaluating the effectiveness of various TCMs.

In order to fully understand the impacts of various contaminants and the extent to which TCMs reduce emissions of these pollutants, the behavior and harmful effects of these substances should be known. The National Ambient Air Quality Standards (NAAQS) set ceilings on six different contaminants generated primarily from transportation sources. The rest of the chapter will discuss eight mobile source emissions, six of which are regulated in the NAAQS.

Carbon Monoxide (CO) is a colorless, odorless gas produced by the incomplete combustion of organic fuels. CO reduces the ability of the blood to carry oxygen, thereby posing a serious health threat to humans. Cardiovascular disorders may be aggravated and mental functions impaired by the presence of moderate CO concentrations. High concentrations of this contaminant may be fatal to humans.

CO concentrations at any given location are highly dependent upon proximity to the source of the emission. This may be a congested highway or a downtown central business district (CBD). Generally speaking, CO levels are high near their source, but decrease dramatically as the distance from the source increases. Owing to the behavior of CO in the atmosphere, many strategies aimed at reducing areas of high CO concentrations ("hot spots") address only small geographic areas of larger regions. Only recently is CO being viewed as an area-wide problem.

Nitrogen Oxides (NO_x) represent a number of compounds produced during combustion, including nitrogen monoxide (NO) and nitrogen dioxide (NO_2). NO_2 is a brownish gas with a pungent odor. Most NO_x are emitted from automobiles as NO and react to form NO_2, which is a precursor for acid rain and ozone (O_3). NO_x alone may aggravate respiratory disorders and create other health problems.

The behavior of NO_x in the atmosphere is quite different from that of CO. NO_x emissions are area-wide in nature; therefore, strategies to reduce concentrations of NO_x should be at least regional in scale. Wind and sunlight also play a key role in NO_x concentrations at specific sites, but that role is somewhat unclear, as the level of solar intensity may increase or decrease NO_x depending upon the particular stage of the chemical reaction process.

Hydrocarbons (HC) are compounds of carbon and hydrogen and are occasionally referred to as volatile organic compounds (VOCs). (Note: for the purposes of this report, HC will be synonymous with VOCs). HC is produced primarily from unburned fuel which escapes in motor vehicle fuel exhaust. HC, collectively, consists of either methane hydrocarbons or non-methane hydrocarbons (NMHC). Neither of these is directly harmful to humans, but NMHC or "reactive hydrocarbons" react with NO_x in the presence of sunlight to produce ozone, which *is* harmful to human health.

Ozone (O_3), also referred to as smog, is produced by the reaction of HC and NO_x in sunlight. It is known as a secondary pollutant because it is not emitted directly from mobile or stationary sources, but rather is formed by reactions of two major mobile source emissions, which make O_3 a major transportation-related contaminant. O_3 is a strong pulmonary irritant and eye irritant, is toxic to plants, and may impair lung functions in humans. High ozone concentrations may also cause significant damage to crops and ecosystems.

Ozone is an area-wide pollutant greatly affected by wind, sunlight, topographic characteristics, and temperature. Transportation strategies aimed at reducing O_3 must be applied on at least a regional level. Although it would seem logical that a reduction in precursor emissions would decrease ozone formation, this is not necessarily true. Consequently, O_3 reductions may be more complicated and possibly not even feasible through the use of transportation control measures.

Particulates include all solid particles and liquid droplets in the air except pure water. The NAAQS have regulated particulates with an aerodynamic diameter smaller than 10 micrometers (PM-10) which encompasses particles small enough to enter the lungs. The health effects of PM-10 are not extensive, but recent studies indicate that PM-10 may contribute to respiratory cancer. Aside from this, particulates can impair visibility and cause corrosion of exposed materials.

Sulfur Dioxide (SO_2) is another contaminant regulated in the NAAQS. SO_2 is not considered a major transportation-related emission because it is not produced from the burning of organic fuels in vehicles. Much of the SO_2 in the atmosphere is produced by electricity-generating power plants. If electrified rail systems increase dramatically, SO_2 concentrations are also likely to increase. The importance of SO_2 is its strong contribution to the formation of acid rain, which has major adverse effects on ecosystems, crops, and human health.

Carbon Dioxide is a by-product from the burning of fossil fuels (gasoline included). Due, in part, to the increase of gasoline burning, CO_2 has increased dramatically in the U.S. and around the world. The importance of the presence of CO_2 is its contribution to global warming or the "greenhouse effect." Some scientists believe this warming may eventually shift the climatic zones, change rainfall patterns, and possibly melt the polar ice caps, causing flooding of numerous coastal cities and farms.

Lead (Pb) is a poisonous heavy metal which damages the nervous system, harms the kidneys, and impairs mental functions. Lead in the atmosphere is produced from the burning of fuel containing lead compounds. As a result of the phase-out of leaded fuels, a substantial decrease in lead concentrations is being observed, and it is no longer considered a major problem.

Although eight of the previously mentioned contaminants are very important, only three major transportation-related emissions -- CO, NO_x, and HC -- will be studied in the analysis of this report. The interrelationships between these pollutants and speed are shown through Figures 1 through 3. These figures illustrate how the basic emission rates for CO, HC, and NO_x vary with speed, as reflected in the MOBILE4.1* model for a temperature of 78^0 F (26^0 C). HC and CO emission rates decrease on a gram/mile basis with an increase in speed, and are very sensitive to changes in speed in the range from 0 to 25 mph (0 - 40 km/hr). The lowest emission rates for HC and CO are at about 45 mph (72 km/hr) with the rates increasing beyond this speed. The heavy-duty gasoline truck (HDGT) has the greatest HC and CO emission rates among all types of vehicles. The NO_x emission rate for HDGT, however, is much less than that for the heavy-duty diesel truck (HDDT). Both of them are well above their counterparts for all other types of vehicles. The NO_x emissions may increase with greater speed. The critical value is around 35 mph (56 km/hr). A study by Evans [1977] suggests that HC emissions are strongly correlated with average travel speed, while both CO and NO_x emissions have a high correlation with acceleration and/or deceleration. Figures 4 through 6 illustrates the basic idle emission rates of HC, CO, and NO_x for different kinds of vehicles in MOBILE4.1. The HC or CO idle emissions from gasoline vehicles or

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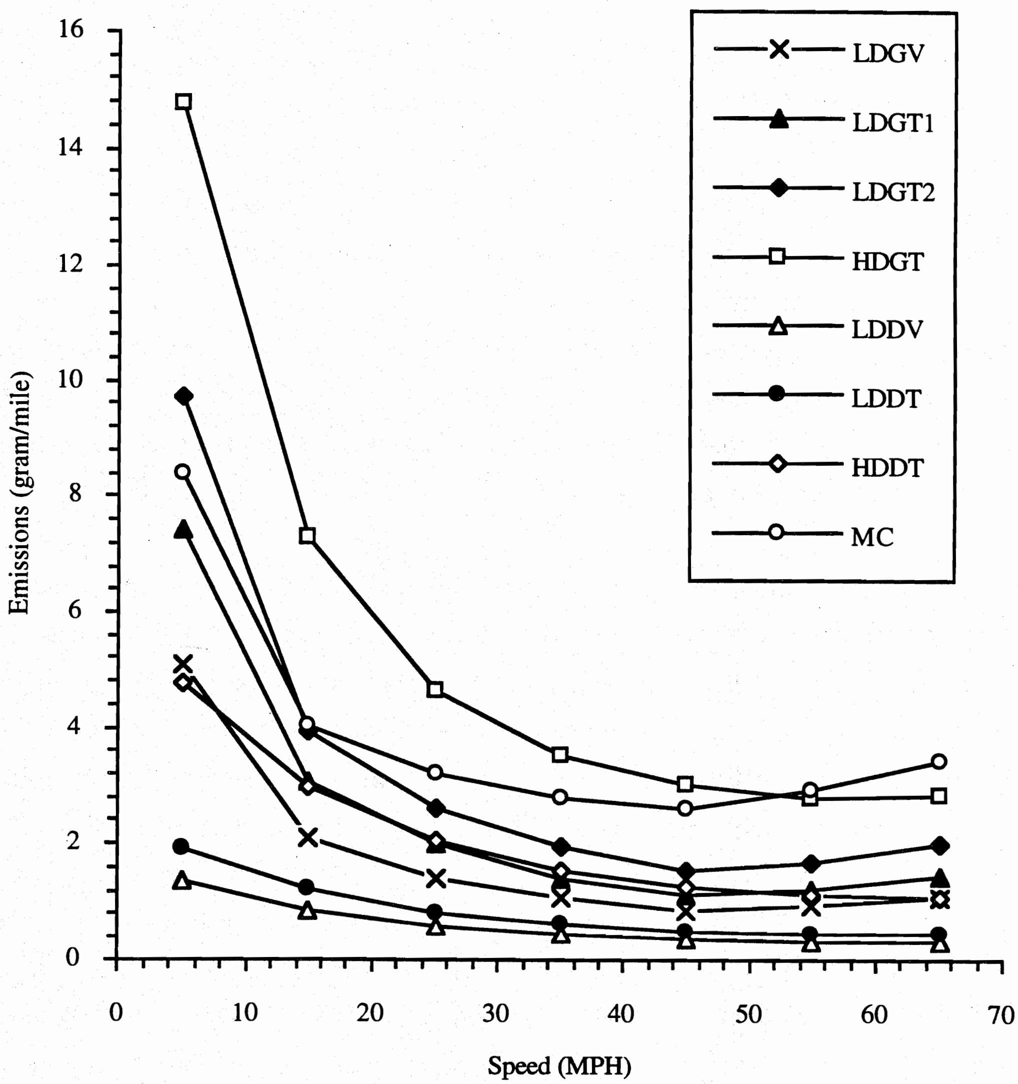
*More recent versions of MOBILE are now available. However, during the conduct and analysis of the study, only Version 4.1 was available.

Figure 1

Relationship Between HC Running Emissions and Speed [1,2]



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[1] Figures 1 - 6 are based on MOBILE4.1 basic emission rates at 78°F.

[2] LDGV -- Light-Duty Gasoline Vehicle
LDGT1 -- Light-Duty Gasoline Truck 1
LDGT2 -- Light-Duty Gasoline Truck 2
HDGT -- Heavy-Duty Gasoline Truck
LDDV -- Light-Duty Diesel Vehicle
LDDT -- Light-Duty Diesel Truck
HDDT -- Heavy-Duty Diesel Truck
MC -- Motorcycle

Figure 2

Relationship Between CO Running Emissions and Speed

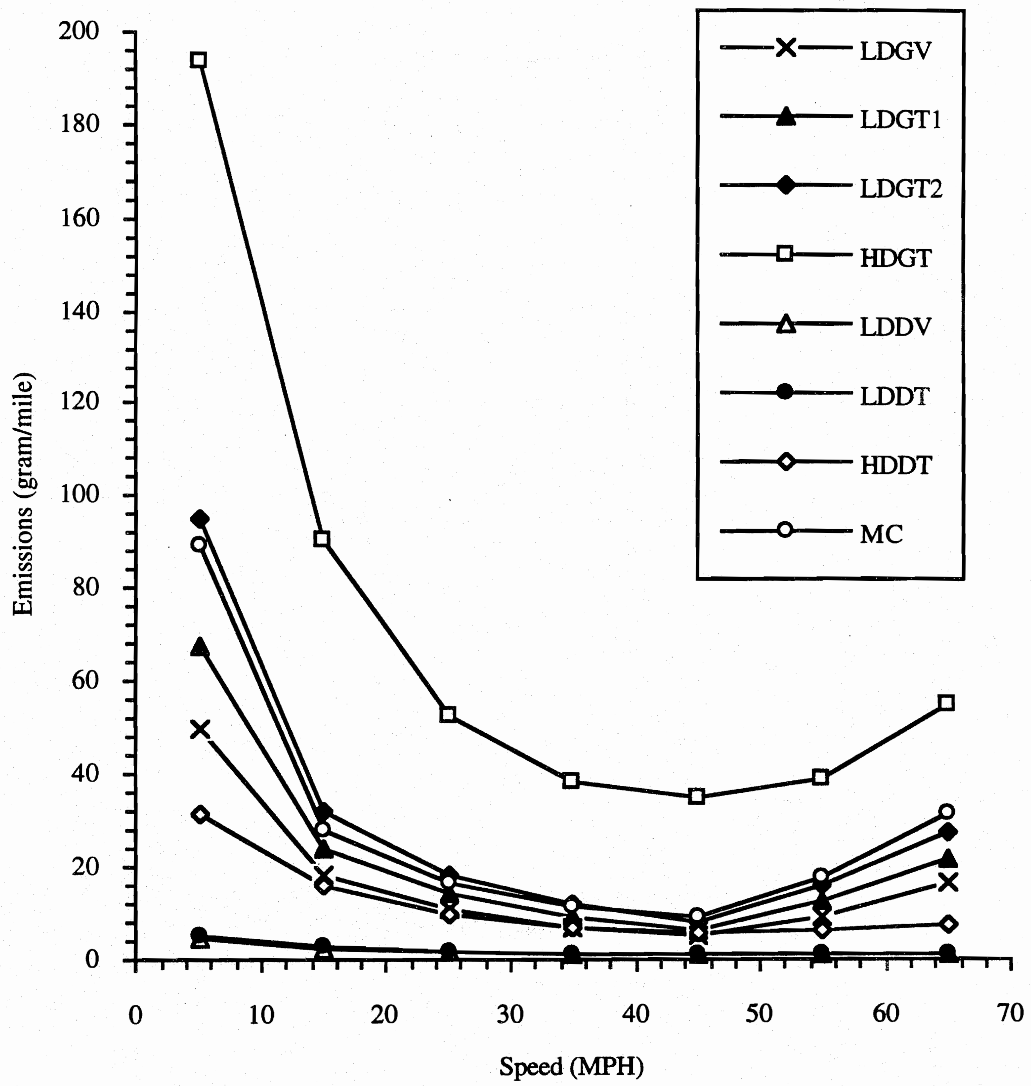


Figure 3

Relationship Between NO_x Running Emissions and Speed

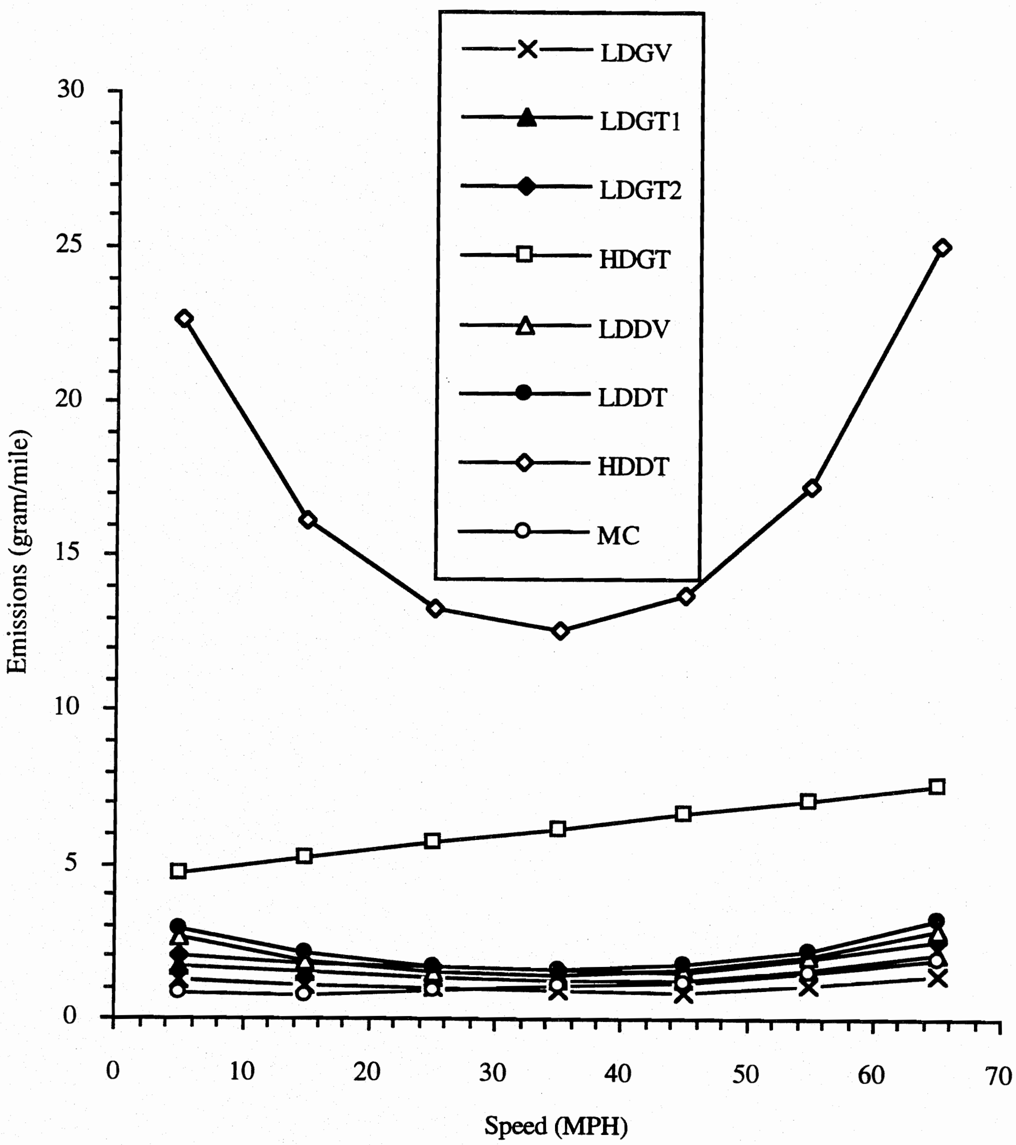


Figure 4
HC Idle Emission Rates

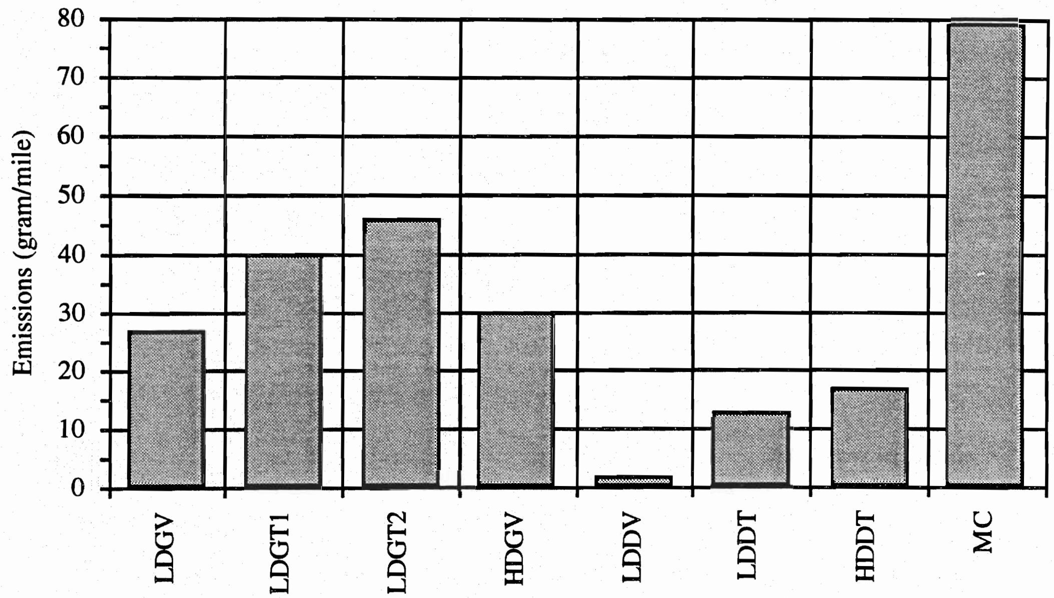


Figure 5
CO Idle Emission Rates

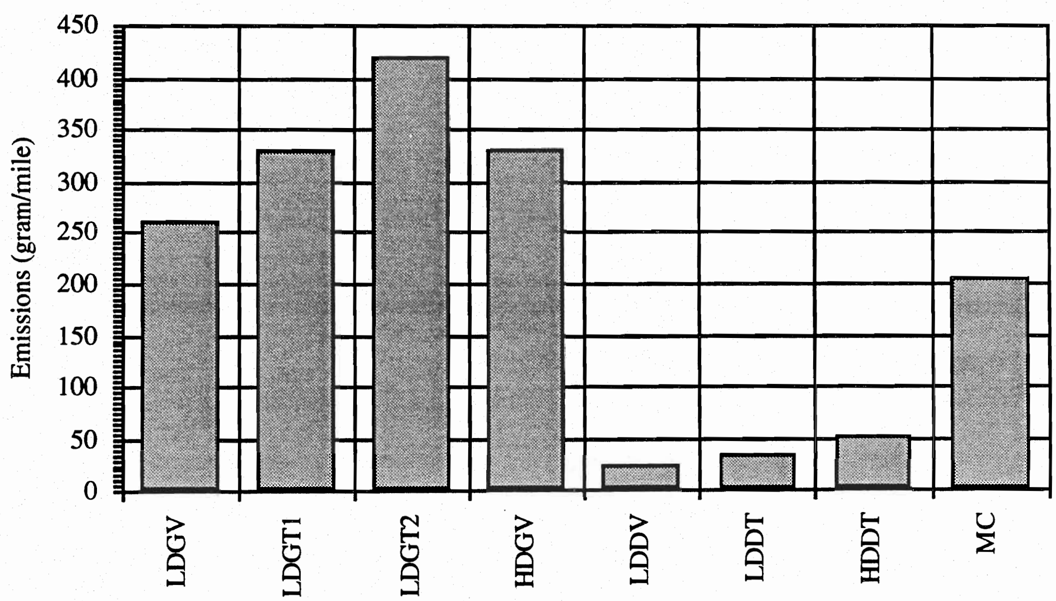
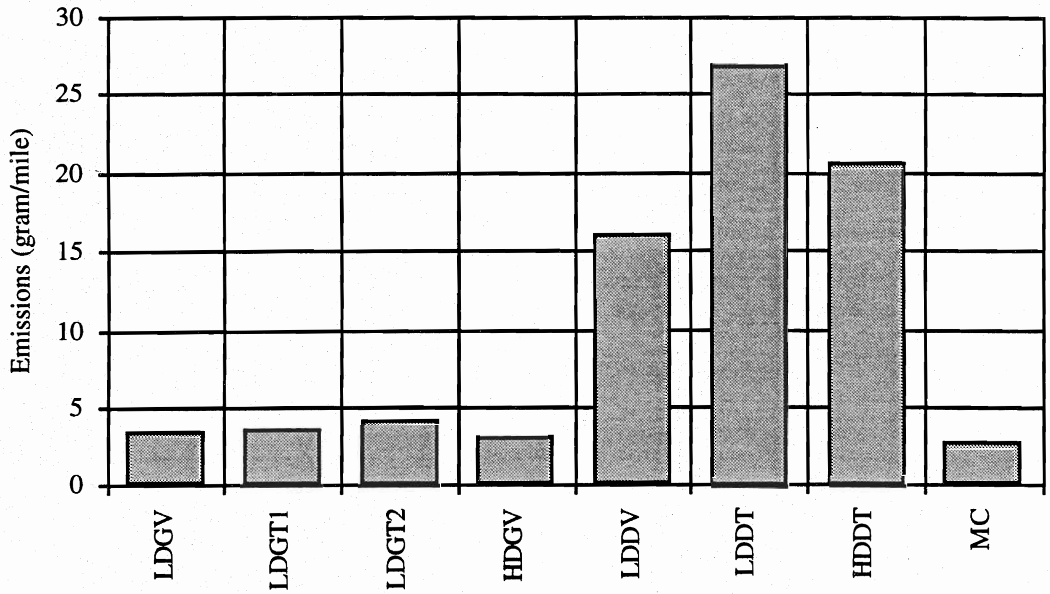


Figure 6

NO_x Idle Emission Rates



motorcycles are higher than those from diesel vehicles, while diesel engines emit more idle NO_x pollutant. This report will attempt to develop a methodology for estimating the effect of TCMs on the level of these contaminants in urban areas.

CHAPTER 3. TRANSPORTATION CONTROL MEASURES

The design of transportation emission control strategies depends on the reduction of transportation-related emissions, namely the reduction of emission levels of individual vehicles, and the reduction of emissions resulting from vehicle miles of travel (VMT) and vehicle trips. The latter can be reduced through the implementation of a series of transportation control measures (TCMs), such as the improvement of public transportation systems, preferential treatment for high-occupancy vehicles, parking management, carpooling and ride-sharing, etc. Compared to the reduction of individual vehicle emission levels, this approach has significant advantages such as energy conservation, reduction of congestion, and reduction of the need for highway construction, in addition to air quality improvement.

TCMs seek to maximize the use of existing transportation facilities by altering travel demand, improving traffic flow, or increasing vehicle occupancy. TCMs include those which attempt to reduce the number of vehicle trips, re-orient travel to off-peak periods, re-orient travel to alternate routes, or reduce total travel demand. Some of these measures were initiated in the late 1960's, but an increasing number of communities are utilizing existing TCMs and formulating new methods. These measures can be grouped into two categories: 1) those which attempt to alter travel behavior through various consumer incentives and 2) those which attempt to improve the transportation system to alter travel behavior. This chapter is devoted to discussing these categories.

CONSUMER-ORIENTED STRATEGIES

Consumer-oriented strategies attempt to alter an individual's travel behavior by providing incentives for ride-sharing, a mode switch from automobile to transit or other high-occupancy vehicle (HOV), or eliminating the individual's trips altogether. These strategies do not require physical system alterations, but may be more effective when combined with those types of improvements.

Trip Reduction Ordinances

Trip reduction ordinances (TROs) are localized regulations requiring employers and developers to coordinate programs to reduce commuting distances and also to target specific commuter services which need to be upgraded. Most TROs focus on work trips, but some have expanded to include non-work trips. These ordinances are designed to create incentives for motorists to seek alternatives to the single-occupant vehicle form of transportation. The stringency of TROs may vary, but the goals for most are similar. They attempt to alleviate congestion, improve local air quality, and reduce costs associated with additional road capacity. Specific sections of the TROs may not reduce trips, but they provide an avenue by which TDM measures and incentives for high-occupancy vehicle (HOV) usage may be implemented. This is usually accomplished through various area-wide ride-share incentives [Urban Land Institute, 1991] [USEPA, 1991].

One of the major goals of TROs is to create individual or employer incentives so that places of employment will be enticed into reducing the number of vehicle trips which they generate. Regional carpooling and ride-sharing have considerable potential for incorporation into TROs to perform this function, since most cars can carry more than four passengers, while average automobile occupancy in the United States is around 1.4 persons per vehicle for work trips. There are three types of activities which provide these incentives: commute management organizations, tax incentives, and transportation management agencies [USEPA, 1991].

Commute management organizations match the supply of commuter services to the demand of drive-alone alternatives (carpool matching services). Tax incentives for ride-sharing may include exemptions for shared ride arrangements and subsidies for employers or other programs which facilitate van-pool, carpool, or transit ridership. Transportation management associations (TMAs) are groups which employers form to help them capitalize on available incentives. The association attempts to manage its trip generation through numerous employee incentives. It should be understood that the creation of a TMA and other incentives alone will not reduce vehicle trips or emissions. TMAs facilitate the implementation of programs which might not otherwise exist [USEPA, 1991].

Employer-based or other ride-share incentives can be an extremely important component in TROs because they help provide the motivation for reducing vehicle trips. The main obstacle facing the car-poolers or ride-sharers is that they must have trip origins and destinations close to one another and must travel at the same time. Carpools are more desirable than individual travel by car because they result in less congestion and emissions. The greatest potential for carpooling and ride-sharing is work trips. Since carpooling and ride-sharing cannot be organized or scheduled by any government agency, their use can be encouraged by preferential treatment on the street and parking restrictions which can be included in automobile user charges.

Congestion may be eased and emissions can be reduced significantly through continuous efforts to encourage carpooling or ride-sharing. TROs may also be crucial to energy savings, as some experts believe ride-sharing is the primary method by which fuel can be conserved. The major problem with ordinances to reduce emissions or ride-share incentives is that the impacts of these programs are largely unevaluated and the extent to which they focus on non-work, off-peak trips is limited [USEPA, 1991].

Vehicle Use Restrictions/Limitations

Restrictions on vehicle use generally aim at single-occupant vehicle users. Restrictions can be area-wide or, sometimes, in a small geographic area of a larger region. These areas are commonly referred to as automobile restricted zones (ARZs). The shortcoming of these strategies is their limitation on mobility [USEPA, 1991].

ARZs are designated areas which prohibit or limit automobile use and are usually reserved for pedestrian and bicycle traffic. They may be effective for the vehicle-prohibited area, particularly in the case of CO emissions, but may be detrimental to other nearby zones because the traffic and resultant air quality burden is shifted to another part of the city or region [USEPA, 1991] [Horowitz, 1982].

Other forms of restrictions include no-drive days. To date, these programs are solely voluntary, but may become mandatory in future years. The objective is to encourage individuals to search for alternatives to the single-occupant vehicle mode of transportation on certain days of the week. This is usually implemented through license plate numbers. All automobile owners' license plate numbers ending with a particular number are encouraged to carpool on a particular day of the week. No-drive days are estimated to have a minimal impact in reducing emissions and energy consumption [USEPA, 1991].

Two other less common forms of vehicle use restrictions are traffic cells and central business district (CBD) tolls. Traffic cells are accessible by origin-destination traffic and not by through-traffic. As an example, consider a CBD developed along a highway. Motorists traveling along this highway may access the CBD or pass through this zone to reach another destination. With a traffic cell in place in the CBD area, motorists using the freeway would be physically barred from passing through to another zone. The diversion of through-traffic will reduce congestion along this particular area of the highway, resulting in higher speeds and, therefore, fewer emissions in the traffic cell area. The implementation of traffic cells may lead to increased circuitry of travel, which can have adverse effects on energy consumption and possibly on regional emissions [Horowitz, 1982].

A CBD toll is similar to a pricing measure because a fee is levied on motorists who attempt to enter a CBD by automobile. Fees for entrance into a CBD may reduce downtown congestion and improve CO emissions in the downtown area, but may have adverse effects on area businesses and, like traffic cells, lead to greater circuitry of travel [Bellomo, 1973].

Pricing Policies

The concept of pricing — or "road pricing" and "congestion pricing," as it is referred to in the literature — is to create an economic disincentive for automobile use, and in particular, for single-occupant vehicle use. The four types of pricing measures which will be discussed in this chapter are 1) fuel tax increases, 2) vehicle metering, 3) local area licensing, and 4) toll roads.

Increases in gasoline taxes and vehicle metering are similar in nature. Vehicle metering involves the installation of an odometer in all vehicles. A fee would be levied on the owner of a vehicle proportionate to the distance the vehicle was driven. This situation is similar to raising fuel taxes. Fuel tax increases would seem to be more "fair" because drivers of fuel-inefficient vehicles would be penalized to a greater degree and drivers of alternative-fueled vehicles would not be penalized at all. It would be difficult to determine the effect of this type of pricing on higher-polluting vehicles as opposed to lower-polluting vehicles. If fuel tax increases are to reduce VMT significantly, the increases would have to be very high, thereby introducing political constraints. Vehicle metering would be difficult to implement legally, practically, and politically, thereby eliminating it as a realistic solution to mobile source emission reduction and energy conservation [Horowitz, 1982].

Local area licensing focuses on the reduction of interurban travel as opposed to total vehicle travel. The driver would be economically penalized for choosing a destination outside the region in which his/her trip originated. A significant reduction in interurban travel could be expected, resulting in fewer long-distance trips. This VMT decrease would reduce emissions slightly, but most of the decreases would be felt outside the urban area. A slight decrease in fuel consumption could also be expected, but this pricing technique would be difficult to implement and enforce [Horowitz, 1982].

Toll roads are another method of direct user financing. A fee is charged to motorists driving on a toll road. Tolls may be effective in reducing congestion along the tolled arterial, but are not effective for significant regional emission reductions if alternate routes are available. As a result, energy savings are minimal and, although emissions may be reduced along some roadways, aggregate emission reduction is limited [Urban Land Institute, 1991].

A recent innovation with toll roads is variable lane charging whereby drivers are allowed to purchase, or more accurately rent, excess capacity. For example, single-occupant vehicles would be allowed to buy permits to use an HOV facility. Evaluation of such TCMs must recognize the impacts on persons at different income levels.

Alternative Work Schedules

Since many of the vehicle trips which are generated in a given urban area are work trips and since many of them occur at the same time, adjusting schedules in the workplace is a rapidly growing TCM. These types of adjustments attempt to eliminate work trips altogether or divert them to off-peak time. The three major types of schedule changes are 1) telecommuting, 2) flextime, and 3) the compressed work week [USEPA, 1991].

Telecommuting is the process by which the employee works at a location other than the central office. This may be at home or at a satellite work center. If employees stay at home and work, the work trip is eliminated. This would reduce VMT and the number of cold starts and hot soaks, which would be beneficial to air quality and, to a lesser extent, reduce energy consumption. This strategy, at present, may not be plausible because of the lack of investment in telecommuting networks and in businesses' present state of knowledge about telecommuting. There is much misunderstanding by employers about telecommuting.

Flextime is the process by which employers may spread their employees' work shifts over the entire day, thereby reducing peak-period traffic congestion. The number of vehicle trips would not be reduced, but low levels of service are less likely to occur during the peak hours, thereby increasing speeds and reducing running emissions and energy consumption [Rosenbloom, 1988]. Flextime, however, is resisted by many companies and agencies owing to the management difficulties.

Using a compressed working week, employees travel to work four days instead of five and, as a result, eliminate two work trips per employee (the journey to work and back on the fifth day). Because the shift hours will be different on the days the employees do work, at least one of the two trips will not be made during the peak periods. The U.S. Environmental Protection Agency (EPA) estimates that these vehicle trip and VMT decreases may result in significant urban air quality improvements. The main problem is the adverse effect on production output. As a result, alternative work schedules are not likely to be applied in the near future.

Parking Management

The improved management of vehicle parking spaces can reduce the demand for vehicle trips by eliminating the trip or providing incentives for the trip to be made by another mode or in a ride-share arrangement. The four main parking management strategies are 1) control of the parking supply, 2) preferential parking for HOVs, 3) parking pricing policies, and 4) parking requirements in zoning codes [USEPA, 1991].

The most common method of controlling the parking supply of an area is to set a maximum ceiling on the number of spaces so that the demand must adjust downward to meet the limited supply. Preferential parking for HOVs can either offer attractively proximal spaces for carpools or van-pools or eliminate parking fees for HOVs which would normally be levied on single-occupant vehicles. Parking pricing policies can aim at either increasing existing prices, imposing new fees, or eliminating parking subsidies. Zoning codes can also be used to manage congestion and the demand for vehicle trips by limiting the number of parking spaces required for site development [USEPA, 1991] [Horowitz, 1982].

Parking management strategies are most effective when implemented in dense CBDs that have limited parking. It is argued, however, that these strategies will have an adverse impact on downtown businesses. This could lead to increased development and economic activities in the suburbs, thereby increasing fuel consumption and regional emissions [USEPA, 1991] [Horowitz, 1982] [Lutin, 1976] [Bellomo, 1973].

Metropolitan areas similar to the New York City area are characterized by their advanced age, extensive rapid rail systems, and dense CBDs. Other cities displaying these traits are the large, highly industrialized cities like Chicago, Philadelphia, Washington D.C., Baltimore, etc.

Owing to the characteristics of limited parking spots in these regions, the management of parking, particularly in the downtown area, may yield significant improvements. These include reduced CBD traffic congestion and routes leading to the CBD; improved air quality, particularly in the downtown area; and a reduction in total energy consumption. Depending upon the specific parking availability of a region, pricing of single-occupant vehicles and proximal spaces reserved for high-occupancy vehicles may be effective, as well as control of the parking supply in the CBD area.

If parking management were implemented appropriately and ride-sharing and transit use increased accordingly, a single-occupant vehicle reduction of up to 30 percent would be possible in New York City. This translates into a reduction of roughly 6.9 million vehicle trips or nearly 62 million daily VMT. Approximately 132 million vehicle miles (212.4 million vehicle km) are traveled daily on major arterial and freeways in the New York City urbanized area. This means that congestion can be cut almost in half if significant parking management improvements were to take place area-wide. These are lofty improvements and, in reality, would be difficult to achieve.

SYSTEM IMPROVEMENTS

The second major category of TCMs is system improvements, those which involve altering the transportation system in some way to achieve a reduction in vehicle trip demand or make the system operate more efficiently.

Mass Transit

One of the oldest and least complex of all TCMs is the improvement of mass transit systems. A variety of improvements are feasible and can be grouped into five categories: 1) system expansions, 2) operational improvements, 3) improvement of transit routes, 4) introduction of rail transit, and 5) market strategies, including reduced transit fare and automobile user charges [USEPA, 1991].

System expansions can take the form of construction or extensions of fixed guideway systems or express and circumferential bus service. Various rail options exist, ranging from heavy rapid rail to light rail. These types of improvements are usually high in cost, characteristic of most older, industrialized urban areas, and are most effective when highly clustered polynucleated development exists [USEPA, 1991] [Bellomo, 1973] [Lutin, 1976] [Pikarsky, 1978].

Operational modifications focus on improving and optimizing existing transit systems. A wide variety of strategies can be used, such as schedule modifications, stop-frequency changes, bus traffic signal preemption, maintenance improvements, and monitoring. These measures are generally lower in cost than service expansions and, in some cases, can prove to be more cost-effective.

Most urban area automobile emissions are caused by trips originating and/or terminating in suburban areas. Hence, the achievement of significant reductions in automobile emissions must be associated with reductions in suburban travel. In other words urban air quality can be improved only if suburban motorists shift to higher-occupancy vehicles. Most current transit systems serve suburban areas very poorly. The obstacle for high-quality transit service in suburban areas is the difficulty of collecting and distributing passengers in low-density areas. However, it is feasible to bridge the CBD and suburban residential areas by using a transit system, which is successfully illustrated by the Shirley Highway HOV lanes in Washington, D.C.

Movement away from single-occupant vehicles to mass transit will require significant expansion of transit systems. In terms of capacity, rail transit can accommodate from 100-250 persons per vehicle. This compares favorably to bus transit, which can carry between 50-80 persons per vehicle. Rail transit does require significant outlays for construction.

The excessive use of the automobile in cities, especially for work trips, is a result of underpricing of automobiles. A study by the World Resources Institute found that motor vehicles are subsidized nearly $300 billion per year, or an equivalent of an additional $2/gallon ($0.53/liter) fuel tax [MacKenzie, 1994]. This underpricing of motor vehicles represents a large subsidy to automobile users which contributes to the decline of the transit industry in the United States. Market strategies use economic incentives to increase transit ridership. This can be done through employee incentives, reduced fares, monthly passes, passenger amenities, and other activities. These strategies are more consumer-induced approaches because they attempt to create financial incentives for automobile users to switch modes as opposed to improving the transit service. There are two possible ways to balance transit and automobile user costs. One is to reduce the transit fare. The other is to increase the cost of automobile use.

The studies and experiments conducted in Atlanta and Boston in the 1970's have shown that a reduction in transit fares has only a slight effect on auto use. The explanations of this result are: 1) the existing cost imbalance is caused by the underpricing of auto use, not the overpricing of transit use; and/or 2) the fare reduction was not accompanied by adequate improvements in transit service quality. The end result is that a realistic reduction in transit fares is not a feasible way to reducing automobile use.

The other method to balance the user costs between automobile and transit is to increase the price of vehicle use to reflect the true value of automobile transportation. A study submitted to the Department of Transportation concluded that "Peak-hour private auto travel is heavily subsidized. Charges sufficient to cover the true cost of auto travel in urban areas would surely cause restructuring of travel behavior and urban form." The only disadvantage of this approach is that it is burdensome to people who are far removed from high-quality transit systems. To realize the purpose of reduction in auto use and emissions, the auto user charges should be flexible and assessed on auto use frequency. The possible methods include fuel tax increases and parking restrictions. The increase in fuel tax may switch the public to driving small cars, which use less fuel -- but do not necessarily pollute less -- than large cars, whereas modest reductions in auto use can be expected in association with high-quality public transit systems.

The effectiveness of future transit systems will depend upon their ability to adapt to new and changing urban structure. Well-developed downtown areas with connecting developments are becoming obsolete and are being replaced by dispersed, linear development. If transit ridership is to increase, new technologies must be used to make systems more useful, cost-efficient, and attractive to consumers [USEPA, 1991].

High-Occupancy Vehicle (HOV) Facilities

A number of urban areas are experimenting with preferential treatment for HOVs on major roadways. The speed and reliability of buses can be increased significantly by using exclusive or reserved lanes. Furthermore, this kind of treatment can be applied to carpools and ride-sharing. The predominant method is the designation of exclusive lanes for these vehicles. These facilities may be located on freeways or arterials in a separate right-of-way or buffer-separated. If they are well-designed for a specific area, significant reductions in travel time can be achieved.

The principal purpose of preferential treatment for HOVs is to make them immune to congestion during peak hour, when the ridership of HOVs is highest, and to make them more attractive. Some successful examples include the Shirley Highway in Washington, D.C., and the El Monte Busway in Los Angeles.

Two considerations should be included in HOV priority treatment. One is that HOV travel time can be improved substantially only if there is a large portion of preferential treatment along the vehicle route. For example, a 10-mile priority route can save 5 minutes, but a 2-mile priority route saves only 1 minute, if the vehicle speed is increased from 30 MPH to 60 MPH. This phenomenon requires that the HOV priority be treated only on travel routes of relatively long distance.

The other consideration is the improvement of the quality of bus service system and carpooling management. Since the essence of priority treatment for HOVs is to attract more auto users to mass transit or ride-sharing, the effects of HOV priority treatment on auto use and emissions rely on the state of the improvement of transit and traffic management measures that may be taken. Reservation of an exclusive lane for HOVs on the arterial or freeway can only aggravate air equality if the current transit system remains unchanged because of reduced roadways [Horowitz, 1982] [USEPA, 1991].

Traffic Flow Improvements

Improvements in traffic flow most often occur in the form of engineering improvements along a roadway. Some examples are road widening, speed and signalization improvements, turn-lane installation, on-street parking prohibition, and contra-flow lanes. These improvements attempt to achieve a smoother flow of traffic which would reduce speed variations, thereby benefiting air quality and conserving energy. Three popular forms of improvements are 1) super-streets, 2) ramp metering, and 3) incident management systems [Horowitz, 1982] [USEPA, 1991].

The formation of a super-street is done by making cost-effective improvements to an existing arterial to increase its capacity. Some examples are signal timing, speed improvements, no left turns, and other traffic flow techniques, all on the same roadway. The increased capacity of the these roads will likely attract travelers from congested alternate routes, thereby easing congestion on those routes. This would reduce running emissions somewhat and conserve energy which would have otherwise been lost in delays [Urban Land Institute, 1991].

Ramp metering is usually performed at entrance ramps on freeways. When the freeway's critical point is reached, vehicles are prevented from accessing the freeway. Long queues may form at these points, which increases idling of the queued vehicles and increases emissions near the access ramp. Little or no energy conservation can be expected for the same reason. This technique may also increase traffic on non-metered roadways. Additional studies have shown that much of the traffic entering metered roads is from alternate routes, suggesting that overall travel times are actually improved [Horowitz, 1982] [USEPA, 1991].

Incident management systems can take the form of increased use of roving tow or service vehicles, detectors in the roadway, or motorist-aid call boxes. The concept is to clear accidents and breakdowns as quickly as possible by using these systems to respond to congestion caused by breakdowns or accidents. A Federal Highway Administration (FHWA) study indicated that a significant reduction in urban congestion can be expected from these systems. This may greatly reduce running emissions along many highways, particularly during peak periods. Fuel would also be conserved from the reduced speed variations of vehicles on roadways where incidents occur [USEPA, 1991].

Urban Form Restructuring

Most strategies attempting to alleviate traffic congestion relate directly to discovering more efficient methods for travelers to reach their destinations. The concept of altering land use development in urban areas involves bringing destinations closer to their origins and reducing society's dependence on the single-occupant automobile. Current urban structure is very different from older, traditional land development patterns. Centralized patterns are almost entirely obsolete, and multiple-nuclei urban areas are becoming less common. They are being replaced by dispersed, linear development which is not compatible to efficient use of current transportation systems. If urban regions are to address their congestion and mobile source emissions problems, they need to combine travel demand efforts with urban restructuring.

The three most prominent types of favorable urban structure are 1) centralized development, 2) decentralized development, and 3) polynucleated development. No matter which scenario is modeled, all three options have the same basic focus. This is to increase population and employment densities in certain areas and develop transit systems accordingly so that mass transit systems can become more effective. Land use centralization will most likely create a trade-off between increased pollutant concentrations in the center city and reduced regional emissions. Increased center city congestion may also limit substantial energy savings. Land use decentralization may be beneficial to the center city air quality problem, but longer trip lengths will likely result, thereby increasing aggregate emissions and fuel consumption. The polynucleated development alternative may be the most viable of the three scenarios. It would likely be the easiest to attain, given present regional urban structure, and it would also be more conducive to effective transit than the other two options. This would make it the optimal urban development alternative in relieving congestion, improving air quality, and reducing energy consumption. It should be understood that urban restructuring alone will not provide significant benefits unless it is accompanied by mass transit improvements and other TCMs [Lutin, 1976] [Pikarsky, 1978] [Urban Land Institute, 1991] [Wilson and Smith, 1987].

Park-and-Ride Areas

Park-and-ride areas provide facilities for a mode switch from automobile to transit to occur. The goal of constructing these lots is to attract travelers from an area and direct them to their common destinations via rail transit or some form of HOV. This reduces overall VMT. The reduced VMT would ease congestion on heavily traveled freeways and provide substantial energy savings. The effect on air quality is mixed. Benefits will be experienced from the reduced VMT, but emissions may increase near the lots and routes leading to the lots [Bellomo, 1973] [USEPA, 1991].

Many park-and-ride areas are used in conjunction with other TCMs; therefore, it can be difficult to assess their contribution to emissions reduction when they are present. The most effective park-and-ride lots will most likely be those where the governing body incorporates the facility with other TCMs and factors in the specific characteristics of that urban area.

Non-Motorized Facilities

Other methods which can be used to reduce vehicle traffic include improvements to bicycle and pedestrian facilities. Some of these improvements are attractive because of their low cost, negligible social and political implications, and ease of implementation. Some examples of non-motorized facilities are an increased number of bicycle lanes, routes, paths, maps, sidewalks, storage and ancillary facilities, and even transit connections to bike paths and walkways. Although the presence of these facilities will not deter many people from automobile use, only a small percentage of people would have to switch modes for an area to experience significant results. This is because of the 100 percent reduction in emissions and fuel consumption from the elimination of each vehicle trip [USEPA, 1991].

CHAPTER 4. ADVANCED TECHNOLOGIES

Most advanced transportation technologies can be categorized into a rapidly developing concept called Intelligent Vehicle Highway Systems (IVHS). The basic vision of IVHS is to improve communications among drivers, vehicles, and roadways. This increased communication will enhance driver information on the road, thereby creating a higher probability of producing faster, safer trips. The four main techniques utilized in this technology are 1) advanced driver information systems (ADIS), 2) advanced traffic management systems (ATMS), 3) advanced vehicle control systems (AVCS), and 4) commercial vehicle operations (CVO) [Urban Land Institute, 1991] [Working Group on Operational Benefits, 1990].

MANAGING CONGESTION WITH IVHS

A higher level of communication between vehicles and highways should improve traffic flow and reduce travel times. With these improvements, an increased capacity level of existing transportation systems can be expected. IVHS technologies aid in the improvement of many TCMs, thereby making them more effective. Detectors used in incident management systems, telecommunications equipment, and demand-responsive signalization are very much a part of optimizing these TCMs so that they can become more effective. These methods, together with computerized surveillance, can eliminate some trips and improve speeds on others, which would help alleviate congestion.

IMPLICATIONS FOR AIR QUALITY AND ENERGY CONSUMPTION

The implementation of IVHS technologies, in particular ATMS and ADIS, will create potential fuel savings in three ways. Travel times and delays will be reduced, drivers will experience fewer stops and starts, and excess vehicle miles of travel (VMT) will be eliminated through the use of the least-distance path choice.

Air quality also may improve with the use of IVHS. Some experts believe VMT growth is the most important factor in air quality problems, as opposed to vehicle fuel inefficiency. IVHS will reduce congestion, provide optimum routing, and avoid wasted trips, thereby producing a smoother traffic flow and reduced VMT. These factors should have an immediate effect on the level of running emissions generated in urban areas.

Because IVHS' initiatives complement traffic management strategies, its existence will not be counterproductive in that sense. The extent of IVHS' impact on emissions reduction and energy conservation depends upon its coordination with other environmentally beneficial transportation efforts and the cooperation of environmental and transportation officials.

CHAPTER 5. METHODOLOGY

The traditional four-step transportation planning model in widespread use was mostly developed for the narrow purpose of transportation engineering, not for air quality and energy consumption analysis. Many aspects of the current standard practice in transportation modeling are inadequate to meet the challenges of transportation planning, energy consumption, and air quality analysis in the future. Work needs to be done on immediate quick fixes to support the next round of air quality conformity analysis.

Over the past two decades there has been relatively little innovation in transportation planning modeling. The vehicle-trip-oriented models in trip generation focus on vehicle trip generation instead of person trip generation. They cannot reflect the potential of transportation control measures (TCMs) to divert short automobile trips to non-motorized modes. A set of default travel times between origins and destinations assumed by many state Department of Transportations (DOTs) in trip distribution ignore traffic congestion, which is a major concern in the analysis of fuel consumption and air quality. This makes the model insensitive to congestion or changes in transportation capacity. To achieve the purpose of coordinating of transportation planning, air quality, and energy consumption, models must become sensitive to many more factors. Travel time needs to be accounted for in the effects of congestion and capacity changes on spatial and temporal trip distribution and mode choice. A more detailed highway network simulation model separating link and intersection capacity and delay is needed to improve the values of travel time.

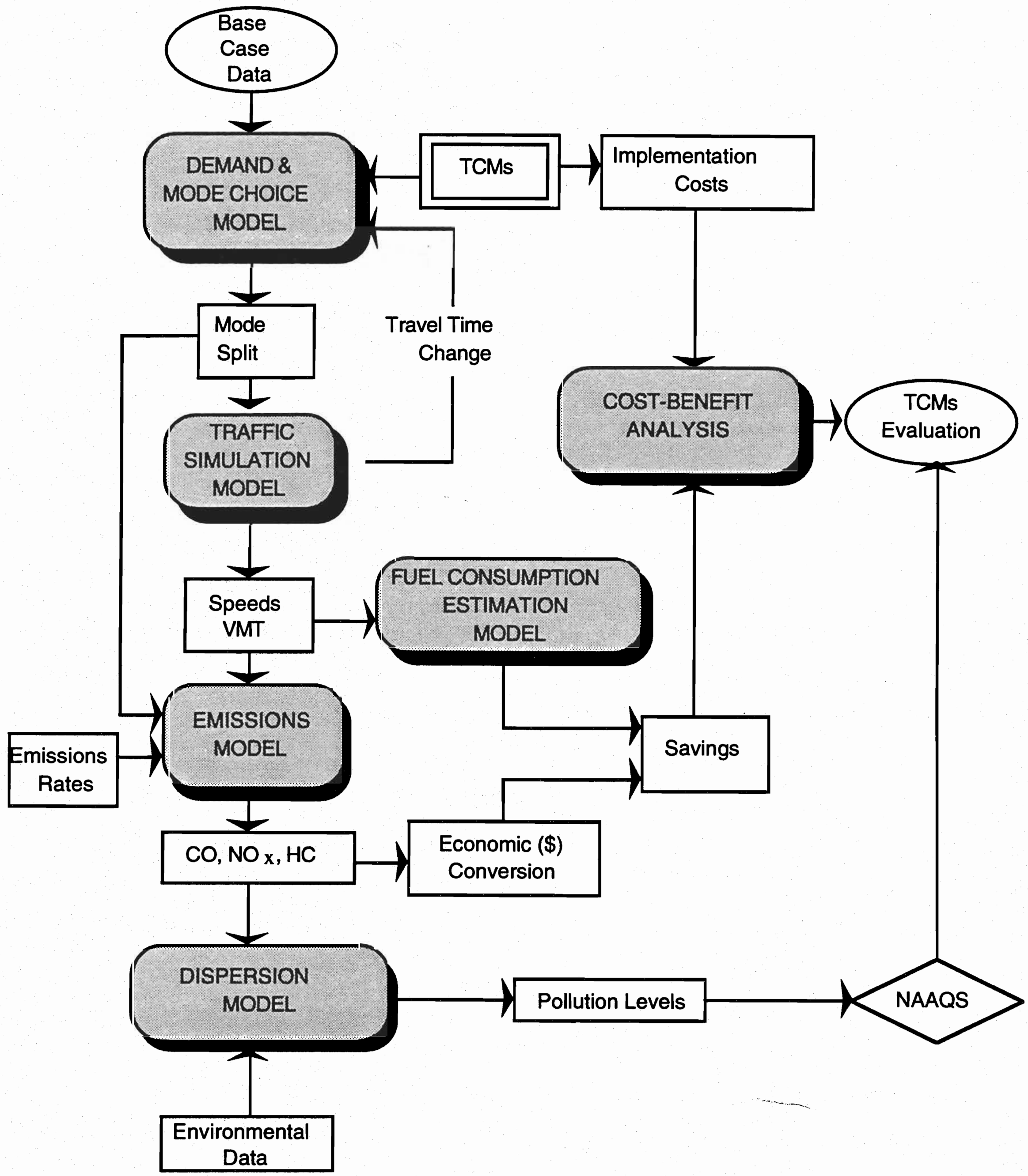
This report develops a consistent methodology linking transportation planning, energy consumption, and air quality analysis. The methodology is designed to predict the impact of TCMs on travel behavior, pollutant emissions, and energy consumption to identify which TCMs have the greatest potential and appear to be most attractive for implementation within a region. It provides a bridge of knowledge and common understanding between transportation planners and regulators charged with improving air quality.

The general framework of the model developed in this project is illustrated in Figure 7. The model framework consists of five models as well as cost-benefit analysis.

1. *Demand and mode choice model.* This model is used to predict the changes of probabilities concerning which mode, destination, and route individuals will choose to travel in an urban area as a result of implementation of TCMs. The model should encompass all possible modes that are affected by TCMs. These modes are, for example, non-motorized, drive alone,

FIGURE 7

Model Framework for Evaluating TCMs



carpool, transit, or even whether the individuals choose *not* to travel — as a result of telecommuting, for instance.

2. *Traffic simulation model.* A traffic simulation model can be used to study effects of traffic management strategies on the system's operational performance. This performance is generally expressed in terms of measures of effectiveness such as vehicle miles of travel (VMT), person miles of travel (PMT), average vehicle speeds, vehicle stops, and average and maximum queue length. These parameters are important in the estimation of pollutants.

3. *Emissions estimation model.* This model takes into account the factors affecting emissions, such as speed, VMT, vehicle classes, and modes of operation.

4. *Fuel consumption estimation model.* This model estimates the fuel consumption changes as a result of TCM implementation.

5. *Dispersion model.* This model is used to estimate emissions concentration as a function of atmospheric conditions, e.g., winds, temperature, and altitude.

The inputs of the model include a description of the characteristics of the TCMs to be implemented, baseline information on current travel characteristics, e.g., travel time and/or travel cost, current socioeconomic attributes, current emissions inventory, and local cost parameters.

The model system is designed to evaluate a broad range of candidate TCMs, which are listed in Table 2. Moreover, it can be used to measure the effectiveness of user-specified TCMs.

TABLE 2

Available Transportation Control Measures

• Improve Public Transit	• High-Occupancy Vehicle (HOV) Lanes
• Employer-Based Transportation Program	• Trip Reduction Ordinances
• Traffic Flow Improvements	• Park-and-Ride/Fringe Parking
• Limit Vehicle Use in Downtown Areas	• Area-Wide Ride-Sharing Incentives
• Bicycle and Pedestrian Facilities	• Control of Extended Vehicle Idling
• Reduce Extreme Cold Start Emissions	• Flexible Work Schedules
• Programs for Large Activity Centers and Special Events	• Voluntary Removal of Pre-1980 Vehicles

DEMAND AND MODE CHOICE MODEL

The TCMs identified in the Clean Air Act Amendments of 1990 (CAAA), as shown previously in Table 2, influence travel decisions primarily in the short-term through frequency, route, and mode of travel, but may have some long-term effects on workplace location, for example. TCMs also encompass decisions regarding whether or not an individual chooses to travel, as well as travel to different workplace locations according to different schedules, as a result of telecommuting and flexible work schedules. The influence of TCMs on travel decisions can be explained by discrete choice models, which are flexible enough to accommodate long-, medium-, and short-term decisions.

As discussed earlier, the traditional four-stage transportation planning sequence does not account for the manner in which individuals make travel decisions, particularly those in the long- and medium-term time range. As an alternative approach, a discrete choice model may be used. Figure 8 demonstrates a broad range of behavioral decision making which may influence the traveler's decision in the long-, medium-, or short-term time range. A transportation system based on this structure was initially developed by Ben-Akiva and Atherton to analyze potential energy conservation policies [Ben-Akiva and Atherton, 1977]. Emissions estimated for various TCMs are merely an extended application of this model. The impacts of TCMs on air pollution should be assessed for different ranges of travel decisions. Importantly, employment of this approach takes into account travel decisions for the long, medium, and short terms.

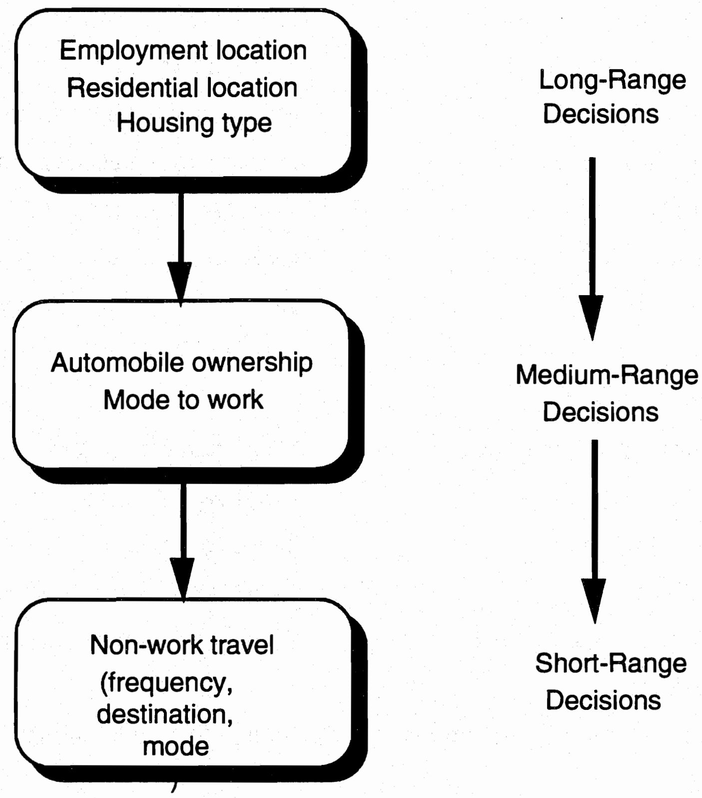
Even though this approach is more applicable than the traditional four-stage planning models, its outputs are still not sufficient to meet the data requirements of emissions factor models. The emissions factor models require vehicle type for work and non-work trips, as well as engine type (gasoline, diesel, or other fuel).

Moreover, the model structure should be adaptable to inclusion of new modes into the urban transportation system. For instance, if light rail is to be developed, then the model should yield an accurate share of rail's ridership to investigate the effectiveness of this transit investment. Also, the model should be able to forecast individual behavior when telecommuting, using compressed work weeks, or flexible work hours.

Significant variables in the mode choice model generally are transportation level of service and socioeconomic variables. The transportation level of service variables are travel time, disaggregated to in-vehicle time, out-of-vehicle time, and travel cost. The socioeconomic variables include income, workplace, mode availability, and employment density. Effects of a TCM entering the choice model as shown in Figure 7 change values of the utility function variables. Some effects are summarized in Table 3.

FIGURE 8

The Choice Hierarchy



Source: Ben-Akiva and Atherton, 1977

TABLE 3

Effects of TCMs on Utility Functions in Mode Choice Model

TCMs	Effects
Improved public transit	
• Increase service frequency	Reduce transit wait time
• Extend light rail system	Reduce transit travel time
• Add new bus route	Reduce transit access time
• Add light rail and bus stations	Reduce transit access time
• Decrease fares	Reduce travel costs
Park-and-ride and fringe parking	Reduce transit and auto in-vehicle times
	Change out-of-vehicle times
	Change travel costs
Traffic flow improvement	
• Build new freeway and arterial	May either reduce or increase travel time
• Increase parking rate	Increase auto cost
• Increase gasoline price	Increase auto cost
• Build HOV lanes	Reduce ride-share and bus in-vehicle time
• Expand ramp metering with HOV bypass lane	Reduce ride-share and transit travel time
• Install bus-actuated traffic signals	Reduce transit travel time
Work schedule changes	
• Flextime	Reduce travel time
• Telecommuting	Affects trip decisions
Vehicle use limitations/restrictions	
• Auto-free zone	Increase travel time

When route choice is predicted, route length can be determined. Then we may assume, for example, that home-to-work trips are cold started. If the route is longer than 505 seconds or 3.59 miles (5.78 km) (the current U.S. Environmental Protection Agency [EPA] assumption), the vehicle is in running mode. A fraction of shopping trips may be assumed cold start, with the remaining portion assumed to be hot start. This should result in a more accurate estimation of emissions.

Traffic Simulation Models

As noted earlier, many DOTs assume a static default set of travel times between origins and destinations for future years. This makes the models insensitive to the effect of major implementation of TCMs, thus leading to frequent overestimation or underestimation of travel time savings, congestion reduction, and emission reduction associated with the capacity changes. In addition to these shortcomings, the models cannot provide the delay time, queue length, vehicle stops, and acceleration and deceleration, which are key factors in estimating vehicle emissions and fuel consumption.

Computer simulation models can play a major role in the analysis and assessment of the transportation network and its components. Simulation is a numerical technique for conducting experiments on a digital computer, which may include stochastic characteristics, be microscopic or macroscopic in nature, and involve mathematical models that describe the behavior of a transportation system over extended periods of real time. Several traffic simulation models are available for arterial network applications, including TRAF-NETSIM, TRANSYT-7F, and SSTOP, to study the effects of TCMs aimed at improving traffic flow. The INTRAS model is the only microscopic computer simulation model available for freeway corridors. There are several macroscopic models available, including CORQ, FREQ, FRECON2, and KRONOS.

TRANSYT-7F is a macroscopic model which considers platoons of vehicles rather than individual vehicles. Inputs to TRANSYT-7F include those that can be obtained from the previous demand and choice model, such as traffic volume resulting from change in modes. Also included as inputs are saturation flows, signal parameters, existing cruise speed, and intersection geometry. TRANSYT-7F generates travel times, delays, and stops which can be linked to an emissions estimation model. Since TRANSYT-7F is a macroscopic model, its outputs indicate average values, and, therefore, it cannot identify specific vehicle classes, yielding less accurate emissions estimates.

FRECON2 is a dynamic macroscopic freeway simulation model that can simulate freeway performance under normal and incident conditions. The model can generate a traffic-responsive priority entry control strategy and evaluate its effectiveness. The traffic performance measures include travel times, queue characteristics, delay, fuel consumption, and emissions.

A microscopic traffic simulation model, like TRAF-NETSIM, can accommodate traffic controls and track the positions of vehicles as they move through the network. Thus, it is possible to estimate emissions along the links. Up to 16 classes of vehicles can be specified in TRAF-NETSIM, with private autos, trucks, buses and carpool vehicles as the default vehicles. However, TRAF-NETSIM requires traffic volumes as an input. This means it is unable to forecast the changes in the volumes as traffic flow improvement measures are implemented. Several TCMs, particularly the ones affecting travel time — e.g., HOV facilities, traffic signal improvement, and improved public transit — are likely to cause a change in travel time, since they affect the individual choice and thus traffic volumes. This requires a number of iterations to converge the average travel time value in the traffic simulation model to the value in the demand and choice model.

NETSIM can be used to evaluate the impact of various congestion mitigation strategies on energy consumption and air pollution. The fuel consumption and emissions are calculated based on vehicle speeds, acceleration and deceleration. Unfortunately, NETSIM measures only automotive emissions; therefore; the emissions analysis is not conclusive. Moreover, NETSIM emission factors are based on earlier automobile models, and it does not take into account elevation, temperature, vehicle age, etc., as do other emission models.

Emissions Estimation Models

A key in estimating air pollution is the conversion of vehicle speeds and vehicle classes into amounts of pollutants. This is accomplished through the use of emissions factor models such as EMFAC7E in the California area, or HPMS AP and MOBILE in non-California areas.

One of the emissions models that can be used is Highway Performance Monitoring System Analytical Process (HPMS AP). This method estimates average speeds for various vehicle types as a function of the initial running speed, the geometry conditions, the number of speed change and stop cycles, and the fraction of idling time. The average speeds do take into account idle, acceleration, and deceleration, which are assumed as constants, e.g., 2.5 feet/second^2 (0.76 m/second^2) for speeds above 30 mph (48 km/hr) and 5 feet/second^2 (1.52 m/second^2) for speeds below 30 mph (48 km/hr).

The other method is the computer software MOBILE. The MOBILE computer model, developed by EPA, computes the hydrocarbon (HC), carbon monoxide (CO), and nitrogen oxide (NO_x) emissions for eight types of gasoline- and diesel-fueled motor vehicles for different altitude regions in the United States. The eight types of vehicles include gasoline-fueled light-duty vehicles, light-duty trucks, heavy-duty vehicles, their diesel counterparts, and motorcycles. It accounts for many variables that affect the production of emissions by motor vehicles. Among these variables are vehicle average speed, fuel volatility, daily ambient temperature, altitude, humidity, vehicle type, age of the vehicle, VMT split of different types of vehicles, maintenance program, and analysis year. The emission factors can be used, when combined with the estimated VMT, to calculate the total emissions of a pollutant within a region.

A key attribute of the MOBILE model is the calculation of correction factors. The general emissions factor from MOBILE is a product of a basic emissions rate and a series of correction factors that account for the above variables. Both basic emissions rates and correction factors are determined by the Federal Test Procedure. The speed correction factor for each pollutant included in the composite correction factor is a function of average travel speed and its polynomial terms. It is an attempt to recognize the fact that many combinations of the amount of time spent in each of the elements of the driving cycle — accelerating, cruising, decelerating, and idling — can produce the same average travel speed. For example, the emissions factor for very low driving speeds employs a greater amount of accelerating, decelerating, and idling than the basic emissions rate does. Inherently, MOBILE assumes that the amounts of cruising, accelerating, decelerating, and idling are applicable to all driving situations. Moreover, sensitivity to the amount of accelerating, decelerating, cruising, and idling, and to the intensity of accelerations and decelerations, is not included in the model.

A test conducted by Cottrell [1992] shows that the speed correction factors in MOBILE are accurate for travel speeds between 2.5 and 48 mph (4.0 and 77 km/hr). HPMS AP, however, is inappropriate for simulating very low speeds. EPA has released several versions of MOBILE. MOBILE4.1 was used in this application analysis since the newest version, MOBILE5.0, was not available.

In estimating emissions, two model types are used for different applications. The microscale models determine a vehicle's instantaneous exhaust HC, CO, and NO_X emissions per unit time as a function of speed and acceleration, whereas the macroscale models determine total vehicle emissions or average emissions per unit distance traveled, including trip-end emissions, during an entire trip or part of a trip. In relation to the framework, both micro- and macro- scale models can be used in conjunction with the traffic simulation model. For example, in a large urban network, originating and terminating trips, such as sink/source nodes available in TRAF-NETSIM, may be used to represent the points where trips start or end. With a known number of trips and hot soak and start-up emission factors for vehicle type, model year, and age (or the weighted average over the model years of vehicles in the area of concern), macroscale emissions can be estimated. When only trip segments are of interest, hot soak and start-up emissions may be disregarded, thus giving microscale emissions.

Fuel Consumption Estimation Models

Fuel consumption can be estimated by the modal choice model with additional computations or by some traffic simulation models, e.g., TRAF-NETSIM and TRANSYT-7F. It may be omitted from the framework, but with some limitations. For example, in TRANSYT-7F, a stepwise multiple regression is used with the model parameters derived from a study of only one test vehicle, and the model coefficients are adjusted to represent an "average" vehicle. In the cities where the fuel consumption models have been calibrated to account for specific conditions such as grade, roadway geometry, mix of vehicles, etc., the outputs from the traffic simulation can be used in that local fuel consumption model. Variables normally significant for fuel consumption estimation are travel time, stops, and stop times, which are generally provided by a traffic simulation model.

Dispersion Models

Volatile organic compound (VOC) outputs from emissions factor models are one of the inputs for a dispersion model. Dispersion or diffusion models are quantitative models used for determining the relationship between emissions and atmospheric concentrations of air pollutants. The pollutants, once emitted, are dispersed by winds, and may chemically react to form new compounds. An example is ozone (O_3) produced by the photochemical reaction of HC and NO_x. EPA-approved models for the estimation of ozone levels are the Empirical Kinetics Modeling Approach (EKMA) or the Urban Airshed Model (UAM). Emissions, temperature, winds, water vapor, initial concentrations, and the modeling period are model inputs. The models yield ozone concentrations which are compared to National Ambient Air Quality Standards (NAAQS).

Cost-Benefit Analysis

Finally, the effectiveness of TCMs should be measured economically through cost-benefit or cost minimization analysis. The costs should include traditional expenses for new facilities or improvements, i.e., HOV lanes, improved transit operations, traffic signal improvements, etc., but should also include vehicle operating, delay, accident, and environmental costs. The expected benefits are the cost reductions associated with various alternatives. Some of the costs are difficult to quantify monetarily. Small [1977] developed a method for estimating the air pollution costs of transport modes by quantifying health and material damage. With some assumptions, he arrived at the cost per mile of different modes as shown in Table 4a (cost per km is shown in Table 4b). These costs are based on 1974 economic conditions and technologies. More recently, the California Air Resource Board (CARB) has developed production costs per ton of pollutants for stationary source control measures in California. These "going rates" are shown in Table 5a (cost per ton) and in Table 5b (cost per metric ton). New estimates for pollution costs are needed for a more robust analysis.

TABLE 4a

Air Pollution Emissions and Costs [Small, 1977]

Vehicle Type	Emissions[a] (grams/mile)						1974 Cost[b]
	CO	HC[c]	HC[d]	NO_x	SO_x	PM	¢/mile
Automobiles							
Pre-1961 Model (in year 1974)	95.0	8.9	6.6	3.3	0.13	0.54	0.36
1969 Model (in year 1974)	68.0	5.0	2.5	5.1	0.13	0.54	0.33
1974 Model (new)	37.0	3.2	1.76	3.1	0.13	0.25	0.20
1974 Model (5 years old)	47.0	4.7	1.76	4.1	0.13	0.25	0.25
1974 Composite[e]	60.0	5.6	2.4	3.9	0.13	0.47	0.28
Post-1977 Model[f] (new)	2.8	0.27	1.76	0.24	0.13	0.25	0.04
Post-1977 Model (5 years old)	4.2	0.54	1.76	0.73	0.13	0.25	0.06
1995 Composite[g]	3.9	0.48	1.76	0.66	0.13	0.25	0.06
Diesel Bus or Truck							
Pre-1973 Model	21.3	4.0	–	21.5	2.8	1.3	0.96

[a]Emissions assume low altitudes and urban arterial driving at an average speed of 19.6 mph (31.5 km/hr).

[b]Costs are inflated or deflated by current-dollar gross national product per capita.

[c]Exhaust emissions.

[d]Crankcase and evaporative emissions.

[e]Exhaust emissions from 1974 and earlier models are weighted by the aggregate mileage driven on each model in 1974.

[f] Assuming enforcement of the last reductions called for in the 1970 Clean Air Act, originally scheduled for 1975 models and subsequently postponed to 1978 models.

[g]Composite exhaust emissions are calculated on the assumption of a steady-state population of post-1977 model cars, with age distribution and estimated deterioration from EPA.

TABLE 4b

Air Pollution Emissions and Costs [Small, 1977]

Vehicle Type	Emissions[a] (grams/km)						1974 Cost[b]
	CO	HC[c]	HC[d]	NO_x	SO_x	PM	¢/km
Automobiles							
Pre-1961 Model (in year 1974)	59.0	5.5	4.1	2.1	0.08	0.34	0.22
1969 Model (in year 1974)	42.3	3.1	1.6	3.2	0.08	0.34	0.21
1974 Model (new)	23.0	2.0	1.09	1.9	0.08	0.16	0.12
1974 Model (5 years old)	29.2	2.9	1.09	2.5	0.08	0.16	0.16
1974 Composite[e]	37.3	3.5	1.5	2.4	0.08	0.29	0.17
Post-1977 Model[f] (new)	1.7	0.17	1.09	0.15	0.08	0.16	0.03
Post-1977 Model (5 years old)	2.6	0.34	1.09	0.45	0.08	0.16	0.04
1995 Composite[g]	2.4	0.30	1.09	0.41	0.08	0.16	0.04
Diesel Bus or Truck							
Pre-1973 Model	13.2	2.5	–	13.4	1.7	0.81	0.60

[a]Emissions assume low altitudes and urban arterial driving at average speed of 31.5 km/hour.
[b]Costs are inflated or deflated by current-dollar gross national product per capita.
[c]Exhaust emissions.
[d]Crankcase and evaporative emissions.
[e]Exhaust emissions from 1974 and earlier models are weighted by the aggregate mileage driven on each model in 1974.
[f]Assuming enforcement of the last reductions called for in the 1970 Clean Air Ace Amendments, originally scheduled for 1975 models and subsequently postponed to 1978 models.
[g]Composite exhaust emissions are calculated on the assumption of a steady-state population of post-1977 model cars, with age distribution and estimated deterioration from the U.S. Environmental Protection Agency.

Table 5a

Pollutant "Going Rates"

Pollutant	Average Rate (per ton)	Highest Rate (per ton)
HC	\$4,000 - \$10,000	\$22,000
CO	\$200	\$2,000
NO_x	\$2,000 - \$10,000	\$24,000

Sources: California Air Resources Board.

Table 5b

Pollutant "Going Rates"

Pollutant	Average Rate (per metric ton)	Highest Rate (per metric ton)
HC	\$4,408 - \$11,020	\$24,244
CO	\$220	\$2,204
NO_x	\$2,204 - \$11,020	\$26,448

Sources: California Air Resources Board.

Finally, some expected cost and benefits to urban transportation systems for different TCMs are summarized in Table 6.

TABLE 6

Some Costs and Benefits Related to TCM Implementation and Air Pollution

Costs	Benefits
Improved public transit	
• Operation	• Fuel consumption reduction
• Additional initial investment	• Emissions reduction
Traffic flow improvement	
• Construction (HOV lanes)	• Fuel consumption reduction for some users
• Operation and enforcement	• Travel time saving for some users
Work schedule changes	
• Construction and operation of work satellite centers for telecommuting	• Fuel consumption reduction • Emissions reduction
• Building energy consumption	• Office space savings and reduced parking requirements
• Telecommunication and computer use	
• Congestion near satellite centers	
Park and ride and fringe parking	
• Facility construction	• Fuel consumption reduction for some users
• Traffic congestion near facilities	• Emissions reduction in central business district (CBD)
• Emissions near facilities	
Road pricing	
• Travel costs for users	• Fuel consumption reduction for overall systems • Emissions reduction
Alternative engines and fuels	
• Conversion of engines	• Emissions reduction
• Facilities for re-fueling stations	

CHAPTER 6. SAMPLE ANALYSIS

Application of the framework is demonstrated through the use of two examples. Two networks are created to evaluate a few strategies, namely implementation of a high-occupancy vehicle (HOV) lane or increased auto operating cost, for reducing congestion. For simplicity and illustrative comparison purposes, the sample networks are linear corridors. Evaluation of transportation control measures (TCMs) for considerably larger or more complex networks can be done using the same procedures, provided that computational time and cost as well as computer capacity are adequate. This is an inherent limitation of this study and the reason for the simple sample networks. Therefore, in these illustrative sample analyses, only microscale emissions estimation is considered.

The choice or "split" among several transportation modes depends on both the socioeconomic characteristics of the decision makers and the transportation alternatives available to them. The mode choice model used in both networks is a multinomial logit model developed by Ben-Akiva and Lerman [1985]. It is assumed that the traveler has the ability to compare all possible alternatives -- in this case, car, carpool, and bus -- and make the short-range decision to select the one with the highest utility, which is viewed as the index of his/her socioeconomic attributes. To predict changes in mode split for either the HOV lane implementation or the auto operating cost increase, we can use the choice probabilities in the base case (without TCMs) and the change in utility due only to the affected variable, travel time or operating cost. The probability of traveler "n" choosing any alternative "i" after the implementation of either of the above two TCMs can be expressed as:

$$P_n'(i) = \frac{P_n(i)e^{\Delta V_{in}}}{\sum_{j=1}^{3} P_n(j)e^{\Delta V_{jn}}}$$

where $P_n(j)$ is the choice probability in the base case; j=1 if auto is selected, j=2 if carpool is the alternative, and j=3 if bus is chosen. DV_{jn} is the change of individual utility which is formulated as:

$$DV_{jn} = b_1 \times \text{changes in travel time} + b_2 \times \frac{\text{changes in operating cost}}{\text{household income}}$$

The values of β_1 and β_2 are usually obtained from a regional survey. They are assumed as β_1 = -0.0307 and β_2 = -28.7 in the examples. Similarly, $28,000 is assumed as the average annual household income.

NETWORK A

In Network A, a highly congested urban street is created. The characteristics of the network and the street geometry are illustrated in Figure 9. All intersections are signalized. Turning volume is prescribed and constant for all cases. The volume of 3,520 persons during peak hour is assumed to travel from node 48 to node 1. The analysis is performed for the peak period, and the choice of time of day is not under consideration. Traffic volumes entering this network are assumed to be the same for all cases, except that entering node 48, which varied according to the modal splits obtained for different cases. Bus service is provided along the main street.

Six different scenarios are examined for Network A. For each case, several iterations are required such that the travel time used in the utility function of the mode choice model is, within a specified tolerance level, equal to that obtained from TRAF-NETSIM. These cases are:

1. *Base case.* The network geometry, traffic movements, and entering volume were described above. The person miles of travel (PMT), speed, and fuel consumption from NETSIM are listed in Table 7.
2. *HOV-4.* The traffic engineering data and basic geometry are the same as those in the base case, except the right lane along the main street is reserved for 4-person carpools and buses.
3. *HOV-3.* Same as HOV-4, except that a 3-person carpool is used instead of a 4-person.
4. *Bus-lane.* The extension of cases (2) and (3), with only buses allowed on the HOV lane.
5. *No-left-turn.* Left turns are not permitted along the main street.
6. *Pricing.* Operating costs for auto and carpool are increased by 25 percent and 10 percent, respectively. Bus prices remain the same.

The center lane in Network A is assumed to be a reversible lane for inbound/outbound traffic for morning and afternoon peak periods. Auto occupancy is assumed to be 1.3; carpool occupancy is 3 for all scenarios except scenario 2, which is 4; bus occupancy is 50 for scenarios 1, 5, and 6 and 70 scenarios for 2, 3, and 4. The simulation time is limited to 15 minutes owing to the limitation of microcomputer memory.

Simulations for non-base-case scenarios are performed in the following manner:

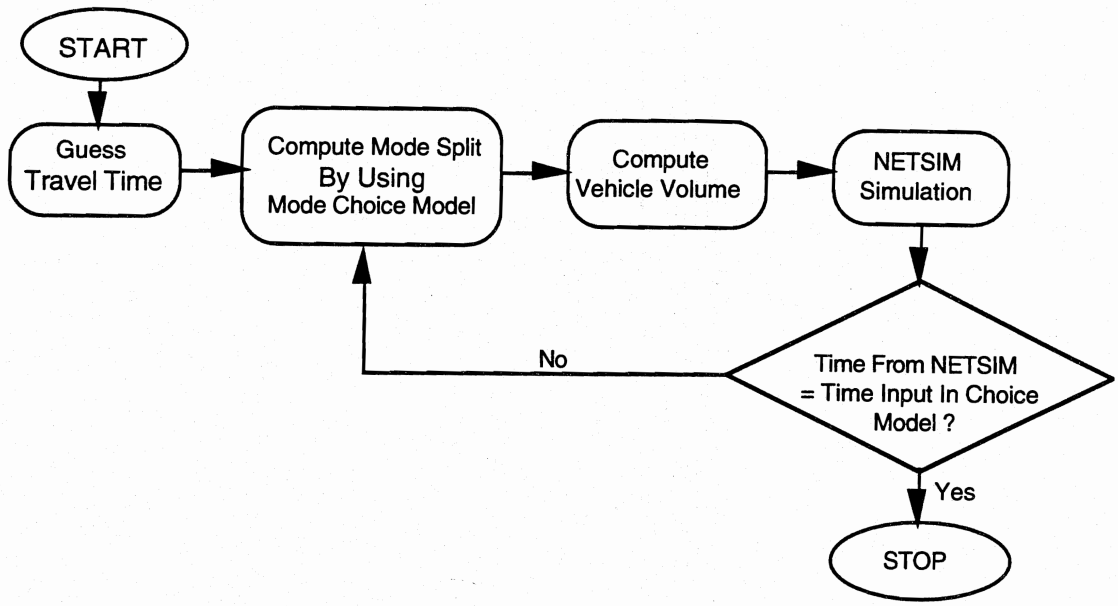
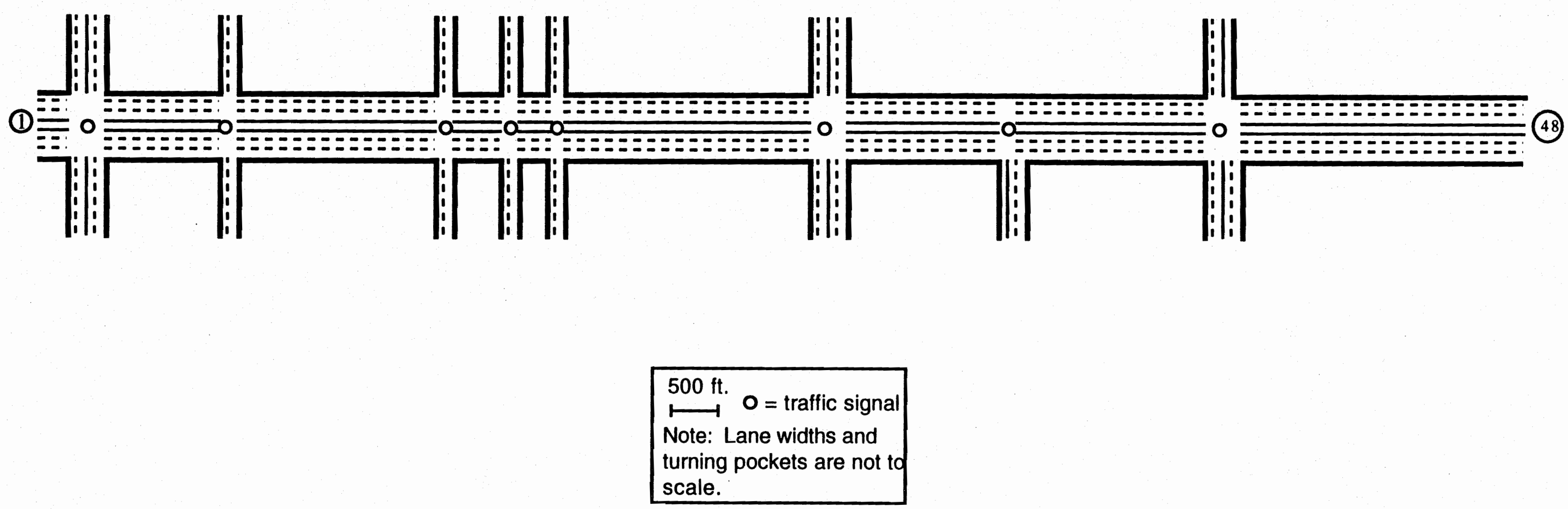


FIGURE 9
Sample Network A



In cases 2-6, the speed changes in autos, carpools, and buses after implementation of a TCM cause the changes in the utility function, and in turn yield the switch among the selections of drive-alone, carpool, and bus. The details of mode split and other traffic measurements at equilibrium are shown in Table 7.

Mobility can be subjectively evaluated by examining PMT in a unit time period or average speed. PMT is the same for all scenarios if a given level of demand is being analyzed. For example, 10,560 PMT is the input value in Network A. Owing to the difference in congestion levels in peak hour, however, the PMT in a unit time period (in this case, 15 minutes) may exhibit variation. The lower the congestion level, the shorter the congestion period, and in turn the larger the PMT in a unit time period during the congestion. The calculations in both networks are limited to the simulation period. All of the alternatives improve PMT during the 15-minute simulation period over the base case (except pricing in which PMT remains unchanged). The variations in PMT-in-15-minutes are due to the different congestion levels. The average speed improves for the HOV lanes and pricing, but decreases for the bus-lane and no-left-turn scenarios. The nominal changes for the left-turn outputs are primarily the result of the low percentage of left turns prescribed in the base case. From an energy standpoint, all scenarios except the no-left-turn option result in reduced fuel consumption. When accounting for the change in the mode split, there are some interesting results. All the scenarios, except the no-left-turn option, result in high vehicle occupancies, i.e., fewer automobile trips.

The speed and VMT resulting from NETSIM are the inputs for the emissions model. The vehicle emission results from MOBILE4.1 are listed in Table 8. (A more recent MOBILE version is now available. However, at the time this analysis was conducted, MOBILE4.1 was the current version.) Compared with the results in the base case, only the implementation of an HOV lane (both HOV-3 and HOV-4) in this network results in effective air pollution reduction. All other tested strategies achieve minor improvements in air quality. This is due to the fact that the demand largely exceeds the capacity in the network, which is reflected by the particularly slow speed in Table 7. The inclusion of an HOV lane can improve the PMT on the HOV lane, while the traffic in the other lanes of the network remain congested. This increases the denominator in calculating average emission results (on per-person per-distance basis), and in turn lowers average air pollution.

It is evident that properly designed TCMs can both relieve peak hour congestion and reduce emissions. In addition, TCMs can save significant amounts of money by avoiding the need for costly roadway expansion. The basic algorithm for TCM cost-effectiveness analysis is:

$$\text{Effectiveness} = \frac{\text{cost of TCM implementation} - \text{user savings}}{\text{money savings resulting from amounts of emissions reduced}}$$

The lower ratio indicates the more efficient TCM. As the ratio exceeds one, the implementation of TCM may not be cost-effective.

TABLE 7a

Mobility and Fuel Consumption Results for Network A

	Base	HOV-4	HOV-3	Bus-Lane	No Left	Pricing
PMT in 15 Minutes						
Auto	1,157	1,541	1,575	1,129	1,206	1,114
Carpool	548	872	860	535	561	587
Bus	313	536	529	555	290	317
Total	2,018	2,949	2,964	2,219	2,057	2,018
Average Speed (mph)						
Auto	6.4	10.4	10.9	6.0	6.3	7.2
Carpool	6.4	16.7	15.9	6.0	6.3	7.2
Bus	6.1	16.7	15.9	16.3	5.3	6.2
All Vehicles	6.4	11.4	11.9	6.0	6.3	7.2
Fuel Consumption (gallons/person-mile)						
Auto	.0632	.0396	.0403	.0550	.0631	.0631
Carpool	.0130	.0076	.0095	.0113	.0129	.0148
Bus	.0046	.0028	.0028	.0028	.0047	.0047
All Vehicles	.0405	.0233	.0245	.0315	.0410	.0398
Traveler Mode Split (%)						
Auto	57.33	52.24	53.15	50.88	58.34	55.18
Carpool	27.16	29.58	29.01	24.11	27.14	29.11
Bus	15.51	18.18	17.84	25.01	14.02	15.71

If it is assumed that there are total 3,520 trip-makers (for a peak period lasting 1 hour) using this 3.22-mile roadway facility for the morning and afternoon working trips, the amounts of pollutants reduced due to the implementation of HOV-3 are:

HC: (6.1788-2.1103) * 3520 * 3.22 * 2 trips/day * 250 days/yr = 23.1 tons/yr

CO: (58.717 - 18.752) *3520 *3.22 * 2 trips/day * 250 days/yr = 226.5 tons/yr

NO_X (1.2703 - 0.7860) *3520 * 3.22 *2 trips/day * 250 days/yr = 2.74 tons/yr

TABLE 7b

Mobility and Fuel Consumption Results for Network A

	Base	HOV-4	HOV-3	Bus-Lane	No Left	Pricing
Person-km of Travel in 15 Minutes						
Auto	1,862	2,479	2,534	1,817	1,940	1,792
Carpool	882	1,403	1,384	861	903	944
Bus	504	862	851	893	467	510
Total	3,248	4,744	4,769	3,571	3,310	3,246
Average Speed (mph)						
Auto	10.3	16.7	17.5	9.7	10.1	11.6
Carpool	10.3	26.9	25.6	9.7	10.1	11.6
Bus	9.8	26.9	25.6	26.2	8.5	10.0
All Vehicles	10.3	18.3	19.2	9.7	10.1	11.6
Fuel Consumption (liters/person-km)						
Auto	.1487	.0932	.0948	.1294	.1484	.1484
Carpool	.0306	.0179	.0223	.0266	.0303	.0348
Bus	.0108	.0066	.0066	.0066	.0111	.0111
All Vehicles	.0953	.0548	.0576	.0741	.0964	.0936
Traveler Mode Split (%)						
Auto	57.33	52.24	53.15	50.88	58.34	55.18
Carpool	27.16	29.58	29.01	24.11	27.14	29.11
Bus	15.51	18.18	17.84	25.01	14.02	15.71

If it is assumed that there are total 3,520 trip-makers (for a peak period lasting 1 hour) using this 5.18 km roadway facility for the morning and afternoon working trips, the amounts of pollutants reduced due to the implementation of HOV-3 are:

HC: (6.1788-2.1103) * 3520 * 3.22 * 2 trips/day * 250 days/yr = 21.0 metric tons/yr

CO: (58.717 - 18.752) *3520 *3.22 * 2 trips/day * 250 days/yr = 205.5 metric tons/yr

NO_X (1.2703 - 0.7860) *3520 * 3.22 *2 trips/day * 250 days/yr = 2.49 metric tons/yr

TABLE 8a

Emission Results for Network A

(gram/person-mile)

		Base	HOV-4	HOV-3	Bus-Lane	No Left	Pricing
Auto							
Running							
	HC	3.2710	2.0350	1.9930	3.2920	3.2090	3.6150
	CO	30.6160	17.6070	17.1440	30.9930	30.1170	33.8370
	NOx	1.0000	0.8340	0.8470	0.9600	0.9690	1.1050
Idle							
	HC	3.4090	1.2820	1.5580	3.3930	3.3230	3.3960
	CO	32.6810	12.2890	14.9310	32.5280	31.8540	32.5550
	NOx	0.4400	0.1660	0.2010	0.4380	0.4290	0.4390
Carpool							
Running							
	HC	1.4110	0.4960	0.6650	1.4250	1.4200	1.4000
	CO	13.1960	3.9520	5.3360	13.4140	13.3240	13.1070
	NOx	0.4310	0.2680	0.3510	0.4160	0.4290	0.4280
Idle							
	HC	7.1960	0.0090	0.0100	7.1610	7.1430	6.4380
	CO	68.9830	0.0850	0.0930	68.6450	68.4730	61.7110
	NOx	0.9300	0.0010	0.0010	0.9250	0.9230	0.8320
Bus							
Running							
	HC	0.0900	0.1190	0.1230	0.1210	0.0930	0.0900
	CO	0.5790	0.6080	0.6370	0.6220	0.6160	0.5790
	NOx	0.4340	0.6630	0.6760	0.6700	0.4480	0.4340
Idle							
	HC	0.0420	0.0270	0.0290	0.0280	0.0500	0.0420
	CO	0.1240	0.0810	0.0870	0.0840	0.1490	0.1230
	NOx	0.0500	0.0330	0.0350	0.0340	0.0600	0.0500
Weighted Average							
Running							
	HC	2.2725	1.2314	1.2741	2.0488	2.2706	2.4164
	CO	21.2260	10.4774	10.7737	19.1589	21.2728	22.5777
	NOx	0.7577	0.6355	0.6726	0.7563	0.7446	0.8025
Idle							
	HC	3.9153	0.6773	0.8362	3.4599	3.8843	3.7546
	CO	37.4910	6.4596	7.9783	33.1216	37.1881	35.9472
	NOx	0.5126	0.0930	0.1134	0.4544	0.5092	0.4923
Total							
	HC	6.1878	1.9087	2.1103	5.5087	6.1548	6.1710
	CO	58.7170	16.9371	18.7520	52.2805	58.4608	58.5249
	NOx	1.2703	0.7285	0.7860	1.2107	1.2537	1.2948

TABLE 8b

Emission Results for Network A

(gram/person-km)

		Base	HOV-4	HOV-3	Bus-Lane	No Left	Pricing
Auto							
Running							
	HC	2.033	1.265	1.239	2.046	1.994	2.247
	CO	19.028	10.943	10.655	19.262	18.718	21.030
	NOx	0.622	0.518	0.526	0.597	0.602	0.687
Idle							
	HC	2.119	0.797	0.968	2.109	2.065	2.111
	CO	20.311	7.638	9.280	20.216	19.797	20.233
	NOx	0.273	0.103	0.125	0.272	0.267	0.273
Carpool							
Running							
	HC	0.877	0.308	0.413	0.886	0.883	0.870
	CO	8.201	2.456	3.316	8.337	8.281	8.146
	NOx	0.268	0.167	0.218	0.259	0.267	0.266
Idle							
	HC	4.472	0.006	0.006	4.451	4.439	4.001
	CO	42.873	0.053	0.058	42.663	42.556	38.354
	NOx	0.578	0.001	0.001	0.575	0.574	0.517
Bus							
Running							
	HC	0.056	0.074	0.076	0.075	0.058	0.056
	CO	0.360	0.378	0.400	0.387	0.382	0.361
	NOx	0.270	0.412	0.420	0.416	0.278	0.271
Idle							
	HC	0.026	0.178	0.018	0.017	0.031	0.026
	CO	0.080	0.050	0.054	0.052	0.092	0.076
	NOx	0.031	0.021	0.022	0.021	0.037	0.031
Weighted Average							
Running							
	HC	1.412	0.765	0.792	1.273	1.411	1.502
	CO	13.192	6.512	6.706	11.907	13.221	14.032
	NOx	0.471	0.395	0.418	0.470	0.463	0.598
Idle							
	HC	2.433	0.421	0.520	2.150	2.414	2.333
	CO	23.300	4.015	4.969	20.590	23.113	22.341
	NOx	0.319	0.068	0.070	0.282	0.316	0.306
Total							
	HC	3.846	1.186	1.311	3.424	3.825	3.835
	CO	36.493	10.526	11.654	32.492	36.334	36.373
	NOx	0.790	0.489	0.489	0.752	0.779	0.805

The total savings associated with the emission reductions are $300,000 per year if hydrocarbon (HC) and nitrogen oxides (NO_X) "going rates" (see Table 5) are each assumed as $10,000 per ton ($11,020 per metric ton). In addition, the annual user savings resulting from fuel consumption are about $100,000 if gas prices remain at $1.15 per gallon ($0.30 per liter). This shows that it is beneficial on the average to reserve an HOV lane if total cost is less than $400,000. This limit may be over $1,000,000 if the highest "going rates" are applied. This analysis is conservative since the commuter savings in time are not included.

NETWORK B

In Network B, an urban arterial street, including three residential zones and a central business district (CBD), is simulated. The street, illustrated in Figure 10, consists of 9 links from west to east. The three major residential zones are node 1, node 31, and node 62, and the CBD is node 10. It is assumed that the number of persons living in the residential zones with the mode choice alternatives of drive-alone, carpool, and transit bus includes 3,000 persons in node 1 and 1,000 persons each in node 31 and 62. The assumed mode shares are listed as the base case in Table 9. There is a transit route from each residential area to the CBD. Auto occupancy is assumed to be 1.3; carpool occupancy is 3 for all scenarios; bus maximum occupancy is 25 for the base scenario and 30 for the other two study cases in order to meet the demand. The bus headway is 5 minutes for all three routes, which enables the mass transit servicing under its maximum capacity. Each case was a 1-hour simulation performed on a PC486DX/50 requiring 45-50 minutes of real time.

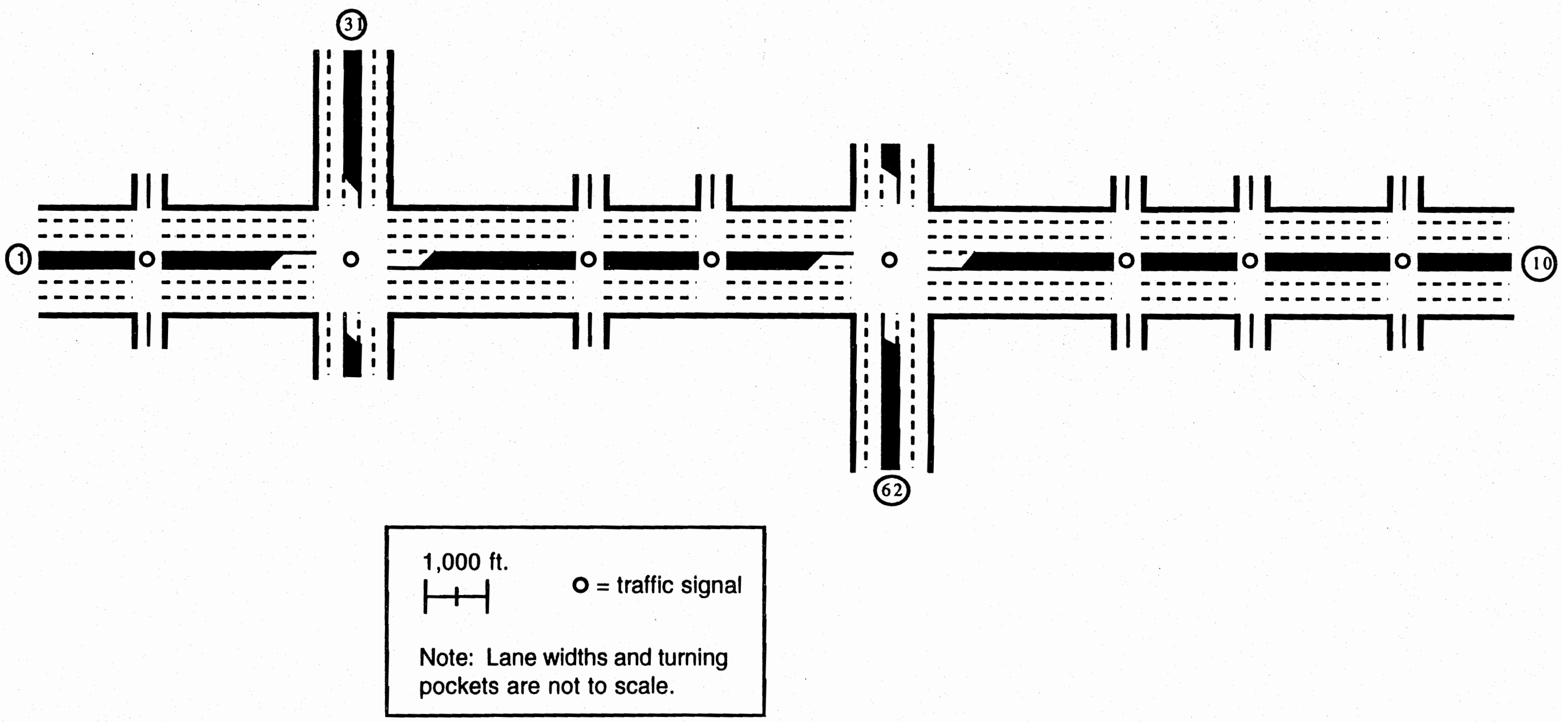
Because of the computation time, only three different cases are examined in this network simulation:

1. *Base case* as described above.
2. *HOV-3.* The right lane along the main street (from node 1 to node 10) is reserved for 3-person carpools and buses.
3. *Pricing.* Operating costs for auto and carpool are increased by 25 percent and 10 percent, respectively. No change in selecting bus.

The different travel time from each residential zone to the CBD results in the different mode shares among travelers in the residential zones. This information is detailed in Table 9. The weighted averages for the various modes in the network (aggregated values) are listed in Table 10.

The mobility and fuel consumption measurements for the Network B scenarios are described in Table 10. With respect to the base case, PMT in the simulation period decreases for

FIGURE 10
Sample Network B



the HOV scenario but increases for the pricing option. Likewise, there is a decrease in average speed for the HOV option and an increase for the pricing option. Average fuel consumption, however, improved (decreased) for both of the strategies relative to the base case.

The emission results in Table 11 show that the incentives for existing mass transit use can achieve a limited reduction in pollution. The most attractive strategy examined is the increase in the auto operating cost, through parking costs, gas taxes, etc. The program reduces the emissions of HC, carbon monoxide (CO), and NOx by about 2-3 percent on the average per-person-per-distance basis. The exclusive HOV lane can decrease average emissions from buses by improving the traffic flow on the HOV lane. These results, however, are offset by the slower auto movements owing to the reduction in the number of regular lanes. Furthermore, the carpools which are slowed by the frequently stopped buses at the stations worsen the air pollution in the network.

TABLE 9

Travel Time and Mode Split from Residential Area to CBD

		Base	HOV-3	Pricing
1 - 10 (%)				
Time (min)	Auto	13.83	16.98	13.36
	Carpool	13.83	13.19	13.36
	Bus	16.62	13.19	15.85
Mode Split (%)	Auto	65.00	61.71	62.31
	Carpool	25.00	26.67	26.69
	Bus	10.00	11.62	11.00
31 - 10 (%)				
Time (min)	Auto	14.55	16.08	13.36
	Carpool	14.55	13.64	13.36
	Bus	17.19	13.64	15.85
Mode Split (%)	Auto	65.00	62.72	62.29
	Carpool	25.00	26.00	26.68
	Bus	10.00	11.28	11.03
62 - 10 (%)				
Time (min)	Auto	8.76	9.31	8.06
	Carpool	8.76	12.41	8.06
	Bus	10.59	12.41	10.17
Mode Split (%)	Auto	65.00	66.77	62.43
	Carpool	25.00	23.35	26.74
	Bus	10.00	9.88	10.83

TABLE 10a

Mobility and Fuel Consumption Results for Network B

	Base	HOV-3	Pricing
PMT in 30 minutes			
Auto	5,332	4,344	4,940
Carpool	2,100	2,242	2,491
Bus	786	890	865
Total	8,218	7,476	8,296
Average Speed (mph)			
Auto	14.50	12.40	15.13
Carpool	14.50	14.44	15.13
Bus	11.72	14.44	12.19
All Vehicles	14.22	13.15	14.81
Fuel Consumption (gallons/person-mile)			
Auto	.0718	.0773	.0736
Carpool	.0311	.0335	.0322
Bus	.0185	.0148	.0155
All Vehicles (Avg.)	.0570	.0551	.0560
Traveler Mode Split (%)			
Auto	65.00	62.92	62.33
Carpool	25.00	25.87	26.70
Bus	10.00	11.20	10.97
Avg. Vehicle Occupancy	1.703	1.742	1.748

TABLE 10b

Mobility and Fuel Consumption Results for Network B

	Base	HOV-3	Pricing
PKT in 30 minutes			
Auto	8,579	6,989	7,948
Carpool	3,379	3,607	4,008
Bus	1,265	1,432	1,392
Total	13,223	12,028	13,348
Average Speed (km/hr)			
Auto	23.33	19.95	24.34
Carpool	23.33	23.23	24.34
Bus	18.86	23.23	19.61
All Vehicles	22.88	21.16	23.83
Fuel Consumption (liters/person-km)			
Auto	.1689	.1818	.1731
Carpool	.0732	.0788	.0757
Bus	.0435	.0348	.0365
All Vehicles (Avg.)	.0134	.1296	.1317
Traveler Mode Split (%)			
Auto	65.00	62.92	62.33
Carpool	25.00	25.87	26.70
Bus	10.00	11.20	10.97
Avg. Vehicle Occupancy	1.703	1.742	1.748

TABLE 11a

Emission Results for Network B

(gram/person-mile)

	Base	HOV-3	Pricing
Auto			
Running			
HC	1.7308	1.9213	1.6846
CO	14.1231	16.1308	13.6538
NOx	0.8615	0.8769	0.8615
Idle			
HC	1.0209	1.3498	1.1541
CO	9.7865	12.9388	11.0631
NOx	0.1319	0.1744	0.1491
Carpool			
Running			
HC	0.7500	0.7533	0.7300
CO	6.1200	6.1533	5.9167
NOx	0.3733	0.3767	0.3733
Idle			
HC	0.4424	0.5849	0.4338
CO	4.2408	5.6068	4.1579
NOx	0.0572	0.0756	0.0560
Bus			
Running			
HC	0.2177	0.1715	0.1847
CO	1.2243	0.9121	1.0060
NOx	1.1250	0.9205	0.9745
Idle			
HC	0.0596	0.0450	0.0621
CO	0.1770	0.1338	0.1843
NOx	0.0716	0.0541	0.0745
Weighted Average			
Running			
HC	1.3354	1.3627	1.2416
CO	10.8442	11.3265	10.0119
NOx	0.7619	0.7321	0.7267
Idle			
HC	0.7811	0.9801	0.8240
CO	7.4502	9.2153	7.8554
NOx	0.1070	0.1304	0.1134
Total			
HC	2.1165	2.3428	2.0656
CO	18.2994	20.5418	17.8673
NOx	0.8689	0.8625	0.8401

TABLE 11b

Emission Results for Network B

(gram/person-km)

	Base	HOV-3	Pricing
Auto			
Running			
HC	1.086	1.194	1.047
CO	8.778	10.025	8.486
NOx	0.535	0.545	0.535
Idle			
HC	0.634	0.839	0.717
CO	6.082	8.042	6.876
NOx	0.082	0.108	0.622
Carpool			
Running			
HC	0.466	0.468	0.454
CO	3.804	3.824	3.677
NOx	0.232	0.234	0.232
Idle			
HC	0.275	0.364	0.270
CO	2.636	3.485	2.584
NOx	0.036	0.047	0.035
Bus			
Running			
HC	0.135	0.107	0.115
CO	0.761	0.567	0.625
NOx	0.700	0.572	0.606
Idle			
HC	0.037	0.028	0.039
CO	0.110	0.083	0.115
NOx	0.044	0.034	0.046
Weighted Average			
Running			
HC	0.830	0.847	0.772
CO	6.740	7.040	6.222
NOx	0.474	0.455	0.452
Idle			
HC	0.485	0.609	0.512
CO	4.630	5.727	4.882
NOx	0.067	0.081	0.070
Total			
HC	1.315	1.456	1.284
CO	11.373	12.767	11.105
NOx	0.540	0.536	0.522

CHAPTER 7. DISCUSSION AND CONCLUSION

Although available transportation planning tools cannot be directly used for emissions estimation, a macro-analysis framework is proposed herein which links the transportation planning and air quality analysis models in order to develop a matrix of strategies to assist decision makers in examining specific mobility strategies for an urban area. The purpose of the report is to illustrate a framework for identifying energy, air quality, and mobility trade-offs of various congestion mitigation strategies. Based on this methodological framework, two sample networks are evaluated in this project. In both central business district (CBD) type networks, the implementation of transportation control measures (TCM) can decrease overall vehicle miles of travel (VMT). The air pollution resulting from mobile sources, nevertheless, may not be effectively alleviated, or it may even be worsened by applying inappropriate TCM strategies. The effects of TCMs on air quality are more effective as an urban street network becomes more and more congested. This is illustrated by the two sample networks, which are very congested. In network A, changing the pattern of vehicle flow can achieve the goal of reducing air pollution, while in network B it is more effective to increase auto operating costs. The reason for the radically different results from network A and B may be the extraordinary congestion for drive-alone in network B, resulting from changing one lane from a regular lane to an HOV lane. The results of the analysis illustrate the need for careful study before implementation of any TCMs. Failure to analyze the implications of TCMs prior to their implementation may yield results inconsistent with environmental and energy policy objectives.

The validity of VMT as a meaningful measure requires careful scrutiny. In network B, it is quite obvious to reduce VMT by including a HOV lane in order to increase the average vehicle occupancy. The mobility in the network, however, decreases due to the heavier congestion in the regular lanes, which is illustrated by the reduced auto speed. The decrease in total VMT resulting from some TCMs may produce more frequent stop-and-go situations, which may in turn emit more mobile source pollution.

The effectiveness of the auto operating cost increase in network B reminds us of the role of pricing in TCM strategies. It turns out that many policy makers are considering a variety of pricing innovations, though some of them may be difficult to implement under current laws and regulations. Some states are now realizing substantial increases in transportation revenues through sales tax increments. In California, these revenues are used to improve specific transit and transportation infrastructure. Substantial vehicle registration fee increases to help fund TCMs are also under consideration, as are pollution taxes on the heaviest emitting vehicles. In New

York, imposing tolls on previously free bridges is being attempted to link them to specific repair and maintenance benefits.

The program to reduce automotive pollutants, in order to assure the highest cost-effectiveness over the entire lifetime of the program, must incorporate both short- and long-term solutions. The significance of the automobile to urban lifestyles and the considerable cost of altering its use necessitates a flexible approach to controlling its environmental impacts.

The choice of an emissions model is very critical in air quality analysis. MOBILE4.1 (or the newer releases) takes into account elevation, temperature, operating modes, cold starts, vehicle age, etc., which may not be included in other emissions models, yielding more accurate results. The emissions from NETSIM may result in biased conclusions, e.g., the inclusion of an exclusive HOV lane in the sample network B is plausible by NETSIM for reducing (hydrocarbon) HC and (carbon dioxide) CO pollution. However, as illustrated in Table 12, this is not the case using MOBILE4.1. NETSIM's emissions factors are dated and its analysis is not nearly as sophisticated as that of MOBILE.

Use of the framework as demonstrated in this report, clearly points to the need for additional modeling work. Existing models may be calibrated for some analysis but cannot be relied upon for directing future transportation investment. They can, however, provide some relative comparison of TCMs. The framework presented in this report should assist analysts in the interim, while work proceeds on the development of more comprehensive transportation demand/air quality models.

TABLE 12a

Comparison of the Emissions Results

(gram/person-mile)

	HC	CO	NOx
Network A			
Base			
NETSIM	0.1734	3.1556	0.5904
MOBILE4.1	6.1878	58.7170	1.2703
HOV-4			
NETSIM	0.1096	2.1878	0.4692
MOBILE4.1	1.9087	16.9371	0.7285
HOV-3			
NETSIM	0.1157	2.3250	0.4991
MOBILE4.1	2.1103	18.7520	0.7860
Bus-Lane			
NETSIM	0.1509	2.7787	0.5184
MOBILE4.1	5.5087	52.2805	1.2107
No Left			
NETSIM	0.1726	3.2555	0.5776
MOBILE4.1	6.1548	58.4608	1.2537
Pricing			
NETSIM	0.1778	3.3739	0.6245
MOBILE4.1	6.1710	58.5249	1.2948
Network B			
Base			
NETSIM	0.2724	5.8290	1.2640
MOBILE4.1	2.1165	18.2994	0.8689
HOV-3			
NETSIM	0.2636	5.5280	1.1800
MOBILE4.1	2.3428	20.5418	0.8625
Pricing			
NETSIM	0.2681	5.6350	1.2150
MOBILE4.1	2.0656	17.8673	0.8401

TABLE 12b

Comparison of the Emissions Results

(gram/person-mile)

	HC	CO	NOx
Network A			
Base			
NETSIM	0.108	1.961	0.367
MOBILE4.1	3.845	36.493	0.789
HOV-4			
NETSIM	0.0682	1.36	0.292
MOBILE4.1	1.186	10.53	0.453
HOV-3			
NETSIM	0.072	1.445	0.310
MOBILE4.1	1.312	11.654	0.489
Bus-Lane			
NETSIM	0.094	1.727	0.322
MOBILE4.1	3.424	32.493	0.752
No Left			
NETSIM	0.107	2.023	0.359
MOBILE4.1	3.826	36.334	0.779
Pricing			
NETSIM	0.111	2.097	0.388
MOBILE4.1	3.835	36.374	0.805
Network B			
Base			
NETSIM	0.167	3.623	0.786
MOBILE4.1	1.315	11.373	0.540
HOV-3			
NETSIM	0.164	3.436	0.733
MOBILE4.1	1.456	12.777	0.536
Pricing			
NETSIM	0.167	3.502	0.76
MOBILE4.1	1.284	11.11	0.52

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Appendix A

TRAF-NETSIM Input for Network A

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




                                           RELEASE DATE = 10/10/89
                                                 VERSION 3.00
1                                           TRAF SIMULATION MODEL

                                                 START OF CASE   1

 ******************************************************************************************************************************

1                                             TRAF SIMULATION MODEL

                                                 DEVELOPED FOR

                                      U. S. DEPARTMENT OF TRANSPORTATION
                                        FEDERAL HIGHWAY ADMINISTRATION
                                           TRAFFIC SYSTEMS DIVISION
0******************************************************************************************************************************

                                                 START OF CASE   1

 ******************************************************************************************************************************
0
0                     AIR QUALITY ANALYSIS
0


                                         DATE =    3/  15/  93
0                                        USER = J.MEESOMBOON
0                                      AGENCY = UT @ AUSTIN
1                                               RUN CONTROL DATA


                  VALUE                          RUN PARAMETERS AND OPTIONS

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

0                          NETSIM ENVIRONMENTAL OPTIONS
                           ----------------------------
                      0    FUEL/EMISSION RATE TABLES ARE NOT PRINTED
                      0    SIMULATION:  PERFORMED                            ENVIRONMENTAL MEASURES:  CALCULATED
                           RATE TABLES: EMBEDDED                             TRAJECTORY FILE:         NOT WRITTEN
0                     0    INPUT  UNITS CODE = (0,1) IF INPUT IS IN (ENGLISH, METRIC) UNITS
                      0    OUTPUT UNITS CODE = (0,1,2,3) IF OUTPUT IS IN (SAME AS INPUT, ENGLISH, METRIC, BOTH) UNITS
0                   700    CLOCK TIME AT START OF SIMULATION (HHMM)
0                     0    SIGNAL TRANSITION CODE = (0,1,2,3) IF (NO, IMMEDIATE, 2-CYCLE, 3-CYCLE) TRANSITION WAS REQUESTED
0                  7581    RANDOM NUMBER SEED
                   7781    RANDOM NUMBER SEED TO GENERATE TRAFFIC STREAM FOR NETSIM OR LEVEL I SIMULATION

                    120    DURATION (SEC) OF TIME PERIOD NO.  1
0                    60    LENGTH OF A TIME INTERVAL, SECONDS
0                    10    MAXIMUM INITIALIZATION TIME, NUMBER OF TIME INTERVALS
0                     0    NUMBER OF TIME INTERVALS BETWEEN SUCCESSIVE STANDARD OUTPUTS
0                     0    TIME INTERMEDIATE OUTPUT WILL BEGIN AT INTERVALS OF     0 SECS. FOR     0 SECS. FOR MICROSCOPIC MODEL
0                     0    NETSIM MOVEMENT-SPECIFIC OUTPUT CODE = (0,1) (IF NOT, IF) REQUESTED FOR NETSIM SUBNETWORK
0                     0    NETSIM GRAPHICS OUTPUT CODE = (0,1) IF GRAPHICS OUTPUT (IS NOT, IS) REQUESTED
1******************************************************************************************************************************

                                      TIME PERIOD    1 - NETSIM DATA

 ******************************************************************************************************************************
1

                                                  NETSIM LINKS
0                  -LANES-        -CHANNEL-

                   F              C
                   U              U                                   LOST  Q DIS   FREE                    LANE
            LENGTH L PKT GRD LINK R          DESTINATION NODE  OPP.   TIME  HDWY.   SPEED     RTOR PED    ALIGN    STREET
    LINK    FT / M L L R PCT TYPE B234567  LEFT THRU RGHT DIAG NODE   SEC   SEC     MPH/KMPH  CODE CODE   -MENT     NAME
```

(70, 1)	300/ 91	2	0	0	0	1*	0000000	0	8001	0	0	8001	2.5*	1.9	40/ 64	0	0	1-1*
(40, 70)	400/ 122	2	0	0	0	1*	0000000	0	1	0	0	1	2.5*	1.9	40/ 64	0	0	1-1*
(71, 40)	400/ 122	3	0	0	0	1*	0010000	28	70	2	0	70	2.5*	1.9	40/ 64	0	1	1-1*
(41, 71)	1184/ 361	2	0	0	0	1*	0000000	0	40	0	0	40	2.5*	1.9	40/ 64	0	0	1-1*
(42, 41)	2112/ 644	2	1	0	0	1*	0000000	27	71	3	0	71	2.5*	1.9	40/ 64	0	1	1-1*
(43, 42)	528/ 161	2	1	0	0	1*	0000000	26	41	4	0	41	2.5*	1.9	40/ 64	0	1	1-1*
(44, 43)	264/ 80	2	1	0	0	1*	0000000	25	42	5	0	42	2.5*	1.9	40/ 64	0	1	1-1*
(45, 44)	2640/ 805	2	1	1	0	1*	0000000	24	43	6	0	43	2.5*	1.9	40/ 64	0	1	1-1*
(46, 45)	1584/ 483	2	1	1	0	1*	0000000	23	44	7	0	44	2.5*	1.9	40/ 64	0	1	1-1*
(47, 46)	1848/ 563	2	1	0	0	1*	0000000	22	45	0	0	45	2.5*	1.9	40/ 64	0	1	1-1*
(48, 47)	2904/ 885	2	0	1	0	1*	0000000	21	46	9	0	46	2.5*	1.9	40/ 64	0	1	1-1*
(8048, 48)	0/ 0	2	0	0	0	1*	0000000	0	47	0	0	47	2.5*	2.1	0/ 0	0	0	1-1*
(8001, 1)	0/ 0	2	0	0	0	1*	0000000	0	70	0	0	70	2.5*	1.9	0/ 0	0	0	1-1*
(1, 70)	300/ 91	2	0	0	0	1*	0000000	0	40	0	0	40	2.5*	1.9	40/ 64	0	0	1-1*
(70, 40)	400/ 122	3	0	0	0	1*	0010000	2	71	28	0	71	2.5*	1.9	40/ 64	0	1	1-1*
(40, 71)	400/ 122	2	0	0	0	1*	0000000	0	41	0	0	41	2.5*	1.9	40/ 64	0	0	1-1*
(71, 41)	1184/ 361	2	1	0	0	1*	4000000	3	42	27	0	42	2.5*	1.9	40/ 64	0	1	1-1*
(41, 42)	2112/ 644	2	1	0	0	1*	4000000	4	43	26	0	43	2.5*	1.9	40/ 64	0	1	1-1*
(42, 43)	528/ 161	2	1	0	0	1*	4000000	5	44	25	0	44	2.5*	1.9	40/ 64	0	1	1-1*
(43, 44)	264/ 80	2	1	0	0	1*	4000000	6	45	24	0	45	2.5*	1.9	40/ 64	0	1	1-1*
(44, 45)	2640/ 805	2	1	1	0	1*	0000000	7	46	23	0	46	2.5*	1.9	40/ 64	0	1	1-1*
(45, 46)	1584/ 483	2	0	1	0	1*	0000000	0	47	22	0	47	2.5*	1.9	40/ 64	0	0	1-1*
(46, 47)	1848/ 563	2	0	1	0	1*	0000000	9	48	21	0	48	2.5*	1.9	40/ 64	0	1	1-1*
(47, 48)	2904/ 885	2	0	0	0	1*	0000000	0	8048	0	0	0	2.5*	1.9	40/ 64	0	0	1-1*
(8028, 28)	0/ 0	2	0	0	0	1*	0000000	0	40	0	0	40	2.5*	2.1	0/ 0	0	0	1-1*
(28, 40)	700/ 213	2	0	1	0	1*	0000000	70	2	71	0	2	2.5*	2.1	30/ 48	0	1	1-1*
(40, 2)	700/ 213	2	0	0	0	1*	0000000	0	8002	0	0	8002	2.5*	2.1	30/ 48	0	0	1-1*
(8002, 2)	0/ 0	2	0	0	0	1*	0000000	0	40	0	0	40	2.5*	2.1	0/ 0	0	0	1-1*
(2, 40)	700/ 213	2	0	1	0	1*	0000000	71	28	70	0	28	2.5*	2.1	30/ 48	0	1	1-1*
(40, 28)	700/ 213	2	0	0	0	1*	0000000	0	8028	0	0	8028	2.5*	2.1	30/ 48	0	0	1-1*
(8027, 27)	0/ 0	1	0	0	0	1*	0000000	0	41	0	0	41	2.5*	2.1	0/ 0	0	0	1-1*
(27, 41)	700/ 213	1	0	0	0	1*	0000000	71	3	42	0	3	2.5*	2.1	30/ 48	0	1	1-1*
(41, 3)	700/ 213	1	0	0	0	1*	0000000	0	8003	0	0	8003	2.5*	2.1	30/ 48	0	0	1-1*
(8003, 3)	0/ 0	1	0	0	0	1*	0000000	0	41	0	0	41	2.5*	2.1	0/ 0	0	0	1-1*
(3, 41)	700/ 213	1	0	0	0	1*	0000000	42	27	71	0	27	2.5*	2.1	30/ 48	0	1	1-1*
(41, 27)	700/ 213	1	0	0	0	1*	0000000	0	8027	0	0	8027	2.5*	2.1	30/ 48	0	0	1-1*
(8026, 26)	0/ 0	1	0	0	0	1*	0000000	0	42	0	0	42	2.5*	2.1	0/ 0	0	0	1-1*
(26, 42)	700/ 213	1	0	0	0	1*	0000000	41	4	43	0	4	2.5*	2.1	30/ 48	0	1	1-1*
(42, 4)	700/ 213	1	0	0	0	1*	0000000	0	8004	0	0	8004	2.5*	2.1	30/ 48	0	0	1-1*
(8004, 4)	0/ 0	1	0	0	0	1*	0000000	0	42	0	0	42	2.5*	2.1	0/ 0	0	0	1-1*
(4, 42)	700/ 213	1	0	0	0	1*	0000000	43	26	41	0	26	2.5*	2.1	30/ 48	0	1	1-1*
(42, 26)	700/ 213	1	0	0	0	1*	0000000	0	8026	0	0	8026	2.5*	2.1	30/ 48	0	0	1-1*
(8025, 25)	0/ 0	1	0	0	0	1*	0000000	0	43	0	0	43	2.5*	2.1	0/ 0	0	0	1-1*
(25, 43)	700/ 213	1	0	0	0	1*	0000000	42	5	44	0	5	2.5*	2.1	30/ 48	0	1	1-1*
(43, 5)	700/ 213	1	0	0	0	1*	0000000	0	8005	0	0	8005	2.5*	2.1	30/ 48	0	0	1-1*

1

NETSIM LINKS (CONT.)

0 -LANES- -CHANNEL-

LINK	LENGTH FT / M	FUL L	PKT L	PKT R	GRD PCT	LINK TYPE	CUR B234567	DESTINATION NODE LEFT	THRU	RGHT	DIAG	OPP. NODE	LOST TIME SEC	Q DIS HDWY. SEC	FREE SPEED MPH/KMPH	RTOR CODE	PED CODE	LANE ALIGN -MENT	STREET NAME
(8005, 5)	0/ 0	1	0	0	0	1*	0000000	0	43	0	0	43	2.5*	2.1	0/ 0	0	0	1-1*	
(5, 43)	700/ 213	1	0	0	0	1*	0000000	44	25	42	0	25	2.5*	2.1	30/ 48	0	1	1-1*	
(43, 25)	700/ 213	1	0	0	0	1*	0000000	0	8025	0	0	8025	2.5*	2.1	30/ 48	0	0	1-1*	
(8024, 24)	0/ 0	1	0	0	0	1*	0000000	0	44	0	0	44	2.5*	2.1	0/ 0	0	0	1-1*	
(24, 44)	700/ 213	1	0	1	0	1*	0000000	43	6	45	0	6	2.5*	2.1	30/ 48	0	1	1-1*	
(44, 6)	700/ 213	1	0	0	0	1*	0000000	0	8006	0	0	8006	2.5*	2.1	30/ 48	0	0	1-1*	
(8006, 6)	0/ 0	1	0	0	0	1*	0000000	0	44	0	0	44	2.5*	2.1	0/ 0	0	0	1-1*	
(6, 44)	700/ 213	1	0	0	0	1*	0000000	45	24	43	0	24	2.5*	2.1	30/ 48	0	1	1-1*	
(44, 24)	700/ 213	1	0	0	0	1*	0000000	0	8024	0	0	8024	2.5*	2.1	30/ 48	0	0	1-1*	
(8023, 23)	0/ 0	2	0	0	0	1*	0000000	0	45	0	0	45	2.5*	2.1	0/ 0	0	0	1-1*	
(23, 45)	700/ 213	2	0	0	0	1*	0000000	44	7	46	0	7	2.5*	2.1	30/ 48	0	1	1-1*	
(45, 7)	700/ 213	2	0	0	0	1*	0000000	0	8007	0	0	8007	2.5*	2.1	30/ 48	0	0	1-1*	
(8007, 7)	0/ 0	2	0	0	0	1*	0000000	0	45	0	0	45	2.5*	2.1	0/ 0	0	0	1-1*	
(7, 45)	700/ 213	2	0	0	0	1*	0000000	46	23	44	0	23	2.5*	2.1	30/ 48	0	1	1-1*	
(45, 23)	700/ 213	2	0	0	0	1*	0000000	0	8023	0	0	8023	2.5*	2.1	30/ 48	0	0	1-1*	
(8022, 22)	0/ 0	1	0	0	0	1*	0000000	0	46	0	0	46	2.5*	2.1	0/ 0	0	0	1-1*	
(22, 46)	700/ 213	2	0	0	0	1*	4100000	45	0	47	0	0	2.5*	2.1	30/ 48	0	1	1-1*	
(46, 22)	700/ 213	1	0	0	0	1*	0000000	0	8022	0	0	8022	2.5*	2.1	30/ 48	0	0	1-1*	
(8021, 21)	0/ 0	1	0	0	0	1*	0000000	0	47	0	0	47	2.5*	2.1	0/ 0	0	0	1-1*	
(21, 47)	700/ 213	2	0	0	0	1*	0100000	46	9	48	0	9	2.5*	2.1	30/ 48	0	1	1-1*	
(47, 9)	700/ 213	1	0	0	0	1*	0000000	0	8009	0	0	8009	2.5*	2.1	30/ 48	0	0	1-1*	
(8009, 9)	0/ 0	1	0	0	0	1*	0000000	0	47	0	0	47	2.5*	2.1	0/ 0	0	0	1-1*	
(9, 47)	700/ 213	2	0	0	0	1*	0100000	48	21	46	0	21	2.5*	2.1	30/ 48	0	1	1-1*	
(47, 21)	700/ 213	2	0	0	0	1*	0000000	0	8021	0	0	8021	2.5*	2.1	30/ 48	0	0	1-1*	

* INDICATES DEFAULT VALUES WERE SPECIFIED

LINK TYPE	LANE CHANNELIZATION CODES	RTOR CODES	PEDESTRIAN CODES
IDENTIFIES THE DISTRIBUTION USED FOR QUEUE DISCHARGE AND START-UP LOST TIME	0 UNRESTRICTED	0 RTOR PERMITTED	0 NO PEDESTRIANS
	1 LEFT TURNS ONLY	1 RTOR PROHIBITED	1 LIGHT
	2 BUSES ONLY		2 MODERATE
	3 CLOSED		3 HEAVY

CHARACTERISTICS.

4 RIGHT TURNS ONLY
5 CAR - POOLS
6 CAR - POOLS + BUSES

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NETSIM TURNING MOVEMENT DATA

LINK	TURN MOVEMENT PERCENTAGES LEFT	THROUGH	RIGHT	DIAGONAL	TURN MOVEMENT POSSIBLE LEFT	THROUGH	RIGHT	DIAGONAL	POCKET LENGTH (IN FEET/METERS LEFT	RIGHT
(70, 1)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(40, 70)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(71, 40)	2	96	2	0	YES	YES	YES	NO	0/ 0	0/ 0
(41, 71)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(42, 41)	2	96	2	0	YES	YES	YES	NO	500/ 152	0/ 0
(43, 42)	2	96	2	0	YES	YES	YES	NO	250/ 76	0/ 0
(44, 43)	2	90	8	0	YES	YES	YES	NO	150/ 46	0/ 0
(45, 44)	5	92	3	0	YES	YES	YES	NO	500/ 152	125/ 38
(46, 45)	2	96	2	0	YES	YES	YES	NO	225/ 69	125/ 38
(47, 46)	4	96	0	0	YES	YES	NO	NO	75/ 23	0/ 0
(48, 47)	0	95	5	0	YES	YES	YES	NO	0/ 0	50/ 15
(8048, 48)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8001, 1)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(1, 70)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(70, 40)	29	67	4	0	YES	YES	YES	NO	0/ 0	0/ 0
(40, 71)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(71, 41)	8	88	4	0	YES	YES	YES	NO	250/ 76	0/ 0
(41, 42)	3	94	3	0	YES	YES	YES	NO	500/ 152	0/ 0
(42, 43)	9	88	3	0	YES	YES	YES	NO	250/ 76	0/ 0
(43, 44)	5	74	21	0	YES	YES	YES	NO	150/ 46	0/ 0
(44, 45)	22	73	5	0	YES	YES	YES	NO	225/ 69	125/ 38
(45, 46)	0	93	7	0	NO	YES	YES	NO	0/ 0	125/ 38
(46, 47)	5	78	17	0	YES	YES	YES	NO	0/ 0	125/ 38
(47, 48)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8028, 28)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(28, 40)	90	5	5	0	YES	YES	YES	NO	0/ 0	225/ 69
(40, 2)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8002, 2)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(2, 40)	5	5	90	0	YES	YES	YES	NO	0/ 0	225/ 69
(40, 28)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8027, 27)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(27, 41)	90	5	5	0	YES	YES	YES	NO	0/ 0	0/ 0
(41, 3)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8003, 3)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(3, 41)	5	5	90	0	YES	YES	YES	NO	0/ 0	0/ 0
(41, 27)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8026, 26)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(26, 42)	85	10	5	0	YES	YES	YES	NO	0/ 0	0/ 0
(42, 4)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8004, 4)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(4, 42)	5	10	85	0	YES	YES	YES	NO	0/ 0	0/ 0
(42, 26)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8025, 25)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(25, 43)	85	10	5	0	YES	YES	YES	NO	0/ 0	0/ 0
(43, 5)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0

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NETSIM TURNING MOVEMENT DATA (CONT.)

LINK	TURN MOVEMENT PERCENTAGES LEFT	THROUGH	RIGHT	DIAGONAL	TURN MOVEMENT POSSIBLE LEFT	THROUGH	RIGHT	DIAGONAL	POCKET LENGTH (IN FEET/METERS LEFT	RIGHT
(8005, 5)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(5, 43)	5	10	85	0	YES	YES	YES	NO	0/ 0	0/ 0
(43, 25)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8024, 24)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(24, 44)	85	10	5	0	YES	YES	YES	NO	0/ 0	75/ 23
(44, 6)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8006, 6)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(6, 44)	5	10	85	0	YES	YES	YES	NO	0/ 0	0/ 0
(44, 24)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8023, 23)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(23, 45)	85	10	5	0	YES	YES	YES	NO	0/ 0	0/ 0
(45, 7)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8007, 7)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(7, 45)	5	10	85	0	YES	YES	YES	NO	0/ 0	0/ 0
(45, 23)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8022, 22)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(22, 46)	85	0	15	0	YES	NO	YES	NO	0/ 0	0/ 0
(46, 22)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8021, 21)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(21, 47)	0	62	38	0	YES	YES	YES	NO	0/ 0	0/ 0
(47, 9)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8009, 9)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(9, 47)	5	10	85	0	YES	YES	YES	NO	0/ 0	0/ 0
(47, 21)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0

1 SPECIFIED FIXED-TIME SIGNAL CONTROL, AND SIGN CONTROL, CODES

0 NODE 1 IS UNDER SIGN CONTROL

INTERVAL NUMBER	DURATION (SEC)	(PCT)	APPROACHES (8001, 1)	(70, 1)
1	0	100	1	1

0 NODE 2 IS UNDER SIGN CONTROL

```
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8002,    2)    (  40,    2)
              1         0     100         1               1
0                                                 NODE    3 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8003,    3)    (  41,    3)
              1         0     100         1               1
0                                                 NODE    4 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8004,    4)    (  42,    4)
              1         0     100         1               1
0                                                 NODE    5 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8005,    5)    (  43,    5)
              1         0     100         1               1
0                                                 NODE    6 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8006,    6)    (  44,    6)
              1         0     100         1               1
0                                                 NODE    7 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8007,    7)    (  45,    7)
              1         0     100         1               1
0                                                 NODE    9 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8009,    9)    (  47,    9)
              1         0     100         1               1
0                                                 NODE   21 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8021,   21)    (  47,   21)
              1         0     100         1               1
1
0                                                 NODE   22 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8022,   22)    (  46,   22)
              1         0     100         1               1
0                                                 NODE   23 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8023,   23)    (  45,   23)
              1         0     100         1               1
0                                                 NODE   24 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8024,   24)    (  44,   24)
              1         0     100         1               1
0                                                 NODE   25 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8025,   25)    (  43,   25)
              1         0     100         1               1
0                                                 NODE   26 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8026,   26)    (  42,   26)
              1         0     100         1               1
0                                                 NODE   27 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8027,   27)    (  41,   27)
              1         0     100         1               1
0                                                 NODE   28 IS UNDER SIGN CONTROL
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (8028,   28)    (  40,   28)
              1         0     100         1               1
1
0                                                           NODE    40
                      OFFSET    0 SEC                                                  CYCLE LENGTH   90 SEC
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (  70,   40)    (   2,   40)    (  71,   40)    (  28,   40)
              1        12     13          9               2               9               2
              2         4      4          9               2               0               2
              3         9     10          1               2               2               2
              4         4      4          0               2               2               2
              5        32     35          2               9               2               9
              6         4      4          2               0               2               0
              7         1      1          2               2               2               2
              8        20     22          2               2               1               2
              9         4      4          2               2               0               2
0                                                           NODE    41
                      OFFSET   50 SEC                                                  CYCLE LENGTH   90 SEC
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (  71,   41)    (   3,   41)    (  42,   41)    (  27,   41)
              1        59     65          1               2               1               2
              2         4      4          0               2               0               2
              3        13     14          2               1               2               1
              4         4      4          2               0               2               0
              5         6      6          1               2               2               2
              6         4      4          0               2               2               2
0                                                           NODE    42
                      OFFSET   12 SEC                                                  CYCLE LENGTH   90 SEC
0           INTERVAL    DURATION     +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
            NUMBER    (SEC)  (PCT)   (  41,   42)    (   4,   42)    (  43,   42)    (  26,   42)
              1        69     76          1               2               1               2
              2         4      4          0               2               0               2
              3        13     14          2               1               2               1
              4         4      4          2               0               2               0
```

0 NODE 43

OFFSET 2 SEC — CYCLE LENGTH 90 SEC

0

INTERVAL NUMBER	DURATION (SEC)	(PCT)	APPROACHES (42, 43)	(5, 43)	(44, 43)	(25, 43)
1	66	73	1	2	1	2
2	4	4	0	2	0	2
3	16	17	2	1	2	1
4	4	4	2	0	2	0

1

0 NODE 44

OFFSET 83 SEC — CYCLE LENGTH 90 SEC

0

INTERVAL NUMBER	DURATION (SEC)	(PCT)	APPROACHES (43, 44)	(6, 44)	(45, 44)	(24, 44)
1	70	77	1	2	1	2
2	4	4	0	2	0	2
3	12	13	2	1	2	1
4	4	4	2	0	2	0

0 NODE 45

OFFSET 0 SEC — CYCLE LENGTH 90 SEC

0

INTERVAL NUMBER	DURATION (SEC)	(PCT)	APPROACHES (44, 45)	(7, 45)	(46, 45)	(23, 45)
1	23	25	9	2	9	2
2	4	4	9	2	0	2
3	8	8	1	2	2	2
4	4	4	0	2	2	2
5	21	23	2	9	2	9
6	4	4	2	0	2	0
7	22	24	2	2	1	2
8	4	4	2	2	0	2

0 NODE 46

OFFSET 19 SEC — CYCLE LENGTH 90 SEC

0

INTERVAL NUMBER	DURATION (SEC)	(PCT)	APPROACHES (45, 46)	(47, 46)	(22, 46)
1	73	81	9	1	2
2	4	4	0	0	2
3	8	8	2	2	1
4	4	4	2	2	0
5	1	1	2	2	2

0 NODE 47

OFFSET 70 SEC — CYCLE LENGTH 90 SEC

0

INTERVAL NUMBER	DURATION (SEC)	(PCT)	APPROACHES (46, 47)	(9, 47)	(48, 47)	(21, 47)
1	57	63	1	2	9	2
2	4	4	1	2	0	2
3	5	5	1	2	2	2
4	4	4	0	2	2	2
5	16	17	2	9	2	9
6	4	4	2	0	2	0

0 NODE 48 IS UNDER SIGN CONTROL

0

INTERVAL NUMBER	DURATION (SEC)	(PCT)	APPROACHES (8048, 48)	(47, 48)
1	0	100	1	1

1

0 NODE 70 IS UNDER SIGN CONTROL

0

INTERVAL NUMBER	DURATION (SEC)	(PCT)	APPROACHES (1, 70)	(40, 70)
1	0	100	1	1

0 NODE 71 IS UNDER SIGN CONTROL

0

INTERVAL NUMBER	DURATION (SEC)	(PCT)	APPROACHES (40, 71)	(41, 71)
1	0	100	1	1

1 INTERPRETATION OF SIGNAL CODES

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

1 TRAFFIC CONTROL TABLE - SIGNS AND FIXED TIME SIGNALS

CONTROL CODES
GO = PROTECTED
NOGO = NOT PERMITTED
AMBR = AMBER
PERM = PERMITTED NOT PROTECTED
PROT = PROTECTED
STOP = STOP SIGN
YLD = YIELD SIGN

```
      NODE     1     SIGN CONTROL

INTERVAL DURATION    -------------------------------------------  APPROACHES   -------------------------------------------
                         (8001,    1)          (  70,    1)
                     LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
      1         0          GO                   GO


      NODE     2     SIGN CONTROL

INTERVAL DURATION    -------------------------------------------  APPROACHES   -------------------------------------------
                         (8002,    2)          (  40,    2)
                     LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
      1         0          GO                   GO


      NODE     3     SIGN CONTROL

INTERVAL DURATION    -------------------------------------------  APPROACHES   -------------------------------------------
                         (8003,    3)          (  41,    3)
                     LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
      1         0          GO                   GO


      NODE     4     SIGN CONTROL

INTERVAL DURATION    -------------------------------------------  APPROACHES   -------------------------------------------
                         (8004,    4)          (  42,    4)
                     LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
      1         0          GO                   GO


      NODE     5     SIGN CONTROL

INTERVAL DURATION    -------------------------------------------  APPROACHES   -------------------------------------------
                         (8005,    5)          (  43,    5)
                     LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
      1         0          GO                   GO
1


      NODE     6     SIGN CONTROL

INTERVAL DURATION    -------------------------------------------  APPROACHES   -------------------------------------------
                         (8006,    6)          (  44,    6)
                     LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
      1         0          GO                   GO


      NODE     7     SIGN CONTROL

INTERVAL DURATION    -------------------------------------------  APPROACHES   -------------------------------------------
                         (8007,    7)          (  45,    7)
                     LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
      1         0          GO                   GO


      NODE     9     SIGN CONTROL

INTERVAL DURATION    -------------------------------------------  APPROACHES   -------------------------------------------
                         (8009,    9)          (  47,    9)
                     LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
      1         0          GO                   GO


      NODE    21     SIGN CONTROL

INTERVAL DURATION    -------------------------------------------  APPROACHES   -------------------------------------------
                         (8021,   21)          (  47,   21)
                     LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
      1         0          GO                   GO


      NODE    22     SIGN CONTROL

INTERVAL DURATION    -------------------------------------------  APPROACHES   -------------------------------------------
                         (8022,   22)          (  46,   22)
                     LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
      1         0          GO                   GO
```

NODE 23 SIGN CONTROL

INTERVAL	DURATION	(8023, 23)				(45, 23)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

1

NODE 24 SIGN CONTROL

INTERVAL	DURATION	(8024, 24)				(44, 24)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 25 SIGN CONTROL

INTERVAL	DURATION	(8025, 25)				(43, 25)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 26 SIGN CONTROL

INTERVAL	DURATION	(8026, 26)				(42, 26)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 27 SIGN CONTROL

INTERVAL	DURATION	(8027, 27)				(41, 27)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 28 SIGN CONTROL

INTERVAL	DURATION	(8028, 28)				(40, 28)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

1

NODE 40 FIXED TIME CONTROL OFFSET = 0 SECONDS CYCLE LENGTH = 90 SECONDS

INTERVAL	DURATION	(70, 40)				(2, 40)				(71, 40)				(28, 40)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	12	NOGO	GO	GO		NOGO	NOGO	NOGO		NOGO	GO	GO		NOGO	NOGO	NOGO					
2	4	NOGO	GO	GO		NOGO	NOGO	NOGO		NOGO	AMBR	AMBR		NOGO	NOGO	NOGO					
3	9	PROT	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
4	4	AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
5	32	NOGO	NOGO	NOGO		NOGO	GO	GO		NOGO	NOGO	NOGO		NOGO	GO	GO					
6	4	NOGO	NOGO	NOGO		NOGO	AMBR	AMBR		NOGO	NOGO	NOGO		NOGO	AMBR	AMBR					
7	1	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
8	20	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PROT	GO	GO		NOGO	NOGO	NOGO					
9	4	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		AMBR	GO	GO		NOGO	NOGO	NOGO					

NODE 41 FIXED TIME CONTROL OFFSET = 50 SECONDS CYCLE LENGTH = 90 SECONDS

INTERVAL	DURATION	(71, 41)				(3, 41)				(42, 41)				(27, 41)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	59	PERM	GO	GO		NOGO	NOGO	NOGO		PERM	GO	GO		NOGO	NOGO	NOGO					
2	4	AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		AMBR	AMBR	AMBR		NOGO	NOGO	NOGO					
3	13	NOGO	NOGO	NOGO		PERM	GO	GO		NOGO	NOGO	NOGO		PERM	GO	GO					
4	4	NOGO	NOGO	NOGO		AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		AMBR	AMBR	AMBR					
5	6	PROT	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
6	4	AMBR	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					

NODE 42 FIXED TIME CONTROL OFFSET = 12 SECONDS CYCLE LENGTH = 90 SECONDS

INTERVAL DURATION -- APPROACHES --

		(41, 42)				(4, 42)				(43, 42)				(26, 42)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	69	PERM	GO	GO		NOGO	NOGO	NOGO		PERM	GO	GO		NOGO	NOGO	NOGO					
2	4	AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		AMBR	AMBR	AMBR		NOGO	NOGO	NOGO					
3	13	NOGO	NOGO	NOGO		PERM	GO	GO		NOGO	NOGO	NOGO		PERM	GO	GO					
4	4	NOGO	NOGO	NOGO		AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		AMBR	AMBR	AMBR					

NODE 43 FIXED TIME CONTROL OFFSET = 2 SECONDS CYCLE LENGTH = 90 SECONDS

INTERVAL	DURATION	APPROACHES																			
		(42, 43)				(5, 43)				(44, 43)				(25, 43)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	66	PERM	GO	GO		NOGO	NOGO	NOGO		PERM	GO	GO		NOGO	NOGO	NOGO					
2	4	AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		AMBR	AMBR	AMBR		NOGO	NOGO	NOGO					
3	16	NOGO	NOGO	NOGO		PERM	GO	GO		NOGO	NOGO	NOGO		PERM	GO	GO					
4	4	NOGO	NOGO	NOGO		AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		AMBR	AMBR	AMBR					

1

NODE 44 FIXED TIME CONTROL OFFSET = 83 SECONDS CYCLE LENGTH = 90 SECONDS

INTERVAL	DURATION	APPROACHES																			
		(43, 44)				(6, 44)				(45, 44)				(24, 44)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	70	PERM	GO	GO		NOGO	NOGO	NOGO		PERM	GO	GO		NOGO	NOGO	NOGO					
2	4	AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		AMBR	AMBR	AMBR		NOGO	NOGO	NOGO					
3	12	NOGO	NOGO	NOGO		PERM	GO	GO		NOGO	NOGO	NOGO		PERM	GO	GO					
4	4	NOGO	NOGO	NOGO		AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		AMBR	AMBR	AMBR					

NODE 45 FIXED TIME CONTROL OFFSET = 0 SECONDS CYCLE LENGTH = 90 SECONDS

INTERVAL	DURATION	APPROACHES																			
		(44, 45)				(7, 45)				(46, 45)				(23, 45)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	23	NOGO	GO	GO		NOGO	NOGO	NOGO		NOGO	GO	GO		NOGO	NOGO	NOGO					
2	4	NOGO	GO	GO		NOGO	NOGO	NOGO		NOGO	AMBR	AMBR		NOGO	NOGO	NOGO					
3	8	PROT	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
4	4	AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
5	21	NOGO	NOGO	NOGO		NOGO	GO	GO		NOGO	NOGO	NOGO		NOGO	GO	GO					
6	4	NOGO	NOGO	NOGO		NOGO	AMBR	AMBR		NOGO	NOGO	NOGO		NOGO	AMBR	AMBR					
7	22	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PROT	GO	GO		NOGO	NOGO	NOGO					
8	4	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		AMBR	GO	GO		NOGO	NOGO	NOGO					

NODE 46 FIXED TIME CONTROL OFFSET = 19 SECONDS CYCLE LENGTH = 90 SECONDS

INTERVAL	DURATION	APPROACHES																			
		(45, 46)				(47, 46)				(22, 46)											
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	73		GO	GO		PERM	GO			NOGO		NOGO									
2	4		AMBR	AMBR		AMBR	AMBR			NOGO		NOGO									
3	8		NOGO	NOGO		NOGO	NOGO			PROT		GO									
4	4		NOGO	NOGO		NOGO	NOGO			AMBR		AMBR									
5	1		NOGO	NOGO		NOGO	NOGO			NOGO		NOGO									

NODE 47 FIXED TIME CONTROL OFFSET = 70 SECONDS CYCLE LENGTH = 90 SECONDS

INTERVAL	DURATION	APPROACHES																			
		(46, 47)				(9, 47)				(48, 47)				(21, 47)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	57	PERM	GO	GO		NOGO	NOGO	NOGO		NOGO	GO	GO		NOGO	NOGO	NOGO					
2	4	PERM	GO	GO		NOGO	NOGO	NOGO		NOGO	AMBR	AMBR		NOGO	NOGO	NOGO					
3	5	PROT	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
4	4	AMBR	AMBR	AMBR		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
5	16	NOGO	NOGO	NOGO		NOGO	GO	GO		NOGO	NOGO	NOGO		NOGO	GO	GO					
6	4	NOGO	NOGO	NOGO		NOGO	AMBR	AMBR		NOGO	NOGO	NOGO		NOGO	AMBR	AMBR					

1

NODE 48 SIGN CONTROL

INTERVAL	DURATION	APPROACHES																			
		(8048, 48)				(47, 48)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 70 SIGN CONTROL

INTERVAL	DURATION	APPROACHES																			
		(1, 70)				(40, 70)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG

1	0	GO	GO

NODE 71 SIGN CONTROL

INTERVAL	DURATION	APPROACHES (40, 71) LEFT THRU RITE DIAG	(41, 71) LEFT THRU RITE DIAG	LEFT THRU RITE DIAG	LEFT THRU RITE DIAG	LEFT THRU RITE DIAG
1	0	GO	GO			

1 ENTRY LINK VOLUMES

LINK	FLOW RATE (VEH/HOUR)	TRUCKS (PERCENT)	CAR POOLS (PERCENT)
(8001, 1)	800	0	17
(8028, 28)	450	0	17
(8002, 2)	450	0	17
(8027, 27)	300	0	17
(8003, 3)	300	0	17
(8026, 26)	300	0	17
(8004, 4)	300	0	17
(8025, 25)	300	0	17
(8005, 5)	300	0	17
(8024, 24)	300	0	17
(8006, 6)	300	0	17
(8023, 23)	1000	0	17
(8007, 7)	1000	0	17
(8022, 22)	200	0	17
(8021, 21)	1200	0	17
(8009, 9)	1200	0	17
(8048, 48)	1875	0	17

1 AVERAGE VEHICLE OCCUPANCIES
(HUNDREDTHS-OF-A-PERSON / VEHICLE)

AUTOS	CAR-POOLS	TRUCKS	BUSES
130	300	120	500

1

VEHICLE TYPE SPECIFICATIONS

	VEHICLE TYPE	LENGTH FEET/METERS	MAXIMUM ACCELERATION (MPH/SEC)/(KMPH/SEC)	MAXIMUM SPEED (MPH)/(KMPH)	Q DSCHG HDWY FACTOR (PCT)	AVG. OCCUP.	FLEET COMPONENT PERCENTAGES AUTO	TRUCK	CARPOOL	BUS
0	1**	17.0/ 5.2	5.5/ 8.8	75.0/ 120.7	100	1.3	100	0	0	0
0	2**	34.0/ 10.4	3.0/ 4.8	60.0/ 96.6	120	1.2	0	100	0	0
0	3**	17.0/ 5.2	5.5/ 8.8	75.0/ 120.7	100	3.0	0	0	100	0
0	4	47.0/ 14.3	2.0/ 3.2	50.0/ 80.5	150	50.0	0	0	0	100

0 ** INDICATES THAT ALL PARAMETERS FOR VEHICLE TYPE ASSUME DEFAULT VALUES

1 EMBEDDED DATA CHANGES IN EFFECT

	SCALAR OR ARRAY	C O N T E N T S	CHANGED BY CARD TYPE
0	SPLPCT	100 100 100 100	141
0	LTLAGP	0 0 0	141
0	VEHLNG	20 FT. (6 M)37 FT. (11 M)20 FT. (6 M)50 FT. (15 M)	141

1 PROPERTIES OF BUS STATIONS

STATION NO.	LANE SERVICED	LINK	DISTANCE FROM UPSTREAM NODE FEET	/ METERS	CAPACITY (BUSES)	MEAN DWELL (SEC)	TYPE	PERCENT OF BUSES STOPPING
1	1	(48, 47)	2854	870	1	30	1	95
2	1	(47, 46)	1798	548	1	30	1	95
3	1	(46, 45)	1534	468	1	30	1	95
4	1	(45, 44)	2590	789	1	30	1	95
5	1	(43, 42)	478	146	1	30	1	95
6	1	(42, 41)	2062	628	1	30	1	95
7	1	(71, 40)	350	107	1	30	1	95
8	1	(40, 70)	350	107	1	30	1	95
9	1	(70, 40)	350	107	1	30	1	95
10	1	(71, 41)	1134	346	1	30	1	95
11	1	(41, 42)	2062	628	1	30	1	95
12	1	(43, 44)	214	65	1	30	1	95
13	1	(44, 45)	2590	789	1	30	1	95
14	1	(45, 46)	1534	468	1	30	1	95
15	1	(46, 47)	1798	548	1	30	1	95
16	1	(47, 48)	2854	870	1	30	1	95

0 THE TYPE CODE IDENTIFIES THE APPLICABLE STATISTICAL DISTRIBUTION OF DWELL TIME

1 BUS ROUTE PATHS

	ROUTE	SEQUENCE OF NODES DEFINING PATH													
0	1	8048	48	47	46	45	44	43	42	41	71	40	70	1	8001
0	2	8001	1	70	40	71	41	42	43	44	45	46	47	48	8048

1 BUS STATIONS BY ROUTE

	ROUTE	SEQUENCE OF STATIONS SERVICED BY ROUTE							
0	1	1	2	3	4	5	6	7	8
0	2	9	10	11	12	13	14	15	16

1 BUS VOLUMES

ROUTE	VOLUME	MEAN HEADWAY

		(VEH/HR)	(SEC)
0	1	12	300
0	2	12	300

Appendix B

TRAF-NETSIM Input for Network B

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

```
                                        RELEASE DATE = 10/10/89
                                             VERSION 3.00
0*************************************************************************************************************

                                             START OF CASE   1

**************************************************************************************************************

0                        Traffic Simulation Model
0


                                          DATE =   3/  16/  93
0                                         USER = qin
0                                       AGENCY = Civil Engineering
1                                              RUN CONTROL DATA


                  VALUE                          RUN PARAMETERS AND OPTIONS

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

0                            NETSIM ENVIRONMENTAL OPTIONS
                             ----------------------------
                      0      FUEL/EMISSION RATE TABLES ARE NOT PRINTED
                      1      SIMULATION:  PERFORMED                           ENVIRONMENTAL MEASURES:  CALCULATED
                             RATE TABLES: EMBEDDED                            TRAJECTORY FILE:         WRITTEN
0                     0      INPUT  UNITS CODE = (0,1) IF INPUT IS IN (ENGLISH, METRIC) UNITS
                      0      OUTPUT UNITS CODE = (0,1,2,3) IF OUTPUT IS IN (SAME AS INPUT, ENGLISH, METRIC, BOTH) UNITS
0                   800      CLOCK TIME AT START OF SIMULATION (HHMM)
0                     0      SIGNAL TRANSITION CODE = (0,1,2,3) IF (NO, IMMEDIATE, 2-CYCLE, 3-CYCLE) TRANSITION WAS REQUESTED
0                  7581      RANDOM NUMBER SEED
                   7781      RANDOM NUMBER SEED TO GENERATE TRAFFIC STREAM FOR NETSIM OR LEVEL I SIMULATION

                   1800      DURATION (SEC) OF TIME PERIOD NO.  1
0                    75      LENGTH OF A TIME INTERVAL, SECONDS
0                    12      MAXIMUM INITIALIZATION TIME, NUMBER OF TIME INTERVALS
0                     0      NUMBER OF TIME INTERVALS BETWEEN SUCCESSIVE STANDARD OUTPUTS
0                     0      TIME INTERMEDIATE OUTPUT WILL BEGIN AT INTERVALS OF     0 SECS. FOR     0 SECS. FOR MICROSCOPIC MODEl
0                     0      NETSIM MOVEMENT-SPECIFIC OUTPUT CODE = (0,1) (IF NOT, IF) REQUESTED FOR NETSIM SUBNETWORK
0                     0      NETSIM GRAPHICS OUTPUT CODE = (0,1) IF GRAPHICS OUTPUT (IS NOT, IS) REQUESTED
1*************************************************************************************************************

                                          TIME PERIOD   1 - NETSIM DATA

**************************************************************************************************************
1

                                                    NETSIM LINKS
0                   -LANES-          -CHANNEL-
```

LINK	LENGTH FT / M	LANES: FUL L	PKT L	PKT R	GRD PCT	LINK TYPE	CHANNEL: CUR B234567	DESTINATION NODE LEFT	THRU	RGHT	DIAG	OPP. NODE	LOST TIME SEC	Q DIS HDWY. SEC	FREE SPEED MPH/KMPH	RTOR CODE	PED CODE	LANE ALIGN -MENT	STREET NAME
(8001, 1)	0/ 0	3	0	0	0	1	0000000	0	2	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	Entry1
(1, 2)	1500/ 457	3	0	0	0	1*	0000000	21	3	22	0	3	2.5	2.2	45/ 72	0	0	1-1	
(2, 1)	1500/ 457	3	0	0	0	1*	0000000	0	8001	0	0	0	2.5	2.2	45/ 72	0	0	1-1	
(2, 3)	2500/ 762	3	1	0	0	1*	0000000	31	4	32	0	4	2.5	2.2	45/ 72	0	0	1-1	
(3, 2)	2500/ 762	3	0	0	0	1*	0000000	22	1	21	0	1	2.5	2.2	45/ 72	0	0	1-1	
(3, 4)	3000/ 914	3	0	0	0	1*	0000000	41	5	42	0	5	2.5	2.2	45/ 72	0	0	1-1	
(4, 3)	3000/ 914	3	1	0	0	1*	0000000	32	2	31	0	2	2.5	2.2	45/ 72	0	0	1-1	
(4, 5)	1500/ 457	3	0	0	0	1*	0000000	51	6	0	0	6	2.5	2.2	45/ 72	0	0	1-1	
(5, 4)	1500/ 457	3	0	0	0	1*	0000000	42	3	41	0	3	2.5	2.2	45/ 72	0	0	1-1	
(5, 6)	2000/ 610	3	1	0	0	1*	0000000	61	7	62	0	7	2.5	2.2	45/ 72	0	0	1-1	
(6, 5)	2000/ 610	3	0	0	0	1*	0000000	0	4	51	0	0	2.5	2.2	45/ 72	0	0	1-1	
(6, 7)	3000/ 914	3	0	0	0	1*	0000000	71	8	72	0	8	2.5	2.2	45/ 72	0	0	1-1	
(7, 6)	3000/ 914	3	1	0	0	1*	0000000	62	5	61	0	5	2.5	2.2	45/ 72	0	0	1-1	
(7, 8)	1500/ 457	3	0	0	0	1*	0000000	81	9	82	0	9	2.5	2.2	45/ 72	0	0	1-1	

LINK	LENGTH FT / M	FUL L	PKT L	PKT R	GRD PCT	LINK TYPE	CHANNEL CUR B234567	LEFT	THRU	RGHT	DIAG	OPP. NODE	LOST TIME SEC	Q DIS HDWY. SEC	FREE SPEED MPH/KMPH	RTOR CODE	PED CODE	LANE ALIGN -MENT	STREET NAME
(8, 7)	1500/ 457	3	0	0	0	1*	0000000	72	6	71	0	6	2.5	2.2	45/ 72	0	0	1-1	
(8, 9)	2000/ 610	3	0	0	0	1*	0000000	91	10	92	0	10	2.5	2.2	45/ 72	0	0	1-1	
(9, 8)	2000/ 610	3	0	0	0	1*	0000000	82	7	81	0	7	2.5	2.2	45/ 72	0	0	1-1	
(9, 10)	1500/ 457	3	0	0	0	1*	0000000	0	8010	0	0	0	2.5	2.2	45/ 72	0	0	1-1	
(10, 9)	1500/ 457	3	1	0	0	1*	0000000	92	8	91	0	8	2.5	2.2	45/ 72	0	0	1-1	
(8010, 10)	0/ 0	3	0	0	0	1	0000000	0	9	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(2, 21)	500/ 152	1	0	0	0	1*	0000000	0	8021	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(21, 2)	500/ 152	1	0	0	0	1*	0000000	3	22	1	0	22	2.5	2.2	25/ 40	0	0	1-1	
(8021, 21)	0/ 0	1	0	0	0	1	0000000	0	2	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(2, 22)	500/ 152	1	0	0	0	1*	0000000	0	8022	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(22, 2)	500/ 152	1	0	0	0	1*	0000000	1	21	3	0	21	2.5	2.2	25/ 40	0	0	1-1	
(3, 31)	2500/ 762	2	0	0	0	1*	0000000	0	8031	0	0	0	2.5	2.2	35/ 56	0	0	1-1	
(31, 3)	2500/ 762	2	1	0	0	1*	0000000	4	32	2	0	32	2.5	2.2	35/ 56	0	0	1-1	
(8031, 31)	0/ 0	2	0	0	0	1	0000000	0	3	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(3, 32)	1000/ 305	2	0	0	0	1*	0000000	0	8032	0	0	0	2.5	2.2	35/ 56	0	0	1-1	
(32, 3)	1000/ 305	2	1	0	0	1*	0000000	2	31	4	0	31	2.5	2.2	35/ 56	0	0	1-1	
(8032, 32)	0/ 0	2	0	0	0	1	0000000	0	3	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(4, 41)	500/ 152	1	0	0	0	1*	0000000	0	8041	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(41, 4)	500/ 152	1	0	0	0	1*	0000000	5	42	3	0	42	2.5	2.2	25/ 40	0	0	1-1	
(8041, 41)	0/ 0	1	0	0	0	1	0000000	0	4	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(4, 42)	500/ 152	1	0	0	0	1*	0000000	0	8042	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(42, 4)	500/ 152	1	0	0	0	1*	0000000	3	41	5	0	41	2.5	2.2	25/ 40	0	0	1-1	
(8042, 42)	0/ 0	1	0	0	0	1	0000000	0	4	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(5, 51)	500/ 152	1	0	0	0	1*	0000000	0	8051	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(51, 5)	500/ 152	1	0	0	0	1*	0000000	6	0	4	0	0	2.5	2.2	25/ 40	0	0	1-1	
(8051, 51)	0/ 0	1	0	0	0	1	0000000	0	5	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(6, 61)	1000/ 305	2	0	0	0	1*	0000000	0	8061	0	0	0	2.5	2.2	35/ 56	0	0	1-1	
(61, 6)	1000/ 305	2	1	0	0	1*	0000000	7	62	5	0	62	2.5	2.2	35/ 56	0	0	1-1	
(8061, 61)	0/ 0	2	0	0	0	1	0000000	0	6	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(6, 62)	2500/ 762	2	0	0	0	1*	0000000	0	8062	0	0	0	2.5	2.2	35/ 56	0	0	1-1	
(62, 6)	2500/ 762	2	1	0	0	1*	0000000	5	61	7	0	61	2.5	2.2	35/ 56	0	0	1-1	

1

NETSIM LINKS (CONT.)

0

LINK	LENGTH FT / M	-LANES- FUL L	PKT L	PKT R	GRD PCT	LINK TYPE	-CHANNEL- CUR B234567	DESTINATION NODE LEFT	THRU	RGHT	DIAG	OPP. NODE	LOST TIME SEC	Q DIS HDWY. SEC	FREE SPEED MPH/KMPH	RTOR CODE	PED CODE	LANE ALIGN -MENT	STREET NAME
(8062, 62)	0/ 0	2	0	0	0	1	0000000	0	6	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(7, 71)	500/ 152	1	0	0	0	1*	0000000	0	8071	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(71, 7)	500/ 152	1	0	0	0	1*	0000000	8	72	6	0	72	2.5	2.2	25/ 40	0	0	1-1	
(8071, 71)	0/ 0	1	0	0	0	1	0000000	0	7	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(7, 72)	500/ 152	1	0	0	0	1*	0000000	0	8072	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(72, 7)	500/ 152	1	0	0	0	1*	0000000	6	71	8	0	71	2.5	2.2	25/ 40	0	0	1-1	
(8072, 72)	0/ 0	1	0	0	0	1	0000000	0	7	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(8, 81)	500/ 152	1	0	0	0	1*	0000000	0	8081	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(81, 8)	500/ 152	1	0	0	0	1*	0000000	9	82	7	0	82	2.5	2.2	25/ 40	0	0	1-1	
(8081, 81)	0/ 0	1	0	0	0	1	0000000	0	8	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(8, 82)	500/ 152	1	0	0	0	1*	0000000	0	8082	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(82, 8)	500/ 152	1	0	0	0	1*	0000000	7	81	9	0	81	2.5	2.2	25/ 40	0	0	1-1	
(8082, 82)	0/ 0	1	0	0	0	1	0000000	0	8	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(9, 91)	500/ 152	1	0	0	0	1*	0000000	0	8091	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(91, 9)	500/ 152	1	0	0	0	1*	0000000	10	92	8	0	92	2.5	2.2	25/ 40	0	0	1-1	
(8091, 91)	0/ 0	1	0	0	0	1	0000000	0	9	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(9, 92)	500/ 152	1	0	0	0	1*	0000000	0	8092	0	0	0	2.5	2.2	25/ 40	0	0	1-1	
(92, 9)	500/ 152	1	0	0	0	1*	0000000	8	91	10	0	91	2.5	2.2	25/ 40	0	0	1-1	
(8092, 92)	0/ 0	1	0	0	0	1	0000000	0	9	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	
(8022, 22)	0/ 0	1	0	0	0	1	0000000	0	2	0	0	0	2.5*	2.2*	0/ 0	0	0	1-1	

* INDICATES DEFAULT VALUES WERE SPECIFIED

LINK TYPE

IDENTIFIES THE DISTRIBUTION USED FOR QUEUE DISCHARGE AND START-UP LOST TIME CHARACTERISTICS.

LANE CHANNELIZATION CODES

0 UNRESTRICTED
1 LEFT TURNS ONLY
2 BUSES ONLY
3 CLOSED
4 RIGHT TURNS ONLY
5 CAR - POOLS
6 CAR - POOLS + BUSES

RTOR CODES

0 RTOR PERMITTED
1 RTOR PROHIBITED

PEDESTRIAN CODES

0 NO PEDESTRIANS
1 LIGHT
2 MODERATE
3 HEAVY

1

NETSIM TURNING MOVEMENT DATA

LINK	TURN MOVEMENT PERCENTAGES LEFT	THROUGH	RIGHT	DIAGONAL	TURN MOVEMENT POSSIBLE LEFT	THROUGH	RIGHT	DIAGONAL	POCKET LENGTH (IN FEET/METERS LEFT	RIGHT
(8001, 1)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(1, 2)	0	100	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(2, 1)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(2, 3)	3	90	7	0	YES	YES	YES	NO	300/ 91	0/ 0
(3, 2)	0	100	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(3, 4)	0	100	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(4, 3)	20	60	20	0	YES	YES	YES	NO	300/ 91	0/ 0
(4, 5)	0	100	0	0	YES	YES	NO	NO	0/ 0	0/ 0

LINK	LEFT	THROUGH	RIGHT	DIAGONAL	LEFT	THROUGH	RIGHT	DIAGONAL	LEFT	RIGHT
(5, 4)	0	100	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(5, 6)	7	90	3	0	YES	YES	YES	NO	300/ 91	0/ 0
(6, 5)	0	100	0	0	NO	YES	YES	NO	0/ 0	0/ 0
(6, 7)	0	100	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(7, 6)	30	60	10	0	YES	YES	YES	NO	300/ 91	0/ 0
(7, 8)	0	100	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(8, 7)	0	90	10	0	YES	YES	YES	NO	0/ 0	0/ 0
(8, 9)	0	100	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(9, 8)	0	100	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(9, 10)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(10, 9)	20	60	20	0	YES	YES	YES	NO	300/ 91	0/ 0
(8010, 10)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(2, 21)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(21, 2)	100	0	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(8021, 21)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(2, 22)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(22, 2)	0	0	100	0	YES	YES	YES	NO	0/ 0	0/ 0
(3, 31)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(31, 3)	50	42	8	0	YES	YES	YES	NO	300/ 91	0/ 0
(8031, 31)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(3, 32)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(32, 3)	0	0	100	0	YES	YES	YES	NO	300/ 91	0/ 0
(8032, 32)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(4, 41)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(41, 4)	100	0	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(8041, 41)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(4, 42)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(42, 4)	0	0	100	0	YES	YES	YES	NO	0/ 0	0/ 0
(8042, 42)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(5, 51)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(51, 5)	100	0	0	0	YES	NO	YES	NO	0/ 0	0/ 0
(8051, 51)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(6, 61)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(61, 6)	100	0	0	0	YES	YES	YES	NO	300/ 91	0/ 0
(8061, 61)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(6, 62)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(62, 6)	8	47	45	0	YES	YES	YES	NO	300/ 91	0/ 0

1

NETSIM TURNING MOVEMENT DATA (CONT.)

LINK	TURN MOVEMENT PERCENTAGES LEFT	THROUGH	RIGHT	DIAGONAL	TURN MOVEMENT POSSIBLE LEFT	THROUGH	RIGHT	DIAGONAL	POCKET LENGTH (IN FEET/METERS LEFT	RIGHT
(8062, 62)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(7, 71)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(71, 7)	100	0	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(8071, 71)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(7, 72)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(72, 7)	0	0	100	0	YES	YES	YES	NO	0/ 0	0/ 0
(8072, 72)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8, 81)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(81, 8)	100	0	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(8081, 81)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8, 82)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(82, 8)	0	0	100	0	YES	YES	YES	NO	0/ 0	0/ 0
(8082, 82)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(9, 91)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(91, 9)	100	0	0	0	YES	YES	YES	NO	0/ 0	0/ 0
(8091, 91)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(9, 92)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(92, 9)	0	0	100	0	YES	YES	YES	NO	0/ 0	0/ 0
(8092, 92)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0
(8022, 22)	0	100	0	0	NO	YES	NO	NO	0/ 0	0/ 0

```
1               SPECIFIED FIXED-TIME SIGNAL CONTROL, AND SIGN CONTROL, CODES
0                                  NODE    1 IS UNDER SIGN CONTROL
0    INTERVAL   DURATION    +- - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
     NUMBER   (SEC)  (PCT)   (8001,   1)    (  2,   1)
        1       0    100         1              1
0                                               NODE    2
                OFFSET   0 SEC                                      CYCLE LENGTH  75 SEC
0    INTERVAL   DURATION    +- - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
     NUMBER   (SEC)  (PCT)   (  1,   2)    ( 21,   2)    ( 22,   2)    (  3,   2)
        1      50     66         1             2             2              1
        2      25     33         2             1             1              2
0                                               NODE    3
                OFFSET  45 SEC                                      CYCLE LENGTH  90 SEC
0    INTERVAL   DURATION    +- - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
     NUMBER   (SEC)  (PCT)   (  2,   3)    (  4,   3)    ( 31,   3)    ( 32,   3)
        1       7      7         1             2             2              2
        2      33     36         1             1             2              2
        3       5      5         2             1             2              2
        4      15     16         2             2             2              1
        5      30     33         2             2             1              2
0                                               NODE    4
                OFFSET  15 SEC                                      CYCLE LENGTH  75 SEC
0    INTERVAL   DURATION    +- - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
     NUMBER   (SEC)  (PCT)   (  3,   4)    (  5,   4)    ( 41,   4)    ( 42,   4)
        1      50     66         1             1             2              2
        2      25     33         2             2             1              1
0                                               NODE    5
                OFFSET  40 SEC                                      CYCLE LENGTH  65 SEC
```

```
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (   4,    5)    (   6,    5)    (  51,    5)
         1        50     76          1               1               2
         2        15     23          2               2               1
0                                                   NODE    6
                 OFFSET  10 SEC                                                    CYCLE LENGTH  90 SEC
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (   5,    6)    (   7,    6)    (  61,    6)    (  62,    6)
         1         7      7          1               2               2               2
         2        33     36          1               1               2               2
         3         5      5          2               1               2               2
         4        30     33          2               2               2               1
         5        15     16          2               2               1               2
1
0                                                   NODE    7
                 OFFSET  55 SEC                                                    CYCLE LENGTH  75 SEC
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (   6,    7)    (   8,    7)    (  71,    7)    (  72,    7)
         1        50     66          1               1               2               2
         2        25     33          2               2               1               1
0                                                   NODE    8
                 OFFSET  25 SEC                                                    CYCLE LENGTH  75 SEC
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (   7,    8)    (   9,    8)    (  81,    8)    (  82,    8)
         1        50     66          1               1               2               2
         2        25     33          2               2               1               1
0                                                   NODE    9
                 OFFSET  60 SEC                                                    CYCLE LENGTH  75 SEC
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (   8,    9)    (  10,    9)    (  91,    9)    (  92,    9)
         1        50     66          1               1               2               2
         2        25     33          2               2               1               1
0                                       NODE   10 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (   9,   10)    (8010,   10)
         1         0    100          1               1
0                                       NODE   21 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8021,   21)    (   2,   21)
         1         0    100          1               1
0                                       NODE   22 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8022,   22)    (   2,   22)
         1         0    100          1               1
0                                       NODE   31 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8031,   31)    (   3,   31)
         1         0    100          1               1
0                                       NODE   32 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8032,   32)    (   3,   32)
         1         0    100          1               1
1
0                                       NODE   41 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8041,   41)    (   4,   41)
         1         0    100          1               1
0                                       NODE   42 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8042,   42)    (   4,   42)
         1         0    100          1               1
0                                       NODE   51 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8051,   51)    (   5,   51)
         1         0    100          1               1
0                                       NODE   61 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8061,   61)    (   6,   61)
         1         0    100          1               1
0                                       NODE   62 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8062,   62)    (   6,   62)
         1         0    100          1               1
0                                       NODE   71 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8071,   71)    (   7,   71)
         1         0    100          1               1
0                                       NODE   72 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8072,   72)    (   7,   72)
         1         0    100          1               1
0                                       NODE   81 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8081,   81)    (   8,   81)
         1         0    100          1               1
0                                       NODE   82 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
       NUMBER    (SEC)  (PCT)    (8082,   82)    (   8,   82)
         1         0    100          1               1
1
0                                       NODE   91 IS UNDER SIGN CONTROL
0      INTERVAL    DURATION      +- - - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
```

NUMBER (SEC) (PCT) (8091, 91) (9, 91)
1 0 100 1 1

0 NODE 92 IS UNDER SIGN CONTROL

0 INTERVAL DURATION +- - - - - - - - - - - - - - - APPROACHES - - - - - - - - - - - - - - - - +
NUMBER (SEC) (PCT) (8092, 92) (9, 92)
1 0 100 1 1

1 INTERPRETATION OF SIGNAL CODES

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

1 TRAFFIC CONTROL TABLE - SIGNS AND FIXED TIME SIGNALS

CONTROL CODES
GO = PROTECTED
NOGO = NOT PERMITTED
AMBR = AMBER
PERM = PERMITTED NOT PROTECTED
PROT = PROTECTED
STOP = STOP SIGN
YLD = YIELD SIGN

NODE 1 SIGN CONTROL

INTERVAL	DURATION	(8001, 1)				(2, 1)													
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 2 FIXED TIME CONTROL OFFSET = 0 SECONDS CYCLE LENGTH = 75 SECONDS

INTERVAL	DURATION	(1, 2)				(21, 2)				(22, 2)				(3, 2)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	50	PERM	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PERM	GO	GO					
2	25	NOGO	NOGO	NOGO		PERM	GO	GO		PERM	GO	GO		NOGO	NOGO	NOGO					

NODE 3 FIXED TIME CONTROL OFFSET = 45 SECONDS CYCLE LENGTH = 90 SECONDS

INTERVAL	DURATION	(2, 3)				(4, 3)				(31, 3)				(32, 3)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	7	PROT	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
2	33	PERM	GO	GO		PERM	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
3	5	NOGO	NOGO	NOGO		PROT	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
4	15	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PROT	GO	GO					
5	30	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PROT	GO	GO		NOGO	NOGO	NOGO					

NODE 4 FIXED TIME CONTROL OFFSET = 15 SECONDS CYCLE LENGTH = 75 SECONDS

INTERVAL	DURATION	(3, 4)				(5, 4)				(41, 4)				(42, 4)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	50	PERM	GO	GO		PERM	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
2	25	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PERM	GO	GO		PERM	GO	GO					

1

NODE 5 FIXED TIME CONTROL OFFSET = 40 SECONDS CYCLE LENGTH = 65 SECONDS

INTERVAL	DURATION	(4, 5)				(6, 5)				(51, 5)											
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	50	PROT	GO				GO	GO		NOGO		NOGO									
2	15	NOGO	NOGO				NOGO	NOGO		PROT		GO									

NODE 6 FIXED TIME CONTROL OFFSET = 10 SECONDS CYCLE LENGTH = 90 SECONDS

APPROACHES

INTERVAL	DURATION	(5, 6)				(7, 6)				(61, 6)				(62, 6)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	7	PROT	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
2	33	PERM	GO	GO		PERM	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
3	5	NOGO	NOGO	NOGO		PROT	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
4	30	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PROT	GO	GO					
5	15	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PROT	GO	GO		NOGO	NOGO	NOGO					

NODE 7 FIXED TIME CONTROL OFFSET = 55 SECONDS CYCLE LENGTH = 75 SECONDS

APPROACHES

INTERVAL	DURATION	(6, 7)				(8, 7)				(71, 7)				(72, 7)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	50	PERM	GO	GO		PERM	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
2	25	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PERM	GO	GO		PERM	GO	GO					

NODE 8 FIXED TIME CONTROL OFFSET = 25 SECONDS CYCLE LENGTH = 75 SECONDS

APPROACHES

INTERVAL	DURATION	(7, 8)				(9, 8)				(81, 8)				(82, 8)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	50	PERM	GO	GO		PERM	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
2	25	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PERM	GO	GO		PERM	GO	GO					

NODE 9 FIXED TIME CONTROL OFFSET = 60 SECONDS CYCLE LENGTH = 75 SECONDS

APPROACHES

INTERVAL	DURATION	(8, 9)				(10, 9)				(91, 9)				(92, 9)							
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	50	PERM	GO	GO		PERM	GO	GO		NOGO	NOGO	NOGO		NOGO	NOGO	NOGO					
2	25	NOGO	NOGO	NOGO		NOGO	NOGO	NOGO		PERM	GO	GO		PERM	GO	GO					

1

NODE 10 SIGN CONTROL

APPROACHES

INTERVAL	DURATION	(9, 10)				(8010, 10)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 21 SIGN CONTROL

APPROACHES

INTERVAL	DURATION	(8021, 21)				(2, 21)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 22 SIGN CONTROL

APPROACHES

INTERVAL	DURATION	(8022, 22)				(2, 22)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 31 SIGN CONTROL

APPROACHES

INTERVAL	DURATION	(8031, 31)				(3, 31)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 32 SIGN CONTROL

APPROACHES

INTERVAL	DURATION	(8032, 32)				(3, 32)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

NODE 41 SIGN CONTROL

```
 INTERVAL DURATION    -------------------------------------------   APPROACHES   --------------------------------------------
                          (8041,  41)          (   4,  41)
                      LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
       1        0           GO                   GO
1


       NODE    42     SIGN CONTROL

 INTERVAL DURATION    -------------------------------------------   APPROACHES   --------------------------------------------
                          (8042,  42)          (   4,  42)
                      LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
       1        0           GO                   GO


       NODE    51     SIGN CONTROL

 INTERVAL DURATION    -------------------------------------------   APPROACHES   --------------------------------------------
                          (8051,  51)          (   5,  51)
                      LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
       1        0           GO                   GO


       NODE    61     SIGN CONTROL

 INTERVAL DURATION    -------------------------------------------   APPROACHES   --------------------------------------------
                          (8061,  61)          (   6,  61)
                      LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
       1        0           GO                   GO


       NODE    62     SIGN CONTROL

 INTERVAL DURATION    -------------------------------------------   APPROACHES   --------------------------------------------
                          (8062,  62)          (   6,  62)
                      LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
       1        0           GO                   GO


       NODE    71     SIGN CONTROL

 INTERVAL DURATION    -------------------------------------------   APPROACHES   --------------------------------------------
                          (8071,  71)          (   7,  71)
                      LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
       1        0           GO                   GO


       NODE    72     SIGN CONTROL

 INTERVAL DURATION    -------------------------------------------   APPROACHES   --------------------------------------------
                          (8072,  72)          (   7,  72)
                      LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
       1        0           GO                   GO
1


       NODE    81     SIGN CONTROL

 INTERVAL DURATION    -------------------------------------------   APPROACHES   --------------------------------------------
                          (8081,  81)          (   8,  81)
                      LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
       1        0           GO                   GO


       NODE    82     SIGN CONTROL

 INTERVAL DURATION    -------------------------------------------   APPROACHES   --------------------------------------------
                          (8082,  82)          (   8,  82)
                      LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
       1        0           GO                   GO


       NODE    91     SIGN CONTROL

 INTERVAL DURATION    -------------------------------------------   APPROACHES   --------------------------------------------
                          (8091,  91)          (   9,  91)
                      LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG  LEFT THRU RITE DIAG
       1        0           GO                   GO


       NODE    92     SIGN CONTROL
```

INTERVAL	DURATION	APPROACHES																			
		(8092, 92)				(9, 92)															
		LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG	LEFT	THRU	RITE	DIAG
1	0		GO				GO														

1 ENTRY LINK VOLUMES

LINK	FLOW RATE (VEH/HOUR)	TRUCKS (PERCENT)	CAR POOLS (PERCENT)
(8001, 1)	1750	0	14
(8021, 21)	80	0	0
(8022, 22)	60	0	0
(8031, 31)	1183	0	6
(8032, 32)	150	0	0
(8041, 41)	70	0	0
(8042, 42)	80	0	0
(8051, 51)	80	0	0
(8061, 61)	80	0	0
(8062, 62)	1283	0	6
(8071, 71)	80	0	0
(8072, 72)	100	0	0
(8081, 81)	80	0	0
(8082, 82)	60	0	0
(8091, 91)	60	0	0
(8092, 92)	70	0	0
(8010, 10)	0	0	0

1 AVERAGE VEHICLE OCCUPANCIES
(HUNDREDTHS-OF-A-PERSON / VEHICLE)

AUTOS	CAR-POOLS	TRUCKS	BUSES
130	300	120	500

0***** WARNING - MESSAGE NUMBER 253, ROUTINE GDMNFN, PARAMETER(S) - P1 = 8010, P2 = 10

1

VEHICLE TYPE SPECIFICATIONS

	VEHICLE TYPE	LENGTH FEET/METERS	MAXIMUM ACCELERATION (MPH/SEC)/(KMPH/SEC)	MAXIMUM SPEED (MPH)/(KMPH)	Q DSCHG HDWY FACTOR (PCT)	AVG. OCCUP.	FLEET COMPONENT PERCENTAGES AUTO	TRUCK	CARPOOL	BUS
0	1**	17.0/ 5.2	5.5/ 8.8	75.0/ 120.7	100	1.3	100	0	0	0
0	2**	34.0/ 10.4	3.0/ 4.8	60.0/ 96.6	120	1.2	0	100	0	0
0	3**	17.0/ 5.2	5.5/ 8.8	75.0/ 120.7	100	3.0	0	0	100	0
0	4**	47.0/ 14.3	2.0/ 3.3	50.0/ 80.5	120	50.0	0	0	0	100

0 ** INDICATES THAT ALL PARAMETERS FOR VEHICLE TYPE ASSUME DEFAULT VALUES

1 PROPERTIES OF BUS STATIONS

STATION NO.	LANE SERVICED	LINK	DISTANCE FROM UPSTREAM NODE FEET	/ METERS	CAPACITY (BUSES)	MEAN DWELL (SEC)	TYPE	PERCENT OF BUSES STOPPING
1	1	(1, 2)	1000	305	1	20	1	90
2	1	(2, 3)	1500	457	1	20	1	90
3	1	(3, 4)	1500	457	1	20	1	90
4	1	(4, 5)	1000	305	1	20	1	90
5	1	(5, 6)	1500	457	1	20	1	90
6	1	(6, 7)	1500	457	1	20	1	90
7	1	(7, 8)	1000	305	1	20	1	90
8	1	(8, 9)	1000	305	1	20	1	90
9	1	(9, 10)	1000	305	1	20	1	90
10	1	(31, 3)	500	152	1	20	1	90
11	1	(31, 3)	2000	610	1	20	1	90
12	1	(62, 6)	500	152	1	20	1	90
13	1	(62, 6)	2000	610	1	20	1	90
14	1	(10, 9)	1000	305	1	20	1	90
15	1	(9, 8)	1000	305	1	20	1	90
16	1	(8, 7)	1000	305	1	20	1	90
17	1	(7, 6)	2500	762	1	20	1	90
18	1	(6, 5)	1000	305	1	20	1	90
19	1	(5, 4)	1000	305	1	20	1	90
20	1	(4, 3)	2000	610	1	20	1	90
21	1	(3, 2)	1000	305	1	0	1	0
22	1	(2, 1)	1000	305	1	0	1	0
23	1	(3, 31)	500	152	1	0	1	0
24	1	(3, 31)	2000	610	1	0	1	0
25	1	(6, 62)	500	152	1	0	1	0
26	1	(6, 62)	2000	610	1	0	1	0

0 THE TYPE CODE IDENTIFIES THE APPLICABLE STATISTICAL DISTRIBUTION OF DWELL TIME

1 BUS ROUTE PATHS

	ROUTE	SEQUENCE OF NODES DEFINING PATH										
0	1	8001	1	2	3	4	5	6	7	8	9	10 8010
0	2	8031	31	3	4	5	6	7	8	9	10 8010	
0	3	8062	62	6	7	8	9	10 8010				
0	4	8010	10	9	8	7	6	5	4	3	2	1 8001
0	5	8010	10	9	8	7	6	5	4	3	31 8031	
0	6	8010	10	9	8	7	6	62 8062				

1 BUS STATIONS BY ROUTE

	ROUTE	SEQUENCE OF STATIONS SERVICED BY ROUTE								
0	1	1	2	3	4	5	6	7	8	9
0	2	10	11	3	4	5	6	7	8	9
0	3	12	13	6	7	8	9			
0	4	14	15	16	17	18	19	20	21	22

0	5	14	15	16	17	18	19	20	23	24
0	6	14	15	16	17	25	26			

1 BUS VOLUMES

	ROUTE	VOLUME (VEH/HR)	MEAN HEADWAY (SEC)
0	1	12	300
0	2	12	300
0	3	12	300
0	4	12	300
0	5	12	300
0	6	12	300

Appendix C

Emissions Calculation for Network B

Appendix C1: Base Case

Table C1-1. Mobility from NETSIM

Link	Length (mile)	VMT			Persons			PMT		
		Auto	Carpool	Bus	Auto	Car-pool	Bus	Auto	Carpool	Bus
n1-n2	0.2841	214.58	36.63	1.70	981.93	386.77	150.00	278.96	109.88	42.61
n2-n3	0.4735	385.84	65.86	2.84	1059.37	417.28	150.00	501.59	197.57	71.02
n3-n4	0.5682	585.90	100.01	6.25	1340.55	528.03	200.00	761.68	300.02	113.64
n4-n5	0.2841	298.82	51.00	3.41	1367.38	538.60	200.00	388.46	153.01	56.82
n5-n6	0.3788	365.37	62.36	3.41	1253.94	493.92	200.00	474.98	187.09	75.76
n6-n7	0.5682	619.41	105.73	7.95	1417.22	558.23	250.00	805.24	317.18	142.05
n7-n8	0.2841	332.64	56.78	4.26	1522.17	599.57	250.00	432.44	170.33	71.02
n8-n9	0.3788	459.70	78.47	5.68	1577.71	621.44	250.00	597.62	235.40	94.70
n9-n10	0.2841	356.25	60.81	4.26	1630.21	642.13	250.00	463.13	182.42	71.02
n31-n3	0.4735	236.24	40.32	2.84	648.61	255.48	50.00	307.11	120.97	23.67
n62-n6	0.4735	247.06	42.17	2.37	678.33	267.19	50.00	321.18	126.51	23.67
Sum	4.4508	4101.83	700.12	44.98	13477.43	5308.64	2000.00	5332.37	2100.37	785.98

Table C1-2. Total Running Emissions (grams)

Link	Auto			Car-pool			Bus		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	482.81	3939.75	240.33	82.41	672.46	41.02	5.86	32.98	30.31
n2-n3	868.14	7084.06	432.14	148.18	1209.15	73.76	9.77	54.97	50.51
n3-n4	1318.28	10757.20	656.21	225.01	1836.10	112.01	21.50	120.94	111.13
n4-n5	672.34	5486.27	334.67	114.76	936.43	57.12	11.73	65.97	60.61
n5-n6	822.08	6708.14	409.21	140.32	1144.99	69.85	11.73	65.97	60.61
n6-n7	1393.68	11372.45	693.74	237.88	1941.12	118.41	27.36	153.92	141.43
n7-n8	748.45	6107.32	372.56	127.75	1042.43	63.59	14.66	82.46	75.77
n8-n9	1034.34	8440.18	514.87	176.55	1440.62	87.88	19.55	109.94	101.02
n9-n10	801.57	6540.80	399.00	136.82	1116.42	68.10	14.66	82.46	75.77
n31-n3	531.53	4337.32	264.59	90.73	740.32	45.16	9.77	54.97	50.51
n62-n6	555.89	4536.03	276.71	94.88	774.24	47.23	8.14	45.81	42.09
Sum	9229.11	75309.52	4594.04	1575.28	12854.28	784.14	154.73	870.38	799.76

Table C1-3. Average Running Emissions (grams/person-mile)

Link	Auto			Car-pool			Bus		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.1376	0.7740	0.7112
n2-n3	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.1376	0.7740	0.7112
n3-n4	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.1892	1.0643	0.9779
n4-n5	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.2064	1.1610	1.0668
n5-n6	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.1548	0.8708	0.8001
n6-n7	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.1926	1.0836	0.9957
n7-n8	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.2064	1.1610	1.0668
n8-n9	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.2064	1.1610	1.0668
n9-n10	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.2064	1.1610	1.0668
n31-n3	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.4128	2.3220	2.1336
n62-n6	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.3440	1.9350	1.7780
Avg.	1.7308	14.1231	0.8615	0.7500	6.1200	0.3733	0.2177	1.2243	1.1250

Table C1-4. Total Idle Emissions (grams)

Link	Delay Time (Veh-minutes)			Auto			Carpool			Bus		
	Auto	Carpool	Bus	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	231.6	39.5	5.1	102.5	982.3	13.2	17.5	167.7	2.3	1.5	4.3	1.8
n2-n3	607.8	103.8	6.5	269.0	2578.3	34.7	45.9	440.1	5.9	1.9	5.5	2.2
n3-n4	510.8	87.2	10.2	226.0	2166.7	29.2	38.6	369.8	5.0	2.9	8.7	3.5
n4-n5	1047.3	178.8	11.8	463.4	4442.4	59.9	79.1	758.3	10.2	3.4	10.0	4.0
n5-n6	4766.4	813.6	43.0	2109.1	20217.6	272.5	360.0	3450.9	46.5	12.3	36.5	14.8
n6-n7	604.2	103.1	13.3	267.3	2562.7	34.5	45.6	437.4	5.9	3.8	11.3	4.6
n7-n8	667.0	113.8	13.3	295.1	2829.0	38.1	50.4	482.9	6.5	3.8	11.3	4.6
n8-n9	459.5	78.4	12.0	203.3	1948.9	26.3	34.7	332.7	4.5	3.4	10.2	4.1
n9-n10	215.7	36.8	10.5	95.4	914.9	12.3	16.3	156.2	2.1	3.0	8.9	3.6
n31-n3	976.9	166.7	16.1	432.3	4143.5	55.8	73.8	707.2	9.5	4.6	13.7	5.5
n62-n6	2215.8	378.2	22.1	980.5	9398.7	126.7	167.4	1604.2	21.6	6.3	18.8	7.6
Sum	12303.0	2099.9	163.9	5444.1	52185.0	703.3	929.2	8907.3	120.0	46.8	139.1	56.2

Table C1-5. Average Idle Emissions (grams/person-mile)

	Auto			Carpool			Bus		
Link	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	0.3673	3.5212	0.0475	0.1592	1.5258	0.0206	0.0342	0.1016	0.0411
n2-n3	0.5362	5.1402	0.0693	0.2324	2.2274	0.0300	0.0262	0.0777	0.0314
n3-n4	0.2968	2.8446	0.0383	0.1286	1.2327	0.0166	0.0257	0.0762	0.0308
n4-n5	1.1930	11.4360	0.1541	0.5170	4.9556	0.0668	0.0594	0.1763	0.0713
n5-n6	4.4405	42.5655	0.5737	1.9242	18.4450	0.2486	0.1622	0.4818	0.1948
n6-n7	0.3320	3.1825	0.0429	0.1439	1.3791	0.0186	0.0268	0.0795	0.0321
n7-n8	0.6825	6.5421	0.0882	0.2957	2.8349	0.0382	0.0535	0.1590	0.0643
n8-n9	0.3402	3.2612	0.0440	0.1474	1.4132	0.0190	0.0362	0.1076	0.0435
n9-n10	0.2061	1.9754	0.0266	0.0893	0.8560	0.0115	0.0423	0.1255	0.0507
n31-n3	1.4075	13.4921	0.1818	0.6099	5.8466	0.0788	0.1944	0.5773	0.2334
n62-n6	3.0528	29.2631	0.3944	1.3229	12.6807	0.1709	0.2668	0.7924	0.3203
Avg.	1.0209	9.7865	0.1319	0.4424	4.2408	0.0572	0.0596	0.1770	0.0716

Appendix C2: HOV-3 Case

Table C2-1. Mobility from NETSIM

Link	Length (mile)	VMT Auto	VMT Carpool	VMT Bus	Persons Auto	Persons Car-pool	Persons Bus	PMT Auto	PMT Carpool	PMT Bus
n1-n2	0.2841	193.95	43.39	1.70	887.53	458.15	175.00	252.14	130.16	49.72
n2-n3	0.4735	338.68	75.76	2.84	929.88	480.01	175.00	440.28	227.28	82.86
n3-n4	0.5682	450.08	100.68	6.25	1029.79	531.58	230.00	585.11	302.04	130.68
n4-n5	0.2841	219.71	49.15	3.41	1005.40	519.00	230.00	285.63	147.44	65.34
n5-n6	0.3788	284.25	63.58	4.55	975.53	503.58	230.00	369.52	190.75	87.12
n6-n7	0.5682	488.80	109.34	9.09	1118.37	577.32	280.00	635.44	328.02	159.09
n7-n8	0.2841	265.07	59.29	4.55	1212.95	626.13	280.00	344.59	177.88	79.55
n8-n9	0.3788	371.79	83.16	6.06	1275.97	658.67	280.00	483.32	249.49	106.06
n9-n10	0.2841	290.53	64.99	4.26	1329.47	686.28	280.00	377.69	194.97	79.55
n31-n3	0.4735	223.10	49.91	2.37	612.55	316.21	55.00	290.03	149.72	26.04
n62-n6	0.4735	215.69	48.25	1.89	592.20	305.70	50.00	280.40	144.74	23.67
Sum	4.4508	3341.65	747.50	46.97	10969.65	5662.64	2265.00	4344.15	2242.49	889.68

Table C2-2. Total Running Emissions (grams)

Link	Auto HC	Auto CO	Auto NOx	Car-pool HC	Car-pool CO	Car-pool NOx	Bus HC	Bus CO	Bus NOx
n1-n2	484.89	4067.22	221.11	98.05	800.90	49.03	5.22	27.73	27.99
n2-n3	846.70	7102.13	386.10	171.22	1398.52	85.61	8.69	46.22	46.65
n3-n4	1125.20	9438.20	513.09	227.53	1858.53	113.77	19.13	101.69	102.63
n4-n5	549.28	4607.37	250.47	111.07	907.26	55.54	10.43	55.47	55.98
n5-n6	710.62	5960.65	324.04	143.70	1173.75	71.85	13.91	73.95	74.64
n6-n7	1222.00	10250.14	557.23	247.11	2018.42	123.55	27.82	147.91	149.27
n7-n8	662.67	5558.45	302.18	134.00	1094.55	67.00	13.91	73.95	74.64
n8-n9	929.46	7796.33	423.84	187.95	1535.22	93.98	18.55	98.61	99.52
n9-n10	726.33	6092.43	331.21	146.88	1199.70	73.44	13.04	69.33	69.97
n31-n3	557.76	4678.49	254.34	112.79	921.27	56.39	7.24	38.52	38.87
n62-n6	539.23	4523.06	245.89	109.04	890.66	54.52	5.80	30.81	31.10
Sum	8354.13	70074.47	3809.48	1689.34	13798.79	844.67	143.73	764.20	771.24

Table C2-3. Average Running Emissions (grams/person-mile)

	Auto			Car-pool			Bus		
Link	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.1049	0.5578	0.5630
n2-n3	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.1049	0.5578	0.5630
n3-n4	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.1463	0.7781	0.7853
n4-n5	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.1597	0.8489	0.8567
n5-n6	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.1597	0.8489	0.8567
n6-n7	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.1749	0.9297	0.9383
n7-n8	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.1749	0.9297	0.9383
n8-n9	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.1749	0.9297	0.9383
n9-n10	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.1639	0.8716	0.8796
n31-n3	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.2782	1.4791	1.4927
n62-n6	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.2448	1.3016	1.3136
Avg.	1.9231	16.1308	0.8769	0.7533	6.1533	0.3767	0.1715	0.9121	0.9205

Table C2-4. Total Idle Emissions (grams)

	Delay Time (Veh-min)			Auto			Carpool			Bus		
Link	Auto	Carpool	Bus	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	208.6	46.7	5.1	92.3	884.9	11.9	20.7	198.0	2.7	1.5	4.3	1.8
n2-n3	1368.5	306.1	6.1	605.6	5804.6	78.2	135.5	1298.4	17.5	1.7	5.2	2.1
n3-n4	1592.5	356.2	10.2	704.7	6754.8	91.0	157.6	1511.0	20.4	2.9	8.7	3.5
n4-n5	1218.2	272.5	9.3	539.1	5167.2	69.6	120.6	1155.9	15.6	2.7	7.9	3.2
n5-n6	3683.2	823.9	17.8	1629.8	15622.9	210.6	364.6	3494.7	47.1	5.1	15.1	6.1
n6-n7	474.8	106.2	15.5	210.1	2013.9	27.1	47.0	450.5	6.1	4.4	13.2	5.3
n7-n8	455.1	101.8	15.0	201.4	1930.4	26.0	45.0	431.8	5.8	4.3	12.7	5.1
n8-n9	389.4	87.1	13.6	172.3	1651.7	22.3	38.5	369.5	5.0	3.9	11.5	4.7
n9-n10	172.2	38.5	10.6	76.2	730.3	9.8	17.0	163.4	2.2	3.0	9.0	3.6
n31-n3	1101.3	246.3	12.6	487.3	4671.2	63.0	109.0	1044.9	14.1	3.6	10.7	4.3
n62-n6	2587.7	578.8	24.4	1145.0	10976.0	147.9	256.1	2455.2	33.1	7.0	20.7	8.4
Sum	13251.4	2964.2	140.2	5863.7	56208.0	757.5	1311.7	12573.2	169.5	40.1	119.0	48.1

Table C2-5. Average Idle Emissions (grams/person-mile)

	Auto			Carpool			Bus		
Link	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	0.3661	3.5097	0.0473	0.1587	1.5209	0.0205	0.0293	0.0871	0.0352
n2-n3	1.3754	13.1839	0.1777	0.5960	5.7130	0.0770	0.0210	0.0625	0.0253
n3-n4	1.2043	11.5445	0.1556	0.5219	5.0026	0.0674	0.0223	0.0663	0.0268
n4-n5	1.8873	18.0908	0.2438	0.8178	7.8393	0.1057	0.0407	0.1208	0.0488
n5-n6	4.4106	42.2789	0.5698	1.9113	18.3208	0.2469	0.0584	0.1734	0.0701
n6-n7	0.3306	3.1693	0.0427	0.1433	1.3734	0.0185	0.0278	0.0827	0.0334
n7-n8	0.5844	5.6020	0.0755	0.2532	2.4275	0.0327	0.0539	0.1601	0.0647
n8-n9	0.3565	3.4174	0.0461	0.1545	1.4809	0.0200	0.0367	0.1088	0.0440
n9-n10	0.2017	1.9337	0.0261	0.0874	0.8379	0.0113	0.0381	0.1131	0.0457
n31-n3	1.6802	16.1056	0.2171	0.7281	6.9791	0.0941	0.1383	0.4107	0.1660
n62-n6	4.0836	39.1442	0.5276	1.7696	16.9625	0.2286	0.2946	0.8749	0.3537
Avg.	1.3498	12.9388	0.1744	0.5849	5.6068	0.0756	0.0450	0.1338	0.0541

Appendix C3: Pricing Case

Table C3-1. Mobility from NETSIM

Link	Length (mile)	VMT			Persons			PMT		
		Auto	Carpool	Bus	Auto	Car-pool	Bus	Auto	Carpool	Bus
n1-n2	0.2841	200.30	43.76	1.70	916.57	462.11	165.00	260.39	131.28	46.88
n2-n3	0.4735	360.97	78.86	2.84	991.08	499.67	165.00	469.26	236.58	78.13
n3-n4	0.5682	542.34	118.49	6.82	1240.88	625.61	220.00	705.05	355.46	125.00
n4-n5	0.2841	278.27	60.80	3.41	1273.39	642.00	220.00	361.76	182.39	62.50
n5-n6	0.3788	343.93	75.14	3.79	1180.37	595.10	220.00	447.11	225.42	83.33
n6-n7	0.5682	571.67	124.90	7.39	1307.99	659.45	275.00	743.18	374.69	156.25
n7-n8	0.2841	304.22	66.46	3.98	1392.10	701.85	275.00	395.48	199.39	78.13
n8-n9	0.3788	419.30	91.60	5.68	1439.02	725.51	275.00	545.08	274.81	104.17
n9-n10	0.2841	322.07	70.36	3.98	1473.78	743.03	275.00	418.69	211.09	78.13
n31-n3	0.4735	227.10	49.62	2.84	623.54	314.37	55.00	295.24	148.85	26.04
n62-n6	0.4735	230.17	50.28	2.37	631.94	318.60	55.00	299.21	150.85	26.04
Sum	4.4508	3800.34	830.27	44.79	12470.66	6287.28	2200.00	4940.44	2490.81	864.58

Table C3-2. Total Running Emissions (grams)

Link	Auto			Car-pool			Bus		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	438.66	3555.33	224.34	95.83	776.74	49.01	5.49	29.90	28.96
n2-n3	790.52	6407.19	404.28	172.71	1399.79	88.32	9.15	49.83	48.27
n3-n4	1187.73	9626.59	607.42	259.49	2103.14	132.71	21.95	119.59	115.84
n4-n5	609.42	4939.38	311.67	133.14	1079.12	68.09	10.98	59.80	57.92
n5-n6	753.21	6104.77	385.20	164.55	1333.72	84.16	12.20	66.44	64.36
n6-n7	1251.97	10147.23	640.28	273.52	2216.89	139.88	23.78	129.56	125.49
n7-n8	666.24	5399.85	340.72	145.55	1179.72	74.44	12.81	69.76	67.57
n8-n9	918.26	7442.50	469.61	200.61	1625.98	102.60	18.30	99.66	96.53
n9-n10	705.33	5716.69	360.72	154.09	1248.94	78.81	12.81	69.76	67.57
n31-n3	497.36	4031.10	254.36	108.66	880.68	55.57	9.15	49.83	48.27
n62-n6	504.06	4085.43	257.79	110.12	892.55	56.32	7.62	41.52	40.22
Sum	8322.75	67456.06	4256.38	1818.29	14737.26	929.90	144.23	785.65	761.01

Table C3-3. Average Running Emissions (grams/person-mile)

Link	Auto			Car-pool			Bus		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.1171	0.6378	0.6178
n2-n3	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.1171	0.6378	0.6178
n3-n4	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.1756	0.9567	0.9267
n4-n5	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.1756	0.9567	0.9267
n5-n6	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.1464	0.7973	0.7723
n6-n7	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.1522	0.8292	0.8032
n7-n8	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.1639	0.8929	0.8649
n8-n9	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.1756	0.9567	0.9267
n9-n10	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.1639	0.8929	0.8649
n31-n3	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.3513	1.9135	1.8535
n62-n6	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.2927	1.5945	1.5445
Avg.	1.6846	13.6538	0.8615	0.7300	5.9167	0.3733	0.1847	1.0060	0.9745

Table C3-4. Total Idle Emissions (grams)

Link	Delay Time (Veh-min)			Auto			Carpool			Bus		
	Auto	Carpool	Bus	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	222.0	42.1	5.2	98.2	941.8	12.7	18.6	178.5	2.4	1.5	4.4	1.8
n2-n3	582.8	110.4	6.6	257.9	2471.9	33.3	48.9	468.4	6.3	1.9	5.6	2.3
n3-n4	523.5	99.2	10.7	231.7	2220.5	29.9	43.9	420.8	5.7	3.1	9.1	3.7
n4-n5	966.8	183.2	12.7	427.8	4100.9	55.3	81.1	777.1	10.5	3.6	10.8	4.4
n5-n6	4877.4	924.2	57.9	2158.3	20688.3	278.8	409.0	3920.1	52.8	16.5	49.1	19.9
n6-n7	730.7	138.5	13.5	323.4	3099.5	41.8	61.3	587.3	7.9	3.9	11.5	4.6
n7-n8	607.8	115.2	12.7	269.0	2578.2	34.7	51.0	488.5	6.6	3.6	10.8	4.4
n8-n9	475.8	90.1	14.3	210.5	2018.0	27.2	39.9	382.4	5.2	4.1	12.1	4.9
n9-n10	245.7	46.6	10.8	108.7	1042.3	14.0	20.6	197.5	2.7	3.1	9.2	3.7
n31-n3	1004.5	190.3	15.0	444.5	4260.6	57.4	84.2	807.3	10.9	4.3	12.7	5.1
n62-n6	2648.6	501.9	28.3	1172.0	11234.6	151.4	222.1	2128.8	28.7	8.1	24.0	9.7
Sum	12885.7	2441.6	187.7	5701.9	54656.7	736.6	1080.4	10356.6	139.6	53.7	159.3	64.4

Table C3-5. Average Idle Emissions (grams/person-mile)

	Auto			Carpool			Bus		
Link	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
n1-n2	0.3773	3.6168	0.0487	0.1418	1.3593	0.0183	0.0317	0.0942	0.0381
n2-n3	0.5495	5.2677	0.0710	0.2065	1.9798	0.0267	0.0241	0.0717	0.0290
n3-n4	0.3286	3.1495	0.0424	0.1235	1.1837	0.0160	0.0245	0.0727	0.0294
n4-n5	1.1826	11.3360	0.1528	0.4445	4.2605	0.0574	0.0581	0.1725	0.0697
n5-n6	4.8271	46.2712	0.6236	1.8142	17.3905	0.2344	0.1986	0.5898	0.2384
n6-n7	0.4351	4.1707	0.0562	0.1635	1.5675	0.0211	0.0247	0.0733	0.0296
n7-n8	0.6801	6.5191	0.0879	0.2556	2.4501	0.0330	0.0465	0.1380	0.0558
n8-n9	0.3862	3.7021	0.0499	0.1452	1.3914	0.0188	0.0392	0.1165	0.0471
n9-n10	0.2597	2.4895	0.0336	0.0976	0.9357	0.0126	0.0395	0.1173	0.0474
n31-n3	1.5055	14.4313	0.1945	0.5658	5.4238	0.0731	0.1646	0.4889	0.1977
n62-n6	3.9170	37.5469	0.5060	1.4721	14.1116	0.1902	0.3106	0.9224	0.3729
Avg.	1.1541	11.0631	0.1491	0.4338	4.1579	0.0560	0.0621	0.1843	0.0745