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Sensitivity analysis of combined travel demand / air pollution model for the Davenport area

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Sensitivity analysis of combined travel demand / air pollution model for the Davenport area

by

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Signatures have been redacted for privacy

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CHAPTER 1. INTRODUCTION

RATIONALE

Air pollution is a major concern in many urban areas. It is defined as the contamination of air by the discharge of harmful substances. (1) It is usually concentrated in areas where significant industrial activity and vehicular travel occur. Air pollution produces two main undesirable effects. First, it has major health effects, particularly for more sensitive members of the population, such as children and the elderly. Particulate pollution from all sources is estimated to cause 65,000 deaths annually (2) surpassing deaths from auto accidents by a wide margin. Second, it is responsible for a number of undesirable environmental effects such as acid rain, reduced visibility, crop damage, and global warming.

Given this situation, it is important to know exactly which pollutants are being emitted, where are they emitted and in what quantity they are emitted. To accomplish this, it is necessary to model air pollution. The sole emissions of interest in this thesis are mobile source (on-road) emissions, which are responsible for nearly two-thirds of the carbon monoxide, a third of the nitrogen oxides, and a quarter of the hydrocarbons emitted in the atmosphere from anthropogenic sources. (3, 4, 5)

Over the last twenty years, emissions from mobile sources have decreased following introduction of new technology to automobiles and trucks such as catalytic converters, EGR (Exhaust Gas Recirculation), and unleaded and lower sulphur content fuels. However, the VMTs (Vehicle Miles Traveled) have been constantly increasing threatening to overtake technological improvements. This negative trend is forecasted to accelerate in the future as emissions control technology reaches a plateau while VMTs continue to increase.

Currently, on-road mobile source emission modeling is carried out in urban areas that are classified as being in non-attainment for one of the transportation-related criteria pollutants specified in the National Ambient Air Quality Standards (NAAQs) set forth in the Clean Air Act Amendments. Areas are required to use modeling to evaluate impacts of transportation projects and demonstrate progress towards conformity. Carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NO_x) are the three criteria pollutants typically modeled for on-road mobile sources. On road mobile source emissions modeling for estimates of current or future emissions involves multiplying emission rates by vehicle activity estimates. Emission rates are usually developed using the U.S. EPA's MOBILE series of models. Vehicle activity data in the form of VMT is obtained either from HPMS (Highway Performance Monitoring System) or from travel demand forecasting model output. Future scenarios are usually modeled using travel demand models.

Most urban areas in non-attainment are typically large metropolitan areas. Large urban areas have collected data and calibrated and fine-tuned their travel demand models over time to meet emissions modeling and planning requirements. However, new air quality standards are in the process of implementation and may affect smaller urban areas that may not be as well equipped to handle modeling requirements. New eight-hour ozone standards will take effect in late 2003 after finalization of the implementation rule. The original rule was finalized in 1997 but implementation was delayed by numerous court challenges in the proceeding years. These challenges have now been resolved. New $PM_{2.5}$ transport rules are in place and are about two years behind the ozone rules for implementation with finalization not expected until 2006. (6) $PM_{2.5}$ refers to particulate matter 2.5 microns in diameter or smaller and includes fuel particles, dust etc. Similarly PM_{10} refers to particulate matter 10 microns or less in diameter. Small and medium sized communities are expected to be impacted by the regulations as well as large urban areas. Small communities frequently do not have well-developed travel demand models and may lack the resources to collect and develop additional data to make better estimates as well as implement better modeling procedures to meet air quality requirements.

Problem Statement and Scope of Work

New air quality standards are expected to impact small and medium sized communities who have not dealt with air quality problems in the past and may not have adequate travel demand forecasting models in place to meet transportation air quality modeling requirements. This research intends to assist smaller areas in developing travel demand forecasting models by evaluating which model inputs most significantly affect emissions so that resources can be targeted appropriately. This research evaluates how the combined travel demand / emissions factor model reacts to changes in key inputs and answers key questions including "Which input factor(s) is/are most responsible for the output results?", "Are any of the input factors interacting?" and "How significant are the other factors in the determination of the final emission results?".

A sensitivity analysis on different combinations of input factors used in the models was selected as the best method to answer these questions. Travel demand model input that may affect output and subsequently emissions, include socioeconomic characteristics of the area such as household income, average household size, and number and types of employment activity in the area. The travel demand portion of the model consists of a three or four step process. (Dependent on the extent of use of alternative travel modes and hence mode split). These steps include in order of processing, the trip generation step, the trip distribution step, the mode split step – (Optional) and finally, the traffic assignment step. A major travel demand model input is the friction factor (defined as model weighting factors used to describe the travel behavior with regards to trip time distribution in the area). Other major inputs include the representation of the roadway network in the study area.

Information such as average vehicle link traversal speeds, peak roadway capacity, directionality of the roadways (one way or bidirectional) and others are usually included in the roadway network. For the emissions factor portion of the model, major inputs are average speeds of network links and VMT output from the travel demand model (TDM), ambient temperatures, VMT fleet mix, and elevation.

This research focused on three factors used in the travel demand forecasting model that may affect vehicle speeds and VMT that are used as input to emissions models. They include: friction factors, traffic assignment technique used, and the presence/absence of dynamic feedback looping. The factors were analyzed by multi-factor Analysis of Variance ANOVA. All statistical analyses were conducted with the SPSS statistical software application. Standard diagnostic analysis and confidence intervals using multi-pair analysis methods like Tamhane were used to determine the significance of each set of factors.

THESIS ORGANIZATION

The thesis is organized into five main areas. Chapter 1 presented an overview; Chapter 2 is a literature review of the current practices and issues involved in the emissions modeling process. Additionally, a description of a promising alternative emissions modeling approach, the TRANSIMS system of travel forecasting models is presented.

Chapter 3 is a short description of the study area. Among items discussed are the data sources and procurement. A basic map of the major transportation and geographic features of the area is included.

Chapter 4 is a step-by-step description of the process and tools used to convert the data from Bi-State TRANPLAN® format to TransCAD® format. Included in this chapter are example screenshots of dialog boxes used to perform data conversion and manipulation, the filenames that were manipulated etc. Also included is a comparison of the Bi-State TRANPLAN® results and the TransCAD® results using simple statistical techniques. Visual traffic assignment results for both scenarios are illustrated for emphasis.

Chapter 5 details the sensitivity testing procedure. A brief discussion of the principle of sensitivity analysis is performed. Graphical illustrations of the different combinations of input factors are presented. The methods used to change friction factor levels; to include feedback looping and to change the traffic assignment technique are also presented.

Chapter 6 is a description of the process used to combine the assignment output from TransCAD® with emissions factor output from MOBILE6. Included in this description are flowcharts illustrating the main algorithm used in a custom Visual Basic® program that automates the entire combination process. The Visual Basic® code is illustrated in Appendix C.

Chapter 7 includes the presentation of the overall emission results by input factor, season and pollutant type. In addition, emission, speed and VMT results for specifically selected links are also presented.

Chapter 8 contains the ANOVA statistical analysis of the input factor sensitivity. Relevant graphs and tables are illustrated as appropriate to assist in determination of the conclusion. Analysis of seasonal pollutant variation is also performed in Chapter 6.

Chapter 9 presents the overall conclusions of the research. Limitations in the research procedure used and recommendations for future research close out the chapter.

CHAPTER 2. LITERATURE REVIEW AND CURRENT PRACTICE

In general, conventional air quality modeling practice involves the use of a travel demand model to obtain VMT and link speed. These data are then used in conjunction with emissions factor models to estimate quantities of pollutants generated in the study area. Average vehicle speed is used as an input to emission rate models. VMT is multiplied by emission rates output by emission rate models. A description of the methods to calculate emission rates and the travel demand forecasting process including model limitations is presented in the following sections.

EMISSIONS FACTOR MODELS

The most common model to estimate emission factors is EPA's MOBILE models or in the case of California, the EMFAC model. The default values used by MOBILE were developed by the EPA based on a standard 11 mile-drive cycle FTP-75 (Federal Test Procedure). In this cycle, vehicles are placed on a chassis dynamometer with the exhaust connected to Teflon bags from which emissions are measured and recorded. A driver follows the exact test procedure, which represents the starting, accelerating, decelerating, constant speeds, and idling that is usual of a typical urban trip. The cycle consists of three phases with the first being for cold starts, the second being the hot stabilized portion and the last being hot starts. In the hot start phase, the vehicle is shut down and allowed to soak for about 10 minutes and then the procedure followed during the cold start phase is repeated. A cold start is defined as an engine start after a vehicle's engine has been shut down for at least an hour. The hot stabilized portion is defined as that phase of the test after the vehicle's engine has been running long enough to reach normal operating temperatures. A hot start is defined as an engine startup after a brief shut down period thus preventing the engine temperature from dropping to the levels of a cold start. For each phase, a separate Teflon bag is used to capture the emissions and the results analyzed accordingly. The results from several vehicles classes are then averaged to arrive at the default emission values used in MOBILE6.

MOBILE6 is the most current emission rate model available from the EPA. MOBILE6 requires a number of input parameters to estimate emission rates including average travel speeds, temperatures, vehicle mix, humidity, etc. By using averaged data, these models are of little use in analyzing specific "micro scale" evaluation that requires specific speed and acceleration rate information. (7) The FTP-75 test in addition does not accurately represent the real driver in an actual urban operating environment. It must also be acknowledged that there are great differences in the operating environment for differing urban areas that may negatively affect results. An example would be differences in acceleration rates; percent time spent idling in traffic, air conditioning use and others. Attempts have been made to modify the FTP-75 test to more accurately account for these limitations. Another modeling approach to overcome such problems has been to use modal emissions models that give more detailed emissions information, in some cases second by second emissions by vehicle type. (8) This allows highly variable transient emissions from aggressive driving behavior (high accelerations and decelerations) to be captured.

TRAVEL DEMAND MODELING

As one of the prime components of the modeling strategy being pursued in the research, it is necessary to describe the principles in some detail. Travel demand modeling was first used in the 1950s by state highway agencies to determine the need for new roads. It comprises a four-step sequence that eventually leads to an estimate of the vehicular activity on a particular network link. The four main steps are illustrated on the right of the diagram on page 7 and include:

- Trip Generation
- Trip Distribution
- Mode Split
- Traffic Assignment

Before the 4-step process is applied a network model is created. To perform travel demand modeling, data processing limitations dictate that the transportation network will need to be simplified compared to the real network. Consequently, networks in the travel demand model, represented as sets of nodes with connecting links, do not include all the roadways in the area. Local roadways are typically not included and depending on the scope and the area being modeled, some collectors may also not be included. The omitted local and collector roadways are represented collectively as links to zone centroids and are referred to as centroid connectors. Traffic Analysis Zones or TAZ's are the basic geographic unit in travel demand modeling. They represent the sources and destinations of trips within the region. A zone centroid is defined by a single point in a TAZ that represents the center of gravity of trip activity for the entire zone.

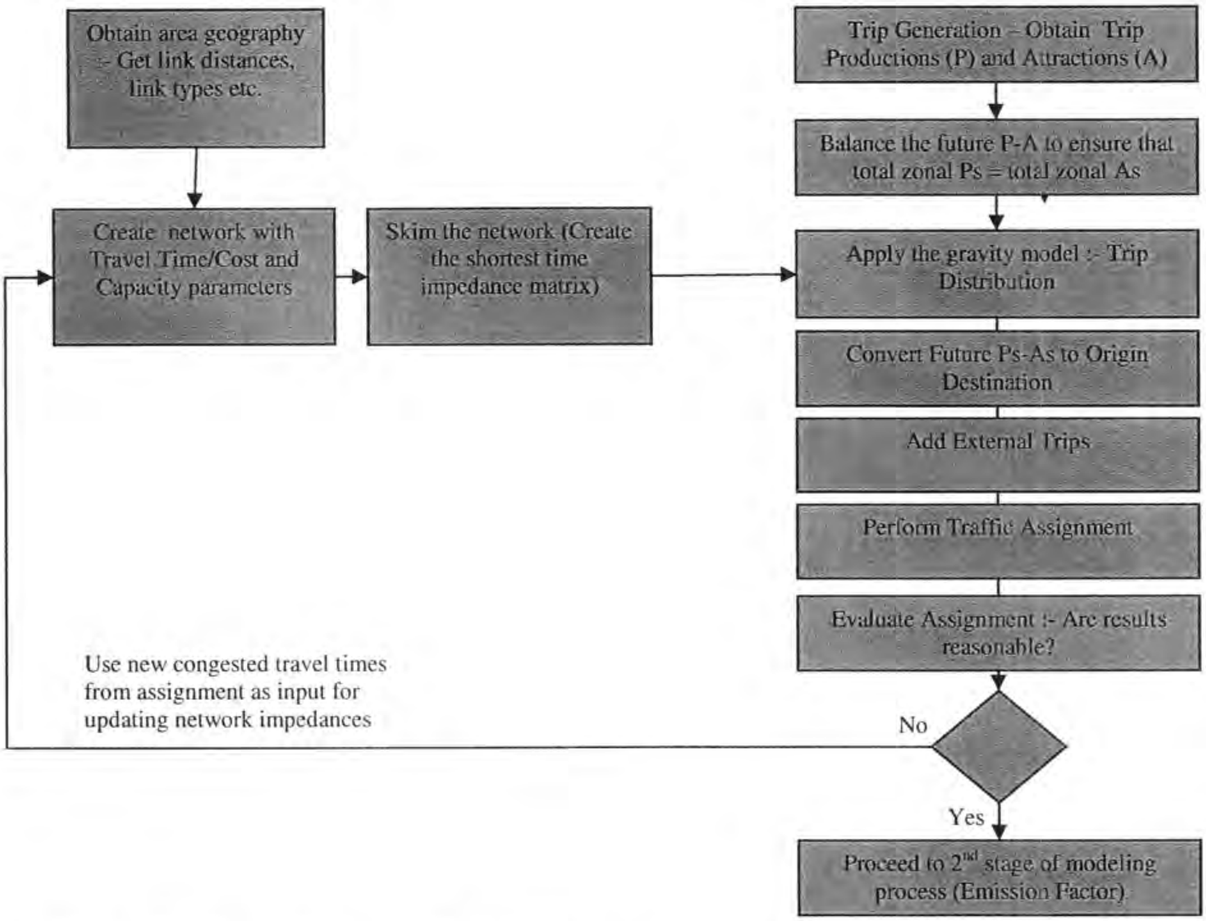

Figure 2.1 Travel Demand Modeling Process

Traffic Analysis Zones are discrete geographic entities within the modeled region that are set up such that their attributes are as homogenous as possible. Hence, geographic areas with large variations in household population, businesses etc. will need more TAZs than would be the case otherwise. The TAZ boundaries can be determined from existing census boundaries or they can be specifically developed from the known land-use, socioeconomic and transportation characteristics of the area. TAZs are the basic unit in travel demand modeling and represent the areas of trip productions and attractions. It is important that the network detail matches the detail of the defined zones. If zones are small, it implies that the network should be detailed enough to represent connections between such zones. This may necessitate using collector streets and some local streets in the model on occasion.

Trip Generation

The purpose of trip generation is to determine the trip making capacity for the area. This capacity is affected by variables such as the affluence of the inhabitants of the region; the number of inhabitants; the number of commercial and industrial establishments in the area; and the presence of extraordinary establishments such as airports, universities, military bases and sporting stadiums (special generators). Trip Generation can be divided into two distinct segments known as trip productions and trip attractions. Trip producers are the sources of trips while trip attractors are the recipients of the trips. Each trip that takes place involves both this source and recipient and is referred to as a trip generation. Trips are further divided according to source of production and purpose. Examples include HBW (Home Based Work), HBO (Home Based Other) and NHB (Non Home Based) trips. There can also be truck trips, taxi trips and other miscellaneous specific trip types depending on the modeling scenario present.

There are several methods used to calculate the total trip generation of a model. The most commonly utilized are activity unit rates such as the ITE trip generation rates, regression methods and cross-classification. In regression methods that are often used to calculate trip attractions, the trip rates are determined by applying the input socioeconomic and other variables to a regression equation. This equation is believed to represent an accurate algebraic relationship between the trip rate and the variables used as inputs. The regression equation can be locally developed for the area under study if specific local information is available. In the absence of such information, it is necessary to use generalized rates found for example in NCHRP 365 (National Cooperative Highway Research Program) table 7 (10) or the ITE trip generation handbook. An example of a regression equation is as follows:

HBW Attraction = 1.45 * Total Employment in analysis area. (NCHRP 365 table 7)

Cross-Classification involves grouping the input factors into specific categories each with a corresponding trip rate. This rate represents the rate that has been observed for similar groups in other areas. As with regression, specific rates or general rates from NCHRP 365 and the ITE handbook can be utilized. Cross-classification is most commonly used to obtain trip productions, particularly for home based trips. It is seen as more reliable than the regression methods but requires more detailed information to obtain trip rates for each category.

After the trip productions and attractions are determined and balanced (made to be equal to correct differences between trip production and attraction results), trip distribution is then performed.

Trip Distribution

As opposed to trip generation where the task is to determine the number of trips produced or attracted in the study area, the aim of trip distribution is to predict the destination of the generated trips. This is critical to determine the likelihood of a particular link being used during the assignment phase and thus the number of trips on each link. In trip distribution, a matrix is created of the number of generated trips from a specific TAZ and attracted to another TAZ. An example of such a matrix is illustrated.

Matrix6 - Union Combine (QuickSum)

	1	2	3	4	5	6	7	8	9	
1	198.60	191.16	47.97	107.17	82.60	41.44	55.22	138.70	73.11	91
2	191.16	186.32	47.85	103.62	80.29	42.47	54.95	133.98	74.52	88
3	47.97	47.85	12.77	25.84	15.27	11.57	14.14	33.44	26.14	50
4	107.17	103.62	25.84	56.36	44.75	21.78	28.31	28.03	38.94	44
5	82.60	80.29	15.27	44.75	34.72	18.13	9.63	21.72	31.97	21
6	41.44	42.47	11.57	21.78	18.13	10.60	12.16	28.15	23.59	16
7	55.22	54.95	14.14	28.31	9.63	12.16	14.61	36.60	22.20	48
8	138.70	133.98	33.44	28.03	21.72	28.15	36.60	94.32	70.79	140
9	73.11	74.52	26.14	38.94	31.97	23.59	22.20	70.79	2855.16	78
10	91.56	88.87	50.88	44.69	21.72	16.51	48.33	140.51	78.36	161
11	18.01	17.52	6.78	8.39	7.01	3.07	5.99	18.19	25.75	39
12	31.43	32.72	10.72	14.83	9.55	4.91	7.25	24.87	46.84	37
13	48.33	47.55	30.46	13.97	11.29	10.19	13.26	32.91	52.51	123
14	1.39	1.58	0.61	0.65	0.47	0.42	0.54	1.30	3.33	2
15	106.45	103.69	10.89	51.41	18.80	8.51	18.31	28.25	28.61	18
16	45.15	44.13	6.30	24.45	10.29	5.80	7.50	17.34	27.03	18
17	143.64	139.22	14.90	59.04	25.60	11.46	31.32	38.88	38.69	42
18	37.97	38.58	5.94	19.82	10.44	5.29	10.84	16.07	34.96	15
19	170.77	154.16	22.40	45.56	40.67	15.89	32.33	59.18	76.17	54
20	110.73	106.13	14.41	29.54	26.43	10.06	20.51	38.35	50.72	34
21	133.28	127.80	30.31	65.32	30.91	13.37	29.51	84.73	88.02	58
22	145.49	139.37	32.21	67.44	26.46	22.58	28.01	87.31	54.62	82

Figure 2.2 TransCAD Matrix Example

The column and row numbers are TAZs whereas the matrix values represent the number of trips between the TAZs. The row totals represent the total productions from a zone whereas the column totals represent the total attractions to the zone. In trip distribution, two techniques are commonly utilized. They are growth factor methods and the gravity method. Of the two, the gravity method is the more popular.

Growth Factor method

In the growth factor method, the procedure involves the application of a scaling factor to an existing Production-Attraction matrix file that represents the current travel conditions of the study area. This factor represents the amount by which the traffic is expected to increase in the studied time frame. There are three major types of growth factor methods, each differing in the manner in which the factor is applied. They are as follows:

- The Uniform Growth Factor method
- The Singly Constrained Growth Factor method
- The Doubly Constrained Growth Factor method (Fratar)

In the uniform growth factor method, the assumption is that the entire area grows by the same rate and thus the original P-A matrix is multiplied throughout by the factor. It is the simplest of the growth factor methods to be implemented but requires the unrealistic assumption that the all segments of the modeled area grow by the same value.

In the singly constrained method, a different growth rate can be applied to either the forecast productions or attractions for each zone. This allows the use of specific knowledge on the manner in which the zones are expected to grow to be utilized in the model. The singly constrained growth factor method (production) is represented by the following equation. (11)

Source: Travel Demand Modeling with TransCAD 4.0 page 73.

$T_{ij} = \left[\frac{P_i}{\sum_z t_{i_z}} \right] \cdot t_{ij}$ It must be noted that $\left[\frac{P_i}{\sum_z t_{i_z}} \right]$ represents the production growth factor where: T_{ij} =forecasted flow from zone i to zone j

P_i = forecast productions for zone i

t_{ij} = the original flow from zone i to zone j.

In the Fratar method, both the productions and attractions are used to update the original matrix as opposed to the singly constrained model where either the productions or the attractions are used. In this case, an iterative procedure is used to balance the resulting zonal productions and attractions after application of the growth factors. The Fratar method is commonly used to distribute external trips in models owing to lack of information on external trip productions/ attractions. This renders use of the alternative gravity technique in external trip distribution inapplicable. The corresponding equation for this technique is as follows:

$T_{ij} = t_{ij} * a_i * b_j$.

Source: Travel Demand Modeling with TransCAD 4.0 page 76.

The Gravity Model

This method of performing trip distribution is the most popular. It accounts for the impedance between the TAZ's in the model. The impedance can be the travel time between zones, the cost of travel between zones or combinations of the two. The gravity model is similar in principle to Newton's law of gravitation where it is assumed that the P-A activity will be proportional to zone size and the impact of such P-As will diminish with increased distance/travel time or cost between zones. It can be expressed by the relationship (10):

$$T_{ij} = P_i \cdot \frac{A_j . f(d_{ij})}{\sum_z P_z \cdot f(d_{zj})} \text{ if constrained to productions}$$

Or

$$T_{ij} = A_j \cdot \frac{A_j . f(d_{ij})}{\sum_z P_z \cdot f(d_{zj})} \text{ if constrained to attractions}$$

where: T_{ij} = the forecasted flow produced by zone i and attracted to zone j.

P_i = the forecasted number of trips produced by zone i.

A_j = the forecasted number of trips attracted to zone j.

d_{ij} = the impedance between zone i and zone j (time, cost or both).

$f(d_{ij})$ = the friction factor between zone i and zone j.

The friction factor represents a weight that is put on the time/distance (impedance) between the zones. Closer distances/shorter times are usually given higher weights. By this method, it becomes possible to accurately describe the travel behavior for the modeled area. If local knowledge indicates that a higher proportion of trips in the area are of short distance, the friction factor weightings can be adjusted to represent that reality. Friction factors are among the three input factors that are varied during the sensitivity analysis performed in this research.

Mode Split

In the mode split phase, the proportions of trips by auto, transit, bicycle, pedestrian etc. is determined. The most commonly utilized methods include multinomial logit models that generate the probability that a person will use a particular mode in the total set of modes available by comparing the utility of each mode. The utility of a mode refers to the ease of use of that particular mode with respect to travel time, cost or both. The comparisons can be made at either the aggregate or disaggregate (individual decision maker) levels. Another method is the incremental logit method that compares one mode choice to an existing situation and is used often to study the impacts of improvements to a particular mode choice.

Traffic Assignment

The final stage of the travel demand modeling section, traffic assignment places origin/destination trips from the trip distribution/ mode split phase onto the actual network links. Several techniques are utilized including the following:

1. All or Nothing
2. Capacity Restraint
3. User Equilibrium
4. Stochastic
5. Stochastic User Equilibrium

6. Incremental

In the All or Nothing approach, the traffic flows between origin-destination pairs are assigned on the shortest network paths connecting the origin and destination. It assumes that only a single path is used despite the existence of alternative paths. It also does not handle the potential delaying effect of increased volume/capacity ratios.

The Capacity Restraint approach is an attempt to account for the volume/capacity delay effect by recalculating the link travel times in an iterative process. This process has the tendency however to bounce back and forth with the loadings on some high volume links. This renders the results unreliable and hence other volume delay assignment techniques have superseded Capacity Restraint.

In the User Equilibrium technique, a mathematical relationship is set up where no traveler can benefit from improved travel times by shifting routes. A volume-delay relationship similar to that for the Capacity Restraint technique is used to adjust link travel times. If a certain proportion of travelers shift routes, the travel times may be adjusted such that the route is no longer an attractive alternative.

In the Incremental Assignment technique, volumes are progressively loaded onto the network in steps. The actual assignment is based on the All or Nothing technique but the difference is that only a fraction of the total volume is assigned in each step, after which new volume-delay travel times are calculated. After each step, the assigned volumes are progressively reduced until all the volumes are assigned. In many instances, particularly when numerous steps are used, the output resembles that of Equilibrium Assignment mentioned earlier.

In Stochastic Assignment, a logit model is used to determine the probability that a particular reasonable path will be utilized. This probability is calculated based on the travel time and cost of using a particular path. Paths that are circuitous are not usually considered reasonable. Stochastic Assignment attempts to overcome the unrealistic assumption of the All or Nothing technique of only one possible path being used.

In Stochastic User Equilibrium, an attempt is made to combine the logit techniques in pure Stochastic assignment with the User Equilibrium technique. It was developed in an attempt to model the fact that travelers do not have perfect travel cost information that is an implicit assumption in the pure User Equilibrium approach. Thus, under Stochastic User Equilibrium, even very unattractive routes will have some volume assigned compared with the pure UE approach. This for instance might capture a scenario where a driver prefers a longer route that bypasses a toll way despite the toll way path being much shorter. In such a scenario under normal UE, such a route might not be predicted to be used at all because of the extra travel time.

DATA NEEDS

Before any modeling can proceed, a large quantity of data must be collected and tested for validity. Such data includes the travel network of the modeled area, the projected population of the area, projected land-use, projected economic conditions and other data.

Accurate regional population and economic forecasts are vital for modeling given the fact that the resulting travel activity is directly related to such factors. Such information is obtained from custom run population and econometric growth models or publicly available data from metropolitan, regional, state or federal sources. Demographic models, Input-Output models, regional simulation models for demographic and economic change and detailed studies of particular industries, population groups etc. are likely sources of such data. Techniques used to predict growth can also be estimated by simply extrapolating past trends though this technique carries some risk. Careful studies of the modeled area would need to be undertaken to determine whether extrapolation is appropriate.

After the broad regional level population and employment estimates have been obtained, it is necessary to allocate the estimates by zone in the region. There are two main techniques for allocating totals by zone. (12) In the negotiated estimates technique, the preparer's judgment and desires based on political realities is used when apportioning the estimates. This technique is used to some extent in almost all jurisdictions at present. In this technique, local plans and projections are the primary guide. Allocations can be either by an initially agreed across the board percentage between jurisdictions or the allocations can be via negotiations between local jurisdictions. In the mathematical model approach, formal relationships between economic factors are defined and used to determine how estimates are apportioned. This technique ignores political realities and institutional constraints in favor of a strong market force approach. The mathematical model approach is not very popular at present owing to being perceived as inaccurate. It is used in a minority of jurisdictions. (12)

Another important data input for travel models is the rate of vehicle ownership. Vehicle ownership models have been developed that take into account the income, household size, number of licensed drivers, gender, labor force participation, housing type, accessibility to transit and other variables to estimate number of vehicles per household. These data are usually applied at the zonal level. From a cursory analysis of some of the variables mentioned, it is clear that some are statistically correlated thus necessitating care in model estimation and analysis.

Data Collection Methods for Models

In any transportation modeling process, the first step involves collection of the necessary travel and socioeconomic data. Several methods are used including U.S Census Bureau information and travel surveys. In particular, the Summary Tape File 3 and the PUMS (Public Use Microdata) samples provide detailed information on many household and individual characteristics of relevance to transportation planning.

Several types of surveys are commonly carried out to gather information for the estimation and calibration of travel models. They include household travel surveys, commercial vehicle surveys, transit rider surveys and external cordon station surveys. (13) In recent years, there has been more activity with workplace surveys that are better able to provide data for calibration with regards to the trip attraction stage of modeling. Such data can be hard to capture in a traditional household survey but are nonetheless important for overall model calibration.

In the common household travel surveys, information is obtained on the trip activity of individual household members. Several techniques can be applied to obtain such information such as telephone interviews and mailed surveys. In both cases, the data collection costs can be high. Consequently, in recent years there has been a tendency for surveys to get smaller with sample sizes in the range of 1,500 to 2,500 households. Large surveys are now only conducted in the largest of cities such as New York, Los Angeles and Minneapolis where surveys upwards of 10,000 households have been undertaken on occasion. Recently, it has been suggested that instead of focusing on household trips, it is more appropriate to study household activities. This focus, it is thought will lead to a more accurate recording of the trips made because individuals easily forget trips made, especially short trips. In contrast, activities tend to be well remembered and can then be used to deduce the trips made to link the activities. Increased accuracy will then directly translate into a more useful travel model particularly where it is being used for emissions estimation..

In transit on-board surveys, passengers on transit vehicles are surveyed primarily by using short questionnaires to be completed by the rider. Other experimental techniques include data collection by the use of laptop computers. In many cases, the results of transit surveys have been combined with household results to enable greater calibration accuracy particular in the case of small sample household surveys.

External station surveys attempt to capture information on trips that either do not originate or terminate in the modeled area. This information is very valuable for a model given that in some areas external trips can be a significant percentage of the total trips traveling through the region. In external station surveying as with other surveying, several techniques can be used to gather the information. In roadside interviews, vehicles are stopped at the external station and drivers are interviewed. This method has the potential to quickly provide reliable data and high response rates. The main disadvantages are the potential for traffic delays and disruption and the need for coordination with many organizations, primarily law enforcement. Other data collection methods include postcard handout/mailback surveys and license plate recording mailing surveys. These rely on the driver eventually completing the survey at home and mailing in the results. The difference between them is the manner in which the driver receives the survey material. For the postcard handout method, the surveyor simply gives the driver the survey material whereas for the license plate recording method, the license plate is used to match against vehicle registrations and mailing the surveys to vehicle owners. In these methods, the response rate is lower than for roadside interviews and there is also an issue of privacy in the case of the license plate method.

Other survey types normally used to gather data for travel modeling include commercial vehicle surveys, stated preference surveys and longitudinal surveys. These surveys are more difficult to implement than the surveys previously mentioned such as transit rider and household surveys and thus are not as widely utilized. There have been attempts such as in the Puget Sound area of Washington State to carry out longitudinal surveys where a select sample of households is surveyed over time to determine the changes in travel behavior as changes in transportation supply and socioeconomic conditions occur. As is the case for all survey types, there are benefits and drawbacks with a major problem being attrition bias. In this phenomenon, the number of respondents participating at later stages in the survey program is less than at the start owing to program dropouts during the course of the survey. This tendency will introduce an inherent bias into model estimation by focusing on only the respondents who are inclined to see the survey through to the end. It is important that this phenomenon is recognized and corrected in model estimation.

DYNAMIC FEEDBACK LOOPING

A major recognized flaw of the conventional travel demand modeling process involves the sequential nature of the various stages. This leads to a situation where for instance, the travel times used to skim the network initially cannot account for the volume delay effects because that information is not available until the traffic assignment phase of the modeling. One attempt to counter this problem has been the use of feedback loops where the volume dependent travel times from traffic assignment are used to repeatedly skim the network; perform new trip distribution with the newly skimmed network values; and finally to redo mode split and traffic assignment. This iterative process is done until there is either convergence in the results or stopped after a fixed number of iterations.

Despite the use of feedback looping, there are still major flaws. It has been suggested in a paper "Towards Consistent Travel Demand Estimation in Transportation Planning: A Guide to the Theory and Practice of Equilibrium Travel Demand Modeling" (14) that feedback looping does not guarantee convergence to a consistent answer. Instead, answers bounce around from one value to another thus not giving any meaningful result. The paper goes on to suggest that a better approach is to use Equilibrium travel demand models. In these models, in addition to the traffic assignment stage, the other three stages also follow an equilibrium technique similar to that for User Equilibrium assignment where no traveler can benefit by shifting paths. Complex heuristic techniques are used to predict trip making behavior in these models.

If for instance network wide traffic congestion levels are very high, there may be the tendency for fewer trips to be generated. These trips are postponed, canceled or replaced by teleconferencing etc. In a situation where congestion on specific links is a problem, the tendency is for trips to be diverted to more accessible areas. In this instance, the results of the trip distribution process will be altered. For the mode split example, if the travel costs on the highway mode increases, there is the potential that some trips will be diverted to transit, ride sharing etc. Complex heuristic procedures again automatically attempt to reestablish equilibrium.

It is thought that equilibrium travel demand models, despite added computational complexity are worth the effort. It overcomes one of the major flaws in the 4-step approach by generating consistent, reliable estimates and it integrates aggregate travel demands with discrete-choice theory in a consistent manner. It is also the first step to dynamic modeling as attempted in activity based disaggregate models such as TRANSIMS®.

CALIBRATION AND VALIDATION OF TRAVEL DEMAND MODELS

Upon reviewing the available literature, it became apparent that among the primary issues to be tackled in the modeling process being pursued is the actual usefulness of the output from the travel demand model. It is of vital importance to calibrate the travel demand model as much as possible to represent real-world conditions particularly since emission rates are highly dependent on volume and speed estimates.

Calibration involves use of model inputs to determine model estimates. Following accurate calibration, it then becomes necessary to check the reasonableness of the model results by comparing to predicted outputs to actual outputs and subsequently fine-tuning model variables until results with an acceptable range of error are obtained. This step is referred to as Model Validation and Reasonableness.

Issues in Model Calibration

Calibration refers to the task of modifying model input parameters until the output is similar to observed travel behavior. (15) This means that the results of the distribution process, Origin-Destination matrixes are consistent with real trip Origin-Destination values. On the emissions end, it is important that the correct vehicle operating mode classification, VMT distribution, trip purpose, ambient temperature etc. are selected. These variables have an important impact on the actual emissions output necessitating great care in their selection and use.

The main parameters adjusted in calibration of travel demand models are

(i) Friction factors: - They determine how trips will be distributed and it is very important to get factors that accurately describe the distribution of trips by trip purpose. For example, changing the friction factor curves can adjust the average length of trips either upwards or downwards and significantly change the trip distribution results. It must be noted that the friction factors for different trip purposes will be different thus each trip purpose will have to be separately calibrated.

(ii) Network parameters: - Parameters such as number of links, direction of flow on the links, speed of the links, intrazonal travel times, turn restrictions and number and placement of centroid connections from the link-node network to zone centroids need to be accurately described. Results will be of little use, for instance if a link that is in reality one-way flow is coded as having flow in the opposite direction. Incorrectly defined link speeds can also affect the results of trip distribution, as impedance values will be inaccurate.

(iii) Trip generation parameters such as socioeconomic variables like average household size, CPI (Consumer Price Index), average auto occupancy in the modeled area, household income and others need to be carefully evaluated to ensure that they are up to date and relevant. Special Generators need to be applied as appropriate to describe unconventional trip patterns.

(iv) The impact of truck trips, external trips and other non-standard trip types needs to be carefully observed and integrated into the model.

For the assignment phase, it is important to account for the impact of volumes on trip times. If the area being studied does not have high volumes, simple assignment procedures such as the All or Nothing can produce acceptable results, otherwise a technique with volume delay attributes like Equilibrium Assignment will be necessary. It should be noted that in conventional practice, the most common assignment technique is the Equilibrium technique.

Issues in Model Validation and Reasonableness

Ideally, after each stage in the Travel Demand Modeling process, the output should be checked for validity and reasonableness. This minimizes the scale of the errors that inevitably propagate as the various stages in the TDM model are executed. Two main types of validation tests include Reasonableness tests and Sensitivity tests. (16) The first category of tests can include Absolute and Relative difference tests, Statistical correlation tests and variance tests such as RMSE (Root Mean Square Error). The sensitivity tests check the model behavior when inputs are varied.

Model Inputs and Trip generation

In this phase, it is necessary to check that the socioeconomic and land use data actually being used for the model is accurate. Items to check for include population densities, workers per household, vehicles per household among others. Transportation network entities also need to be checked for such things as correct link alignments etc. In other words, verification that the link and node network present in the model represents the real transportation network for the study area is required.

Trip Distribution

The main validation check in trip distribution is the check for correct travel impedances (i.e. Are the distances, speeds and consequent travel times in the network representative of actual values. Statistical tests that compare distributions (coincidence ratios) are used for to determine for example if observed and average trip lengths are significantly different. This can quickly highlight problems that are occurring in the distribution phase with the usual result being an adjustment of friction factors assuming the trip generation phase validation errors were acceptable.

Mode Choice and Auto Occupancy

Typically, this validation usually involves sensitivity tests with known data from other regions for determination of appropriate model coefficients. For the auto occupancy rates, comparisons with either generic socioeconomic or known local data using absolute difference tests would suffice.

Traffic Assignment

The main validation for this step involves comparing model outputs with observed counts. The main test is a t-test to compare differences in means. Issues of relevance in validation of traffic assignment include the type of link; i.e. whether it is major, medium or minimal in terms of average daily traffic. Major links by necessity should have lower values for error given that the consequences for forecast errors on such links will be greater (greater cost to add lanes, change geometry, traffic signaling etc.). Tables of acceptable error ranges are usually referred to following this stage. A growing trend and also recommended practice involves using feedback loops to alter the impedance inputs to the trip distribution phase giving for example more realistic travel times. This in turn should produce more realistic assignment results.

SUGGESTIONS FOR IMPROVED MODELING PRACTICE

It has been recognized in a number of recent research papers and manuals such as the "Manual of Regional Transportation Modeling Practice for Air Quality Analysis" (12) that most models have endured significant underinvestment for over 20 years. It is felt that for present models to be more relevant and useful, existing gaps in input data such as detailed land use and employment data; transit ridership patterns; up to date demographic information etc. need to be corrected. Another major concern is the dearth of knowledge of trip timing and trip chaining which in recent years has seen significant increases. Trip chaining is described as the combination of several trips into one such as making a trip to perform several errands. An example includes the trip home from work that includes stops at the grocery store, child pick up from school and other miscellaneous stops. Trip chaining is not handled very well in present models because of the need to stratify trips into rigid purposes. Chained trips can have major implications for emissions output given that in many instances they are short thus necessitating more frequent engine starts.

Other issues mentioned in the manual include the ability of present regional models to represent pedestrian, bicycle and other urban design transportation control measures. It has been suggested that land use impacts of transportation investments be determined and the models adjusted accordingly if such impacts are indeed found to be significant.

Given these and other shortfalls, the manual suggests some areas that should be given priority for improvements. They include the following items:

- Accurate up to date travel surveys including household surveys, transit surveys etc. are vital to ensure that the best available information is used to develop model estimates. In addition to the standard information such as household income, size and auto availability, other key variables to be garnered include number of school aged children, number of workers, transit accessibility and type of housing unit. These additional variables have a key influence on the trip production rate of the household, particularly by trip type. (12)
- Accurate VMT information is required. This will necessitate increased traffic counts. It is also important pursue accurate speed monitoring which will be of great importance in air quality estimation. (12)
- It has been suggested that more trip purposes should be used. This will allow a better representation of the more complex trip patterns commonly observed in contemporary trip making. Examples include school trips, shopping trips, sporting event trips, miscellaneous errand trips etc. Trip chaining will be better represented under this scenario. (12)
- It is important to have as detailed a highway network as practicable representing all roadways carrying significant interzonal traffic. Networks of 2,000 or more links have been feasible for the last decade owing to increased computer processing power. As processor power increases in the future, maximum advantage should be taken to improve model detail.
- For modeling bicycle, pedestrian and other non-motorized trips, calculations should be performed separate from the model by hand if necessary and the results integrated at a later stage. While not the perfect solution, it is nonetheless a better strategy than to completely ignore such modes if they represent significant modal shares. (12)
- More realistic assumptions are needed. For instance, the assumption in many current models that vehicle speeds do not exceed the legal speed limit is not acceptable. This introduces inaccuracies in the travel forecasts and consequent emissions estimates. (12) For freeways, such assumptions could have a negative impact on emissions estimates whereas for arterials, the converse may be true.

- It has been suggested that transportation control measure TCM effectiveness can be used to improve analysis capabilities. For instance, TCM effectiveness found from before and after studies could be used to determine if calibrated model parameters are actually representative.
- Finally, present models are acknowledged to have poor documentation. (12) This makes it difficult for model improvements to be implemented. In addition, lack of sufficient documentation makes it very difficult for trends monitoring and repeat analysis. It is thus suggested that documentation be improved particularly on documentation describing how the model functions. Over the long run, it is thought that extensive documentation will actually lead to reduced expenditures and more easily improved models that are able to respond to fast changing inputs.

ALTERNATIVE MODELING APPROACHES

In recent years, there have been attempts to employ a completely different process for travel model/emissions estimation. One such approach has been the use of activity based travel models combined with emissions models that have modal characteristics. Known as TRANSIMS (Transportation Analysis SIMulation System), this approach contains significant differences from the traditional travel demand/emissions factor model approach.

TRANSIMS is an integrated system of travel forecasting models designed to give transportation planners accurate, complete information on traffic impacts, congestion, and pollution (17). It differs from the traditional approach by attempting to model the individual traveler in the system as opposed to an aggregation of behaviors of travelers in a zone (TAZ). It is hoped that modeling on the disaggregate level will provide more accurate results given the ability to explicitly model individual traveler characteristics, activities and their interactions with the transportation system.

As opposed to the four-step process combined with vehicle activity estimates in the traditional process, TRANSIMS consists of a Framework that includes several sub modules as follows:

- Population Synthesizer
- Activity Generator
- Route Planner

- Traffic Microsimulator
- Selector/Iteration Database
- Emissions Estimator
- Output Visualizer

The Population Synthesizer module is used to generate a virtual population of all the individuals in the region under study. Data sources, as in the case of the traditional modeling approach include U.S Census Bureau population information, population projection information and geographic correspondence engines to link the related population geographically. A series of algorithms is performed to convert the census information to discrete individual travelers in the model.

Once each population member has been generated, the Activity Generator is used to compile a list of activities that such members will partake in. The demographics of the population will be used to determine the types of activities selected. For each activity, its type, time frame, preferred transportation mode, location and other possible participants are noted. Survey data from actual households is used to estimate likely activities in the model. Once the attributes for each activity is accurately captured, it then becomes possible to model trips by mode, length etc. Information such as travel time from the Route Planner and Traffic Microsimulator is fed back to this stage and used to help determine activity locations.

The Route Planner is then used after travel activities have triggered trip requests to determine the actual travel routes for each traveler in the model. Trip requests consist of an origin and destination, the time frame in which the trip is to be completed and the mode choice to be used for the trip. The trip request information along with the TRANSIMS network information, traveler information etc. is then used to determine a shortest path route similar to that of network skimming in the traditional TDM process. This shortest path is time dependent and thus could be negatively affected by delays. To accommodate such a situation, a mechanism for feedback from the Traffic Microsimulator is available.

The Traffic Microsimulator attempts to simulate the movements of all the individual travelers in the system including the effects of their interactions. The main input is the trip plan produced by the Route Planner for each traveler. Detailed algorithms are used to simulate the interactions between each traveler and the modes they utilize. The Traffic Microsimulator allows for the modeling of walking stages in addition to transit and car stages thus representing a big improvement over the traditional process. The output from the Traffic

Microsimulator consists of spatial and temporal summary data, traveler events and snapshot data that allows for traffic animation. (18)

The Selector/Iteration Databases module is used to implement the iterative feedback process that is critical to model accuracy. With this module, it is possible to use optimized travel times for instance in activity location. It is also possible to use this module to select particular types of travelers for detailed analysis or to direct the travelers to certain choices known to occur in the region. This module can thus be thought of as a way to tweak the overall model without having to redefine the entire model. (18)

The Emissions Estimator uses information from the Population Synthesizer regarding vehicle population and the output from the Traffic Microsimulator to generate emissions estimates. The vehicle type, speed, age and operating mode and other data similar to that used in the Emissions Factor stage of traditional modeling is used. With the travel output from TRANSIMS at a disaggregate level, it is possible to determine vehicle operating mode, speed, age etc. far more precisely thus leading hopefully to more accurate emissions estimates than is the case in the traditional process. (18)

Finally, the Output Visualizer enables various input and output data sets to be displayed. This facilitates easy analysis of the overall model and can be regarded as a model management tool. (18)

It is hoped that this new activity based disaggregate approach to transportation modeling will provide a significant improvement over the traditional process. Nevertheless, high data processing needs will for the foreseeable future limit application to only those metropolitan areas provided with sufficient resources. For instance, parallel computer processing using multiple computers and other expensive hardware is required to model a city of greater than 1 million at an individual level. The data input needs are also formidable thus necessitating costly detailed surveys.

CHAPTER 3. DESCRIPTION OF PILOT STUDY AREA

As stated in Chapter 2, high input data accuracy in travel modeling is desired. In addition, the models should be well calibrated and validated. The travel demand model inputs and calibrated parameters developed for the Quad Cities area of Davenport, Moline, Bettendorf and Rock Island in the states of Iowa and Illinois was selected for the pilot study area. This model incorporated dynamic distribution that theoretically should result in a better calibrated model. Additionally, the effect of dynamic distribution is among the major areas of research in this thesis, hence the Bi-State model served as a useful model on which to perform the research.

The Bi-State Regional Commission is an agency responsible for transportation planning in the Quad-Cities region of Iowa and Illinois. It is an organization of five Iowa and Illinois counties and 44 municipalities including the cities mentioned previously. This region is comprised of a population of approximately 300,000 located about midway between the midwestern cities of St. Louis, Minneapolis, Chicago and Des Moines. The Mississippi River bisects the region in a general Northeast to Southwest direction. Interstates 80, 74 and 280, each of which has a Mississippi River crossing, serve the area. The busiest crossing had a January 2001 ADT (Annual Daily Traffic) count of just over 70,000 vehicles while the freeways in the area carry between 15,000 and 40,000 vehicles per day. (19)

BI-STATE TRIP GENERATION DATA

Originally to develop the model, the Bi-State Commission in cooperation with the Iowa DOT used a program called PLANPAC. PLANPAC was a mainframe computer software package and was used before 1992 when an exponential increase in electronic processing power enabled personal computer based modeling applications. Further updates have been made to the original TAZs to reflect changes in socioeconomic conditions, land use and consequent urban travel activity.

Data such as the number of housing starts, population per square mile by TAZ, manufacturing, service and retail employment levels were used to estimate future trends. These trends were then converted using trip generation analysis to forecasted trip activity by TAZ. Population data were obtained in the 1998 base case from updated 1990 census block level data. Data including employment per residence, place of work, school enrollment and school age population obtained from census 1990 data; Iowa Department of Employment Services; and Illinois Department of Employment Security were used in trip generation. Population forecasts for the 2025 year were projected in a straight line fashion based on historical trends in the Quad Cities area. It is projected in the model that a net population increase of 19% will occur between the 1998 and 2025 years.

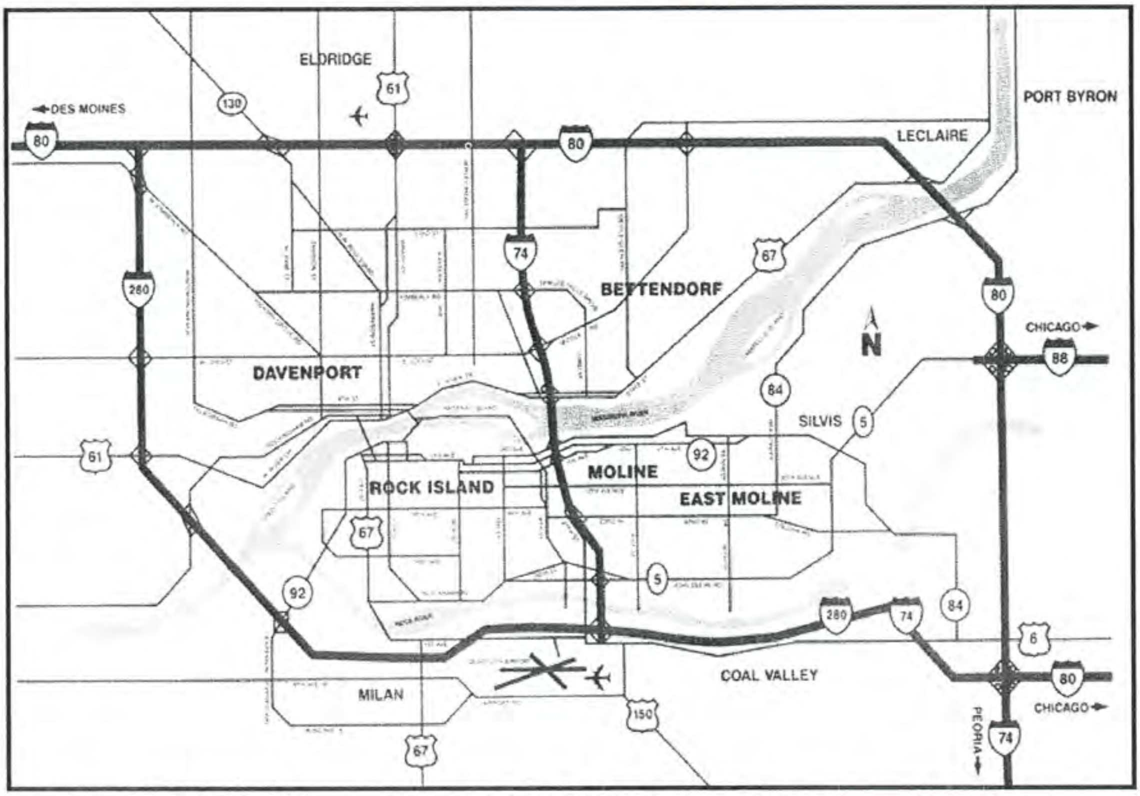

Figure 3.1 Basic Transportation Map of Study Area taken from Broadway Historic District Website. (36)

Employment forecasts were determined by calculating a ratio of employment per capita in each county for 1998 data. For the Iowa cities, the ratio was found to be 0.54 whereas the value for the Illinois cities was 0.51. These ratios were then extrapolated to the year 2025 using 2025 population values to obtain employment values.

Following the acquisition of population, employment, school data etc., the Bi-State Commission used initial trip rates from Des Moines MPO. Des Moines is regarded as possessing similar population and transportation infrastructure as the Quad Cities area.

Adjustments were then made to the resulting trip rates to accommodate the specific differences between the Quad Cities area and Des Moines. The rates were adjusted in accordance with the NCHRP Report 187 (Quick-Response Urban Travel Estimation Techniques and Transferable Parameters) parameters. The Cross-Classification trip generation technique was also used in the trip rate adjustment. Truck trips or Internal Commercial Vehicle trips were calculated using an equation utilized by the Des Moines MPO given that no specific truck data was available for the Quad Cities area.

BI-STATE TRIP DISTRIBUTION (FRICTION FACTORS)

Friction factors were developed from a travel time study performed in 1998. The study was performed primarily on major arterials in the Quad Cities at the request of city traffic engineers. Both the AM (morning) peak and the PM (evening) peak were included. Each trip type was individually calibrated to produce acceptable trip distribution results following an iterative process.

CHAPTER 4. CALIBRATING TRANSCAD MODEL WITH BISTATE TRANPLAN MODEL

Several tools are available to perform conventional travel demand analysis. Among the more popular are TRANPLAN®, TransCAD®, QRSII and MINUTP. Each tool tends to have different features and strengths. TRANPLAN® for instance is valued for its flexibility and power; QRSII for its user friendliness and TransCAD® for its tight integration of GIS functionality with traditional travel modeling functionality. For the purposes of this thesis research, the two tools of interest are TRANPLAN® and TransCAD®.

The original Bi-State travel model used for the pilot study was implemented using TRANPLAN®. TRANPLAN® is a command line FORTRAN based set of integrated programs for the transportation planning process. (20) As with all other travel demand modeling software, it allows all four stages of the four step process to be implemented. Output from TRANPLAN® is a text or binary output file representing the network with loaded volumes and travel times. Despite being an older travel demand modeling application, TRANPLAN® remains a widely used application. Compared to other travel demand modeling applications, it provides powerful and flexible travel demand modeling capabilities.

Although the Bi-State model was originally available in TRANPLAN® format, TRANSCAD® was selected as the platform to complete the 4-step model and sensitivity analysis since TRANSCAD® provides the best GIS functionality of all the tools used in conventional travel demand planning and was most familiar. TRANSCAD® is a GIS based travel demand forecasting software tool developed by Caliper Corp. in Massachusetts. Common functions such as polygon overlay analysis, buffers and geocoding are all notable GIS features. In addition, transportation specific functionality such as networks, transit route systems, matrices and linear referencing (identifying location of transportation features as distance from a fixed point along a route) are available. (21)

In order to use the TRANPLAN® model in TRANSCAD®, TRANPLAN® files were imported. Before the sensitivity analysis was conducted, it was necessary to ensure that the TransCAD® model was a reasonable approximation of the original Bi-State TRANPLAN model. To achieve this objective, the Bi-State model data was converted from the TRANPLAN® Fortran format to TransCAD® geographic files, matrices and DBASE IV files. A description of the conversion and validation process is presented in the following sections.

CONVERTING TRANPLAN FILES

The following files were obtained from the Bi-State Regional Commission and are described in the 1998 and 2025 Readme Microsoft Word files. Please refer to Appendix G.

- 1998attr.f98 Year 1998 Attraction file in Tranplan format;
- 1998prod.f98 Year 1998 Production file in Tranplan format;
- Eetab.98 Year 1998 Ext – Ext trip table;
- Ffr2.dat Friction factor file;
- Hnet1.f98 Year 1998 Base Network;
- Hrldxyi3.f98 Year 1998 initial network. This network is used to skim paths;
- Run98f.in Year 1998 Tranplan control file;
- Ttprep.tem Terminal time for all Traffic Analysis Zones;
- Turn.txt Year 2025 Turn penalty file.
- Ttprep.tem Terminal time for all Traffic Analysis Zones;
- 2025attr.f25 Year 2025 Attraction file in Tranplan format;
- 2025prod.f25 Year 2025 Production file in Tranplan format;
- Eetab.25 Year 2025 Ext – Ext trip table;
- Ffr2.dat Friction factor file;
- Hnet1.f25 Year 2025 Base Network. This includes year 2025 Transportation Projects;
- Hrldxyi3.f25 Year 2025 initial network. This network is used to skim paths;
- Run25f.in Year 2025 Tranplan control file;
- Turn.txt Year 2025 Turn penalty file;

The friction factor, turn penalty and production/attraction data files were converted to DBASE IV files by importing them into the Microsoft Excel spreadsheet program. Each file was then formatted to the requirements of TransCAD® modeling with the deletion of unnecessary columns and insertion of column heading for trip types, zones etc. The files were then converted to a DBASE file format that could be imported into TransCAD®.

The TRANPLAN® network files were first converted to a standard flat text file format via NETCARD. NETCARD is a DOS utility program that was used to export the binary network file (.f98) to a flat text file format readable by the TransCAD® import routine. Shown below is an example of the NETCARD commands used to create the text files.

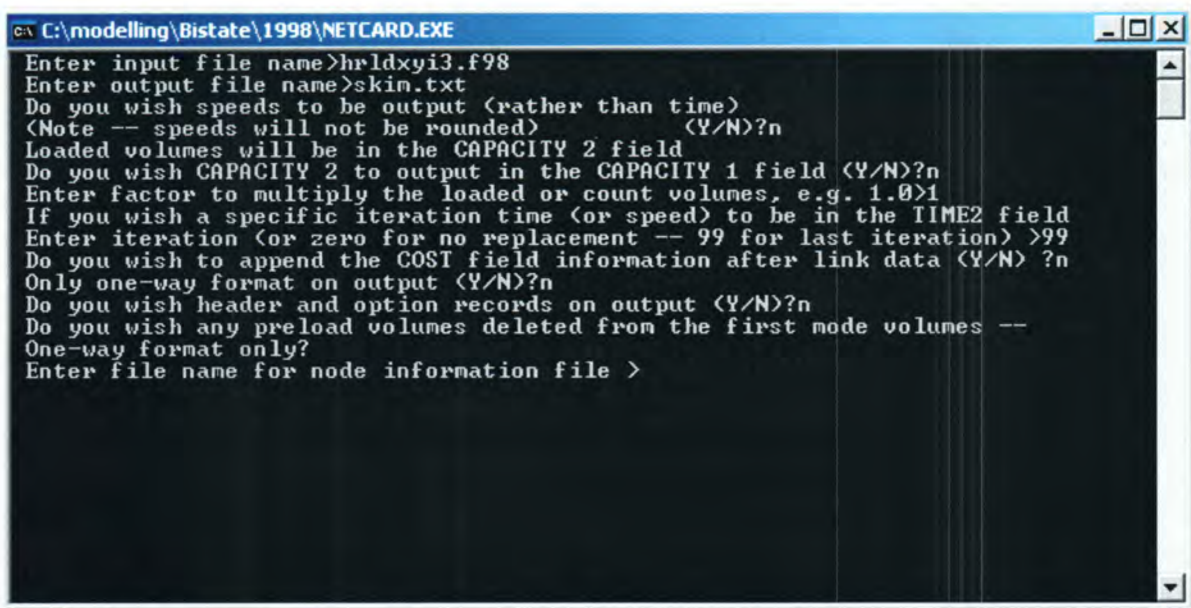

Figure 4.1 NETCARD DOS utility inputs

In this example, the input TRANPLAN® binary file is hrldxyi3.f98 which represents the 1998 Bi-State network file used to do the initial skim before feedback looping. The output file from this stage is a text file called skim.txt. The other inputs are responses to network specific issues such as whether one-way or two-way links should be utilized. The same procedure was followed for the base TRANPLAN® network file. (Hnet1.f98) This network file was used to perform the initial traffic assignment and then subsequently updated following feedback looping with the congested times.

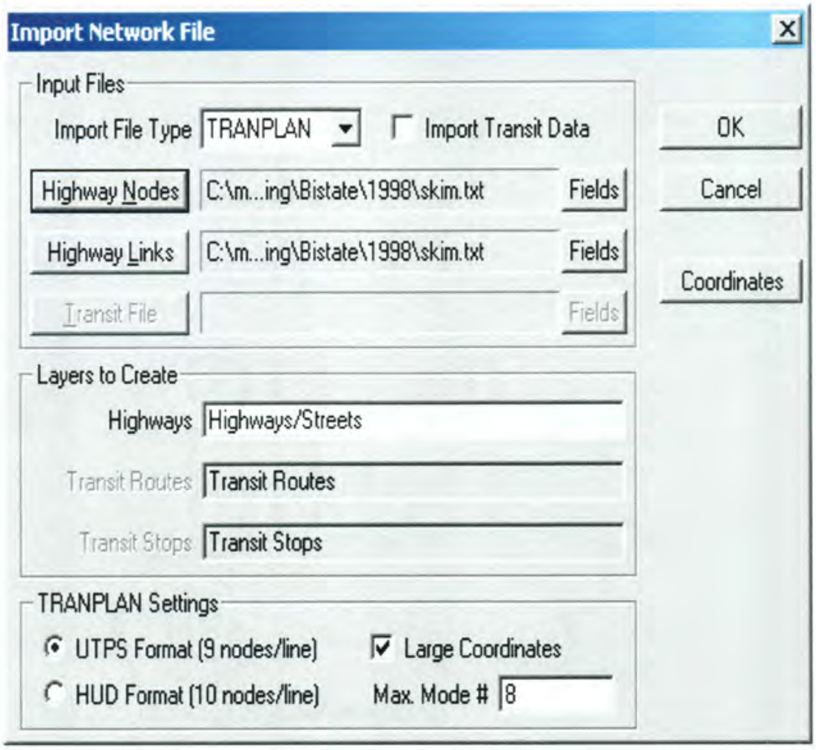

Figure 4.2 Network Import Dialog box

The above dialog was used to import the converted flat text files to TransCAD® node link network file format. In the Bi-State travel demand model, the first 444 nodes in the node file are considered the zone centroids. Figure 4.3 overleaf shows the zone centroids.

The conversion procedure for the turn penalty text file (Turn.txt) involved importing the file into TransCAD® in DBASE IV format. This turn penalty file identifies the intersections in the model where turns are prohibited. It was critical that the correct turn penalty information was associated with the link node network that was active. Failure to ensure that this situation was satisfied could result in incorrect impedance (travel time) values. This in turn could potentially lead to incorrect trip distributions and eventually wrong assigned link volumes. Prohibited turns could significantly increase trip times owing to the elimination of hitherto shorter paths and it is important that such scenarios are correctly represented. Following importation of the DBASE file, the "Convert Turn Penalties" TransCAD® utility was utilized to convert the node/node turn TRANPLAN® prohibitions to link/link turn prohibition format in TransCAD®. To verify the validity of the turn information, the turn penalty and shortest path tools were used to test the turn prohibitions.

Below is an example of the turn penalty conversion dialog. On the dialog, it indicates that the turn through node N3 from N2 to N4 is prohibited.

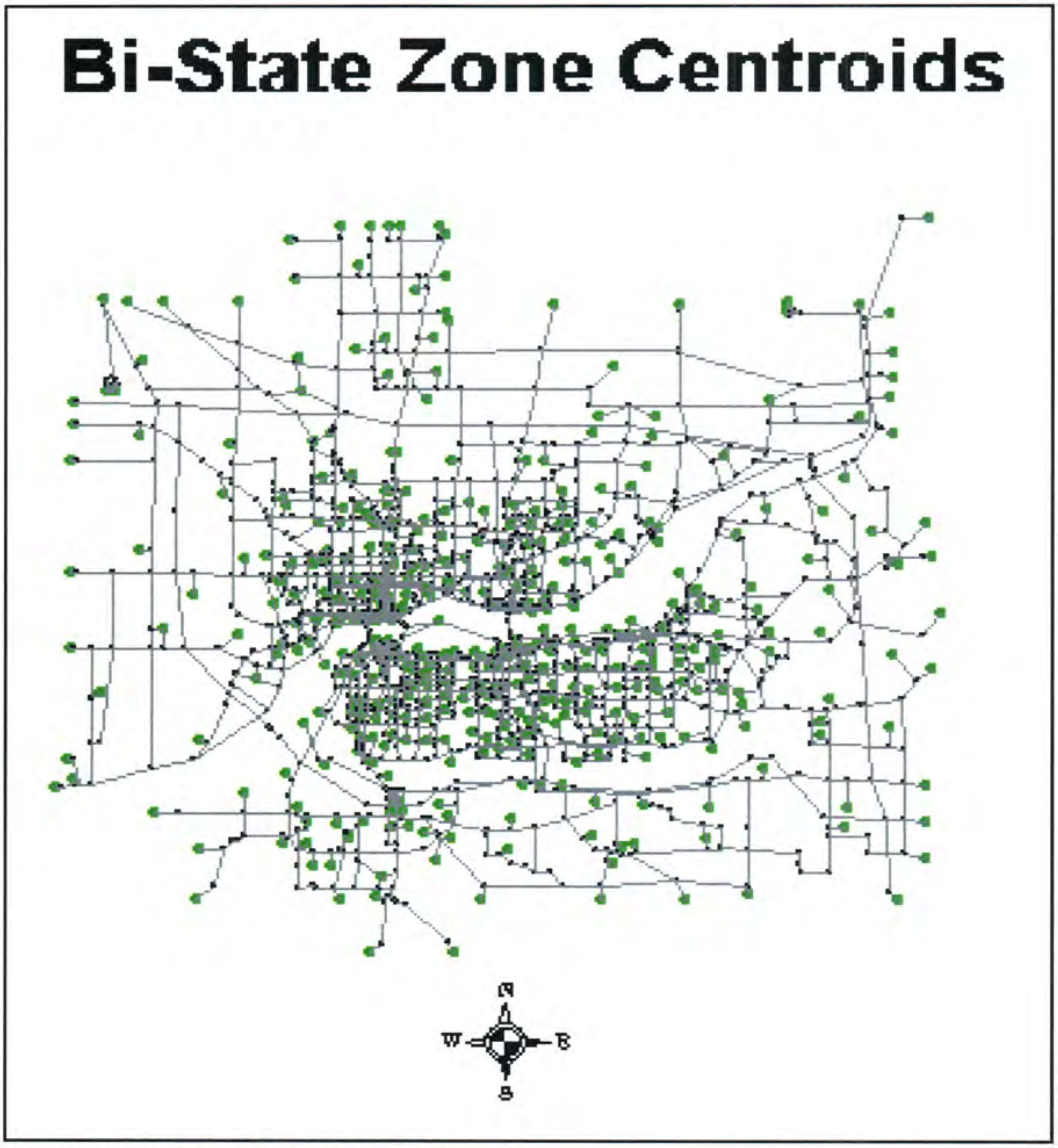

Figure 4.3 Bi-State Zone Centroids

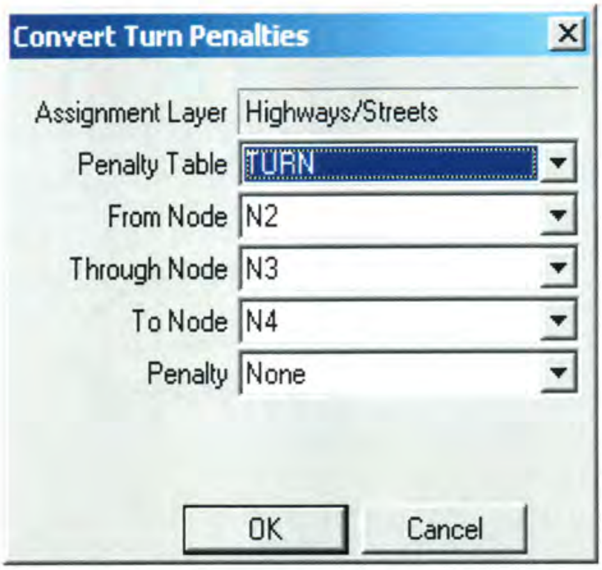

Figure 4.4 Convert Turn Penalties dialog box

Once the turn prohibitions were converted and assigned to the correct network, checks were made to verify that the penalties were indeed effective. The final data file to be converted was the external matrix. An external matrix is a representation of the trips between external cordon stations in the model. External cordon stations are similar to zone centroids and represent the traffic flow into and out of the area being modeled. Data is obtained at external stations by counting vehicles passing specific points in the transportation network. Owing to the fact that origin/destination information about external-external trips is not readily available, growth projections are usually done by using a growth factor applied to existing cordon counts. These methods are described in some detail on page 10 in the literature review. Conversion of the TRANPLAN® matrix eetab.98 required renaming the file to eetab.dat using operating system commands. This was necessary to enable TransCAD's TRANPLAN matrix import utility to recognize the file as a TRANPLAN® matrix. Following this, the file was imported using the utility.

FORMATTING THE CONVERTED INPUTS FOR TRANSCAD MODELING

The converted data required formatting before TransCAD® modeling could be performed. Formatting included the following:

- Combining the separate production and attraction data files into a single PA file. Redundant columns were removed and missing column headings added.

- The friction factor table required the removal of unnecessary columns and the addition of column headings for time and trip purposes.
- The imported network needed to have a time column added, the distance column needed accurate values and the capacity of centroid connectors needed to be changed from 0. Zero link capacity would preclude any trips being loaded onto the network.

THE FOUR STEP TRAVEL DEMAND PROCESS

TransCAD® allows the performance of the travel demand modeling process via a set of dialog boxes. The data obtained from the Bi-State Commission included the trip production/ attraction data and thus eliminated the need to perform trip generation using TransCAD®. It was however necessary to perform trip balancing. Trip balancing refers to the process whereby trip productions and attractions are adjusted to ensure that the totals are equal as Produced trips must be attracted somewhere. Trip balancing is necessary because of the fact that different techniques are utilized in calculation of the trip attractions (usually regression) and trip productions (usually cross-classification) thus causing differing values for totals. Shown overleaf is the TransCAD® dialog used to perform the balancing technique. The vectors represent productions and attractions by trip purpose, with the purposes being defined as follows:

HBW – Home Based Work
HBO- Home Based Other
NHB – Non-Home Based
TRK – Trucks
IEEI – Internal/ External and External/Internal trips

For home based trips, the balancing adjustments were done to trip productions whereas the other purposes had balancing adjustments done to the trip attractions. It is generally acknowledged that home based trip production data is more reliable than trip attraction data. For NHB, TRK and IEEI trips, the converse is acknowledged to be true.

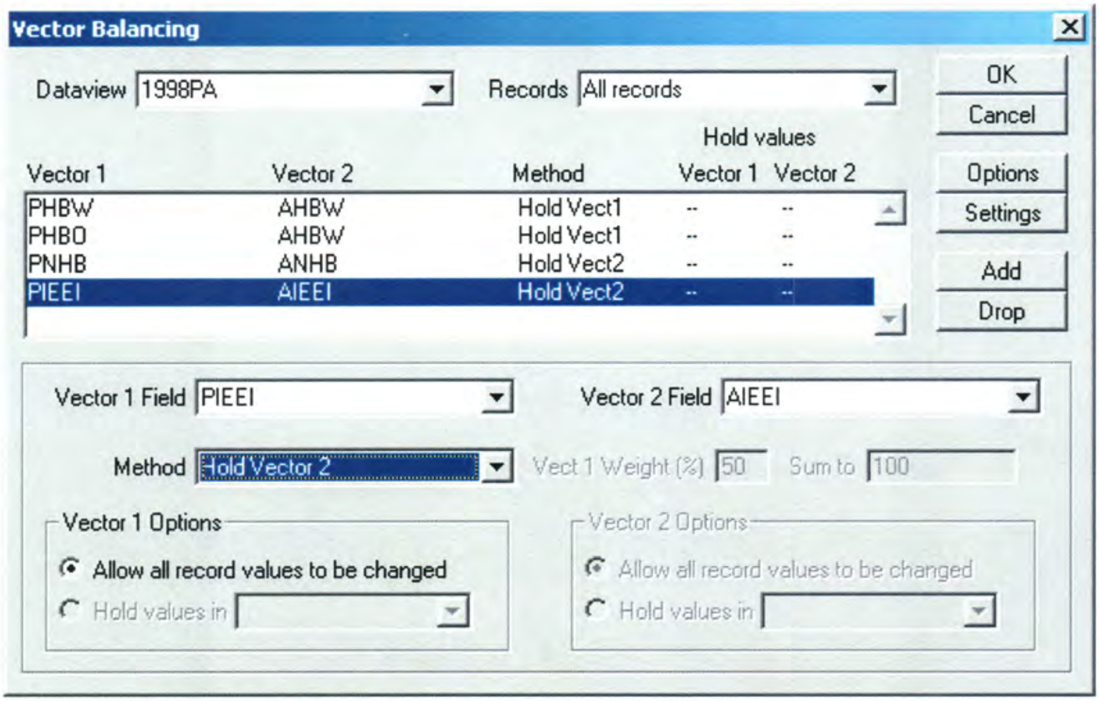

Figure 4.5 Trip Balance Dialog Box

Skimming the Network (Shortest Paths)

Before the trip distribution step was performed, it was necessary to get an impedance matrix. The updated network file, with centroids and turn prohibitions correctly represented was skimmed to obtain the desired result. It must be noted that intrazonal travel times had to be accounted for and the impedance matrix was adjusted accordingly. For the intrazonal travel times, the TransCAD utility to perform that procedure was utilized. The Shortest Path and intrazonal travel time dialog boxes are shown below.

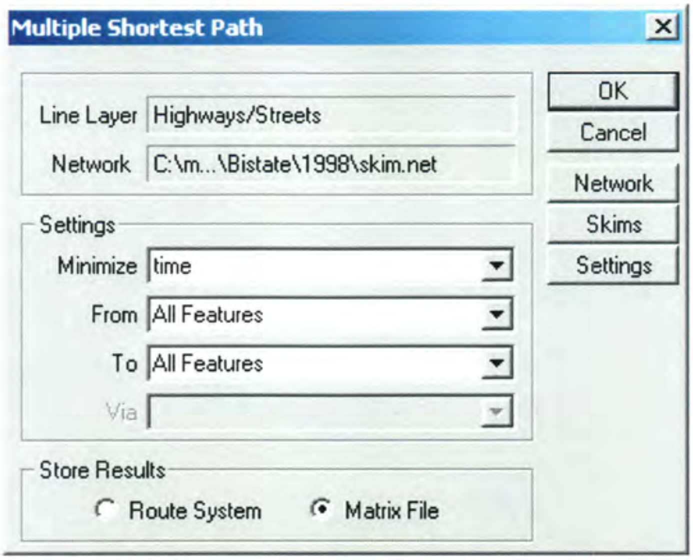

Figure 4.6 Multiple Shortest Path Dialog Box

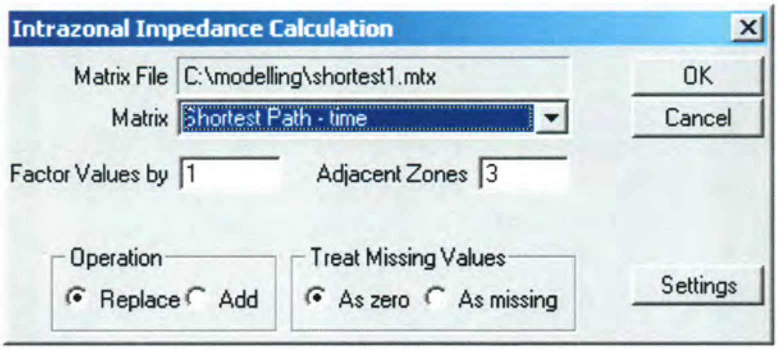

Figure 4.7 Intrazonal travel time dialog box

Distributing the Trips

Following the creation of the shortest path matrix, the next step involved performing trip distribution. As mentioned in Chapter 2, the gravity model is the primary technique used to perform trip distribution. Consequently, the trip distribution procedure selected was the gravity model. Inputs included the balanced production/attraction data file, the friction factor file converted from TRANPLAN and the shortest path impedance matrix previously generated. In some travel demand models, mode split would follow trip distribution but was excluded from this model however. This decision was arrived at after studying the Bi-State model execution in TRANPLAN® using the "RUN98" FORTRAN command file. It was ascertained from Bi-State professionals that the share of alternative modes of transport was not significant enough in the Quad Cities area to warrant inclusion in their model. Hence, the mode split phase was omitted in the TransCAD model.

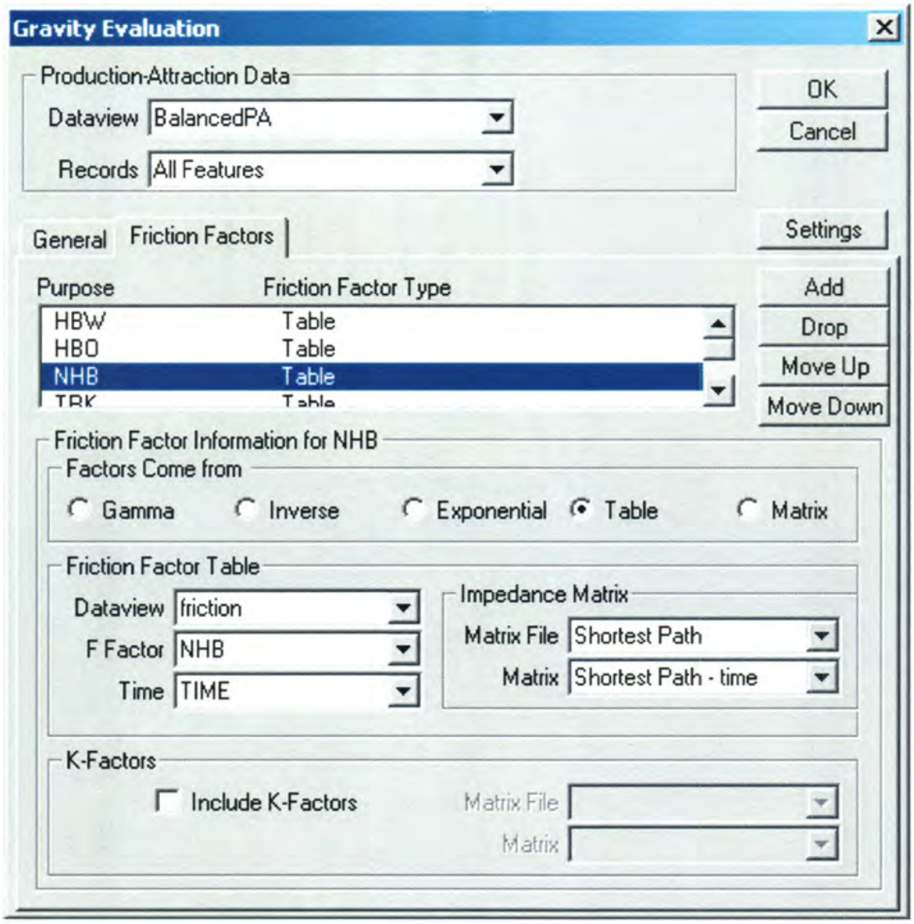

Figure 4.8 Gravity Model dialog box

From the above dialog, it can be seen that friction factors are applied by trip type. This is necessary given the tendency for different trip types to exhibit different trip distributions. For example, staff at the Bi-State Commission have observed that HBW trips tend to be longer than trip types such as HBO and NHB trips. IEEI trips with part of the trip occurring outside the modeled area will tend to be longer.

Origin / Destination

In travel demand modeling, trip productions and attractions do not necessarily represent the actual trip origins and destinations. Home Based Work trips for instance do not always originate at home but may also originate at the workplace for the return trip home. In such an example, despite the return trip home originating at the workplace, it is generally acknowledged that the home was responsible for the production of both the initial and return trips. Given this situation, it was then necessary to convert the productions and attractions to actual trip origins and destinations. Shown below is an example of the PA to OD dialog box available in TransCAD®.

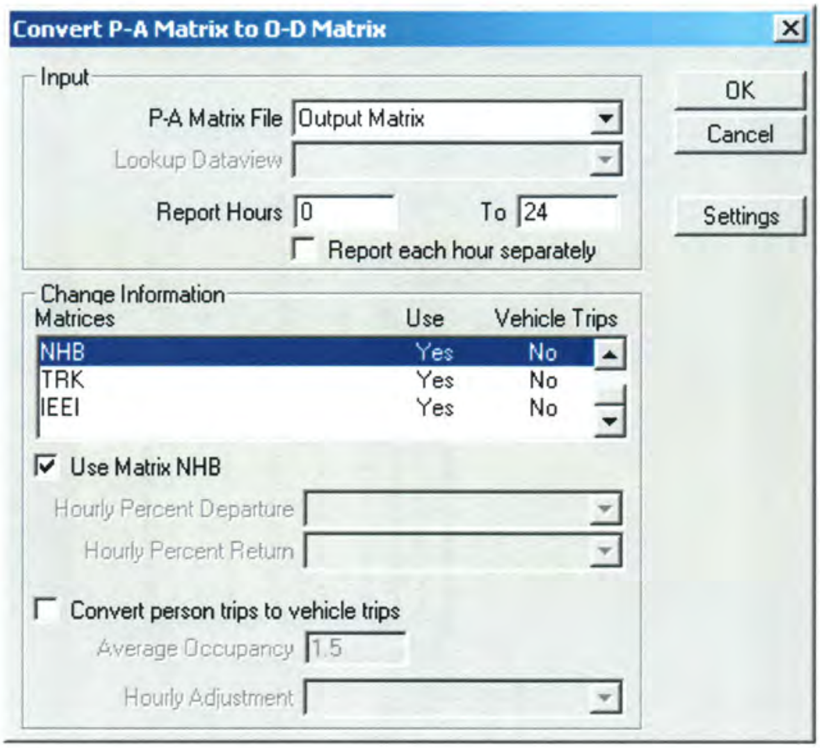

Figure 4.9 PA to OD conversion dialog box

The dialog above allows the option of reporting trips hourly or daily. It was decided after consultation with Bi-State Commission staff to use the daily reporting procedure and factor the totals to be assigned by a Peak Hour factor. For each trip purpose, a separate OD matrix was produced thus necessitating a combine procedure to aggregate the data for traffic assignment. The External-External trip totals also had to be combined with totals from the other trip purposes prior to traffic assignment. To accomplish the tasks described, the TransCAD® Matrix Combine and Matrix Quicksum routines were used. Shown below is the Combine Matrix dialog.

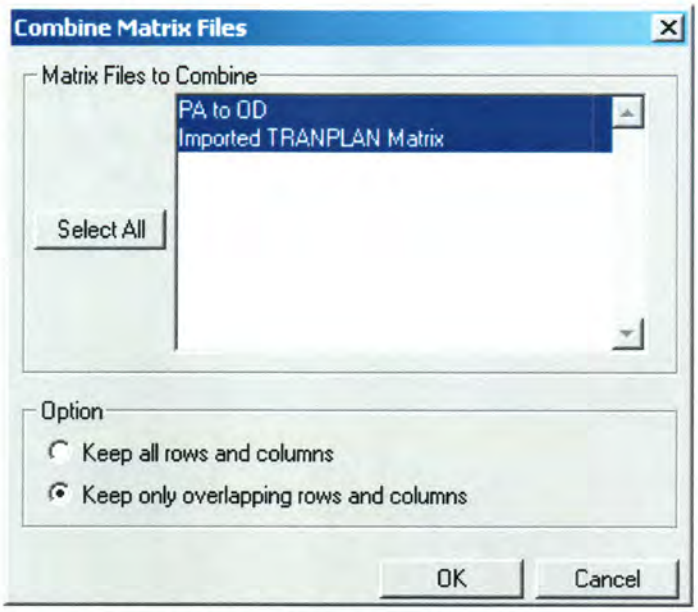

Figure 4.10 Matrix Combine dialog box

Traffic Assignment

After obtaining the OD trip totals, the next phase involved loading the trips on the network. The network capacity values represent capacities for peak hour travel. This subsequently required factoring the daily trip totals obtained from previous steps by the peak hour factors used by the Bi-State Regional Commission. A factor of 10% or 0.1 of total daily travel was being utilized in the Bi-State model. The assignment technique chosen was the Equilibrium assignment to ensure consistency with the Equilibrium technique used in the Bi-State TRANPLAN model. An illustration of the Traffic Assignment dialog is shown.

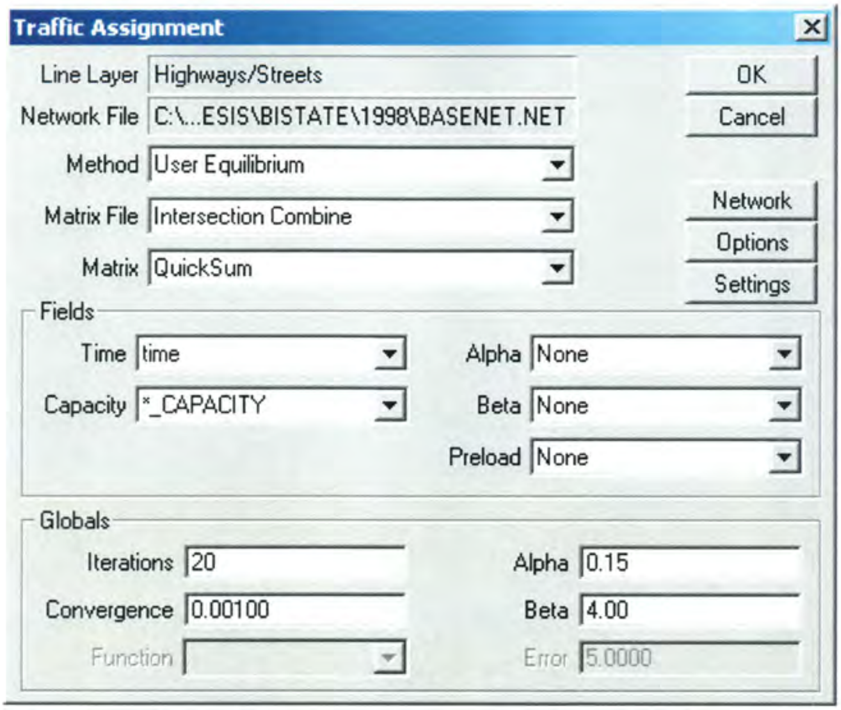

Figure 4.11 Traffic Assignment dialog box (Equilibrium)

Using the "Options" button to display a new dialog with a field called "Parameters Loading Multiplier" allowed the factoring of the trip totals. The value in the field was changed from the default of 1 (load all trips) to 0.1 (load 10% of trips). It must be noted that after the modeling was complete, it was necessary to adjust the loaded volumes upward by a factor of 10 (the inverse of the peak hour factor used) to get the non-factored daily assignment values. This adjustment was made after completion of the feedback process prior to comparison with Bi-State TRANPLAN® values. The output from the traffic assignment step included link volumes, speeds, travel times and volume / capacity (v/c) ratios. The v/c ratios are of particular interest as they represent the congestion level and thus affect the link travel times.

FEEDBACK LOOPING

As mentioned in Chapter 2, dynamic distribution is necessary to account for the effect of congestion on the shortest paths. Hence, following the initial assignment results, as was done in the Bi-State TRANPLAN® model; an iterative process of reskimming the network with updated congested travel times was performed. A rerun of the gravity model trip distribution process using the newly calculated impedance values accompanied each iteration. As with the initial steps described above, the Production/Attraction to Origin/Destination step as well as the aggregation with the External/External trip information was completed. Three iterations were completed and the final assignment results compared with the Bi-State results. The following steps were followed to perform each feedback iteration:

1. Set the "**Time**" variable in the highway/streets file to the maximum travel time variable "**Max_Time**" obtained from the joined assignment results.

AB_Time	BA_Time	MAX_Time
3.7600	3.7600	3.7600
1.8000	1.8000	1.8000
1.0800	1.0800	1.0800
1.3200	1.3200	1.3200
1.2400	1.2400	1.2400
1.0800	1.0800	1.0800
1.2400	1.2400	1.2400
2.0941	2.0945	2.0945
1.5424	1.5423	1.5424
4.6062	4.6067	4.6067
1.2600	1.2600	1.2600
0.5712	0.5712	0.5712
1.1700	1.1700	1.1700
1.2157	1.2136	1.2157
2.6714	2.6714	2.6714

time	ID1	AB_Flow
3.76	374	23.7615
1.80	394	23.3187
1.08	719	5.5000
1.32	720	74.1500
1.24	721	1.5000
1.08	722	165.6000
1.24	750	692.9500
1.44	1473	792.8940
1.54	1474	1098.1618
4.55	1486	317.3500
1.26	1493	0.0000
0.57	1505	1176.5180
1.17	1519	40.6797
1.15	1882	435.6260
2.67	1892	139.0838

Figure 4.12 Illustration of "Time" Column with "Max_Time" Column values

2. After the "**Time**" variable was updated in the Highway/Streets table, it was then necessary to update the network file with the new travel time and perform the shortest path network as illustrated above. The following is an illustration of the TransCAD® dialog for updating network parameters.

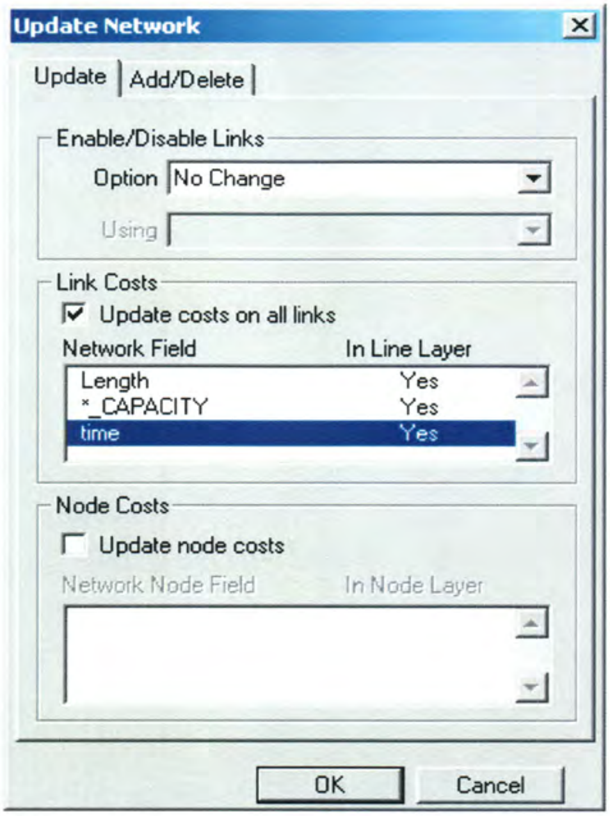

Figure 4.13 Network Update dialog

3. The trip distribution, PA to OD, matrix aggregation and traffic assignment steps described earlier were repeated three times and the resulting TransCAD® assignment map is shown below with screenlines.

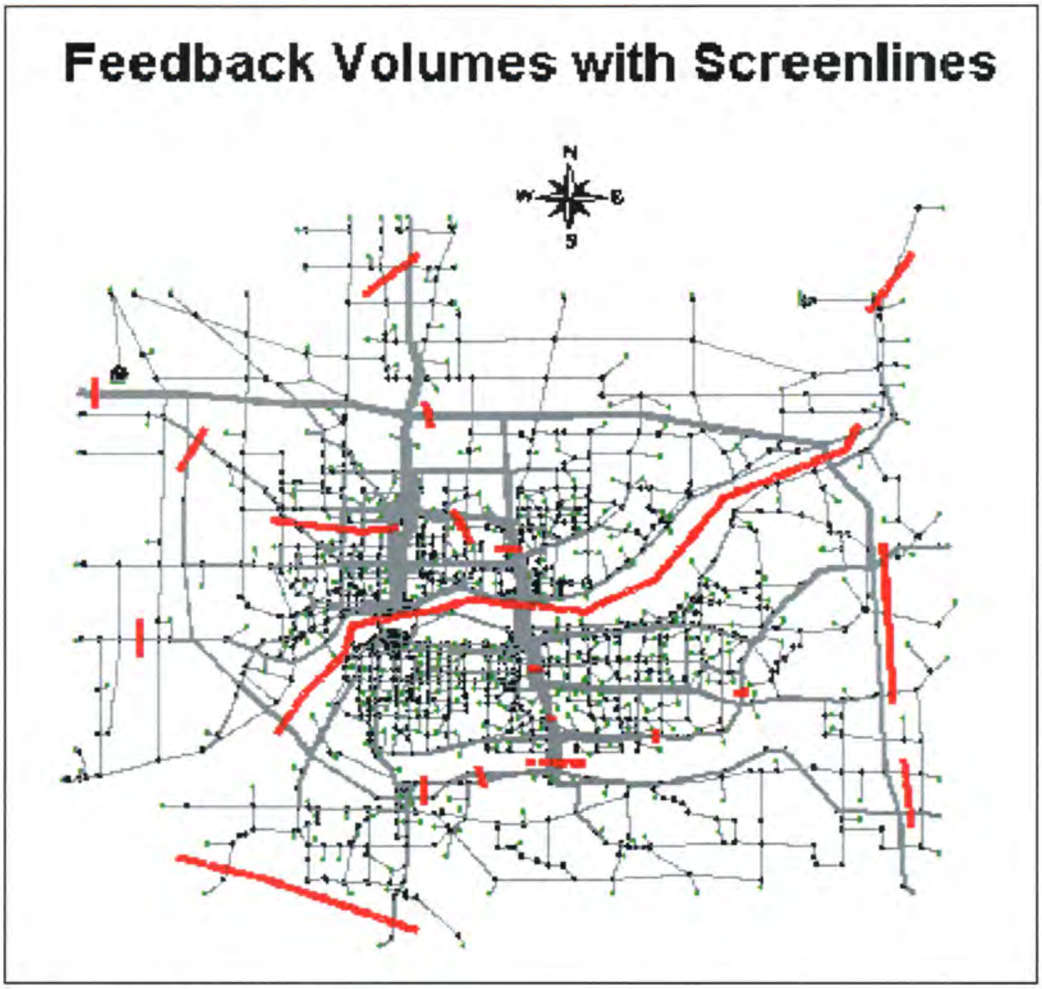

Figure 4.14 Screenlines

COMPARING 1998 ASSIGNED RESULTS

Using the TransCAD® screenline tool it was possible to obtain the flows across selected important links and have them compared with the Bi-State model results. The Bi-State values were represented in an ESRI Arcview® DBASE IV file containing a traffic volume assignment attribute. The Bi-State values and the TransCAD® values were then put in a common DBASE file and compared.

To perform the comparison, several tests were applied including Root Mean Square Variance analysis on the difference in the compared results, percentage difference on key cross river and freeway links and the percentage difference between the TransCAD® assignment totals and the Bi-State totals. As mentioned in the Model Validation and

Reasonableness manual, (16) these tests are standard validation checks used in travel modeling. The following table shows percentage differences on key links in the Bi-State model. Consultation with Bi-State modeling professionals indicated that focus should be placed on the links selected. These links represent the Mississippi River crossings and the interstates near the cordon points in the map.

Table 4.1 1998 Assignment Differences on Key Links

Link No.	Bi-State Results	TransCAD Results	Absolute Difference	% Difference
4525	15250	14536	714	**5**
4526	15250	14536	714	**5**
776	10800	9022	1778	**16**
5606	10800	9162	1638	**15**
752	7600	7154	446	**6**
5602	7600	6929	671	**9**
761	9150	8643	507	**6**
846	9150	8816	334	**4**
4101	8850	7895	955	**11**
5614	8850	8290	560	**6**
1242	36100	32474	3626	**10**
5618	36100	32024	4076	**11**
5132	11800	12161	361	**3**
5622	11800	12264	464	**4**
4534	13300	12902	398	**3**
4787	13300	14215	915	**7**
3318	7100	6652	448	**6**
3347	7100	6690	410	**6**
3317	8400	7770	630	**8**
3320	8400	7873	527	**6**

Upon observation of the table, it can be seen that the maximum percentage difference was 16% with the majority being below 10%. It was thus decided that such variances were acceptable after consultation with the Model Validation and Reasonableness manual. (16)

To verify this conclusion, the other tests mentioned such as the comparison of all links and RMSD were performed. When all links were compared, the total for the Bi-State model was 10,737,298 trips while that for the TransCAD® model was 9,326,533 trips. This gave an absolute difference of 1,410,765 and a percentage difference of approximately 0.13 or 13%. The file of all the links is not referenced owing to size. Performance of Root Mean Square analysis on the links crossed by screenlines shown in Figure 3.0 indicated a %RMSD (Root Mean Square Difference) of approximately 26%. (See Appendix E) The percentage RMSD was calculated using the following formula.

$$\%RMSD = \frac{(\sum_j (Modela_j - Modelb_j)^2 / (Count - 1))^{0.5} * 100}{(\sum_j Modelb_j / Count)}$$

where model*a* is the TransCAD® model result per link and model*b* is the Bi-State TRANPLAN model result. *(Model Validation and Reasonableness Manual Part 7)* (16)

Theoretically, the results from the two models should be the same but underlying differences in model implementation of some algorithms can cause differences. Based on the results obtained in the three tests above, it was concluded that for the purposes of this research, the 1998 TRANPLAN® model and the TransCAD® model were sufficiently close in predicted results to perform 2025 analysis.

COMPARING 2025 ASSIGNED RESULTS

Following validation of the 1998 models, the next task involved running the models with future 2025 data. All the steps described earlier such as converting data, running the four step process and doing feedback modeling were repeated for the 2025 data. The 2025 TransCAD® 2025 assignment map is shown overleaf.

Table 4.2 2025 Assignment Differences on Key Links

Link No.	Bi-State Results	TransCAD Results	Difference	% Difference
2680	23357	22184	1173	**5**
5788	22979	22122	857	**4**
4681	31911	27561	4350	**14**
4682	31907	27397	4510	**14**
757	17237	16606	631	**4**
5782	17248	16538	710	**4**
5795	5631	6526	895	**16**
5797	6758	6435	323	**5**
766	6366	7331	965	**15**
879	6804	7240	436	**6**
1401	39217	39311	94	**0**
5798	37886	39256	1370	**4**
18	4830	5011	181	**4**
1378	5364	5012	352	**7**
2032	11001	11605	604	**5**
5808	11032	11485	453	**4**
5803	16012	17494	1482	**9**
5805	16018	17401	1383	**9**
3473	19130	17065	2065	**11**
3476	19131	16941	2190	**11**
4683	21918	20598	1320	**6**
4687	21901	20109	1792	**8**

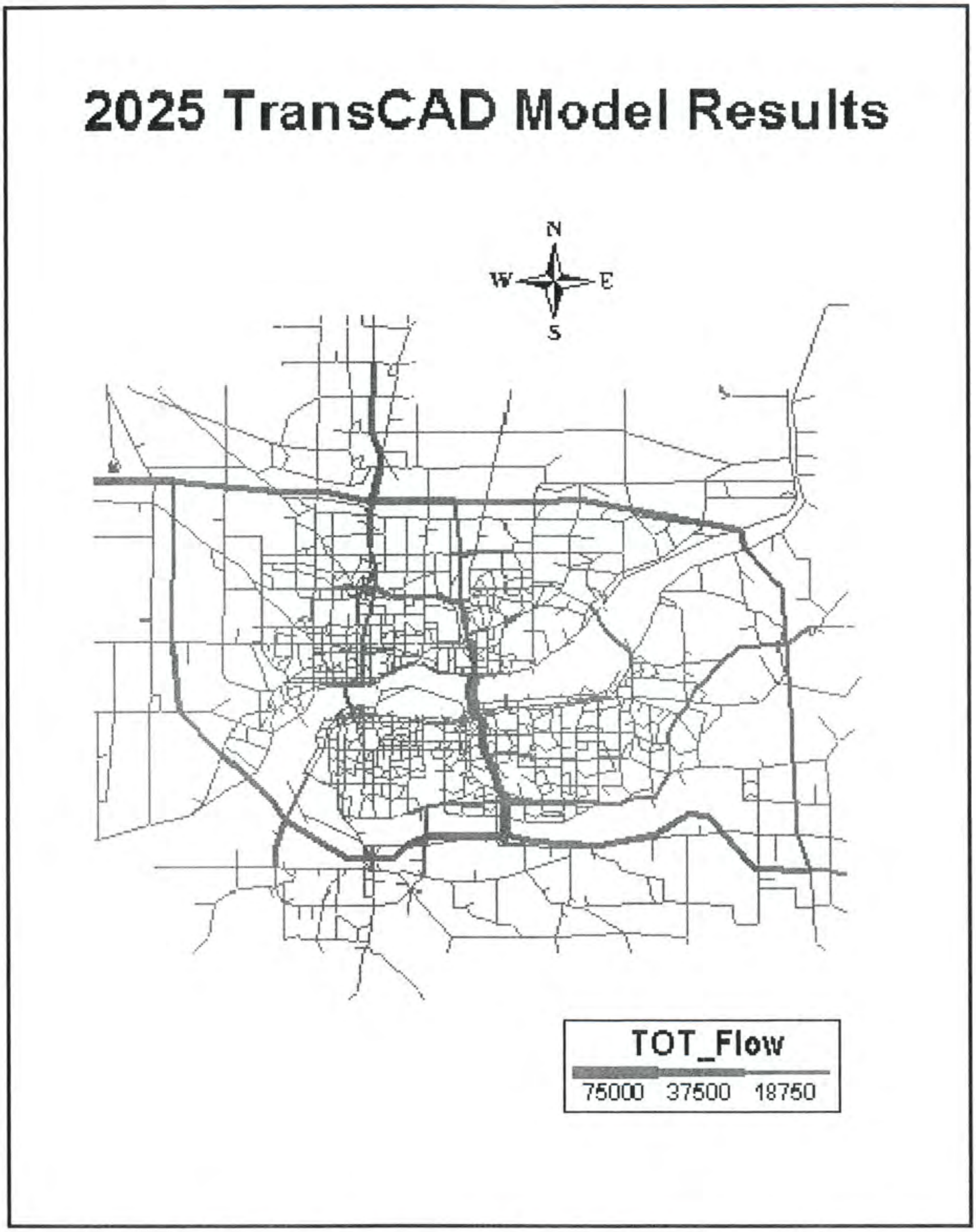

Figure 4.15 2025 TransCAD Research Assignment Results

Like the 1998 results, no difference was greater than approximately 16% with the majority of the links reporting differences below 10%. It may be noted that the links highlighted represent an additional Mississippi River bridge crossing representing a planned network improvement. The percentage Root Mean Square difference calculated for all the links was determined to be 28%. The %RMSD calculated on the links crossed by TransCAD® screenlines (links with significant traffic volumes) illustrated in the map above was determined to be approximately 13%. See Appendix E. The percentage difference between the trips assigned on all links in the Bi-State model and the TransCAD® model was 4%.

Given all this information, it could be concluded that for the purposes of sensitivity analysis, the model predictions were close enough to warrant proceeding to the sensitivity testing phase of the research. In sensitivity analysis, it is not critical that the models match exactly since the main objective is to analyze changes in model output. In travel and emissions forecasting however, it is important that the absolute output values are as accurate as possible given that large expenditures of money, time and effort may be dependent on the forecasted values.

CHAPTER 5. PERFORMING SENSITIVITY RUNS ON TRANSCAD MODEL

SENSITIVITY ANALYSIS

Sensitivity analysis is defined as "the process used to ascertain how a given model output depends upon the input parameters. This is an important method for checking the quality of a given model, as well as a powerful tool for checking the robustness and reliability of its analysis. The topic is acknowledged as essential for good modeling practice, and is an implicit part of any modeling field".

In this research, the aim is to determine which input factor affects the output emission results by the greatest magnitude. Using the basic principles of sensitivity analysis, the model inputs were adjusted and the output from each run noted. After completion of all model runs, the difference in output emissions levels could then be statistically compared using any of a multitude of techniques. Some useful techniques include regression analysis and ANOVA (Analysis of Variance).

Sensitivity analysis can be applied in a variety of modeling situations. For example, it can be applied to econometric models where future economic attributes such as GDP (Gross Domestic Product) are predicted. Another relevant application is the study of the effect of transportation investments on land use changes. Sensitivity tests in econometric modeling would, for example, enable economists to determine how varying assumptions about interest rates, energy prices, labor costs would affect the actual GDP results.

Sensitivity tests can also be applied to physical models such as hardware control systems. In such applications, the objective is to study the response of the system to varying input conditions such as electrical current, feedback noise (incoherent and corrupted control signaling) and load affect for example motor speed, response time to changes in inputs etc. (22)

A common use of sensitivity tests is the estimation of parameters that represent continuous variables in experiments where it is impossible to measure the values in actual practice. (22) For example sensitivity testing of pyrotechnics to ignition will allow a relationship to be obtained between the stress levels and ignition below the critical threshold pressure, above which samples always ignite. Without sensitivity testing, it would not have been possible to obtain estimates of the parameter since application of pressure to pyrotechnic samples inevitably destroys or damages the sample and makes it impossible to do repeated testing on a particular sample. This technique is known as Maximum Likelihood Estimates and is being increasingly applied to sensitivity analysis. Other common techniques include Probit, Bruceton, Robbins-Monro and Langlie. (22)

The mathematics involved in such tests can become complicated and it is considered beyond the scope of this thesis to analyze the various techniques. In concluding, it can be said that sensitivity analysis allows the following to be achieved:

1. The effects of accuracy in a modeled system can be determined.
2. The effects of changes in both magnitude and direction in a modeled system can be determined.
3. Facilitates model calibration.

SENSITIVITY TESTING PROCEDURE

As stated in the introductory section on research questions, the main goal of this research was to determine which of three input factors has the greatest effect on the predicted emissions output. The input factors considered in the research include

1. The traffic assignment methodology used. Five assignment techniques were investigated including stochastic, user equilibrium, stochastic user equilibrium, incremental and capacity restraint.
2. The use or non-use of dynamic feedback modeling.
3. The type of the friction factor distribution used. (3 distributions were used)

Determination of the most significant factors on the emissions output required running the model over all combinations of levels of the input variables. Each combination of levels represented a unique sensitivity scenario resulting in different output values. In total, 30 combinations of inputs were used giving 30 emissions outputs. (5 Assignment levels × 2 dynamic modeling levels × 3 friction distributions.)

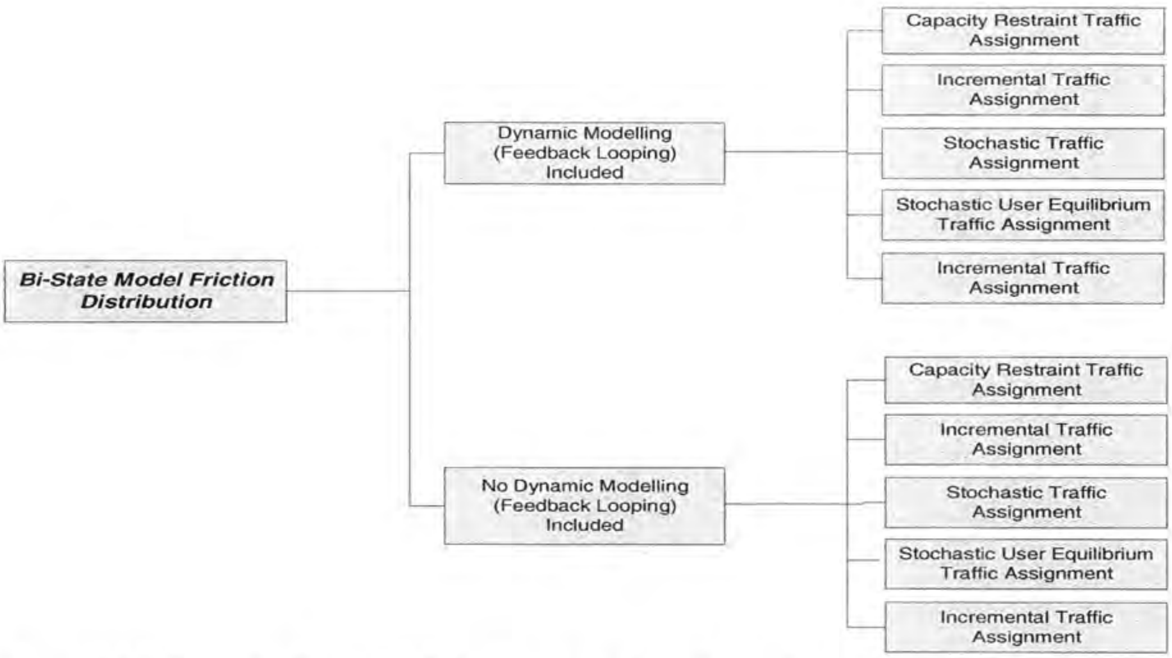

Figure 5.1 Schematic diagram of the input combinations with original Bi-State Friction Factors.

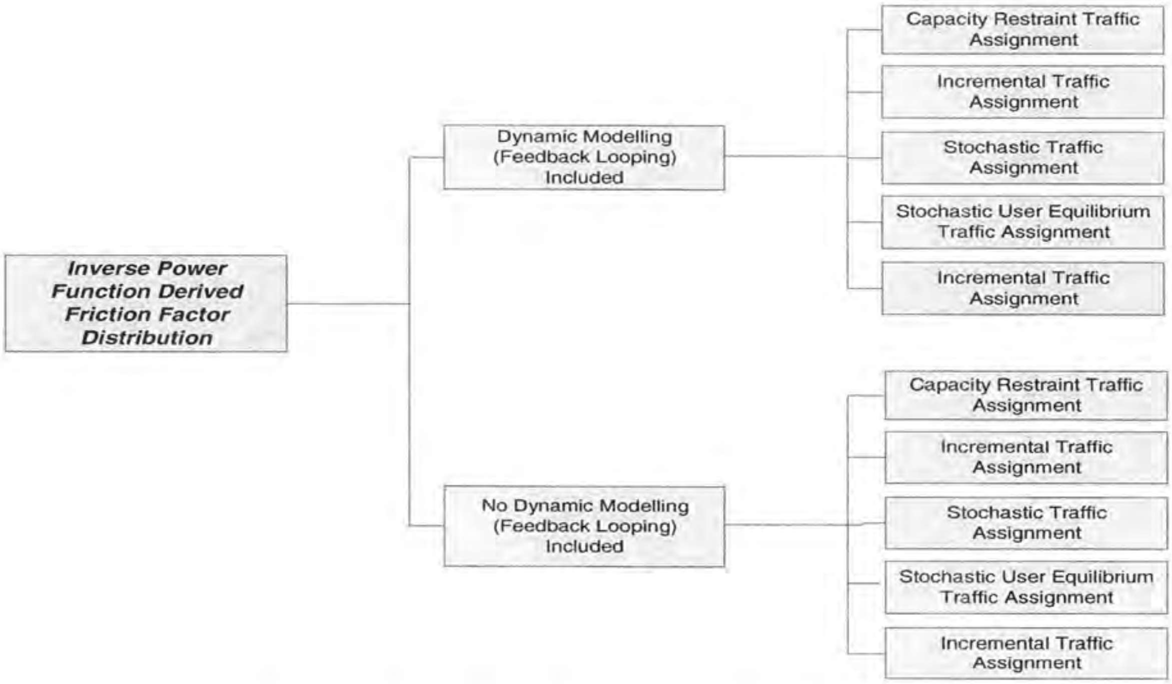

Figure 5.2 Schematic diagram of the input combinations with Inverse Power Function developed Friction Factors.

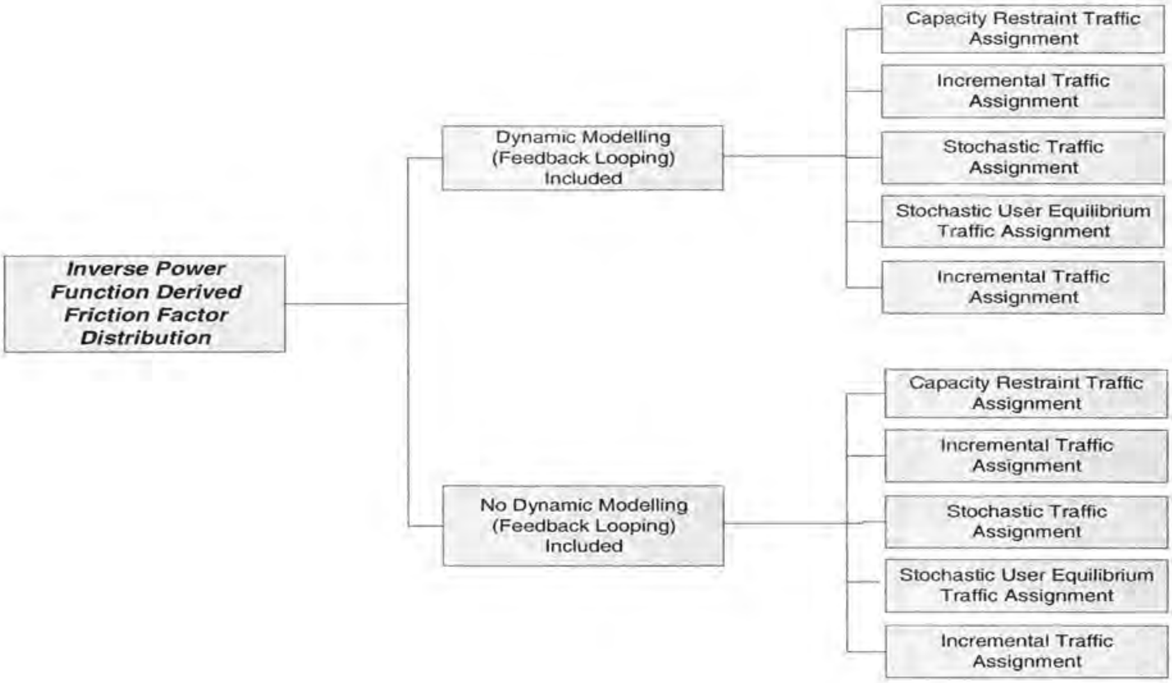

Figure 5.3 Schematic diagram of the input combinations with Inverse Power Function developed Friction Factors.

For each combination of inputs, the procedure followed involved performing the sequence of steps described in Chapter 4 including trip distribution, PA to OD, trip purpose combination and traffic assignment. The sequence of steps described in Chapter 4 for feedback modeling was performed for corresponding feedback input factors. In non-feedback modeling, the travel modeling process was halted after the first assignment results were obtained using the initial skim network.

FRICTION FACTOR DISTRIBUTIONS

Friction Distribution 1

The first set of friction factors used in the model was simply the friction factor file supplied from the Bi-State Commission and converted for TransCAD®. In addition to using tables developed from observation of actual conditions, it is also possible to develop friction factors by using impedance functions. In general, friction factors are inversely related to impedance (travel time, distance, cost etc.). As a result, a simple inverse function can be used to develop friction factors. Such a function would take the form $f(d_{ij}) = d_{ij}^{-1}$ where:

- d_{ij} = impedance between zones i and j
- $f(d_{ij})$ = friction factor between zones i and j

It has however been shown that the simple inverse function is not the best performing impedance function (11). Hence, more complicated functions have been devised that have been shown to perform better. Among the more popular functions are the exponential function, the inverse power function and the gamma function. (11)

exponential	$f(d_{ij}) = e^{-c(d_{ij})}$	where c is constant > 0
inverse power	$f(d_{ij}) = d_{ij}^{-b}$	where b is constant > 0
gamma	$f(d_{ij}) = a \cdot d_{ij}^{-b} \cdot e^{-c(d_{ij})}$	where a > 0 and c >= 0

Source: Travel Demand Modeling with TransCAD 4.0 page 176.

It should be noted that the gamma function is a combination of the inverse power function and the exponential function. Application of these functions involves adjusting the parameters a, b or c to replicate the actual conditions found in the modeled area.

Friction Distribution 2

The inverse power function was applied and a new friction factor table developed for friction distribution number 2. The parameter chosen for b was 1.45. Application of this function and parameter gave a distribution that had a sharper curve (more L shaped) than that of the original Bi-State data. The factors calculated for long trips were higher. Theoretically, such a difference should result in proportionately fewer intermediate distance trips but more very long and very short trips.

Friction Distribution 3

In this case, the gamma function was applied. The values chosen for a, b and c were 1, 1.45 and 0.025 respectively giving a very sharp distribution curve. In addition the row corresponding to a time of 1 minute was removed with the gamma being applied from time 3 minutes onwards. The maximum friction factor value of 10,000 was used for all times t = 2 minutes or less. The overall result of this application was the most L like distribution of the three being evaluated. Theoretically, based on this distribution, there should be a larger number of very short trips than was the case for the previous two. In addition, the friction factors at higher travel times were lower which should lead to fewer long trips in the model.

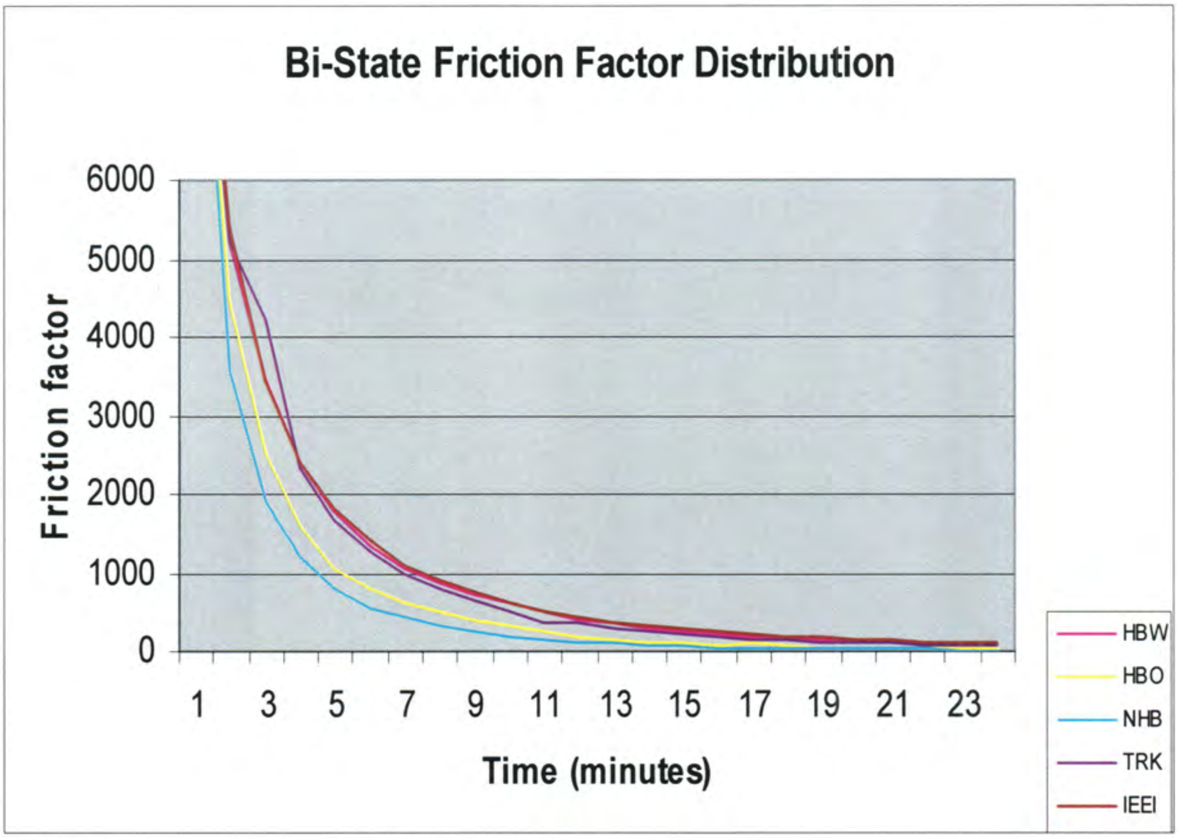

Figure 5.4 Bi-State Friction Distribution

Please see Appendix A for corresponding friction factor tables.

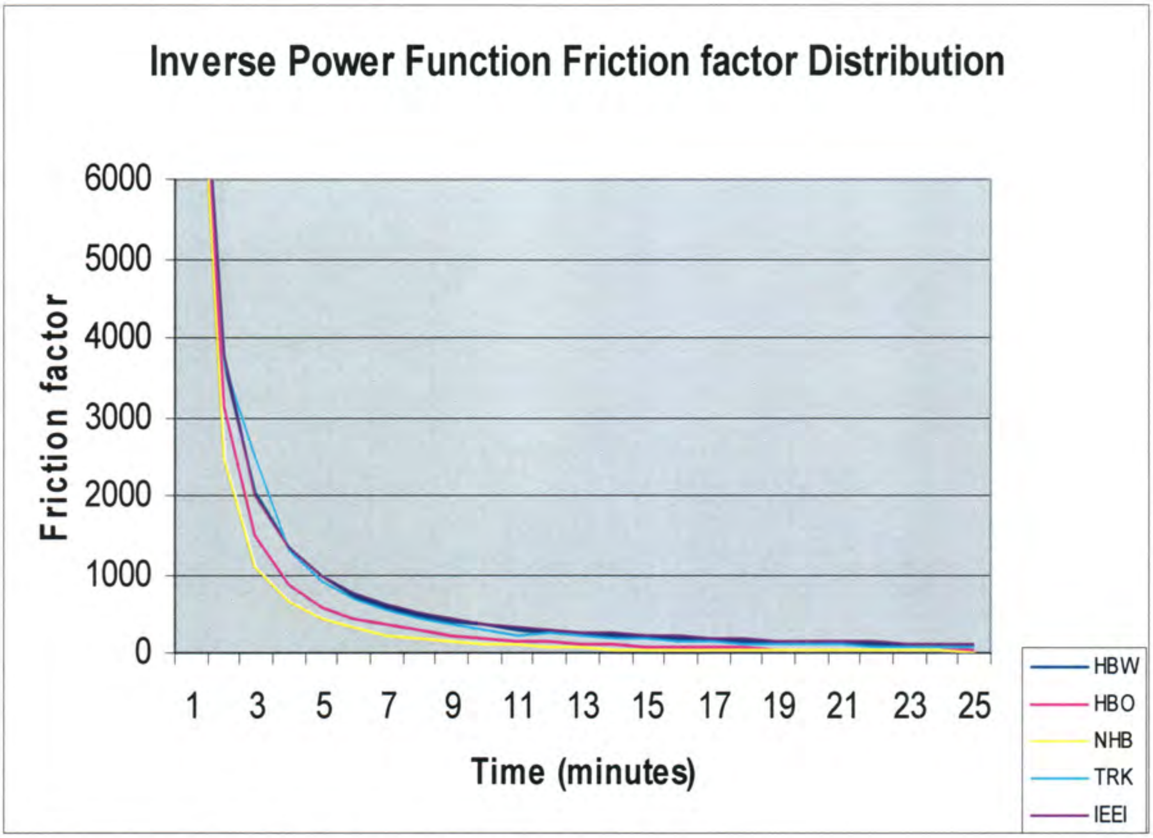

Figure 5.5 Inverse Power Function Friction Factors

EFFECT OF VOLUME ON TRAVEL TIMES (IMPACT OF FEEDBACK MODELING)

With the exception of the All or Nothing and Stochastic assignment techniques, all traffic assignment methodologies incorporate a volume delay relationship. This better describes the actual impact of traffic congestion on network travel times. The most common function used to describe volume delay is the Bureau of Public Roads relationship. This relationship is defined as (17)

$$t = t_0 \left[1 + \alpha \left(\frac{v}{c} \right)^{\beta} \right]$$

where: t = Congested link travel time

t_0 = free flow travel time on link

v = link volume

c = link capacity

α, β = calibration parameters.

Source: Travel Demand Modeling with TransCAD 4.0 page 176.

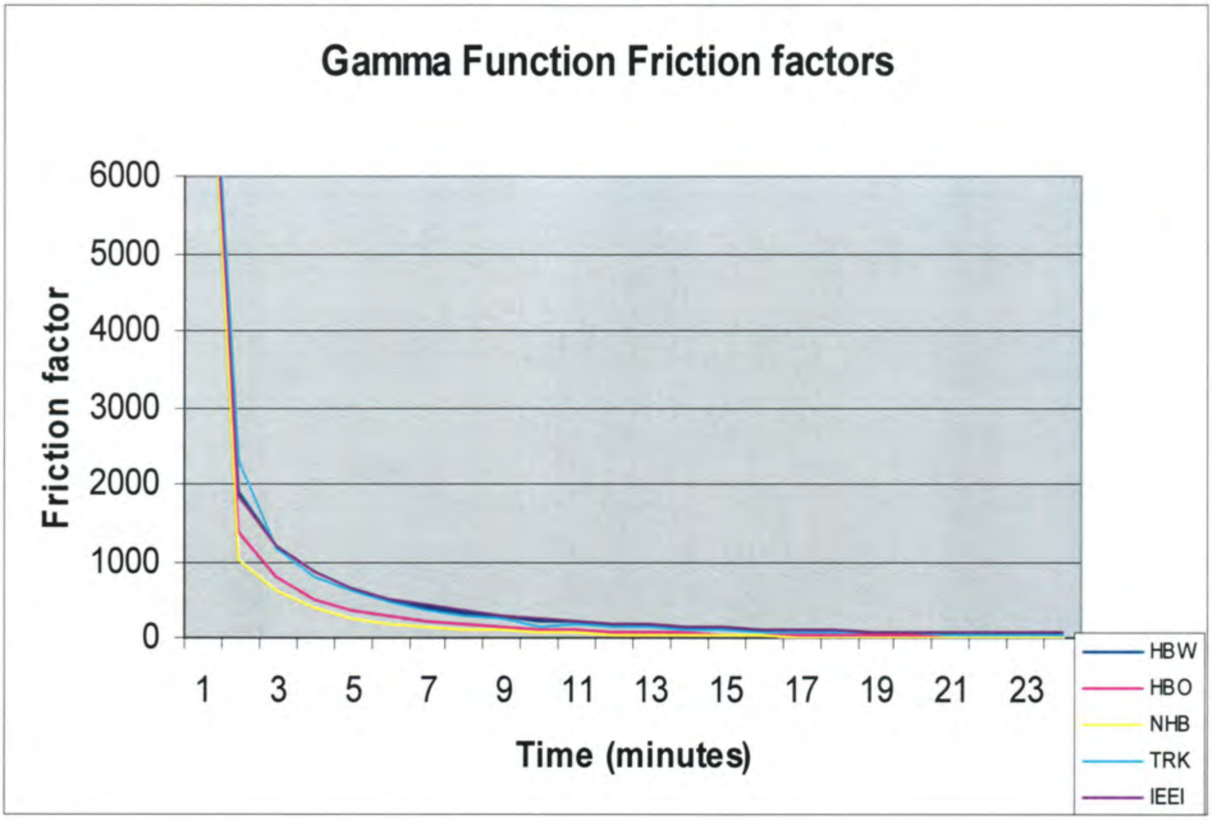

Figure 5.6 Gamma Function Friction Factors

Historically common values used for α and β are 0.15 and 4.0 respectively. Based on such values, it is easily recognized that as soon as the v/c ratio tends to 1 and above, t becomes much larger than t_0.It must be noted that v/c ratios greater than 1 are possible only in theory given that a roadway cannot possibly accommodate a greater volume than its capacity dictates. Such a situation could thus be interpreted as unmet trip demand along a particular link. Other volume delay functions have been utilized but is generally recognized that by simply adjusting the parameters α and β, most of the other functions can be approximated by the BPR function.

As described in Chapter 2, this volume delay effect can significantly affect validity of the assigned results. Initially, uncongested travel times are used to obtain the trip assignments but in reality, the congested times must be utilized to give realistic assigned results. Hence the use of feedback loops where the congested travel times are fed back to the network skimming (shortest path) phase. This in turn affects the trip distribution and finally the assignment results. Runs were performed both with/without feedback for all three friction factor distributions.

TRAFFIC ASSIGNMENT METHODOLOGIES

For each combination of friction factor distribution and feedback/no-feedback, the five traffic assignment techniques mentioned at the beginning of this chapter were utilized. This was accomplished by varying the option selected in the TransCAD® Traffic Assignment dialog box. Shown next are the dialogs for each of the other four techniques used in addition to the User Equilibrium illustrated on page 41. Of note are the disabled capacity, alpha and beta fields in the Stochastic Assignment dialog box. That is expected given the fact that the Stochastic assignment technique does not rely on the volume delay BPR function and its associated parameters illustrated earlier. Following the completion of the 30 sensitivity combinations of inputs, it was necessary to produce and analyze the emissions results.

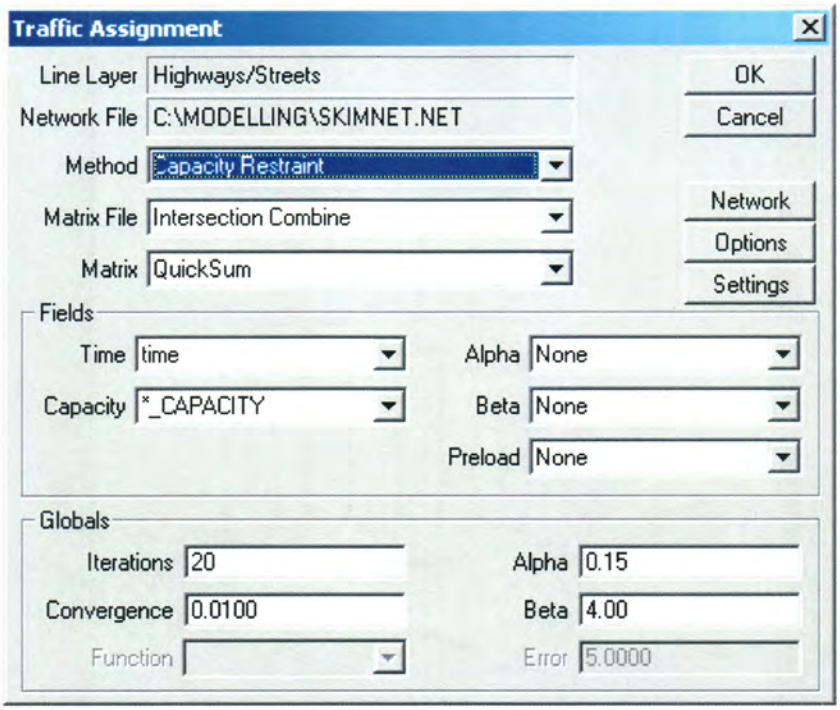

Figure 5.7 Capacity Restraint

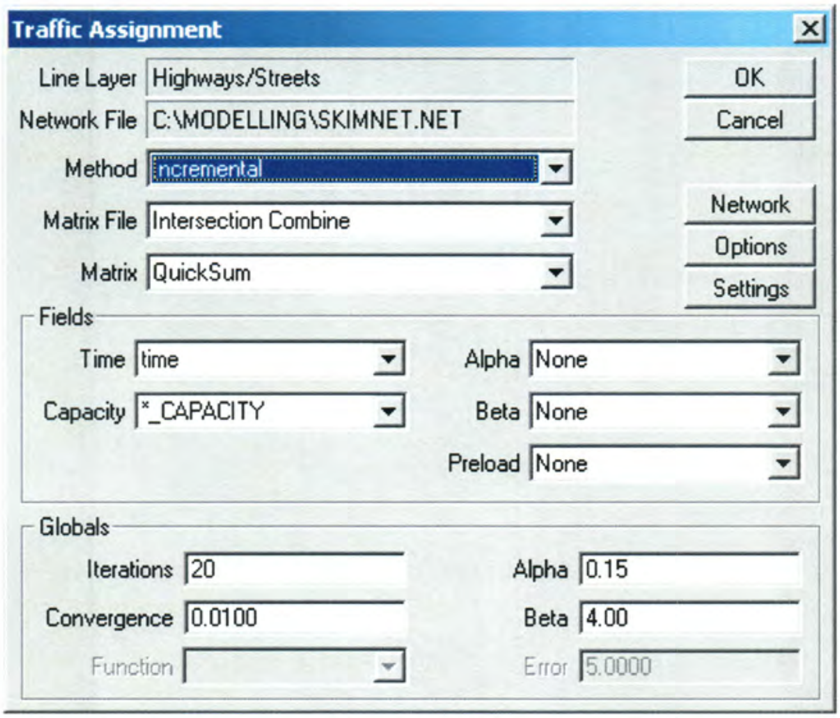

Figure 5.8 Incremental Assignment

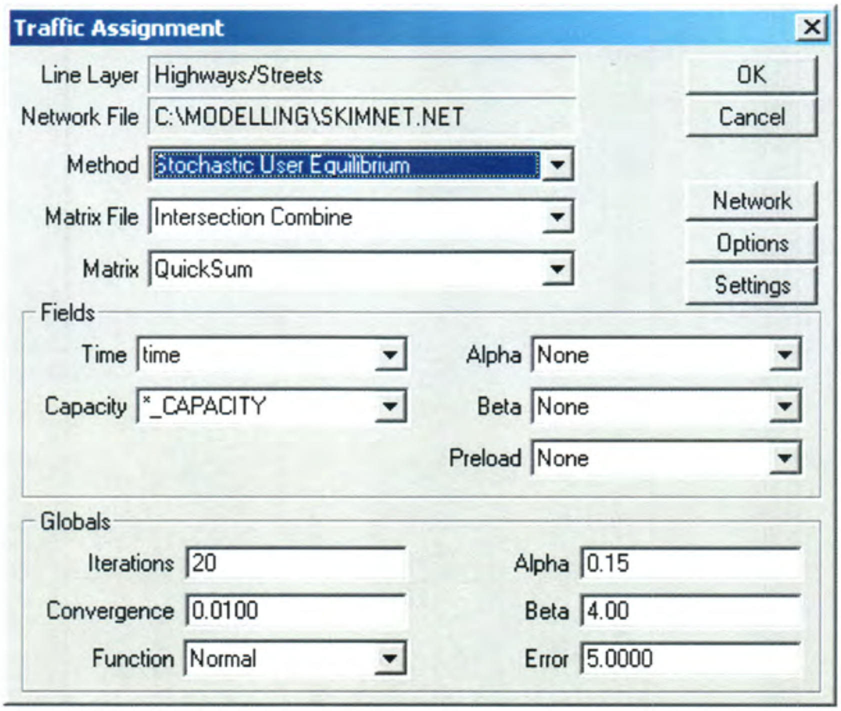

Figure 5.9 Stochastic User Equilibrium

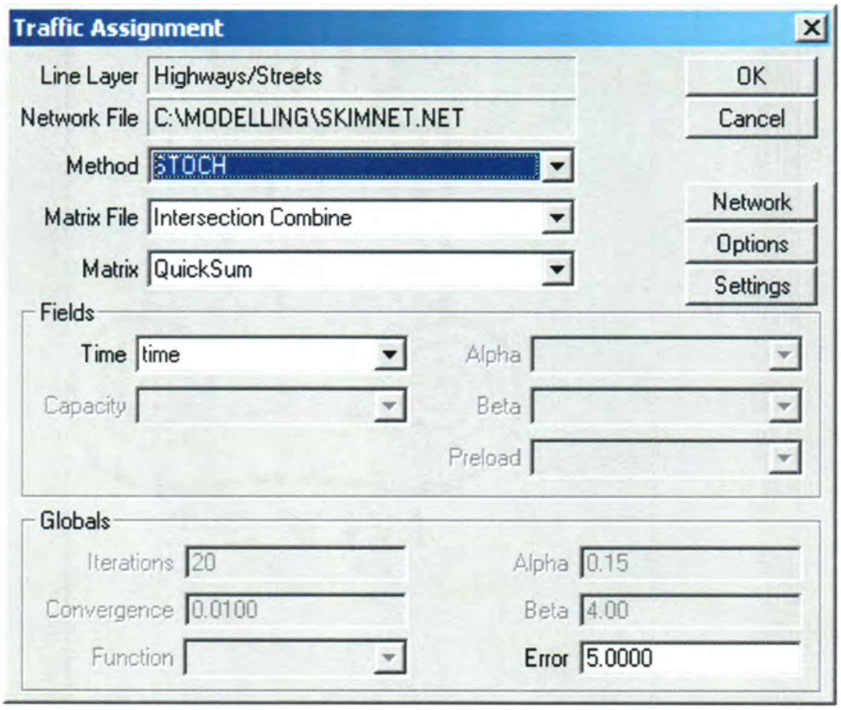

Figure 5.10 Stochastic Assignment

CHAPTER 6. LINKING TRAVEL MODEL OUTPUT WITH EMISSIONS RESULTS

MOBILE 6 EMISSIONS FACTOR MODEL

Following the completion of the sensitivity runs in the TransCAD® travel demand model, it was then necessary to obtain emissions factors and combine the results as described in the introductory chapter on page 2. The tool used to get the emissions factor results for this research was the Environmental Protection Agency's (EPA) MOBILE6. The MOBILE6 program is supplied with a number of tables that represent the defaults values to be used in the absence of specific information for the area under study. These tables were developed from data collected in the FTP tests and from numerous jurisdictions across the country. Among the tables included are the vehicle age distribution, mileage accumulation rates, VMT fractions, average speed distributions and many others used to ultimately calculate the average emissions rate per vehicle.

MOBILE6 calculates emissions for three of the criteria pollutants including oxides of nitrogen (NO_x), carbon monoxide (CO) and volatile organic compounds (VOCs). Ozone (O_3), another criteria pollutant, cannot be directly calculated with the MOBILE6 program given the fact that ozone is a secondary pollutant. Low level ozone is formed by complex atmospheric reactions in the presence of sunlight (energy source) between atmospheric oxygen O_2, nitrogen oxides (NO_x) and hydrocarbons (HC). (23)

MOBILE6 is a command line based FORTRAN language program requiring an input command file that directs the program to generate the desired options and output formats. Two input files were used for this research; one representing emissions data for arterial streets and the other representing emissions data for freeways.

Roadways are classified by MOBILE6 into 4 types: (24)

1. Freeway :- High speed, limited access roadways
2. Arterial :- Arterial and Collector roadways
3. Local :- Urban Local Roadways
4. Fwy Ramp :- Freeway on and off ramps.

For the purposes of this research, only the freeway and arterial categories were analyzed given that insufficient travel network detail was available to properly include local roadways and freeway ramps.

The input files to MOBILE6 allow several default parameters to be specified so that the model can be tailored to local conditions. For this research, the primary items adjusted were the speeds, season, temperature and oxygenated fuels components. For 2002 in Iowa, a significant proportion ≈ 55% of the gasoline sold in the state was a 10% ethanol 90% gasoline blend regarded as an oxygenated fuel. (25) At this blend, the oxygen content in the fuel is about 3.5% resulting in > 30% reduction in CO emissions particularly in winter. (26) As a result, it was decided to utilize the MOBILE6 oxygenated fuels command to more accurately represent the actual situation in Iowa. Illinois, the other state in the Bi-State area also has a significant percentage of ethanol-blended gasoline sales. Illustrated below is an example of a portion of the input file for freeways with the selected options.

```
MOBILE6 INPUT FILE :
DATABASE OUTPUT   :
AGGREGATED OUTPUT :
WITH FIELDNAMES   :

DATABASE EMISSIONS : 2222 2222
DATABASE FACILITIES: Freeway
DATABASE VEHICLES  : 22222 22222222 2 222 22222222 222

RUN DATA
MIN/MAX TEMP     : 70. 90.
SEASON           : 1
FUEL RVP         : 7.0
OXYGENATED FUELS  : 0 .55 0 .035 2

SCENARIO REC      : Scenario Title Text - Freeway 2.5
CALENDAR YEAR     : 2025
AVERAGE SPEED     : 2.5 Freeway
EVALUATION MONTH  : 7
```

Figure 6.1 Freeway MOBILE6 Input File

The MOBILE6 input file is divided into three sections; the Header section, the Run section and the Scenario section. Shown above are the header section, one run section and one scenario section. The full input files for both freeway and arterial are shown in Appendix B.

Header Section

The Header section controls the overall input, output and execution of the program. (4) Options specified in this section apply to all runs and scenarios defined in the file. In the example shown, the DATABASE OUTPUT option was chosen to allow output in a database file format that would facilitate processing in Visual Basic. In addition, it was also specified to aggregate the database output over daily time periods given that the TransCAD® link volumes were also for daily time periods. The DATABASE EMISSIONS and DATABASE VEHICLES commands were used to specify that all emissions and vehicle categories be reported in the database output file. The DATABASE FACILITIES command was used to specify the kind of roadway being analyzed. In the above example, freeways and other high speed divided roadways were being analyzed.

Run Section

The Run section identified by the RUN DATA command is used to define specific options that apply to local or customized situations. In the above example, each run corresponded to either the winter season or the summer season. The MIN/MAX temperature command was used to specify the minimum and maximum ambient temperatures that in the illustrated case above were set at 70° F and 90° F respectively. The SEASON command of 1 specified summer conditions whereas the fuel RVP specified the fuel Reid Vapor Pressure in PSI (Pounds per square inch). The OXYGENATED FUELS command was used to specify that 55% of the gasoline fuel sold contained ethanol and the oxygen content was 3.5% of total fuel mass based on a 1:9 ratio of ethanol to gasoline. For diesel fuel applicable primarily to heavy trucks, the MOBILE6 default diesel fractions were assumed.

Scenario Section

This section details the individual circumstances for which emissions factors were to be calculated. In the example above, each scenario corresponds to a different average speed value starting from the low speed of 2.5 mph up to 65 mph. For each scenario, the CALENDAR YEAR input was set to 2025, the year being modeled. The AVERAGE SPEED command was used to set the average speed for each scenario along with the roadway type. The EVALUATION MONTH determines whether calculations should be done for January or July. In the example given, the month was set to July corresponding to summer. Shown below is an example of the MOBILE6 command line DOS input illustrating the use of the "Freeway" input file.

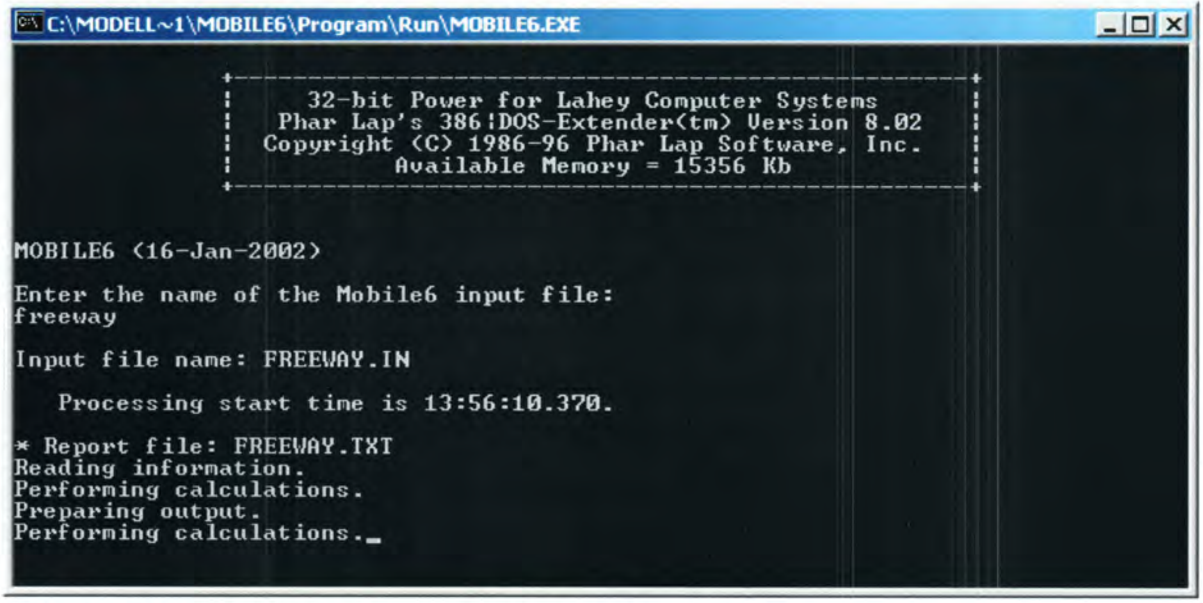

Figure 6.2 MOBILE6 Command Line Interface

Following the MOBILE6 runs for the freeway and arterial cases, two database files and two report files were produced. The database files were subsequently used in a Visual Basic® VB program along with the TransCAD® link volume files to produce emissions per link. The report files were used to manually validate some of the results calculated obtained by the VB program in a random manner. Shown below is a portion of the report file illustrating the output from one scenario. (Speed = 2.5 mph)

```
*************************************************************************
* MOBILE6 (16-Jan-2002)                              *
* Input file: ARTERIAL.IN (file 1, run 1).                *
*************************************************************************

* #########################
* Scenario Title Text - Arterial 2.5
* File 1, Run 1, Scenario 1.
* #########################

* A user supplied arterial average speed of 2.5 will
* be used for all hours of the day. 100% of VMT has been
* assigned to the arterial/collector roadway type for all
* hours of the day and all vehicle types.

 M 48 Warning:
       there are no sales for vehicle class HDGV8b
 M 48 Warning:
       there are no sales for vehicle class LDDT12

              Calendar Year: 2025
                      Month: July
                   Altitude: Low
        Minimum Temperature: 70.0 (F)
        Maximum Temperature: 90.0 (F)
          Absolute Humidity: 75. grains/lb
           Nominal Fuel RVP: 7.0 psi
              Weathered RVP: 7.4 psi
         Fuel Sulfur Content: 30. ppm

         Exhaust I/M Program: No
            Evap I/M Program: No
                 ATP Program: No
            Reformulated Gas: No

  Ether Blend Market Share: 0.000    Alcohol Blend Market Share: 0.550
  Ether Blend Oxygen Content: 0.000   Alcohol Blend Oxygen Content: 0.035
                     Alcohol Blend RVP Waiver: Yes
     Vehicle Type:   LDGV  LDGT12  LDGT34   LDGT   HDGV   LDDV   LDDT   HDDV
MC  All Veh
         GVWR:          <6000   >6000   (All)
                  ------  ------  ------  ------  ------  ------  ------  ------  ------  ------
  VMT Distribution:  0.2788  0.4388  0.1507         0.0365  0.0003  0.0022  0.0876  0.0051  1.0000
---------------------------------------------------------------------------------------------------
 Composite Emission Factors (g/mi):
    Composite VOC :   2.536   2.513   3.643   2.802   2.997  0.122   0.361   0.772    8.57   2.581
    Composite CO  :   18.79   20.43   25.50   21.72   30.76  2.126   1.637   1.417  103.86  19.830
    Composite NOX :   0.534   0.625   1.020   0.726   0.253  0.051   0.293   1.531    1.03   0.726
---------------------------------------------------------------------------------------------------
```

Figure 6.3 MOBILE 6 Report File

As indicated earlier, a custom designed Visual Basic® program was used to automatically calculate the total emissions per network link. The program was used to check link speed, get emission factors for that speed, get the link VMT and calculate the product of the two. (Link emissions = emission factor * link volume × link distance in miles) A flowchart of the process is illustrated.

Figure 6.4 Overall Procedure to Obtain Link Emission Results

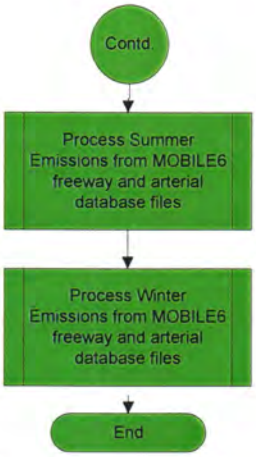

Figure 6.4 Cont'd

The following is a flowchart of the subroutines described above to process winter and summer emissions from MOBILE6 database files.

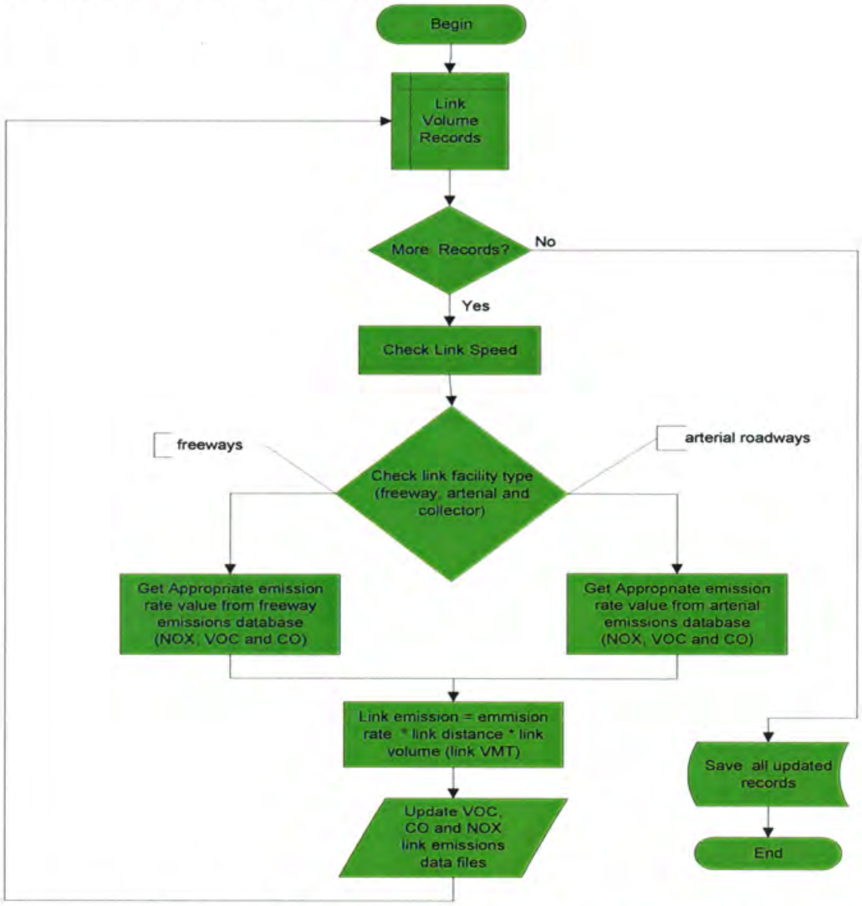

Figure 6.5 Winter and summer processing subroutine

The Visual Basic® code is illustrated in Appendix C. The subsequent emissions results were then aggregated for all the network links in the model. Results are presented in Chapter 7. SPSS ANOVA analysis of all links along with the aggregated emissions table mentioned above was then utilized to arrive at conclusions on the input model factors having the greatest effect on overall emissions output. Also discussed were the differences in emissions outputs per pollutant for winter and summer conditions.

CHAPTER 7. RESULTS

The tabular results of the sensitivity analysis process are presented in this chapter. The first table presented describes the overall emissions results for all links and both the winter and summer seasons. Following this, the tabular results for some of the selected links including approximate speeds and the VMTs are presented. The remaining results not shown here are described in Appendix F. Finally, a summary of the averaged emissions results over these 20 selected links is presented.

The 20 selected links consisted of a mixture of high speed, high volume links and low speed, low volume links. Analysis of these individual links helps to illustrate trends that are masked with aggregated results. An example of such an occurrence would be one link registering large changes whereas another similar link showing little or no change. Figure 7.1 below illustrates the selected links.

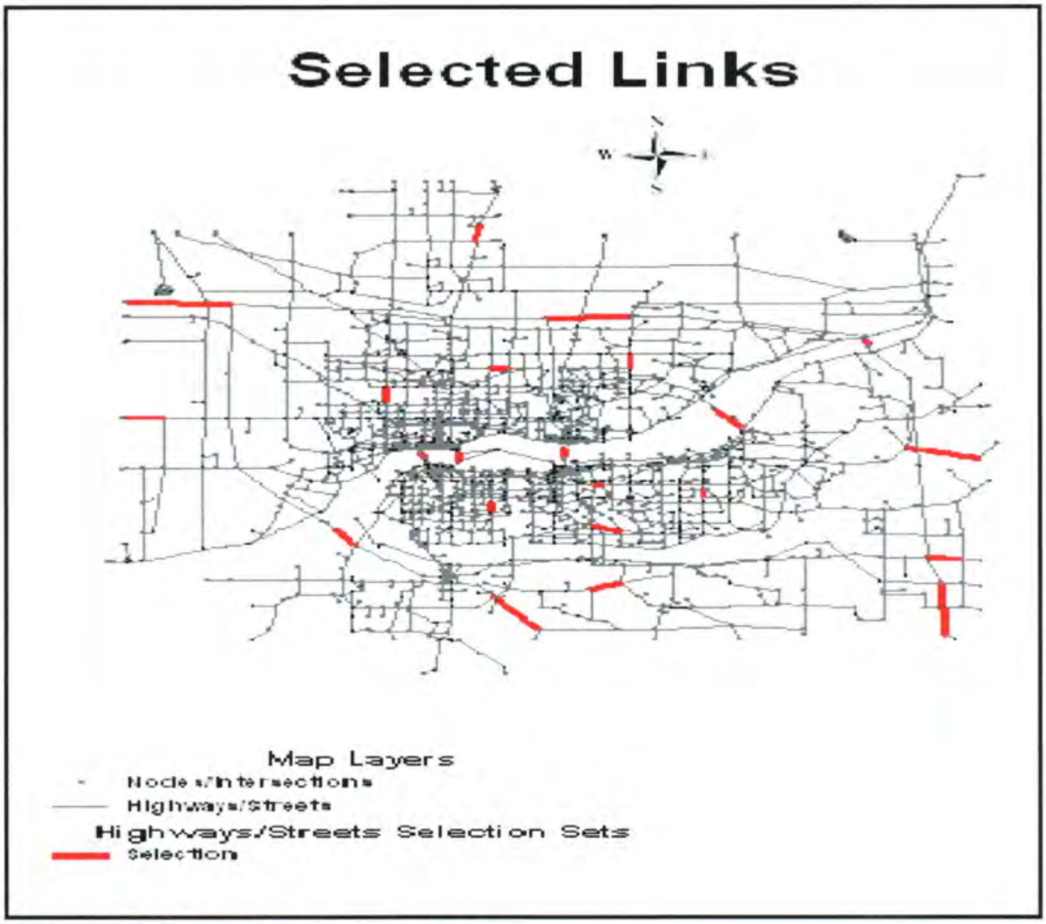

Figure 7.1 The 20 Selected Links

Table 7.1 Total Emissions Results by Input Factor, Season, and Pollutant

Run	Friction Distribution	Feedback	Assignment Technique	Winter CO g	Winter NOx g	Winter VOC g	Summer CO g	Summer NOx g	Summer VOC g
1	1st	Yes	Capacity Restraint	147,825,931	4,159,144	3,643,655	55,948,335	3,381,116	2,976,097
2		No		118,397,237	3,346,661	2,854,652	45,076,925	2,719,986	2,320,827
3		Yes	User Equilibrium	147,875,213	4,158,125	3,663,714	55,935,360	3,381,509	2,997,879
4		No		118,367,036	3,344,155	2,856,162	45,047,169	2,717,901	2,322,335
5		Yes	Incremental	146,544,498	4,121,042	3,644,783	55,433,625	3,352,083	2,985,770
6		No		117,793,423	3,321,157	2,884,804	44,711,221	2,700,519	2,355,029
7		Yes	Stochastic	122,024,515	3,445,276	2,987,062	46,325,415	2,801,935	2,438,084
8		No		122,024,515	3,445,276	2,987,062	46,325,415	2,801,935	2,438,084
9		Yes	Stochastic User Equilibrium	146,200,646	4,108,973	3,642,089	55,250,195	3,341,846	2,983,266
10		No		117,799,695	3,318,097	2,894,194	44,654,104	2,697,783	2,363,634
11	2nd	Yes	Capacity Restraint	160,711,897	4,509,024	4,058,903	60,683,927	3,669,723	3,340,385
12		No		166,444,545	4,680,308	4,139,514	63,041,112	3,807,822	3,394,798
13		Yes	User Equilibrium	162,894,661	4,578,514	4,059,384	61,619,184	3,724,102	3,327,705
14		No		166,053,234	4,681,478	4,054,543	62,964,166	3,805,306	3,304,296
15		Yes	Incremental	161,686,778	4,541,730	4,070,112	61,118,931	3,696,311	3,347,498
16		No	Incremental	163,068,702	4,576,803	4,099,436	61,722,071	3,725,786	3,374,338
17		Yes	Stochastic	170,756,087	4,813,035	4,205,872	64,670,897	3,914,436	3,436,646
18		No	Stochastic	170,756,087	4,813,035	4,205,872	64,670,897	3,914,436	3,436,646
19		Yes	Stochastic User Equilibrium	162,096,949	4,549,939	4,081,216	61,225,948	3,702,169	3,355,344
20		No		167,350,847	4,709,643	4,131,985	63,330,982	3,829,286	3,377,247
1	3rd	Yes	Capacity Restraint	137,016,115	3,854,036	3,376,645	51,860,254	3,132,903	2,758,006
2		No		140,454,049	3,963,711	3,406,265	53,352,563	3,221,316	2,771,991
3		Yes	User Equilibrium	138,126,085	3,892,452	3,387,472	52,379,939	3,164,598	2,764,793
4		No		140,746,913	3,971,356	3,414,644	53,462,490	3,227,460	2,778,903
5		Yes	Incremental	138,370,988	3,899,777	3,391,332	52,479,476	3,170,519	2,767,574
6		No	Incremental	140,473,384	3,966,910	3,409,092	53,376,111	3,224,472	2,775,200
7		Yes	Stochastic	145,663,783	4,114,576	3,525,116	55,375,939	3,344,386	2,867,798
8		No	Stochastic	145,663,783	4,114,576	3,525,116	55,375,939	3,344,386	2,867,798
9		Yes	Stochastic User Equilibrium	138,510,938	3,904,564	3,393,941	52,542,099	3,174,575	2,769,794
10		No		141,438,547	3,994,487	3,424,562	53,756,861	3,246,489	2,786,052

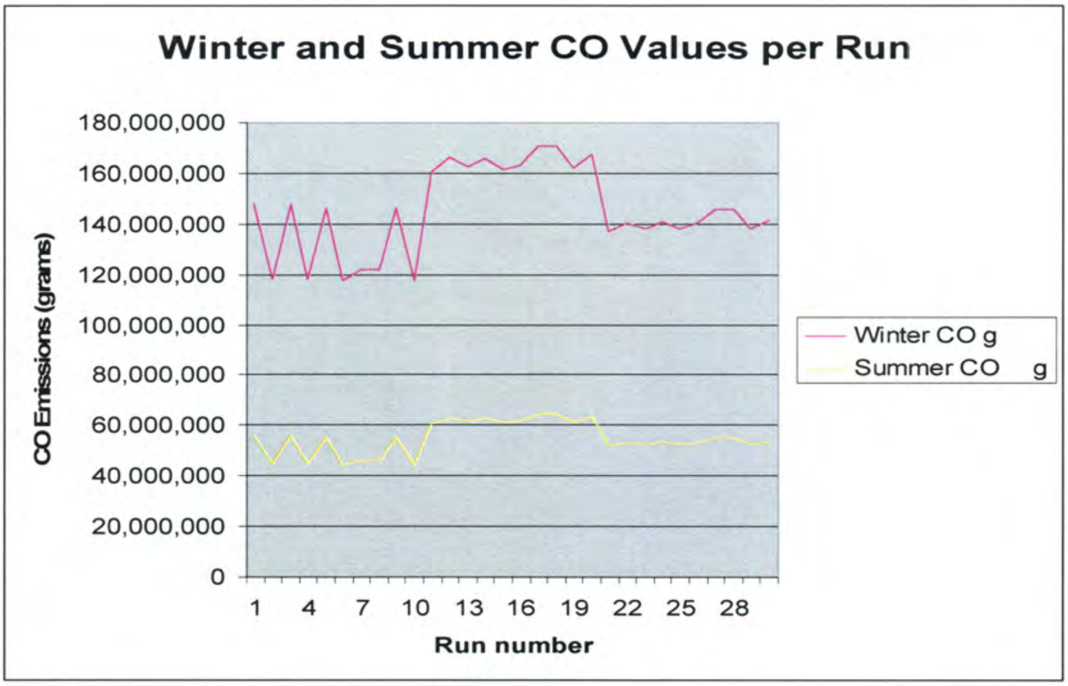

Figure 7.2 CO Emission results per sensitivity run

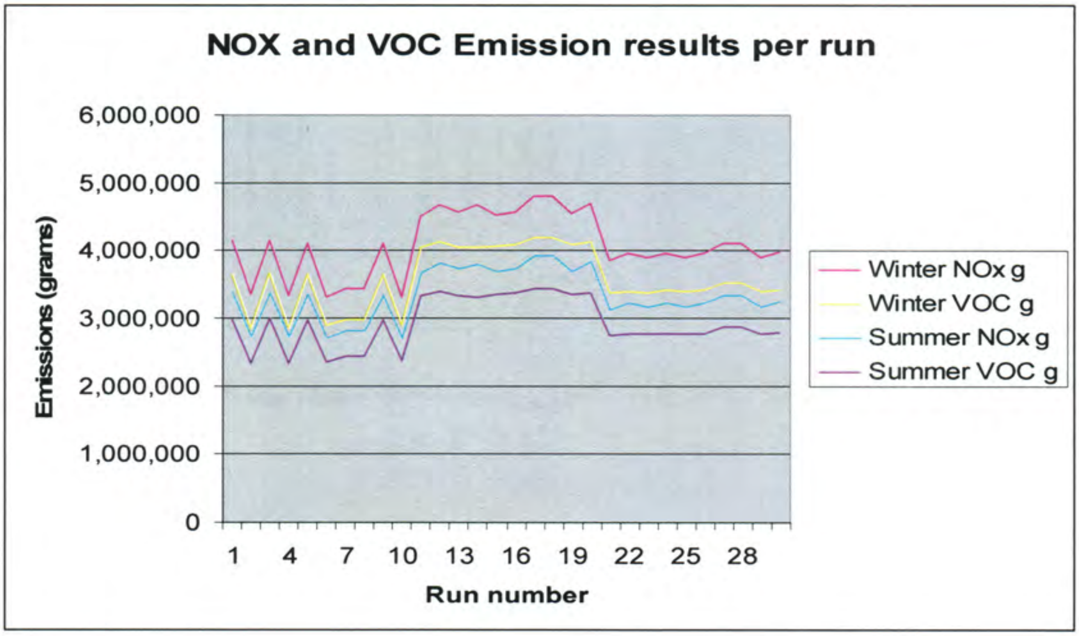

Figure 7.3 NOX and VOC Emission results per sensitivity run

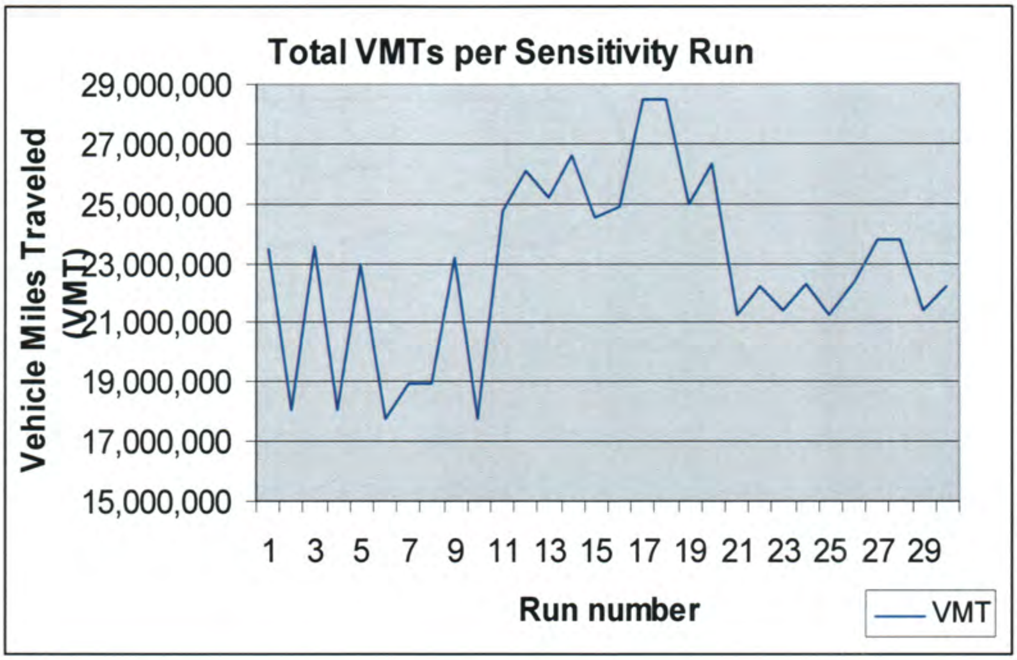

Figure 7.3 Total VMT's per Sensitivity Run

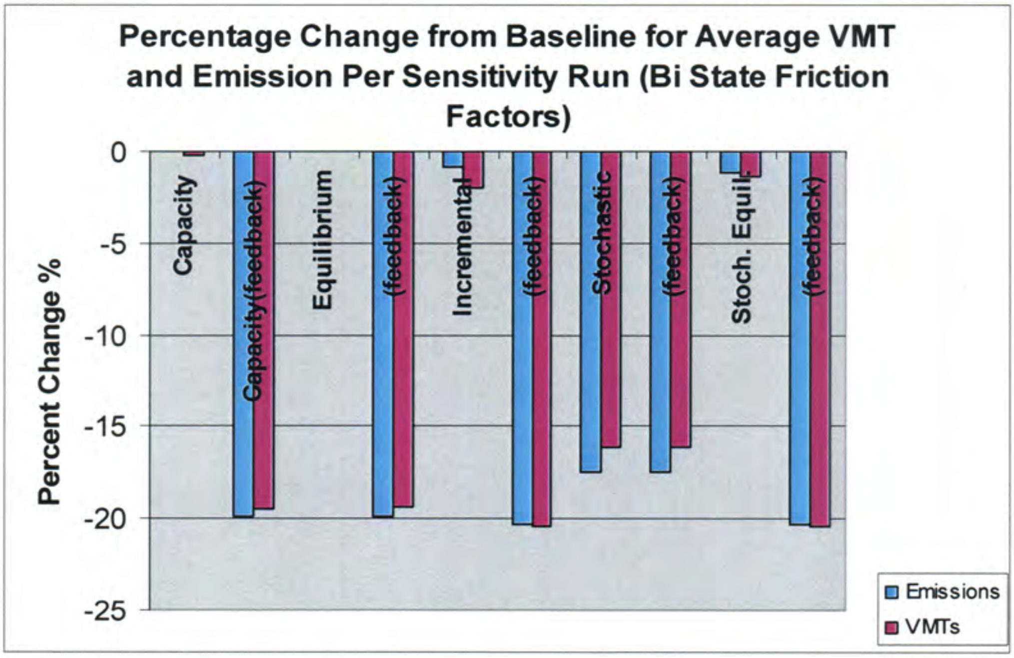

Figure 7.4 Percent Change from Baseline (Bi-State Friction Factor Distribution)

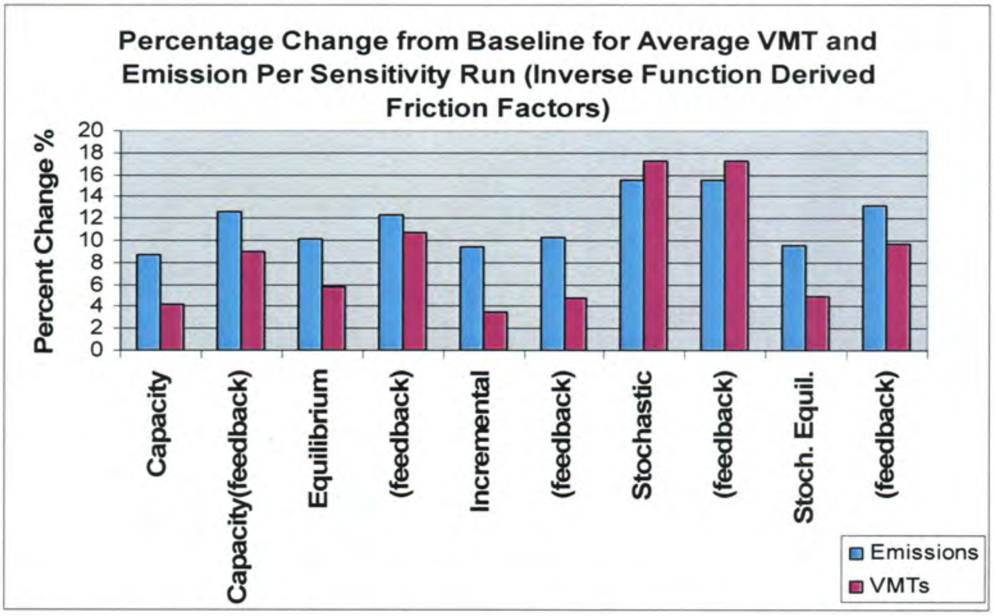

Figure 7.5 Percent Change from Baseline (Inverse Function Friction Factor Distribution)

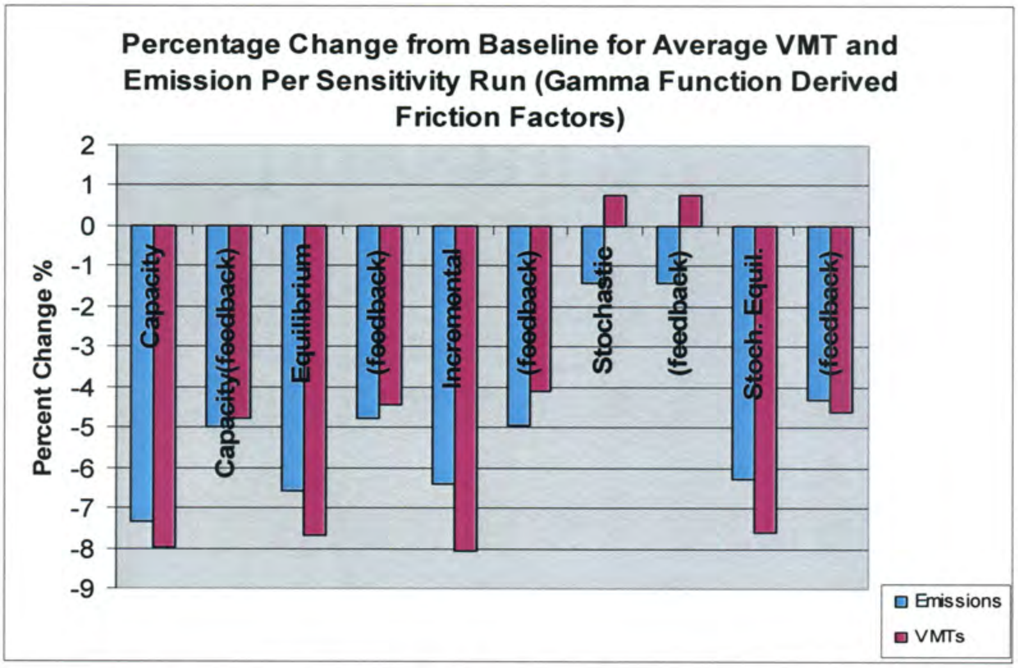

Figure 7.6 Percent Change from Baseline (Gamma Function Friction Factor Distribution)

For the following tables, the yellow row represents the initial input factor combination that was used during the calibration phase. Table 7.3 below represents the comparison for link ID 757 which is an undivided arterial. (roadway class = 3)

Table 7.2 Link ID 757 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	0.18	3	5,665	22	63,366	2,407	2,426	-3.35
2	0.18	3	3,290	25	36,808	1,398	1,409	-43.86
3	0.18	3	5,861	21	65,562	2,490	2,510	0
4	0.18	3	3,270	25	36,581	1,389	1,400	-44.2
5	0.18	3	5,115	20	57,217	2,173	2,190	-12.73
6	0.18	3	2,752	23	30,787	1,169	1,178	-53.04
7	0.18	3	3,593	23	40,190	1,526	1,538	-38.7
8	0.18	3	3,593	23	40,190	1,526	1,538	-38.7
9	0.18	3	5,234	21	58,553	2,224	2,241	-10.69
10	0.18	3	3,202	23	35,814	1,360	1,371	-45.37
11	0.18	3	6,085	15	66,628	2,494	2,457	1.62
12	0.18	3	7,844	18	91,682	3,520	3,674	39.84
13	0.18	3	6,647	16	77,684	2,983	3,113	18.49
14	0.18	3	7,205	22	80,593	3,061	3,085	22.93
15	0.18	3	4,987	15	63,244	1,923	2,706	-3.54
16	0.18	3	5,210	15	60,895	2,338	2,440	-7.12
17	0.18	3	11,734	21	131,259	4,985	5,024	100.21
18	0.18	3	11,734	21	131,259	4,985	5,024	100.21
19	0.18	3	6,010	15	76,215	2,936	3,261	16.25
20	0.18	3	7,535	18	88,070	3,381	3,530	34.33
21	0.18	3	5,648	21	63,176	2,399	2,418	-3.64
22	0.18	3	5,903	23	66,036	2,508	2,528	0.72
23	0.18	3	5,192	21	58,084	2,206	2,223	-11.41
24	0.18	3	6,010	23	67,226	2,553	2,573	2.54
25	0.18	3	5,212	21	58,298	2,214	2,231	-11.08
26	0.18	3	6,180	23	69,133	2,626	2,646	5.45
27	0.18	3	7,291	25	79,839	2,988	2,944	21.78
28	0.18	3	7,291	25	79,839	2,988	2,944	21.78
29	0.18	3	5,267	21	58,923	2,238	2,255	-10.13
30	0.18	3	5,644	24	63,130	2,398	2,416	-3.71

From the table, it is apparent that the greatest change in emissions (100%) occurred with the use of the second friction factor distribution with stochastic assignment. The highest emissions values were also recorded on that run which corresponded with the highest VMT value of 11,734.04. The speed was 21.38 mph, higher than the mean value for all runs of 20.97 mph. Other notable changes include the 53% decline in run 6.

The following table shows link ID 1286 that is a collector. (Roadway class = 4)

Table 7.3 Link ID 1286 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	0.24	4	1677	26	28541	1068	1052	-7.88
2	0.24	4	2829	31	18373	679	646	-40.7
3	0.24	4	1690	26	30983	1160	1142	0
4	0.24	4	2061	31	18519	684	651	-40.23
5	0.24	4	1657	24	23056	876	883	-25.59
6	0.24	4	1414	27	18141	679	669	-41.45
7	0.24	4	1414	27	15485	580	571	-50.02
8	0.24	4	2209	27	15485	580	571	-50.02
9	0.24	4	1497	24	24706	938	946	-20.26
10	0.24	4	2286	27	16396	614	605	-47.08
11	0.24	4	2735	19	26713	1026	1071	-13.78
12	0.24	4	2415	24	30595	1162	1171	-1.25
13	0.24	4	3320	22	27011	1026	1034	-12.82
14	0.24	4	2500	26	36352	1361	1340	17.33
15	0.24	4	2721	20	31706	1051	1357	2.33
16	0.24	4	2302	22	30440	1156	1165	-1.75
17	0.24	4	2302	26	25203	943	929	-18.66
18	0.24	4	2510	26	25203	943	929	-18.66
19	0.24	4	2582	20	28082	1067	1075	-9.36
20	0.24	4	2224	24	28886	1097	1106	-6.77
21	0.24	4	2621	25	24357	912	898	-21.39
22	0.24	4	2528	29	28699	1074	1058	-7.37
23	0.24	4	2390	26	27685	1036	1021	-10.64
24	0.24	4	1400	30	30304	1167	1297	-2.19
25	0.24	4	2757	25	17750	684	760	-42.71
26	0.24	4	2028	29	30187	1130	1113	-2.57
27	0.24	4	2028	31	22218	821	781	-28.29
28	0.24	4	2428	31	22218	821	781	-28.29
29	0.24	4	2571	26	26586	995	980	-14.19
30	0.24	4	0	29	28152	1054	1038	-9.14

Unlike the case for the previous link, the largest change occurred between the base case and runs 7 and 8 which corresponded to friction distribution 1; assignment technique stochastic with and without feedback looping. As with the previous case however, the greater emissions corresponded to higher VMT and average speed values, which is generally expected from modeling theory.

The following table presents the results for link 2898. This link is a freeway link representing the Interstate 80 Mississippi River bridge crossing. (Roadway Class = 1)

Table 7.4 Link ID 2898 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	0.18	1	6,722	51	83,271	3,043	2,425	5.31
2	0.18	1	5,166	53	63,994	2,338	1,864	-19.07
3	0.18	1	6,383	53	79,073	2,889	2,303	0
4	0.18	1	4,492	54	55,640	2,033	1,620	-29.64
5	0.18	1	7,215	51	89,376	3,266	2,603	13.03
6	0.18	1	6,294	52	77,969	2,849	2,271	-1.4
7	0.18	1	6,405	53	79,340	2,899	2,311	0.34
8	0.18	1	6,405	53	79,340	2,899	2,311	0.34
9	0.18	1	6,532	50	78,565	2,852	2,395	-0.64
10	0.18	1	6,259	52	77,533	2,833	2,258	-1.95
11	0.18	1	9,925	42	115,957	4,213	3,706	46.65
12	0.18	1	8,351	49	100,431	3,645	3,062	27.01
13	0.18	1	9,577	48	115,187	4,181	3,512	45.67
14	0.18	1	8,888	52	110,102	4,023	3,206	39.24
15	0.18	1	11,078	43	129,435	11,702	4,137	63.69
16	0.18	1	9,755	48	117,325	4,259	3,577	48.38
17	0.18	1	8,345	52	103,371	3,777	3,010	30.73
18	0.18	1	8,345	52	103,371	3,777	3,010	30.73
19	0.18	1	9,889	43	115,538	4,198	3,693	46.12
20	0.18	1	9,322	49	112,119	4,070	3,418	41.79
21	0.18	1	6,066	51	75,139	2,746	2,188	-4.98
22	0.18	1	7,121	53	88,212	3,223	2,569	11.56
23	0.18	1	7,716	52	95,586	3,493	2,784	20.88
24	0.18	1	6,016	54	74,519	2,723	2,170	-5.76
25	0.18	1	6,709	52	83,104	3,037	2,420	5.1
26	0.18	1	6,259	53	77,527	2,833	2,258	-1.95
27	0.18	1	6,246	54	77,378	2,827	2,253	-2.14
28	0.18	1	6,246	54	77,378	2,827	2,253	-2.14
29	0.18	1	7,143	52	88,489	3,233	2,577	11.91
30	0.18	1	6,313	53	78,204	2,857	2,278	-1.1

For this link, the largest emissions values and greatest changes were obtained between runs 11 and 20 that correspond to friction distribution 2. The average speeds were lower in these runs than the other runs. The effect of the lower speeds was however countered by much higher VMT values, in some cases the differences being nearly 4000 vehicle miles per day.

The following table presents the results for link 2830. This link is an arterial link located on the Davenport Iowa side of the Bi-State area near the Central Business District. (Roadway class = 3)

Table 7.5 Link ID 2830 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	0.6	3	12,101	37	136,804	4,977	4,541	-4.9
2	0.6	3	11,240	39	127,071	4,623	4,218	-11.66
3	0.6	3	12,724	37	143,851	5,233	4,774	0
4	0.6	3	10,683	39	120,781	4,394	4,009	-16.04
5	0.6	3	10,881	35	123,014	4,475	4,083	-14.48
6	0.6	3	10,856	37	122,739	4,465	4,074	-14.68
7	0.6	3	10,479	38	118,471	4,310	3,932	-17.64
8	0.6	3	10,479	38	118,471	4,310	3,932	-17.64
9	0.6	3	10,846	35	118,825	4,390	4,177	-17.4
10	0.6	3	10,554	37	119,320	4,341	3,960	-17.05
11	0.6	3	11,334	34	124,175	4,587	4,365	-13.68
12	0.6	3	13,806	36	156,089	5,678	5,181	8.51
13	0.6	3	12,592	35	140,858	5,349	5,392	-2.08
14	0.6	3	13,834	38	156,398	5,689	5,191	8.72
15	0.6	3	11,457	34	125,515	2,135	4,412	-12.75
16	0.6	3	13,167	35	144,253	5,329	5,071	0.28
17	0.6	3	12,807	38	144,786	5,267	4,806	0.65
18	0.6	3	12,807	38	144,786	5,267	4,806	0.65
19	0.6	3	11,490	33	125,877	4,650	4,425	-12.49
20	0.6	3	13,573	36	153,453	5,582	5,093	6.68
21	0.6	3	10,137	38	114,610	4,169	3,804	-20.33
22	0.6	3	11,218	39	126,821	4,614	4,209	-11.84
23	0.6	3	10,694	38	120,906	4,398	4,013	-15.95
24	0.6	3	11,560	39	130,693	4,754	4,338	-9.15
25	0.6	3	10,666	37	120,590	4,387	4,002	-16.17
26	0.6	3	12,035	39	136,067	4,950	4,516	-5.41
27	0.6	3	10,695	40	120,918	4,399	4,013	-15.94
28	0.6	3	10,695	40	120,918	4,399	4,013	-15.94
29	0.6	3	9,964	38	112,648	4,098	3,739	-21.69
30	0.6	3	11,242	39	127,099	4,624	4,218	-11.64

As in the case of the freeway link, the highest overall emissions values were noted for runs between 11 and 20. (Inverse Function friction factors) In contrast to the freeway link however, the changes were much smaller with the highest positive change being 8.5%. In addition, the majority of runs produced declines in emission values. For most of the runs showing declines, average speeds were between 35 and 40 mph with VMT values lower than the base scenario.

The following table presents the results for link 1551, a collector link located on the Illinois side in Moline. (Roadway class = 4)

Table 7.6 Link 1551 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	0.25	4	2,252	33	24,671	911	867	-0.55
2	0.25	4	2,304	38	26,048	948	865	5
3	0.25	4	2,264	33	24,808	916	872	0
4	0.25	4	2,330	37	26,342	958	874	6.18
5	0.25	4	2,121	30	23,233	858	817	-6.35
6	0.25	4	1,988	33	21,783	805	766	-12.19
7	0.25	4	1,982	34	21,719	802	763	-12.45
8	0.25	4	1,982	34	21,719	802	763	-12.45
9	0.25	4	1,981	32	21,706	802	763	-12.5
10	0.25	4	1,371	34	15,015	555	528	-39.48
11	0.25	4	2,261	30	24,753	927	913	-0.22
12	0.25	4	2,558	34	28,022	1,035	985	12.95
13	0.25	4	2,229	32	24,423	902	858	-1.55
14	0.25	4	2,510	37	28,381	1,032	942	14.4
15	0.25	4	2,193	30	24,010	1,046	885	-3.22
16	0.25	4	2,278	31	24,960	922	877	0.61
17	0.25	4	2,457	36	27,776	1,010	922	11.96
18	0.25	4	2,457	36	27,776	1,010	922	11.96
19	0.25	4	2,206	31	24,166	893	849	-2.59
20	0.25	4	2,263	34	24,796	916	872	-0.05
21	0.25	4	2,129	35	23,327	862	820	-5.97
22	0.25	4	2,236	38	25,282	920	839	1.91
23	0.25	4	1,979	35	22,368	814	742	-9.83
24	0.25	4	2,242	38	25,347	922	841	2.17
25	0.25	4	1,997	34	21,879	808	769	-11.81
26	0.25	4	2,400	37	27,137	987	901	9.39
27	0.25	4	2,433	39	27,510	1,001	913	10.89
28	0.25	4	2,433	39	27,510	1,001	913	10.89
29	0.25	4	1,839	36	20,786	756	690	-16.21
30	0.25	4	2,044	38	23,107	841	767	-6.86

Following the general trend of the previously studied links, the highest emission values were observed in the runs between 11 and 20. Of note however are the high values for runs 27 and 28 which are Stochastic (feedback and non feedback cases). In all cases where emissions are high, the VMTs and average speeds per run are correspondingly high.

The following table presents the results for link 1131, a freeway link representing the Interstate 74 Mississippi River bridge crossing. (Roadway class = 1)

Table 7.7 link 1131 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	0.37	1	29,179	46	350,927	12,737	10,699	1.22
2	0.37	1	14,779	50	183,079	6,690	5,332	-47.86
3	0.37	1	28,827	46	346,697	12,584	10,570	0
4	0.37	1	14,817	50	183,540	6,706	5,345	-47.73
5	0.37	1	27,735	44	324,042	11,774	10,358	-4.99
6	0.37	1	15,181	47	182,574	6,627	5,566	-47.34
7	0.37	1	14,189	48	170,655	6,194	5,203	-50.78
8	0.37	1	14,189	48	170,655	6,194	5,203	-50.78
9	0.37	1	27,289	43	318,834	11,585	10,191	-6.52
10	0.37	1	15,140	47	182,083	6,609	5,551	-47.48
11	0.37	1	28,249	34	314,755	11,646	11,087	-3.93
12	0.37	1	37,583	38	426,829	15,636	14,332	27.65
13	0.37	1	31,760	36	360,698	13,213	12,112	7.87
14	0.37	1	41,416	43	483,886	17,582	15,467	41.87
15	0.37	1	27,066	34	301,578	6,387	10,623	-20.59
16	0.37	1	28,766	35	407,585	14,837	18,942	38.22
17	0.37	1	37,931	43	443,164	16,102	14,165	29.93
18	0.37	1	37,931	43	443,164	16,102	14,165	29.93
19	0.37	1	27,941	35	311,325	11,519	10,966	-4.97
20	0.37	1	37,046	38	420,725	15,412	14,127	25.83
21	0.37	1	27,315	44	319,137	11,596	10,201	-6.43
22	0.37	1	30,373	48	365,296	13,259	11,137	5.36
23	0.37	1	27,473	44	320,980	11,663	10,260	-5.89
24	0.37	1	30,417	48	365,817	13,278	11,153	5.51
25	0.37	1	27,341	44	319,446	11,607	10,211	-6.34
26	0.37	1	30,718	48	369,441	13,409	11,263	6.56
27	0.37	1	33,804	50	418,752	15,301	12,195	19.25
28	0.37	1	33,804	50	418,752	15,301	12,195	19.25
29	0.37	1	26,411	44	308,571	11,212	9,863	-9.53
30	0.37	1	30,512	48	366,958	13,319	11,188	5.84

The VMT and emissions values were highest between runs 11 and 20. In addition, the absolute value of the percentage changes was also high in this range. The largest percentage change was an approximately 50% decline from the base situation when the Stochastic assignment technique was utilized. (Runs 7 and 8) The average speeds were lower in runs 11 - 20 than between runs 1 – 10 and 21 – 30 and indicate some measure of congestion on the bridge when friction distribution 2 is applied.

The following table presents the results for link 2648, a freeway link representing the Interstate 80 in the Western sector of the model. (Roadway class = 1)

Table 7.8 Link ID 2648 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	2.61	1	143,435	54	1,776,807	64,923	51,746	0
2	2.61	1	142,475	60	1,821,858	67,518	50,851	1.6
3	2.61	1	143,435	54	1,776,807	64,923	51,746	0
4	2.61	1	142,475	60	1,821,858	67,518	50,851	1.6
5	2.61	1	143,435	49	1,725,081	62,614	52,593	-1.61
6	2.61	1	142,475	54	1,764,905	64,488	51,399	-0.67
7	2.61	1	142,475	57	1,821,858	67,518	50,851	1.6
8	2.61	1	142,475	57	1,821,858	67,518	50,851	1.6
9	2.61	1	143,435	49	1,725,081	62,614	52,593	-1.61
10	2.61	1	142,475	54	1,764,905	64,488	51,399	-0.67
11	2.61	1	143,435	52	1,776,807	64,923	51,746	0
12	2.61	1	143,435	57	1,834,144	67,974	51,194	2.29
13	2.61	1	143,435	54	1,776,807	64,923	51,746	0
14	2.61	1	143,435	60	1,834,144	67,974	51,194	2.29
15	2.61	1	143,435	51	1,776,807	31,550	51,746	-6.13
16	2.61	1	143,435	54	1,776,807	64,923	51,746	0
17	2.61	1	143,435	60	1,834,144	67,974	51,194	2.29
18	2.61	1	143,435	60	1,834,144	67,974	51,194	2.29
19	2.61	1	143,435	51	1,776,807	64,923	51,746	0
20	2.61	1	143,435	57	1,834,144	67,974	51,194	2.29
21	2.61	1	143,435	54	1,776,807	64,923	51,746	0
22	2.61	1	143,435	60	1,834,144	67,974	51,194	2.29
23	2.61	1	143,435	54	1,776,807	64,923	51,746	0
24	2.61	1	143,435	60	1,834,144	67,974	51,194	2.29
25	2.61	1	143,435	54	1,776,807	64,923	51,746	0
26	2.61	1	143,435	60	1,834,144	67,974	51,194	2.29
27	2.61	1	143,435	63	1,896,665	72,031	50,870	5.33
28	2.61	1	143,435	63	1,896,665	72,031	50,870	5.33
29	2.61	1	143,435	54	1,776,807	64,923	51,746	0
30	2.61	1	143,435	60	1,834,144	67,974	51,194	2.29

Unlike the previous comparisons, the changes on this link were very small. There was no percentage change greater than 7%. This is possibly explained by the fact that the link represents the western departure from the model of Interstate 80. Consequently, the influence of the sensitivity runs was diminished given that a greater proportion of the trips are external, the OD values of which were not varied during the sensitivity runs.

The following table presents the results for link 1439, an arterial link representing a new Mississippi River crossing immediately to the Southwest of the Interstate 80 crossing.

Table 7.9 Link ID 1439

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case CO
1	0.8	4	18,687	29	204,625	7,659	7,544	0.34
2	0.8	4	7,560	30	82,778	3,098	3,052	-59.41
3	0.8	4	18,624	29	203,931	7,633	7,519	0
4	0.8	4	7,531	30	82,462	3,087	3,040	-59.56
5	0.8	4	18,517	28	202,766	7,590	7,476	-0.57
6	0.8	4	7,555	29	82,724	3,096	3,050	-59.44
7	0.8	4	7,415	29	81,198	3,039	2,994	-60.18
8	0.8	4	7,415	29	81,198	3,039	2,994	-60.18
9	0.8	4	19,364	28	212,039	7,937	7,818	3.98
10	0.8	4	7,710	29	84,430	3,160	3,113	-58.6
11	0.8	4	24,383	24	272,749	10,358	10,440	33.75
12	0.8	4	25,152	27	275,414	10,309	10,154	35.05
13	0.8	4	24,200	26	264,993	9,919	9,770	29.94
14	0.8	4	23,316	29	255,311	9,556	9,413	25.19
15	0.8	4	23,917	25	267,535	7,187	10,241	31.19
16	0.8	4	25,467	26	278,869	10,438	10,282	36.75
17	0.8	4	25,996	29	284,656	10,655	10,495	39.58
18	0.8	4	25,996	29	284,656	10,655	10,495	39.58
19	0.8	4	24,221	24	270,946	10,290	10,371	32.86
20	0.8	4	25,550	27	279,774	10,472	10,315	37.19
21	0.8	4	18,287	29	200,242	7,495	7,383	-1.81
22	0.8	4	15,735	30	172,305	6,449	6,353	-15.51
23	0.8	4	18,427	29	201,781	7,553	7,440	-1.05
24	0.8	4	15,478	30	169,486	6,344	6,249	-16.89
25	0.8	4	18,357	29	201,015	7,524	7,411	-1.43
26	0.8	4	15,082	30	165,152	6,182	6,089	-19.02
27	0.8	4	14,075	30	154,126	5,769	5,683	-24.42
28	0.8	4	14,075	30	154,126	5,769	5,683	-24.42
29	0.8	4	18,752	29	205,334	7,686	7,571	0.69
30	0.8	4	16,078	30	176,051	6,590	6,491	-13.67

As with previously analyzed links, the greatest emission and VMT values were observed for runs 11 – 20 with correspondingly high percentage changes from the base case. The average speeds on the link were in the high 20s mph that is close to the mean value observed for the 30 runs of 28.38 mph.

The remaining 12 tables are presented in Appendix F. From the tables, it can be seen that the highest emissions values occurred on freeway links. It was also observed that for most of the links analyzed, the largest changes occurred on the runs using the second friction factor distribution (Inverse Function). The following table illustrates the mean VMT, emission and speed values for each run over all selected links.

Table 7.10 All Selected Links

Run Number	Link Length (miles)	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	Average Percentage change in Emissions
1	0.18	20,391	40	250,237	9,196	7,470	-0.14
2	0.18	16,711	42	210,246	7,809	6,003	-17.02
3	0.18	20,353	40	250,651	9,234	7,457	0
4	0.18	16,387	42	206,700	7,680	5,901	-18.41
5	0.18	20,742	39	250,940	9,204	7,645	0.77
6	0.18	17,313	41	213,872	7,869	6,294	-15.02
7	0.18	17,500	41	218,471	8,084	6,340	-13.43
8	0.18	17,540	41	218,471	8,084	6,340	-13.43
9	0.18	20,414	39	246,947	9,061	7,538	-0.76
10	0.18	17,292	41	212,999	7,839	6,271	-15.35
11	0.18	22,896	36	274,671	10,084	8,511	10.97
12	0.18	23,153	39	284,935	10,532	8,508	13.94
13	0.18	23,163	37	280,688	10,323	8,553	12.82
14	0.18	22,945	41	284,349	10,520	8,393	13.3
15	0.18	23,686	36	284,779	6,650	8,856	1.46
16	0.18	23,533	37	289,895	10,646	9,077	17.55
17	0.18	22,956	41	283,196	10,478	8,397	13.02
18	0.18	22,967	41	283,196	10,478	8,397	13.02
19	0.18	23,144	36	278,361	10,220	8,638	12.52
20	0.18	23,666	39	291,346	10,765	8,695	16.47
21	0.18	19,724	40	241,154	8,865	7,206	-3.72
22	0.18	19,805	42	248,354	9,217	7,182	-1.6
23	0.18	20,333	40	248,938	9,147	7,436	-0.64
24	0.18	19,309	42	242,905	9,020	7,037	-3.69
25	0.18	20,015	40	244,350	8,982	7,301	-2.45
26	0.18	19,360	42	243,119	9,025	7,034	-3.65
27	0.18	19,238	43	243,944	9,136	6,952	-3.51
28	0.18	19,258	43	243,944	9,136	6,952	-3.51
29	0.18	20,243	40	247,650	9,101	7,400	-1.14
30	0.18	19,475	42	245,712	9,122	7,111	-2.61

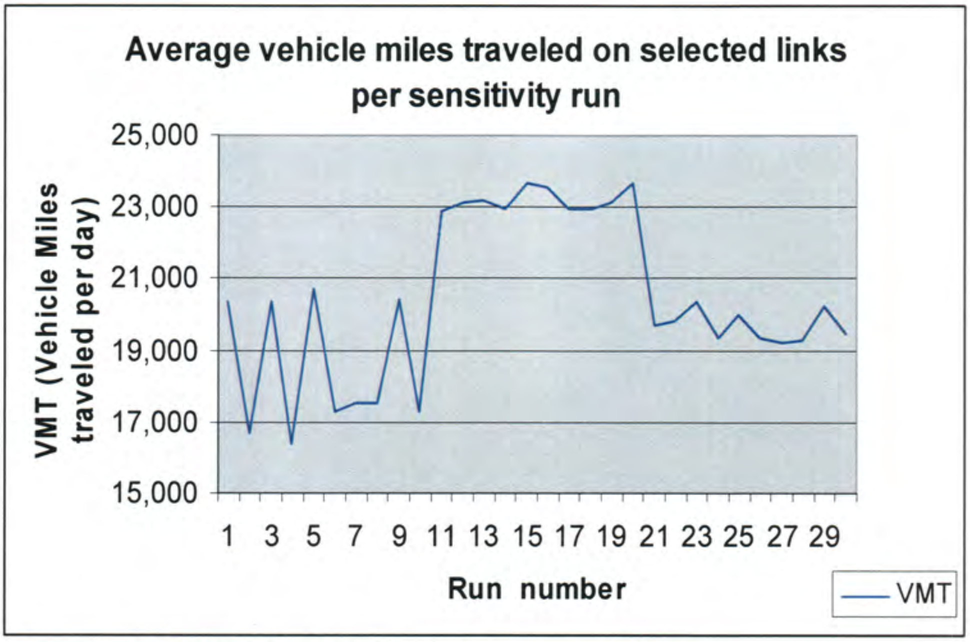

Figure 7.7 Vehicle Miles Traveled per sensitivity run

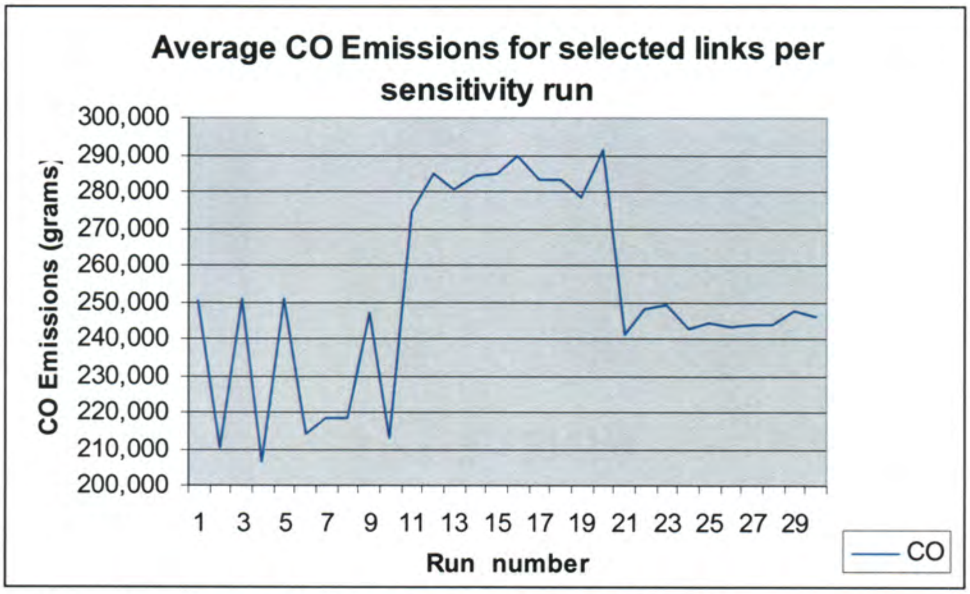

Figure 7.8 Average CO Emissions per sensitivity run

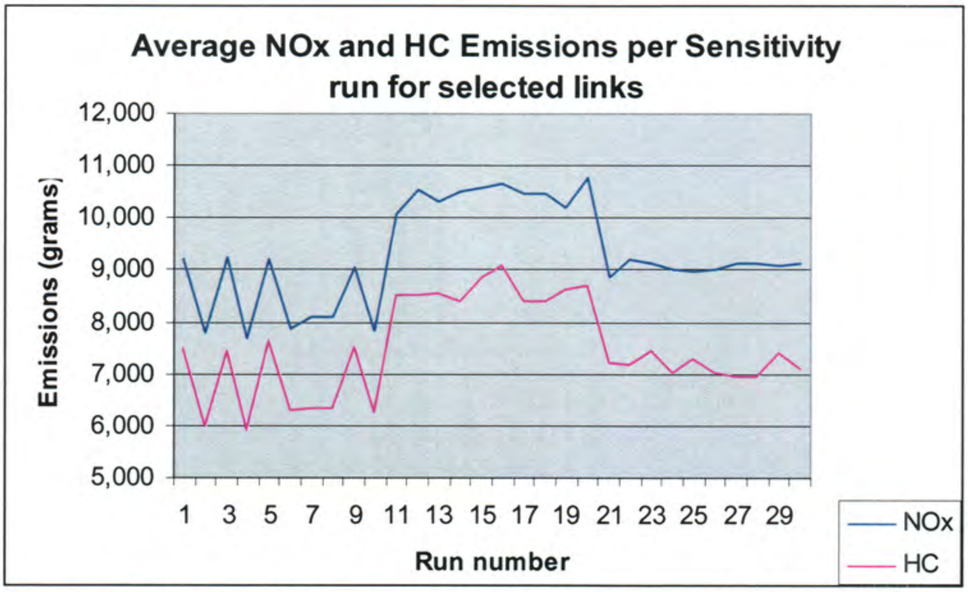

Figure 7.9 Average HC and NOx Results for Selected Links

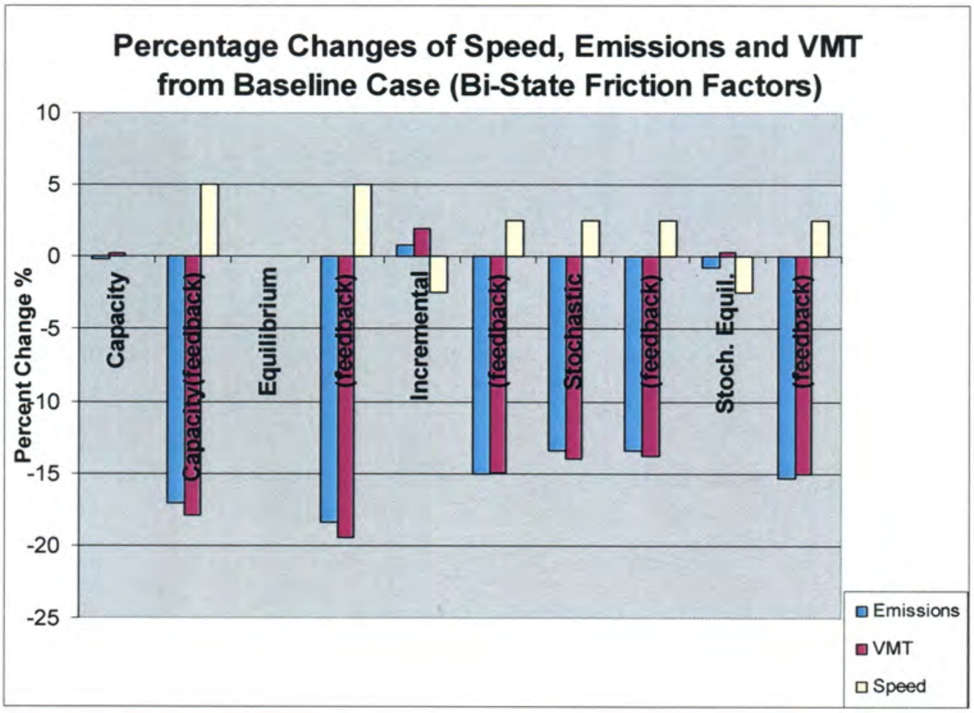

Figure 7.10 Percent change from Baseline for Speed, Emissions and VMTs for selected cases (Bi State Friction Factors)

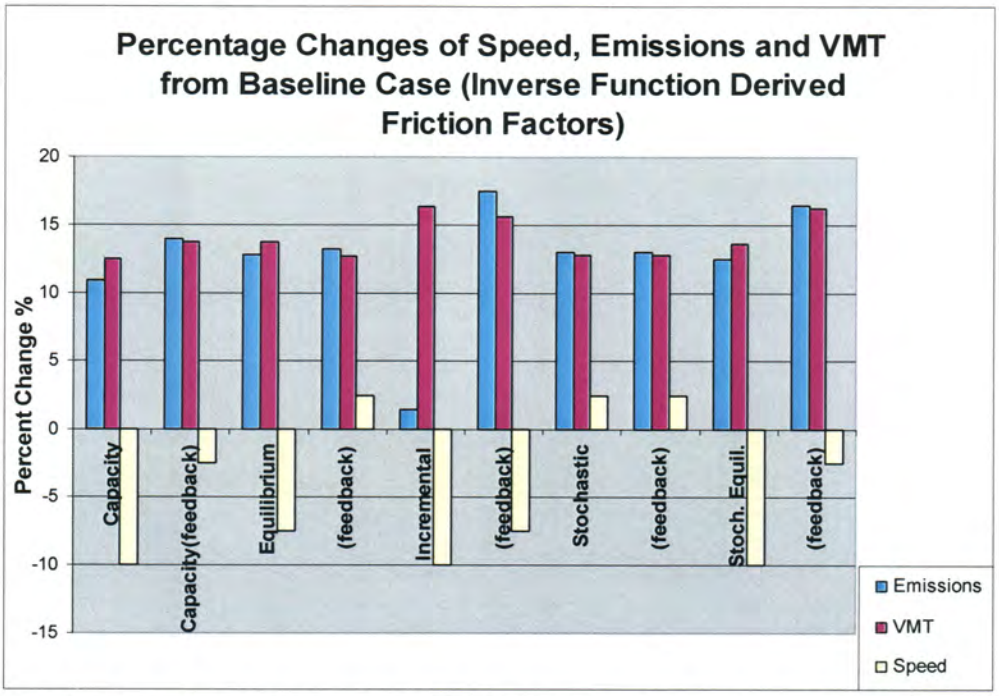

Figure 7.11 Percent Change for Speed, Emissions and VMT from Baseline (Inverse Function Derived Friction Factors)

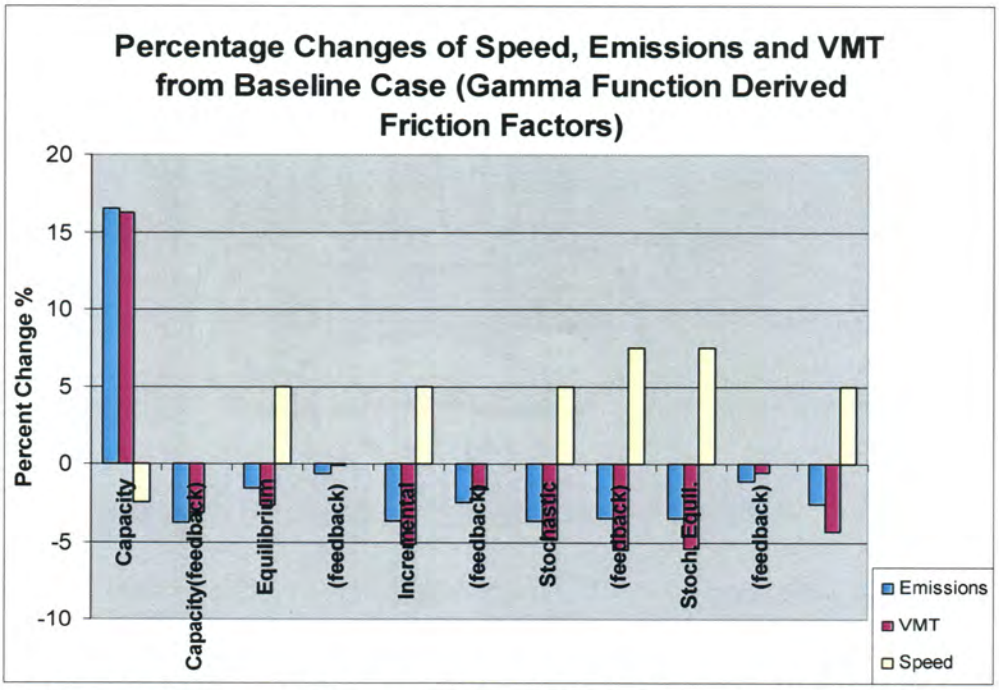

Figure 7.12 Percent Change for Speed, Emissions and VMT from Baseline (Gamma Function Derived Friction Factors)

CHAPTER 8. ANALYSIS OF RESULTS

STATISTICAL ANOVA

The basic task being undertaken in this research is a comparison of the results of a response variable (NO_x, VOC and CO pollutant levels) over categories of three explanatory variables. The basic statistical tool used to compare the means of groups is the difference in means t-test. In such a test, a t-statistic for the group differences is calculated and used via a lookup table to obtain the P-value. Analysis of Variance (ANOVA) represents a generalization of the difference in means t-test where two or more groups can be compared. In fact, the resulting F test statistic for an ANOVA with two groups and one explanatory variable is equivalent to the square of the t-statistic for the t-test. $F = t^2$. (27, 28) The t-test statistic is shown below.

$$t = \frac{(\bar{y}_1 - \bar{y}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \text{ where n is large } (> 30) \quad (27, 28)$$

where $\bar{y}_1$ = the mean for group 1

$\bar{y}_2$ = the mean of group 2

s_1= sample standard deviation of group 1

s_2 = sample standard deviation of group 2

n_1 = number of samples in group 1

n_2 = number of samples in group 2

In addition to comparing dependent variable results over categories of one explanatory factor, multi-factor ANOVA can be employed to compare results for multiple explanatory factors. Each factor is tested independently while automatically controlling for the effects of the other factors. This technique allows for rapid identification of the significant factors and any significant interacting effects between the factors by obviating the need to individually compare two factors at a time using one-factor ANOVA.

ANOVA ANALYSIS OF INPUTS

Following the use of the univariate GLM (General Linear Model) procedure in SPSS to perform multi-factor ANOVA, it was concluded that at least one of the input factors had a statistically significant effect on the output emissions. The following hypothesis test was used to arrive at such a conclusion.

ANOVA Assumptions
(1) Population distribution of the emissions is normal.
(2) Population Standard deviations (variances) of each group are equal.

SPSS histograms were used to check the assumption of normality for the distribution of emissions results over all sensitivity runs.

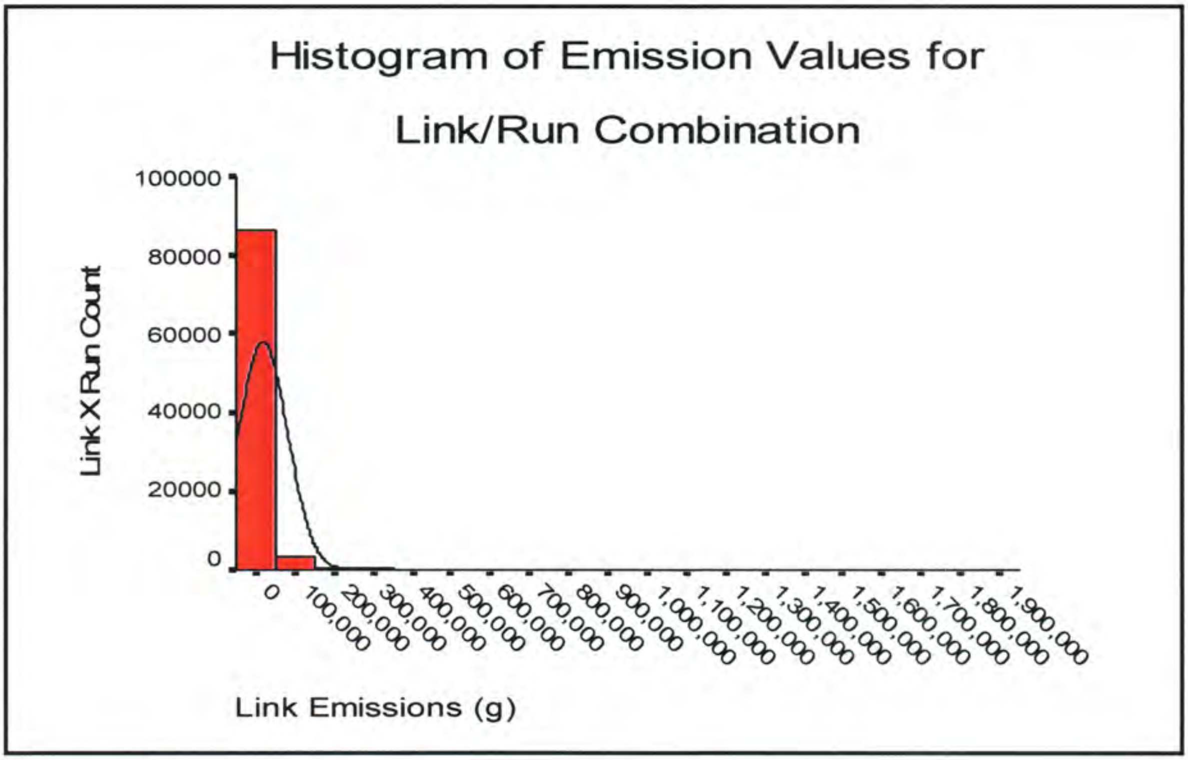

Figure 8.1 Frequency distribution of emissions values

From the histogram above, it was apparent that the emissions data were not perfectly normally distributed. This is not surprising given that in many urban areas, larger roadways carry a disproportionate share of the total traffic. Consequently, it was decided to modify the data by taking the cube root of emissions to get a more normally distributed dataset. This technique is accepted practice in many statistical situations and still allows meaningful conclusions regarding factor effects to be drawn about the group differences despite lower absolute values. (29) The order of the differences between input factor combinations will thus be unchanged for the cube root of emissions allowing the same conclusions to be drawn. The following illustrates the modified distribution, which is now approximately normal in character.

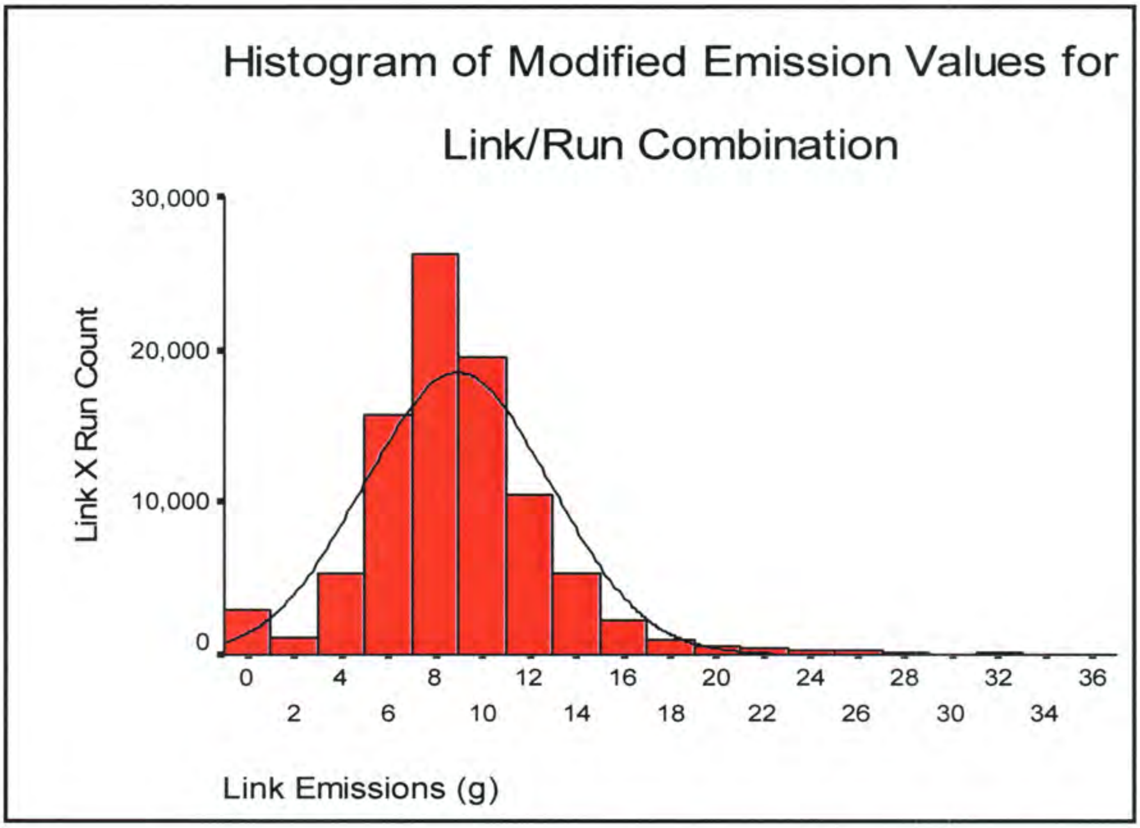

Figure 8.2 Frequency distribution of modified emissions values

For the equality of variances assumption, SPSS provides a test called Levene's test, which is simply an ANOVA on the model variances instead of the model means. The results of Levene's test are displayed along with the ANOVA result table. If the variances are found to be non-homogenous (not equal), several methods may be applied to rectify the problem. They include: (29)

1. Trimming data of outlying values.
2. Transforming the data (similar to procedure done above by getting the cube root of the emissions values).
3. Using ANOVA corrections.
4. Using a distribution free ANOVA test such as the *Kruskall-Wallis* or *Friedman* test where no assumptions are made regarding data normality and variances.

HYPOTHESES:

H_o: mean emissions value for all runs is equal

H_a: At least one mean from the set of runs is different.

Table 8.1
Between-Subjects Factors

		Value Label	N
Friction Scenario	1	first friction run	30590
	2	2nd friction run	30590
	3	3rd friction run	30590
Feedback/No Feedback	1	no feedback	45885
	2	Feedback	45885
Assignment Technique	1	Capacity Restraint	18354
	2	User Equilibrium	18354
	3	Incremental	18354
	4	Stochastic	18354
	5	Stochastic User Equilibrium	18354

Table 8.2 Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
Levene's Test of Equality of Error Variances
Dependent Variable: NEWEMM

F	df1	df2	Sig.
8.21	29	91740	0^{+} **(Yes)**

Based on the results from the Levene's test, it can be concluded that at the 10% significance level, the variances between groups cannot be said to be equal. The calculated F-value was 8.205 giving a P-value ≈ 0^+ for $df_1 = 29$ and $df_2 = \infty$ where df = degrees of freedom. Given this fact, it was necessary to use method number 3 described above to correct for the situation. The technique used was to modify the P-value supplied by SPSS to a more conservative value by using lower degrees of freedoms for given F-values. This approach will lower type I errors at the expense of increased risk of type II errors. Type I errors refer to the probability that we conclude that a factor is not significant when it is in fact significant. Type II errors are the opposite condition; the probability a conclusion is made that a factor is not significant when it is in fact significant. To make the P-values more conservative than those given, a good strategy was to find the critical F-value at 1, n-1 degrees of freedom. (29) Using such a strategy, for any given P-value to be significant, a much larger (and thus more conservative) value of F would be required. From the table above without corrections, it could be concluded that all the input factors and their associated interactions were significant at the 5% significance level. Applying the technique described above to make the results more conservative gave the following table.

Table 8.3 ANOVA Table With Corrections for non Constant Variance

Tests of Between-Subjects Effects

Dependent Variable: NEWEMM

Source	Type III Sum of Squares	df	Mean Square	F	P-Value	Significant
Corrected Model	13516.454	1	466.08461	30.257389	0.000+	Yes
Intercept	7342180.5	1	7342180.5	476641.39	0.000+	Yes
FRICTION	6369.8973	1	3184.9486	206.76124	0.000+	**Yes**
FEEDBACK	1007.9962	1	1007.9962	65.437333	0.000+	**Yes**
ASSIGN	3406.3481	1	851.58704	55.283526	0.000+	**Yes**
FRICTION * FEEDBACK	1686.7964	1	843.39821	54.751922	0.000+	Yes
FRICTION * ASSIGN	365.06635	1	45.633294	2.9624328	0.0852	No
FEEDBACK * ASSIGN	252.89239	1	63.223097	4.1043318	0.0428	Yes
FRICTION * FEEDBACK * ASSIGN	427.45677	1	53.432096	3.4687173	0.0625	No
Error	1413162.3	91740	15.403993			
Total	8768859.3	91770				

Using this modified table, it could be seen that all input factors were statistically significant at the $\alpha = 0.05$ level. However, some of the interactions were determined to be non-significant including the 3rd order interaction. Given that all input factors were found to be significant, further analysis was required to determine which factors and interactions had the largest effect.

EXAMINING THE FRICTION/FEEDBACK INTERACTION EFFECT

In ANOVA analysis, the normal procedure requires the examination of the highest order interaction effects first, followed by lower order effects if such higher order effects are not found to be significant. For this situation, the highest order interaction is a 3rd order given that there are three primary input factors. The corrected ANOVA table however illustrates that the 3rd order interaction (FRICTION × FEEDBACK × ASSIGN) was not found to be significant at the $\alpha = 0.05$ level. Consequently, the three 2nd order interactions were then evaluated with two being found significant. They included the FRICTION × FEEDBACK interaction and the FEEDBACK × ASSIGN effect. Profile plots of these significant interactions were then utilized to draw conclusions regarding their behavior. Illustrated below is the plot for Friction/feedback interaction.

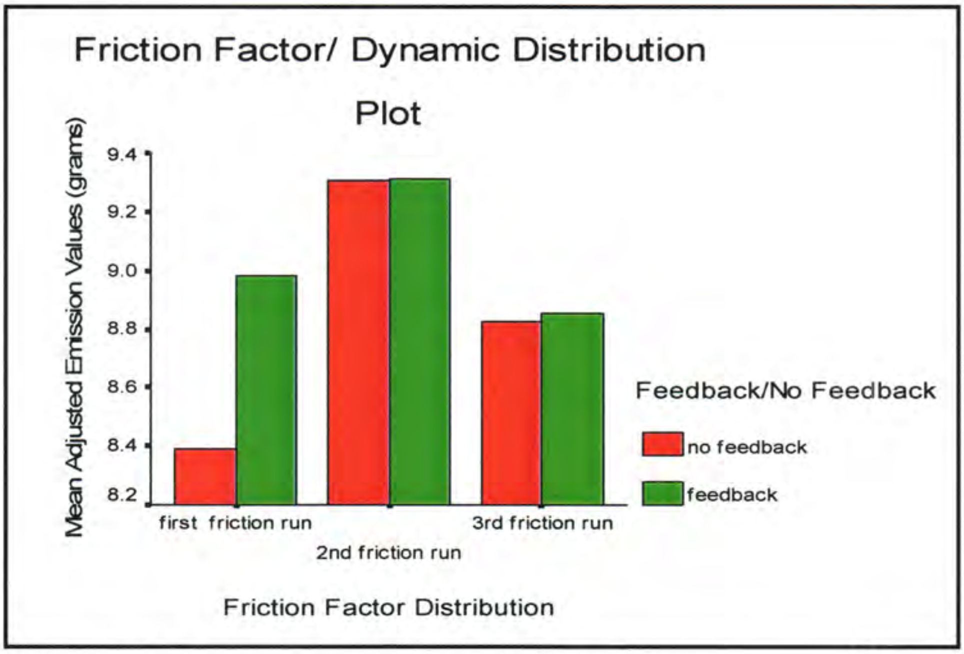

Figure 8.3 Friction Factor/ Feedback Profile Plot

From the plot above, it is clear that particularly between the 1st friction distribution results and the results for the second that a significant interaction is taking place. There is a much less noticeable interaction taking place between the second and the third runs. The interaction can be explained by the fact that the feedback results are directly dependent on the actual friction factors used. Recalling from Chapter 3, the feedback process involves performing the trip distribution stage repeatedly using congested network travel times. It thus becomes clear that any difference in the friction factors will have a direct effect on the trip distribution results and consequently the traffic assignment and emissions results. The much larger difference between friction runs 1 and 2 compared to runs 2 and 3 is the result of a greater difference in the friction factor distributions between runs 1 and 2 than between runs 2 and 3.

For all friction distributions used, the marginal mean emissions values for the feedback case were larger than were the case without feedback. This is not a surprising relationship given the fact that when feedback is incorporated in the model, congestion delay is represented thus increasing average travel times and distances. The proportion of vehicles traveling at inefficient speeds was thus increased. Given that inefficient vehicle operation increases emissions for a given distance traveled and more distance was actually traveled, it was expected that emission values will be greater in the feedback situation.

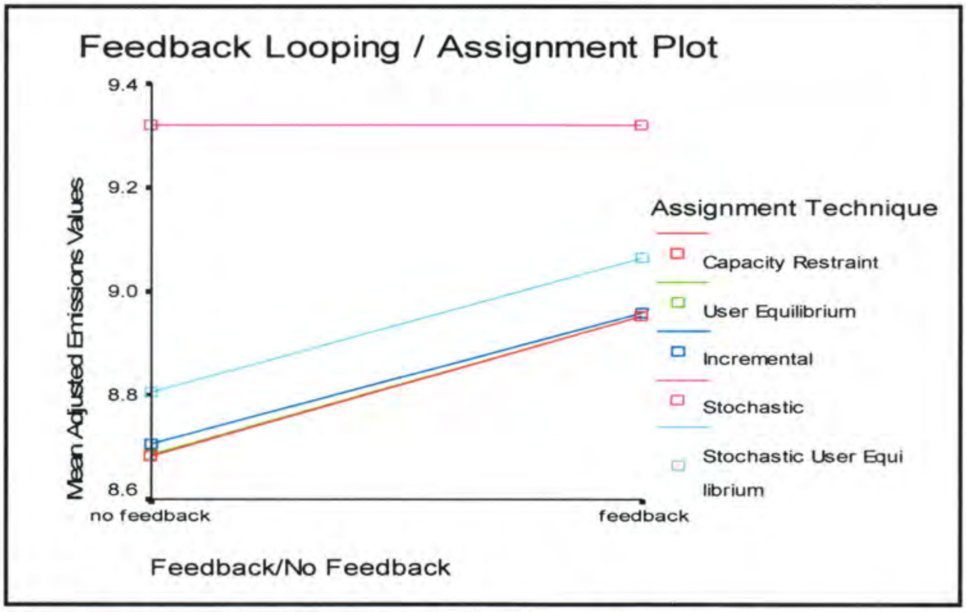

Figure 8.4 Feedback Looping/ Assignment Technique Plot

Interaction effects are indicated when the lines between group categories are not parallel. Observation of the standard statistical profile plot above showed that all assignment techniques with the exception of Stochastic assignment displayed no more than minor interaction effects. However, for Stochastic assignment, owing to no change between the feedback and no feedback cases, a large interaction effect can be observed when compared with the other four assignment techniques. This result is expected given that feedback looping would have no effect on the Stochastic assignment results. Recalling from Chapter 2, Stochastic assignment, like the All or Nothing assignment technique does not use a volume delay function. This in turn implies that traffic volumes will have no effect on travel time and by extension assignment and emissions results between the feedback and no feedback cases. The converse situation is the case for the other four assignment techniques that all include the volume delay function. Consequently, in all those cases, an increased emissions result was observed for the feedback case.

EXAMINING THE INDIVIDUAL INPUT FACTORS

The following are multiple comparison and t-test tables of the mean differences in adjusted emission results by input factor.

Table 8.4 Mean Differences in Emissions Values for Friction Distribution Used

Multiple Comparisons

Dependent Variable: NEWEMM

Tamhane

(I) Friction Scenario	(J) Friction Scenario	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
first friction run	2nd friction run	**-0.62**	0.03	0.00	-0.70	-0.54
	3rd friction run	-0.15	0.03	0.00	-0.23	-0.08
2nd friction run	first friction run	**0.62**	0.03	0.00	0.54	0.70
	3rd friction run	0.47	0.03	0.00	0.39	0.54
3rd friction run	first friction run	0.15	0.03	0.00	0.08	0.23
	2nd friction run	-0.47	0.03	0.00	-0.54	-0.39

Table 8.5 Mean Difference t-test for the Feedback/No Feedback Input Factor

Independent Samples Test

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
NEWEMM	Equal variances assumed	-8.05	91768.00	0.00	**-0.21**	0.03	-0.26	-0.16
	Equal variances not assumed	-8.05	91747.90	0.00	**-0.21**	0.03	-0.26	-0.16

Table 8.6 Mean Differences in Emissions Values for Assignment Technique Used

Dependent Variable: NEWEMM

Tamhane

(I) Assignment Technique	(J) Assignment Technique	Mean Difference (I-J)	Std. Error	Significant	95% Confidence Interval	
					Lower Bound	Upper Bound
Capacity Restraint	User Equilibrium	0.00	0.04	No	-0.12	0.12
	Incremental	-0.01	0.04	No	-0.13	0.10
	Stochastic	**-0.50**	0.04	Yes	-0.61	-0.39
	Stochastic User Equilibrium	-0.12	0.04	Yes	-0.24	0.00
User Equilibrium	Capacity Restraint	0.00	0.04	No	-0.12	0.12
	Incremental	-0.01	0.04	No	-0.13	0.11
	Stochastic	**-0.50**	0.04	Yes	-0.61	-0.39
	Stochastic User Equilibrium	-0.12	0.04	Yes	-0.23	0.00
Incremental	Capacity Restraint	0.01	0.04	No	-0.10	0.13
	User Equilibrium	0.01	0.04	No	-0.11	0.13
	Stochastic	-0.49	0.04	Yes	-0.60	-0.38
	Stochastic User Equilibrium	-0.10	0.04	No	-0.22	0.01
Stochastic	Capacity Restraint	0.50	0.04	Yes	0.39	0.61
	User Equilibrium	0.50	0.04	Yes	0.39	0.61
	Incremental	0.49	0.04	Yes	0.38	0.60
	Stochastic User Equilibrium	0.38	0.04	Yes	0.27	0.49
Stochastic User Equilibrium	Capacity Restraint	0.12	0.04	Yes	0.00	0.24
	User Equilibrium	0.12	0.04	Yes	0.00	0.23
	Incremental	0.10	0.04	No	-0.01	0.22
	Stochastic	-0.38	0.04	Yes	-0.49	-0.27

Upon analysis of the results, it was discerned that the greatest change in adjusted emission values occurred between the 1st friction distribution and the 2nd friction distribution. The change was indicated as approximately -0.62 g indicating that the 2nd distribution produced mean results 0.62 g larger than the first friction factor distribution.

The next largest change was observed to be the change between the Stochastic assignment technique and the Capacity Restraint technique. In fact the absolute differences between the stochastic technique and all other techniques were consistently much larger than the differences between each of the other techniques. As mentioned in the discussion of interaction effects above, this result is not unexpected.

After observing the changes due to each input factor, it could be concluded that the most important factor affecting the results was the friction factor distribution used in the model. The next most important factor was the assignment technique used with differences being 0.5g. Consequently, the least important factor was inferred to be the use/non use of dynamic feedback modeling. The distorting effect of the Stochastic assignment technique should be noted however. The following profile plots illustrate the conclusions graphically.

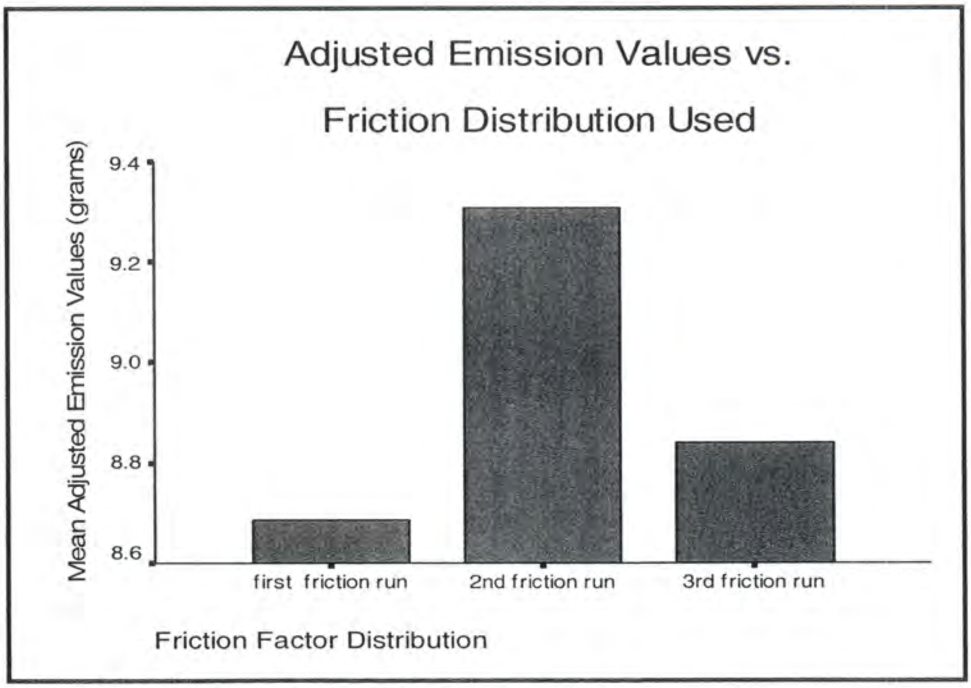

Figure 8.5 Friction Factor Distribution Plot

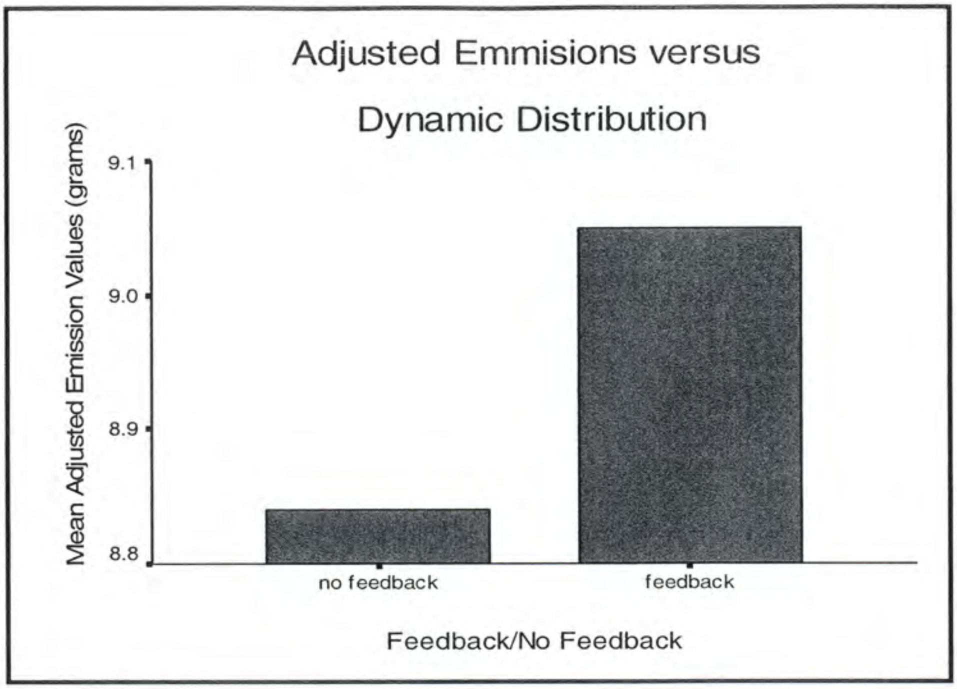

Figure 8.6 Feedback / No Feedback Plot

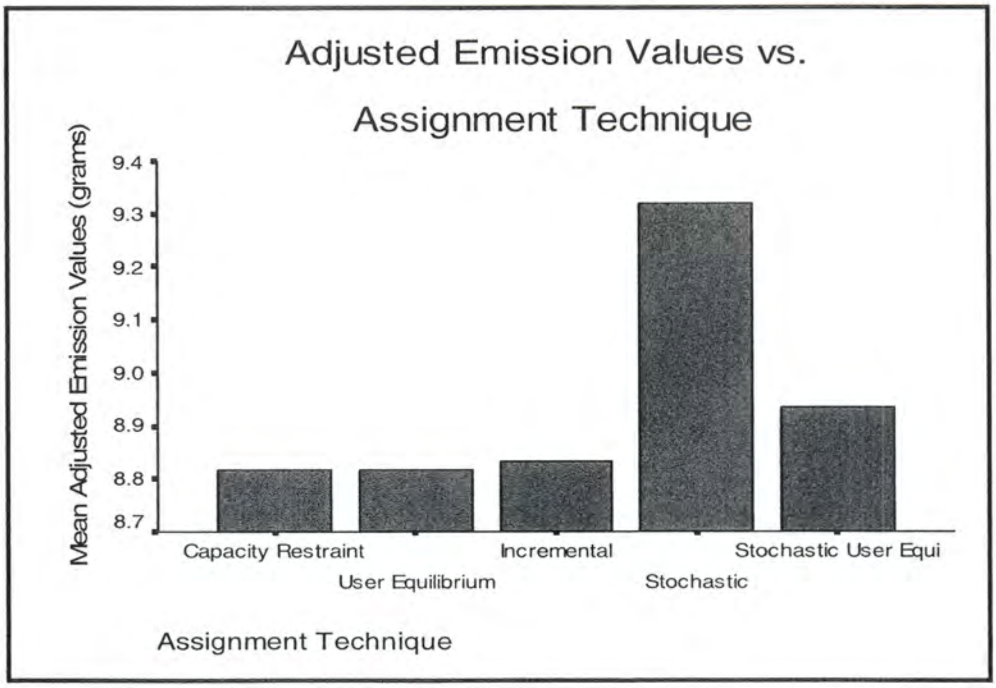

Figure 8.7 Assignment Technique Plot

A quick observation of the three plots shows that the largest changes occurred for the friction factor distribution. The second highest changes were due to the assignment technique used and finally, the use or non-use of dynamic distribution caused the smallest magnitude changes. It should be noted however the disproportionate impact the Stochastic technique imparts on the model results. Removing Stochastic assignment from consideration reverses the order of the 2nd and 3rd input factors. (Assignment technique and the use of dynamic distribution)

Discussion of Input Factor Effects

Having concluded that the order of importance of the input factors is: friction distribution used, assignment technique used and finally the presence / absence of dynamic distribution (feedback looping), it was necessary to provide some insight into their effect on emissions results.

Friction Factor Distribution

From the graphs, in both the feedback and no feedback cases, it was shown that the magnitude of the results for the 2nd friction distribution was larger than was the case for the first distribution. Based on the description of friction distribution 2 in Chapter 4 a larger number of very long and very short trips would be produced compared to the base Bi-State TRANPLAN® model. There would be also be a counteracting drop in the number of intermediate distance trips produced.

Based on the individual link comparisons done in Chapter 7, the increased numbers of shorter trips are concentrated in specific corridors such as the Mississippi River crossings. This had the effect of disproportionately increasing congestion on those links thus causing increased emissions results. The larger number of very long trips would also cause increased emissions owing to an increase in vehicle miles traveled VMT's as compared to the base scenario. The combination of the two effects would thus result in higher emissions as observed on the graph.

The results for the 3rd friction factor distribution without feedback were higher than the original but significantly lower than was the case for the 2nd distribution. Based on the discussion in Chapter 4, the 3rd distribution should produce many very short trips but unlike the case with the 2nd distribution, there should also be fewer longer trips than was the case in the original. The fewer number of long trips explain the significantly lower emissions values than for the 2nd case. Apparently, the greater number of short trips generated enough of an emissions increase over the base case to counteract the fewer long trips. This resulted in a moderate increase in emissions over the base case.

When feedback looping was included, the results for the 3rd distribution were lower than the case for the original. This is a result of increased predicted emissions in the original case under feedback looping. In addition, short trips on congested links were most likely being reassigned to longer but less congested links.

Dynamic Modeling

In general, use of dynamic feedback modeling tended to produce increased emissions. As stated earlier, the greater travel times in the feedback case increases the proportion of inefficient vehicle operation due to slower speed. It was also observed that VMTs increased under dynamic modeling. The net effect of these factors was an increase in emissions values.

Assignment Technique Used

From the graphs, it is apparent that except for the 1st friction distribution used under the feedback looping scenario, the stochastic assignment technique produced the highest emissions results of any of the assignment techniques. This is most likely the result of the Stochastic technique ignoring congestion delay on the greater number of short trips as described in Chapter 4 for the 2nd and 3rd friction factor distributions. Ignoring congestion would tend to place vehicles on slower, more congested links as opposed to faster but longer links. It should be noted that the effect of slower speed (in many cases higher emissions) operations on links must be considered in addition to decreased total VMT on shorter links. The effect on emissions is a complex relationship between type of roadway facility, vehicle speeds and vehicle miles traveled and in many instances, the effects are counteracting.

The Stochastic User Equilibrium technique produced the next highest emissions levels. Though this technique has volume delay characteristics, the stochastic probability component influences the result causing increased emissions owing to the same factors discussed above for the purely Stochastic technique.

The remaining three techniques produced the lowest emissions related to the assignment technique used. The differences between each of the three were negligible and could in part be explained by the fact that they all incorporated a similar volume delay function. In addition, the number of extremely congested (high V/C ratio) links in this model was small in comparison to other major metropolitan models. This in turn would tend to minimize the differences between each of the techniques thus explaining the closeness of the results.

THE EFFECT OF SEASON ON POLLUTANT EMISSIONS

Analysis of aggregate pollutant emissions by season revealed that for all combination of input factors, emissions were greater in winter than in summer. Table 7.1 in Chapter 7 describes the aggregated emissions by pollutant and season. Illustrated in the following section are three line graphs displaying the mean emissions change by pollutant for the winter and summer seasons ignoring all input factors.

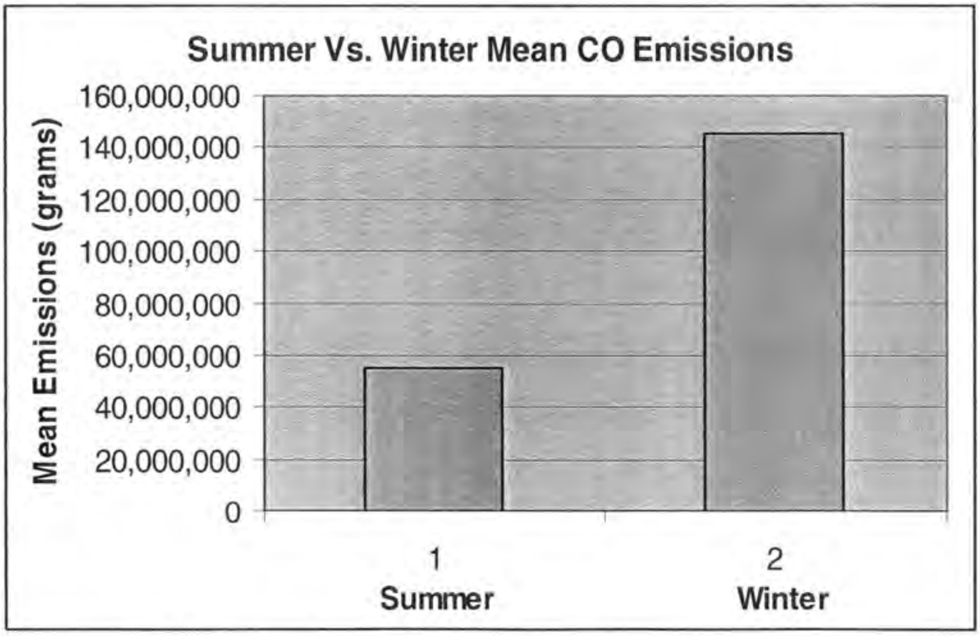

Figure 8.8 Mean CO Emissions Difference

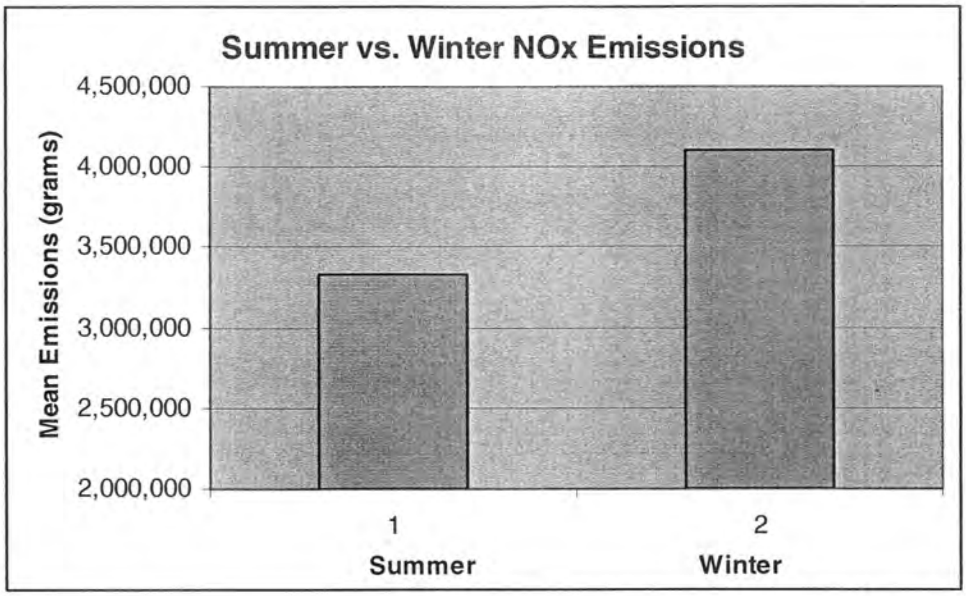

Figure 8.9 Mean NO_x Emissions Difference

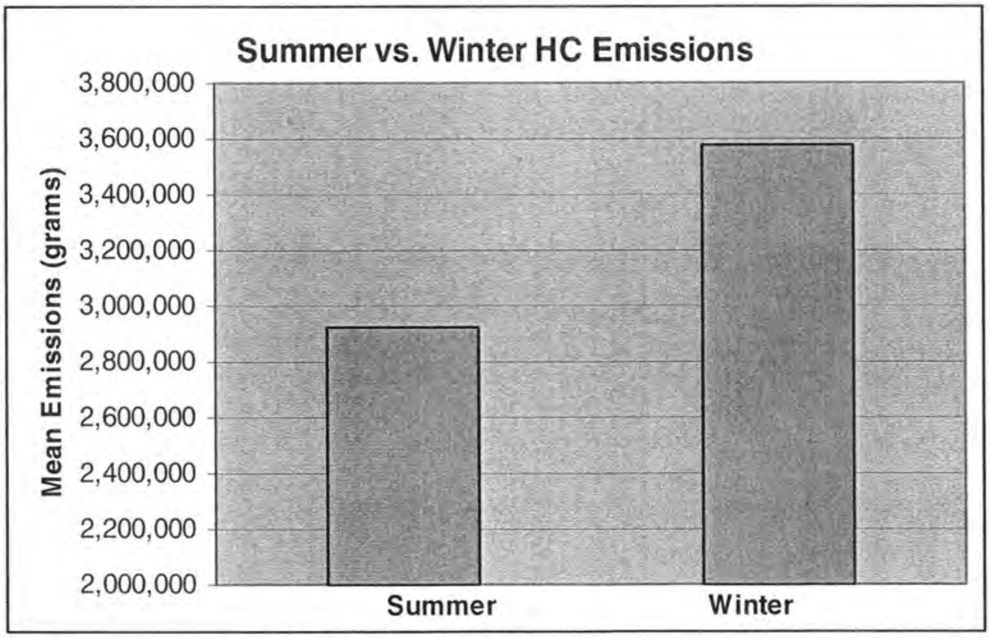

Figure 8.10 Mean VOC Emissions Difference

Table 8.7 Percentage Change between Summer and Winter Conditions

	CO g	NOx g	VOC g
Summer	55,123,918	3,331,237	2,926,127
Winter	145,437,903	4,096,595	3,580,640
% difference	164	23	22

From the table and graphs, the greatest difference between summer and winter values was observed for carbon monoxide (CO) emissions. The differences for the other two pollutants were more moderate being approximately 22% greater. All of the results are best explained by the tendency of internal combustion engines to burn fuel less efficiently under very cold conditions. Cold temperatures will inhibit complete combustion of fuel. This results in a greater proportion of unburnt and incompletely oxidized burnt fuel, hence higher VOC and CO emissions. The emissions of CO and VOC s in winter are significantly increased during engine start, warm up and in stop and go traffic. Under these conditions, the engine does not operate at normal temperatures; lubricating oil is cold and viscous causing higher friction and pumping losses and thus increased fuel consumption; and catalytic converters fail to perform the task of converting the pollutants to carbon dioxide and atmospheric nitrogen efficiently.

Increased fuel consumption as stated earlier and the specification of the use of a 10% ethanol /gasoline mix in the MOBILE6 emissions factor model are most likely responsible for the increased NO_x winter values. This result is counterintuitive given that NO_x is formed by the oxidation of atmospheric oxygen and nitrogen at high temperatures. Higher fuel consumption will lead to higher values for all pollutants including NO_x.

SUMMARY

In summary, the ANOVA analysis on the inputs indicated that the most significant input factor was the friction factor distribution used followed by the assignment technique used with the use or non-use of dynamic modeling being least important. The seasonal variation in results was indicated in all cases by higher winter emissions than summer emissions particularly for carbon monoxide with more than a doubling in the values being noted.

CHAPTER 9. CONCLUSIONS

INPUT FACTOR SIGNIFICANCE AND CONSEQUENCES FOR EMISSIONS MODELING

As long as transportation is 98% dependent on hydrocarbons (petroleum and natural gas) as fuel sources, (5) automobile emissions will be a matter of concern. Hence, the tools used to model and forecast future emissions must be clearly understood for proper analyses to be undertaken. Among the tools used to model future transportation emissions is the 4-step travel demand model / emissions factor model process. The thesis presented examined the behavior of this specific forecasting tool with regards to certain input factors and modeling strategies including the friction factors used, dynamic modeling utilization and the assignment technique used.

Friction Factor Distribution

The ANOVA tests and subsequent graphic analysis indicated that the friction distribution had the greatest effect on the overall model. It was also found that the assignment technique had a large distorting effect on the model results when the Stochastic assignment technique was accounted for.

The results indicate that in performing emissions modeling, great care must be taken when calibrating friction factors. It may be necessary to conduct extensive surveys and information gathering, some of which were described in Chapter 2 to ensure that the actual trip performing behavior of the public is accurately captured. Failure to do so may lead to wildly inaccurate emissions estimates indicating conformity/non-conformity with EPA emissions regulations than would be the actual case. As is well known by transportation professionals, the costs of having either situation can be high. For the case where non-conformity is predicted, federal funding of some transportation infrastructure projects may be withheld and costly remedial actions undertaken to regain conformity status. For the converse situation, it must be remembered that the EPA conformity regulations were enacted primarily to protect the health of the public. Hence, it is likely that the health care costs would be increased while the physical health of the population diminished potentially leading to higher mortality rates. Additionally, future emissions monitoring would eventually identify the errors in model predictions. The financial and infrastructure consequences of this situation can be severe for metropolitan areas.

Dynamic Modeling

It was also made clear from the ANOVA analysis that the use of feedback modeling had a noticeable emissions effect despite the proportion of high V/C ratio links being comparatively small. It should be noted however the counteracting factor of peak hour extrapolation to 24 hours that will tend to minimize the effect of dynamic distribution. Dynamic feedback modeling is particularly sensitive to high V/C ratios (hence traffic congestion) in the model for reasons discussed in Chapter 4. This situation clearly illustrates the disproportionate impact of bottleneck areas in the region such as the bridge crossings and some freeway links and intersections. With this knowledge, it becomes important to account for the special effects of bottlenecks in future infrastructure planning. As was the case for the friction factors, failure to properly plan and account for bottlenecks today could potentially lead to inappropriate future investments and costly corrective actions.

Assignment Technique

Apart from the Stochastic assignment technique results, the differences between the techniques used proved that for the Bi-State area emissions modeling, it is not critical that great emphasis be placed on the assignment technique utilized. Had the All or Nothing technique been studied as well, similar conclusions could be drawn as those drawn for the Stochastic assignment approach. Like Stochastic Assignment, the All or Nothing technique ignores volume delay and would thus have no effect on dynamic modeling.

Seasonal Variations

In any emissions modeling scenario, it is important to account for the seasonal differences in emissions values that can be significant. The environmental and health concerns are different depending on season. For instance, under winter conditions the main emissions concern is CO (carbon monoxide) formed by the incomplete combustion of carbon based fuels. In summer, the main concerns are NO_x and VOCs.

Carbon Monoxide

CO is an emissions concern in winter mainly because of the tendency to have temperature inversions in winter that make polluted air stay close to ground level. CO exposure causes detrimental health effects such as nausea, vomiting and if concentrations are high enough, unconsciousness and even death. Unfortunately, in the very season for which it is a primary concern, the predicted CO emissions were observed to be significantly increased (a factor of approximately 2.5) over the summer values for reasons discussed in Chapter 6. This implies that careful monitoring and enforcement of regulations limiting CO emissions is necessary particularly in winter months.

Nitrogen Oxides and Volatile Organic Compounds

Unlike CO, which is primarily a winter emissions problem nitrogen oxides and volatile organic compounds are summer problems. In addition to specific health problems related to each pollutant, the two are ingredients in the formation of ozone that is greatest during hot, bright summer daylight conditions. Fortunately, emissions of VOCs and NO_x were analyzed to be lower in summer months than in winter according to the results from the MOBILE6 emissions factor model. It must be noted however that specific areas can possibly register contrasting results depending on local environmental conditions. As with CO in the winter, it is necessary to carefully control emissions via various strategies. Included among these strategies are sound future planning arising from emissions modeling, auto manufacturer regulations, travel demand reduction using transportation control measures, vehicle emissions testing programs and others.

MODEL APPROACH LIMITATIONS

The research was performed under the following limitations:

1. The derived friction factor curves were not individually calibrated for each model run. In actual modeling practice, friction factors are painstakingly calibrated to produce reasonable trip distribution results. Hence, simply changing friction factors without calibration to the model will result in some error in model predictions.
2. The model assignments were done using the 10% PHF (Peak Hour Factor) used by the Bi-State Commission and then extrapolated for all hours. This

strategy is not ideal as the effect of volume delay is extrapolated beyond the peak hour when congestion delay will be inconsequential. The result of this limitation is that recognition must be given to the likelihood that the effect on the model of dynamic distribution and the assignment technique used will be over predicted.

3. The sensitivity analysis in this research was performed using future 2025 data that made comparison with ground counts impossible.

4. It is usually more desirable to have the most detailed information feasible. Included in this information should be a detailed network description symbolizing the road network at the highest detail possible. Instead of using a blanket 10% peak hour assignment factor for traffic assignment, it would be preferable to compare assignments hourly against hourly counts from the Bi-State area. This should provide much more relevant information with regards to emissions modeling. Emissions are highly dependent on the general traffic conditions with congested periods having disproportionately higher pollutant emissions.

Correction of these limitations implies that much more data will need to be collected. Data collection can be an expensive process thus implying that improvements in the modeling approach described in this thesis will be slow in coming given the differences in resources between metropolitan areas across the country.

There is also the option to switch to other modeling approaches being introduced such as the TRANSIMS approach described in Chapter 2. The problem of greater data needs and processing resources will also slow the adoption of that approach.

FUTURE RESEARCH

The traditional four-step travel demand model as its name implies has four stages with inputs that can be analyzed. The focus of this thesis was on step number 2 and step number 4, trip distribution and traffic assignment. Future research could extend the sensitivity analysis to the other two steps.

In trip generation for instance, it would be desirable to determine the emissions effect of changes in land use patterns, economic conditions and population. These factors all have significant effects on the trip rates in any particular area. Such studies would help identify the best patterns of settlement for reduced emissions. (34) It is anticipated that in the near future, the pattern of settlement will be extensively scrutinized given the projected increases in automobile traffic. Resources for new infrastructure will become increasing expensive to procure thus placing great pressure on the efficient use of invested assets. A parallel concern is the likelihood that transportation energy will become increasingly costly as resource extraction rates approach a maximum in the near future. This will also place great pressure on ensuring the most efficient land use and transportation arrangements feasible for a given area.

An interesting area of future research could involve an investigation into the emissions impact of a switch to electric traction and hydrogen fuel in both automobiles and transit. This would necessitate devising a tool other than MOBILE6 or similar emissions factor model that would consider power plant emissions, zero emission electricity sources and vehicle on board vehicle energy efficiency.

In concluding, the research covered in this thesis has barely scratched the surface of potential areas for future study as described above. It is hoped that the work initiated here will be continued as emissions and energy concerns become greater.

APPENDIX A. FRICTION FACTOR TABLES

Table A1 Friction Factors obtained from Bi-State Commission

TIME	HBW	HBO	NHB	TRK	IEEI
1	10000	10000	10000	10000	10000
2	5248	4467	3548	5248	5432
3	3467	2512	1884	4217	3428
4	2399	1585	1189	2317	2399
5	1778	1059	794	1660	1820
6	1348	794	562	1274	1413
7	1072	631	422	1000	1096
8	871	501	316	794	912
9	724	398	251	638	759
10	602	316	200	525	610
11	501	251	150	347	525
12	416	200	119	363	442
13	355	158	94	302	380
14	302	126	71	260	331
15	263	106	56	219	288
16	224	89	47	188	251
17	195	94	38	160	224
18	170	63	32	138	197
19	151	53	27	120	168
20	132	47	24	105	150
21	119	40	21	93	135
22	105	38	20	81	122
23	98	33	18	74	110
24	89	30	17	66	101
25	82	28	16	61	93
26	76	25	16	56	85
27	72	24	16	52	79
28	66	22	15	49	75
29	63	21	15	47	71
30	60	20	15	44	66
31	57	19	15	42	63
32	54	18	14	40	60
33	52	17	14	38	58
34	50	16	13	37	55
35	48	15	13	35	52
36	47	15	13	34	50
37	45	14	13	33	48
38	42	13	13	33	46
39	41	13	13	32	44
40	40	13	13	32	42

Table A2 Inverse function derived friction factor table

Constant b = 1.45

TIME	HBW	HBO	NHB	TRK	IEEI
1	10000	10000	10000	10000	10000
2	3660	3116	2475	3660	3789
3	2033	1473	1105	2473	2010
4	1340	885	664	1294	1340
5	969	577	433	905	992
6	744	438	310	703	780
7	595	350	234	555	608
8	490	282	178	447	513
9	413	227	143	364	433
10	355	186	118	309	360
11	309	155	93	214	324
12	272	131	78	238	289
13	243	108	64	206	260
14	218	91	51	188	239
15	197	79	42	164	216
16	179	71	38	151	201
17	164	79	32	135	189
18	151	56	28	123	175
19	140	49	25	111	156
20	130	46	24	103	148
21	121	41	21	95	137
22	113	41	22	87	131
23	106	36	19	80	119
24	100	34	19	74	113
25	94	32	18	70	107
26	89	29	19	65	99
27	84	28	19	61	92
28	80	27	18	59	91
29	76	25	18	57	85
30	72	24	18	53	79
31	69	23	18	51	76
32	66	22	17	49	73
33	63	21	17	46	70
34	60	19	16	45	66
35	58	18	16	42	62
36	55	18	15	40	59
37	53	17	15	39	57
38	51	16	16	40	56
39	49	16	16	38	53
40	48	15	15	38	50

Table A3 Gamma Function derived friction factor table.

Constant a = 1, b = 1.45, c = 0.025

TIME	HBW	HBO	NHB	TRK	IEEI
2	10000	10000	10000	10000	10000
3	1886	1367	1025	2294	1865
4	1212	801	601	1171	1212
5	855	510	382	799	876
6	641	377	267	605	671
7	500	294	197	466	511
8	401	231	146	366	420
9	330	181	114	291	346
10	276	145	92	241	280
11	235	118	70	163	246
12	202	97	58	176	214
13	175	78	46	149	188
14	154	64	36	132	168
15	135	55	29	113	148
16	120	48	25	101	135
17	107	52	21	88	123
18	96	36	18	78	112
19	87	31	16	69	97
20	79	28	14	63	90
21	72	24	13	56	81
22	65	24	12	50	76
23	60	20	11	45	67
24	55	18	10	41	62
25	50	17	10	37	57
26	46	15	10	34	52
27	43	14	10	31	47
28	40	13	9	29	45
29	37	12	9	27	41
30	34	11	9	25	37
31	32	11	8	23	35
32	30	10	8	22	33
33	28	9	7	20	31
34	26	8	7	19	28
35	24	8	7	18	26
36	23	7	6	16	24
37	21	7	6	15	23
38	20	6	6	16	22
39	19	6	6	15	20
40	17	6	6	14	18

APPENDIX B MOBILE6 INPUT FILES (FREEWAY AND ARTERIAL)

Arterial Input File Text

```
MOBILE6 INPUT FILE :
DATABASE OUTPUT    :
AGGREGATED OUTPUT  :
WITH FIELDNAMES    :

DATABASE EMISSIONS : 2222 2222
DATABASE FACILITIES: Arterial
DATABASE VEHICLES  : 22222 22222222 2 222 22222222 222

RUN DATA
MIN/MAX TEMP       : 70. 90.
SEASON             : 1
FUEL RVP           : 7.0
OXYGENATED FUELS   : 0 .55 0 .035 2

SCENARIO REC       : Scenario Title Text - Arterial 2.5
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 2.5 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 5
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 5 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 10
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 10 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 15
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 15 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 20
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 20 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 25
CALENDAR YEAR      : 2025
```

```
AVERAGE SPEED      : 25 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 30
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 30 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 35
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 35 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 40
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 40 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 45
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 45 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 50
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 50 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 55
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 55 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 60
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 60 Arterial
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Arterial 65
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 65 Arterial
EVALUATION MONTH   : 7

END OF RUN

MIN/MAX TEMP       : 10. 20.
SEASON             : 2
FUEL RVP           : 7.0
OXYGENATED FUELS   : 0 .55 0 .035 2
```

SCENARIO REC : Scenario Title Text - Arterial 2.5
CALENDAR YEAR : 2025
AVERAGE SPEED : 2.5 Arterial

SCENARIO REC : Scenario Title Text - Arterial 5
CALENDAR YEAR : 2025
AVERAGE SPEED : 5 Arterial

SCENARIO REC : Scenario Title Text - Arterial 10
CALENDAR YEAR : 2025
AVERAGE SPEED : 10 Arterial

SCENARIO REC : Scenario Title Text - Arterial 15
CALENDAR YEAR : 2025
AVERAGE SPEED : 15 Arterial

SCENARIO REC : Scenario Title Text - Arterial 20
CALENDAR YEAR : 2025
AVERAGE SPEED : 20 Arterial

SCENARIO REC : Scenario Title Text - Arterial 25
CALENDAR YEAR : 2025
AVERAGE SPEED : 25 Arterial

SCENARIO REC : Scenario Title Text - Arterial 30
CALENDAR YEAR : 2025
AVERAGE SPEED : 30 Arterial

SCENARIO REC : Scenario Title Text - Arterial 35
CALENDAR YEAR : 2025
AVERAGE SPEED : 35 Arterial

SCENARIO REC : Scenario Title Text - Arterial 40
CALENDAR YEAR : 2025
AVERAGE SPEED : 40 Arterial

SCENARIO REC : Scenario Title Text - Arterial 45
CALENDAR YEAR : 2025
AVERAGE SPEED : 45 Arterial

```
SCENARIO REC        : Scenario Title Text - Arterial 50
CALENDAR YEAR        : 2025
AVERAGE SPEED       : 50 Arterial


SCENARIO REC        : Scenario Title Text - Arterial 55
CALENDAR YEAR        : 2025
AVERAGE SPEED       : 55 Arterial


SCENARIO REC        : Scenario Title Text - Arterial 60
CALENDAR YEAR        : 2025
AVERAGE SPEED       : 60 Arterial


SCENARIO REC        : Scenario Title Text - Arterial 65
CALENDAR YEAR        : 2025
AVERAGE SPEED       : 65 Arterial


END OF RUN
```

Figure B1 Arterial Input File

Freeway Input File Text

```
MOBILE6 INPUT FILE :
DATABASE OUTPUT    :
AGGREGATED OUTPUT  :
WITH FIELDNAMES    :

DATABASE EMISSIONS : 2222 2222
DATABASE FACILITIES: Freeway
DATABASE VEHICLES  : 22222 22222222 2 222 22222222 222

RUN DATA
MIN/MAX TEMP       : 70. 90.
SEASON             : 1
FUEL RVP           : 7.0
OXYGENATED FUELS   : 0  .55  0  .035  2

SCENARIO REC        : Scenario Title Text - Freeway 2.5
CALENDAR YEAR        : 2025
AVERAGE SPEED       : 2.5 Freeway
EVALUATION MONTH   : 7

SCENARIO REC        : Scenario Title Text - Freeway 5
CALENDAR YEAR        : 2025
```

AVERAGE SPEED : 5 Freeway
EVALUATION MONTH : 7

SCENARIO REC : Scenario Title Text - Freeway 10
CALENDAR YEAR : 2025
AVERAGE SPEED : 10 Freeway
EVALUATION MONTH : 7

SCENARIO REC : Scenario Title Text - Freeway 15
CALENDAR YEAR : 2025
AVERAGE SPEED : 15 Freeway
EVALUATION MONTH : 7

SCENARIO REC : Scenario Title Text - Freeway 20
CALENDAR YEAR : 2025
AVERAGE SPEED : 20 Freeway
EVALUATION MONTH : 7

SCENARIO REC : Scenario Title Text - Freeway 25
CALENDAR YEAR : 2025
AVERAGE SPEED : 25 Freeway
EVALUATION MONTH : 7

SCENARIO REC : Scenario Title Text - Freeway 30
CALENDAR YEAR : 2025
AVERAGE SPEED : 30 Freeway
EVALUATION MONTH : 7

SCENARIO REC : Scenario Title Text - Freeway 35
CALENDAR YEAR : 2025
AVERAGE SPEED : 35 Freeway
EVALUATION MONTH : 7

SCENARIO REC : Scenario Title Text - Freeway 40
CALENDAR YEAR : 2025
AVERAGE SPEED : 40 Freeway
EVALUATION MONTH : 7

SCENARIO REC : Scenario Title Text - Freeway 45
CALENDAR YEAR : 2025
AVERAGE SPEED : 45 Freeway
EVALUATION MONTH : 7

SCENARIO REC : Scenario Title Text - Freeway 50
CALENDAR YEAR : 2025
AVERAGE SPEED : 50 Freeway
EVALUATION MONTH : 7

SCENARIO REC : Scenario Title Text - Freeway 55

```
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 55 Freeway
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Freeway 60
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 60 Freeway
EVALUATION MONTH   : 7

SCENARIO REC       : Scenario Title Text - Freeway 65
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 65 Freeway
EVALUATION MONTH   : 7

END OF RUN

MIN/MAX TEMP       : 10. 20.
SEASON             : 2
FUEL RVP           : 7.0
OXYGENATED FUELS   : 0  0.55  0  0.035  2

SCENARIO REC       : Scenario Title Text - Freeway 2.5
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 2.5 Freeway

SCENARIO REC       : Scenario Title Text - Freeway 5
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 5 Freeway


SCENARIO REC       : Scenario Title Text - Freeway 10
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 10 Freeway


SCENARIO REC       : Scenario Title Text - Freeway 15
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 15 Freeway


SCENARIO REC       : Scenario Title Text - Freeway 20
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 20 Freeway


SCENARIO REC       : Scenario Title Text - Freeway 25
CALENDAR YEAR      : 2025
AVERAGE SPEED      : 25 Freeway
```

```
SCENARIO REC      : Scenario Title Text - Freeway 30
CALENDAR YEAR     : 2025
AVERAGE SPEED     : 30 Freeway


SCENARIO REC      : Scenario Title Text - Freeway 35
CALENDAR YEAR     : 2025
AVERAGE SPEED     : 35 Freeway


SCENARIO REC      : Scenario Title Text - Freeway 40
CALENDAR YEAR     : 2025
AVERAGE SPEED     : 40 Freeway


SCENARIO REC      : Scenario Title Text - Freeway 45
CALENDAR YEAR     : 2025
AVERAGE SPEED     : 45 Freeway


SCENARIO REC      : Scenario Title Text - Freeway 50
CALENDAR YEAR     : 2025
AVERAGE SPEED     : 50 Freeway


SCENARIO REC      : Scenario Title Text - Freeway 55
CALENDAR YEAR     : 2025
AVERAGE SPEED     : 55 Freeway


SCENARIO REC      : Scenario Title Text - Freeway 60
CALENDAR YEAR     : 2025
AVERAGE SPEED     : 60 Freeway


SCENARIO REC      : Scenario Title Text - Freeway 65
CALENDAR YEAR     : 2025
AVERAGE SPEED     : 65 Freeway


END OF RUN
```

Figure B2 Freeway Input File

APPENDIX C VISUAL BASIC CODE AND PROGRAM SCREENSHOT

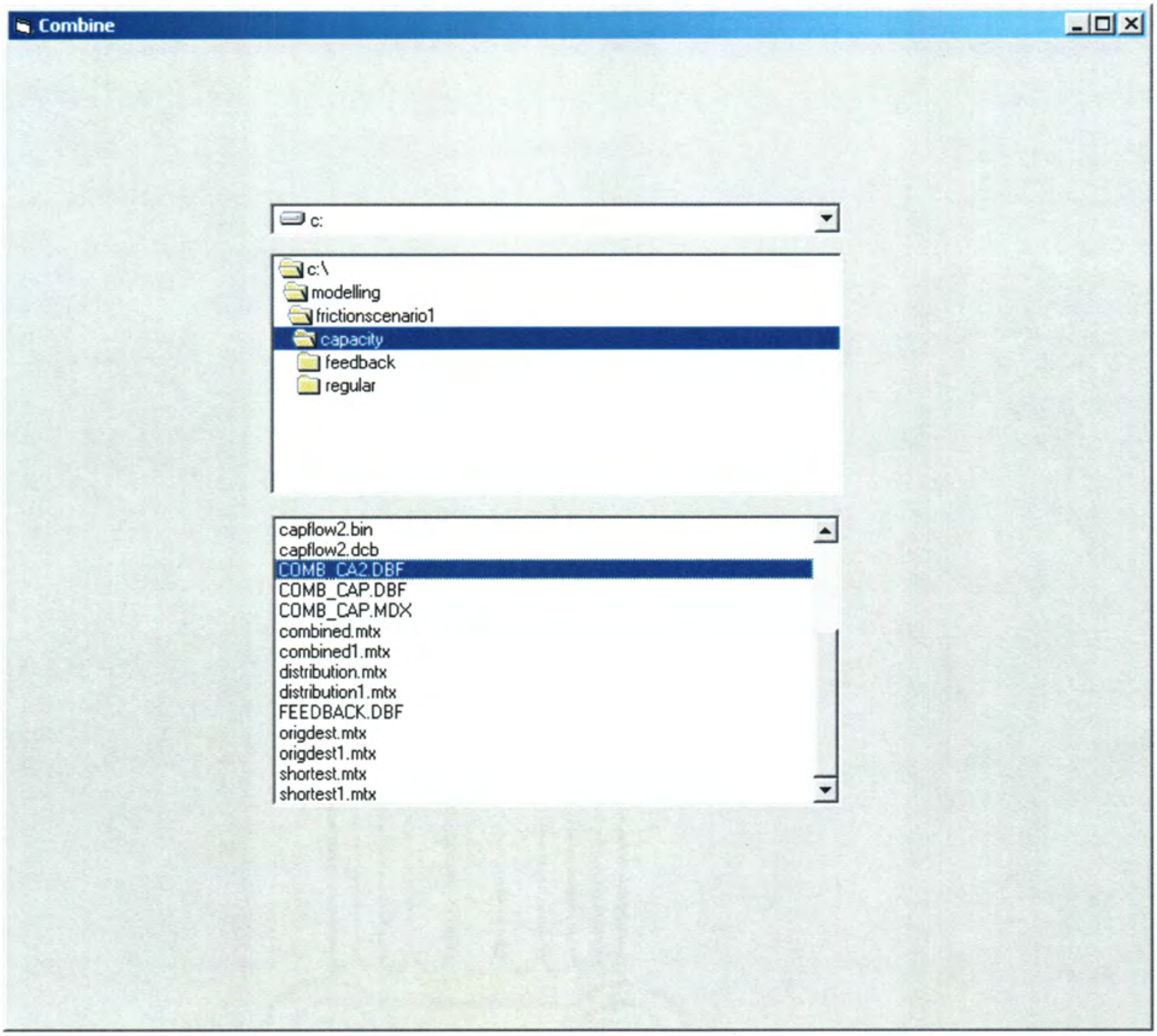

Figure C1 Screenshot of Program Used to Combine the Travel Demand Model Results with MOBILE6 Results

Main Form Code

```
Private mPath As String
Private Sub Form_Load()

  lstDirlist.Path = lstDrive.Drive & "\"

End Sub

Private Sub Form_Unload(Cancel As Integer)

  Set mDBEngine = Nothing
  Set bldTable = Nothing
  Set clsrun = Nothing
  Set mdatabase1 = Nothing
  Set mrecordset1 = Nothing
  Set mSummerfreeway = Nothing
  Set mSummerfreeway1 = Nothing
  Set mSummerfreeway2 = Nothing
  Set mWinterfreeway = Nothing
  Set mWinterfreeway1 = Nothing
  Set mWinterfreeway2 = Nothing

End Sub

Private Sub lstDirlist_Change()

  lstFile.Path = lstDirlist.Path

End Sub

Private Sub lstDirlist_Click()

  lstFile.Path = lstDirlist.Path

End Sub

Private Sub lstDrive_Change()

  lstFile.Path = lstDrive.Drive
  lstDirlist.Path = lstDrive.Drive

End Sub

Private Sub lstFile_DblClick()
Dim mDBEngine As New DAO.DBEngine
Dim mdatabase As DAO.Database
Dim mrecordset1 As DAO.Recordset
Dim mSummerfreeway As Collection
Dim mSummerfreeway2 As Collection
Dim mSummerfreeway3 As Collection
Dim mWinterfreeway As Collection
Dim mWinterfreeway2 As Collection
Dim mWinterfreeway3 As Collection
```

```
Dim mSummerarterial As Collection
Dim mSummerarterial2 As Collection
Dim mSummerarterial3 As Collection
Dim mWinterarterial As Collection
Dim mWinterarterial2 As Collection
Dim mWinterarterial3 As Collection
Dim init_scen As Integer
Dim agg_break As Boolean
Dim clsrun As clsPerformrun
Dim bldTable As clsDBbuilder
Dim wieghted_pol As Double

  mPath = App.Path
  Set bldTable = New clsDBbuilder
  bldTable.prgPath = lstFile.Path
  bldTable.maketable
  Set mdatabase = mDBEngine.OpenDatabase(mPath, False, False, "DBASE IV")

' Hydrocarbon emissions Summer
  Set mrecordset1 = mdatabase.OpenRecordset("select * from freeway where run = 1 and pol = 1")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mSummerfreeway = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mSummerfreeway.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop

  mSummerfreeway.Add weighted_pol
  Set mrecordset1 = Nothing

' CO emissions Summer
  Set mrecordset1 = mdatabase.OpenRecordset("select * from freeway where run = 1 and pol = 2")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mSummerfreeway2 = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mSummerfreeway2.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
  mSummerfreeway2.Add weighted_pol
  Set mrecordset1 = Nothing
```

```
'
' NOX emissions Summer
  Set mrecordset1 = mdatabase.OpenRecordset("select * from freeway where run = 1 and pol = 3")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mSummerfreeway3 = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mSummerfreeway3.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
  mSummerfreeway3.Add weighted_pol
  Set mrecordset1 = Nothing

' Hydrocarbon emissions Winter
  Set mrecordset1 = mdatabase.OpenRecordset("select * from freeway where run = 2 and pol = 1")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mWinterfreeway = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mWinterfreeway.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
  mWinterfreeway.Add weighted_pol
  Set mrecordset1 = Nothing

' CO emissions Winter
  Set mrecordset1 = mdatabase.OpenRecordset("select * from freeway where run = 2 and pol = 2")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mWinterfreeway2 = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mWinterfreeway2.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
  mWinterfreeway2.Add weighted_pol
  Set mrecordset1 = Nothing
```

```
'
' NOX emissions Winter
  Set mrecordset1 = mdatabase.OpenRecordset("select * from freeway where run = 2 and pol = 3")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mWinterfreeway3 = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mWinterfreeway3.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
  mWinterfreeway3.Add weighted_pol
  Set mrecordset1 = Nothing

' Arterial
' Hydrocarbon emissions Summer

  Set mrecordset1 = mdatabase.OpenRecordset("select * from arterial where run = 1 and pol = 1")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mSummerarterial = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mSummerarterial.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
  mSummerarterial.Add weighted_pol
  Set mrecordset1 = Nothing

' CO emissions Summer
  Set mrecordset1 = mdatabase.OpenRecordset("select * from Arterial where run = 1 and pol = 2")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mSummerarterial2 = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mSummerarterial2.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
```

```
  mSummerarterial2.Add weighted_pol
  Set mrecordset1 = Nothing
  '
' NOX emissions Summer
  Set mrecordset1 = mdatabase.OpenRecordset("select * from Arterial where run = 1 and pol = 3")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mSummerarterial3 = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mSummerarterial3.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
  mSummerarterial3.Add weighted_pol
  Set mrecordset1 = Nothing

' Hydrocarbon emissions Winter
  Set mrecordset1 = mdatabase.OpenRecordset("select * from Arterial where run = 2 and pol = 1")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mWinterarterial = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mWinterarterial.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
  mWinterarterial.Add weighted_pol
  Set mrecordset1 = Nothing

' CO emissions Winter
  Set mrecordset1 = mdatabase.OpenRecordset("select * from Arterial where run = 2 and pol = 2")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mWinterarterial2 = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mWinterarterial2.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
```

```
  mWinterarterial2.Add weighted_pol
  Set mrecordset1 = Nothing
  '
' NOX emissions Winter
  Set mrecordset1 = mdatabase.OpenRecordset("select * from Arterial where run = 2 and pol = 3")
  mrecordset1.MoveFirst
  init_scen = mrecordset1.Fields("scen").value
  Set mWinterarterial3 = New Collection
  weighted_pol = 0
  Do While Not mrecordset1.EOF
    If init_scen <> mrecordset1.Fields("scen").value Then
      init_scen = mrecordset1.Fields("scen").value
      mWinterarterial3.Add weighted_pol
      weighted_pol = 0
    End If
    weighted_pol = weighted_pol + mrecordset1.Fields("gm_mile").value * mrecordset1.Fields("vmt")
    mrecordset1.MoveNext
  Loop
  mWinterarterial3.Add weighted_pol
  Set mrecordset1 = Nothing
  '
  '
  '
  Set clsrun = New clsPerformrun
  clsrun.Path = lstFile.Path
  Set clsrun.sarterial = mSummerarterial
  Set clsrun.sarterial1 = mSummerarterial2
  Set clsrun.sarterial2 = mSummerarterial3
  Set clsrun.sfreeway = mSummerfreeway
  Set clsrun.sfreeway1 = mSummerfreeway2
  Set clsrun.sfreeway2 = mSummerfreeway3
  Set clsrun.warterial = mWinterarterial
  Set clsrun.warterial1 = mWinterarterial2
  Set clsrun.warterial2 = mWinterarterial3
  Set clsrun.wfreeway = mWinterfreeway
  Set clsrun.wfreeway1 = mWinterfreeway2
  Set clsrun.wfreeway2 = mWinterfreeway3

  clsrun.summer
  clsrun.winter

End Sub
```

Summer and Winter Processing Code

```
Private mSfreeway As Collection
Private mSfreeway1 As Collection
Private mSfreeway2 As Collection
Private mWfreeway As Collection
Private mWfreeway1 As Collection
Private mWfreeway2 As Collection
Private mSarterial As Collection
Private mSarterial1 As Collection
Private mSarterial2 As Collection
Private mWarterial As Collection
Private mWarterial1 As Collection
Private mWarterial2 As Collection
Private mDBEngine As New DAO.DBEngine
Private mdatabase As DAO.Database
Private mRecordset As DAO.Recordset
Private SNOX_recset As DAO.Recordset
Private SCO_recset As DAO.Recordset
Private SVOC_recset As DAO.Recordset
Private WNOX_recset As DAO.Recordset
Private WCO_recset As DAO.Recordset
Private WVOC_recset As DAO.Recordset
Private mPath As String
Private file_name As String
Private total_emission_hc As Double
Private total_emission_co As Double
Private total_emission_nox As Double

Public Property Let Path(ByVal value As String)

  mPath = value
  file_name = Left(Form1.lstFile.FileName, 8)
  Set mdatabase = mDBEngine.OpenDatabase(mPath, False, False, "DBASE IV")
  Set mRecordset = mdatabase.OpenRecordset("select * from " & file_name)

End Property

Public Property Set sfreeway(ByVal value As Variant)

  Set mSfreeway = value

End Property

Public Property Set sfreeway1(ByVal value As Variant)

  Set mSfreeway1 = value

End Property

Public Property Set sfreeway2(ByVal value As Variant)

  Set mSfreeway2 = value
```

```
End Property
Public Property Set wfreeway(ByVal value As Variant)
  Set mWfreeway = value
End Property
Public Property Set wfreeway1(ByVal value As Variant)
  Set mWfreeway1 = value
End Property
Public Property Set wfreeway2(ByVal value As Variant)
  Set mWfreeway2 = value
End Property
Public Property Set sarterial(ByVal value As Variant)
  Set mSarterial = value
End Property
Public Property Set sarterial1(ByVal value As Variant)
  Set mSarterial1 = value
End Property
Public Property Set sarterial2(ByVal value As Variant)
  Set mSarterial2 = value
End Property
Public Property Set warterial(ByVal value As Variant)
  Set mWarterial = value
End Property
Public Property Set warterial1(ByVal value As Variant)
  Set mWarterial1 = value
End Property
Public Property Set warterial2(ByVal value As Variant)
  Set mWarterial2 = value
```

```
End Property

Public Sub summer()
Dim speed As Double
Dim scenario As Integer

  Set SNOX_recset = mdatabase.OpenRecordset("select * from SNOX_com")
  Set SVOC_recset = mdatabase.OpenRecordset("select * from SVOC_com")
  Set SCO_recset = mdatabase.OpenRecordset("select * from SCO_comb")

  mRecordset.MoveFirst

  Do While Not mRecordset.EOF
    SNOX_recset.AddNew
    SVOC_recset.AddNew
    SCO_recset.AddNew
    If mRecordset.Fields("BA_SPEED") <> Null Then
      speed = mRecordset.Fields("AB_SPEED") + mRecordset.Fields("BA_SPEED") / 2
    Else
      speed = mRecordset.Fields("AB_SPEED")
    End If
    '
    Select Case speed
      Case 0 To 2.5
        scenario = 1
      Case 2.51 To 5
        scenario = 2
      Case 5.1 To 10
        scenario = 3
      Case 10.1 To 15
        scenario = 4
      Case 15.1 To 20
        scenario = 5
      Case 20.1 To 25
        scenario = 6
      Case 25.1 To 30
        scenario = 7
      Case 30.1 To 35
        scenario = 8
      Case 35.1 To 40
        scenario = 9
      Case 40.1 To 45
        scenario = 10
      Case 45.1 To 50
        scenario = 11
      Case 50.1 To 55
        scenario = 12
      Case 55.1 To 60
        scenario = 13
      Case 60.1 To 65
        scenario = 14
    End Select
    '
    If mRecordset.Fields("group_code").value = 1 Or mRecordset.Fields("group_code").value = 2 Then
```

```
      total_emission_hc = mSfreeway.Item(scenario) * mRecordset.Fields("length").value * _
                  mRecordset.Fields("tot_flow").value
      summer_add_fields "hc", total_emission_hc
      total_emission_co = mSfreeway1.Item(scenario) * mRecordset.Fields("length").value * _
                  mRecordset.Fields("tot_flow").value
      summer_add_fields "co", total_emission_co
      total_emission_nox = mSfreeway2.Item(scenario) * mRecordset.Fields("length").value * _
                  mRecordset.Fields("tot_flow").value
      summer_add_fields "nox", total_emission_nox
    ElseIf mRecordset.Fields("group_code").value > 2 Then
      total_emission_hc = mSarterial.Item(scenario) * mRecordset.Fields("length").value * _
                  mRecordset.Fields("tot_flow").value
      summer_add_fields "hc", total_emission_hc
      total_emission_co = mSarterial1.Item(scenario) * mRecordset.Fields("length").value * _
                  mRecordset.Fields("tot_flow").value
      summer_add_fields "co", total_emission_co
      total_emission_nox = mSarterial2.Item(scenario) * mRecordset.Fields("length").value * _
                  mRecordset.Fields("tot_flow").value
      summer_add_fields "nox", total_emission_nox
    End If
    '
    SNOX_recset.Update
    SVOC_recset.Update
    SCO_recset.Update
    mRecordset.MoveNext
  Loop

  Set SNOX_recset = Nothing
  Set SVOC_recset = Nothing
  Set SCO_recset = Nothing

End Sub

Public Sub winter()
Dim speed As Double
Dim scenario As Integer

  Set WNOX_recset = mdatabase.OpenRecordset("select * from WNOX_com")
  Set WVOC_recset = mdatabase.OpenRecordset("select * from WVOC_com")
  Set WCO_recset = mdatabase.OpenRecordset("select * from WCO_comb")

  mRecordset.MoveFirst

  Do While Not mRecordset.EOF
    WNOX_recset.AddNew
    WVOC_recset.AddNew
    WCO_recset.AddNew
    '
    If mRecordset.Fields("BA_SPEED") <> Null Then
      speed = mRecordset.Fields("AB_SPEED") + mRecordset.Fields("BA_SPEED") / 2
    Else
      speed = mRecordset.Fields("AB_SPEED")
    End If
    '
```

```
Select Case speed
  Case 0 To 2.5
    scenario = 1
  Case 2.51 To 5
    scenario = 2
  Case 5.1 To 10
    scenario = 3
  Case 10.1 To 15
    scenario = 4
  Case 15.1 To 20
    scenario = 5
  Case 20.1 To 25
    scenario = 6
  Case 25.1 To 30
    scenario = 7
  Case 30.1 To 35
    scenario = 8
  Case 35.1 To 40
    scenario = 9
  Case 40.1 To 45
    scenario = 10
  Case 45.1 To 50
    scenario = 11
  Case 50.1 To 55
    scenario = 12
  Case 55.1 To 60
    scenario = 13
  Case 60.1 To 65
    scenario = 14
End Select
'
If mRecordset.Fields("group_code").value = 1 Or mRecordset.Fields("group_code").value = 2 Then
  total_emission_hc = mWfreeway.Item(scenario) * mRecordset.Fields("length").value * _
            mRecordset.Fields("tot_flow").value
  winter_add_fields "hc", total_emission_hc
  total_emission_co = mWfreeway1.Item(scenario) * mRecordset.Fields("length").value * _
            mRecordset.Fields("tot_flow").value
  winter_add_fields "co", total_emission_co
  total_emission_nox = mWfreeway2.Item(scenario) * mRecordset.Fields("length").value * _
            mRecordset.Fields("tot_flow").value
  winter_add_fields "nox", total_emission_nox
ElseIf mRecordset.Fields("group_code").value > 2 Then
  total_emission_hc = mWarterial.Item(scenario) * mRecordset.Fields("length").value * _
            mRecordset.Fields("tot_flow").value
  winter_add_fields "hc", total_emission_hc
  total_emission_co = mWarterial1.Item(scenario) * mRecordset.Fields("length").value * _
            mRecordset.Fields("tot_flow").value
  winter_add_fields "co", total_emission_co
  total_emission_nox = mWarterial2.Item(scenario) * mRecordset.Fields("length").value * _
            mRecordset.Fields("tot_flow").value
  winter_add_fields "nox", total_emission_nox
End If
'
WNOX_recset.Update
```

```
    WVOC_recset.Update
    WCO_recset.Update
    mRecordset.MoveNext
  Loop

  Set WNOX_recset = Nothing
  Set WVOC_recset = Nothing
  Set WCO_recset = Nothing

End Sub

Private Sub summer_add_fields(emm_type As String, emissions As Double)

  If emm_type = "hc" Then
    cnt = 0
    Do While cnt < SVOC_recset.Fields.Count - 1
      SVOC_recset.Fields(cnt).value = mRecordset.Fields(cnt).value
      cnt = cnt + 1
    Loop
    SVOC_recset.Fields(cnt).value = emissions
  ElseIf emm_type = "co" Then
    cnt = 0
    Do While cnt < SCO_recset.Fields.Count - 1
      SCO_recset.Fields(cnt).value = mRecordset.Fields(cnt).value
      cnt = cnt + 1
    Loop
    SCO_recset.Fields(cnt).value = emissions
  ElseIf emm_type = "nox" Then
    cnt = 0
    Do While cnt < SNOX_recset.Fields.Count - 1
      SNOX_recset.Fields(cnt).value = mRecordset.Fields(cnt).value
      cnt = cnt + 1
    Loop
    SNOX_recset.Fields(cnt).value = emissions
  End If

End Sub

Private Sub winter_add_fields(emm_type As String, emissions As Double)

  If emm_type = "hc" Then
    cnt = 0
    Do While cnt < WVOC_recset.Fields.Count - 1
      WVOC_recset.Fields(cnt).value = mRecordset.Fields(cnt).value
      cnt = cnt + 1
    Loop
    WVOC_recset.Fields(cnt).value = emissions
  ElseIf emm_type = "co" Then
    cnt = 0
    Do While cnt < WCO_recset.Fields.Count - 1
      WCO_recset.Fields(cnt).value = mRecordset.Fields(cnt).value
      cnt = cnt + 1
    Loop
    WCO_recset.Fields(cnt).value = emissions
```

```
  ElseIf emm_type = "nox" Then
    cnt = 0
    Do While cnt < WNOX_recset.Fields.Count - 1
      WNOX_recset.Fields(cnt).value = mRecordset.Fields(cnt).value
      cnt = cnt + 1
    Loop
    WNOX_recset.Fields(cnt).value = emissions
  End If

End Sub

Private Sub Class_Terminate()

  Set mdatabase = Nothing
  Set mRecordset = Nothing
  Set mDBEngine = Nothing

End Sub
```

File Manipulation Code

```
Option Explicit

Private mEmissions As Double
Private mPath As String
Private mDBE As New DAO.DBEngine
Private mOutputdatabase As DAO.Database

Public Property Let prgPath(ByVal value As String)

  mPath = value

End Property

Public Sub maketable()
Dim mNewdef1 As TableDef
Dim mNewdef2 As TableDef
Dim mNewdef3 As TableDef
Dim mNewdef4 As TableDef
Dim mNewdef5 As TableDef
Dim mNewdef6 As TableDef
Dim mField As Field
Dim cnt As Integer
Dim file_name As String

On Error GoTo delete_file


  Set mOutputdatabase = mDBE.OpenDatabase(mPath, False, False, "DBASE IV;")
  Set mNewdef1 = New TableDef
  Set mNewdef2 = New TableDef
  Set mNewdef3 = New TableDef
  Set mNewdef4 = New TableDef
  Set mNewdef5 = New TableDef
  Set mNewdef6 = New TableDef

  file_name = Left(Form1.lstFile.FileName, 8)
  mNewdef1.Name = "SNOX_" & mOutputdatabase.TableDefs(file_name).Name
  mNewdef2.Name = "SCO_" & mOutputdatabase.TableDefs(file_name).Name
  mNewdef3.Name = "SVOC_" & mOutputdatabase.TableDefs(file_name).Name
  mNewdef4.Name = "WNOX_" & mOutputdatabase.TableDefs(file_name).Name
  mNewdef5.Name = "WCO_" & mOutputdatabase.TableDefs(file_name).Name
  mNewdef6.Name = "WVOC_" & mOutputdatabase.TableDefs(file_name).Name
  '
  cnt = 0
  Do While cnt < mOutputdatabase.TableDefs(file_name).Fields.Count
    Append mNewdef1, cnt, file_name
    Append mNewdef2, cnt, file_name
    Append mNewdef3, cnt, file_name
    Append mNewdef4, cnt, file_name
    Append mNewdef5, cnt, file_name
    Append mNewdef6, cnt, file_name
    cnt = cnt + 1
```

```
  Loop
  '
  Set mField = New Field
  Appendend mNewdef1
  Appendend mNewdef2
  Appendend mNewdef3
  Appendend mNewdef4
  Appendend mNewdef5
  Appendend mNewdef6
  '
  mOutputdatabase.TableDefs.Append mNewdef1
  mOutputdatabase.TableDefs.Append mNewdef2
  mOutputdatabase.TableDefs.Append mNewdef3
  mOutputdatabase.TableDefs.Append mNewdef4
  mOutputdatabase.TableDefs.Append mNewdef5
  mOutputdatabase.TableDefs.Append mNewdef6

  Set mDBE = Nothing
  Set mOutputdatabase = Nothing
  Set mNewdef1 = Nothing
  Set mNewdef2 = Nothing
  Set mNewdef3 = Nothing
  Set mNewdef4 = Nothing
  Set mNewdef5 = Nothing
  Set mNewdef6 = Nothing
  Set mField = Nothing

  Exit Sub

delete_file:
  mOutputdatabase.TableDefs.Delete Left(mNewdef1.Name, 8)
  mOutputdatabase.TableDefs.Delete Left(mNewdef2.Name, 8)
  mOutputdatabase.TableDefs.Delete Left(mNewdef3.Name, 8)
  mOutputdatabase.TableDefs.Delete Left(mNewdef4.Name, 8)
  mOutputdatabase.TableDefs.Delete Left(mNewdef5.Name, 8)
  mOutputdatabase.TableDefs.Delete Left(mNewdef6.Name, 8)
  mOutputdatabase.TableDefs.Append mNewdef1
  mOutputdatabase.TableDefs.Append mNewdef2
  mOutputdatabase.TableDefs.Append mNewdef3
  mOutputdatabase.TableDefs.Append mNewdef4
  mOutputdatabase.TableDefs.Append mNewdef5
  mOutputdatabase.TableDefs.Append mNewdef6
  Set mDBE = Nothing
  Set mOutputdatabase = Nothing
  Set mNewdef1 = Nothing
  Set mNewdef2 = Nothing
  Set mNewdef3 = Nothing
  Set mNewdef4 = Nothing
  Set mNewdef5 = Nothing
  Set mNewdef6 = Nothing
  Set mField = Nothing

End Sub
```

```
Private Sub Append(mTabledef As Variant, cnt As Integer, fName As String)
Dim mField As Field

  Set mField = New Field
  mField.Name = mOutputdatabase.TableDefs(fName).Fields(cnt).Name
  mField.Size = mOutputdatabase.TableDefs(fName).Fields(cnt).Size
  mField.Type = mOutputdatabase.TableDefs(fName).Fields(cnt).Type
  mTabledef.Fields.Append mField
  Set mField = Nothing

End Sub

Private Sub Appendend(mTabledef As Variant)
Dim mField As Field

  Set mField = New Field
  mField.Name = "Link_emmission"
  mField.Size = 22
  mField.Type = dbDouble
  mTabledef.Fields.Append mField
  Set mField = Nothing

End Sub
```

APPENDIX D ILLUSTRATION OF MAPPED EMISSIONS OUTPUT FOR 1ST INPUT FACTOR COMBINATION

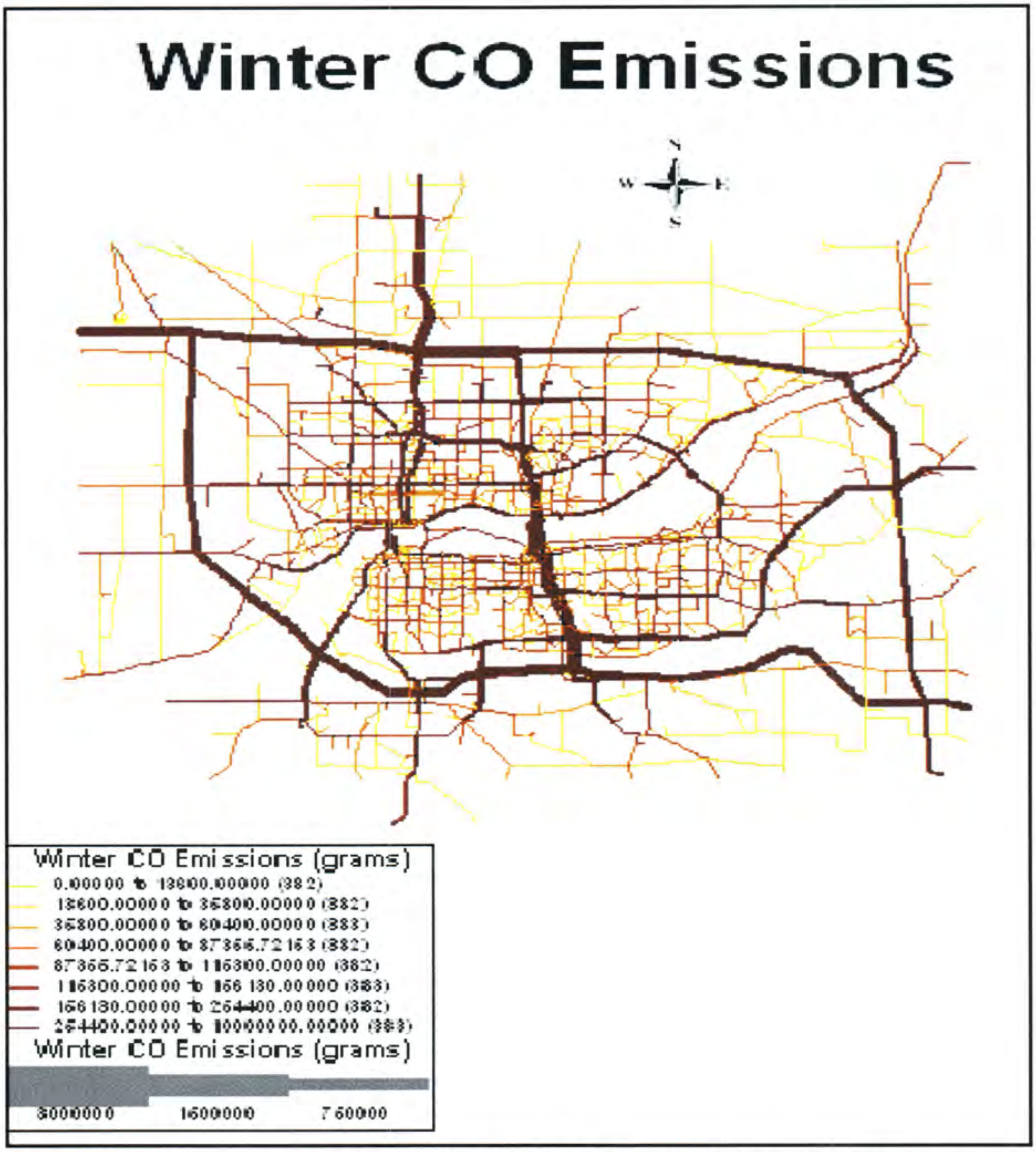

Figure D1 CO Emissions (Friction Distribution 1, Feedback, User Equilibrium)

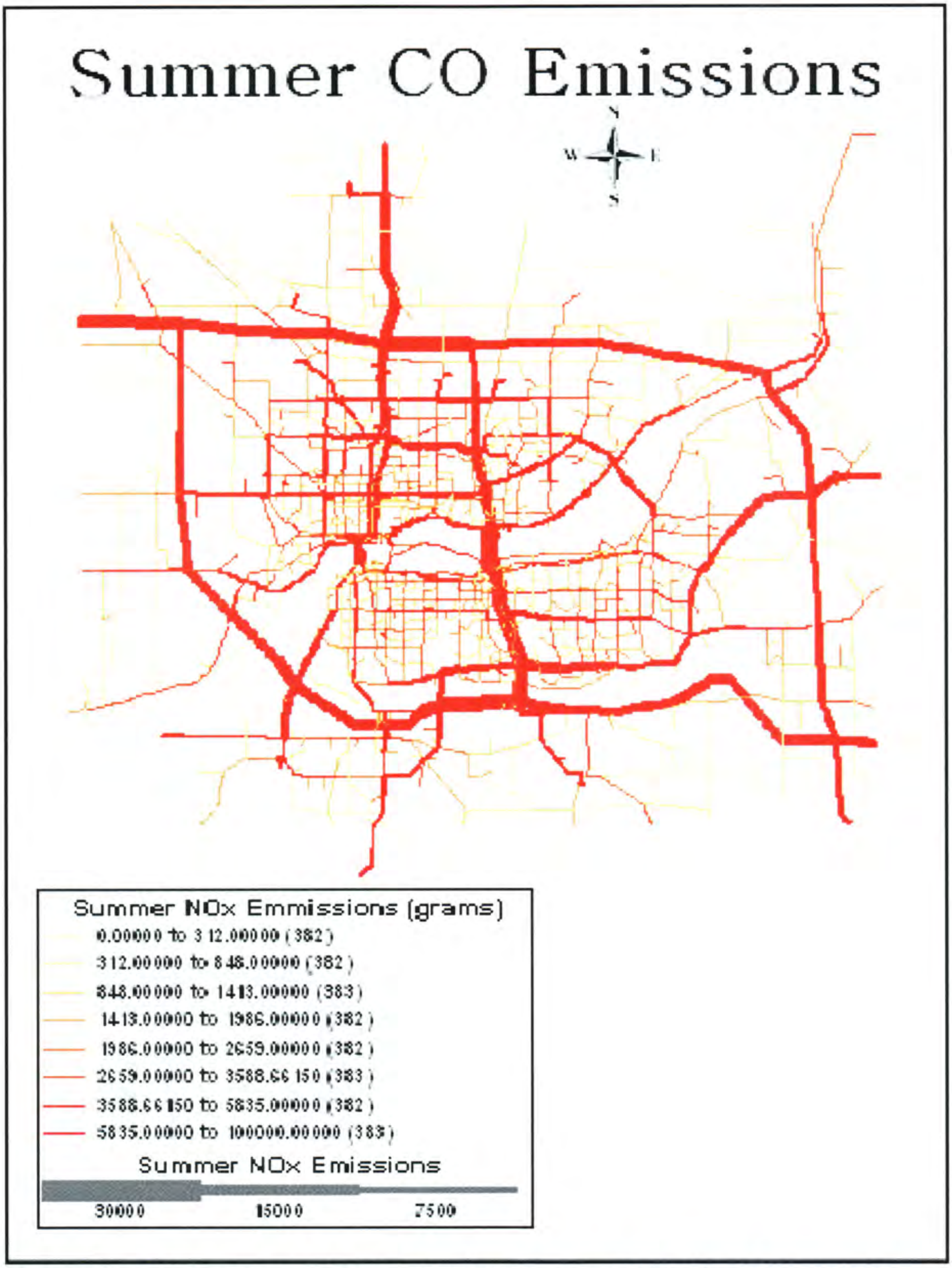

Figure D2 NOx Emissions (Friction Distribution 1, Feedback, User Equilibrium)

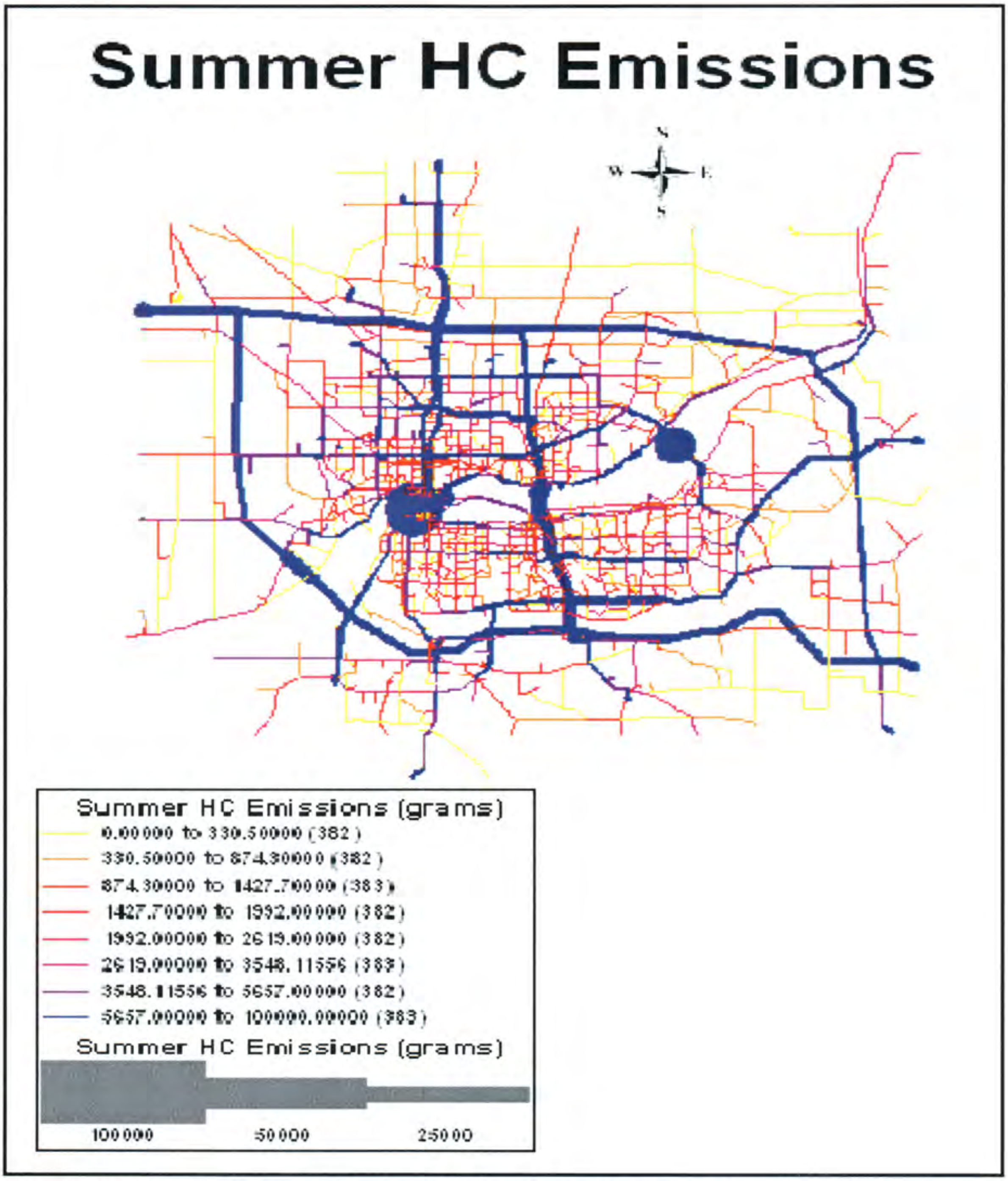

Figure D3 HC Emissions (Friction Distribution 1, Feedback, User Equilibrium)

APPENDIX E SCREENLINE RMSD TABLES FOR 1998 AND 2025 DATA

Table E1 1998 Screenline Results

ID	Roadway Type	BI-STATE Flow	Base Time sec	Total Flow (TransCAD) veh/day	Loaded Time sec	V/C Ratio	Speed mph	MSD (Mean Squared Difference)
752	3	7600	0.43	7153.368	0.43	0.42	25.00	199480.14
2559	4	7100	1.29	6078.026	1.44	0.94	35.05	1044430.86
2571	1	10450	1.48	5045.827	1.48	0.14	55.13	29205085.81
2572	1	10450	1.48	4874.552	1.48	0.14	55.13	31085620.40
2725	2	3600	1.40	3681.5	1.40	0.23	47.98	6642.25
2727	2	3600	1.40	3588.5	1.40	0.22	47.98	132.25
2882	1	20500	1.84	19208.899	1.86	0.53	48.33	1666941.79
2903	3	9200	1.04	8864.795	1.06	0.59	37.39	112362.39
2918	4	7100	1.29	6237.42	1.45	0.96	34.66	744044.26
2925	1	12270	2.44	10528.081	2.44	0.29	55.02	3034281.80
2926	1	20500	1.84	19366.839	1.86	0.54	48.31	1284053.85
2927	1	12270	2.44	10522.519	2.44	0.29	55.02	3053689.85
2936	4	6550	2.22	3772.663	2.27	0.63	38.03	7713600.81
2940	4	6550	2.22	3842.475	2.28	0.64	37.96	7330691.63
2948	3	9200	1.04	8859.368	1.06	0.59	37.39	116030.16
4172	4	4600	0.64	4269.931	0.64	0.36	41.15	108945.55
4194	3	7200	1.09	2299.252	1.09	0.15	37.98	24017330.96
4204	1	19850	1.19	18579.031	1.20	0.52	49.39	1615362.20
4651	4	3000	0.68	3655.698	0.69	0.61	38.04	429939.87
4652	5	4850	1.40	3639.289	1.43	0.61	35.70	1465821.13
4653	4	3000	0.68	3683.394	0.69	0.61	38.01	467027.36
4661	5	4850	1.40	3608.957	1.43	0.60	35.73	1540187.73
4684	5	2400	2.00	145.399	2.00	0.02	30.00	5083225.67
4700	5	2400	2.00	146.255	2.00	0.02	30.00	5079366.53
4702	4	5200	1.41	5200.476	1.50	0.80	29.27	0.23
4716	4	5200	1.41	5152.655	1.49	0.79	29.33	2241.55
4718	1	8700	1.11	6863.5	1.11	0.19	56.21	3372732.25
4789	1	14100	2.58	18158.16	2.61	0.50	55.51	16468662.59
4803	1	8700	1.11	6929.5	1.11	0.19	56.20	3134670.25

Table E1 Cont'd.

ID	Roadway Type	BI-STATE Flow	Base Time sec	Total Flow (TransCAD) veh/day	Loaded Time sec	V/C Ratio	Speed mph	MSD (Mean Squared Difference)
4973	3	10100	0.90	8875.477	0.92	0.59	39.28	1499456.58
4982	3	6600	0.84	6275.463	0.84	0.42	39.82	105324.26
4985	3	6600	0.84	4176.143	0.84	0.28	39.96	5875082.76
5120	1	14100	2.58	18139.312	2.60	0.50	55.51	16316041.43
5128	4	5000	2	4641.226	2.13	0.81	39.40	128718.78
5134	4	5000	2	4640.226	2.13	0.81	39.40	129437.33
5346	1	19850	1.19	18194.853	1.20	0.51	49.43	2739511.59
5450	3	7200	1.09	2296.984	1.09	0.15	37.98	24039565.90
5602	3	7600	0.43	6928.339	0.43	0.41	25.01	451128.50
1444	1	23400	0.92	25952.585	0.96	0.72	47.01	6515690.18
1514	4	5600	0.7	1399.834	0.70	0.11	32.57	17641394.43
1690	1	23400	0.92	25910.017	0.96	0.72	47.02	6300185.34
1693	4	5600	0.7	1772.231	0.70	0.14	32.57	14651815.52
1755	1	19100	1.74	13838.407	1.75	0.38	48.81	27684360.90
2176	2	7550	1.27	4575.537	1.27	0.25	41.55	8847430.14
2879	1	19100	1.74	14492.397	1.75	0.40	48.77	21230005.41
3080	2	7550	1.27	6291.766	1.27	0.35	41.48	1583152.80
3101	2	12750	0.91	8065.011	0.92	0.45	41.29	21949121.93
3110	2	12750	0.91	7911.822	0.92	0.44	41.31	23407966.36
3292	4	2050	1.26	2046.56	1.26	0.36	41.80	11.83
3296	4	2050	1.26	2036.56	1.26	0.36	41.80	180.63
3317	1	8400	0.62	7770	0.62	0.22	50.31	396900.00
3320	1	8400	0.62	7873	0.62	0.22	50.31	277729.00
3365	1	7300	2.05	4004.102	2.05	0.11	55.02	10862943.63
3480	3	5700	1.33	5751.076	1.45	0.88	41.31	2608.76
3485	3	5700	1.33	5740.076	1.45	0.88	41.34	1606.09
4525	1	15250	2.8	14535.5	2.81	0.40	55.71	510510.25
4526	1	15250	2.8	14535.5	2.81	0.40	55.71	510510.25
4549	4	3350	1.5	3959.561	1.54	0.66	38.89	371564.61

Table E1 Cont'd.

ID	Roadway Type	BI-STATE Flow	Base Time sec	Total Flow (TransCAD) veh/day	Loaded Time sec	V/C Ratio	Speed mph	MSD (Mean Squared Difference)
4551	1	7300	2.05	4208.408	2.05	0.12	55.02	9557941.09
4554	4	3350	1.5	3874.049	1.54	0.65	38.98	274627.35
4970	2	15650	0.46	14046.484	0.49	0.83	39.01	2571263.56
5075	4	2600	2.83	2527	2.84	0.42	38.83	5329.00
5078	4	2600	2.83	2526	2.84	0.42	38.83	5476.00
5250	2	15650	0.46	14221.489	0.49	0.84	38.88	2040643.68
5440	4	4600	0.64	4749.595	0.64	0.40	41.10	22378.66
							RMSD =	2428.449
							% RMSD =	26.33

Table E2 2025 Screenline Results

ID	Roadway Type	BI-STATE Flow	Base Time sec	Total Flow (TransCAD) veh/day	Loaded Time sec	V/C Ratio	Speed mph	MSD (Mean Squared Difference)
2706	4	8580.00	1.40	8163.46	1.40	0.63	36.13	173502.24
3071	4	9199.00	1.39	8350.32	1.39	0.64	36.27	720262.83
4951	1	28999.00	2.58	28734.52	2.58	0.80	56.09	69950.73
5293	1	28343.00	2.56	28322.09	2.56	0.79	56.45	437.06
2812	5	2869.00	1.89	2051.48	1.89	0.39	31.68	668337.32
2814	5	2874.00	1.89	2053.48	1.89	0.39	31.68	673251.43
2872	2	8215.00	1.42	6979.08	1.42	0.44	47.48	1527505.66
2874	2	8218.00	1.42	7023.08	1.42	0.44	47.47	1427840.98
2718	1	24514.00	1.37	22381.21	1.37	0.62	59.56	4548780.39
2719	1	24680.00	1.37	22031.16	1.37	0.61	59.72	7016342.75
2680	1	23357.00	0.42	22183.65	0.42	0.62	52.91	1376754.92
5788	1	22979.00	0.42	22121.37	0.42	0.61	52.93	735536.08
757	3	17237.00	0.50	16605.39	0.50	0.83	21.75	398933.72
5782	3	17248.00	0.49	16537.71	0.49	0.83	21.90	504517.57
5795	4	5631.00	5.83	6526.13	5.83	0.73	0.10	801261.30
5797	4	6758.00	5.87	6435.08	5.87	0.72	0.10	104279.91
4681	1	31911.00	2.75	27560.05	2.75	0.77	56.88	18930748.50
4682	1	31907.00	2.75	27396.05	2.75	0.76	57.01	20348651.86
4810	4	4778.00	0.68	3939.97	0.68	0.33	38.70	702297.63
4812	4	4883.00	0.68	4292.03	0.68	0.36	38.65	349245.54
4811	5	6742.00	1.43	6851.55	1.43	0.57	35.63	12001.20
4820	5	5604.00	1.43	6586.59	1.43	0.55	35.73	965477.21
5142	3	9834.00	0.96	10400.68	0.96	0.69	37.50	321121.69
5195	3	10252.00	0.95	10441.70	0.95	0.70	37.85	35985.71
5152	3	7499.00	0.85	7924.53	0.85	0.53	39.37	181072.38
5154	3	6221.00	0.85	6871.02	0.85	0.46	39.59	422519.50
1013	2	22564.00	0.43	21668.41	0.43	0.60	40.93	802077.87
4861	3	8229.00	1.43	7768.66	1.43	0.52	30.57	211912.92
4875	3	8238.00	1.43	7664.78	1.43	0.51	30.61	328581.17

Table E2 Cont'd

ID	Roadway Type	BI-STATE Flow	Base Time sec	Total Flow (TransCAD) veh/day	Loaded Time sec	V/C Ratio	Speed mph	MSD (Mean Squared Difference)
4877	1	12578.00	1.11	10514.09	1.11	0.29	56.09	4259712.10
4964	1	12574.00	1.11	10485.09	1.11	0.29	56.10	4363532.45
4843	5	874.00	2.00	794.67	2.00	0.13	30.00	6294.04
4859	5	867.00	2.00	794.67	2.00	0.13	30.00	5232.35
3078	1	29067.00	2.38	26533.30	2.38	0.74	56.47	6419630.62
3080	1	29096.00	2.37	26194.94	2.37	0.73	56.72	8416160.73
3090	4	2393.00	1.81	4497.32	1.81	0.37	47.85	4428154.25
3094	4	2319.00	1.81	4395.71	1.81	0.37	47.86	4312711.96
1400	1	37886.00	0.66	39255.65	0.66	1.23	22.69	1875930.17
4604	1	39217.00	0.66	39310.16	0.66	1.23	22.58	8677.85
3030	1	32327.00	1.47	27967.11	1.47	0.52	61.30	19008684.41
3055	3	3143.00	1.04	5187.33	1.04	0.35	37.99	4179297.41
3079	1	32385.00	1.47	28289.11	1.47	0.52	61.24	16776347.66
3102	3	3153.00	1.04	5201.96	1.04	0.35	37.99	4198245.28
976	1	21650.00	1.00	21329.92	1.00	0.59	46.73	102451.85
2032	4	11001.00	1.66	11604.19	1.66	0.58	28.84	363841.80
5808	4	11032.00	1.66	11484.89	1.66	0.57	28.88	205108.45
5803	1	16012.00	6.52	17493.76	6.52	0.51	0.09	2195621.59
5805	1	16018.00	6.52	17400.42	6.52	0.51	0.09	1911096.12
2406	4	4313.00	4.62	3196.49	4.62	0.53	38.05	1246596.81
2408	4	4317.00	4.62	3197.49	4.62	0.53	38.05	1253304.88
3636	2	7238.00	1.34	5791.20	1.34	0.39	44.83	2093224.45
3641	2	7249.00	1.34	5782.20	1.34	0.39	44.84	2151496.37
3521	1	17840.00	2.07	15462.93	2.07	0.43	54.39	5650466.54
4707	1	17789.00	2.07	15450.40	2.07	0.43	54.38	5469059.31
4705	4	4366.00	1.55	3403.75	1.55	0.57	38.82	925930.84
4710	4	4504.00	1.54	3173.02	1.54	0.53	38.98	1771513.08
3253	2	16691.00	0.93	12644.46	0.93	0.47	40.44	16374518.34
3262	2	16739.00	0.94	12744.13	0.94	0.47	40.42	15958986.32

Table E2 Cont'd

ID	Roadway Type	BI-STATE Flow	Base Time sec	Total Flow (TransCAD) veh/day	Loaded Time sec	V/C Ratio	Speed mph	MSD (Mean Squared Difference)
3265	3	184.00	1.22	1799.51	1.22	0.24	37.85	2609879.02
3291	3	190.00	1.22	1790.54	1.22	0.24	37.85	2561731.49
1909	1	31095.00	1.39	29078.90	1.39	0.54	61.51	4064651.15
3027	1	32235.00	1.39	30086.87	1.39	0.56	61.15	4614471.09
1668	4	1638.00	0.70	1744.86	0.70	0.13	32.57	11419.06
1844	1	35821.00	0.98	35037.78	0.98	0.65	46.04	613430.44
1847	4	3253.00	0.70	2146.67	0.70	0.17	32.57	1223977.13
2323	2	8890.00	1.27	8241.06	1.27	0.31	41.42	421128.32
3234	2	8931.00	1.27	8428.76	1.27	0.31	41.46	252250.04
4352	3	2260.00	1.09	2648.59	1.09	0.18	37.97	150999.86
5527	1	20397.00	1.00	20575.52	1.00	0.57	46.94	31870.10
5634	3	2232.00	1.09	2822.51	1.09	0.19	37.97	348702.06
1011	4	4924.00	0.41	4855.29	0.41	0.40	40.67	4721.34
5624	4	5870.00	0.42	5743.70	0.42	0.48	40.45	15951.69
5139	2	16953.00	0.47	18243.30	0.47	0.68	40.45	1664881.83
5427	2	16766.00	0.47	18236.11	0.47	0.68	40.43	2161208.71
3473	1	19130.00	0.51	17064.78	0.51	0.47	61.47	4265137.78
3476	1	19131.00	0.51	16940.78	0.51	0.47	61.49	4797068.03
3397	5	5240.00	1.60	4199.62	1.60	0.70	34.06	1082400.95
3402	5	5239.00	1.60	4210.01	1.60	0.70	34.05	1058824.54
3450	4	4405.00	1.33	3793.22	1.33	0.67	39.84	374275.99
3454	4	4416.00	1.32	3770.22	1.32	0.66	39.88	417036.97
2482	4	256.00	2.63	181.31	2.63	0.03	41.98	5578.75
2487	4	267.00	2.63	183.31	2.63	0.03	41.98	7004.18
2462	1	19468.00	0.98	16615.69	0.98	0.46	54.42	8135678.04
2470	1	19553.00	0.98	16599.46	0.98	0.46	54.43	8723404.44
5246	4	4169.00	2.91	3343.16	2.91	0.56	37.91	682013.36
5249	4	4175.00	2.91	3329.16	2.91	0.55	37.92	715447.00

Table E2 Cont'd

ID	Roadway Type	BI-STATE Flow	Base Time sec	Total Flow (TransCAD) veh/day	Loaded Time sec	V/C Ratio	Speed mph	MSD (Mean Squared Difference)
							RMSD =	1729.36
							%RMSD =	0.13

APPENDIX F LINK COMPARISON TABLES

Table F1 Link ID 764 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams
1	0.32	4	2,427	24	27,144	1,031	1,039
2	0.32	4	915	25	10,231	389	392
3	0.32	4	2,324	24	26,000	987	995
4	0.32	4	917	25	10,257	390	393
5	0.32	4	2,255	24	25,224	958	966
6	0.32	4	1,043	24	11,664	443	446
7	0.32	4	2,188	24	24,474	929	937
8	0.32	4	2,188	24	24,474	929	937
9	0.32	4	2,507	22	28,048	1,065	1,074
10	0.32	4	1,520	24	16,999	646	651
11	0.32	4	2,409	19	28,161	1,081	1,129
12	0.32	4	1,792	20	20,948	804	840
13	0.32	4	2,031	20	23,738	911	951
14	0.32	4	4,541	21	50,792	1,929	1,944
15	0.32	4	3,311	18	38,701	1,509	1,551
16	0.32	4	3,007	19	35,149	1,349	1,409
17	0.32	4	1,191	20	13,326	506	510
18	0.32	4	1,191	20	13,326	506	510
19	0.32	4	2,215	19	25,892	994	1,038
20	0.32	4	2,541	20	29,696	1,140	1,190
21	0.32	4	1,971	24	22,051	837	844
22	0.32	4	2,360	25	26,400	1,003	1,011
23	0.32	4	2,460	24	27,518	1,045	1,053
24	0.32	4	2,296	25	25,689	976	983
25	0.32	4	2,197	24	24,573	933	941
26	0.32	4	2,176	25	24,339	924	932
27	0.32	4	3,020	25	33,783	1,283	1,293
28	0.32	4	3,020	25	33,783	1,283	1,293
29	0.32	4	2,662	22	29,772	1,131	1,140
30	0.32	4	3,149	24	35,221	1,338	1,348

Table F2 Link ID 872 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams
1	2.05	1	79,789	53	988,385	36,115	28,785
2	2.05	1	60,255	55	770,491	28,555	21,506
3	2.05	1	76,231	55	944,313	34,504	27,501
4	2.05	1	52,424	56	670,353	24,843	18,711
5	2.05	1	85,360	53	1,057,393	38,636	30,794
6	2.05	1	73,096	54	905,476	33,085	26,370
7	2.05	1	71,511	55	885,848	32,368	25,799
8	2.05	1	71,511	55	885,848	32,368	25,799
9	2.05	1	76,646	52	949,458	34,692	27,651
10	2.05	1	73,003	54	904,319	33,043	26,336
11	2.05	1	100,170	48	1,204,735	43,728	36,729
12	2.05	1	92,115	52	1,141,076	41,694	33,232
13	2.05	1	101,673	51	1,259,470	46,020	36,679
14	2.05	1	102,740	54	1,272,689	46,503	37,064
15	2.05	1	115,850	48	1,393,317	23,972	42,479
16	2.05	1	104,850	51	1,298,825	47,458	37,826
17	2.05	1	92,972	54	1,151,695	42,082	33,541
18	2.05	1	92,972	54	1,151,695	42,082	33,541
19	2.05	1	103,803	48	1,248,430	45,314	38,062
20	2.05	1	104,569	52	1,295,344	47,331	37,724
21	2.05	1	70,847	53	877,616	32,067	25,559
22	2.05	1	82,107	55	1,049,918	38,910	29,305
23	2.05	1	90,513	54	1,121,235	40,969	32,654
24	2.05	1	69,018	56	882,544	32,707	24,633
25	2.05	1	79,446	54	984,132	35,959	28,661
26	2.05	1	71,163	55	909,975	33,724	25,399
27	2.05	1	68,058	56	870,280	32,253	24,291
28	2.05	1	68,058	56	870,280	32,253	24,291
29	2.05	1	83,773	54	1,037,738	37,918	30,222
30	2.05	1	73,379	55	938,313	34,774	26,190

Table F3 Link ID 1353 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams
1	0.28	4	2,552	34	27,958	1,033	983
2	0.28	4	1,792	39	20,264	737	673
3	0.28	4	2,333	34	25,557	944	898
4	0.28	4	2,158	38	24,403	888	810
5	0.28	4	2,376	32	26,030	962	915
6	0.28	4	1,941	35	21,942	798	728
7	0.28	4	1,808	36	20,445	744	679
8	0.28	4	1,808	36	20,445	744	679
9	0.28	4	2,189	33	23,981	886	843
10	0.28	4	1,792	35	20,263	737	673
11	0.28	4	2,307	32	25,278	934	889
12	0.28	4	2,403	34	26,322	972	925
13	0.28	4	2,249	33	24,635	910	866
14	0.28	4	2,884	36	32,604	1,186	1,082
15	0.28	4	2,501	31	27,396	6,608	963
16	0.28	4	2,558	33	28,022	1,035	985
17	0.28	4	3,069	36	34,698	1,262	1,152
18	0.28	4	3,069	36	34,698	1,262	1,152
19	0.28	4	2,322	32	25,443	940	894
20	0.28	4	2,164	35	23,704	876	833
21	0.28	4	2,205	35	24,925	907	827
22	0.28	4	2,310	38	26,111	950	867
23	0.28	4	1,679	36	18,985	691	630
24	0.28	4	2,511	37	28,385	1,033	942
25	0.28	4	2,240	35	25,329	921	841
26	0.28	4	2,265	38	25,607	932	850
27	0.28	4	2,410	39	27,245	991	904
28	0.28	4	2,410	39	27,245	991	904
29	0.28	4	2,009	35	22,714	826	754
30	0.28	4	2,518	37	28,468	1,036	945

Table F4 Link ID 1711 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams
1	0.82	1	34,885	60	446,080	16,532	12,451
2	0.82	1	26,239	63	346,961	13,177	9,306
3	0.82	1	36,751	60	485,963	18,456	13,034
4	0.82	1	29,345	63	388,028	14,736	10,407
5	0.82	1	34,810	58	445,125	16,496	12,424
6	0.82	1	22,739	61	300,687	11,419	8,065
7	0.82	1	21,124	61	279,328	10,608	7,492
8	0.82	1	21,124	61	279,328	10,608	7,492
9	0.82	1	37,874	57	484,298	17,948	13,517
10	0.82	1	22,662	61	299,667	11,381	8,037
11	0.82	1	48,901	46	588,121	21,347	17,930
12	0.82	1	53,092	55	678,900	25,160	18,949
13	0.82	1	49,459	51	612,673	22,387	17,843
14	0.82	1	40,146	61	530,858	20,161	14,238
15	0.82	1	48,308	47	580,995	10,742	17,713
16	0.82	1	54,342	50	673,156	24,597	19,604
17	0.82	1	39,084	61	516,813	19,627	13,861
18	0.82	1	39,084	61	516,813	19,627	13,861
19	0.82	1	51,403	47	618,215	22,439	18,848
20	0.82	1	49,920	57	638,335	23,657	17,817
21	0.82	1	37,924	59	484,941	17,972	13,535
22	0.82	1	30,425	62	402,310	15,279	10,790
23	0.82	1	29,922	60	382,621	14,180	10,680
24	0.82	1	35,213	62	465,629	17,684	12,489
25	0.82	1	35,305	60	451,456	16,731	12,601
26	0.82	1	33,202	62	439,036	16,674	11,775
27	0.82	1	23,867	63	315,597	11,986	8,465
28	0.82	1	23,867	63	315,597	11,986	8,465
29	0.82	1	34,187	59	437,152	16,201	12,202
30	0.82	1	34,461	62	455,686	17,306	12,222

Table F5 Link ID 1851 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams
1	0.65	4	3,088	39	34,914	1,270	1,159
2	0.65	4	1,131	39	12,783	465	424
3	0.65	4	2,897	39	32,748	1,191	1,087
4	0.65	4	1,134	39	12,822	466	426
5	0.65	4	4,287	38	48,462	1,763	1,608
6	0.65	4	1,455	39	16,446	598	546
7	0.65	4	4,257	39	48,127	1,751	1,597
8	0.65	4	4,257	39	48,127	1,751	1,597
9	0.65	4	4,458	37	50,397	1,833	1,673
10	0.65	4	1,537	39	17,380	632	577
11	0.65	4	5,735	35	64,839	2,359	2,152
12	0.65	4	4,388	38	49,613	1,805	1,647
13	0.65	4	5,323	37	60,180	2,189	1,997
14	0.65	4	2,507	39	28,344	1,031	941
15	0.65	4	6,191	34	67,828	1,788	2,384
16	0.65	4	6,222	37	70,340	2,559	2,335
17	0.65	4	6,707	39	75,831	2,759	2,517
18	0.65	4	6,707	39	75,831	2,759	2,517
19	0.65	4	5,733	35	64,810	2,358	2,151
20	0.65	4	4,603	38	52,041	1,893	1,727
21	0.65	4	2,896	39	32,737	1,191	1,087
22	0.65	4	1,655	39	18,708	681	621
23	0.65	4	2,384	39	26,949	980	894
24	0.65	4	1,662	39	18,786	683	624
25	0.65	4	2,781	39	31,436	1,144	1,043
26	0.65	4	1,422	39	16,080	585	534
27	0.65	4	3,617	39	40,897	1,488	1,357
28	0.65	4	3,617	39	40,897	1,488	1,357
29	0.65	4	3,338	39	37,736	1,373	1,252
30	0.65	4	2,151	39	24,321	885	807

Table F6 Link ID 1911 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams
1	0.76	5	2,331	32	25,532	943	897
2	0.76	5	1,952	32	21,382	790	752
3	0.76	5	2,300	32	25,196	931	886
4	0.76	5	1,964	32	21,522	795	756
5	0.76	5	2,365	32	25,907	957	911
6	0.76	5	1,506	32	16,503	610	580
7	0.76	5	2,118	32	23,208	857	816
8	0.76	5	2,118	32	23,208	857	816
9	0.76	5	2,432	32	26,648	984	937
10	0.76	5	1,420	32	15,553	575	547
11	0.76	5	3,014	32	33,018	1,220	1,161
12	0.76	5	2,370	32	25,970	959	913
13	0.76	5	2,580	32	28,269	1,044	994
14	0.76	5	2,706	32	29,648	1,095	1,042
15	0.76	5	2,912	32	31,907	1,087	1,122
16	0.76	5	2,664	32	29,189	1,078	1,026
17	0.76	5	3,216	32	35,228	1,301	1,238
18	0.76	5	3,216	32	35,228	1,301	1,238
19	0.76	5	3,119	32	34,167	1,262	1,201
20	0.76	5	2,654	32	29,075	1,074	1,022
21	0.76	5	2,358	32	25,836	954	908
22	0.76	5	2,427	32	26,588	982	935
23	0.76	5	2,220	32	24,323	899	855
24	0.76	5	2,429	32	26,613	983	935
25	0.76	5	2,277	32	24,947	922	877
26	0.76	5	2,495	32	27,338	1,010	961
27	0.76	5	2,585	32	28,325	1,046	996
28	0.76	5	2,585	32	28,325	1,046	996
29	0.76	5	2,268	32	24,852	918	874
30	0.76	5	2,463	32	26,985	997	949

Table F7 Link ID 1921 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	1.77	4	8,021	42	93,615	3,386	2,946	1.53
2	1.77	4	4,310	42	50,300	1,820	1,583	-45.45
3	1.77	4	7,900	42	92,202	3,335	2,901	0
4	1.77	4	4,272	42	49,852	1,803	1,569	-45.93
5	1.77	4	8,551	41	99,797	3,610	3,140	8.24
6	1.77	4	6,840	42	79,824	2,888	2,512	-13.42
7	1.77	4	5,478	42	63,928	2,313	2,012	-30.66
8	1.77	4	5,478	42	63,928	2,313	2,012	-30.66
9	1.77	4	9,899	41	115,527	4,179	3,635	25.3
10	1.77	4	6,894	42	80,460	2,911	2,532	-12.73
11	1.77	4	9,854	41	115,003	4,160	3,619	24.73
12	1.77	4	8,257	42	96,365	3,486	3,032	4.52
13	1.77	4	8,480	42	98,973	3,580	3,114	7.34
14	1.77	4	6,131	42	71,550	2,588	2,251	-22.4
15	1.77	4	9,634	41	112,439	2,468	3,538	21.95
16	1.77	4	9,090	42	106,090	3,838	3,338	15.06
17	1.77	4	6,351	42	74,124	2,681	2,332	-19.61
18	1.77	4	6,351	42	74,124	2,681	2,332	-19.61
19	1.77	4	9,889	41	115,409	4,175	3,631	25.17
20	1.77	4	8,091	42	94,429	3,416	2,971	2.42
21	1.77	4	6,849	42	79,931	2,891	2,515	-13.31
22	1.77	4	5,048	42	58,912	2,131	1,854	-36.11
23	1.77	4	7,029	42	82,030	2,967	2,581	-11.03
24	1.77	4	5,073	42	59,203	2,142	1,863	-35.79
25	1.77	4	6,913	42	80,685	2,919	2,539	-12.49
26	1.77	4	4,832	42	56,393	2,040	1,774	-38.84
27	1.77	4	4,934	42	57,578	2,083	1,812	-37.55
28	1.77	4	4,934	42	57,578	2,083	1,812	-37.55
29	1.77	4	7,336	42	85,618	3,097	2,694	-7.14
30	1.77	4	5,564	42	64,940	2,349	2,043	-29.57

Table F8 Link ID 2029 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	0.88	4	6,826	39	77,172	2,807	2,561	0.48
2	0.88	4	5,249	41	61,262	2,216	1,928	-20.24
3	0.88	4	6,794	39	76,807	2,794	2,549	0
4	0.88	4	5,253	41	61,309	2,218	1,929	-20.18
5	0.88	4	6,793	37	76,802	2,794	2,549	-0.01
6	0.88	4	5,657	40	63,961	2,327	2,123	-16.72
7	0.88	4	5,592	40	65,268	2,361	2,054	-15.02
8	0.88	4	5,592	40	65,268	2,361	2,054	-15.02
9	0.88	4	6,572	37	74,302	2,703	2,466	-3.26
10	0.88	4	5,420	40	61,276	2,229	2,034	-20.22
11	0.88	4	7,087	36	80,124	2,915	2,659	4.32
12	0.88	4	7,182	39	81,194	2,954	2,695	5.71
13	0.88	4	7,180	37	81,172	2,953	2,694	5.68
14	0.88	4	6,991	40	81,591	2,951	2,567	6.23
15	0.88	4	7,123	36	80,528	1,468	2,673	4.84
16	0.88	4	7,152	37	80,857	2,941	2,684	5.27
17	0.88	4	6,933	40	80,916	2,927	2,546	5.35
18	0.88	4	6,933	40	80,916	2,927	2,546	5.35
19	0.88	4	7,089	36	80,147	2,916	2,660	4.35
20	0.88	4	7,137	39	80,685	2,935	2,678	5.05
21	0.88	4	6,841	38	77,342	2,814	2,567	0.7
22	0.88	4	6,334	41	73,920	2,674	2,326	-3.76
23	0.88	4	6,849	38	77,431	2,817	2,570	0.81
24	0.88	4	6,337	41	73,956	2,675	2,327	-3.71
25	0.88	4	6,855	38	77,495	2,819	2,572	0.9
26	0.88	4	6,214	41	72,519	2,623	2,282	-5.58
27	0.88	4	6,344	42	74,042	2,678	2,330	-3.6
28	0.88	4	6,344	42	74,042	2,678	2,330	-3.6
29	0.88	4	6,570	39	74,281	2,702	2,465	-3.29
30	0.88	4	6,357	41	74,193	2,684	2,335	-3.4

Table F9 Link ID 2040 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	2.04	1	34,640	63	458,045	17,396	12,285	0
2	2.04	1	33,870	63	447,869	17,009	12,012	-2.22
3	2.04	1	34,640	63	458,045	17,396	12,285	0
4	2.04	1	33,870	63	447,869	17,009	12,012	-2.22
5	2.04	1	34,640	63	458,045	17,396	12,285	0
6	2.04	1	33,870	63	447,869	17,009	12,012	-2.22
7	2.04	1	33,870	63	447,869	17,009	12,012	-2.22
8	2.04	1	33,870	63	447,869	17,009	12,012	-2.22
9	2.04	1	34,640	63	458,045	17,396	12,285	0
10	2.04	1	33,870	63	447,869	17,009	12,012	-2.22
11	2.04	1	34,640	63	458,045	17,396	12,285	0
12	2.04	1	34,640	63	458,045	17,396	12,285	0
13	2.04	1	34,640	63	458,045	17,396	12,285	0
14	2.04	1	34,640	63	458,045	17,396	12,285	0
15	2.04	1	34,640	63	458,045	9,414	12,285	-2.3
16	2.04	1	34,640	63	458,045	17,396	12,285	0
17	2.04	1	34,640	63	458,045	17,396	12,285	0
18	2.04	1	34,640	63	458,045	17,396	12,285	0
19	2.04	1	34,640	63	458,045	17,396	12,285	0
20	2.04	1	34,640	63	458,045	17,396	12,285	0
21	2.04	1	34,640	63	458,045	17,396	12,285	0
22	2.04	1	34,640	63	458,045	17,396	12,285	0
23	2.04	1	34,640	63	458,045	17,396	12,285	0
24	2.04	1	34,640	63	458,045	17,396	12,285	0
25	2.04	1	34,640	63	458,045	17,396	12,285	0
26	2.04	1	34,640	63	458,045	17,396	12,285	0
27	2.04	1	34,640	63	458,045	17,396	12,285	0
28	2.04	1	34,640	63	458,045	17,396	12,285	0
29	2.04	1	34,640	63	458,045	17,396	12,285	0
30	2.04	1	34,640	63	458,045	17,396	12,285	0

Table F10 Link ID 2053 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	0.92	4	3,576	42	41,731	1,510	1,313	0
2	0.92	4	3,268	42	38,138	1,380	1,200	-8.61
3	0.92	4	3,576	42	41,731	1,510	1,313	0
4	0.92	4	3,268	42	38,138	1,380	1,200	-8.61
5	0.92	4	3,576	42	41,731	1,510	1,313	0
6	0.92	4	3,268	42	38,138	1,380	1,200	-8.61
7	0.92	4	3,268	42	38,138	1,380	1,200	-8.61
8	0.92	4	3,268	42	38,138	1,380	1,200	-8.61
9	0.92	4	3,576	42	41,731	1,510	1,313	0
10	0.92	4	3,268	42	38,138	1,380	1,200	-8.61
11	0.92	4	3,576	42	41,731	1,510	1,313	0
12	0.92	4	3,576	42	41,731	1,510	1,313	0
13	0.92	4	3,576	42	41,731	1,510	1,313	0
14	0.92	4	3,576	42	41,731	1,510	1,313	0
15	0.92	4	3,576	42	41,731	1,510	1,313	0
16	0.92	4	3,576	42	41,731	1,510	1,313	0
17	0.92	4	3,576	42	41,731	1,510	1,313	0
18	0.92	4	3,576	42	41,731	1,510	1,313	0
19	0.92	4	3,576	42	41,731	1,510	1,313	0
20	0.92	4	3,576	42	41,731	1,510	1,313	0
21	0.92	4	3,576	42	41,731	1,510	1,313	0
22	0.92	4	3,576	42	41,731	1,510	1,313	0
23	0.92	4	3,576	42	41,731	1,510	1,313	0
24	0.92	4	3,576	42	41,731	1,510	1,313	0
25	0.92	4	3,576	42	41,731	1,510	1,313	0
26	0.92	4	3,576	42	41,731	1,510	1,313	0
27	0.92	4	3,576	42	41,731	1,510	1,313	0
28	0.92	4	3,576	42	41,731	1,510	1,313	0
29	0.92	4	3,576	42	41,731	1,510	1,313	0
30	0.92	4	3,576	42	41,731	1,510	1,313	0

Table F11 Link ID 2797 Comparisons

Run Num ber	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	0.5	4	3,040	38	34,370	1,250	1,141	-30.46
2	0.5	4	330	39	3,732	136	124	-92.45
3	0.5	4	4,371	38	49,422	1,798	1,640	0
4	0.5	4	330	39	3,735	136	124	-92.44
5	0.5	4	6,366	34	69,741	2,576	2,451	41.11
6	0.5	4	1,313	39	14,844	540	493	-69.96
7	0.5	4	7,069	39	79,915	2,907	2,652	61.7
8	0.5	4	7,069	39	79,915	2,907	2,652	61.7
9	0.5	4	5,289	34	57,940	2,140	2,037	17.24
10	0.5	4	3,102	38	35,070	1,276	1,164	-29.04
11	0.5	4	4,923	30	53,913	2,018	1,988	9.09
12	0.5	4	4,144	35	45,403	1,677	1,596	-8.13
13	0.5	4	5,697	31	62,380	2,335	2,300	26.22
14	0.5	4	658	39	7,437	271	247	-84.95
15	0.5	4	6,159	30	67,437	2,651	2,486	36.45
16	0.5	4	6,574	33	72,020	2,661	2,532	45.72
17	0.5	4	11,040	39	124,812	4,540	4,143	152.55
18	0.5	4	11,040	39	124,812	4,540	4,143	152.55
19	0.5	4	5,452	31	59,730	2,207	2,100	20.86
20	0.5	4	5,293	36	57,988	2,142	2,038	17.33
21	0.5	4	2,338	39	26,430	961	877	-46.52
22	0.5	4	351	39	3,970	144	132	-91.97
23	0.5	4	1,673	39	18,909	688	628	-61.74
24	0.5	4	353	39	3,991	145	132	-91.93
25	0.5	4	1,331	39	15,051	548	500	-69.55
26	0.5	4	319	39	3,605	131	120	-92.71
27	0.5	4	6,885	39	77,843	2,832	2,584	57.51
28	0.5	4	6,885	39	77,843	2,832	2,584	57.51
29	0.5	4	3,600	38	40,697	1,480	1,351	-17.65
30	0.5	4	491	39	5,554	202	184	-88.76

Table F12 Link ID 2936 Comparisons

Run Number	Link Length (miles)	Roadway Class	Total Flow VMT	Average Speed mph	Average CO grams	Average NOx grams	Average HC grams	percentage change from base case
1	0.52	4	6921	40	80776	2922	2542	-3.05
2	0.52	4	5270	41	61506	2225	1935	-26.18
3	0.52	4	7139	40	83317	3014	2622	0
4	0.52	4	5140	41	59992	2170	1888	-28
5	0.52	4	6789	40	76759	2792	2548	-6.02
6	0.52	4	5010	41	58465	2115	1840	-29.83
7	0.52	4	3766	41	43952	1590	1383	-47.25
8	0.52	4	3766	41	43952	1590	1383	-47.25
9	0.52	4	6019	40	70244	2541	2210	-15.69
10	0.52	4	2355	41	27486	994	865	-67.01
11	0.52	4	6891	39	77907	2834	2586	-4.61
12	0.52	4	7954	40	89925	3271	2985	10.11
13	0.52	4	6620	40	74839	2723	2484	-8.37
14	0.52	4	8271	41	96525	3492	3037	15.85
15	0.52	4	6671	39	75418	6802	2503	37.23
16	0.52	4	5602	40	63339	2304	2102	-22.45
17	0.52	4	5343	41	62352	2255	1962	-25.16
18	0.52	4	5343	41	62352	2255	1962	-25.16
19	0.52	4	5860	40	66246	2410	2199	-18.89
20	0.52	4	7187	40	83872	3034	2639	0.67
21	0.52	4	6400	41	74696	2702	2350	-10.35
22	0.52	4	6313	41	73672	2665	2318	-11.58
23	0.52	4	6408	41	74791	2705	2353	-10.23
24	0.52	4	6512	41	76001	2749	2391	-8.78
25	0.52	4	6274	41	73223	2649	2304	-12.12
26	0.52	4	6762	41	78915	2855	2483	-5.28
27	0.52	4	4808	42	56114	2030	1766	-32.65
28	0.52	4	4808	42	56114	2030	1766	-32.65
29	0.52	4	5528	41	64515	2334	2030	-22.57
30	0.52	4	5479	41	63940	2313	2012	-23.26

APPENDIX G BI-STATE MODEL FILES

The following files are included in the accompanying CD. They were obtained from the Bi-State Commission during the initial phases of the research undertaken.

- 1998attr.f98 Year 1998 Attraction file in Tranplan format;
- 1998prod.f98 Year 1998 Production file in Tranplan format;
- Eetab.98 Year 1998 Ext – Ext trip table;
- Ffr2.dat Friction factor file;
- Hnet1.f98 Year 1998 Base Network;
- Hrldxyi3.f98 Year 1998 initial network. This network is used to skim paths;
- Run98f.in Year 1998 Tranplan control file;
- Ttprep.tem Terminal time for all Traffic Analysis Zones;
- Turn.txt Year 1998 Turn penalty file.
- Ttprep.tem Terminal time for all Traffic Analysis Zones;
- 2025attr.f25 Year 2025 Attraction file in Tranplan format;
- 2025prod.f25 Year 2025 Production file in Tranplan format;
- Eetab.25 Year 2025 Ext – Ext trip table;
- Ffr2.dat Friction factor file;
- Hnet1.f25 Year 2025 Base Network. This includes year 2025 Transportation Projects;
- Hrldxyi3.f25 Year 2025 initial network. This network is used to skim paths;
- Run25f.in Year 2025 Tranplan control file;
- Turn.txt Year 2025 Turn penalty file;
- Netcard.exe

The non .f98 and .f25 files can be accessed by use of standard text editors available in the Microsoft Windows personal computer environment. The Netcard.exe is run in a command line (DOS) mode and returns a flat text file able to be viewed in standard text editors.

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