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This research enhances the Dallas System Planning Study methodology. It includes data from other freeway and HOV systems from around the country. The congestion cost analysis was improved by developing a linear relationship between vehicular volume or flow and delay. Cost estimating procedures for fuel consumption, and delay to passenger and commercial vehicles are included in the alternatives analysis. The new methodology is a more complete analysis of the costs and benefits of alternatives and is applicable to other communities in their selection of freeway improvement alternatives. It also allows the alternative with the least energy consumption to be identified. The results of this project will be implemented to reduce energy consumption in Texas by allowing transportation planning teams to select the least energy intensive alternative being considered for any freeway corridor or system plan.

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Incorporating Intermodalism into Freeway System Planning

by

Carol H. Walters, Research Engineer

Tim J. Lomax, Research Engineer

Mark D. Middleton, Assistant Research Scientist

Douglas A. Skowronek, Assistant Research Engineer

SWUTC/96/465030-1

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ABSTRACT

The Dallas Freeway/HOV System Planning Study presented a methodology for selecting the least-cost alternative for freeway improvement projects for the Dallas area. This methodology included the cost of congestion when comparing freeway and HOV lane alternatives recognizing that some motorists will change modes to transit or carpools to avoid congestion delays. HOV ridership estimates for the Dallas System Planning Study were developed from existing data obtained from HOV facilities in Houston.

This research enhances the Dallas System Planning Study methodology. It includes data from other freeway and HOV systems from around the country. The congestion cost analysis was improved by developing a linear relationship between vehicular volume or flow and delay. Cost estimating procedures for fuel consumption, and delay to passenger and commercial vehicles are included in the alternatives analysis. The new methodology is a more complete analysis of the costs and benefits of alternatives and is applicable to other communities in their selection of freeway improvement alternatives. It also allows the alternative with the least energy consumption to be identified. The results of this project will be implemented to reduce energy consumption in Texas by allowing transportation planning teams to select the least energy intensive alternative being considered for any freeway corridor or system plan.

EXECUTIVE SUMMARY

The Dallas Freeway/HOV System Planning Study developed by the Texas Transportation Institute (TTI) is a methodology for freeway system planning, based on peak hour and peak period person demand, considering the interaction between congestion and HOV ridership. The goal of the study was to identify the optimum combination of mainlane and HOV lanes, based on lowest public cost, which includes both congestion delay cost and facility improvement cost. The study developed a means of estimating HOV ridership based on freeway congestion using data from the Houston HOV system. The system planning methodology views travel delay, construction or capital costs, and operation and maintenance of roadways as costs to the public. It also recognizes that some motorists will change their mode of travel when given the opportunity to avoid congestion, resulting in more transit and carpool use. The proposed Dallas System Plan balances money saved in construction against money lost in delay to find the optimum combination of mixed-flow, HOV, and express lanes necessary to move the demand.

The main goal of this project was to enhance the Dallas Freeway/HOV System Planning Study methodology. The enhanced methodology includes data from HOV systems from around the country to improve the relationship between freeway congestion and HOV ridership. The congestion cost analysis was improved by developing a linear relationship between vehicular volume or flow and delay which is more reflective of actual freeway conditions. The enhanced methodology also includes cost estimating procedures for fuel consumption, and delay cost for commercial vehicles.

The Dallas System Planning Study methodology used carpool and bus ridership data from Houston to develop a regression equation relationship between HOV ridership and congestion. This research sought to advance the HOV ridership relationship by analyzing data from HOV systems in operation across the United States. However, it was determined due to variations in the data collection techniques, and project and urban area characteristics from HOV projects from across the U.S. that a regression equation that focused on Texas HOV data would be better suited to predicting ridership for Texas projects.

To estimate the energy and emissions cost for each alternative the fuel consumption and emissions must be quantified. Fuel consumption rates were derived with the use of the ARFCOM computer program, and emission rates were obtained from the MOBILE5a model. Both the fuel consumption and emissions rates are in units of volume or mass per unit of distance. The amount of fuel consumption or emissions can be estimated for a section of corridor by multiplying the VDT by the specific fuel consumption or emissions rate for the average speed of that section of corridor. This method of quantifying fuel consumption and emissions is known as an average speed methodology, and it is considered to result in fairly accurate estimates of fuel consumption. However, the estimates of emissions are known to be inaccurate, and improved methods are not currently available. Therefore, the cost of emissions was not incorporated into the improved methodology. This should be done when the results of research underway in Georgia and California are available.

The method to estimate delay due to congestion from the Dallas System Planning Study was reviewed and changed to better reflect real freeway lane capacity and flow conditions. A linear relationship of volume to delay and speed was approximated to improve the congestion cost methodology. Also, simultaneous travel data from freeways and parallel arterial and frontage roads were analyzed to determine a relationship between freeway speed and alternate route speed. The results indicate that the original assumptions were sound, and this part of the methodology was not changed.

Additional costs were added to the methodology for fuel consumption, and the cost of congestion for commercial vehicles. The local cost of fuel per volume was used to estimate the annual cost of fuel consumption. The cost estimate per hour for trucks was obtained from the American Trucking Association and was used to estimate the annual cost of congestion for commercial vehicles.

The Dallas System Planning Study methodology used a spreadsheet-based iterative process to compare freeway alternatives. This spreadsheet process is retained for the new methodology, though the useability and appearance of the spreadsheets have been improved. The methodology consists of a Design Hour Volume spreadsheet and a Cost Estimation spreadsheet. The DHV spreadsheet determines the design hour volume for the critical sections of a corridor which are used directly in the Cost Estimation spreadsheet. The Cost Estimation spreadsheet outputs the public costs so that each alternative can be compared and the lowest public cost determined.

The new methodology was validated with a corridor which had been analyzed in the Dallas System Planning Study, and the outputs of the DHV and the Cost Estimation spreadsheets are included in the appendix. The validation results of the improved lowest public cost methodology show that the alternative with the lowest fuel consumption cost also has the lowest total public cost. Other corridors can be expected to show similar results since the lower energy cost is due primarily to increased occupancy rates which result from HOV alternatives. Other alternatives which have either high congestion cost or no congestion cost will tend to have higher energy cost.

The improved methodology will be useful throughout Texas, especially to planners in the age of constrained budgets. The lowest public cost methodology allows for greater efficiency and the dynamic planning for HOV ridership under congested freeway conditions allows for incorporation of increasing mode splits, in an age of increasing air quality concern. The methodology also allows the alternative with the least energy consumption to be identified which could be implemented to reduce energy consumption in Texas

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INTRODUCTION

As a result of ISTEA and the Clean Air Act amendments, it has become necessary to evaluate proposed freeway improvements in relationship to public transit improvements, such as HOV lanes. A research project conducted by TTI for the Dallas District of the Texas Department of Transportation has broken ground in developing a methodology for system planning, based on peak hour and peak period person demand, considering the interaction between congestion and HOV ridership. The goal of the study was to identify the optimum combination of mainlane and HOV lanes, based on lowest public cost. These costs were identified as person-trip congestion delay costs, capital costs of construction, and corridor operating and maintenance costs. Further refinements were needed to address and incorporate additional public costs such as; fuel consumption costs, vehicle emission costs, and commercial vehicle congestion delay costs. In addition, the study developed a means of estimating HOV ridership based on freeway congestion, but the data set used was limited to the Houston HOV System.

The Dallas Freeway/HOV System Planning Study was guided by a joint committee composed of the Texas Department of Transportation (TxDOT), Dallas Area Rapid Transit (DART), the North Central Texas Council of Governments (NCTCOG), as well as TTI, and has been accepted as the basis for testing a capital-constrained system. The intent of this effort was to assist in the development of an area-wide freeway/HOV system that recognizes implementation constraints (right-of-way and construction costs), and provides reasonable peak-hour operating conditions on all freeway facilities, while incorporating the long-range plans developed by TxDOT, DART, and NCTCOG.

The recommended system in the Dallas System Planning Study was developed using a methodology that focuses on peak-hour passenger travel demand in the year 2015 for the freeways in Dallas, and surrounding counties. The goal of the Dallas System Planning Study has been to find the lowest-public-cost alternative in each corridor, for a given volume of peak-hour person trips. This framework views travel delay, construction or capital costs, and operation and maintenance of roadways as costs to the public. It also recognizes that some motorists will change their mode of travel when given the opportunity to avoid congestion, resulting in more transit and carpool use. The methodology uses an iterative process to examine congestion and the consequent shift in mode so that these two factors are consistent for an alternative. The proposed Dallas System Plan balances money saved in construction against money lost in delay to find the optimum combination of mixed-flow, HOV, and express lanes necessary to move the demand.

The Dallas System Planning Study developed a methodology to estimate the costs of construction, operation, and, where the system did not meet the demand, congestion. The main goal of this project is to enhance the methodology by including data on other HOV systems outside of Texas, by improving the congestion cost analysis, and by incorporating the additional public costs of fuel consumption, vehicle emissions, and congestion delay cost to commercial vehicles.

HOV RIDERSHIP ESTIMATION

The methodology developed for the Dallas System Planning Study included a means to relate carpool and bus ridership with freeway congestion levels. The original ridership relationship used data from Houston, Texas high-occupancy vehicle (HOV) lane projects from the years 1989 and 1990. That procedure used the average daily traffic per lane as an indicator of congestion. The percentage of traffic in the peak hour (K-factor) and percentage of traffic in the peak direction (D) on these freeways were similar. The average daily volume varied significantly across the operating projects and the best relationship was obtained using ADT per lane to predict the percentage of daily traffic volume in the HOV lane in the peak hour. This combined the observed relationship between congestion level and HOV ridership with a factor (HOV ridership as a percentage of daily freeway volume) that could be used with a range of freeway volumes. The percentage of HOV ridership versus congestion level for Houston showed a coefficient of determination (R^2) of 0.67, indicating a relatively close correlation.

The project described in this report sought to advance the Dallas System Planning Study HOV ridership relationship. This was accomplished by analyzing data from HOV systems in operation across the United States (Table 1). Values for each variable used in the analysis are included in Appendix A.

Freeway Characteristics Considered

Several data items thought to have some relationship to HOV lane usage in freeway corridors were obtained for operating HOV projects in the U.S. The data collection methodologies varied widely from those collected only one time during an evaluation process, to those collected several times per year for an ongoing analysis. Other variables, such as parking cost, violation fine or state location were added by the project team upon examination of the initial data. A few projects that represent significantly different circumstances were removed from the analysis as it proceeded; that process is described in this chapter.

Table 1. Operating HOV Facilities Used as Data Sources

Type of Facility	City and County	Freeway Corridor
Barrier-Separated	Los Angeles Co., CA	I-10
	San Diego Co., CA	I-15
	Minneapolis, MN	I-394
	Pittsburgh, PA	I-279
	Houston, TX	I-10W
		I-45S
		I-45N
		US 59
		US 290N
	Northern Virginia	I-66
		I-395
	Norfolk, VA	I-64
Concurrent-Flow: Buffer-Separated and Non-Separated	Phoenix, AZ	I-10
		SR 202
	Alameda Co., CA	I-880
	Contra Costa Co., CA	I-580
	Los Angeles Co., CA	SR 91
	Marin Co., CA	US 101
	Orange Co., CA	I-5
		SR 55
		SR 57
		I-405
	Riverside Co., CA	SR 91
	Sacramento Co., CA	SR 99
	San Mateo Co., CA	US 101
	Santa Clara Co., CA	SR 85
		US 101
		SR 237
		I-280
	Minneapolis, MN	I-394
	Nashville, TN	I-65
	Northern Virginia	I-95
	Norfolk, VA	SR 44
	Seattle, WA	I-5 N of CBD (SB)
		I-5 N of CBD (NB)
		I-5 S of CBD (SB)
		I-90
		I-405 (SB)
		I-405 (NB)
Contraflow: Barrier-Separated	Dallas, TX	I-30E

[1] Northern Virginia facilities are in the Washington, D.C. area.

The variables used, and the method of identifying the data are described below. These variables represent those for which a relatively complete data set was obtained. Variables were examined as numerical values, and as two or more divisions of the numerical values. The divisions are arranged so that higher numbers correspond to those factors that provide higher HOV ridership. The divisions are used to reflect the lower level of accuracy that might be available to HOV lane planners and designers.

- ADT/Lane (ADTLN)—Average daily traffic per lane can be used as an indicator of congestion level. Values of this variable and the following divisions were tested:
  1 = less than 20,000 vehicles per day per lane
  2 = between 20,000 and 25,000 vehicles per day per lane
  3 = between 25,000 and 30,000 vehicles per day per lane
  4 = between 30,000 and 35,000 vehicles per day per lane
  5 = more than 35,000 vehicles per day per lane
  It should be noted that to estimate demand in a design year, future volumes would be used.

- Directional Hourly Volume per Lane (DHVLN)—An estimate of the freeway volume per lane in the peak direction was derived from the daily volume. This may be a better estimate of peak congestion level if it is estimated at the point where traffic flow exits from a congested section and begins to increase speed. Frequently, however, a volume count is made within the congested section and low volume per lane values are obtained. These values are not indicative of the congestion in the corridor. The DHV value used in this analysis was derived from Equation 1.

$$\underset{per\ lane}{DHV} = \underset{per\ lane}{ADT} \times \underset{\substack{(\%\,traffic \\ in\ peak \\ hour)}}{K} \times \underset{\substack{(\%\,traffic \\ in\,peak \\ direction)}}{D} \qquad \text{Eq. 1}$$

- CA—The value used for this variable was either "1" if the freeway was not located in California or "2" if it was a California HOV facility. This factor was used because the California corridors tended to have higher person movement on the HOV lanes for similar congestion levels. This distinction would allow the effects of the higher California ridership to be tested.

- CLASS—This variable was established to test for variations in ridership which could be attributable to the differences in HOV facility types. The values assigned for each classification are as follows:
  1 = Barrier-Separated
  2 = Concurrent-Flow: Buffer-Separated/Non-Separated
  3 = Contraflow

- FINE—This factor accounts for the effect of the first time fine amount charged for violating occupancy requirements on the HOV lane. The ranges of fines used and their assigned numbers are listed below:
  1 = less than $50
  2 = $50 to $100
  3 = $100 to $250
  4 = more than $250
- LANE—The number of HOV lanes.

- OCCUP—This variable accounts for the HOV occupancy requirements. For 2+ HOV facilities, the value of "1" was assigned, and all others were distinguished by using "2." The Katy Freeway (Houston) HOV lane that changes operation during the day from 2+ to 3+ HOV, the value of "1" was used.

- OPHOURS—The length of time that the HOV facility operates during a day was accounted for with this factor. For this variable, two categorical divisions were tested. One of the divisions had the following groupings:
  1 = less than 4 hours
  2 = 4 to 8 hours
  3 = 9 to 24 hours
  4 = 24 hours

  The second division had the following numbers assigned:
  1 = less than 4 hours
  2 = 4 to 20 hours
  3 = more than 20 hours

- PARK—This variable was used to test the effect that parking costs around the destination end of the HOV corridor would have on HOV ridership. For this factor, the parking cost categories were:
  1 = less than $75 per month
  2 = $75 to $125 per month
  3 = more than $125 per month

  It should be noted that no carpool discount rates were used. This factor tests how much the higher single-occupant parking rates will encourage additional formation of carpools.

- RADIAL—This variable was employed to test the impact on ridership associated with whether the freeway can be considered circumferential ("1") or radial ("2") relative to the Central Business District (CBD).

- YEARS—The number of years that an HOV facility has been opened appears to affect HOV ridership. Three alternatives were used to test the relationship to ridership. One alternative used ranges as follows:

1 = 5 years or fewer
2 = 6 to 10 years
3 = 10 to 20 years
4 = more than 20 years

A second alternative used a two-stage categorical listing; values of "1" were assigned to HOV lanes in operation for 10 or fewer years, and values of "2" were used for facilities operating more than 10 years. The third alternative used the actual reported number of years of operation. It should be noted that the design year minus the completed HOV construction year would have to be used when trying to predict HOV ridership for new facilities.

Data Analysis

The initial step in the data analysis was to identify projects or values which might represent "outlying" data. During this process, the need for the "California" and parking cost variables were identified. The parking cost data could not be determined with sufficient detail for enough projects to make it a useful part of the analysis; the cost information is in the Appendix, but was not used.

The I-395 HOV project in northern Virginia (Shirley Highway) was removed from the data set due to the significant influence of the high parking cost and low parking availability in Washington, D.C. on HOV ridership.

The I-580 project in Contra Costa County, California was also removed because the HOV ridership was much lower than the other projects.

The data from all remaining projects were tested to identify the model with the best combination of good predictability of HOV ridership with the fewest number of factors. Single variables were tested to identify those with the best predictability, and to identify whether actual values or divisions were more appropriate. Combinations of variables were subsequently tested.

Simplicity in equation type and compatibility with a spreadsheet format were the two main concerns in developing an HOV ridership estimation procedure. While there may be more confidence in equations with high coefficients of determination (R^2), if the factors are difficult to estimate or exhibit relationships that are not logical, an equation with a lower R^2 and higher "usefulness" may be selected. The goal of this task was to achieve an equation or procedure that would be appropriate for a wide range of situations.

<u>All HOV Lane Data</u>

The initial assessment strategy utilized the information from the database for all cities remaining after the initial steps. Within this strategy, several schemes were tested.

Single Variable Tests. The first scheme involved testing the groupings for the parameters where more than one division was provided. The parameters that were tested in this scheme include the variations on traffic volume per lane, HOV operating hours, and years of HOV operation. The linear relationships obtained by comparing the categorical listings versus HOV ridership were tested in these trials. A comparison of the R^2 values obtained are listed in Table 2 along with the percent of HOV ridership (in decimal percent) equations that can be formed from each variable.

Table 2. Comparison of Parameters with Differing Categorical Divisions

Parameter[1]	Category Used	R^2	Equation Values	
			Constant[1]	Coefficient[1]
Freeway Volume	Actual Values of ADT per Lane	.17	.0000045	-.0081
	5 Divisions of ADT per Lane	.16	.023203	.0439
	Actual Values of DHV	.02	.000003632	.0763
	Actual Values of DHV per Lane	.07	.0000248	.0489
HOV Operating Hours	4 Divisions	.24	.037162	-.0031
	3 Divisions	.43	.089043	-.0985
Years of HOV Operation	4 Divisions	.05	.026097	.0712
	2 Divisions	.01	-.041224	.1474
	Actual Number of Years	.04	.004843	.0854

[1] The equations are in the general form of: HOV ridership percentage = Constant + Coefficient (Parameter)

Table 2 illustrates that single variable equations do not predict HOV ridership well. Some improvements are identified when categories, rather than actual values are used. Daily volume factors appear to be slightly better than hourly volume, and hours of operation is the strongest predictor.

Figure 1 shows the plot of ADT per lane versus HOV ridership for all the data used in this test. The relationship between HOV ridership and directional hourly volume per lane is illustrated in Figure 2.

Figure 1. National HOV Ridership Versus Daily Traffic Volume

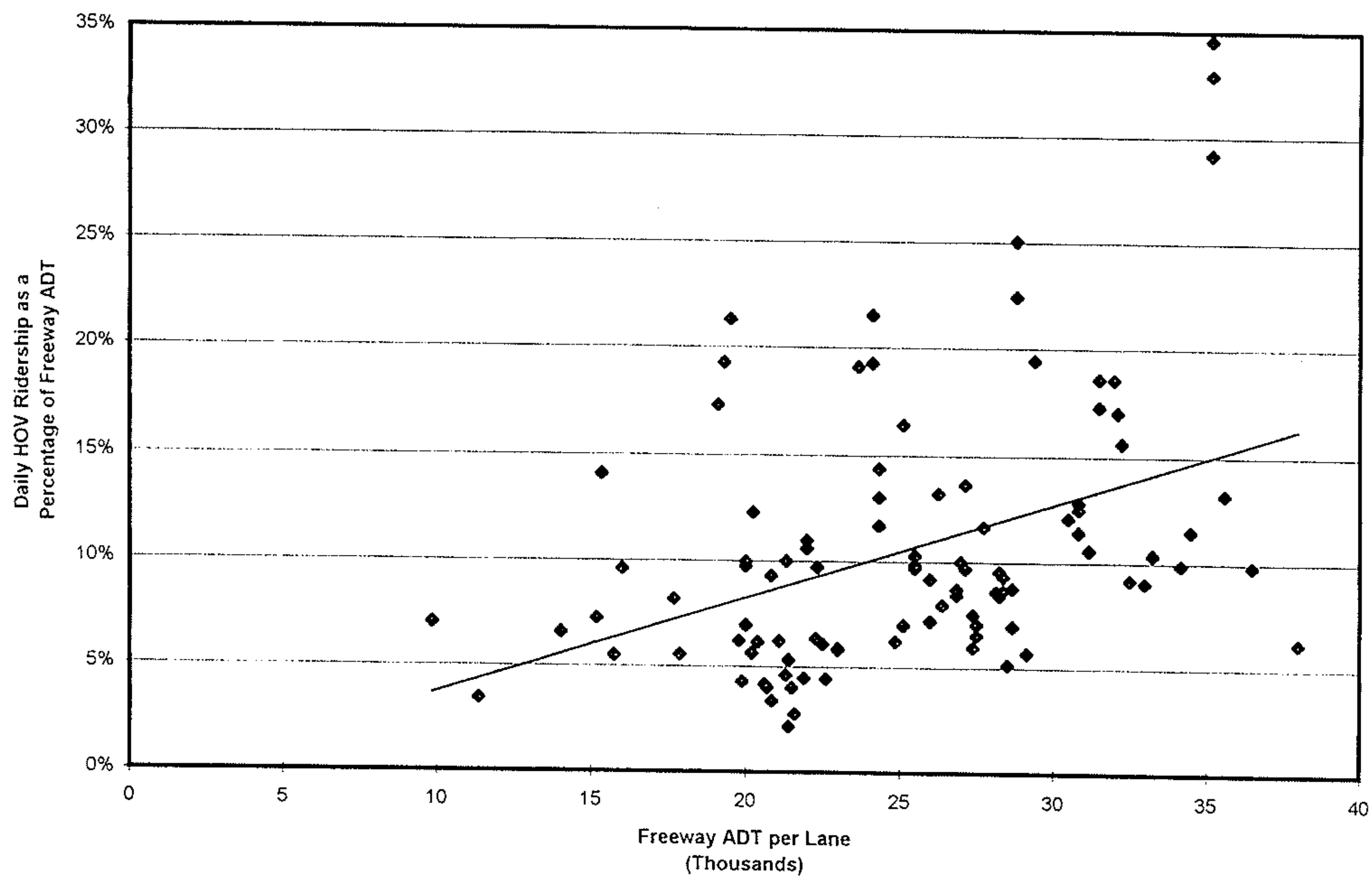
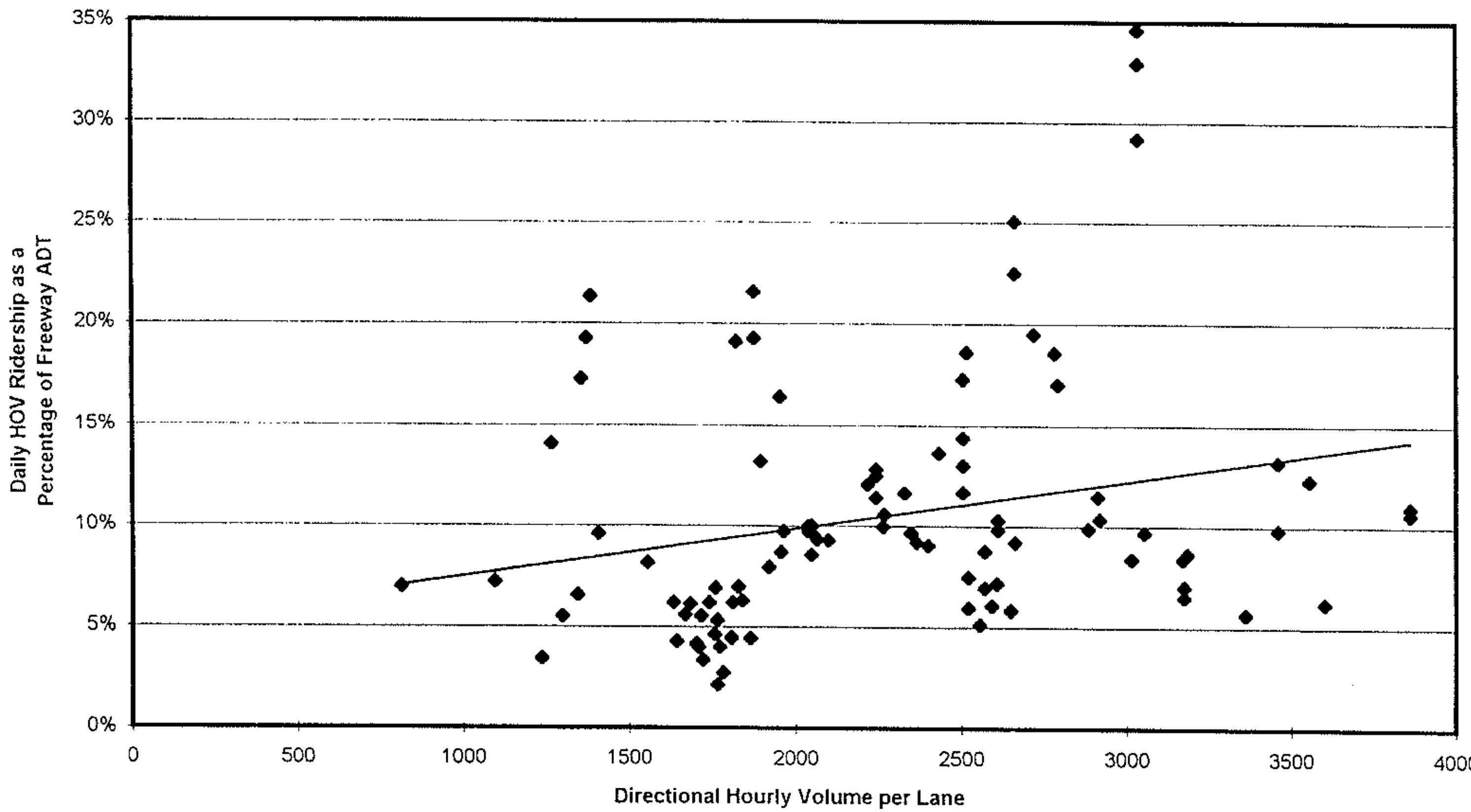


Figure 2. National HOV Ridership Versus Hourly Traffic Volume



Multi-Variable Tests

Based on the initial tests of individual variables, several multi-variable models were tested. The best results of the tests (with the type of category used for each parameter) are presented in Tables 3, 4 and 5.

Table 3. Coefficients of Determination for HOV Ridership Prediction Models Using Three Parameters

Parameters Tested and Type of Value Used[1]	R^2 Value[2]
ADT/lane (5D), Hours (3D), Years (2D)	.55
DHV/lane (V), Hours (3D), Years (2D)	.52
ADT/lane (V), Hours (3D), Years (4D)	.52
ADT/lane (V), Occupancy, Radial	.45
ADT/lane (5D), Occupancy, Radial	.44
DHV/lane (V), Occupancy, Radial	.37
ADT/lane (V), Hours (4D), Years (2D)	.37
ADT/lane (5D), Hours (4D), Years (4D)	.36

[1] V = value; D = division
[2] Coefficient of determination

Table 4. Coefficients of Determination for HOV Ridership Prediction Models Using Four Parameters

Parameters Tested and Type of Value Used[1]	R^2 Value[2]
ADT/lane (V), Occupancy, Radial, Years (4D)	.45
ADT/lane (V), Occupancy, Radial, Years (V)	.45
ADT/lane (V), Occupancy, Radial, Years (2D)	.45
ADT/lane (5D) Occupancy, Radial, Years (4D)	.44
ADT/lane (5D), Occupancy, Radial, Years (2D)	.44
ADT/lane (5D), Occupancy, Radial, Years (V)	.44
DHV/lane (V), Occupancy, Radial, Years (4D)	.39
DHV/lane (V), Occupancy, Radial, Years (V)	.38
DHV/lane (V), Occupancy, Radial, Years (2D)	.37

[1] V = value; D = division
[2] Coefficient of determination

Table 5. Coefficients of Determination for HOV Ridership Prediction Models Using Five Parameters

Parameters Tested and Type of Value Used[1]	R^2 Value[2]
ADT/lane (5D), Occupancy, Radial, Years (2D), Hours (3D)	.65
ADT/lane, Occupancy, Radial, Years (4D), Hours (3D)	.63
DHV/lane, Occupancy, Radial, Years (2D), Hours (3D)	.62
ADT/lane, Occupancy, Radial, Years (2D), Hours (4D)	.57
ADT/lane (5D), Occupancy, Radial, Years (4D), Hours (4D)	.56
ADT/lane, Occupancy, Radial, Years (4D), Hours (4D)	.56
DHV/lane, Occupancy, Radial, Years (4D), Hours (4D)	.53

[1] V = value; D = divisions
[2] Coefficient of determination

While both factors are useful in explaining existing ridership levels, they did not appear to be useful in estimating HOV ridership for corridor feasibility studies and similar efforts. At this point in the study, the researchers decided to eliminate years of operation, and operating hours as candidates for use in an equation to predict HOV ridership.

The operating hours variable does have a high coefficient of determination, but the parameter coefficient for the linear regression equation is negative, indicating ridership would decrease with increasing hours of operation. The years of operation variable had low r^2 values, indicating surprisingly small correlation between project duration and ridership.

Operating hours are more often set by local operating policy and philosophy than in the project operations office. This typically means that any HOV project in an area would have similar operating hours, and would not be a differentiating variable.

Project duration reflects the normal tendency in relatively new technologies—the best candidates are chosen first. Including this experience in a procedure to estimate HOV ridership in other projects tends to overstate the growth potential for HOV projects. If data become available in the future, a more appropriation version of this variable would be project ridership growth since the end of the first month or year.

The following three equations utilize the remaining three parameters congestion level variations, OCCUP, and RADIAL. The value of ridership obtained from Equations 2, 3, and 4 will be in decimal percent.

$$\frac{Ridership}{(\%\ of\ ADT)} = .000003176*\left(\frac{ADTPERLN}{values}\right) + .035855*(OCCUP) - .088215*(RADIAL) \quad R^2 = .45 \quad \text{Eq. 2}$$

$$\frac{Ridership}{(\%\ of\ ADT)} = .000007077*\left(\frac{DDHVLN}{values}\right) + .041902*(OCCUP) - .094955*(RADIAL) \quad R^2 = .37 \quad \text{Eq. 3}$$

$$\frac{Ridership}{(\%\ of\ ADT)} = .015873*\left(\frac{ADTPERLN}{5\ divisions}\right) + .036453*(OCCUP) - .088286*(RADIAL) \quad R^2 = .44 \quad \text{Eq. 4}$$

Conclusions Regarding Potential National HOV Ridership Estimation Equation

The selection of one of the HOV ridership models must be performed only after examining the possible limiting constraints. The data used to form the models will greatly influence the ability to predict HOV ridership. Most of the national data was obtained from various operating or planning agencies. These groups use different concepts in their data collection process. For instance, it is best to use the constrained section of the freeway for the count locations. The relationship between HOV ridership and congestion is governed by these sections, but it is often difficult to get data for these sections of freeway.

The models may also be influenced by the different views that the public and governing agencies take towards HOV projects across the U.S. For example, some areas may not have adequate enforcement or marketing to promote consistent HOV use. Parking cost and availability are also key to determining mode of travel, particularly in work trips. Transit availability (number of routes, bus trips, park-and-ride lots, etc.) and ridesharing efforts are also key variables not included in the data set.

The variation in data collection techniques, and project and urban area characteristics led the study team to conclude that a regression equation that focused on Texas HOV data would be better suited to predicting ridership for Texas projects. As evaluation data are collected for more HOV projects and as better models are developed to predict HOV ridership, there may be another opportunity to develop national HOV ridership estimation tools for such broad planning level applications. Additional data will also help answer the question of how much of the variability is due to data collection procedures, and how much is due to factors that are not included in regular evaluation programs. There are not enough HOV projects with extensive evaluations to answer these questions.

Texas HOV Ridership Prediction

The data from the HOV projects in Dallas and Houston were tested independently to determine alternative relationships between HOV ridership and freeway characteristics. This involved data from the years 1992 and 1993 for IH 30 East in Dallas and the years from 1988 to 1994 for Houston. These projects include a range of congestion levels from very high on I-10W to relatively low on I-45 South. The directional hourly volume counts for some of these freeways were conducted in congested sections, and the traffic volumes are not consistent with a high congestion level. The daily volumes were, therefore, multiplied by actual D values and by somewhat higher than actual K values that are more consistent with peak-hour demand rather than the constrained peak-hour volumes.

Two HOV ridership prediction models were tested for the Texas data set using daily and hourly traffic volume per lane. The regression coefficients and equations are presented in Equations 5 and 6 and Figures 3 and 4.

$$\frac{\textit{Ridership as a}}{\textit{\% of ADT}} = -5.33 + 0.51 \; x \left[\frac{\textit{ADT per Lane}}{(1000)}\right] \qquad R^2 = 0.58 \quad \textit{Standard Error} = 2.0 \qquad \text{Eq. 5}$$

$$\frac{\textit{Ridership as a}}{\textit{\% of ADT}} = -14.0 + 11.0 \; x \left[\frac{\textit{Directional Hourly Volume per Lane}}{(1000)}\right] \qquad R^2 = 0.71 \quad \textit{Standard Error} \; 1.6 \qquad \text{Eq. 6}$$

Figure 3. Texas HOV Ridership Versus Daily Traffic Volume

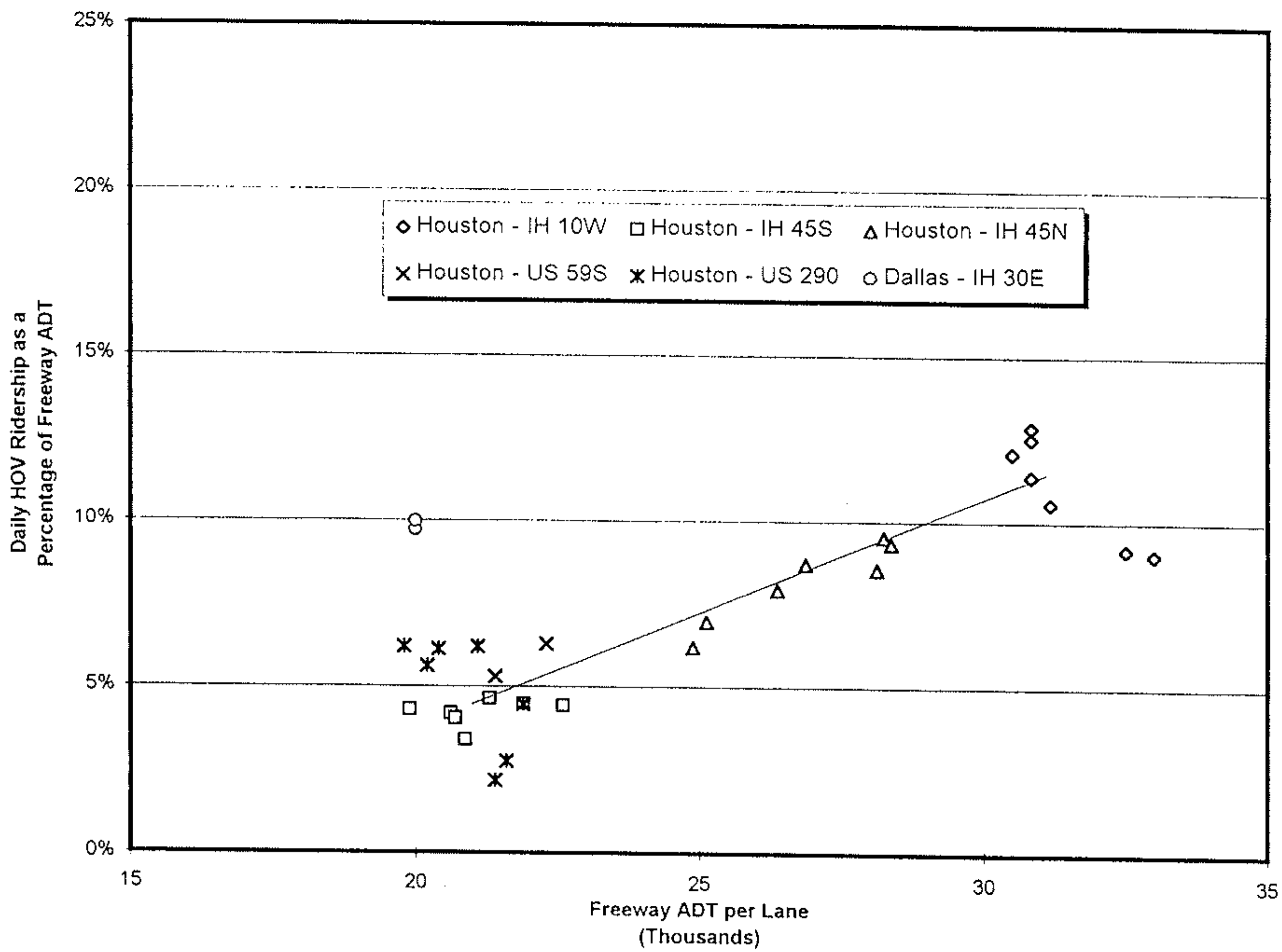
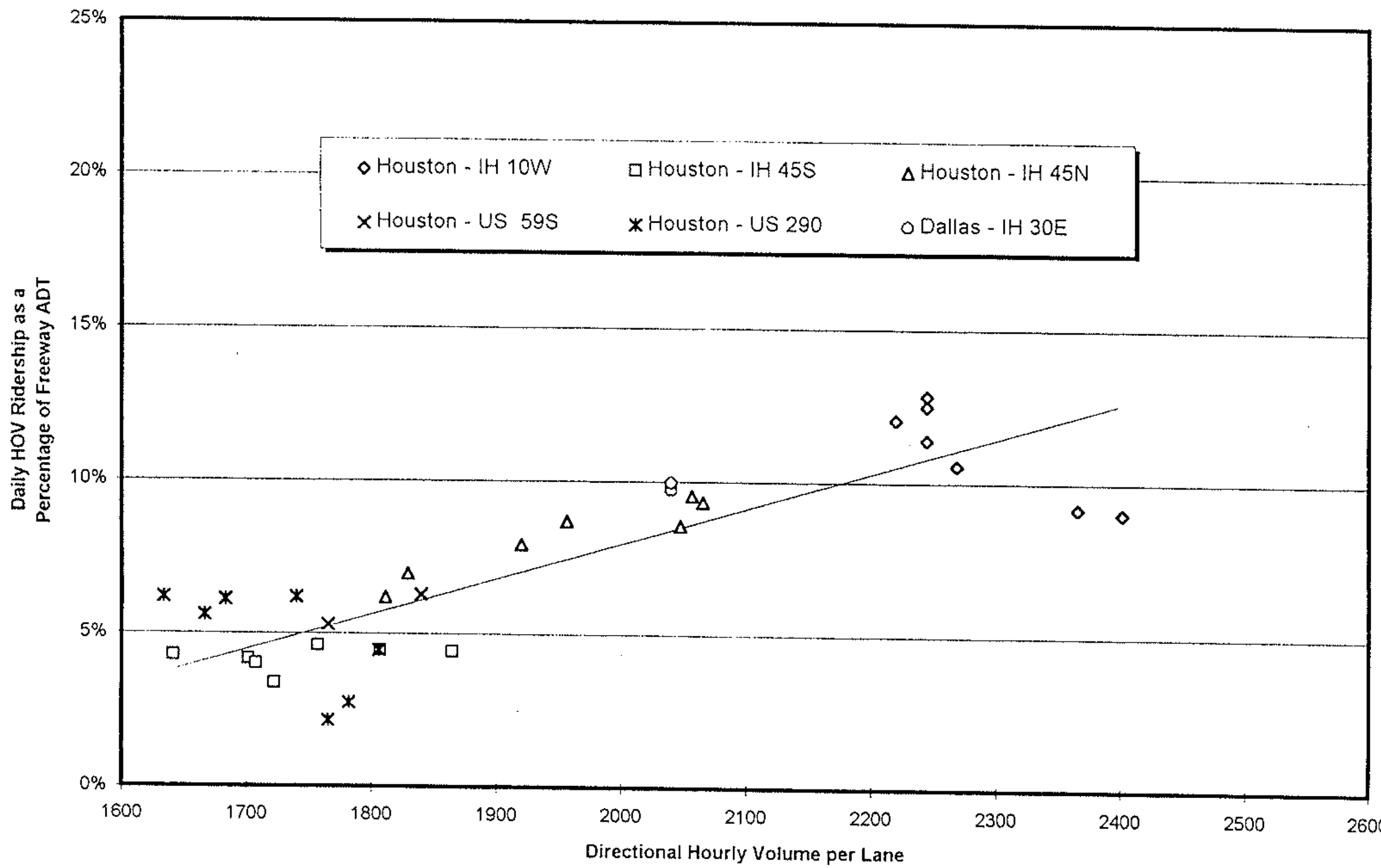


Figure 4. Texas HOV Ridership Versus Hourly Traffic Volume



The adjustments for peak hour and directional distribution of traffic significantly improve the regression statistics beyond the daily traffic volume per lane factor. The R^2 of 0.71 for the directional hourly volume per lane factor is a good relationship for the purpose intended. At a 95% confidence level, and with the 32 HOV lane ridership observations the standard error of 1.6 yields a confidence interval of plus or minus 0.55 percent. This interval is approximately 5 to 15 percent of the ridership percentage values of most of the observations, which would seem to be acceptable for most applications of this model.

Conclusions of HOV Estimation

It is advisable to pursue the collection of national data using more consistent terms and procedures for all the parameters used in this study. The relationships between HOV ridership and the various parameters can be improved if the data issues are addressed. If this consistency cannot be obtained, the best models will be developed on a state or local area basis.

The information from Texas provides good relationships for predicting HOV ridership. It might be useful for other areas with parking, land use, and other characteristics that are similar to Houston and Dallas. TTI is involved in the data collection efforts for the HOV lanes in Houston and Dallas. The data collection process utilized for Texas addresses the concerns listed for the national data. The Texas projects are also relatively homogenous in design and operation and have similar park-and-ride and rideshare information availability. For Texas applications and TxDOT system planning studies, Equation 3 using the variable of directional hourly volume per lane should be employed because it provides a simple equation, adjusts the daily volume for peak hour traffic characteristics and maintains an acceptable coefficient of determination and standard error.

ENERGY AND EMISSIONS ESTIMATION

The Dallas Freeway/HOV System Planning Study methodology did not include in the lowest public cost the cost for fuel consumption or vehicle emissions. The fuel consumption cost is simple to incorporate into the cost estimating methodology, though the cost for emissions is more difficult to quantify. To estimate the amount of fuel consumption and emissions for an alternative the average speed and the vehicle distance of travel (VDT) must be estimated for each section of an alternative. The total amount of fuel consumption or emissions is equal to the specified fuel consumption rate or emissions rate multiplied by the VDT. This method of quantifying fuel consumption and emissions is known as an average speed methodology.

The fuel consumption rates and emissions rates used with this methodology vary with the average speed and are given in units of volume or mass per unit of distance. The vehicular volume per hour per lane (vphpl) or vehicular flow is used to estimate the average delay per vehicle. This method is also used to estimate the average speed. The VDT is estimated simply by multiplying the vehicular flow (vphpl) by the section length and the number of lanes in the peak direction for each section of each alternative. For most alternatives the off-peak direction will have the same fuel consumption and emission loads for each alternative and is therefore not estimated. However, if congestion occurs in the off-peak direction for some alternatives the fuel consumption and emissions loads for the off-peak direction should be estimated as well.

TTI investigated the fuel consumption and air quality impacts of freeway bottleneck improvements in a research project sponsored by the Southwest University Transportation Center (SWUTC) titled *Energy and Air Quality Benefits of Freeway Bottleneck Improvements* (3). This research investigated the relationships between traffic operating characteristics and fuel consumption, hydrocarbon or volatile organic compound emissions (VOC), carbon monoxide emissions (CO), and nitrogen oxide emissions (NO_X). An average speed methodology was utilized to analyze the existing before and after data from several bottleneck improvement projects that have been implemented by TxDOT. The change in fuel consumption and vehicle emissions were estimated and guidelines were developed to help predict energy benefits from implementing future freeway bottleneck improvements. However, air quality benefits were found to be currently unquantifiable due to the discrediting of the traditional planning model (MOBILE5a) for use in micro simulation. The problems generally recognized with the MOBILE model in the research community are that the procedures used to develop the model lack a full range of representative driving cycles or off-cycle driving patterns, and that sometimes major fluctuations in speed and sharp accelerations are not recognized when only an average speed in a section of freeway is used as a profile of driving behavior.

Fuel Consumption Rates

The fuel consumption rates were produced using the fuel consumption model ARFCOM (ARRB Road Fuel Consumption Model) from the Australian Road Research Board which can be used on a personal computer (4). The ARFCOM model is a detailed power model. It estimates the power needed by a vehicle to overcome the forces acting at its wheels given vehicle speed and road geometry. All the power components are summed, and a fuel-to-power efficiency factor is used to calculate fuel consumption. The model can be used with several input data levels from instantaneous speed traces to average speed or running speed over a section of roadway. ARFCOM requires several vehicle parameters and road geometry data as inputs, though default values are supplied for most parameters. The model has been validated with instantaneous speed data and known parameters to estimate fuel consumption to within 5% of measured values. Using only the minimum required vehicle parameters, errors are within 15% of measured values (5).

The fuel consumption rates were estimated with the ARFCOM model. Parameters for five of the eight vehicle classes used in the MOBLE5a program were defined for input to the ARFCOM program. Light duty diesel vehicles, light duty diesel trucks and motorcycles which only make up 2% of the vehicle mix for freeways in Dallas and Tarrant counties, were not considered in the composite fuel rate. This vehicle mix was used to calculate the composite fuel consumption rate for the bottleneck study and for use in this project. The curves for the five vehicle classes and the composite vehicle are shown in Figure 5. A new composite fuel consumption rate can easily be created by changing the percentages for the vehicle mix.

The ARFCOM running speed model was used to estimate the fuel consumption for each of the five vehicle types at average speeds in intervals of 8 kph (5mph) from 8 kph (5 mph) to 113 kph (70 mph). A running speed higher than the average speed was assumed to reflect freeway travel conditions up to 80 kph (50 mph) for each average speed. At 80 kph (50 mph) and above the average speed was assumed to equal the running speed. The model calculates the idle time and travel time based on the given average speed and running speed. Since this analysis was used to create fuel rates for use at several locations the factors for windspeed and roadway grade were assumed to be zero. An important factor in the running speed model is the changes in positive kinetic energy, E_{k+}, which is a measure of the amount of speed fluctuation for a given running speed. Default values of E_{k+} are provided for two types of urban areas in the ARFCOM model. However if known values can be calculated for E_{k+}, the accuracy of the model can be improved since these values have been found to vary considerably between cities (4). Using detailed travel data taken on a Houston freeway values for E_{k+} were obtained for freeway conditions from stop-and-go to free-flow driving.

Emission Rates

The primary models for estimating mobile source emissions are the MOBILE model from the Environmental Protection Agency (EPA) and EMFAC from the California Air Resources Board (CARB) (6). Both these models relate the vehicle distance of travel (VDT) and average speed, which are derived from specific driving cycles that can be duplicated on dynamometers, to emission rates. Most other models are based on the outputs from the MOBILE and EMFAC models (6).

Emissions rates were obtained from the North Central Texas Council of Governments

(NCTCOG). NCTCOG provided a MOBILE5a base year run for 1993 for Dallas and Tarrant County freeways which presents the basic emission rates for nine vehicle types and an all vehicle composite at a specific speed for a typical summer day. These emission rates were given in grams per mile for eight vehicle types and all vehicle composite. The all vehicle composite reflects the Dallas and Tarrant Freeway vehicle mix and was used for all the emissions analysis for this study.

Figure 6 shows the curves for volatile organic compounds (VOC). The total VOC emission factors include all evaporative hydrocarbon (HC) emission factors and the exhaust component of VOC. The exhaust VOC curve shown in the figure consists of the VOC emissions released through the tailpipe. From the figure it can be seen that the evaporative emissions are a major portion of the total VOC emissions. The optimum VOC emission rate occurs at 88 kph (55 mph).

Figure 7 shows the emission rate curve for carbon monoxide (CO). It is similar to the VOC emission curve, but it rises more sharply at speeds in excess of 88 kph (55 mph). The optimum speed for CO emissions occurs at 77 kph (48 mph). Figure 8 shows the emission rate curve for nitrogen oxides (NO_x). This curve differs considerably from the other emission curves as well as the fuel consumption curve. The optimum speed occurs at 40 kph (25 mph), and the curve is almost linear and constant between 32 kph (20 mph) and 77 kph (48 mph). At speeds above 77 kph (48 mph) the emission rate rises sharply.

Most transportation officials agree that VOC and CO emissions from mobile sources are significantly underestimated by existing mobile source models. A significant source of emissions underestimation is that the test procedures to develop the emissions rates do not fully represent actual driving conditions. The federal test procedure (FTP) driving cycle used to develop the MOBILE models specifically does not include high speeds and sharp accelerations (7). These high accelerations and speeds are generally known as off-cycle driving patterns. When a vehicle accelerates, its engine operates in an enriched state that is a state higher than stoichiometric fuel/air ratios. Recent research has shown that enrichment events result in much higher emissions compared to stoichiometric conditions (8). The off-cycle driving patterns not included in the FTP often result in enrichment conditions. Enrichment events have been shown for one specific vehicle to increase CO emissions by about 2,500 times and HC emissions by 40 times over the stoichiometric emission rates (8).

Another problem is the method of estimating driving patterns or modes. When speeds are averaged over a section of freeway or roadway the changes in speed or accelerations and decelerations cannot be recognized resulting in a poor profile of driving behavior. For a regional basis the existing model methodologies are probably adequate. However, to estimate the emissions for local transportation improvements or for corridor analysis, a better methodology is needed. This type of model is known as a modal emissions model (9), and would be similar to the ARFCOM model for estimating fuel consumption. Since this type of model is not currently available the impact of emissions changes were not considered in the cost estimation procedure.

Figure 5. Average Speed Fuel Rates
ARFCOM Model Results

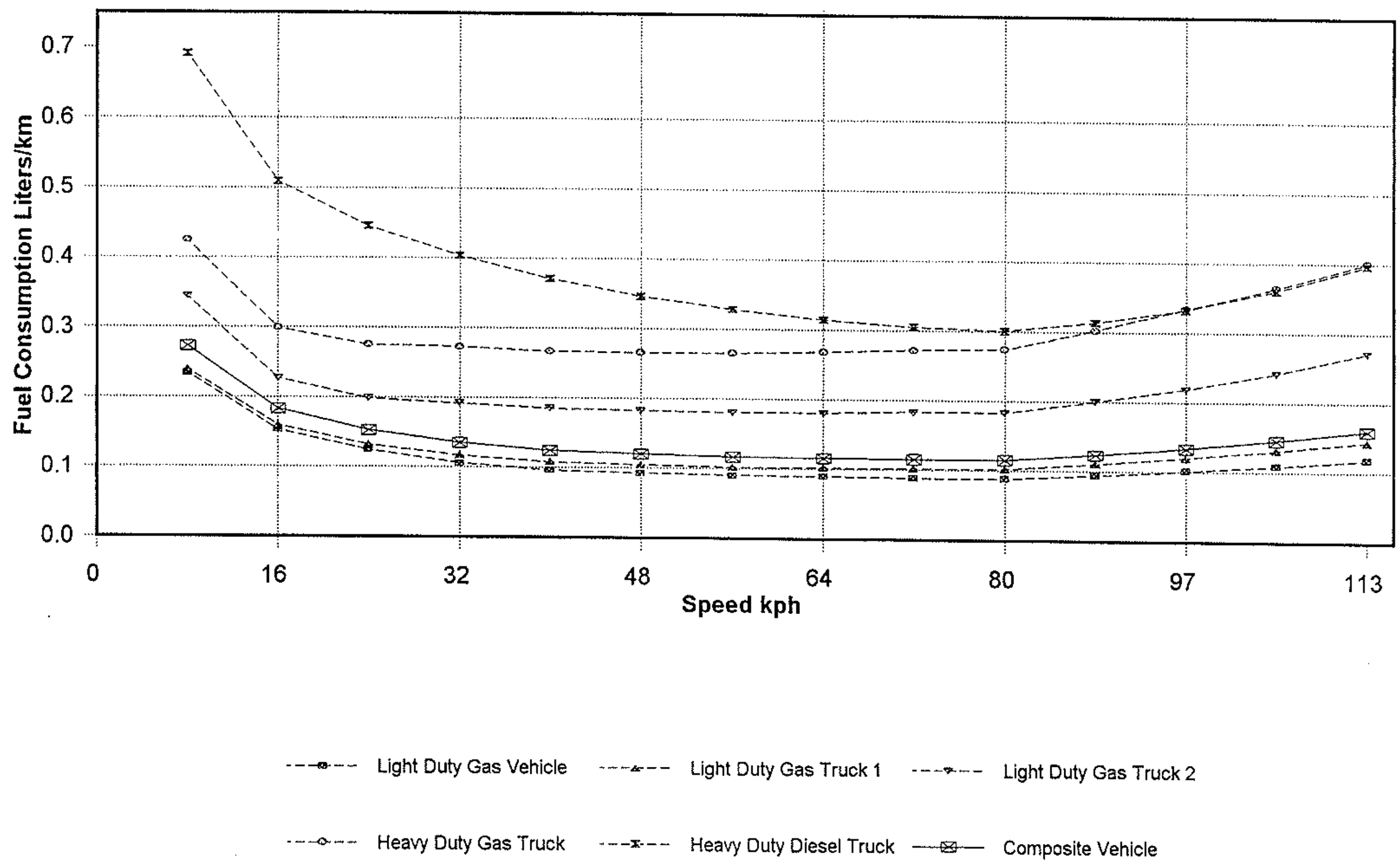


Figure 6. VOC Emission Rates
1993, Dallas/Tarrant Freeways

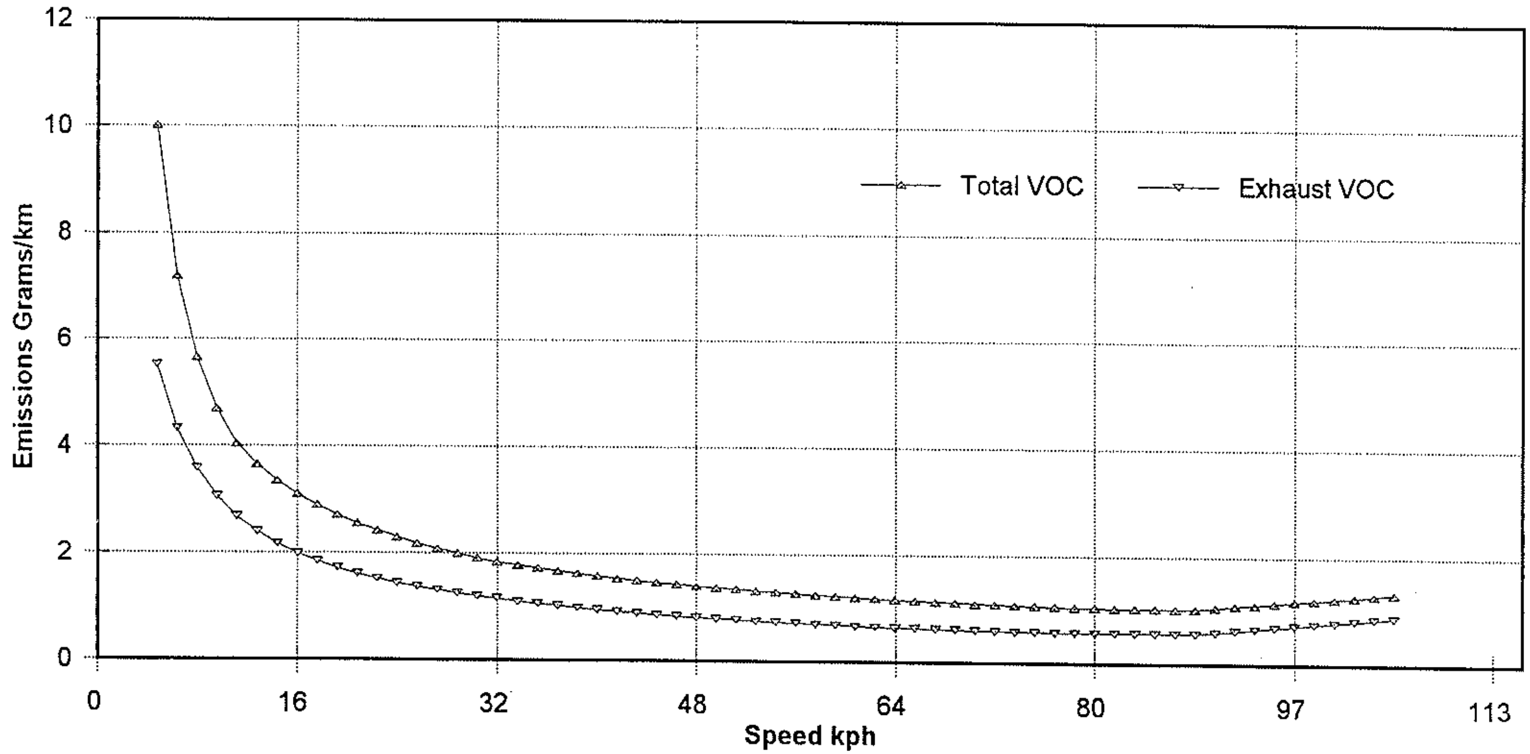


Figure 7. CO Emission Rates
1993, Dallas/Tarrant Freeways

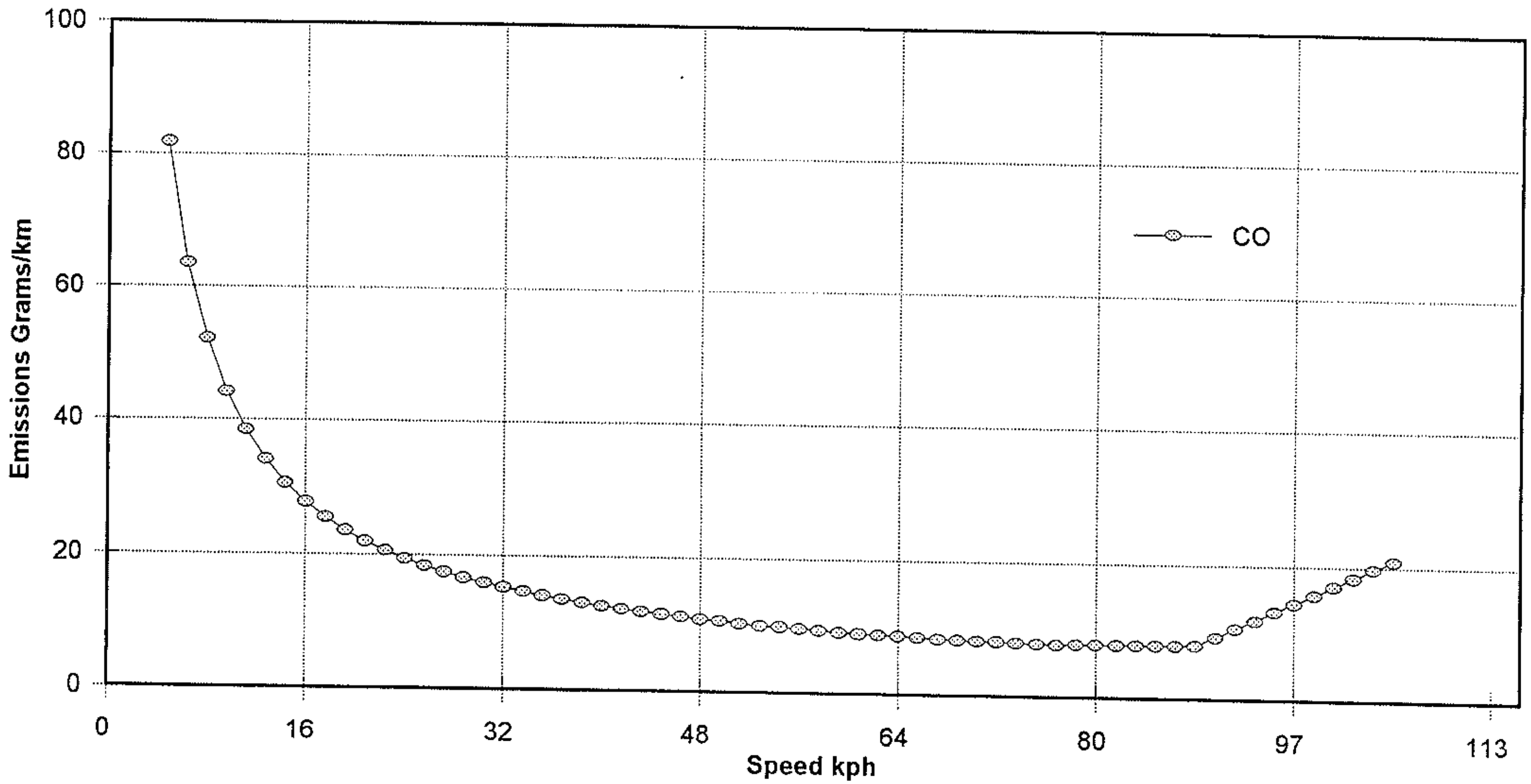
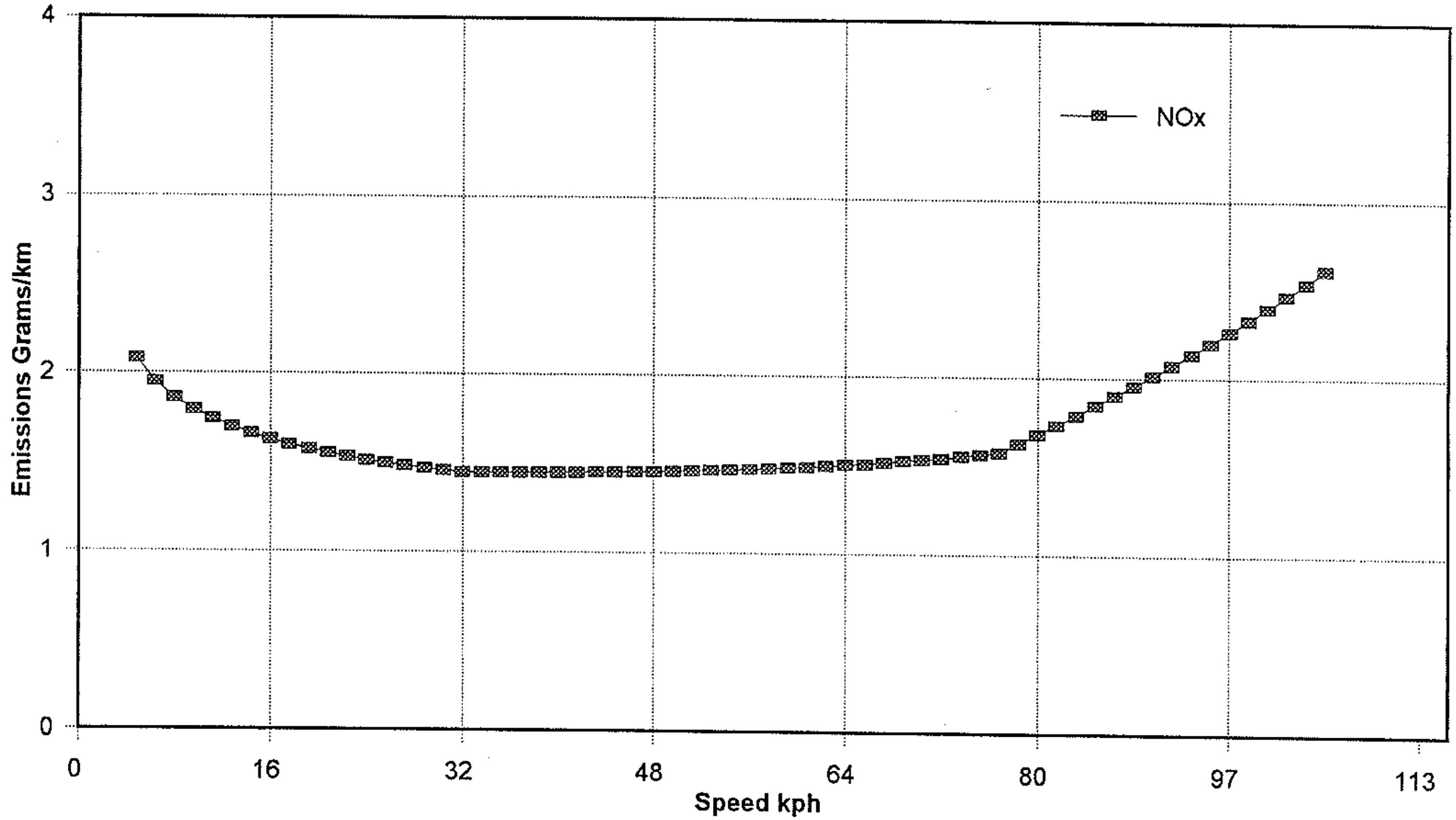


Figure 8. NOx Emission Rates

1993, Dallas/Tarrant Freeways



CONGESTION COST IMPROVEMENTS

In the Dallas System Planning Study, a methodology was developed to estimate the congestion cost using presumed speeds on the main lanes for varying levels of volume-to-capacity ratios. This methodology assumed a simple stepped relationship of vehicle lane volume to delay. If the lane volume was 1849 vph or below there was assumed to be no delay. If the lane volume was between 1850 vph and 1999 vph there was assumed to be a delay of 0.33 minutes per mile of travel per vehicle. If the lane volume was between 2000 vph and 2199 vph there was assumed to be a delay of 1 minute per mile of travel per vehicle. If the lane volume was 2200 vph or greater each vehicle was assumed to suffer 3 minutes of delay per mile of travel. The congestion cost or delay cost was determined simply by multiplying the total delay and the hourly value of time per person (10).

One of the objectives of this project was to improve the congestion cost, and to that end a linear relationship of volume to speed, as well as delay, was derived to better reflect real conditions. The speed is necessary to estimate not only delay but the amounts of fuel consumption and emissions per vehicle for each alternative. Costs were included for fuel consumption, and for commercial vehicles as a special category; all are adversely influenced by congestion. All costs used for this project were 1995 values.

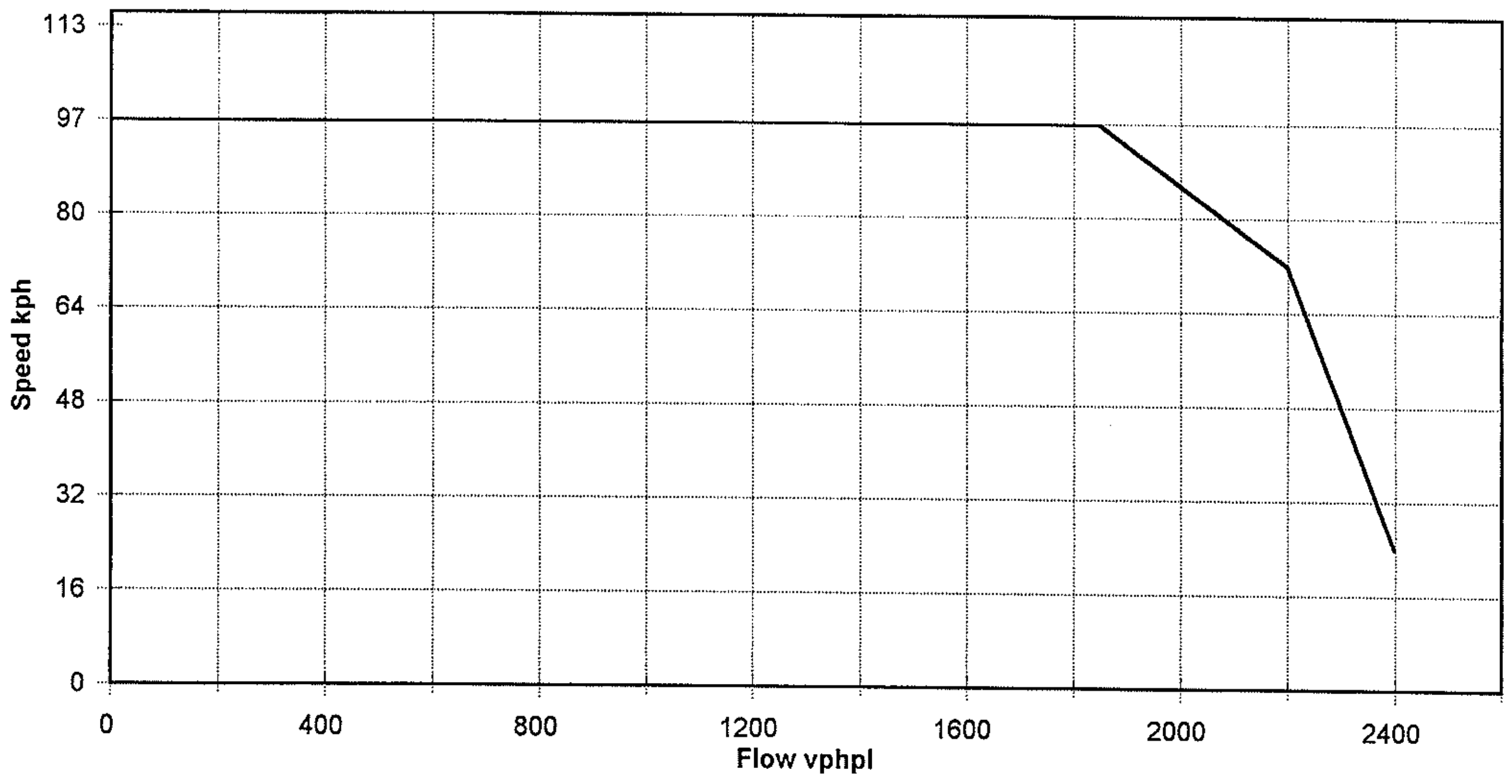
Linear Relationship of Volume to Delay and Speed

To give a linear relationship to volume and delay or speed similar to the standard speed-flow relationship for highways several assumptions were made. Lane volumes or flows below 1850 vehicles per hour (vph) are considered to be at free flow. That is no delay and a speed of 97 kph (60 mph). Lane volumes between 1850 vph and 2200 vph - which is considered maximum flow - have a delay which increases linearly from 0 to 0.21 minutes per km (0.33 minutes per mile) and a speed which decreases from 97 kph (60 mph) to 72 kph (45 mph). Lane volumes between 2200 vph and the theoretical ultimate capacity of 2400 vph have a delay which increases linearly from 0.21 minutes per km (0.33 minutes per mile) to 1.86 minutes per km (3.0 minutes per mile) and a speed which decreases from 72 kph (45 mph) to 24 kph (15 mph). At these low speeds the actual flow or lane volume would likely be below 2200 vph. For any theoretical flow greater than 2400 vph it is assumed that the additional vehicles will be forced to the next hour or to alternate routes. Essentially a delay of greater than 1.86 minutes per km (3.0 minutes per mile) is considered to be unacceptable to the driving public. The linear speed-flow relationship is plotted in Figure 9. The congestion cost due to delay is estimated in the same manner as in the Dallas System Planning Study. The hourly value of time per person for the first half of 1995 is $11.31.

Alternate Routes

For the Dallas HOV/Freeway System planning analysis, arterial speeds were presumed to be constant, and low enough to prevent shifts to the arterials from the freeway during peak

Figure 9. Linear Speed-Flow Relationship Approximation



periods. While diversion to and impacts on arterials or alternate routes resulting from freeway congestion were not included in the cost spreadsheet, at speeds below 24 kph (15 mph), excess freeway vehicles were assumed to be forced to the next hour.

In order to test the assumptions travel speed data was summarized from three corridors in Dallas and three in Houston. Corridors with a parallel arterial street in close proximity to the freeway were used to compare average simultaneous travel speeds on freeways versus alternate routes during the morning and evening peak hour and a three-hour peak period. The locations of the study corridors are shown in Table 6. A frontage road in one of the Dallas corridors was used as an alternate route while arterial streets were used as the alternate route in the remaining corridors. The roadway section lengths over which travel times were collected in each corridor varies from 5 to 11 km (3 to 7 miles). All data were collected on an incident-free day in each corridor. Figure 10 is a plot of the travel speed comparisons.

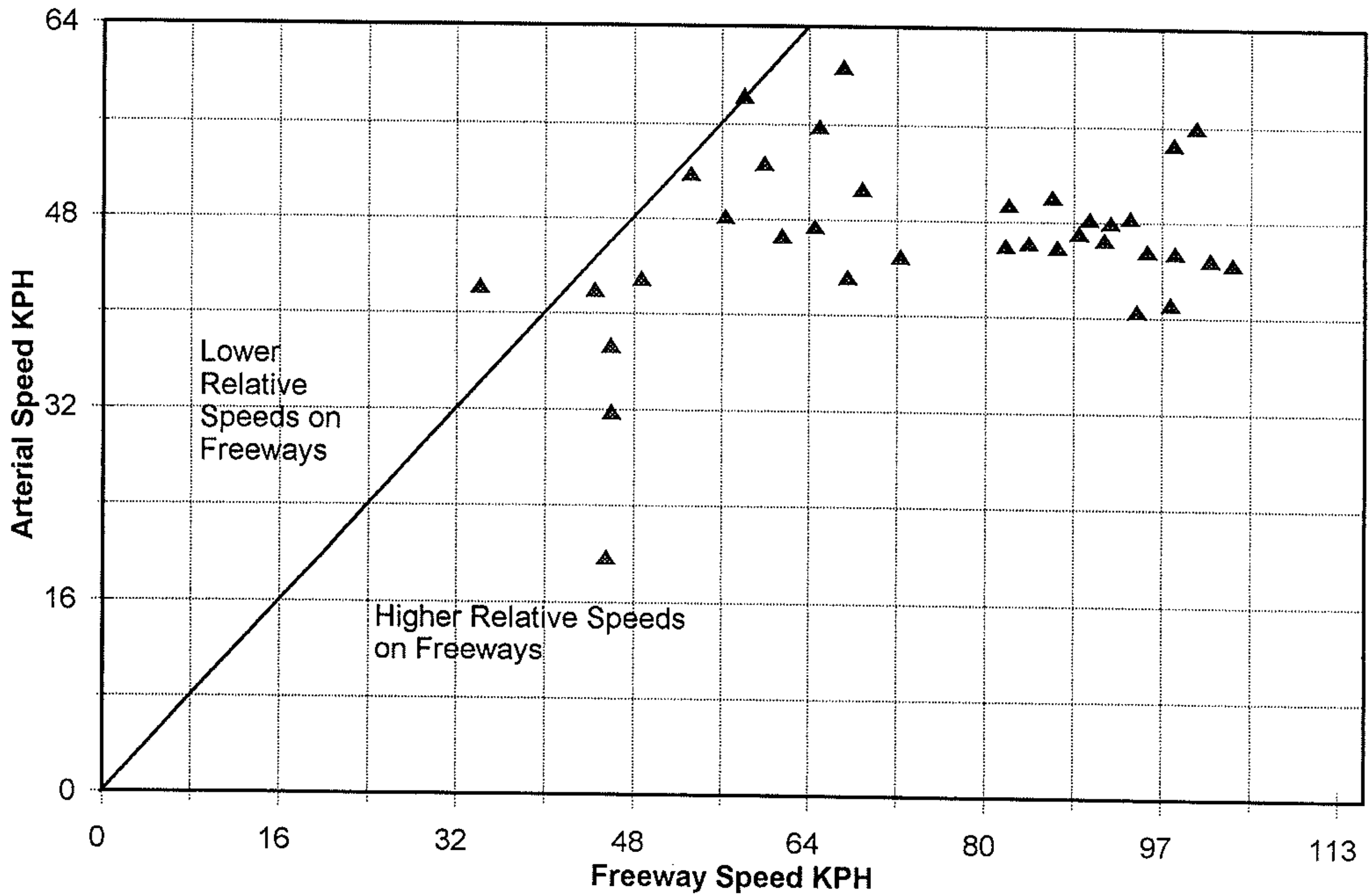
Table 6. Parallel Arterial Routes to Freeways in Dallas and Houston

City	Freeway	Parallel Arterial Route
Dallas	IH635 (LBJ Freeway)	Forest Lane
	IH35E (Stemmons Freeway)	Harry Hines Blvd.
	SH183 (Airport Freeway)	Frontage Road
Houston	IH45 (North Freeway)	N. Sheppard Drive
	IH45 (Gulf Freeway)	Galveston Road (SH3)
	US59 (Southwest Freeway)	Bissonnet Street

The data in Figure 10 indicate that at freeway speeds below 64 kph (40 mph), arterial speeds decrease as freeway speeds decrease. This is likely the result of motorists diverting from the freeway to alternate routes. The rate of diversion can not, however, be determined because volume data was not collected along each of the corridors. Additionally, the amount of diversion will depend not only on the level of freeway congestion but also the number of alternate routes available as well as the characteristics of each alternate route (i.e., proximity to the freeway, number of lanes, number of signalized intersections and the coordination of signal timings, etc.). Only one data point had an arterial speed greater than the corresponding freeway speed indicating in this case that motorists who diverted may have gained a travel time advantage. The original assumption for a planning level of analysis that the minimum speed on freeways is 24 kph (15 mph) is supported by this data as there were not any observed speeds lower than this on the freeways or arterials regardless of the level of congestion. A limited amount of data, however, was collected for this study and definitive conclusions can not be deduced about diversion to alternate routes. Additional research is required to determine the congestion level at which

Figure 10. Freeway vs. Parallel Arterial Speeds During Peak Period

Dallas and Houston



freeway motorists will begin to divert to alternate routes and the diversion rate at various congestion levels. However, the study team felt that the data corroborated the earlier planning assumptions, and the methodology remains the same.

Energy Costs

The total fuel consumption in volume per day for each alternative is estimated using the fuel consumption tables - derived from the ARFCOM program - and the speed-flow relationship discussed above. The total fuel consumption cost is the annual cost of fuel for a particular alternative. The average cost of fuel in the Dallas Fort Worth Region for the first half of 1995 was estimated at $0.28 per liter ($1.05 per gallon) of regular unleaded fuel.

Commercial Vehicle Costs

Unit congestion costs were developed for commercial vehicles, by contacting the American Trucking Association for current estimates of the value of driver and vehicle time, without respect to shipment costs, which vary too widely to be predictable. The American Trucking Association's estimate of the cost of a loaded truck stuck in congestion is $60 per hour, which includes driver cost, truck operating cost, and opportunity cost. This value was used in conjunction with peak period vehicle classification data on Dallas freeways to provide a rational basis for estimating the costs of congestion on the economic health of a community in addition to the personal costs of congestion used in the earlier study.

METHODOLOGY FOR FUTURE PROJECTS

Design Hour Volume Spreadsheet Summary

As part of the "Dallas Freeway/HOV System Planning Study" report, a spreadsheet based iterative process was developed to aid system-wide planning. This process allowed the user to test alternative freeway configurations in sections of a corridor. The technique used a Design Hour Volume (DHV) spreadsheet and a Cost Estimation spreadsheet. The useability and appearance of the DHV and Cost Estimation spreadsheets that make up the methodology were also greatly improved as part of this research.

The DHV spreadsheet is designed to allow the user to estimate input factors to arrive at the number of vehicles, persons, and occupancy rate for sections of a corridor. A detailed description of the DHV spreadsheet and an example printout of the complete DHV spreadsheet are located in Appendix B. The spreadsheet will perform all necessary calculations to estimate output values with the input factors and equations. It is very important for the user to determine the reasonableness and sensitivity of the model to changes in input values. This can be accomplished by changing input values (e.g., increasing and decreasing volume by 10 percent) or testing several alternative cross sections. If HOV lane projects are tested, the user should examine the percentage of new carpools and transit riders for reasonableness; values that are too high should be adjusted before proceeding to the Cost Estimation spreadsheet.

The estimates provided by the DHV spreadsheet are located in the "Outputs" section. The critical lane volume outputs calculated include:

- General Purpose—The number of vehicles in a peak direction general purpose lane in the peak hour of traffic flow.

- Express—The number of vehicles in an express lane during the peak hour.

- HOV—The number of vehicles in an HOV lane during the peak hour of the day.

- General Purpose Auto—The number of vehicles in the critical general purpose lane that are non-truck automobiles.

- General Purpose Truck—The number of trucks in the critical general purpose lane.

Additional descriptive outputs are located in the general outputs section. This information includes:

- Vehicles—Total number of vehicles in a freeway section.

- Persons—Total number of persons in a freeway section.

- Occupancy—The value obtained by dividing the total number of persons by the total number of vehicles in a freeway section.

- Vehicle Distance of Travel (VDT)—Distance traveled by vehicles in the section (units specified by user).

- Person Distance of Travel (PDT)—Distance traveled by persons in the section (units specified by user).

All of these outputs are used in comparing alternatives for a freeway corridor.

The DHV spreadsheet described in the preceding discussion was modified from its original form used in the Dallas Freeway/HOV System Planning Study report. Modifications to the organization were performed to provide a better understanding of the use of the spreadsheet and its output values. Other revisions that were included in the "Outputs" section of the spreadsheet are:

- Estimation of HOV ridership based on the new Texas relationship between directional hourly volume per lane and HOV ridership.

- Adjustment for maximum allowable new HOV users.

- Identification of truck volume in the critical general purpose lane volume

- Calculation of vehicle and person travel distance.

Other modifications can be made to the DHV Spreadsheet to meet particular needs. Caution must be employed, however, when altering the spreadsheet from its current form so that existing cell references are preserved.

Cost Estimation Spreadsheet Summary

The Cost Estimation spreadsheet is the second spreadsheet used as part of the "Dallas Freeway/HOV System Planning Study" report, to aid system-wide planning. This spreadsheet uses the outputs from the Design Hour Volume spreadsheet to obtain the cost of construction, congestion, and the additional cost of fuel consumption, and commercial operations for each section of several alternative configurations of a freeway corridor.

The Cost Estimation spreadsheet is designed to allow the user to estimate input parameters, for each section of corridor, to arrive at the total cost for each alternative. Before inputting values into this spreadsheet, the user should have completed the DHV spreadsheet. A detailed description of the Cost Estimation spreadsheet and an example printout of the spreadsheet results are located in Appendix B. The 1995 default values for the Dallas Fort Worth region for the person-hour of time, truck cost, and volume of fuel cost are provided at the top of the spreadsheet and should be changed if regional data is available. Similarly, the rates for estimating the fuel consumption are contained in worksheet C of the spreadsheet and should be changed if regional data is available. The units for the cost of fuel consumption should match the units used in the fuel consumption rates.

The outputs of the Cost Estimation spreadsheet can be divided into two sections: total cost output and fuel consumption calculations output. The total cost is the sum of construction cost, right-of-way cost, O&M (Operation and Maintenance) cost, peak hour general purpose congestion cost, total general purpose congestion cost, transit congestion cost, and fuel consumption cost.

The fuel consumption calculations are located in worksheet B of the spreadsheet. The fuel consumption output is for the peak direction of flow for both the morning and evening peak periods, and includes the following:

- Fuel consumption - Volume of fuel consumption per day
- Fuel consumption - Cost ($) per day

The Cost Estimation spreadsheet, described in the preceding section, allows the user to compare alternatives for a freeway corridor, based upon total cost, and amount of fuel consumption. This spreadsheet can be modified from the original format to allow the user to base the alternative comparisons on additional parameters; however, caution must be employed when altering the spreadsheet from its current form such that the existing cell references are preserved.

Validation of Methodology

A typical corridor which was analyzed in the Dallas System Planning Study was chosen to validate the new and improved methodology. The same input volumes and freeway section alternatives as used in the earlier study were used for this validation. The output of the DHV and Cost Estimation spreadsheets are included in Appendix C. For this example the distance is measured in miles, the width is measured in feet, and the volume of fuel consumption is measured in gallons.

To analyze a corridor several alternatives are considered. A No-Action alternative and an All General Purpose alternative are analyzed for all corridors primarily for comparison purposes, though occasionally either alternative may be the least cost alternative for a corridor. The No-Action alternative is simply the existing corridor, and the All General Purpose alternative is the minimum number of general purpose lanes needed to provide uncongested travel through the corridor. Other alternatives will consist of general purpose lanes, and either an express lane facility or an HOV lane facility, or a combination of express and HOV lanes. The Cost Estimation spreadsheet is designed to deal with peak direction flows and reversible express and HOV facilities. However, it can be modified to analyze bidirectional flows and concurrent

HOV facilities. However, it can be modified to analyze bidirectional flows and concurrent express and HOV facilities where the directional split is near even.

There are two primary considerations for selecting an alternative for analysis the critical lane volume and lane balance or continuity. Each corridor is divided into sections in the DHV spreadsheet. For any number of lanes input into the DHV spreadsheet a critical lane volume is output. A critical lane volume between 1800 vph and 2200 vph is most desirable. If the critical lane volume is below 1800 vph there may be too many lanes resulting in high construction cost, and if the critical lane volume exceeds 2200 vph the congestion cost may become unacceptable. For most corridors each section will have several combinations of lanes that will produce desirable critical lane volumes. General purpose lane and express lane only alternatives will not change occupancy rates, though HOV lane alternatives may increase occupancy rates for the entire corridor. HOV alternatives may also reduce the critical lane volume in sections of the corridor that do not have HOV lanes.

To provide lane balance or continuity usually only one type of facility is considered for each alternative in a corridor, though HOV and express lane facilities may be considered together through a section of a corridor. It may not be feasible to have express lanes in one section with HOV lanes in the next section. Similarly, HOV lanes with different occupancy requirements from section to section are not desired. HOV and express lane facilities should also be continuous through the corridor and not broken into separate sections. No matter the facility, it is important to note the transition required from section to section. A change in number of lanes implies a connection to another corridor or facility or a lane connection to the arterial street network. A large change in the number of lanes from one section to another section may not be feasible. The connection between two intersecting corridors must be carefully considered as well. The least cost alternative for either corridor may not provide for a good connection between the corridors. For example if the least cost alternative for one corridor is an express facility and the intersecting corridor has a least cost alternative with a 2+ HOV facility, it may be more feasible to have both corridors with the same type of facility either a 2+ HOV or an express and assume a slightly higher cost on one of the corridors.

Results of Validation

For the corridor used for the validation nine different alternatives were considered. The No-Action alternative and the All General Purpose alternative were analyzed in this corridor primarily for comparison to the other alternatives. From the results of the DHV spreadsheet it is apparent either alternative is undesirable. Due to the directional split and radial nature of this corridor all the other alternatives have reversible facilities. Two express lane facility alternatives and five HOV lane facility alternatives were analyzed.

The results of the improved methodology are similar to the original Dallas System Planning Study for the validation corridor. The least cost alternative with the improved methodology is the same 2+ HOV alternative, alternative 9, for both methods. The primary difference with the improved methodology over the original method is slightly lower congestion cost for all but the No-Action alternative, alternative 1, due to the combined effect of the improved regression formulas and the improved congestion cost procedures. The new method also includes the fuel consumption cost. Alternatives with high congestion costs have higher fuel costs, although the No-Action alternative for this validation has the highest congestion cost, it has the lowest fuel consumption cost. The congestion levels are so high for the No-Action alternative that the vehicle demand cannot be served in the time period used by the cost estimation spreadsheet, and the fuel consumption is only estimated for the vehicles that are served by the alternative. The alternatives with no congestion cost such as the All General Purpose alternative, alternative 2, also have high fuel consumption costs. The alternative with the lowest fuel consumption cost, alternative 9, also has the lowest total public cost. Other corridors should show similar results since the lower energy cost is due primarily to increased occupancy rates which result from HOV alternatives. The annual costs for the design year of 2015 for alternative 3 and 9 are shown in Table 7.

Table 7. Validation Results

	Alternative #	Constructionl Cost ($M)	Congestion Cost ($M)	Fuel Cost ($M)	Total Cost ($M)
Original Method	3	13.8	54.0	-	67.8
	9	18.2	4.2	-	22.4
Improved Method	3	13.7	26.3	14.5	54.5
	9	17.1	3.2	13.0	33.3

Identify Energy Savings

The improved methodology allows the alternative with the least energy consumption to be identified. Alternative 9 from the output of the Cost Estimation spreadsheet shown in Appendix C shows the lowest fuel consumption cost of the twelve alternatives analyzed of $13.0 million for the design year of 2015 in 1995 dollars. Alternative 3 of the cost analysis shows the highest fuel consumption cost of $14.5 million. So the energy savings to the citizens of Texas resulting from this research will be $1.5 million in fuel for the 2015 design year for this corridor in Dallas County if alternative 9 is chosen over alternative 3.

Application of Results

The methodology described above is established to be useable in locations other than Dallas. The results of this project - the methodology to arrive at the least public cost - will be implemented to reduce the cost of transportation in Texas by allowing transportation planning teams to consider the construction cost, the congestion cost, and energy cost of various alternatives being considered for any freeway corridor or system plan.

CONCLUSION

The main goal of this research was to enhance the Dallas Freeway/HOV System Planning Study methodology to includes data from HOV systems outside of Texas, to improve the congestion cost analysis, and to include cost estimating procedures for fuel consumption, vehicle emissions reductions, and delay to commercial vehicles. It was also desired to improve the useability and appearance of the DHV and Cost Estimation spreadsheets that make up the methodology.

The Dallas System Planning Study methodology used carpool and bus ridership data from Houston to develop a regression equation relationship between HOV ridership and congestion. This research sought to advance the HOV ridership relationship by analyzing data from HOV systems in operation across the United States. However, it was determined due to variations in the data collection techniques, and project and urban area characteristics from HOV projects from across the U.S. that a regression equation that focused on Texas HOV data would be better suited to predicting ridership for Texas projects.

To estimate the energy cost for each alternative the fuel consumption was quantified. Fuel consumption rates were derived with the use of the ARFCOM computer program, and the rates are given in units of volume per unit of distance. The amount of fuel consumption is estimated for a section of corridor by multiplying the VDT by the specific fuel consumption rate for the average speed of that section of corridor. This method of quantifying fuel consumption is known as an average speed methodology, and it is considered reasonably accurate.

Vehicle emission rates can be estimated in a similar manner. However, the emission estimates are known to be inaccurate for this level of analysis. The emission rates developed with MOBILE5a are generated with a driving cycle which does not include off-cycle driving patterns such as high speeds and sharp accelerations. Also, changes in speed are not recognized when only an average speed in a section of freeway is used to profile driving behavior. Since a better emissions estimate model is not currently available the impact of emissions changes were not considered with the improved methodology.

The method to estimate delay due to congestion from the Dallas System Planning Study was reviewed and changed to better reflect real freeway lane capacity and flow conditions. A linear relationship of volume to delay and speed was developed to improve the congestion cost methodology. With the original method it was assumed that the speeds on alternate routes such as adjacent arterial streets was 24 kph (15 mph). Travel data from several arterial and frontage road routes were reviewed to determine a relationship between freeway speed and alternate route speed. Based on the relative good agreement between the data and the assumptions, the original method of using a minimum speed of 24 kph (15 mph) or a maximum delay of 1.86 minutes per km (3 minutes per mile) was not changed.

Additional costs were added to the methodology for fuel consumption, and the cost of congestion for commercial vehicles. The local cost of fuel per volume was used to estimate the annual cost of fuel consumption. The cost per hour for trucks stuck in congestion was used to estimate the annual cost of congestion for commercial vehicles.

Both the DHV spreadsheet and the Cost Estimation spreadsheet have been improved, and are easier to use. Data from other HOV systems was examined, though only data from Texas locations was used to improve the methodology. The improved methodology is applicable to other communities with similar conditions to Houston or Dallas for selecting freeway improvement alternatives, as well as allowing the user to quickly compare energy consumption of alternatives, and to select the least energy intensive alternative if desired. The validation results of the improved methodology show that the alternative with the lowest total public cost was also the alternative with the lowest fuel consumption cost. The improved methodology will also be useful throughout Texas, and will be especially useful to planners in the age of constrained budgets. The lowest public cost methodology allows for greater efficiency, and the dynamic planning for HOV ridership under congested freeway conditions allows for incorporation of increasing mode splits, in an age of increasing air quality concern.

REFERENCES

1. Poe, C.M., R.H. Henk, C.H. Walters, and T.J. Lomax. "Development of an HOV Demand Estimation Procedure for Use in a Multimodal System Plan," Texas Transportation Institute, Texas A&M University System, College Station, TX, June 1994.

2 Walters, C.H., T.J. Lomax, C.M. Poe, R.H. Henk, D.A. Skowronek, and M.D. Middleton. "The Dallas Freeway/HOV System Planning Study: Year 2015," Research Report 1994-7, Texas Transportation Institute, Texas A&M University System, College Station, TX, December 1992.

3 Middleton, M.D., C.H. Walters, P.B. Wiles. "Energy and Air Quality Benefits of Freeway Bottleneck Improvements," Southwest Region University Transportation Center Research Report SWUTC/96/60039-1, Texas Transportation Institute, College Station, TX, March 1996.

4 ARFCOM 2.03, Computer Model, Programer - Biggs, D.C., Australian Road Research Board Ltd., Nunawading, Victoria, Australia, April 1993.

5 Biggs, D.C., "Vehicle Fuel Consumption Estimation Program, ARFCOM - User Guide," Internal Report ATM, Australian Road Research Board, Vermont South, Victoria, Australia, 1989.

6 Stephenson, A. R., and G. Dresser. " State-of-the Practice Report on Mobile Source Emissions Models," Research Report 1279-3, Texas Transportation Institute, Texas A&M University System, College Station, TX, 1994.

7 Guensler, R., "Data Needs for Evolving Motor Vehicle Emission Modeling Approaches," Wholley, T.F. ed., Proceedings of the National Conference, Transportation Planning and Air Quality II, 1993 May 24-26, p167-196, American Society of Civil Engineers. New York, NY, 1994.

8 Kelly,N.A., P.J. Groblicki. "Real-World Emissions from a Modern Production Vehicle Driven in Los Angeles," Journal of Air and Waste Management, vol 43, p1356, 1995.

9 Barth, M., F. An, J. Norbeck, M. Ross, "Modal Emissions Modeling: A Physical Approach," Paper No. 960905, Transportation Research Board, 75th Annual Meeting, Washington, D.C., January 1996.

10 McFarland, W.F., and M. Chui, "The Value of Travel Time: New Estimates Developed Using a Speed Choice Model," Research Report No. 396-2F, Texas Transportation Institute, College Station, TX., 1985.

APPENDIX A - High-Occupancy Vehicle Lane Data

HOV Type and Location	HOV Facility	Year	Daily Freeway Volume	Freeway Lanes	Daily Volume per Lane	HOV Vehicle Volume	HOV Person Volume	HOV Percentage[1]
Barrier-Separated Two-way								
Los Angeles County, CA	I-10	1991	258,000	8	32,250	12,200	40,260	15.6%
		1992	257,000	8	32,125	13,270	43,790	17.0%
		1993	256,000	8	32,000	14,400	47,520	18.6%
Northern Virginia	I-66	1990	108,000	4	27,000	3,360	10,780	10.0%
		1991	111,000	4	27,750	4,130	12,910	11.6%
Barrier-Separated Reversible								
San Diego County, CA	I-15	1991	215,000	8	26,875	8,200	18,040	8.4%
		1992	226,000	8	28,250	8,600	18,920	8.4%
		1993	227,000	8	28,375	8,900	19,580	8.6%
Minneapolis, MN	I-394	1992	106,000	6	17,667	4,210	8,640	8.2%
		1993	134,000	6	22,333	6,400	13,010	9.7%
Pittsburgh, PA	I-279	1989	63,000	4	15,750	520	3,460	5.5%
		1991	86,000	4	21,500	1,410	3,440	4.0%
		1993	92,000	6	15,333	4,040	12,930	14.1%
Houston, TX	I-10	1988	195,000	6	32,500	5,990	17,900	9.2%
		1989	198,000	6	33,000	5,550	17,870	9.0%
		1990	185,000	6	30,833	7,550	23,130	12.5%
		1991	185,000	6	30,833	7,460	23,750	12.8%
		1992	183,000	6	30,500	5,990	22,070	12.1%
		1993	185,000	6	30,833	6,470	21,090	11.4%
		1994	187,000	6	31,167	6,590	19,750	10.6%
	I-45 Gulf	1988	167,000	8	20,875	1,090	5,630	3.4%
		1989	165,000	8	20,625	1,680	6,870	4.2%
		1990	207,000	10	20,700	2,070	8,310	4.0%
		1991	199,000	10	19,900	2,600	8,520	4.3%
		1992	213,000	10	21,300	2,790	9,820	4.6%
		1993	219,000	10	21,900	2,920	9,770	4.5%
		1994	226,000	10	22,600	2,960	10,000	4.4%

[1]HOV person volume as a percentage of daily freeway volume.

HOV Type and Location	HOV Facility	Year	K[2] (%)	D[3] (%)	HOV Lanes	Hours of Operation	General Occupancy[4]	Years Since Opened	Peak Hour Violation Rate (%)	Fine Amount ($)
Barrier-Separated Two-way										
Los Angeles County, CA	I-10	1991	7.1	61	2	24 hr	3+	2	11	246
		1992	7.1	61	2		3+	3	11	246
		1993	7.1	61	2		3+	4	11	246
Northern Virginia	I-66	1990	7.0	60	2	6:30-9 am	3+	8	na	50
		1991	7.0	60	2	4-6:30 pm	3+	9	na	50
Barrier-Separated Reversible										
San Diego County, CA	I-15	1991	9.1	62	2	6-9 am	2+	3	3	246
		1992	9.1	62	2	3-6 pm		4	3	246
		1993	9.1	62	2			5	3	246
Minneapolis, MN	I-394	1992	8.0	55	2	6-10 am	2+	1	na	55
		1993	8.0	55	2	2-7 pm		2	na	55
Pittsburgh, PA	I-279	1989	7.5	55	1	5 am-12	3+	1	na	82.5
		1991	7.5	55	1	2-8 pm	3+	2	na	82.5
		1993	7.5	55	1		2+	3	na	82.5
Houston, TX	I-10	1988	7.0	52	1	4 am-1 pm &	3+	4	1	75
		1989	7.0	52	1	2-10 pm	Peak Hours	5	1	75
		1990	7.0	52	1	also	2+	6	1	75
		1991	7.0	52	1	4 am-10 pm	Other	7	1	75
		1992	7.0	52	1	WB Sat		8	1	75
		1993	7.0	52	1	4 am-10 pm		9	1	75
		1994	7.0	52	1	EB Sun		10	1	75
	I-45 Gulf	1988	7.5	55	1	4 am-1 pm &	2+	1	1	75
		1989	7.5	55	1	2-10 pm		2	1	75
		1990	7.5	55	1			3	1	75
		1991	7.5	55	1			4	1	75
		1992	7.5	55	1			5	1	75
		1993	7.5	55	1			6	1	75
		1994	7.5	55	1			7	1	75

[2]Percent of daily traffic in the peak hour.
[3]Percent of peak hour traffic in the peak direction.
[4]Minimum vehicle occupancy eligible for HOV lane (e.g., 2+ is 2-or-more persons).

HOV Type and Location	HOV Facility	Year	Daily Freeway Volume	Freeway Lanes	Daily Volume per Lane	HOV Vehicle Volume	HOV Person Volume	HOV Percentage[1]
Barrier-Separated Reversible								
Houston, TX	I-45 North	1988	201,000	8	25,125	2,890	13,980	7.0%
		1989	199,000	8	24,875	2,550	12,330	6.2%
		1990	211,000	8	26,375	3,460	16,720	7.9%
		1991	215,000	8	26,875	3,610	18,700	8.7%
		1992	225,000	8	28,125	4,730	19,260	8.6%
		1993	226,000	8	28,250	4,780	21,540	9.5%
		1994	227,000	8	28,375	4,770	21,150	9.3%
	US 59	1993	214,000	10	21,400	3,470	11,350	5.3%
		1994	223,000	10	22,300	5,050	14,030	6.3%
	US 290	1988	214,000	10	21,400	1,570	4,630	2.2%
		1989	216,000	10	21,600	2,060	5,920	2.7%
		1990	219,000	10	21,900	3,520	9,750	4.5%
		1991	202,000	10	20,200	4,130	11,330	5.6%
		1992	198,000	10	19,800	4,420	12,250	6.2%
		1993	204,000	10	20,400	4,550	12,490	6.1%
		1994	211,000	10	21,100	4,710	13,080	6.2%
Northern Virginia	I-395	1990	200,000	8	25,000	12,180	71,370	35.7%
		1993	178,000	8	22,250	11,990	60,130	33.8%
Norfolk, VA	I-64	1992	122,000	6	20,333	5,380	12,320	10.1%
		1993	125,000	6	20,833	5,280	11,610	9.3%
Concurrent Flow								
Phoenix, AZ	I-10	1992	210,000	8	26,250	13,410	27,700	13.2%
	SR 202	1992	91,000	6	15,167	3,380	6,560	7.2%
Alameda County, CA	I-880	1991	219,000	8	27,375	6,020	13,010	5.9%
		1992	219,000	8	27,375	7,580	16,370	7.5%
		1993	204,000	8	25,500	9,140	19,730	9.7%
Contra Costa County, CA	I-580	1991	72,000	4	18,000	260	540	0.8%
		1992	77,000	4	19,250	360	760	1.0%
		1993	76,000	4	19,000	470	980	1.3%
Los Angeles County, CA	SR 91	1991	266,000	8	33,250	12,400	27,530	10.4%

[1]HOV person volume as a percentage of daily freeway volume.

HOV Type and Location	HOV Facility	Year	K[2] (%)	D[3] (%)	HOV Lanes	Hours of Operation	General Occupancy[4]	Years Since Opened	Peak Hour Violation Rate (%)	Fine Amount ($)
Barrier-Separated Reversible										
Houston, TX	I-45 North	1988	7.0	52	1	4 am-1 pm & 2-10 pm	2+	3	1	75
		1989	7.0	52	1			4	1	75
		1990	7.0	52	1			5	1	75
		1991	7.0	52	1			6	1	75
		1992	7.0	52	1			7	1	75
		1993	7.0	52	1			8	1	75
		1994	7.0	52	1			9	1	75
	US 59	1993	7.5	55	1	4 am-1 pm & 2-10 pm	2+	1	1	75
		1994	7.5	55	1			2	1	75
	US 290	1988	7.5	55	1	4 am-1 pm & 2-10 pm	2+	1	1	75
		1989	7.5	55	1			2	1	75
		1990	7.5	55	1			3	1	75
		1991	7.5	55	1			4	1	75
		1992	7.5	55	1			5	1	75
		1993	7.5	55	1			6	1	75
		1994	7.5	55	1			7	1	75
Northern Virginia	I-395	1990	8.0	55	2	6-9 am 3:30-6 pm	3+	15	5	50
		1993	8.0	55	2			18	5	50
Norfolk, VA	I-64	1992	8.0	63	2	5-8:30 am 3-6 pm	2+	1	na	50
		1993	8.0	63	2			2	na	50
Concurrent Flow										
Phoenix, AZ	I-10	1992	7.2	50	1	24 hr	2+	2	na	250
	SR 202	1992	7.2	50	1	24 hr	2+	1	na	250
Alameda County, CA	I-880	1991	9.0	51	1	5-9 am 3-7 pm	2+	1	na	246
		1992	9.0	51	1			2	na	246
		1993	9.0	51	1			3	na	246
Contra Costa County, CA	I-580	1991	7.5	55	1	7-8 am 5-6 pm	2+	1	na	246
		1992	7.5	55	1			2	na	246
		1993	7.5	55	1			3	na	246
Los Angeles County, CA	SR 91	1991	7.8	56	2	24 hr	2+	6	7	246

[2]Percent of daily traffic in the peak hour.
[3]Percent of peak hour traffic in the peak direction.
[4]Minimum vehicle occupancy eligible for HOV lane (e.g., 2+ is 2-or-more persons).

HOV Type and Location	HOV Facility	Year	Daily Freeway Volume	Freeway Lanes	Daily Volume per Lane	HOV Vehicle Volume	HOV Person Volume	HOV Percentage[1]
Concurrent Flow								
Marin County, CA	US 101	1991	156,000	6	26,000	3,710	14,310	9.2%
		1992	153,000	6	25,500	3,890	15,020	9.8%
		1993	153,000	6	25,500	4,080	15,740	10.3%
Orange County, CA	I-5	1991	191,000	10	19,100	15,000	33,000	17.3%
		1992	193,000	10	19,300	16,900	37,180	19.3%
		1993	195,000	10	19,500	18,900	41,580	21.3%
	SR-55	1991	211,000	6	35,167	28,000	61,600	29.2%
		1992	211,000	6	35,167	31,600	69,520	33.0%
		1993	211,000	6	35,167	33,200	73,040	34.6%
	SR-57	1991	201,000	8	25,125	15,000	33,000	16.4%
		1992	193,000	8	24,125	16,900	37,180	19.3%
		1993	193,000	8	24,125	18,900	41,580	21.5%
	I-405	1991	294,000	10	29,400	26,000	57,200	19.5%
		1992	288,000	10	28,800	29,400	64,680	22.5%
		1993	288,000	10	28,800	32,800	72,160	25.1%
Riverside County, CA	SR 91	1992	205,000	6	34,167	9,200	20,240	9.9%
		1993	207,000	6	34,500	10,800	23,760	11.5%
Sacramento County, CA	SR 99	1991	146,000	6	24,333	9,300	20,930	14.3%
		1992	146,000	6	24,333	8,440	18,980	13.0%
		1993	146,000	6	24,333	7,570	17,030	11.7%
San Mateo County, CA	US 101	1991	171,000	6	28,500	3,920	8,780	5.1%
		1992	172,000	6	28,667	5,320	11,920	6.9%
		1993	172,000	6	28,667	6,720	15,050	8.8%
Santa Clara County, CA	SR 85	1991	90,000	4	22,500	2,660	5,450	6.1%
		1992	92,000	4	23,000	2,630	5,390	5.9%
		1993	92,000	4	23,000	2,600	5,340	5.8%
	US 101	1991	228,000	6	38,000	6,350	14,100	6.2%
		1992	219,000	6	36,500	9,960	21,500	9.8%
		1993	219,000	6	36,500	13,020	28,910	13.2%
	SR 237	1991	81,000	4	20,250	4,110	9,940	12.3%
		1992	88,000	4	22,000	3,980	9,630	10.9%
		1993	88,000	4	22,000	3,850	9,320	10.6%

[1] HOV person volume as a percentage of daily freeway volume.

HOV Type and Location	HOV Facility	Year	K[2] (%)	D[3] (%)	HOV Lanes	Hours of Operation	General Occupancy[4]	Years Since Opened	Peak Hour Violation Rate (%)	Fine Amount ($)
Concurrent Flow										
Marin County, CA	US 101	1991 1992 1993	6.8 6.8 6.8	75 75 75	1 1 1	6:30-8:30 am 4:30-7 pm	2+	5 6 7	na na na	246 246 246
Orange County, CA	I-5	1991 1992 1993	6.7 6.7 6.7	53 53 53	1 1 1	24 hr	2+	1 2 3	na na na	246 246 246
	SR-55	1991 1992 1993	7.2 7.2 7.2	60 60 60	1 1 1	24 hr	2+	6 7 8	6 6 6	246 246 246
	SR-57	1991 1992 1993	7.3 7.3 7.3	53 53 53	1 1 1	24 hr	2+	1 2 3	na na na	246 246 246
	I-405	1991 1992 1993	8.3 8.3 8.3	56 56 56	1 1 1	24 hr	2+	2 3 4	6 6 6	246 246 246
Riverside County, CA	SR 91	1992 1993	7.8 7.8	54 54	2 2	24 hr	2+	1 2	na na	246 246
Sacramento County, CA	SR 99	1991 1992 1993	8.1 8.1 8.1	64 64 64	2 2 2	24 hr	2+	1 2 3	na na na	246 246 246
San Mateo County, CA	US 101	1991 1992 1993	8.0 8.0 8.0	56 56 56	1 1 1	5-9 am 3-7 pm	2+	4 5 6	na na na	246 246 246
Santa Clara County, CA	SR 85	1991 1992 1993	8.6 8.6 8.6	67 67 67	1 1 1	5-9 am 3-7 pm	2+	1 2 3	na na na	500 500 500
	US 101	1991 1992 1993	8.0 8.0 8.0	59 59 59	1 1 1	5-9 am 3-7 pm	2+	3 4 5	5 5 5	500 500 500
	SR 237	1991 1992 1993	11.6 11.6 11.6	76 76 76	1 1 1	5-9 am 3-7 pm	2+	7 8 9	5 5 5	500 500 500

[2]Percent of daily traffic in the peak hour.
[3]Percent of peak hour traffic in the peak direction.
[4]Minimum vehicle occupancy eligible for HOV lane (e.g., 2+ is 2-or-more persons).

HOV Type and Location	HOV Facility	Year	Daily Freeway Volume	Freeway Lanes	Daily Volume per Lane	HOV Vehicle Volume	HOV Person Volume	HOV Percentage[1]
Concurrent Flow								
Santa Clara County, CA	I-280	1991 1992 1993	220,000 220,000 233,000	8 8 8	27,500 27,500 29,125	6,450 5,990 5,530	15,420 14,310 13,210	7.0% 6.5% 5.7%
Minneapolis, MN	I-394	1992 1993	96,000 120,000	6 6	16,000 20,000	4,620 4,180	9,200 8,300	9.6% 6.9%
Nashville, TN	I-65	1994	59,000	6	9,833	2,440	4,120	7.0%
Northern Virginia	I-95	1990	142,000	6	23,667	7,040	27,120	19.1%
Norfolk, VA	SR 44	1992 1993	112,000 143,000	8 8	14,000 17,875	3,790 3,820	7,350 7,910	6.6% 5.5%
Seattle, WA	I-5 N of CBD (SB)	1994	190,000	7	27,143	7,990	25,870	13.6%
	I-5 N of CBD (NB)	1994	190,000	7	27,143	6,070	18,390	9.7%
	I-90	1994	125,000	11	11,364	1,680	4,290	3.4%
	I-5 S of CBD (SB)	1994	182,000	7	26,000	4,450	13,020	7.2%
	I-405 (SB)	1994	126,000	4	31,500	7,260	21,780	17.3%
	I-405 (NB)	1994	126,000	4	31,500	7,810	23,430	18.6%
Contraflow								
Dallas, TX	I-30E	1992 1993	160,000 160,000	8 8	20,000 20,000	4,880 4,970	15,560 15,940	9.7% 10.0%

[1]HOV person volume as a percentage of daily freeway volume.

HOV Type and Location	HOV Facility	Year	K[2] (%)	D[3] (%)	HOV Lanes	Hours of Operation	General Occupancy[4]	Years Since Opened	Peak Hour Violation Rate (%)	Fine Amount ($)
Concurrent Flow										
Santa Clara County, CA	I-280	1991 1992 1993	9.5 9.5 9.5	61 61 61	1 1 1	5-9 am 3-7 pm	2+	2 3 4	na na 1	500 500 500
Minneapolis, MN	I-394	1992 1993	8.0 8.0	55 55	1 1	6-9 am 4-7 pm	2+	2 3	na na	55 55
Nashville, TN	I-65	1994	7.5	55	1	7-9 a; 4-6 p	2+	1	na	50
Northern Virginia	I-95	1990	7.0	55	1	6-9a; 3.5-6p	3+	4	na	50
Norfolk, VA	SR 44	1992 1993	8.0 8.0	60 60	1 1	5-8:30 am 3-6 pm	2+	1 2	na na	50 50
Seattle, WA	I-5 N of CBD (SB)	1994	7.6	59	1	24 hr	2+	11	11	47
	I-5 N of CBD (NB)	1994	8.4	67	1	24 hr	2+	11	11	47
	I-90	1994	8.5	64	1	24 hr	2+	5	na	47
	I-5 S of CBD (SB)	1994	8.8	57	1	24 hr	2+	3	11	47
	I-405 (SB)	1994	7.8	51	1	24 hr	2+	8	8	47
Contraflow										
Dallas, TX	I-30E	1992 1993	8.5 8.5	60 60	1 1	6-9 am & 4-7 pm	2+	1 2	na na	200 200

[2]Percent of daily traffic in the peak hour.
[3]Percent of peak hour traffic in the peak direction.
[4]Minimum vehicle occupancy eligible for HOV lane (e.g., 2+ is 2-or-more persons).

APPENDIX B: FREEWAY/HOV SYSTEM PLANNING USER'S MANUAL

As part of the "Dallas Freeway/HOV System Planning Study" report, a spreadsheet-based iterative process was developed to aid system-wide planning, based upon the total cost of congestion and construction of several corridor alternatives. This process allowed the user to test alternative freeway configurations in sections of a corridor. The technique used a Design Hour Volume (DHV) spreadsheet and a Cost Estimation spreadsheet. In order to use the software, the user must have access to a micro computer with QuattroPro version 6.0 or higher. In addition, it is recommended that the user have access to a 80386 computer with 4 megabytes memory, but preferably a 80486 computer.

The first spreadsheet is the DHV spreadsheet. The user defines continuous sections of the corridor according to major changes in traffic volume, or changes in number of lanes, and the user is required to input data for each corridor section. The sectional inputs for this spreadsheet include Average Daily Traffic (ADT), K and D factors, percent carpools and percent express, corridor capacity, bus and carpool occupancy, and proposed number of lanes in each section, and the outputs are critical lane volumes, number of vehicles, persons, and occupancy rate for each user specified corridor section. The second spreadsheet is the Cost Estimation spreadsheet. The inputs for this spreadsheet include proposed number of lanes, critical lane volumes, and transit ridership, which are the outputs from the DHV spreadsheet, and the output is an estimation of total cost for each alternative.

The following two sections describe the inputs and outputs to the DHV spreadsheet and the Cost Estimation spreadsheet.

DESIGN HOUR VOLUME SPREADSHEET

The Design Hour Volume spreadsheet is designed to allow the user to estimate input factors to arrive at the number of vehicles, persons, and occupancy rate for sections of a corridor. The following procedure shows the input steps needed in the "Section Inputs" of the DHV spreadsheet. It should be noted that the cell references made in the following list of instructions correspond to columns and rows that can be found in the attached three pages that show the columns, rows, and cell contents of an example alternative of the DHV spreadsheet.

- **Note the design year to be tested (Row 2) and the corridor for analysis (Row 3) listing all existing conditions and possible freeway expansion or enhancement limitations in the title.** The step also requires the alternative number (Row 4) and description to be specified.

- **Define the number of continuous sections along the corridor according to major changes in traffic volume, changes in the number of lanes or other vehicle movement influencing factors and give the section names according to endpoint markers (Row 6).** The number of sections in a corridor is unlimited; however, the number of columns will have to be increased to the specified number by copying the last column multiple times. The equation shown in location Row 69 must be modified. For the "@SUM($B25..$F25)" part of the equation, the letter of the column corresponding to the last (right most) column used must be inserted for the current value "F". The equations in Rows 100, 101, 106 and 107 must also be altered in the same manner. All other equations refer to only one section or column at a time.

- **Develop and input sectional information (Rows 8 to 21):**

Row 8	Length—Freeway section length in kilometers or miles.
Row 9	Freeway ADT—Predicted 24-hour volumes for design year.
Row 10	HOV ADT—Predicted 24-hour volumes for multiple rider vehicles in a designated HOV lane (from area wide planning model if available).
Row 11	Bus Person ADT—Predicted 24-hour volumes for buses in section.
Row 12	K—Percentage (in decimal) of daily traffic in peak hour.
Row 13	D—Percentage (in decimal) of traffic traveling in the peak direction during the peak hour (also known as the peak-hour directional distribution). This factor can also be used to estimate traffic congestion and HOV ridership in the off peak direction (i.e., D is less than 0.50).
Row 14	Percent Carpools—Percentage (in decimal) of carpools in the defined corridor section that can be expected if no preference is given to bus and carpool traffic.
Row 15	Percent Express—Percentage (in decimal) of through traffic for a corridor.
Row 16	Capacity—Hourly freeway capacity per lane (often determined using the Highway Capacity Manual HCM procedures).
Row 17	Max % New Carpools—The maximum percentage (in percent) of new carpools that are allowed to be formed in the freeway section due to HOV treatment.
Row 18	Bus Occupancy—The average number of persons utilizing a single bus.
Row 19	Carpool Occupancy—The average number of persons per eligible carpool vehicle (e.g., 2.2) in an HOV lane.
Row 20	GP Occupancy—The average number of persons per vehicle in the general purpose lanes if an HOV lane is present in the alternative.
Row 21	GP Truck Percent—The percentage (in decimal) of trucks in general purpose traffic lanes.

- **Input number of general purpose (Row 23), express (Row 24), and HOV (Row 25) lanes to be used in the specified alternative for each section.**

- **Define the intercept (Row 27) and coefficient(s) (Row 28) associated with the ridership equation to be used for the freeway corridor.** The equation assumes that directional hourly volume per lane will be used to predict HOV ridership. If another variable is used, the spreadsheet cells that reference this equation (i.e., Rows 140, 147, 154, 161, and 168) must be modified to reflect the new ridership prediction equation inputs.

The spreadsheet will perform all necessary calculations to estimate output values with the input factors and equations. It is important for the user to determine the reasonableness and sensitivity of the model to changes in input values. This can be accomplished by changing input values (e.g., increasing and decreasing volume by 10 percent) or testing several alternative cross sections. If HOV lane projects are tested, the user should examine the percentage of new carpools and transit riders for reasonableness; values that are too high should be adjusted before proceeding to the Cost Estimation spreadsheet.

Description of Output Variables

The estimates provided by the DHV spreadsheet are located in the "Outputs" section. The critical lane volume outputs (Rows 32 to 37) calculated include:

- General Purpose (Row 32)—The number of vehicles in a peak direction general purpose lane in the peak hour of traffic flow.
- Express (Row 33)—The number of vehicles in an express lane during the peak hour.
- HOV (Row 34)—The number of vehicles in an HOV lane during the peak hour.
- New Bus Passengers (Row 35)—The number of additional transit riders during the peak hour.
- General Purpose Auto (Row 36)—The number of vehicles in the critical general purpose lanes that are automobiles.
- General Purpose Truck (Row 37)—The number of trucks in the critical general purpose lanes.

Additional descriptive outputs are located in the general outputs section (Rows 40 to 44). This information includes:

- Vehicles (Row 40)—Total number of vehicles in a freeway section.
- Persons (Row 41)—Total number of persons in a freeway section.
- Occupancy (Row 42)—The value obtained by dividing the total number of persons by the total number of vehicles in a freeway section.

- Vehicle Distance of Travel (VDT) (Row 43)—Distance traveled by vehicles in the section (units specified by user in Row 8).

- Person Distance of Travel (PDT) (Row 44)—Distance traveled by persons in the section (units specified by user in Row 8).

All of these outputs are used in comparing alternatives for a freeway corridor.

Description of Intermediate Calculation Variables

The final three sections of the DHV spreadsheet are represented by the headings of "Calculations" (A47), "Adjustments" (A66), and "Iterations" (A118). The following discussion will briefly describe the process employed through these sections to manipulate the provided inputs into the listed outputs.

Preliminary values are computed from the input factors in the "Calculations" section. The capacity for the general purpose (Row 50), express (Row 51), and HOV (Row 52) lanes are calculated. The initial DHV information (Rows 54 and 55) is determined from the freeway ADT and HOV ADT inputs. The values of expected carpools (Row 57), new carpools (Row 58), and adjusted freeway DHV (Row 59) are found by employing an iterative adjustment located in the "Iterations" section (Rows 120 to 132). Last, the values of DHV needed for the "Adjustments" section are computed for total general purpose (Row 61), express only general purpose (Row 62), non-express general purpose vehicles (Row 63), and carpools (Row 64).

The "Adjustments" section has the purpose of balancing the freeway, express, and HOV volumes based on various factors. The four adjustments on the values of DHV accomplished in this section are as follows:

- Adjusted DHV from the volume per lane versus Ridership Iteration (Row 68 to Row 72)—This correction takes the input value for freeway DHV and applies the predictive HOV ridership equation to find the number of new HOV riders that can be created. This correction utilizes the "Iterations" section which begins in Row 134 and continues until Row 172. Additional information is also referenced in this adjustment and is provided in Rows 174 to 182. The result is a freeway congestion level that is consistent with the HOV ridership value.

- Adjusted DHV for HOV Capacity (Row 75 to Row 81)—This modification examines the HOV DHV per lane and compares it to the listed capacity. If the capacity has been exceeded, carpool and bus passengers are "sent back" to the general purpose lanes in the occupancy rate specified in Row 20.

- Adjusted DHV for General Purpose Congestion (Row 84 to Row 90)—In some circumstances, new HOV riders are estimated even though freeway capacity is not exceeded. This adjustment "sends back" enough HOV riders to fill the general purpose freeway lanes to capacity.

- Adjusted DHV for Max Percent New Carpools (Row 93 to Row 97)—This adaptation is performed if the calculated percentage of new carpools exceeds the specified limit from the inputs (Row 17). If this occurs, carpools are "sent back" to the general purpose lanes until the percentage is lowered to the maximum permitted.

- Adjusted DHV for Corridor (Row 100 to Row 115)—Knowing that carpools and bus ridership cannot be assembled and dispersed from section to section, this adjustment identifies the critical section of the corridor, and adjusts the HOV riders and bus passengers based on the critical section.

The final adjustments are used to develop the values in the "Outputs" section.

Summary

The DHV spreadsheet described in the preceding discussion was modified from its original form used in the "Dallas Freeway/HOV System Planning Study" report. Modifications to the organization were performed to provide a better understanding of the use of the spreadsheet and its output values. Other revisions that were included in the "Outputs" section of the spreadsheet are:

- Estimation of HOV ridership based on the new Texas relationship between directional hourly volume per lane and HOV ridership.

- Adjustment for maximum allowable new HOV users.

- Identification of truck volume in the critical general purpose lane volume

- Calculation of vehicle and person travel distance.

Other modifications can be made to the DHV Spreadsheet to meet particular needs. Caution must be employed, however, when altering the spreadsheet from its current form so that existing cell references are preserved.

A complete example DHV spreadsheet for an alternative of the IH30 corridor in West Dallas County follows. The IH30 corridor used five freeway sections in the spreadsheet. The first page of the spreadsheet shows the "Section Inputs" and "Outputs." The second page shows the "Calculations" and the "Adjustments." The last page shows the "Iterations."

A	A	B	C	D	E	F
1	19-Oct-95					
2	**Design Year:**	2015				
3	**Freeway:**	Example				
4	Alternative:	8	General Purpose and HOV 2+			
5	Freeway Section:	1	2	3	4	5
6	**Section Limits:**	A-B	B-C	C-D	D-E	E-F
7	Section Inputs:					
8	**Length (miles)**	1.95	6.70	3.21	2.24	0.34
9	**Freeway ADT**	311,172	232,989	211,950	237,453	139,375
10	**HOV ADT**	13,186	10,847	9,261	8,582	2,253
11	**Bus Person ADT**	0	1,421	2,898	4,098	4,098
12	**K**	0.085	0.085	0.085	0.085	0.085
13	**D**	0.60	0.65	0.65	0.65	0.65
14	**Percent Carpools**	0.15	0.15	0.15	0.15	0.15
15	**Percent Express**	0.60	0.60	0.60	0.60	0.60
16	**Capacity**	2,000	2,000	2,000	2,000	2,000
17	**Max % New Carpools**	100	100	100	100	100
18	**Bus Occupancy**	30.00	30.00	30.00	30.00	30.00
19	**Carpool Occupancy**	2.20	2.20	2.20	2.20	2.20
20	**GP Occupancy**	1.05	1.05	1.05	1.05	1.05
21	**GP Truck Percent**	0.03	0.03	0.03	0.03	0.03
22	Number of Lanes Inputs:					
23	**General Purpose**	10	10	10	8	8
24	**Express**	0	0	0	0	0
25	**HOV**	2	2	2	2	0
26	Ridership Equation:					
27	**Intercept**	(4.02)	(4.02)	(4.02)	(4.02)	(4.02)
28	**Coeff. DDHV/Lane**	0.010460	0.010460	0.010460	0.010460	0.010460
29						
30	Outputs:					
31	Critical Lane Volumes Outputs:					
32	General Purpose	2,379	1,898	1,709	2,432	1,801
33	Express	0	0	0	0	0
34	HOV	2,000	1,663	1,447	1,360	0
35	New Bus Passengers	0	68	139	196	196
36	General Purpose Auto	2,284	1,821	1,639	2,334	1,743
37	General Purpose Truck	95	77	70	98	58
38						
39	General Outputs:					
40	Vehicles	15,895	12,818	11,439	12,448	7,204
41	Persons	21,290	17,347	15,468	16,405	9,325
42	Occupancy	1.34	1.35	1.35	1.32	1.29
43	Veh Distance of Travel	30,996	85,877	36,720	27,884	2,449
44	Person Distance of Travel	41,516	116,227	49,653	36,746	3,170

A	A	B	C	D	E	F
47	Calculations:	Alt:	8			
48	Sections	1	2	3	4	5
49	Capacity per Direction:					
50	General Purpose	10,000	10,000	10,000	8,000	8,000
51	Express	0	0	0	0	0
52	HOV	4,000	4,000	4,000	4,000	0
53						
54	Freeway DHV	15,870	12,873	11,710	13,119	7,700
55	HOV DHV (Demand)	3,297	2,712	2,315	2,146	563
56						
57	Expected Carpools	2,500	2,033	1,830	1,991	1,078
58	New Carpools	796	679	486	154	0
59	Adjusted Frwy DHV	16,666	13,551	12,196	13,274	7,700
60						
61	GP DHV	13,369	10,840	9,881	11,128	6,623
62	Express	10,000	8,131	7,317	7,964	4,620
63	GP Non Express	3,370	2,709	2,563	3,164	2,003
64	CP DHV	3,297	2,712	2,315	2,146	1,078
65						
66	Adjustments:					
67	Adjusted DHV from ADT/Lane vs Ridership Iteration					
68	ADT/Lane	29,301	22,680	20,909	28,063	17,246
69	General Purpose	12,176	10,759	9,734	9,729	7,700
70	HOV	3,866	2,750	2,385	2,720	0
71	New Bus Pass	0	0	0	196	0
72	Express	0	0	0	0	0
73						
74	Adjusted DHV for HOV Capacity					
75	GP	12,176	10,759	9,734	9,729	7,700
76	GP From Express	0	0	0	0	0
77	GP From HOV	0	0	0	0	0
78	GP From Bus	0	0	0	0	0
79	Express	0	0	0	0	0
80	HOV	3,866	2,750	2,385	2,720	0
81	New Bus Pass	0	0	0	196	0
82						
83	Adjusted DHV for General Purpose Congestion					
84	Total DHV	16,042	13,509	12,196	12,448	7,700
85	General Purpose	12,176	10,759	9,881	9,729	7,700
86	Express	0	0	0	0	0
87	HOV	3,866	2,750	2,315	2,720	0
88	% New Carpools	17	1	0	27	0
89	New Bus Pass	0	0	0	196	0
90	% New Bus Pass	0	0	0	19	0
91						
92	Adjusted DHV for Max % New Carpools					
93	Total DHV	16,042	13,509	12,196	12,448	7,700
94	General Purpose	12,176	10,759	9,881	9,729	7,700
95	Express	0	0	0	0	0
96	HOV	3,866	2,750	2,315	2,720	0
97	% New Carpools	17	1	0	27	0
98						
99	Adjusted DHV for Corridor					
100	% New Carpools	9	25	27	0	27
101	% New Bus Pass	19	19	19	0	19
102	New Carpools	313	687	620	0	288
103	New Bus Pass	0	68	139	0	196
104	New Carpools	0	0	0	574	0
105	New Bus Pass	0	0	0	196	0
106	Added Carpools	313	574	574	0	288
107	Added Bus Pass	0	68	139	0	196
108	Total DHV	15700	12818	11439	12448	7204
109	General Purpose	11521	9491	8545	9729	6909
110	Express	0	0	0	0	0
111	HOV	4179	3327	2894	2720	295
112	Total DHV	15895	12818	11439	12448	7204
113	General Purpose	11895	9491	8545	9729	7204
114	Express	0	0	0	0	0
115	HOV	4000	3327	2894	2720	0

A	A	B	C	D	E	F	G
118	Iterations:	Alt:	8				
119	Sections	1	2	3	4	5	
120	Iteration for Expected Carpools:						
121	Iteration 1						
122	Expected Carpools	2,380	1,931	1,757	1,968	1,155	
123	New Carpools	916	781	559	178	(592)	
124	Freeway DHV	16,786	13,653	12,269	13,297	7,109	
125	Iteration 2						
126	Expected Carpools	2,518	2,048	1,840	1,995	1,066	
127	New Carpools	(137)	(117)	(84)	(27)	89	
128	Freeway DHV	16,648	13,536	12,185	13,270	7,197	
129	Iteration 3						
130	Expected Carpools	2,497	2,030	1,828	1,991	1,080	
131	New Carpools	21	18	13	4	(13)	
132	Freeway DHV	16,669	13,554	12,198	13,274	7,184	
133							
134	Iteration for Adjustment to DHV from ADT/Lane vs Ridership:						
135	Total ADT	311,172	232,989	211,950	237,453	139,375	
136	Daily Riders	29,009	25,284	23,272	22,978	9,055	
137	GP ADT	297,986	222,142	202,689	228,871	137,122	
138	Iteration 1						
139	ADT/Lane	29,799	22,214	20,269	28,609	17,140	
140	HOV/Frwy ADT	0.12	0.09	0.08	0.13	0.06	
141	Daily Riders	35,390	19,588	15,594	28,640	8,070	
142	New Riders	6,381	(5,696)	(7,678)	5,661	(984)	
143	SOV's Removed	6,381	(5,696)	(7,678)	5,661	(984)	
144	GP ADT	291,605	227,838	210,367	223,210	138,106	
145	Iteration 2						
146	ADT/Lane	29,161	22,784	21,037	27,901	17,263	
147	HOV/Frwy ADT	0.12	0.09	0.08	0.12	0.06	
148	Daily Riders	33,640	20,841	17,118	27,018	8,227	
149	New Riders	(1,750)	1,252	1,524	(1,621)	156	
150	SOV's Removed	(1,750)	1,252	1,524	(1,621)	156	
151	GP ADT	293,356	226,586	208,843	224,831	137,950	
152	Iteration 3						
153	ADT/Lane	29,336	22,659	20,884	28,104	17,244	
154	HOV/Frwy ADT	0.12	0.09	0.08	0.12	0.06	
155	Daily Riders	34,115	20,562	16,810	27,478	8,202	
156	New Riders	476	(279)	(308)	460	(25)	
157	SOV's Removed	476	(279)	(308)	460	(25)	
158	GP ADT	292,880	226,864	209,151	224,371	137,975	
159	Iteration 4						
160	ADT/Lane	29,288	22,686	20,915	28,046	17,247	
161	HOV/Frwy ADT	0.12	0.09	0.08	0.12	0.06	
162	Daily Riders	33,986	20,624	16,872	27,347	8,206	
163	New Riders	(130)	62	62	(131)	4	
164	SOV's Removed	(130)	62	62	(131)	4	
165	GP ADT	293,010	226,803	209,089	224,502	137,971	
166	Iteration 5						
167	ADT/Lane	29,301	22,680	20,909	28,063	17,246	
168	HOV/Frwy ADT	0.12	0.09	0.08	0.12	0.06	
169	Daily Riders	34,021	20,610	16,860	27,384	8,205	
170	New Riders	35	(14)	(12)	37	(1)	
171	SOV's Removed	35	(14)	(12)	37	(1)	
172	GP ADT	292,974	226,816	209,101	224,465	137,972	
173	Reference Information						
174	Bus Pass	0	1,421	2,898	4,098	4,098	
175	Expected CP Pass	29,009	23,863	20,374	18,880	4,957	
176	Percent CP	1.00	0.94	0.88	0.82	0.55	
177	Percent Bus	0.00	0.06	0.12	0.18	0.45	
178	CP Passengers	34,021	19,452	14,760	22,501	4,492	
179	Bus Passengers	0	1,158	2,100	4,884	3,713	
180	Pk Hr CP Pass	8,505	4,863	3,690	5,625	1,123	
181	Pk Hr Bus Pass	0	290	525	1,221	928	
182	Pk Hr CP	3,866	2,210	1,677	2,557	510	
183							

COST ESTIMATION SPREADSHEET

The Cost Estimation spreadsheet is the second spreadsheet used as part of the "Dallas Freeway/HOV System Planning Study" report, to aid system-wide planning. This spreadsheet uses the outputs from the Design Hour Volume (DHV) spreadsheet to obtain the cost of construction and congestion for each section of several alternative configurations of a freeway corridor.

The Cost Estimation spreadsheet is designed to allow the user to estimate input parameters, for each section of corridor, to arrive at the total cost for each alternative. There are three worksheets in the Cost Estimation spreadsheet (worksheet A, B, and C). The inputs and outputs to the Cost Estimation spreadsheet are contained in worksheet A, and the fuel consumption calculations can be found in worksheet B. Worksheet C contains the fuel consumption factors for Dallas Fort Worth. The user only needs to input values into worksheet A, and read the results from worksheet A, though the factors in worksheet C can be replaced if better factors are available.

The following procedure identifies the inputs to the Cost Estimation spreadsheet. Before inputting values into this spreadsheet, the user should have completed the DHV spreadsheet. It should be noted that the cell references made in the following instructions, correspond to columns and rows of worksheet A which is shown on the first page of the example cost estimation spreadsheet. The shaded cells indicate cells in which input values are necessary or may be changed.

- **Enter the system of units to be used in the spreadsheet in Cell E5.** The system of units should be entered as US for U.S. Customary Units or SI for the International System of units.

- **Enter the corridor name in Cell C7.** The corridor name should correspond with Row 3 of the DHV spreadsheet.

- **Enter the cost ($) per hour of person time (Cell B9), the cost ($) per hour of truck time in congestion (Cell B10), and the cost ($) of fuel per volume (Cell B11).** The default values for these parameters are: $11.31 per hour of person time, $60.00 per hour of truck time, and $1.05 per gallon ($0.28 per liter) for fuel.

- **Describe the alternative in Column B.** Each block of values corresponds to an alternative being studied; therefore, a different description should be used in Column B for each block. This entry should identify the alternative being tested (ie. 6 GP lanes & 1 HOV lane) and be the same as Row 4 of the Design Hour Volume Spreadsheet.

- **Record the endpoint markers of all the continuous sections along the corridor in Column C.** Each section denotes major changes in traffic volume, number of lanes, or other vehicle movement influencing factors. Each section should be entered as a separate row in Column C, and should correspond to the section limits in Row 6 of the DHV spreadsheet. The number of sections in a corridor is unlimited; however, the number of rows will have to be increased to the specified number of sections in the corridor, by inserting the needed number of blank rows and copying the preceding row in the block multiple times. This step will need to be repeated for each alternative. As well as for each corresponding alternative in worksheet B. The endpoint marker information will be automatically duplicated in each consecutive alternative as well as for the corresponding alternatives in worksheet B. None of the equations should need to be changed if sections are added for each alternative.

- **Develop and input sectional information (Columns D to O):**

Column D	Length AtGrd - Length of freeway section at grade.
Column E	Length Elev - Length of freeway section elevated. The sum of Column D and Column E, for each section, should be the total length of the section.
Column F	Existing Lanes - Number of lanes in the existing section.

- **Proposed Lanes: Columns G through K refer to the proposed alternative.**

Column G	General Purpose - Number of proposed general purpose lanes.
Column H	Express AtGrd - Proposed number of express lanes at grade.
Column I	Express Elev - Number of proposed elevated express lanes.
Column J	HOV AtGrd - Number of proposed HOV lanes at grade.
Column K	HOV Elev - Proposed number of elevated HOV lanes.

- **Critical Lane Volume: Columns L through N.** The critical lane volume is the number of vehicles in the peak direction during the peak hour of the day.

Column L	GP - Critical lane volume of the general purpose lanes. This value is taken from the output (Row 32) of the DHV spreadsheet.
Column M	Exp - Critical lane volume of the express lanes. The critical lane volume of the express lanes is taken from the DHV spreadsheet output (Row 33).
Column N	HOV-Critical lane of the HOV lanes. This value is taken from the output of the DHV spreadsheet (Row 34).
Column O	Transit Riders-The number (persons) of transit riders. The transit riders are calculated from two values from the DHV spreadsheet, the Bus Person ADT (Row 11) and the New Bus Pass (New Bus Passengers) (Row 35). **Transit Riders is equal to (Bus Person ADT)/4 + New Bus Pass.**
Column R	O&M Cost ($M)-Operating and Maintenance cost (millions of dollars). This parameter needs to be entered **only one time per alternative,** the default values are listed below. Basic directional freeway lanes $0.10

Reversible freeway/express lanes	$0.35
Reversible HOV lanes	$0.45

- **Truck Volumes: Column AN.** Enter the section truck volume (Row 37) from the DHV spreadsheet output.

- **ROW calculations: Columns AV through AX.** The minimum right of way needed for each alternative and its cost is estimated.

Column AV	Base ROW (units of width in feet or meters) - the average width of the existing ROW for each section of the freeway corridor.
Column AW	Existing F.R. Lanes - the existing number of frontage road lanes for each section of the freeway corridor. This spreadsheet only calculates the cost of new frontage roads where the frontage road currently exists and where additional ROW is needed. If no additional ROW is needed it is assumed that the frontage roads are not relocated or reconstructed.
Column AX	ROW Cost $/Area (sq feet or sq meters) - The average cost in dollars per area for additional ROW for each section of the freeway corridor.

- **Construction Costs: Columns BI through BN.** The at-grade construction costs per unit of distance are located in Columns BI through BK, and the elevated structure construction costs per unit of distance are located in Columns BL through BN. The default values can be used, so these values do not have to be changed.

Column BI	GP ($M) - At-grade construction cost (million $) of a general purpose lane per unit of distance per lane. The default value is $2.5 million per mile ($4.0 million per km) per lane.
Column BJ	Exp ($M) - Construction cost (million $) per unit of distance per lane of at-grade express lane. The default value is $3 million per mile ($4.8 million per km) per lane for one or two at-grade express lanes, and $3.33 million per mile ($5.36 million per km) per lane for three or more at grade express lanes.
Column BK	HOV ($M) - Construction cost (million $) per lane per unit of distance of at-grade HOV lane. The default value is $5 million per mile ($8.0 million per km) per lane for one at-grade express lane, and $3.5 million per mile ($5.6 million per km) per lane for two or more at-grade HOV lanes.
Column BL	GP ($M) - Construction cost (million $) per unit of distance per lane of elevated general purpose lane. The default value is $3.5 million per mile ($5.6 million per km) per lane.
Column BM	Exp ($M) - Construction cost (million $) per unit of distance per lane of elevated express lane. The default value is $4.5 million per mile ($7.2 million per km) per lane for one or two elevated express lanes, and $5 million per mile ($8.0 million per km) per lane for three or more elevated

express lanes.

Column BN HOV ($M) - Construction cost (million $) per unit of distance per lane of elevated HOV lane. The default value is $7 million per mile ($11.3 million per km) per lane for one elevated HOV lane, and $5 million per mile ($8.0 million per km) per lane for two or more elevated HOV lanes.

- **Rehabilitation Cost:** The last block of values in the spreadsheet (Row 127) gives the cost to rebuild or rehabilitate the existing freeway. This block is identified by 'X' in Column A and 'Rehabilitation Cost' in Column B. Zero lanes are input in Column F and the existing number of lanes are input in the proposed General Purpose lane column - Column G. There are no volumes to input in this alternative block. The cost estimated for this alternative is the construction cost that is common to each alternative.

The spreadsheet will perform all the calculations, when prompted by pressing the function key F9, necessary to estimate the total cost for each alternative. It is important for the user to determine the reasonableness of the output from the spreadsheet.

Description of Output Variables

The outputs of the Cost Estimation spreadsheet can be divided into two sections: total cost output and fuel consumption and emissions output. The total cost (Column X) is the sum of construction cost (Column P), right-of-way cost (Column Q), Operation and Maintenance cost (Column R), peak hour general purpose congestion cost (Column S), total general purpose congestion cost (Column T), transit congestion cost (Column U), and fuel consumption cost (Column V).

The fuel consumption calculations are located in worksheet B which is shown on the second page of the example Cost Estimation spreadsheet. The cell references in this section correspond to columns that can be found in worksheet B. The fuel consumption output is for the peak period peak direction of flow, and includes the following in addition to the section, lane and volume inputs from worksheet A:

Column O Fuel consumption - Volume of fuel consumption per day

Column P Energy - Cost ($) of fuel consumption per day

Summary

The Cost Estimation spreadsheet, described in the preceding section, allows the user to compare alternatives for a freeway corridor, based upon total cost, and fuel consumption. This spreadsheet can be modified from the original format to allow the user to base the alternative comparisons on additional parameters; however, caution must be employed when altering the spreadsheet from its current form such that the existing cell references are preserved.

Cost Estimation Spreadsheet Worksheet A

Input the system of units SI or US US

Corridor Name: Example

2400 Vehicles per Hour - Ultimate Capacity
$11.31 1995 Value of Person Time
$60.00 1995 Value of Truck Time
$1.05 Gallon of Fuel

Year 2015
26-Apr-96

Alternative	Section	Length Miles AtGrd	Length Miles Elev	Existing Lanes	Proposed Lanes General Purpose	Proposed Lanes Express AtGrd	Proposed Lanes Express Elev	Proposed Lanes HOV AtGrd	Proposed Lanes HOV Elev	Critical Lane Volume GP	Critical Lane Volume Exp	Critical Lane Volume HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Congstn Cost ($ M)	Total Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
1 No Action	A - B	2.00	0.10	6	8	0	0	0	0	3500	0	0	0	$0.07	$0.00	$0.10	$1.68	$12.02	$0.00	$1.80	$13.99
	B - C	4.00	0.20	6	6	0	0	0	0	3000	0	0	300	$0.13	$0.00	$0.00	$3.64	$12.24	$0.25	$2.95	$15.57
	C - D	3.00	0.30	6	6	0	0	0	0	3000	0	0	600	$0.11	$0.00	$0.00	$2.69	$9.05	$0.39	$2.32	$11.86
	D - E	2.00	0.50	6	6	0	0	0	0	4000	0	0	1000	$0.08	$0.00	$0.00	$2.07	$16.91	$0.49	$2.15	$19.63
	E - F	2.00	0.10	6	6	0	0	0	0	3500	0	0	1000	$0.07	$0.00	$0.00	$1.86	$13.33	$0.42	$1.80	$15.62
	F - G	2.00	0.10	6	6	0	0	0	0	3000	0	0	1250	$0.07	$0.00	$0.00	$1.82	$6.12	$0.52	$1.47	$8.18
	G - H	2.00	0.10	6	6	0	0	0	0	2500	0	0	900	$0.07	$0.00	$0.00	$1.81	$2.00	$0.20	$1.14	$3.41
	H - I	0.00	0.60	6	6	0	0	0	0	2000	0	0	750	$0.02	$0.00	$0.00	$0.02	$0.02	$0.00	$0.22	$0.25
		18.9											Subtota	$0.60	$0.00	$0.10	$15.58	$71.69	$2.27	$13.86	$88.52
															$0.70			$73.96			

Alternative	Section	Length Miles AtGrd	Length Miles Elev	Existing Lanes	Proposed Lanes General Purpose	Proposed Lanes Express AtGrd	Proposed Lanes Express Elev	Proposed Lanes HOV AtGrd	Proposed Lanes HOV Elev	Critical Lane Volume GP	Critical Lane Volume Exp	Critical Lane Volume HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Gen Purp Congstn Cost ($ M)	Total Gen Purp Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
2 All Gen Purp	A - B	2.00	0.10	6	12	0	0	0	0	1750	0	0	0	$2.12	$0.00	$0.10	$0.00	$0.00	$0.00	$1.62	$3.85
	B - C	4.00	0.20	6	10	0	0	0	0	1800	0	0	300	$2.87	$0.00	$0.00	$0.00	$0.00	$0.00	$2.79	$5.66
	C - D	3.00	0.30	6	10	0	0	0	0	1800	0	0	600	$2.29	$0.00	$0.00	$0.00	$0.00	$0.00	$2.19	$4.48
	D - E	2.00	0.50	6	12	0	0	0	0	2000	0	0	1000	$5.07	$0.41	$0.00	$0.19	$0.19	$0.01	$2.17	$7.85
	E - F	2.00	0.10	6	12	0	0	0	0	1750	0	0	1000	$4.14	$0.40	$0.00	$0.00	$0.00	$0.00	$1.62	$6.16
	F - G	2.00	0.10	6	10	0	0	0	0	1800	0	0	1250	$3.45	$1.28	$0.00	$0.00	$0.00	$0.00	$1.39	$6.12
	G - H	2.00	0.10	6	8	0	0	0	0	1875	0	0	900	$2.10	$0.14	$0.00	$0.02	$0.02	$0.00	$1.15	$3.41
	H - I	0.00	0.50	6	6	0	0	0	0	2000	0	0	750	$0.02	$0.00	$0.00	$0.02	$0.02	$0.00	$0.22	$0.25
		18.9											Subtota	$22.07	$2.23	$0.10	$0.22	$0.22	$0.02	$13.15	$37.78
															$24.40			$0.23			

Alternative	Section	Length Miles AtGrd	Length Miles Elev	Existing Lanes	Proposed Lanes General Purpose	Proposed Lanes Express AtGrd	Proposed Lanes Express Elev	Proposed Lanes HOV AtGrd	Proposed Lanes HOV Elev	Critical Lane Volume GP	Critical Lane Volume Exp	Critical Lane Volume HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Gen Purp Congstn Cost ($ M)	Total Gen Purp Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
3 Gen Purp & Express	A - B	2.00	0.10	6	8	2	0	0	0	1625	2000	0	0	$1.58	$0.00	$0.35	$0.04	$0.04	$0.00	$1.45	$3.42
	B - C	4.00	0.20	6	6	2	0	0	0	1667	2000	0	300	$1.79	$0.00	$0.00	$0.08	$0.08	$0.00	$2.46	$4.32
	C - D	3.00	0.30	6	6	2	0	0	0	1667	2000	0	600	$1.43	$0.00	$0.00	$0.06	$0.06	$0.00	$1.93	$3.43
	D - E	2.00	0.50	6	8	0	2	0	0	2000	2000	0	1000	$2.38	$0.00	$0.00	$0.17	$0.17	$0.01	$2.07	$4.64
	E - F	2.00	0.10	6	8	0	2	0	0	1625	2000	0	1000	$1.96	$0.00	$0.00	$0.04	$0.04	$0.00	$1.45	$3.45
	F - G	2.00	0.10	6	6	0	2	0	0	1667	2000	0	1250	$1.28	$0.00	$0.00	$0.04	$0.04	$0.00	$1.23	$2.55
	G - H	2.00	0.10	6	8	0	0	0	0	1875	0	0	900	$2.10	$0.14	$0.00	$0.02	$0.02	$0.00	$1.15	$3.41
	H - I	0.00	0.50	6	6	0	0	0	0	2000	0	0	750	$0.02	$0.00	$0.00	$0.02	$0.02	$0.00	$0.22	$0.25
		18.9											Subtota	$12.53	$0.14	$0.35	$0.46	$0.46	$0.02	$11.96	$25.47
															$13.02			$0.48			

A	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
62	Corridor Name:		Example																				
63																							Pg. 2/4
64																							Year 2015
65																							26-Apr-96
66																			Pk Hour	Total			
67							Proposed Lanes												Gen Purp	Gen Purp	Transit	Fuel	
68				Length											Transit	Constrctn	R.O.W.	O&M	Congstn	Congstn	Congstn	Consmptn	Total
69				Miles		Existing	General	Express		HOV		Critical Lane Volume			Riders	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost
70		Alternative	Section	AtGrd	Elev	Lanes	Purpose	AtGrd	Elev	AtGrd	Elev	GP	Exp	HOV	Persons	($ M)	($ M)	($ M)	($ M)	($ M)	($M)	($M)	($ M)
71	4	Gen Purp &	A - B	2.00	0.10	6	8	0	0	1	0	2075	0	1000	0	$1.44	$0.00	$0.45	$0.15	$0.15	$0.00	$1.39	$3.42
72		HOV 2+	B - C	4.00	0.20	6	6	0	0	1	0	1900	0	1500	300	$1.50	$0.00	$0.00	$0.05	$0.05	$0.00	$2.13	$3.69
73			C - D	3.00	0.30	6	6	0	0	2	0	1533	0	1000	600	$1.72	$0.00	$0.00	$0.00	$0.00	$0.00	$1.46	$3.18
74			D - E	2.00	0.50	6	6	0	0	0	2	1800	0	1500	1000	$1.68	$0.00	$0.00	$0.00	$0.00	$0.00	$1.44	$3.12
75			E - F	2.00	0.10	6	6	0	0	0	2	2033	0	1000	1000	$1.41	$0.00	$0.00	$0.10	$0.10	$0.00	$1.19	$2.71
76			F - G	2.00	0.10	6	6	0	0	1	0	1650	0	1800	1250	$2.10	$0.13	$0.00	$0.00	$0.00	$0.00	$0.99	$3.22
77			G - H	2.00	0.10	6	6	0	0	1	0	1680	0	1000	900	$2.10	$0.14	$0.00	$0.00	$0.00	$0.00	$0.90	$3.14
78			H - I	0.00	0.50	6	6	0	0	0	0	1900	0	0	750	$0.02	$0.00	$0.00	$0.01	$0.01	$0.00	$0.21	$0.23
79				18.9											Subtota	$11.96	$0.27	$0.45	$0.31	$0.31	$0.00	$9.71	$22.70
80																	$12.68			$0.31			
81																							
82																							
83																			Pk Hour	Total			
84							Proposed Lanes												Gen Purp	Gen Purp	Transit	Fuel	
85				Length											Transit	Constrctn	R.O.W.	O&M	Congstn	Congstn	Congstn	Consmptn	Total
86				Miles		Existing	General	Express		HOV		Critical Lane Volume			Riders	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost
87		Alternative	Section	AtGrd	Elev	Lanes	Purpose	AtGrd	Elev	AtGrd	Elev	GP	Exp	HOV	Persons	($ M)	($ M)	($ M)	($ M)	($ M)	($M)	($M)	($ M)
88	5	Gen Purp	A - B	2.00	0.10	6	6	0	2	1	0	2000	2000	500	0	$1.96	$0.00	$0.45	$0.11	$0.11	$0.00	$1.50	$4.02
89		Express &	B - C	4.00	0.20	6	6	0	2	1	0	1500	2000	500	300	$3.92	$0.00	$0.00	$0.08	$0.08	$0.00	$2.34	$6.35
90		HOV 2+	C - D	3.00	0.30	6	6	0	2	1	0	1500	2000	600	600	$3.10	$0.00	$0.00	$0.06	$0.06	$0.00	$1.84	$5.01
91			D - E	2.00	0.50	6	8	0	2	1	0	1800	2000	800	1000	$5.65	$0.30	$0.00	$0.05	$0.05	$0.00	$2.02	$8.01
92			E - F	2.00	0.10	6	6	0	2	1	0	2000	2000	500	1000	$1.96	$0.00	$0.00	$0.12	$0.12	$0.00	$1.50	$3.59
93			F - G	2.00	0.10	6	6	0	2	1	0	1500	2000	500	1250	$3.98	$1.15	$0.00	$0.04	$0.04	$0.00	$1.17	$6.34
94			G - H	2.00	0.10	6	8	0	0	1	0	1750	0	500	900	$3.45	$1.42	$0.00	$0.00	$0.00	$0.00	$1.14	$6.02
95			H - I	0.00	0.50	6	6	0	0	0	0	2000	0	0	750	$0.02	$0.00	$0.00	$0.02	$0.02	$0.00	$0.22	$0.25
96				18.9											Subtota	$24.05	$2.86	$0.45	$0.48	$0.48	$0.00	$11.74	$39.58
97																	$27.36			$0.48			
98																							
99																							
100																			Pk Hour	Total			
101							Proposed Lanes												Gen Purp	Gen Purp	Transit	Fuel	
102				Length											Transit	Constrctn	R.O.W.	O&M	Congstn	Congstn	Congstn	Consmptn	Total
103				Miles		Existing	General	Express		HOV		Critical Lane Volume			Riders	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost
104		Alternative	Section	AtGrd	Elev	Lanes	Purpose	AtGrd	Elev	AtGrd	Elev	GP	Exp	HOV	Persons	($ M)	($ M)	($ M)	($ M)	($ M)	($M)	($M)	($ M)
105	6	Gen Purp &	A - B	2.00	0.10	6	8	0	0	1	0	2025	0	800	0	$1.44	$0.00	$0.45	$0.11	$0.11	$0.00	$1.33	$3.33
106		HOV 3+	B - C	4.00	0.20	6	6	0	0	1	0	2200	0	800	300	$1.50	$0.00	$0.00	$0.39	$0.39	$0.00	$2.22	$4.11
107			C - D	3.00	0.30	6	6	0	0	1	0	2200	0	800	600	$1.20	$0.00	$0.00	$0.28	$0.28	$0.00	$1.74	$3.22
108			D - E	2.00	0.50	6	8	0	0	1	0	2100	0	1200	1000	$1.81	$0.00	$0.00	$0.22	$0.22	$0.00	$1.70	$3.73
109			E - F	2.00	0.10	6	8	0	0	1	0	1875	0	1000	1000	$1.44	$0.00	$0.00	$0.02	$0.02	$0.00	$1.28	$2.74
110			F - G	2.00	0.10	6	6	0	0	1	0	2200	0	800	1260	$2.10	$0.13	$0.00	$0.19	$0.19	$0.00	$1.11	$3.53
111			G - H	2.00	0.10	6	6	0	0	1	0	2000	0	600	900	$2.10	$0.14	$0.00	$0.07	$0.07	$0.00	$0.98	$3.29
112			H - I	0.00	0.50	6	8	0	0	0	0	2000	0	0	750	$0.02	$0.00	$0.00	$0.02	$0.02	$0.00	$0.22	$0.25
113				18.9											Subtota	$11.60	$0.27	$0.45	$1.30	$1.30	$0.00	$10.58	$24.19
114																	$12.32			$1.30			
115																							

Cost Estimation Spreadsheet

Worksheet B

Corridor Name: Example

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Year 2015
26-Apr-96

Propsed Lanes

Alternative	Section	Length Miles AtGrd	Elev	Existing Lanes	General Purpose	Express AtGrd	Elev	HOV AtGrd	Elev	Critical Lane Volume GP	Exp	HOV	Fuel Consumptio Gallons/day	Energy $/day
1 No Action	A - B	2	0.1	6	6	0	0	0	0	3500	0	0	6875.66	7219.45
	B - C	4	0.2	6	6	0	0	0	0	3000	0	0	11230.97	11792.51
	C - D	3	0.3	6	6	0	0	0	0	3000	0	0	8824.33	9265.55
	D - E	2	0.5	6	6	0	0	0	0	4000	0	0	8185.31	8594.58
	E - F	2	0.1	6	6	0	0	0	0	3500	0	0	6875.66	7219.45
	F - G	2	0.1	6	6	0	0	0	0	3000	0	0	5615.48	5896.26
	G - H	2	0.1	6	6	0	0	0	0	2500	0	0	4353.01	4570.66
	H - I	0	0.5	6	6	0	0	0	0	2000	0	0	824.93	866.18
		18.9										Total:	52785.36	55424.62

Propsed Lanes

Alternative	Section	Length Miles AtGrd	Elev	Existing Lanes	General Purpose	Express AtGrd	Elev	HOV AtGrd	Elev	Critical Lane Volume GP	Exp	HOV	Fuel Consumptio Gallons/day	Energy $/day
2 All Gen Purp	A - B	2	0.1	6	12	0	0	0	0	1750	0	0	6188.91	6498.35
	B - C	4	0.2	6	10	0	0	0	0	1800	0	0	10609.56	11140.04
	C - D	3	0.3	6	10	0	0	0	0	1800	0	0	8336.08	8752.88
	D - E	2	0.5	6	12	0	0	0	0	2000	0	0	8249.31	8661.78
	E - F	2	0.1	6	12	0	0	0	0	1750	0	0	6188.91	6498.35
	F - G	2	0.1	6	10	0	0	0	0	1800	0	0	5304.78	5570.02
	G - H	2	0.1	6	8	0	0	0	0	1875	0	0	4393.84	4613.53
	H - I	0	0.5	6	6	0	0	0	0	2000	0	0	824.93	866.18
		18.9										Total:	50096.3168	52601.13

Propsed Lanes

Alternative	Section	Length Miles AtGrd	Elev	Existing Lanes	General Purpose	Express AtGrd	Elev	HOV AtGrd	Elev	Critical Lane Volume GP	Exp	HOV	Fuel Consumptio Gallons/day	Energy $/day
3 Gen Purp &	A - B	2	0.1	6	8	2	0	0	0	1625	2000	0	5534.95	5811.70
Express	B - C	4	0.2	6	6	2	0	0	0	1667	2000	0	9368.51	9836.94
	C - D	3	0.3	6	6	2	0	0	0	1667	2000	0	7360.97	7729.02
	D - E	2	0.5	6	8	0	2	0	0	2000	2000	0	7876.91	8270.75
	E - F	2	0.1	6	8	0	2	0	0	1625	2000	0	5534.95	5811.70
	F - G	2	0.1	6	6	0	2	0	0	1667	2000	0	4684.26	4918.47
	G - H	2	0.1	6	8	0	0	0	0	1875	0	0	4393.84	4613.53
	H - I	0	0.5	6	6	0	0	0	0	2000	0	0	824.93	866.18
		18.9										Total:	45579.3197	47858.29

Corridor Name: Example

Propsed Lanes

Alternative	Section	Length Miles AtGrd	Elev	Existing Lanes	General Purpose	Express AtGrd	Elev	HOV AtGrd	Elev	Critical Lane Volume GP	Exp	HOV	Fuel Consumption Gallons/day	Energy $/day
4 Gen Purp &	A - B	2	0.1	6	8	0	0	1	0	2075	0	1000	5280.98	5545.03
HOV 2+	B - C	4	0.2	6	6	0	0	1	0	1900	0	1500	8133.26	8539.92
	C - D	3	0.3	6	6	0	0	2	0	1533	0	1000	5579.46	5858.43
	D - E	2	0.5	6	6	0	0	0	2	1800	0	1500	5475.24	5749.01
	E - F	2	0.1	6	6	0	0	0	2	2033	0	1000	4547.97	4775.37
	F - G	2	0.1	6	6	0	0	1	0	1680	0	1800	3778.25	3967.16
	G - H	2	0.1	6	6	0	0	1	0	1680	0	1000	3419.33	3590.29
	H - I	0	0.5	6	6	0	0	0	0	1900	0	0	792.65	832.28
		18.9										Total:	37007.1322	38857.49

Propsed Lanes

Alternative	Section	Length Miles AtGrd	Elev	Existing Lanes	General Purpose	Express AtGrd	Elev	HOV AtGrd	Elev	Critical Lane Volume GP	Exp	HOV	Fuel Consumption Gallons/day	Energy $/day
5 Gen Purp,	A - B	2	0.1	6	6	0	2	1	0	2000	2000	500	5717.31	6003.17
Express &	B - C	4	0.2	6	6	0	2	1	0	1500	2000	500	8930.17	9376.68
HOV 2+	C - D	3	0.3	6	6	0	2	1	0	1500	2000	500	7016.56	7367.39
	D - E	2	0.5	6	8	0	2	1	0	1800	2000	800	7692.97	8077.62
	E - F	2	0.1	6	6	0	2	1	0	2000	2000	500	5717.31	6003.17
	F - G	2	0.1	6	6	0	2	1	0	1500	2000	500	4465.08	4688.34
	G - H	2	0.1	6	8	0	0	1	0	1750	0	500	4357.11	4574.96
	H - I	0	0.5	6	6	0	0	0	0	2000	0	0	824.93	866.18
		18.9										Total:	44721.4323	46957.50

Propsed Lanes

Alternative	Section	Length Miles AtGrd	Elev	Existing Lanes	General Purpose	Express AtGrd	Elev	HOV AtGrd	Elev	Critical Lane Volume GP	Exp	HOV	Fuel Consumption Gallons/day	Energy $/day
6 Gen Purp &	A - B	2	0.1	6	8	0	0	1	0	2025	0	800	5077.96	5331.86
HOV 3+	B - C	4	0.2	6	6	0	0	1	0	2200	0	800	8444.73	8866.96
	C - D	3	0.3	6	6	0	0	1	0	2200	0	800	6635.14	6966.90
	D - E	2	0.5	6	8	0	0	1	0	2100	0	1200	6487.56	6811.94
	E - F	2	0.1	6	8	0	0	1	0	1875	0	1000	4880.62	5124.65
	F - G	2	0.1	6	6	0	0	1	0	2200	0	800	4222.36	4433.48
	G - H	2	0.1	6	6	0	0	1	0	2000	0	500	3720.32	3906.33
	H - I	0	0.5	6	6	0	0	0	0	2000	0	0	824.93	866.18
		18.9										Total:	40293.6205	42308.30

APPENDIX C: Spreadsheet Outputs for Validation Corridor

Cost Estimation Spreadsheet

Worksheet A

Input the system of units SI or US US

Year 2015
19-Oct-95

Corridor Name: Validation Corridor
2400 Vehicles per Hour - Ultimate Capacity
$11.31 1995 Value of Person Time
$60.00 1995 Value of Truck Time
$1.05 Gallon of Fuel

Alternative	Section	Length Miles AtGrd	Length Miles Elev	Existing Lanes	Proposed Lanes: General Purpose	Proposed Lanes: Express AtGrd	Proposed Lanes: Express Elev	Proposed Lanes: HOV AtGrd	Proposed Lanes: HOV Elev	Critical Lane Volume GP	Critical Lane Volume Exp	Critical Lane Volume HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Congstn Cost ($ M)	Total Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
1 No Action	A - B	1.75	0.20	6	6	0	0	0	0	5555	0	0	0	$0.06	$0.00	$0.10	$1.56	$17.71	$0.00	$1.68	$19.55
	B - C	6.39	0.31	6	6	0	0	0	0	4517	0	0	355	$0.21	$0.00	$0.00	$5.36	$49.48	$0.47	$5.76	$55.92
	C - D	2.95	0.26	6	6	0	0	0	0	4063	0	0	725	$0.10	$0.00	$0.00	$2.57	$21.35	$0.46	$2.76	$24.67
	D - E	1.90	0.34	6	6	0	0	0	0	4425	0	0	1025	$0.07	$0.00	$0.00	$1.80	$16.27	$0.45	$1.93	$18.72
	E - F	0.00	0.34	6	6	0	0	0	0	2567	0	0	1025	$0.01	$0.00	$0.00	$0.27	$0.32	$0.04	$0.19	$0.56
		14.44											Subtotal	$0.46	$0.00	$0.10	$11.57	$105.13	$1.42	$12.31	$119.43
															$0.56			$106.56			

Alternative	Section	Length Miles AtGrd	Length Miles Elev	Existing Lanes	Proposed Lanes: General Purpose	Proposed Lanes: Express AtGrd	Proposed Lanes: Express Elev	Proposed Lanes: HOV AtGrd	Proposed Lanes: HOV Elev	Critical Lane Volume GP	Critical Lane Volume Exp	Critical Lane Volume HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Gen Purp Congstn Cost ($ M)	Total Gen Purp Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
2 All General Purpose	A - B	1.75	0.20	6	18	0	0	0	0	1852	0	0	0	$3.96	$0.82	$0.10	$0.00	$0.00	$0.00	$2.39	$7.27
	B - C	6.39	0.31	6	16	0	0	0	0	1694	0	0	365	$11.13	$1.47	$0.00	$0.00	$0.00	$0.00	$6.69	$19.30
	C - D	2.95	0.26	6	14	0	0	0	0	1742	0	0	725	$4.35	$0.05	$0.00	$0.00	$0.00	$0.00	$2.88	$7.28
	D - E	1.90	0.34	6	18	0	0	0	0	1659	0	0	1025	$3.87	$1.82	$0.00	$0.00	$0.00	$0.00	$2.19	$7.88
	E - F	0.00	0.34	6	10	0	0	0	0	1540	0	0	1025	$0.32	$0.00	$0.00	$0.00	$0.00	$0.00	$0.19	$0.51
		14.44											Subtotal	$23.63	$4.17	$0.10	$0.00	$0.00	$0.00	$14.34	$42.24
															$27.90			$0.00			

Alternative	Section	Length Miles AtGrd	Length Miles Elev	Existing Lanes	Proposed Lanes: General Purpose	Proposed Lanes: Express AtGrd	Proposed Lanes: Express Elev	Proposed Lanes: HOV AtGrd	Proposed Lanes: HOV Elev	Critical Lane Volume GP	Critical Lane Volume Exp	Critical Lane Volume HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Gen Purp Congstn Cost ($ M)	Total Gen Purp Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
3 Gen Purp & HOV 2+	A - B	1.75	0.20	6	10	0	0	1	0	2973	0	1800	0	$2.01	$0.00	$0.45	$2.63	$8.38	$0.00	$2.58	$13.43
	B - C	6.39	0.31	6	10	0	0	1	0	2338	0	1800	423	$6.77	$0.00	$0.00	$6.39	$6.48	$0.00	$6.55	$19.80
	C - D	2.95	0.26	6	8	0	0	1	0	2568	0	1800	864	$2.22	$0.00	$0.00	$3.50	$4.07	$0.00	$2.83	$9.13
	D - E	1.90	0.34	6	8	0	0	1	0	2827	0	1800	1190	$1.59	$0.45	$0.00	$2.45	$7.38	$0.00	$2.35	$11.78
	E - F	0.00	0.34	6	8	0	0	0	0	1887	0	0	1190	$0.16	$0.00	$0.00	$0.00	$0.00	$0.00	$0.19	$0.36
		14.44											Subtotal	$12.76	$0.45	$0.45	$14.97	$26.31	$0.00	$14.51	$54.49
															$13.66			$26.32			

Corridor Name: Validation Corridor

Year 2015
19-Oct-95

Alternative	Section	Length Miles AtGrd	Elev	Existing Lanes	Proposed Lanes: General Purpose	Express AtGrd	Express Elev	HOV AtGrd	HOV Elev	Critical Lane Volume GP	Exp	HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Gen Purp Congstn Cost ($ M)	Total Gen Purp Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
4 Gen Purp & HOV 2+	A - B	1.75	0.20	6	12	0	0	1	0	2478	0	1800	0	$2.66	$0.03	$0.45	$3.16	$3.45	$0.00	$2.38	$8.97
	B - C	6.39	0.31	6	10	0	0	1	0	2338	0	1800	423	$6.77	$0.00	$0.00	$6.39	$6.48	$0.00	$6.55	$19.80
	C - D	2.95	0.26	6	8	0	0	1	0	2668	0	1800	864	$2.22	$0.00	$0.00	$3.50	$4.07	$0.00	$2.83	$9.13
	D - E	1.90	0.34	6	8	0	0	1	0	2827	0	1800	1190	$1.59	$0.45	$0.00	$2.45	$7.38	$0.00	$2.35	$11.78
	E - F	0.00	0.34	6	8	0	0	0	0	1887	0	0	1190	$0.16	$0.00	$0.00	$0.00	$0.00	$0.00	$0.19	$0.36
		14.44											Subtotal	$13.41	$0.49	$0.45	$15.50	$21.38	$0.00	$14.31	$50.03
															$14.34			$21.38			

Alternative	Section	Length Miles AtGrd	Elev	Existing Lanes	Proposed Lanes: General Purpose	Express AtGrd	Express Elev	HOV AtGrd	HOV Elev	Critical Lane Volume GP	Exp	HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Gen Purp Congstn Cost ($ M)	Total Gen Purp Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
5 Gen Purp & Express	A - B	1.75	0.20	6	12	0	3	0	0	1852	1852	0	0	$3.88	$0.00	$0.35	$0.00	$0.00	$0.00	$2.24	$6.48
	B - C	6.39	0.31	6	10	0	3	0	0	1694	1694	0	355	$11.02	$0.00	$0.00	$0.00	$0.00	$0.00	$6.10	$17.12
	C - D	2.95	0.26	6	10	0	2	0	0	1742	1742	0	725	$4.07	$0.00	$0.00	$0.00	$0.00	$0.00	$2.70	$6.78
	D - E	1.90	0.34	6	10	0	2	0	0	1896	1896	0	1025	$2.88	$0.83	$0.00	$0.05	$0.05	$0.00	$2.07	$5.84
	E - F	0.00	0.34	6	10	0	0	0	0	1540	0	0	1025	$0.32	$0.00	$0.00	$0.00	$0.00	$0.00	$0.19	$0.51
		14.44											Subtotal	$22.17	$0.83	$0.35	$0.05	$0.05	$0.00	$13.31	$36.72
															$23.35			$0.05			

Alternative	Section	Length Miles AtGrd	Elev	Existing Lanes	Proposed Lanes: General Purpose	Express AtGrd	Express Elev	HOV AtGrd	HOV Elev	Critical Lane Volume GP	Exp	HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Gen Purp Congstn Cost ($ M)	Total Gen Purp Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
6 Gen Purp & Express	A - B	1.75	0.20	6	12	0	3	0	0	1852	1852	0	0	$3.88	$0.00	$0.35	$0.00	$0.00	$0.00	$2.24	$6.48
	B - C	6.39	0.31	6	10	0	2	0	0	1936	1936	0	355	$8.44	$0.00	$0.00	$0.28	$0.28	$0.01	$6.31	$15.04
	C - D	2.95	0.26	6	10	0	2	0	0	1742	1742	0	725	$4.07	$0.00	$0.00	$0.00	$0.00	$0.00	$2.70	$6.78
	D - E	1.90	0.34	6	10	0	2	0	0	1896	1896	0	1025	$2.88	$0.83	$0.00	$0.05	$0.05	$0.00	$2.07	$5.84
	E - F	0.00	0.34	6	8	0	0	0	0	1925	0	0	1025	$0.16	$0.00	$0.00	$0.01	$0.01	$0.00	$0.19	$0.36
		14.44											Subtotal	$19.45	$0.83	$0.35	$0.33	$0.33	$0.01	$13.52	$34.50
															$20.63			$0.34			

Cost Estimation Spreadsheet — Worksheet A

Input the system of units SI or US US

Corridor Name: Validation Corridor
2400 Vehicles per Hour - Ultimate Capacity
$11.31 1995 Value of Person Time
$60.00 1995 Value of Truck Time
$1.05 Gallon of Fuel

Year 2015
19-Oct-95

		Length Miles			Proposed Lanes															
Alternative	Section	AtGrd	Elev	Existing Lanes	General Purpose	Express AtGrd	Express Elev	HOV AtGrd	HOV Elev	Critical Lane Volume GP	Exp	HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Congstn Cost ($ M)	Total Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
7 Gen. Purp. & HOV 2+	A - B	1.75	0.20	6	12	0	0	2	0	2184	0	1712	0	$2.97	$0.30	$0.45	$0.31	$0.31	$0.00	$2.29	$6.32
	B - C	6.39	0.31	6	10	0	0	2	0	2100	0	1436	355	$7.72	$0.00	$0.00	$0.64	$0.64	$0.00	$6.31	$14.68
	C - D	2.95	0.26	6	10	0	0	2	0	1923	0	1221	725	$3.78	$0.00	$0.00	$0.08	$0.08	$0.00	$2.73	$6.59
	D - E	1.90	0.34	6	10	0	0	2	0	2172	0	1136	1025	$2.75	$1.21	$0.00	$0.28	$0.28	$0.00	$2.09	$6.33
	E - F	0.00	0.34	6	8	0	0	0	0	1908	0	0	1025	$0.16	$0.00	$0.00	$0.01	$0.01	$0.00	$0.19	$0.36
		14.44											Subtotal	$17.39	$1.51	$0.45	$1.32	$1.32	$0.00	$13.61	$34.28
															$19.35			$1.32			

		Length Miles			Proposed Lanes															
Alternative	Section	AtGrd	Elev	Existing Lanes	General Purpose	Express AtGrd	Express Elev	HOV AtGrd	HOV Elev	Critical Lane Volume GP	Exp	HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Gen Purp Congstn Cost ($ M)	Total Gen Purp Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
8 Gen. Purp. & HOV 2+	A - B	1.75	0.20	6	10	0	0	2	0	2379	0	2000	0	$2.33	$0.00	$0.45	$2.47	$2.54	$0.00	$2.26	$7.58
	B - C	6.39	0.31	6	10	0	0	2	0	1898	0	1653	423	$7.72	$0.00	$0.00	$0.11	$0.11	$0.00	$6.01	$13.85
	C - D	2.95	0.26	6	10	0	0	2	0	1709	0	1447	864	$3.78	$0.00	$0.00	$0.00	$0.00	$0.00	$2.55	$6.33
	D - E	1.90	0.34	6	8	0	0	2	0	2432	0	1360	1221	$1.99	$0.76	$0.00	$2.50	$2.64	$0.00	$2.06	$7.45
	E - F	0.00	0.34	6	8	0	0	0	0	1801	0	0	1221	$0.16	$0.00	$0.00	$0.00	$0.00	$0.00	$0.18	$0.34
		14.44											Subtotal	$15.98	$0.76	$0.45	$5.08	$5.30	$0.00	$13.07	$35.55
															$17.19			$5.30			

		Length Miles			Proposed Lanes															
Alternative	Section	AtGrd	Elev	Existing Lanes	General Purpose	Express AtGrd	Express Elev	HOV AtGrd	HOV Elev	Critical Lane Volume GP	Exp	HOV	Transit Riders Persons	Constrctn Cost ($ M)	R.O.W. Cost ($ M)	O&M Cost ($ M)	Pk Hour Gen Purp Congstn Cost ($ M)	Total Gen Purp Congstn Cost ($ M)	Transit Congstn Cost ($M)	Fuel Consmptn Cost ($M)	Total Cost ($ M)
9 Gen. Purp. & HOV 2+	A - B	1.75	0.20	6	12	0	0	2	0	2028	0	1935	0	$2.97	$0.30	$0.45	$0.18	$0.18	$0.00	$2.19	$6.09
	B - C	6.39	0.31	6	10	0	0	2	0	1898	0	1663	423	$7.72	$0.00	$0.00	$0.11	$0.11	$0.00	$6.01	$13.85
	C - D	2.95	0.26	6	8	0	0	2	0	2113	0	1470	864	$2.72	$0.00	$0.00	$0.26	$0.26	$0.00	$2.57	$5.55
	D - E	1.90	0.34	6	8	0	0	2	0	2432	0	1360	1221	$1.99	$0.76	$0.00	$2.50	$2.64	$0.00	$2.06	$7.45
	E - F	0.00	0.34	6	8	0	0	0	0	1801	0	0	1221	$0.16	$0.00	$0.00	$0.00	$0.00	$0.00	$0.18	$0.34
		14.44											Subtotal	$15.57	$1.05	$0.45	$3.05	$3.19	$0.00	$13.02	$33.28
															$17.07			$3.19			

19-Oct-95

Design Year:	2015				
Freeway:	Validation Corridor				
Alternative:	1	No Action			
Freeway Section:	1	2	3	4	5
Section Limits:	A-B	B-C	C-D	D-E	E-F

Section Inputs:

Length (miles)	1.95	6.70	3.21	2.24	0.34
Freeway ADT	311,172	232,989	211,950	237,453	139,375
HOV ADT	13,186	10,847	9,261	8,582	2,253
Bus Person ADT	0	1,421	2,898	4,098	4,098
K	0.085	0.085	0.085	0.085	0.085
D	0.60	0.65	0.65	0.65	0.65
Percent Carpools	0.15	0.15	0.15	0.15	0.15
Percent Express	0.60	0.60	0.60	0.60	0.60
Capacity	2,000	2,000	2,000	2,000	2,000
Max % New Carpools	100	100	100	100	100
Bus Occupancy	30.00	30.00	30.00	30.00	30.00
Carpool Occupancy	2.20	2.20	2.20	2.20	2.20
GP Occupancy	1.05	1.05	1.05	1.05	1.05
GP Truck Percent	0.03	0.03	0.03	0.03	0.03

Number of Lanes Inputs:

General Purpose	6	6	6	6	6
Express	0	0	0	0	0
HOV	0	0	0	0	0

Ridership Equation:

Intercept	(4.02)	(4.02)	(4.02)	(4.02)	(4.02)
Coeff. DDHV/Lane	0.010460	0.010460	0.010460	0.010460	0.010460

Outputs:

Critical Lane Volumes Outputs:

General Purpose	5,555	4,517	4,065	4,425	2,567
Express	0	0	0	0	0
HOV	0	0	0	0	0
New Bus Passengers	0	0	0	0	0
General Purpose Auto	5,397	4,388	3,948	4,293	2,490
General Purpose Truck	159	129	117	131	77

General Outputs:

Vehicles	16,666	13,551	12,196	13,274	7,700
Persons	21,290	17,347	15,468	16,405	9,325
Occupancy	1.28	1.28	1.27	1.24	1.21
Veh Distance of Travel	32,499	90,794	39,149	29,733	2,618
Person Distance of Travel	41,516	116,227	49,653	36,746	3,170

19-Oct-95

Design Year:	2015				
Freeway:	Validation Corridor				
Alternative:	2	All General Purpose			
Freeway Section:	1	2	3	4	5
Section Limits:	A-B	B-C	C-D	D-E	E-F

Section Inputs:

Length (miles)	1.95	6.70	3.21	2.24	0.34
Freeway ADT	311,172	232,989	211,950	237,453	139,375
HOV ADT	13,186	10,847	9,261	8,582	2,253
Bus Person ADT	0	1,421	2,898	4,098	4,098
K	0.085	0.085	0.085	0.085	0.085
D	0.60	0.65	0.65	0.65	0.65
Percent Carpools	0.15	0.15	0.15	0.15	0.15
Percent Express	0.60	0.60	0.60	0.60	0.60
Capacity	2,000	2,000	2,000	2,000	2,000
Max % New Carpools	100	100	100	100	100
Bus Occupancy	30.00	30.00	30.00	30.00	30.00
Carpool Occupancy	2.20	2.20	2.20	2.20	2.20
GP Occupancy	1.05	1.05	1.05	1.05	1.05
GP Truck Percent	0.03	0.03	0.03	0.03	0.03

Number of Lanes Inputs:

General Purpose	18	16	14	16	10
Express	0	0	0	0	0
HOV	0	0	0	0	0

Ridership Equation:

Intercept	(4.02)	(4.02)	(4.02)	(4.02)	(4.02)
Coeff. DDHV/Lane	0.010460	0.010460	0.010460	0.010460	0.010460

Outputs:

Critical Lane Volumes Outputs:					
General Purpose	1,852	1,694	1,742	1,659	1,540
Express	0	0	0	0	0
HOV	0	0	0	0	0
New Bus Passengers	0	0	0	0	0
General Purpose Auto	1,799	1,646	1,692	1,610	1,494
General Purpose Truck	53	48	50	49	46

General Outputs:					
Vehicles	16,666	13,551	12,196	13,274	7,700
Persons	21,290	17,347	15,468	16,405	9,325
Occupancy	1.28	1.28	1.27	1.24	1.21
Veh Distance of Travel	32,499	90,794	39,149	29,733	2,618
Person Distance of Travel	41,516	116,227	49,653	36,746	3,170

19-Oct-95

Design Year:	2015				
Freeway:	Validation Corridor				
Alternative:	3	General Purpose and HOV 2+			
Freeway Section:	1	2	3	4	5
Section Limits:	A-B	B-C	C-D	D-E	E-F

Section Inputs:

Length (miles)	1.95	6.70	3.21	2.24	0.34
Freeway ADT	311,172	232,989	211,950	237,453	139,375
HOV ADT	13,186	10,847	9,261	8,582	2,253
Bus Person ADT	0	1,421	2,898	4,098	4,098
K	0.085	0.085	0.085	0.085	0.085
D	0.60	0.65	0.65	0.65	0.65
Percent Carpools	0.15	0.15	0.15	0.15	0.15
Percent Express	0.60	0.60	0.60	0.60	0.60
Capacity	2,000	2,000	2,000	2,000	2,000
Max % New Carpools	100	100	100	100	100
Bus Occupancy	30.00	30.00	30.00	30.00	30.00
Carpool Occupancy	2.20	2.20	2.20	2.20	2.20
GP Occupancy	1.05	1.05	1.05	1.05	1.05
GP Truck Percent	0.03	0.03	0.03	0.03	0.03

Number of Lanes Inputs:

General Purpose	10	10	8	8	8
Express	0	0	0	0	0
HOV	1	1	1	1	0

Ridership Equation:

Intercept	(4.02)	(4.02)	(4.02)	(4.02)	(4.02)
Coeff. DDHV/Lane	0.010460	0.010460	0.010460	0.010460	0.010460

Outputs:

Critical Lane Volumes Outputs:

General Purpose	2,973	2,338	2,568	2,827	1,887
Express	0	0	0	0	0
HOV	1,800	1,800	1,800	1,800	0
New Bus Passengers	0	68	139	165	165
General Purpose Auto	2,878	2,261	2,480	2,729	1,829
General Purpose Truck	95	77	88	98	58

General Outputs:

Vehicles	16,666	13,491	12,073	13,109	7,549
Persons	21,290	17,347	15,468	16,405	9,325
Occupancy	1.28	1.29	1.28	1.25	1.24
Veh Distance of Travel	32,499	90,391	38,755	29,364	2,567
Person Distance of Travel	41,516	116,227	49,653	36,746	3,170

19-Oct-95

Design Year:	2015				
Freeway:	Validation Corridor				
Alternative:	4	General Purpose and HOV 2+			
Freeway Section:	1	2	3	4	5
Section Limits:	A-B	B-C	C-D	D-E	E-F

Section Inputs:

Length (miles)	1.95	6.70	3.21	2.24	0.34
Freeway ADT	311,172	232,989	211,950	237,453	139,375
HOV ADT	13,186	10,847	9,261	8,582	2,253
Bus Person ADT	0	1,421	2,898	4,098	4,098
K	0.085	0.085	0.085	0.085	0.085
D	0.60	0.65	0.65	0.65	0.65
Percent Carpools	0.15	0.15	0.15	0.15	0.15
Percent Express	0.60	0.60	0.60	0.60	0.60
Capacity	2,000	2,000	2,000	2,000	2,000
Max % New Carpools	100	100	100	100	100
Bus Occupancy	30.00	30.00	30.00	30.00	30.00
Carpool Occupancy	2.20	2.20	2.20	2.20	2.20
GP Occupancy	1.05	1.05	1.05	1.05	1.05
GP Truck Percent	0.03	0.03	0.03	0.03	0.03

Number of Lanes Inputs:

General Purpose	12	10	8	8	8
Express	0	0	0	0	0
HOV	1	1	1	1	0

Ridership Equation:

Intercept	(4.02)	(4.02)	(4.02)	(4.02)	(4.02)
Coeff. DDHV/Lane	0.010460	0.010460	0.010460	0.010460	0.010460

Outputs:

Critical Lane Volumes Outputs:					
General Purpose	2,478	2,338	2,568	2,827	1,887
Express	0	0	0	0	0
HOV	1,800	1,800	1,800	1,800	0
New Bus Passengers	0	68	139	165	165
General Purpose Auto	2,398	2,261	2,480	2,729	1,829
General Purpose Truck	79	77	88	98	58
General Outputs:					
Vehicles	16,666	13,491	12,073	13,109	7,549
Persons	21,290	17,347	15,468	16,405	9,325
Occupancy	1.28	1.29	1.28	1.25	1.24
Veh Distance of Travel	32,499	90,391	38,755	29,364	2,567
Person Distance of Travel	41,516	116,227	49,653	36,746	3,170

19-Oct-95

Design Year:	2015				
Freeway:	Example				
Alternative:	5	General Purpose and Express			
Freeway Section:	1	2	3	4	5
Section Limits:	A-B	B-C	C-D	D-E	E-F

Section Inputs:

Length (miles)	1.95	6.70	3.21	2.24	0.34
Freeway ADT	311,172	232,989	211,950	237,453	139,375
HOV ADT	13,186	10,847	9,261	8,582	2,253
Bus Person ADT	0	1,421	2,898	4,098	4,098
K	0.085	0.085	0.085	0.085	0.085
D	0.60	0.65	0.65	0.65	0.65
Percent Carpools	0.15	0.15	0.15	0.15	0.15
Percent Express	0.60	0.60	0.60	0.60	0.60
Capacity	2,000	2,000	2,000	2,000	2,000
Max % New Carpools	100	100	100	100	100
Bus Occupancy	30.00	30.00	30.00	30.00	30.00
Carpool Occupancy	2.20	2.20	2.20	2.20	2.20
GP Occupancy	1.05	1.05	1.05	1.05	1.05
GP Truck Percent	0.03	0.03	0.03	0.03	0.03

Number of Lanes Inputs:

General Purpose	12	10	10	10	10
Express	3	3	2	2	0
HOV	0	0	0	0	0

Ridership Equation:

Intercept	(4.02)	(4.02)	(4.02)	(4.02)	(4.02)
Coeff. DDHV/Lane	0.010460	0.010460	0.010460	0.010460	0.010460

Outputs:

Critical Lane Volumes Outputs:

General Purpose	1,852	1,694	1,742	1,896	1,540
Express	1,852	1,694	1,742	1,896	0
HOV	0	0	0	0	0
New Bus Passengers	0	0	0	0	0
General Purpose Auto	1,772	1,617	1,672	1,818	1,494
General Purpose Truck	79	77	70	79	46

General Outputs:

Vehicles	16,666	13,551	12,196	13,274	7,700
Persons	21,290	17,347	15,468	16,405	9,325
Occupancy	1.28	1.28	1.27	1.24	1.21
Veh Distance of Travel	32,499	90,794	39,149	29,733	2,618
Person Distance of Travel	41,516	116,227	49,653	36,746	3,170

19-Oct-95

Design Year:	2015				
Freeway:	Example				
Alternative:	6	General Purpose and Express			
Freeway Section:	1	2	3	4	5
Section Limits:	A-B	B-C	C-D	D-E	E-F

Section Inputs:

Length (miles)	1.95	6.70	3.21	2.24	0.34
Freeway ADT	311,172	232,989	211,950	237,453	139,375
HOV ADT	13,186	10,847	9,261	8,582	2,253
Bus Person ADT	0	1,421	2,898	4,098	4,098
K	0.085	0.085	0.085	0.085	0.085
D	0.60	0.65	0.65	0.65	0.65
Percent Carpools	0.15	0.15	0.15	0.15	0.15
Percent Express	0.60	0.60	0.60	0.60	0.60
Capacity	2,000	2,000	2,000	2,000	2,000
Max % New Carpools	100	100	100	100	100
Bus Occupancy	30.00	30.00	30.00	30.00	30.00
Carpool Occupancy	2.20	2.20	2.20	2.20	2.20
GP Occupancy	1.05	1.05	1.05	1.05	1.05
GP Truck Percent	0.03	0.03	0.03	0.03	0.03

Number of Lanes Inputs:

General Purpose	12	10	10	10	8
Express	3	2	2	2	0
HOV	0	0	0	0	0

Ridership Equation:

Intercept	(4.02)	(4.02)	(4.02)	(4.02)	(4.02)
Coeff. DDHV/Lane	0.010460	0.010460	0.010460	0.010460	0.010460

Outputs:

Critical Lane Volumes Outputs:					
General Purpose	1,852	1,936	1,742	1,896	1,925
Express	1,852	1,936	1,742	1,896	0
HOV	0	0	0	0	0
New Bus Passengers	0	0	0	0	0
General Purpose Auto	1,772	1,859	1,672	1,818	1,867
General Purpose Truck	79	77	70	79	58
General Outputs:					
Vehicles	16,666	13,551	12,196	13,274	7,700
Persons	21,290	17,347	15,468	16,405	9,325
Occupancy	1.28	1.28	1.27	1.24	1.21
Veh Distance of Travel	32,499	90,794	39,149	29,733	2,618
Person Distance of Travel	41,516	116,227	49,653	36,746	3,170

19-Oct-95

Design Year:	2015				
Freeway:	Validation Corridor				
Alternative:	7	General Purpose and HOV 2+			
Freeway Section:	1	2	3	4	5
Section Limits:	A-B	B-C	C-D	D-E	E-F

Section Inputs:

Length (miles)	1.95	6.70	3.21	2.24	0.34
Freeway ADT	311,172	232,989	211,950	237,453	139,375
HOV ADT	13,186	10,847	9,261	8,582	2,253
Bus Person ADT	0	1,421	2,898	4,098	4,098
K	0.085	0.085	0.085	0.085	0.085
D	0.60	0.65	0.65	0.65	0.65
Percent Carpools	0.15	0.15	0.15	0.15	0.15
Percent Express	0.60	0.60	0.60	0.60	0.60
Capacity	2,000	2,000	2,000	2,000	2,000
Max % New Carpools	100	100	100	100	100
Bus Occupancy	30.00	30.00	30.00	30.00	30.00
Carpool Occupancy	2.20	2.20	2.20	2.20	2.20
GP Occupancy	1.05	1.05	1.05	1.05	1.05
GP Truck Percent	0.03	0.03	0.03	0.03	0.03

Number of Lanes Inputs:

General Purpose	12	10	10	10	8
Express	0	0	0	0	0
HOV	2	2	2	2	0

Ridership Equation:

Intercept	(4.02)	(4.02)	(4.02)	(4.02)	(4.02)
Coeff. DDHV/Lane	0.010460	0.010460	0.010460	0.010460	0.010460

Outputs:

Critical Lane Volumes Outputs:					
General Purpose	2,184	2,100	1,923	2,172	1,908
Express	0	0	0	0	0
HOV	1,712	1,436	1,221	1,136	0
New Bus Passengers	0	0	0	0	0
General Purpose Auto	2,104	2,023	1,852	2,094	1,850
General Purpose Truck	79	77	70	79	58

General Outputs:					
Vehicles	16,526	13,375	12,056	13,134	7,630
Persons	21,290	17,347	15,468	16,405	9,325
Occupancy	1.29	1.30	1.28	1.25	1.22
Veh Distance of Travel	32,227	89,613	38,701	29,421	2,594
Person Distance of Travel	41,516	116,227	49,653	36,746	3,170

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Design Year:	2015				
Freeway:	Validation Corridor				
Alternative:	8	General Purpose and HOV 2+			
Freeway Section:	1	2	3	4	5
Section Limits:	A-B	B-C	C-D	D-E	E-F

Section Inputs:

Length (miles)	1.95	6.70	3.21	2.24	0.34
Freeway ADT	311,172	232,989	211,950	237,453	139,375
HOV ADT	13,186	10,847	9,261	8,582	2,253
Bus Person ADT	0	1,421	2,898	4,098	4,098
K	0.085	0.085	0.085	0.085	0.085
D	0.60	0.65	0.65	0.65	0.65
Percent Carpools	0.15	0.15	0.15	0.15	0.15
Percent Express	0.60	0.60	0.60	0.60	0.60
Capacity	2,000	2,000	2,000	2,000	2,000
Max % New Carpools	100	100	100	100	100
Bus Occupancy	30.00	30.00	30.00	30.00	30.00
Carpool Occupancy	2.20	2.20	2.20	2.20	2.20
GP Occupancy	1.05	1.05	1.05	1.05	1.05
GP Truck Percent	0.03	0.03	0.03	0.03	0.03

Number of Lanes Inputs:

General Purpose	10	10	10	8	8
Express	0	0	0	0	0
HOV	2	2	2	2	0

Ridership Equation:

Intercept	(4.02)	(4.02)	(4.02)	(4.02)	(4.02)
Coeff. DDHV/Lane	0.010460	0.010460	0.010460	0.010460	0.010460

Outputs:

Critical Lane Volumes Outputs:					
General Purpose	2,379	1,898	1,709	2,432	1,801
Express	0	0	0	0	0
HOV	2,000	1,663	1,447	1,360	0
New Bus Passengers	0	68	139	196	196
General Purpose Auto	2,284	1,821	1,639	2,334	1,743
General Purpose Truck	95	77	70	98	58
General Outputs:					
Vehicles	15,895	12,818	11,439	12,448	7,204
Persons	21,290	17,347	15,468	16,405	9,325
Occupancy	1.34	1.35	1.35	1.32	1.29
Veh Distance of Travel	30,996	85,877	36,720	27,884	2,449
Person Distance of Travel	41,516	116,227	49,653	36,746	3,170

19-Oct-95

Design Year:	2015				
Freeway:	Example				
Alternative:	9	General Purpose and HOV 2+			
Freeway Section:	1	2	3	4	5
Section Limits:	A-B	B-C	C-D	D-E	E-F

Section Inputs:

Length (miles)	1.95	6.70	3.21	2.24	0.34
Freeway ADT	311,172	232,989	211,950	237,453	139,375
HOV ADT	13,186	10,847	9,261	8,582	2,253
Bus Person ADT	0	1,421	2,898	4,098	4,098
K	0.085	0.085	0.085	0.085	0.085
D	0.60	0.65	0.65	0.65	0.65
Percent Carpools	0.15	0.15	0.15	0.15	0.15
Percent Express	0.60	0.60	0.60	0.60	0.60
Capacity	2,000	2,000	2,000	2,000	2,000
Max % New Carpools	100	100	100	100	100
Bus Occupancy	30.00	30.00	30.00	30.00	30.00
Carpool Occupancy	2.20	2.20	2.20	2.20	2.20
GP Occupancy	1.05	1.05	1.05	1.05	1.05
GP Truck Percent	0.03	0.03	0.03	0.03	0.03

Number of Lanes Inputs:

General Purpose	12	10	8	8	8
Express	0	0	0	0	0
HOV	2	2	2	2	0

Ridership Equation:

Intercept	(4.02)	(4.02)	(4.02)	(4.02)	(4.02)
Coeff. DDHV/Lane	0.010460	0.010460	0.010460	0.010460	0.010460

Outputs:

Critical Lane Volumes Outputs:

General Purpose	2,028	1,898	2,113	2,432	1,801
Express	0	0	0	0	0
HOV	1,935	1,663	1,470	1,360	0
New Bus Passengers	0	68	139	196	196
General Purpose Auto	1,948	1,821	2,025	2,334	1,743
General Purpose Truck	79	77	88	98	58

General Outputs:

Vehicles	16,037	12,818	11,390	12,448	7,204
Persons	21,290	17,347	15,468	16,405	9,325
Occupancy	1.33	1.35	1.36	1.32	1.29
Veh Distance of Travel	31,272	85,877	36,560	27,884	2,449
Person Distance of Travel	41,516	116,227	49,653	36,746	3,170