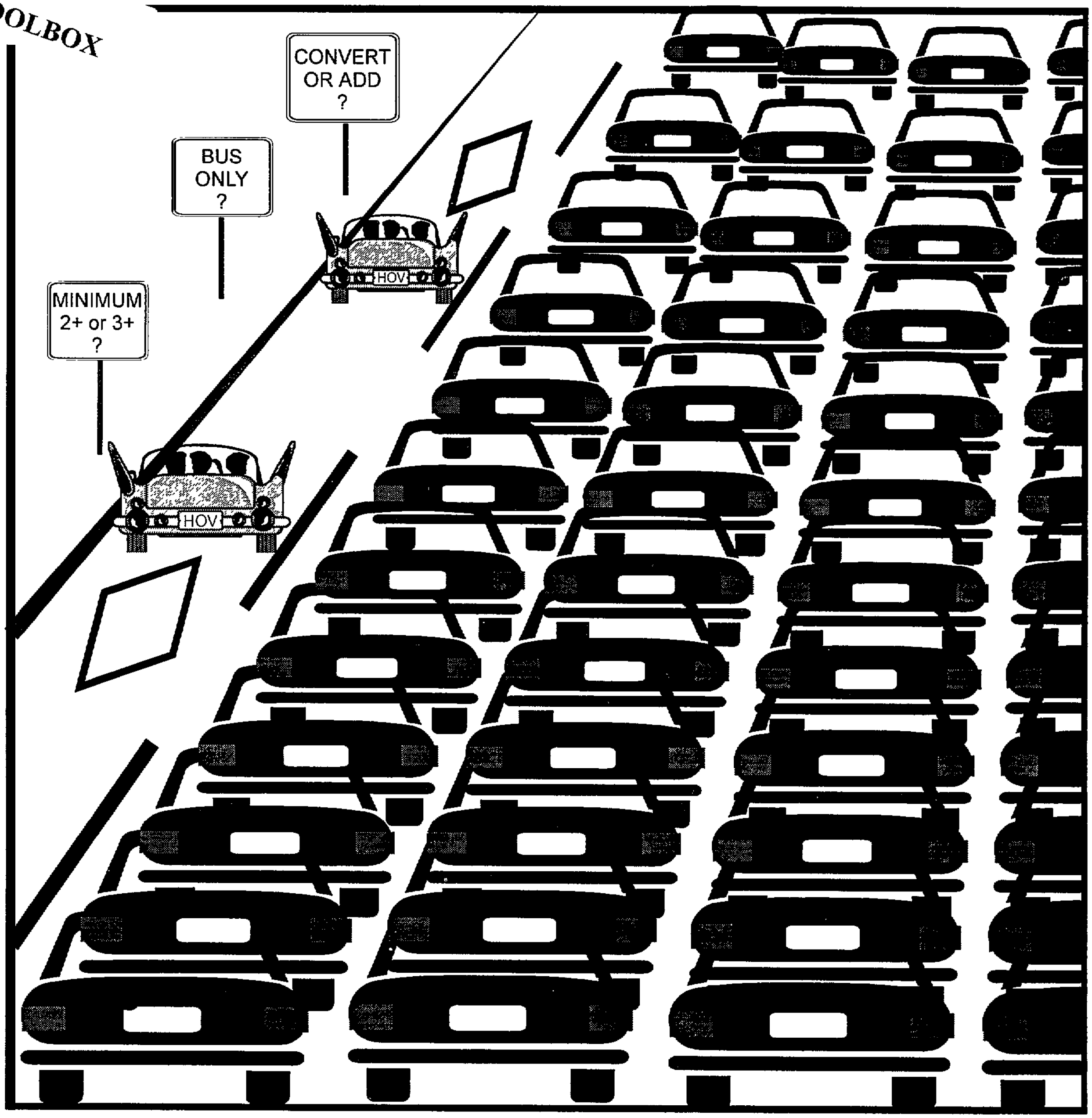
U.S. Department
of Transportation
Federal Highway Administration

Predicting High Occupancy Vehicle Lane Demand

Final Report



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Foreword

The Federal Highway Administration Project #42-10-4172, "Predicting the Demand for High Occupancy Vehicle (HOV) Lanes" is a two year effort to develop a methodology and micro-computer software model for quickly analyzing HOV lane demand and operations.

This document, the Final Report, presents the results of this project.

Notice

Predicting the Demand for High Occupancy Vehicle Lanes

Acknowledgments

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2. Caltrans, Districts 7 and 11, Los Angeles and San Diego, California;
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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd ❑ 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2 = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2 = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (Lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp ❑ 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] ^{o}F ❑ y ^{o}C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliters (ml) ❑ 0.03 fluid ounce (fl oz)
1 liter (1) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] ^{o}C ❑ x ^{o}F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0		1			2			3		4			5			6		7			8		9		10
CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25 / 25.40

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. Cl3 10286.

Predicting the Demand for High Occupancy Vehicle Lanes

Final Report

Preface

This report presents the results of the literature review and data collection effort for the Federal Highway Administration Project #42-10-4172, "Predicting the Demand for High Occupancy Vehicle (HOV) Lanes". This research project is a two year effort to develop a methodology and micro-computer software model for quickly analyzing HOV lane demand and operations. The methodology is designed to be applied by planners and engineers with limited or no access to or experience with regional travel demand modelling.

The methodology provides a set of "quick response" procedures for predicting and evaluating the impacts of HOV lanes on person demand, vehicle demand, auto occupancy, congestion, delay, and air quality. This methodology is applicable to corridor, network, and system level HOV demand analysis.

The objectives of this project have been to:

1. Identify and document state-of-the-art practices in predicting, analyzing, and evaluating travel demand for HOV lanes.
2. Collect, analyze, and report data relevent to the prediction, analysis, and evaluation of HOV lanes.
3. Formulate a methodology for assessing HOV travel demand on freeway and arterial facilities for use by personnel not experienced in regional travel demand modelling.
4. Develop a computer model with a user's guide to predict and analyze planned and actual HOV travel demand that is consistent with the methodology.

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16. Abstract This report presents the results of the Federal Highway Administration Project #42-10-4172, "Predicting the Demand for High Occupancy Vehicle Lanes". The report provides: A review of the available literature and the experiences of public agencies with current methods for predicting the demand for HOV lanes; the recommended new methodology for predicting the demand for HOV lanes; and The data on existing HOV lane projects in the United States that was used to calibrate and validate the new HOV lane demand estimation methodology.		
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Literature Review and Data Collection Report

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Final Report

EXECUTIVE SUMMARY

Federal Highway Administration Project #42-10-4172, "Predicting the Demand for High Occupancy Vehicle Lanes", is a two year effort to develop a methodology and micro-computer software model for quickly analyzing HOV lane demand and operations. The methodology is designed to be applied by planners and engineers with limited or no access to or experience with regional travel demand modeling.

This report presents the interim results of this project, specifically:

1. A review of the available literature and the experiences of public agencies with current methods for predicting the demand for HOV lanes,
2. The proposed new methodology for predicting the demand for HOV lanes, and
3. The data on existing HOV lane projects in the United States that will be used to calibrate and validate the new HOV lane demand estimation methodology.

E.1 Literature Review

The literature review included technical reports, periodicals, computer models, and software documentation. The review began with a search of the National Technical Information Service (NTIS) and Transportation Research Information System (TRIS) data bases, as well as computerized files of newsletters, journals, business news sources and newspaper articles maintained by Dialog Information Service.

Abstracts of reports and articles identified through the initial search process were reviewed and copies of promising references were obtained. The reference list assembled in this fashion was submitted for the review of the consulting team and members of a Steering Committee of state DOT representatives, MPO members, university researchers, practitioners and federal transportation officials assembled under the supervision of FHWA. This process led to the identification and review of over seventy references listed in the bibliography of this report.

E.l.l Regionwide Logit Models

The most prevalent approach to the regionwide estimation of HOV lane mode shares entails the use of disaggregate logit models embedded in the traditional regional four-step transportation planning process of (1) trip generation; (2) trip distribution; (3) mode split; and (4) traffic assignment. Typically these disaggregate models have been respecified to handle carpool modes as well as transit and solo driving, either simultaneously or sequentially in "nested" formats which separate auto and transit ridership before addressing Carpool mode shares.

Regionwide logit models are mathematically tractable and widely used in regional planning, so that their use is well understood in the planning community. Since the models incorporate a regionwide network, they are particularly useful in representing the network impacts of HOV lanes, such as the diversion of carpool and solo driver trips from parallel routes.

Regionwide network models require extensive data input and model calibration. This can be a cumbersome process when the issue at hand deals with the impact of HOV lanes on a limited number of corridors.

These models also require extensive recalibration from location to location. Recalibration is not only a geographic issue. Model parameters are not stable over time. Thus recalibration is necessary to ensure temporal transferability as well.

Many regionwide logit mode split models have been developed and calibrated to estimate HOV mode split only for home based work trips. Non-work trips are not modelled at all, or are dealt with using an expansion factor.

Traditional regionwide network models have limited ability to estimate the operational impacts of HOV facilities on speed, average delays, and traffic queues. As highway networks become more and more congested, regionwide models are less and less successful in estimating travel times and delays. In particular, they fail to replicate the manner in which congestion queues transmit delays throughout the system. As a result, they are ill-equipped to represent the travel-time advantages provided by HOV lanes that are crucial in influencing shifts to ridesharing modes.

As a practical matter, regionwide logit models have historically not performed well in replicating the impact of HOV facilities on actual mode choices. One investigator observes that ". . in the application of travel demand models, there are frequently considerable discrepancies between HOV model estimates and observed roadway counts of multi-occupant vehicles." Another further cautions that "regional mode-choice models in general, and regional mode-choice models with components in particular, have not performed well in terms of their ability to predict mode shares." In view of the fact that most regional models of HOV use were not originally designed to handle trip-dependent changes in travel time and have been carved out of traditional logit models developed with only two modes (transit and auto) in mind and calibrated to match overall corridor flows, it is hardly surprising that they have not performed well in representing the impact of HOV lanes on mode share.

Although regional logit models are used widely to analyze the network-wide impacts of alternative systems, they do not seem to be flexible enough to focus on the corridor-specific impacts of HOV facilities. Existing regionwide models tend to be data-intensive and require extensive recalibration to accommodate transfers both from location to location and from one time frame to another. They are ill-equipped to represent the operational impacts of HOV lanes on travel times and have historically not performed well in predicting the impact of these lanes on modal shifts.

E.1.2 Corridor Models

Many attempts to model HOV demand have focused on a single corridor, usually ignoring impacts of HOV facilities in the broader regionwide network and sometimes glossing over the interdependencies between mode choice and travel times on HOV facilities and adjacent mixed-flow lanes. While some of these models use the multinomial logit formulation described in connection with regionwide network models, others use quick-response regression relationships in which HOV lane usage is computed as a function of travel time savings or some other measure of congestion.

Corridor models can also differ markedly with respect to their field of vision within the corridor. For example, such models can include parallel routes, limit their field of vision to a single freeway (or arterial), or focus on a single point along a freeway segment.

Corridor models fall generally into two classes of models:

- Demand models, which emphasize the estimation of demand and employ only simplistic approaches to estimating changes in facility operations, and

- Supply models that emphasize the modeling of facility operations and employ only simplistic techniques for estimating changes in demand.

Supply Models: In recent years, a number of macroscopic simulations of freeway conditions have been developed as an aid for studying the detailed impacts of design alternatives on speed, delays, and traffic queues in a specific corridor. Examples of these simulation models include FREQ and FREFLO. These models typically take the demand for access to HOV lanes and mixed flow lanes within a specific time frame as an input variable in simulating the propagation of traffic queues and congestion delays from one section of the freeway to another. Although these models focus on the elaborate delineation of freeway operations data, they can be used iteratively with corridor demand models or with regionwide network models in computing the impact of HOV lanes on mode choices.

Demand Models: The corridor demand models reviewed in this report represent simple, transparent approaches that are easy to understand and apply. Data requirements are minimal, and at least one model, that of Parody, appears to perform well in replicating overall demand measurements on existing HOV lanes.

Even the best of existing corridor models have been calibrated on limited data sets, either because relatively few HOV lanes were in operation at the time they were calibrated, or because the modelers had a narrow focus. The geographic transferability of these models is not well understood, and none are equipped to deal with spatial and temporal shifts in trip making. Those models that are based on regression relationships tie their predictions to a single explanatory variable.

Supply/Demand Interaction: Some corridor models of HOV demand ignore the interaction between mode choice and travel time, accepting the travel time differential between HOV lanes and mixed-flow traffic as a given input variable and using it to compute the demand for carpools in the corridor. Other models treat the interaction between demand and travel time explicitly by iterating between demand model results and travel time models until convergence is obtained.

Simple corridor-based regression models, updated to reflect current HOV lane experience, represent a promising means of predicting the overall number of carpools attracted to a new HOV lane. Some mechanism needs to be found for coupling these models with level-of-service estimates and addressing issues of spatial and temporal diversion in a manner consistent with a quick-response modeling effort.

E.1.3 Agency Survey

A survey of HOV Lane planners and engineers was conducted to assist in the identification of gaps and problems with current methodologies for predicting the demand for and impacts of HOV lanes. Another objective of this survey was to obtain technical staff opinions and input regarding possible approaches for modeling HOV facility demand. In addition, information was collected on the availability of input data for estimating HOV demand. The information obtained through this agency survey was used in the methodology development task of the project.

Personnel at nine agencies were selected for the telephone survey.

HOV Lane Analysis Needs: The analysis needs which tended to be most critical were the ability to analyze the impacts of HOV lanes on: vehicle demand, congestion, person demand, and air quality. Other HOV facility analysis needs which were mentioned were cost, noise, transit usage, mode split and trip distribution.

Methods Currently Employed: The agencies use a variety of methodologies and models for predicting HOV lane demand and evaluating its impacts. Three of the agencies stated that they use sketch planning methodologies (pivot-point). Four agencies use macroscopic simulation models, such as FREQ and TRANSYT-7F. Two agencies use microscopic simulation models, such as FRESIM.

All of the agencies use regional travel demand models for some part of their evaluation of HOV facilities. The regional travel demand models being used by the agencies include TRANPLAN, MINUTP, EMME/2, and UTPS or UTPS-based models. Approximately half of the agencies represented in the survey use some sort of post-processors to refine the estimates produced by the regional models. The post-processors tend to be used to enhance speed and emissions estimates, for operational analysis, or for re-estimating mode choice and distribution.

Experience With Current Methods: The agencies were also asked about their experience using the various existing HOV lane methodologies and models, specifically the level of effort involved and any key advantages or weaknesses. On average, the individuals surveyed have been using the existing methodologies and models for over seven years.

With respect to regional travel demand models, most of the agencies stated that once the model was operational, the level of effort was minimal. However, the network coding and calibration efforts required to get the model running is extremely time consuming, demanding of personnel, and data intensive. According to the agencies surveyed, the macroscopic and microscopic simulation models tended to be fairly data intensive, but necessary to obtain the desired output.

Satisfaction/Dissatisfaction With Current Methods: The agencies identified the following key advantages of the current methodologies and models:

- Corridor Supply Models can be calibrated. They are capable of evaluating operations on the first day and for longer time periods. These models are readily available.
- Regionwide Travel Demand Models (when combined with EPA approved emission models) provide better emissions estimates. Regional models represent the entire length of the trip so that route diversions and mode shifts due to HOV lanes can be more reliably estimated. Regional models are well understood and the agencies have confidence in the results.

The agencies however also pointed out the following major weaknesses of the existing methodologies and models:

- Corridor Supply models, for all the detail with which they model road operations, still lack the flexibility to model certain facility geometrics (start and end of HOV lane, right-side HOV facilities, exclusive on- and off-ramps, grade, expanding or constricting number of lanes, HOV merging, extending or shortening HOV facilities, and general condition changes);
- Corridor models, since they model only a portion of the entire trip, are not reliable for predicting spatial diversion of traffic to other corridors.
- There are no generally available models for predicting temporal shifts in trip making;
- Regional models require extensive network coding, calibration, and data collection They are slow and time consuming to run. Many mode split models contained in regional models evaluate only work trips;
- Only produces HOV trips for those with a time savings of greater than five minutes;
- All models assume 100% of the eligible HOV's will use the HOV lane.

Desired Features of New Method: The agencies identified the following desired features of any new or improved method for evaluating the demand for and impacts of HOV lanes:

1. The model and software should be simple and user friendly. The model outputs should be understandable to a lay person. The software should be able to output schematics, maps, and/or graphs of facility geometrics and model outputs (e.g., queuing, air quality, congestion, and speed/flow).
2. The methodology should be consistent with existing models and methodologies. The methodology however should provide improves route shift, time shift, and mode shift estimation capabilities.
3. The methodology should provide for the analysis of
    - Addition of HOV Lane or the conversion of a mixed flow lane to HOV lane,
    - Changes in eligibility rules (2+ versus 3+),
    - HOV lane access design (limited access versus continuous access),
    - Ramp metering with HOV bypass lanes, and

- Arterial HOV lanes.

Relationship to Regional Models. The agencies were also surveyed on what the relationship should be of a new model to an existing regional travel demand model if a regional travel demand model is available for the project study area. Most of the agencies stated that there should be a link or interface between the two models and that the results should be consistent. Most of the agencies also believed that if a regional model is available for the HOV project study area, the regional model should be used (but not necessarily required) for HOV analysis, especially for significant decisions such as major investment studies.

Data Availability. The agencies were asked to identify the types of input data they might have available for an HOV study. Turning movement counts for arterials, estimates of HOV growth , vehicle occupancy, average speeds, and information on parallel facilities were data types that tended to be more difficult for the agencies to obtain for an HOV lane study.

E.2 Recommended Methodology

The Agency survey indicated that agencies have a full spectrum of analytical needs when evaluating the impacts of HOV lanes. The need to be able to perform sketch planning studies to quickly identify and screen for promising locations for HOV lanes. They need more sophisticated corridor level models to evaluate the designs and operation of the HOV lane facility. They need comprehensive regionwide models to forecast the air quality impacts of the HOV lane project and ensure its conformity with the State Implementation Plan (SIP) for complying with the Federal Clean Air Act and Amendments.

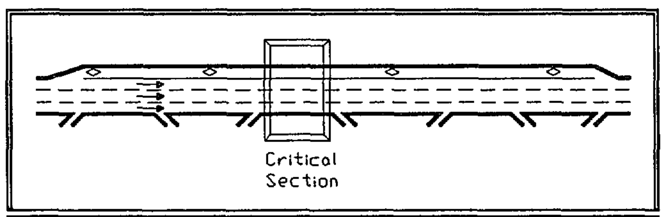
The project team concluded that no single method could hope to accommodate the full spectrum of agency analytical needs. The best way to provide for the full spectrum of analytical needs would be with a multi-level analytical approach. A sketch planning level method would be developed that requires relatively little data and yet can provide approximate answers for delay, congestion, and air quality. However, projects requiring greater detail would have to employ successively more detailed and data intensive methods.

E.2.1 A Multi-Level Analytical Approach

Three distinct levels of HOV analysis are proposed by the team:

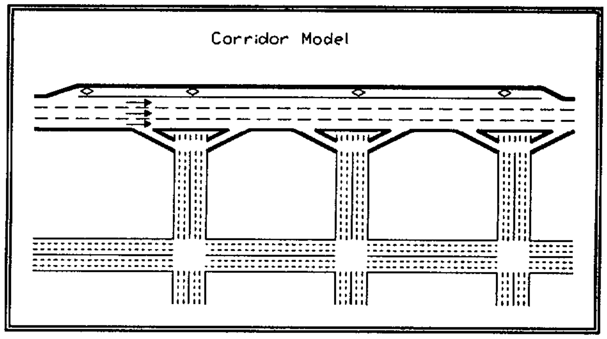
- Level One: The Critical Sub-Section Method;
- Level Two: The Corridor Model Method; and,
- Level Three: The Linked Corridor/Network Travel Demand Model.

The Level One Critical Sub-Section Method would consider only the controlling or critical sub-section of a proposed directional peak period HOV study section. The HOV study section would preferably have a fairly uniform demand and capacity profile over its length. The critical sub-section would be identified by having the highest demand-to-capacity ratio.



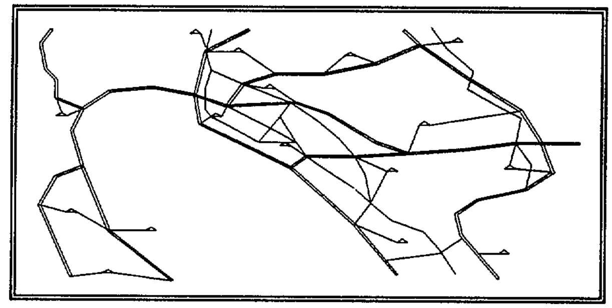
The intent of this approach would be to provide for a quick-response tool for predicting order-of-magnitude HOV and mixed-flow demand and traffic performance, with limited impact estimation capabilities. In this sense, the Critical Sub-Section Model can be considered as a screening tool from which peak-period directional freeway sections could be further investigated at the next level of analysis. This approach can be used to estimate traffic performance and mode shift in the HOV facility opening day, the short-term (e.g. 6 months after opening day), and long-term (e.g. after 7 years of operation).

<u>The Level Two Corridor Model Method</u> would consider the entire directional peak period HOV study section and an appropriate representation of the parallel facilities. Compared to the Critical Sub-Section Model, this model would require additional model input, incorporate a computerized simulation model, and would provide more precise estimates of HOV and mixed-flow demands as well as more accurate and more comprehensive measures of performance. The payoffs for the increased model requirements would include improved travel demand estimation, representation of traffic congestion, more accurate travel speed estimation, and the capability for corridor emissions estimation.



Computer simulation models, such as FREQ and CORFLO, are already available for this corridor modeling approach.

<u>The Level Three Linked Corridor/Network Travel Demand Model Method</u> considers an HOV facility in the context of a transportation network including trip origins and destinations, as well as many alternative routes. This model system also takes into account other transportation modes that might be competing with the HOV facility.



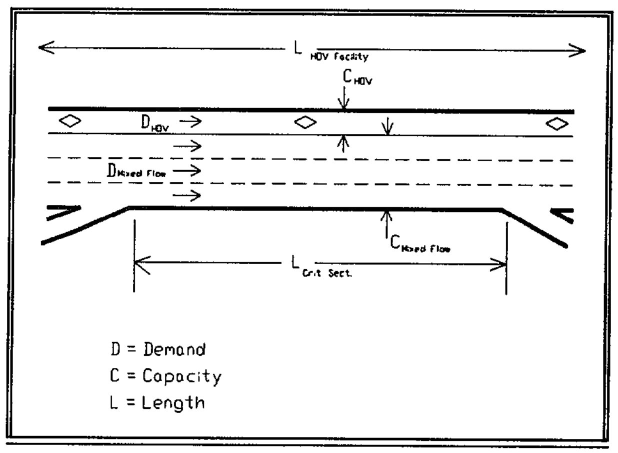
FHWA and Caltrans have recently developed prototypes of such linked regional and corridor models (see "IVHS Benefits Assessment Framework" project by VNTSC/U.S. DOT and "Travel Demand and Simulation Modeling" project by Caltrans headquarters).

E.2.2 Proposed Critical Subsection Methodology

Since software already exists to implement the more data intensive level two and level three methods, this research project focused exclusively on the development of the Level One Critical Subsection Method. This section describes in more detail the critical subsection model methodology which developed as part of this project.

<u>Input Data Requirements</u>:

1. Existing HOV and SOV demand at the critical sub-section (highest demand-to-capacity ratio). Demands would be required for each direction/peak period of the facility and analyzed separately.
2. HOV and SOV lane capacity for the critical sub-section (Example: HOV lane capacity = 1600 vphpl, SOV lane capacity = 2000 vphpl).
3. Existing occupancy distribution (Example: 80% SOV, 15% HOV2, 3% HOV3, 2% HOV3+/buses). Also, average vehicle occupancy for HOV3+/buses.
4. Existing and future number of HOV and SOV lanes at critical sub-section.



5. Length of critical sub-section and overall HOV study section in kilometers.

6. Existing average travel time (or speed in kilometers-per-hour).

7. Existing and estimated future free-flow speed in the HOV lane and mixed-flow lanes.

8. Availability and quality of parallel routes (none, poor, good, excellent).

9. Demand growth estimate for the appropriate year of analysis (Example: 3% annual growth).

10. Design and occupancy requirements for proposed HOV facility (2+, 3+, bus-only, added HOV lane, lane-conversion from mixed-flow to HOV, conversion from 3+ to 2+, conversion from 2+ to 3+).

11. Vehicle type distribution (i.e. percent passenger vehicles, buses, light trucks, heavy trucks, motorcycles, etc.). This information will be used to generate emissions and fuel consumption estimates.

Model Output:

1. HOV lane and mixed-flow lane demand-to-capacity (d/c) ratio.

2. HOV lane and mixed-flow lane volumes by occupancy type.

3. Persons/lane for HOV and mixed-flow lanes.

4. Average speed, trip time, and total travel time for the HOV lane and mixed-flow lanes over the critical sub-section and over the whole length of the HOV lane.

5. Differences in demand-to-capacity ratios, persons-per-lane, Level-of-Service (LOS), average speed, trip time, and total travel time between the HOV lane and mixed-flow lanes.

6. Vehicle-miles of travel (VMT), vehicle-hours of travel (VHT), and delay for HOVs and SOVs.

7. Breakdown of total response between mode shift and induced shift due to spatial diversion.

8. Estimates of emissions and fuel consumption.

Recommended Methodology. The recommended iterative HOV demand/supply estimation process consists of the following steps. The forecasted demand and travel times are equilibrated for both short term and long term demand forecasts.

Step 1: Identify the HOV Study Section and the Critical Sub-Section, and Input Demand and Supply Data

Step 2: Evaluate "Before" Scenario: Supply Model

Step 3: Evaluate "Opening Day" Performance (Before Traveler Response)

Step 4: Estimate Short-Term Traveler Response to the HOV Facility: Demand Model

Step 5: Evaluate Performance After Short-Term Traveler Response, and

Step 6: Continue the Iterative Process Between Demand and Modified Performance until Equilibrium is Obtained

Step 7: After Equilibrium is Achieved Between Steps 4 and 6, Allocate a Portion of the Total Response Estimated in Step 4 to Route Diversion

Step 8: Forecast Long-Term Growth

Step 9: Evaluate Long-Term Performance (Before Traveler Response)

Step 10: Estimate Long-Term Traveler Response

Step 11: Re-evaluate Performance after Long-Term Traveler Response, and

Step 12: Continue the Iterative Process Between Demand and Modified Performance until Equilibrium is Obtained

Step 13: After Equilibrium is Achieved Between Steps 10 and 12, Allocate a Portion of the Total Response Estimated in Step 10 to Route Diversion

Step 14: Compute, Summarize, and Report Measures of Performance.

E.3 Data Collection

This section describes the data collection effort. First the data needs were determined, then nine agencies were identified for data collections. The data sets were then assembled from each agency. The final step was to compile and reduce the various data sets into a single consistent set of HOV lane data for the development and calibration of an HOV lane demand model.

E.3.1. Data Needs

It was determined that the new HOV demand estimation methodology should be sensitive to the impacts of HOV lanes on travel time and should be able to predict HOV and non-HOV vehicle and passenger volumes. The methodology should also be able to predict the effects of different minimum vehicle occupancy rules.

It would have been desirable for the new methodology to be sensitive to tolls, however; it was determined that there was inadequate field experience to date for validating HOV cost sensitivities. (The San Francisco Bay Area has several toll bypass lanes, however; the benefits of a free toll are combined with significant time savings so that the effect of the cost difference cannot be easily isolated from the effect of the time savings.)

The travel time differences (HOV versus non-HOV, and “before” versus “after”) are the “stimulus” to be used in the demand estimation methodology. The differences in the vehicle volumes (“before” versus “after” for HOV and non-HOV vehicles) are the “response” to be predicted by the new methodology.

Thus the following data is required to test and validate the new HOV demand estimation methodology:

1. “Before and after” peak period vehicle volume data by:
   a. Occupancy type (e.g. 1 person, 2 persons, 3 persons, 4+ persons),
   b. Vehicle type (auto, bus, van, truck, motorcycle), and by
   c. Lane type (HOV lane, Other lanes).
2. “Before and after” travel time data by lane type

E.3.2. Selection of Nine Agencies

Nine agencies were selected for data collection based on:

1. The number and variety of HOV projects operated by the agency,
2. The frequency and quality of their past and on-going data collection efforts,
3. Their representativeness of a cross-section of agencies operating HOV facilities throughout the United States, and
4. Their ability to cooperate in this study (some agencies had insufficient human resources to assist in the assembly of the data for this project).

The selected agencies are:

1. Caltrans, District 4, San Francisco, California;
2. Caltrans, Districts 7 and 11, Los Angeles and San Diego, California;
3. Minnesota DOT, Minneapolis, Minnesota;
4. New Jersey DOT, Trenton, New Jersey;
5. Metropolitan Transit Authority of Harris County, Houston, Texas;
6. Virginia DOT, Richmond, Virginia;
7. Washington DOT, Seattle, Washington;
8. Santa Clara County, San Jose, California;
9. Snohomish County, Seattle, Washington.

The nine agencies operate a combined total of 56 freeway and arterial HOV projects with a total of 640 lane-miles (1024 lane-km)(see Table Ex-1). The selected agencies together operate 54% of the 1188 freeway HOV lane-miles (1,912 lane-km) in the United States and Canada. Many of the selected agencies collect and publish data on HOV lane usage annually, semi-annually, or quarterly. Most have conducted "before and after" studies for some of their HOV facilities.

E.3.3. Collection of Before/After Data Sets

Each agency was requested to forward a copy of every available published "before and after" study for HOV facilities under their control. Some agencies no longer had available copies of "before/after" studies for projects which were opened over 20 years ago. In those cases, the University of California, Institute of Transportation Studies library was searched for information on the older projects.

Minnesota DOT, the Texas Transportation Institute, and the California State University, San Diego (Caltrans District 11) had the most extensive series of "before and after" studies available for their HOV facility projects.

New Jersey DOT's "before and after" study of their I-80 facility is still in progress and could not yet be released at the date of publication of this report.

Agencies also provided copies of their monitoring program reports. The Texas Transportation Institute, Caltrans District 4, Washington Metro COG, and Washington State DOT provided extensive monitoring data.

The history of each HOV facility was then reviewed to determine which "changes" in facility operation or characteristics would be useful "actions" for inclusion in the methodology development database. An "action" usually consists of construction of a new HOV facility, a change in the length of an existing HOV facility, or changes in eligibility rules (e.g. 2+ versus 3+ carpools allowed).

It was particularly valuable when several "actions" could be identified on a single facility, because then the effects of different actions on the identical facility could be tested without interference caused by differences in driver types in different geographic areas. The Katy Transitway in Houston, and the I-5 freeway in Seattle were two particularly rich sources of multiple "actions" occurring on the same facility.

A few, otherwise excellent, "before/after" studies were not included in the database because the HOV facility was not the only major change occurring in the corridor at that time. For example, a portion of the I-394 Minneapolis data set was not included in the database because the later portions of the HOV project occurred at the same time as freeway construction was proceeding. Some of the earlier studies of the Shirley Highway in Washington D.C. have not been included because of potential confusion of the effects of gasoline shortages in 1973 and 1979 with the impacts of the HOV facility.

A total of 27 "before/after" data sets out of a total 56 projects operated by the nine agencies have been identified and included in the methodology development database. Table Ex-2 lists the projects and the rationale for including or excluding each one in the database. Table Ex-3 lists the selected project datasets and their salient characteristics.

E.3.4. Data Reduction

The various “before/after” data sets identified in the previous step were reduced and consolidated into a single consistent database. This step involved converting percentages into volumes, translating travel time data into travel time differences, and tilling in gaps in the reported data based upon information available from related sources.

For example, vehicle occupancies were sometimes reported for the overall (HOV plus mixed flow) facility but not specifically for the HOV or mixed flow lanes. This information plus information on violation rates, average vehicle occupancy by lane, and total lane volumes were then used to assign vehicles by occupancy type to each lane type.

In other cases, travel times were reported for a section of the freeway that was longer than the section in which the HOV lane was located. These times were converted to travel times for the shorter section of freeway with the HOV lane by assuming that all of the observed travel time difference between the HOV lane floating car run and the mixed flow lane floating car run was due to the HOV lane.

In some cases, only mean or only maximum travel time savings were reported and these had to be converted to the other missing measurement (mean or maximum) using an estimated ratio of mean to maximum travel times based on data collected on the Houston and San Francisco HOV facilities.

Table Ex-1. Agency Profiles

Agency:	Caltrans 04	Houston Metro	Washington State DOT	Virginia DOT	Minnesota DOT	Caltrans 07 Caltrans 11	New Jersey DOT	Santa Clara County	King/ Snohomish Counties
Metro. Area	San Francisco, California	Houston, Texas	Seattle, Washington	Washington D.C.	Minneapolis, Minnesota	Los Angeles, San Diego, California	Morris County, New Jersey	San Jose, California	Seattle, Washington
Length of HOV Lanes (lane-miles and lane-km)	158 mi. 254 km	64 mi. 103 km	121 mi. 195 km	65 mi. 105 km	34 mi. 55 km	157 mi. 253 km	21 mi. 34 km	22 mi. 35 km	4 mi. 6 km
Barrier Sepa-rated Projects	None	5	2	2	21	3	None	None	None
Concurrent Flow Projects	11	None	7	1	2	6	1	2	4
Queue Bypass Projects	10	None	part of HOV lane projects	part of HOV lane projects	part of HOV lane projects	None	None	1	None
Before & After Studies	7	continuous monitoring	2	tri-annual monitoring	3	7	in progress	1	1
HOV Facility Monitoring Program	semi-annual reports since 1988	Quarterly reports since 1979	Quarterly reports since 1992. No travel time data after 1993	Tri-annual cordon counts, No speed data	Continuous and Biennial counts, No Speeds	None	None	Annual Report	None
HOV Traveler Surveys	8 sites in 1990 1 site in 1995	Annual Surveys 1985 to 1989	Surveys 1990, 1994	1986, 1987 Surveys	1986, 1993 Surveys	1989 on I-15	None	None	None

1 One of these projects was replaced by a new freeway HOV facility.

Table Ex-2. Selection of Projects for Methodology Development Database

Agency	HOV Project	HOV Type	Lane-Miles	Before-After Report?	Selected for Database?	Rationale
1. MnDOT	1. I-394	freeway-reversible	6	Yes	No	HOV lane during freeway construction
Minneapolis	2. I-394	freeway -concurrent	16	Yes	No	HOV lane during freeway construction
Minnesota	3. I-394[2]	expressway -reversible	4	Yes	Yes	shows expressway HOV
	4. I-35 w	freeway -concurrent	12	No	No	No Data
2. Houston	5. Katy	freeway-reversible	13	Yes	Yes	very rich data set for rule changes
Metro	6. North	freeway-reversible	14	Yes	Yes	shows rule change
Houston	7. Northwest	freeway-reversible	14	Yes	Yes	shows HOV lane addition
Texas	8. Gulf	freeway-reversible	12	No	No	No After Data
	9. Southwest	freeway-reversible	12	No	No	No Data
3. caltrans	10. I-10 LA	freeway-barrier	22	Yes	Yes	shows conversion of busway to HOV
Los Angeles	11. I-405 LA	freeway-concurrent	12	No	No	No before data
&	12. SR-91 LA	freeway-concurrent	16	Yes	Yes	shows construction of HOV lanes
San Diego	13. I-105 LA	freeway-barrier	16	No	No	HOV and freeway opened same date
California	14.1210 LA	freeway-concurrent	34	Yes	Yes	shows construction of HOV lanes
	56. SR-55 OR	freeway-concurrent	22	Yes	Yes	shows buffer separated HOV lanes
	15. I-15 SD	freeway-reversible	20	Yes	Yes	Extensive data
	16. SR-163 SD	freeway-concurrent	0	No	No	No data
	17. SR 75 SD	freeway-concurrent	0	No	No	No data
	18. I-5 SD	freeway-concurrent	0	No	No	Customs station bypass
4. WSDOT	19. I-5 (north)	freeway-concurrent	12	No	No	No data
Seattle	20. I-5 (central)	freeway-concurrent	4	Yes	Yes	shows ramp meters, rule change, etc.
Washington	21. I-5 (south)	freeway-concurrent	14	No	No	No data
	22. I-90 (west)	freeway-barrier	3	No	No	No data
	23. I-90 (centr)	freeway-barrier	12	No	No	No data
	24. I-90 (east)	freeway-concurrent	14	Yes	Yes	shows lane conversion
	25. I-405	freeway-concurrent	17	No	No	No data
	26. SR-167	freeway-concurrent	4	No	No	No data
	27. SR-520	freeway-concurrent	2	No	No	No data

2 Tbis project was replaced by freeway HOV facility.

Table Ex-2. Selection of Projects for Methodology Development Database

Agency	HOV Project	HOV Type	Lane-Miles	Before-After Report?	Selected for Database?	Rationale
5. Caltrans 4	28. us-101 Marin (S)	freeway-concurrent	7	No	Yes	shows conversions bus to HOV
San Francisco	29. us-101 Marin (N)	freeway-concurrent	12	No	Yes	shows conversion bus to HOV
California	30. us-101 Santa Clara (N)	freeway-concurrent	37	Yes	Yes	shows HOV add
	31. us-101 Santa Clara (S)	freeway-concurrent	26	Yes	Yes	shows HOV add
	32. I-880	freeway-concurrent	15	No	No	No data
	33. I-280	freeway-concurrent	22	Yes	Yes	shows HOV add
	34. I-680	freeway-concurrent	21	No	No	Too recent for after study
	35. I-580	freeway-concurrent	10	No	No	No data
	36. SR-237	expressway-concurrent	12	Yes	Yes	shows expressway
	37. SR-85	freeway-concurrent	44	No	No	HOV and freeway open same date
	3 8-44. Toll Bypass	freeway-concurrent	N/A.	No	No	No data
6. Santa Clara	45. San Tomas	expressway-concurrent	13	Yes	Yes	shows expressway
San Jose	46. Montague	expressway-concurrent	9	Yes	No	Incomplete before data
California	47. Central	expressway-concurrent	N/A.	No	No	No data
7. Snohomish	48. 2nd/5th	arterial-concurrent	2	?	No	No data
Seattle	49. SR-99	arterial-concurrent	2	?	No	No data
Washington	50. SR-522	arterial-concurrent	1	?	No	No data
	51. Airport/l28	arterial-concurrent	4	Yes	Yes	shows arterial HOV
8. VDOT	52. I-395	freeway-barrier	22	Yes	No	No travel time data
North Virginia	53. I-66 (east)	freeway-barrier	19	Yes	No	study in progress
Virginia	54. I-66 (west)	freeway-concurrent	14	Yes	No	study in progress
9. NJDOT	55. I-80	freeway-concurrent	21	Yes	No	After study not yet available
Total:		lane-miles:	640	398	311	

Table Ex-3. Characteristics of Selected Validation Data Sets

No	Facility	Location	State	Road Type	HOV Facility Type	Eligibility Rule	Action	Length (miles)	Peak Hour Data	Peak Period Data
1	US 12	Minneapolis	Minnesota	Expresswy	Reversible	2+	Add Lane	3.0+1.0	√	
2	I-10	Houston	Texas	Freeway	Reversible	2+	Convert 3+ to 2+	6.4	√	√
3	I-10	Houston	Texas	Freeway	Reversible	2+	Extend 5 miles	11.4	√	√
4	I-10	Houston	Texas	Freeway	Reversible	2+/3+	Convert 2+ to 3+	11.4	√	√
5	I-10	Houston	Texas	Freeway	Reversible	2+	Extend 1.5 miles	12.6	√	√
6	I-45N	Houston	Texas	Freeway	Reversible	2+	Convert 3+ to 2+	13.5	√	
7	US-290	Houston	Texas	Freeway	Reversible	2+	Add Lane	9.5	√	√
8	I-15	San Diego	California	Freeway	Reversible	2+	Add Lane	8.0	√	√
9	I-90	Seattle	Washington	Freeway	Concurrent	2+	Convert SOV to HOV	6.2		√
10	I-5	Seattle	Washington	Freeway	Concurrent	2+	Convert 3+ to 2+	7.7	√	
11	I-5	Seattle	Washington	Freeway	Ramp Meters	?	HOV Bypass Lns	N/A.		√
12	I-5	Seattle	Washington	Freeway	Concurrent	3+	Add Lane	5.6	√	
13	US 101	San Jose	California	Freeway	Concurrent	2+	Add SOV + HOV Lane	6.0	√	√
14	US 101	San Jose	California	Freeway	Concurrent	2+	Add Lane	2.8	√	√
15	I-280	San Jose	California	Freeway	Concurrent	2+	Add Lane	10.7	√	√
16	Airport Rd	Seattle	Washington	Arterial	Concurrent	2+	Add Lane	3.3	√	
17	SR 237	San Jose	California	Expresswy	Concurrent	2+	Add Lane	5.9		√
18	San Tomas	San Jose	California	Expresswy	Concurrent	2+	Add Lane	4.9		√
19	I-10	Santa Monica	California	Freeway	Concurrent	3+	Convert SOV to HOV	12.0		√
20	I-10	San Bernardino	California	Freeway	Barrier Separated	3+	Convert Bus to HOV	11.0		√
21	US 101	Marin	California	Freeway	Concurrent	3+	Convert Bus to HOV	3.7	√	
22	SR 91 EB	Los Angeles	California	Freeway	Concurrent	2+	Add Lane	8.0	√	
23	I-210	Pasadena	California	Freeway	Concurrent	2+	Add Lane	17.0	√	
24	SR 91 WB	Los Angeles	California	Freeway	Concurrent	2+	Add Lane	8.0	√	
25	SR 55	Orange	California	Freeway	Barrier Separated	2+	Add Lane	11.0	√	
26	US 101	Marin (S)	California	Freeway	Concurrent	2+	Convert 3+ to 2+	3.7		√
27	US 101	Marin (N)	California	Freeway	Concurrent	2+	Convert 3+ to 2+	3.0		√

1. INTRODUCTION

This report presents the results of the literature review and data collection effort for the Federal Highway Administration Project #42-10-4172, "Predicting the Demand for High Occupancy Vehicle (HOV) Lanes".

1.1 RESEARCH PROJECT OBJECTIVE AND SCOPE

This research project is a two year effort to develop a methodology and micro-computer software model for quickly analyzing HOV lane demand and operations. The methodology is designed to be applied by planners and engineers with limited or no access to or experience with regional travel demand modeling. The methodology will provide a set of "quick response" procedures for predicting and evaluating the impacts of HOV lanes on person demand, vehicle demand, auto occupancy, congestion, delay, and air quality. This methodology will be applicable to corridor, network, and system level HOV demand analysis.

The objectives of this project are to:

1. Identity and document state-of-the-art practices in predicting, analyzing, and evaluating travel demand for HOV lanes.
2. Collect, analyze, and report data relevant to the prediction, analysis, and evaluation of HOV lanes.
3. Formulate a methodology for assessing HOV travel demand on freeway and arterial facilities for use by personnel not experienced in regional travel demand modeling.
4. Develop a computer model with a user's guide to predict and analyze planned and actual HOV travel demand that is consistent with the methodology.

1.2 OUTLINE OF REPORT

The executive summary provides an overview of the content of this report.

This first chapter of this report serves as an introduction to the project and the report.

The second chapter is an inventory of HOV facilities in the United States and Canada. This information is useful in gaining a perspective of the distribution and type of HOV projects and for determining the validity of the sample used to create the methodology development database.

The third chapter describes the characteristics of HOV lane users that are useful for understanding the basis for developing a methodology for predicting HOV demand.

The fourth chapter describes the available methods for predicting HOV lane demand and their impacts.

The fifth chapter uses the results of a survey of HOV agencies and the results of the literature review to identify the need for a new methodology for predicting HOV lane demand and impacts.

The sixth chapter defines the recommended new methodology for predicting the demand for HOV lanes.

The seventh chapter presents the data that was assembled from various HOV lane operators for the purpose of calibrating and validating the proposed new HOV lane demand estimation methodology.

The Appendices present tabulations of the database, definitions of terminology used in this report, and a bibliography.

2. INVENTORY OF HOV PROJECTS

There are 94 HOV projects consisting of 1,188 lane-miles of facilities currently operating on freeways in 17 states of the United States and in Canada. These 17 states plus North Carolina have plans to add 92 more HOV projects consisting of 2,296 additional lane-miles.

Six states; California, Florida, Virginia, Washington, Texas, and Hawaii, together account for over 75% of the existing lane-miles of freeway HOV facilities in the United States. About one-third of the existing HOV projects and one-half of the proposed HOV projects are located in California.

Over half of the existing HOV projects on freeways and 80% of proposed HOV projects on freeways are for concurrent flow HOV lanes.

This chapter presents an overview of existing and proposed HOV facilities in the United States and Canada, and current HOV planning practices. HOV facilities are categorized by facility type, eligibility requirements, hours of operation, and their location.

The inventory is divided into two broad categories of HOV facilities - freeways and arterials.

2.1 EXISTING HOV PROJECTS

As a starting point, the list compiled by Charles Fuhs published in January 1995 provided a comprehensive inventory of existing and proposed HOV facilities located on freeways and separate rights-of ways in North America.[1] This list is updated every six months. For current freeway HOV lane projects, the inventory includes HOV facility information by type of facility, state route, number of lanes, project length in miles, operation period, eligibility requirements, and changes in rules since opening. The information on proposed HOV lane projects is summarized by state route, project length in miles, and anticipated opening year.

Figure 2-1 shows the geographic distribution of HOV projects in the U.S. and Canada. Currently, HOV facilities are in operation in a total of 17 U.S. states and Canada. The existing freeway HOV facilities include 94 projects which have a total directional mileage of 1,188 miles. Proposed freeway HOV facilities total 92 projects (both new and extension plans) that cover a total directional mileage of 2,296 miles.

2.1.1 Existing Freeway HOV Projects

The inventory of existing HOV facilities are grouped into the following four categories:

- type of HOV design/operations
- location/state
- occupancy requirement
- hours of operation

Current HOV lane projects in the United States and Canada are tabulated by both the total number of projects and the total number of directional lane miles.

1 Charles Fuhs. "Inventory of Current and Proposed HOV Projects in the U.S. and Canada," January 1995.

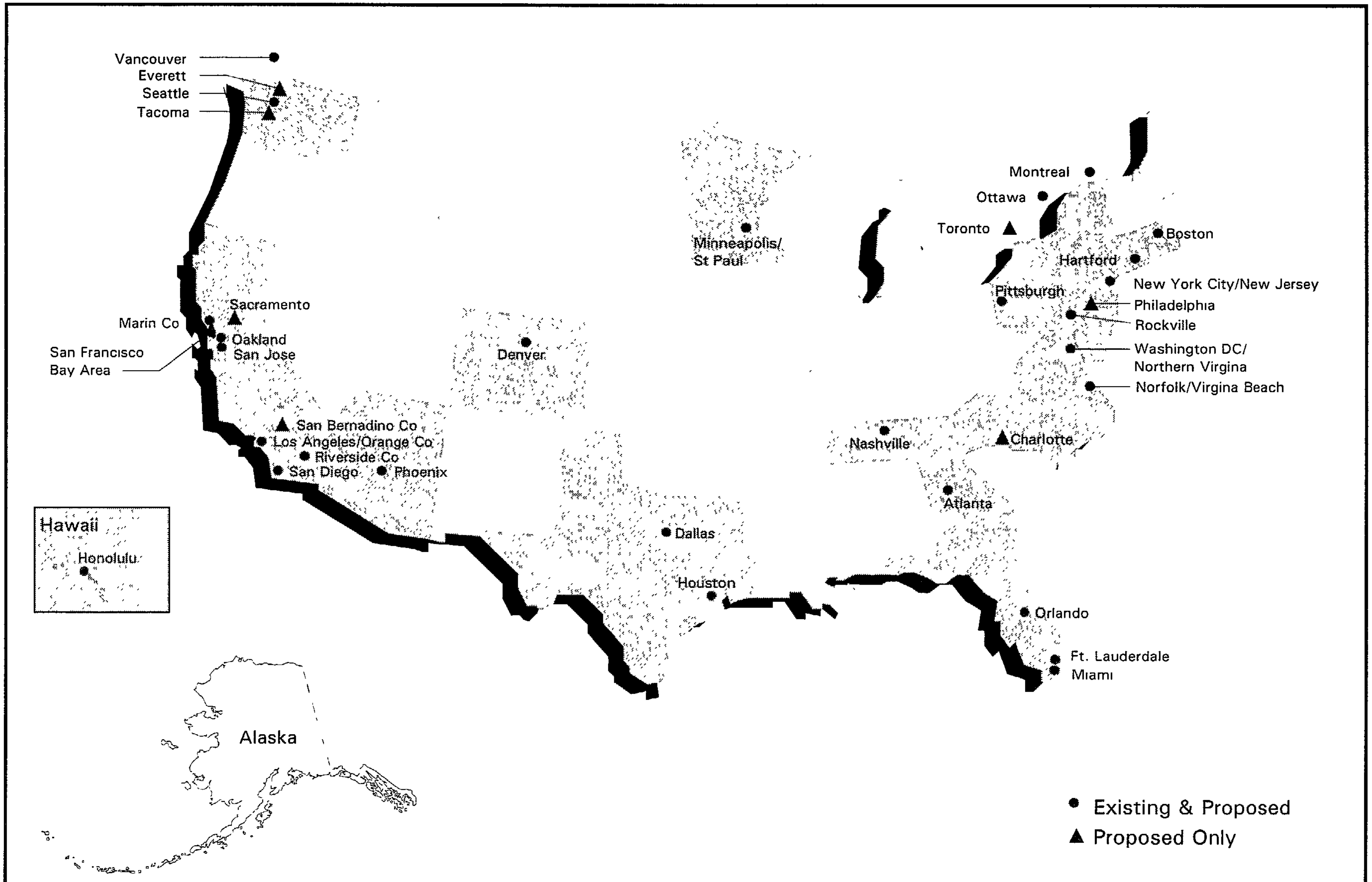


Figure 2-1
Locations of HOV Facilities in US and Canada
(as of January 1995)

94044 FIG2-1.cdr

Geographic Distribution

As shown in Figure 1, existing HOV facilities are located in several cities throughout the U.S. and Canada. California (28) has the largest number of HOV projects followed by Washington (13) and Virginia (8). California also has the most HOV directional lane mileage (454 miles or 38%). Florida and Virginia are the next highest with 138 miles or 12% and 106 miles or l0%, respectively. Figure 2 shows the number of existing HOV projects and the corresponding directional lane mileage by state and Canada.

Facility Types

Concurrent HOV facilities have by far the greatest number of projects (49 out of 94) and directional lane mileage (875 miles or 74%). Figure 3 exhibits the number of existing HOV projects and the directional lane mileage by type of HOV facility into the following categories: busway, barrier-separated (two-way), barrier-separated (reversible), concurrent, contra-flow, and queue bypasses. For the barrier-separated reversible flow HOV facilities, the total lane mileage does not reflect the reversible use of the facility. HOV queue bypass projects are counted on a geographic area basis and not by individual project.

Occupancy Requirements

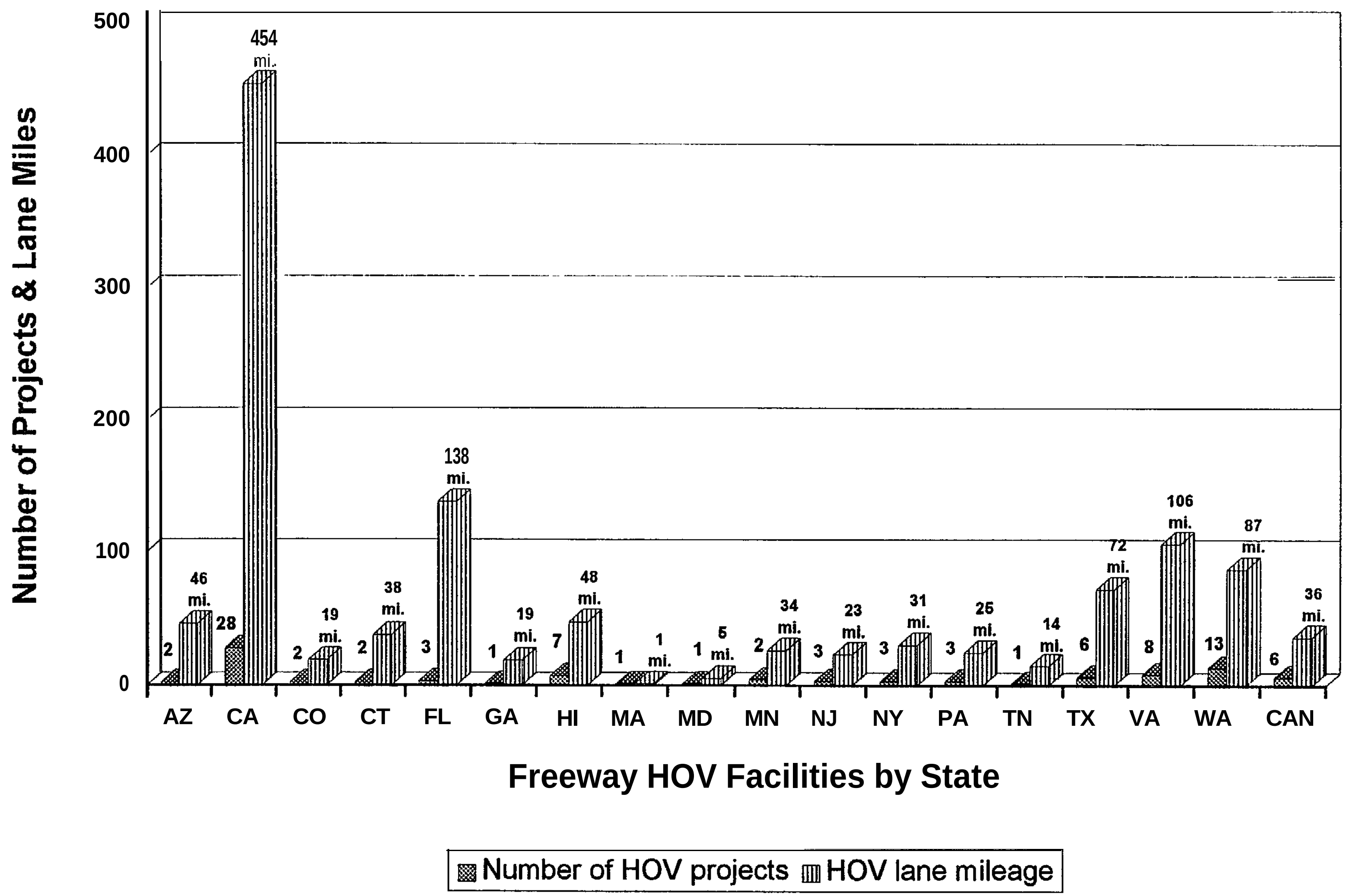
Occupancy requirements for existing HOV facilities range from 2 or more persons per vehicle to bus only facilities. Most existing HOV facilities (68 out of 94) have an occupancy requirement of 2 or more, which amounts to 998 directional lane miles or 84% of the total lane mileage. Those HOV facilities that require 3 or more persons per vehicle total 10 projects (11%) and 104 directional lane miles (9%). The occupancy requirement of buses-only includes 14 projects (15%) and 82 directional lane-mile (7%). Figure 4 displays the number of current HOV projects and the directional lane mileage by HOV eligibility requirement. The eligibility requirements are classified into the following groups: 2+, 3+, buses only, and others. The “others” category includes HOV facilities that are only used by either registered Vanpools or taxis.

Hours of Operation

The hours of operation for a HOV facility vary from a few hours during the morning peak period to 24 hours a day for 7 days a week. HOV lanes operating 24 hours for seven days a week have the largest number of HOV projects (29) and directional lane mileage (462 miles or 39%). Several of these facilities are located in the Los Angeles and Seattle metropolitan areas. Figure 2-5 illustrates the number of current HOV projects and the directional lane mileage by total hours of operation. The existing HOV projects are grouped by total number of hour in operation. Although not evident from the figure, most of the HOV facilities operate during the weekday AM and PM peak periods.

FIGURE 2-2: Freeway HOV Projects by State

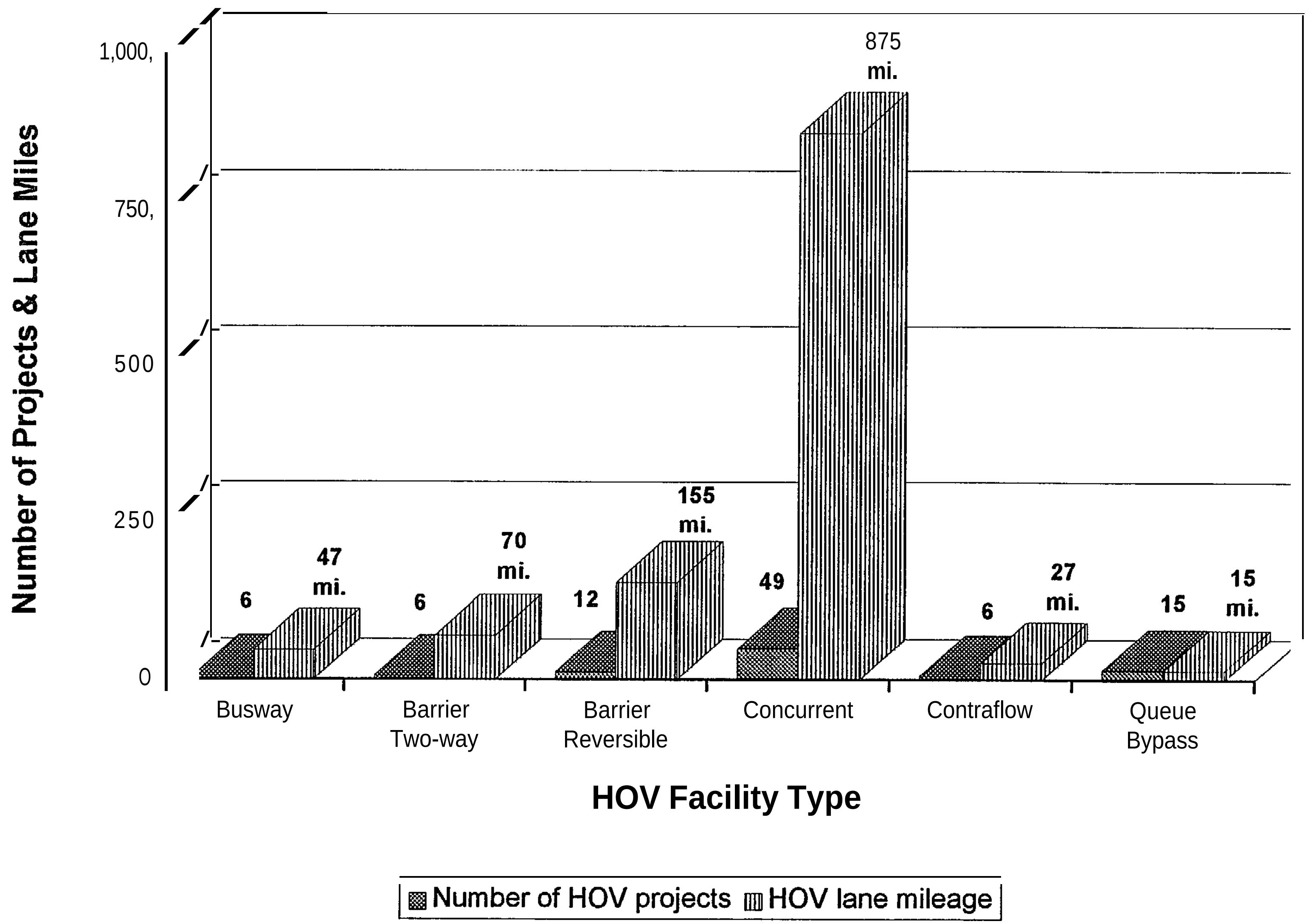
(January 1995 inventory - Total of 94 Projects and 1,188 Miles)



Source: 1. Charles Fuhs. Inventory of Current and Proposed HOV Projects in the U.S. and Canada, January 1995.
2. Dr. Adolf May. TRB Presentation to the HOV Systems Committee

FIGURE 2-3: Freeway HOV Projects in the U.S. and Canada by HOV Facility Type

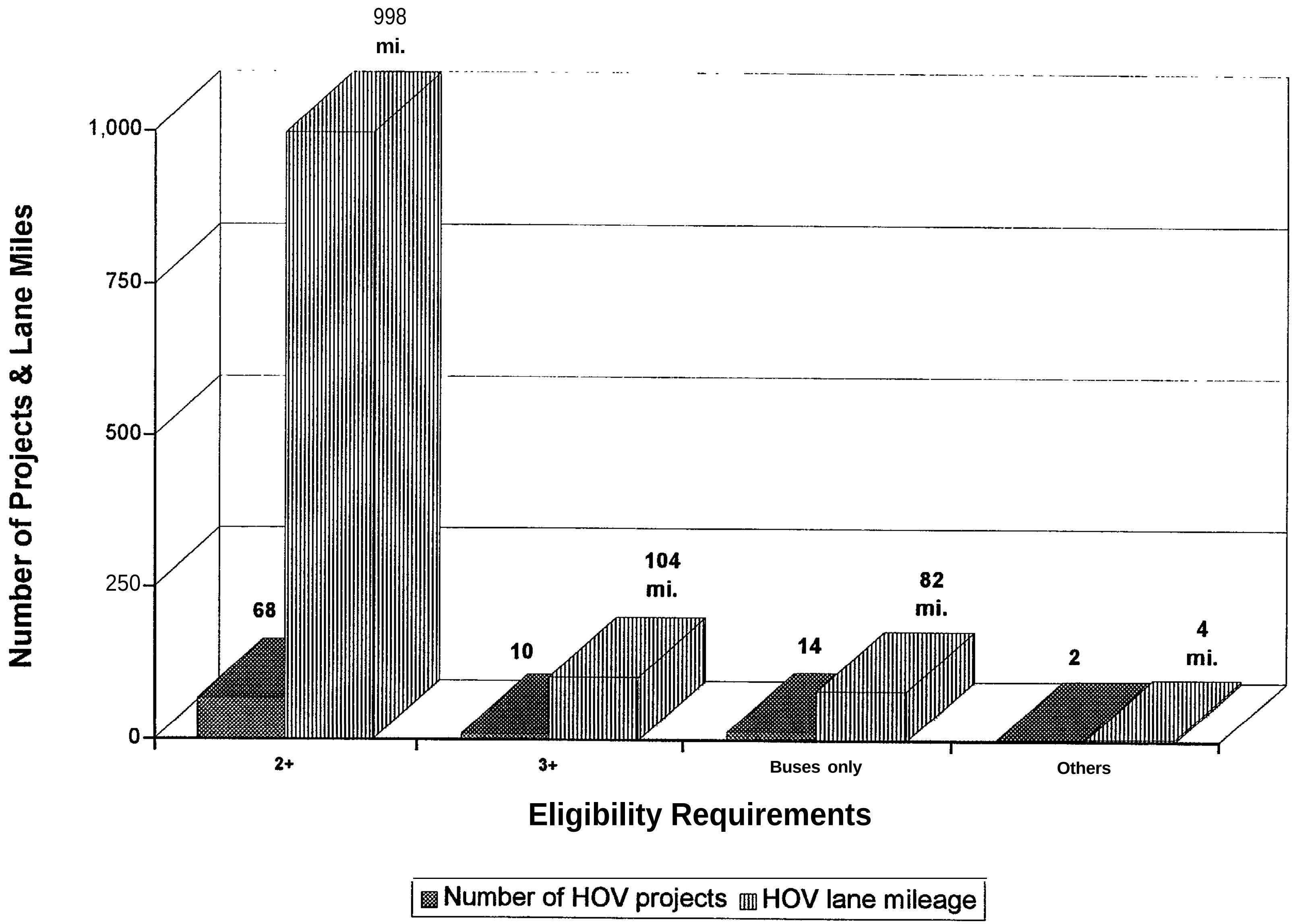
(January 1995 Inventory - Total of 94 Projects and 1,188 Miles)



Source: 1. Charles Fuhs. Inventory of Current and Proposed HOV Projects in the U.S. and **Canada. January 1995.**
2. Dr. Adolf May. TRB Presentation to HOV Systems Committee.

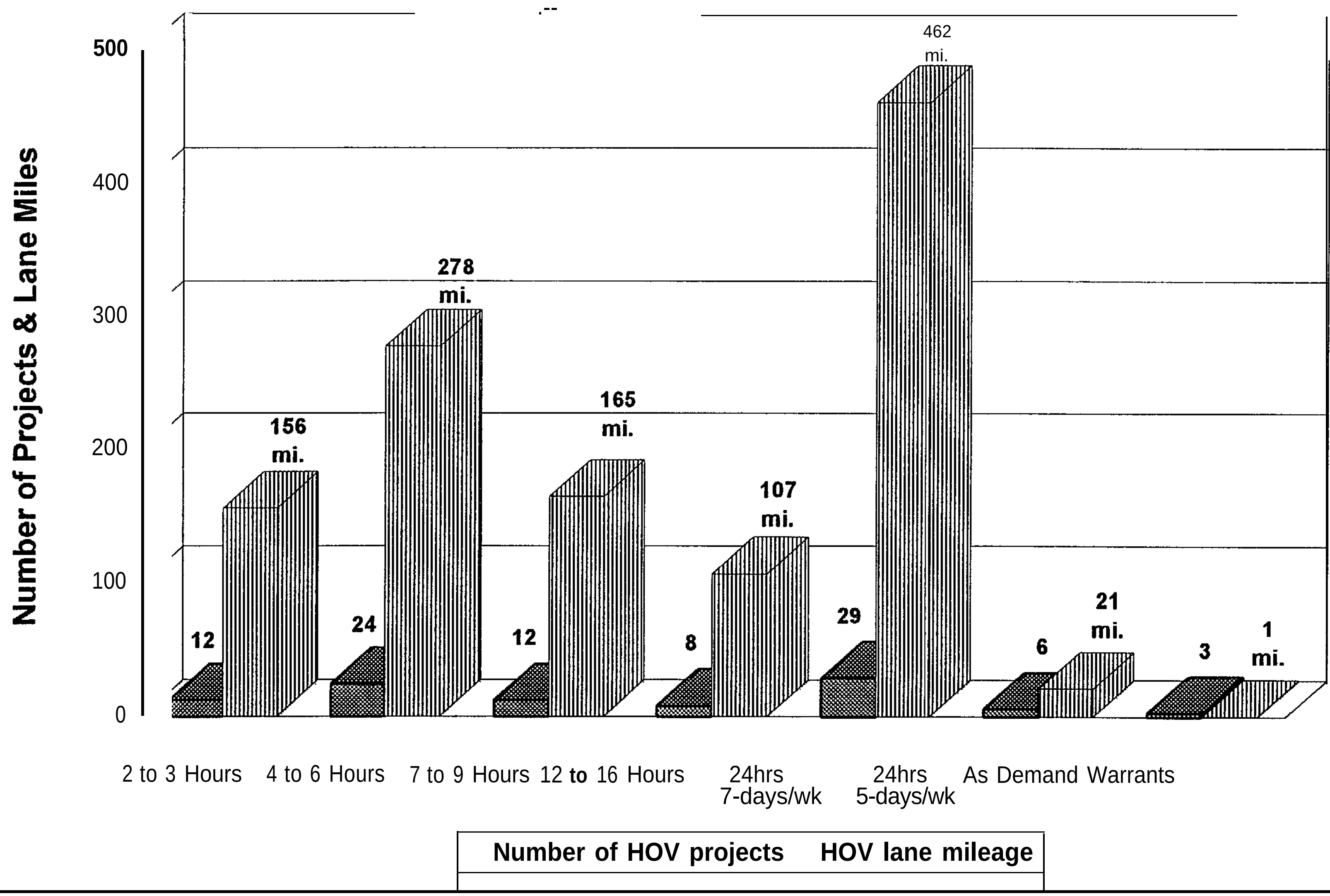
FIGURE 2-4: Freeway HOV Projects in U.S. and Canada by HOV Eligibility

(January 1995 Inventory - Total of 94 Projects and 1,188 Miles)



Source: 1. Charles Fuhs. Inventory of Current and Proposed HOV Projects in the U.S. and Canada, January 1995.
2. Dr. Adolf May. TRB Presentation to HOV Systems Committee.

FIGURE 2-5: Freeway HOV Projects in U.S. and Canada by Hours of Operation
(January 1995 Inventory - Total of 94 Projects and 1,188 Miles)



Source: I, Charles Fuhs. Inventory of Current and Proposed HOV Projects in the U.S. and Canada, January 1995.
2. Dr. Adolf May. TRB Presentation to the HOV Systems Commitee.

2.1.2 Existing Arterial and Expressway HOV Projects

A national database of current arterial HOV facilities does not exist. Arterial HOV facilities range from reserved bus only lanes in the urban core area to suburban HOV lanes that resemble freeway HOV lanes in characteristics and operations, Some arterial HOV lanes are queue bypasses at bottlenecks on major arterials, such as approaches to bridges or tunnels. Arterial HOV lanes are difficult to generalize since the number of facilities nationwide is limited and the differences among operating facilities are great.

A study done in the 1980's found 95 concurrent flow HOV lanes nationally.' Of these, 22 arterial HOV facilities were suspended due to low use, enforcement problems, pedestrian fatalities, or operational problems.

Many of the arterial HOV facilities are bus lanes that are for exclusive use by buses. Carpools are not permitted on these facilities. The location of bus lanes vary from curb lanes to median lanes to contra-flow lanes. Some streets are designated as "bus streets". Examples of bus lanes can be found in most major cities in the U.S. including: Minneapolis, Washington, D.C., Baltimore, New York City, New Orleans, Chicago, and San Francisco.[3]

The following arterial or expressway HOV facilities are not restricted solely to buses:

1. Montague Expressway, Santa Clara County, California
2. San Tomas Expressway, Santa Clara County, California
3. SR 237, Santa Clara County, California[4]
4. SR 99, Seattle, Washington
5. NE Pacific Street, Seattle, Washington
6. Airport Road, Snohomish County, Washington

The arterial HOV facilities in Santa Clara County are part of the Santa Clara County Commuter Lane network. The County's Transportation 2000 Plan includes a 140-mile network of commuter lanes on freeways and expressways. About 17 lane miles of concurrent flow arterial HOV lanes are operational during the peak period only.

The arterial HOV facilities in the Seattle area operate as independent facilities and represent an array of arterial HOV types. The downtown Seattle HOV lanes converts the right parking lane for use by buses only during the AM and PM peak periods. SR 99 reserves the outside right lane for buses, 3+ car-pools, and right turning vehicles. The HOV lane on NE Pacific Street provides a queue bypass for buses and carpools at the Montlake Bridge.

SR 522 in Seattle is an arterial HOV facility that is partially restricted to buses. The northbound parking lane on SR 522 is reserved for buses and 3+ car-pools on the approach to the bottleneck at NE 145th Street during the AM peak period. The southbound direction of SR 522 between Kenmore and 145th (approximately 3 miles) is reserved for buses only 24 hours a day.

The outside lane of Airport Road in the Seattle area is converted to a 2+ HOV lane during the peak periods.

2.2 PROPOSED HOV PROJECTS

The inventory of proposed HOV facilities are grouped into the following two categories: type of HOV design/operations, and location/state. For each category, the data is summarized by both the total number of

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[2]Batz, T.M., "High Occupancy Vehicle Turnouts, Impacts, and Parameters," FHWA, NTIS #PB87203212/HDM, August 1986, Two Volumes.

[3]Herbert S. Levinson, Crosby L. Adams, and William F. Hoey. Bus Use of Highways: Planning and Design Guidelines. NCHRP Report 155, Transportation Research Board, National Research Council, Washington, D.C., 1975, Table 1.

[4]Has since been upgraded to freeway.

projects and the total number of directional lane miles. Proposed freeway HOV lane projects in the U.S. and Canada are included.

The total lane mileage for the proposed HOV facilities almost doubles the number of existing lane miles. The vast majority of proposed HOV lane projects are located in California. Most of the proposed HOV lane projects are concurrent flow facilities. These HOV lane projects are at various stages of development. Some are slated to open in 1995, while others are still in the planning stages.

Similar to existing HOV projects, concurrent HOV lanes have the largest number of projects (73 out of 92) and directional lane miles (2,025 miles or 88%). Figure 2-6 shows the number of proposed HOV projects and the corresponding directional lane mileage by type of HOV facility.

Some of the proposed HOV projects are extensions of existing projects and others are new facilities. As noted in Figure 6, 12% of the proposed HOV projects are HOV extension projects, and 88% of proposed HOV lane projects are new HOV lane projects.

California has the largest number of proposed projects (38) and directional lane miles (1,247 miles or 54%). Washington and Texas continue to extend and expand their HOV systems in Seattle and Houston, respectively. Massachusetts has several HOV projects planned for the Boston area. Figure 2-7 exhibits the number of proposed HOV projects and directional lane mileage by state.

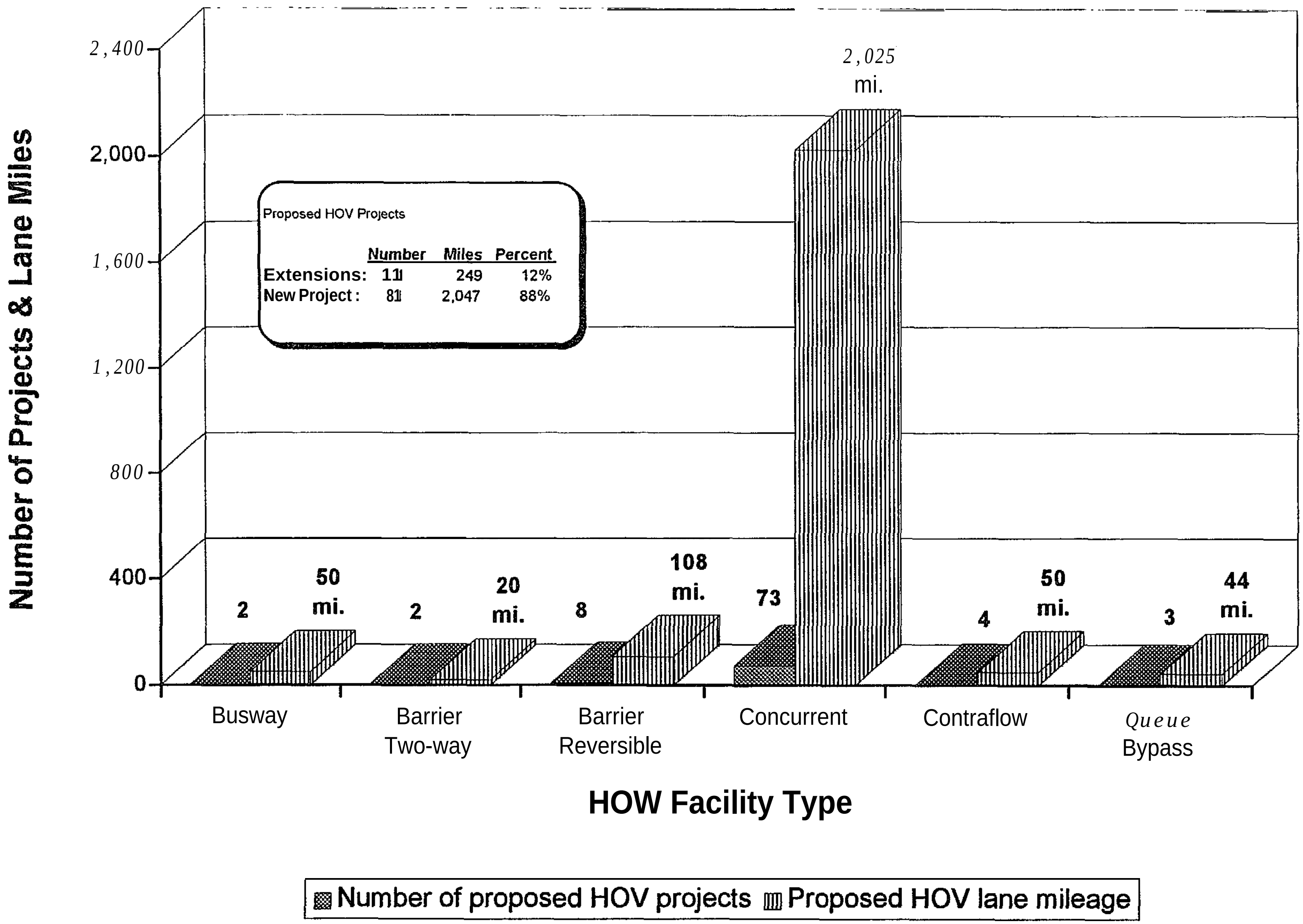
2.3 KEY FINDINGS

The inventory of existing and proposed HOV facilities in the United States and Canada can be summarized as follows:

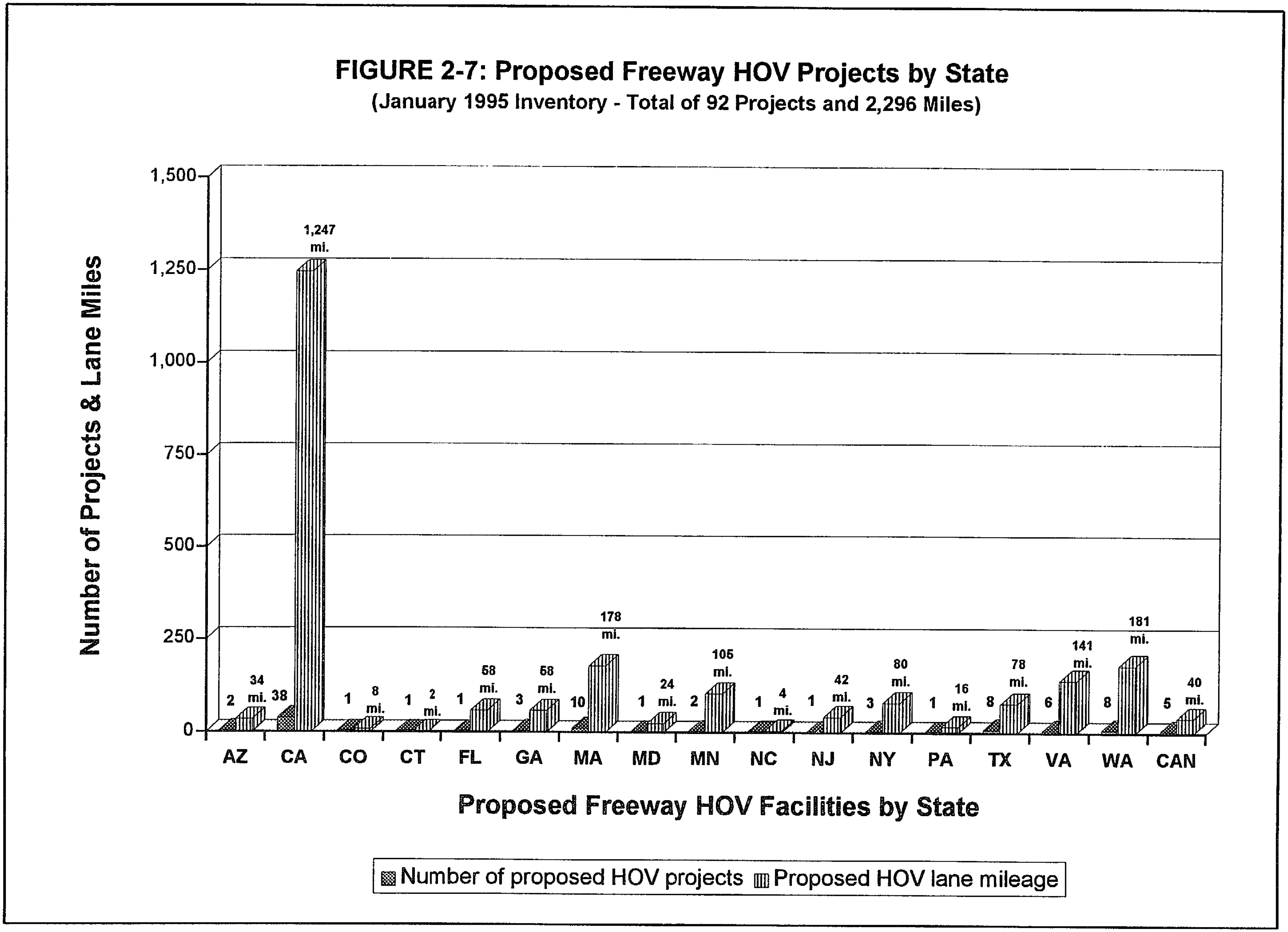
- Six states; California, Florida, Virginia, Washington, Texas, and Hawaii, together account for over 75% of the existing lane-miles of freeway HOV facilities in the United States. About one-third of the existing HOV projects and one-half of the proposed HOV projects are located in California.
- Over half of the existing HOV projects on freeways and 80% of proposed HOV projects on freeways are for concurrent flow HOV lanes.
- About 72% of the existing HOV facilities many of the new facilities define HOV’s as 2 or more persons per vehicle.
- Most HOV facilities operate only during the weekday am and PM peak hours. However, about 30% of the existing HOV facilities operate on a 24-hour basis for 7 days a week.

FIGURE 2-6: Proposed Freeway HOV Projects by Facility Type

(January 1995 inventory - Total of 92 Projects and 2,296 Miles)



Source: Charles Fuhs. Inventory of Current and Proposed HOV Projects in the U.S. and Canada, January 1995.



Source: Charles Fuhs. Inventory of Current and Proposed HOV Projects in the U.S. and Canada, January 1995.

3. CHARACTERISTICS OF HOV DEMAND

3.1 OVERVIEW

Several investigators have interviewed commuters or analyzed the results of driver surveys in an attempt to isolate those demographic, geographic, attitudinal, or trip-specific characteristics which separate carpoolers from drive-alone commuters and transit users. Some of these investigations supported the development of explicit mode-choice models, while others have been undertaken in the course of evaluating specific HOV projects. The findings of these analyses can shed light on the relative importance of different parameters in predicting the use of a new HOV facility.

Driver surveys have been conducted in conjunction with a wide range of existing HOV projects. Sites where drivers have been interviewed extensively include Seattle (Ulberg, 1994), the San Francisco Bay Area (Billheimer, June 1990), Orange County (Giuliano, et al., 1990), Houston (Christiansen and Morris, 1991), and Minneapolis (Strgar-Roscoe-Fausch, 1987). In addition, at least two researchers (Teal, 1987 and Ferguson, 1995) have analyzed driver responses to the Nationwide Personal Transportation Study (NPTS) in an attempt to develop a comprehensive nationwide overview of the demographics and logistics of carpooling. This chapter examines the key findings of these studies with the aim of identifying those parameters which can be expected to affect the use of HOV lanes.

3.2 KEY FINDINGS

3.2.1 Travel Time and Distance

Trip Length Nearly every study of carpooling tendencies has found that carpooling rates increase with travel time and trip length. A recent survey of carpoolers on the Route 91 Freeway linking Riverside and Orange Counties DKS, 1990) found that “only 8% of commuters who travel less than ten miles to work Carpool, as compared to 25% of those who commute 60 miles or more to work.” In terms of travel time, “only 5% of those on the road for 20 to 30 minutes carpool, whereas 21% of those on the road 90 to 110 minutes carpool.” These Southern California statistics show lower carpooling tendencies than have been reported elsewhere. In an analysis of nationwide carpooling trends based on the 1977-78 National Personal Transportation Study (NPTS), Teal (1987) found that carpooling tendencies increased from 15.5% for trips under ten miles to 33% for trips of more than 25 miles. In a more recent study based on the 1990 NPTS, Ferguson (1995) found that carpooling percentages decreased with distance for trips under 10 miles, hovered around 14% for trips between 10 and 20 miles in length and then increased with distance, rising to 20.7% for trips longer than 30 miles. A comparison of year-to-year carpooling trends in the U.S. as revealed in successive NPTS studies showed that overall carpooling declined 34% between 1980 and 1990 (Ferguson, 1995).

Perceived HOV Time Savings Several studies (Dobson and Tischer, 1977, Billheimer 1981, and Billheimer, January 1990) have distinguished between perceived and actual travel times and have found that carpoolers and solo drivers alike tend to overestimate the time savings available from the use of HOV lanes. A recent study of carpool lanes in the San Francisco Bay Area (Billheimer, January, 1990), for example showed that “drivers perceived HOV time savings that were more than double the average savings recorded during the heaviest traffic period and nearly four times the savings realized by all drivers throughout the morning commute period.” (See Figure 3-).

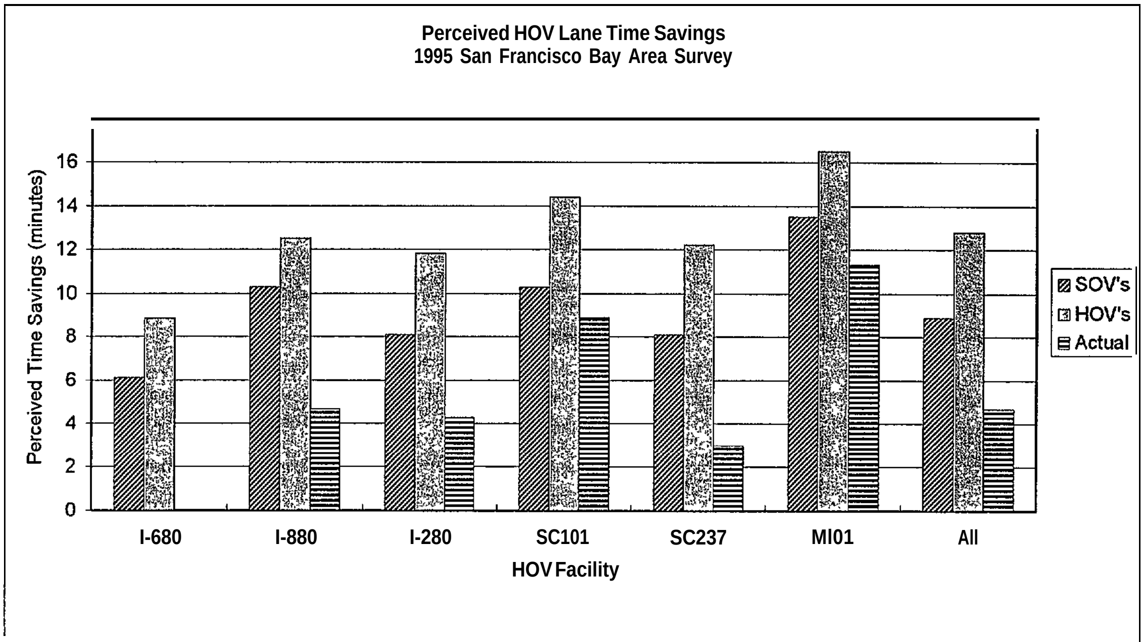


Figure 3-1. Perceived And Actual HOV Lane Travel Time Savings

This tendency to perceive greater time savings in the Carpool alternative lane makes Carpool lanes more attractive to drivers than a direct comparison of alternative travel times might indicate, and suggests that there may be a psychological advantage in providing a Carpool lane even when the available time savings appear minimal.

Carpool Set-Up Time. In view of the importance of travel time in mode choice, one significant barrier to carpooling is the amount of time carpoolers spend driving out of their way to pick-up passengers and waiting for other riders. In a recent MTC-sponsored survey (Billheimer, May 1990) Bay Area carpoolers were asked to estimate these times. The answers varied with car-pool size and location. However, for an average trip of 47 minutes, carpoolers spent 2.4 minutes (5.7% of their time) waiting for other carpoolers to get ready, 4.8 minutes (10.2% of their time) traveling to pick up passengers, and 39.9 minutes (84.7%) traveling to their destination. Three-person carpoolers required twice as much formation time (roughly 11 minutes) as two-person carpoolers.

It should be emphasized that these estimates of Carpool formation time came from carpoolers. It is possible that these times may be perceived to be much greater by non-carpoolers, who stress the need for convenience and minimal door-to-door travel times in justifying their decision to drive alone.

3.2.2 Travel Cost

Researchers have generally found that travel costs are less important than travel time in determining mode choice (McGillivray, 1970; DKS, 1990). Except in areas where drivers incur significant parking costs, travel costs tend to be directly related to travel time and distance.

Perceived Costs. Several researchers (Dobson and Tischer, 1977 and Henley, et al., 1981) have found that drivers tend to underestimate the true cost of their commute by including only gas and oil in their estimates and ignoring the costs of vehicle ownership and maintenance. Reflecting this finding, Dobson and Tischer (1977) demonstrated that perceived costs were more accurate than actual costs as a predictor of mode choice.

Parking Costs. Where they exist, parking costs can be an important element of mode choice. Shoup (1982) estimated that at least 20% of those drive-alone commuters who park for free would switch to ridesharing if they had to pay for parking. Ulberg (1994) reports on a Seattle study that found that only 10% of the bus riders commuting from Northern King County had access to free parking if they drove, while 84% of the commuters driving alone paid nothing to park. The relative proportion of commuters who personally pay for parking varies from area to area, and from destination to destination within an area. A survey of carpoolers on Minnesota's I-394 showed that 50% of those destined for downtown Minneapolis paid parking charges (an average of $85 per month per space), while overall only 20% of all carpoolers in the general Twin-Cities area had to pay for parking (Strgar-Roscoe-Fausch, 1989). A recent survey of carpoolers in the San Francisco Bay Area (Billheimer, June 1990) found that 22% personally paid for parking at their destination. The average charge paid by these carpoolers was $118 per month. Shoup (reported in Ulberg, 1994) estimates that, nationwide, 93% of all commuters park free at work.

Perceived Carpool Savings. Not all carpoolers perceive that carpooling saves them money. In the San Francisco Bay Area survey cited above (Billheimer, June, 1990), 77% of the carpoolers surveyed thought that they saved money by carpooling. Those who didn't recognize any savings tended to be either drivers who bore the entire cost of the trip themselves or members of single-household Carpools who didn't perceive that would be more expensive for household members to travel separately. The average perceived savings reported by all carpoolers was $14.00 per week.

3.2.3 Household Characteristics

Household Size. Carpool research has uuiformly shown that a substantial portion of carpoolers come from the same household. Teal's study of 1977-78 National Personal Transportation Study (NPTS) Data showed that 42% of all carpoolers came from the same household (Teal, 1983). By 1990, the proportion of household-based carpools in the NPTS survey had increased to 59% of all home-based work trips (Ferguson, 1995). A 1988 telephone survey of working Orange County residents found that 54% of the carpoolers surveyed carpooled with members of their own household (OCTD, 1988). A recent survey of Bay Area carpoolers reported that 54% of the car-pools using HOV lanes had been formed with other household members (Billheimer, June 1990). As would be expected, the prevalence of household-based Carpools on HOV lanes depends on the occupancy levels required for the use of the lanes. Household-based carpools are much more likely to be found in lanes admitting two or more occupants than in lanes with higher occupancy requirements. In a survey of eight Bay Area HOV lanes (Billheimer, June 1990) on the Bay Bridge, where the HOV lane requires 3-persons, only 33% of the carpoolers surveyed came from the same household. On HOV projects requiring only two persons, however, in-household carpools always exceeded 50% of the total,

The prevalence of carpools composed of persons from the same household suggests that the number of workers per household might be a useful predictor of Carpool formation. Ferguson (1995) reported that the 1990 NPTS showed that ". . commuters living in households with 5 or more persons are two and one half times more likely to Carpool than those living in single-person households." He also noted that the dramatic increases in carpooling tendencies with household size were related almost entirely to household-based carpools. Carpools formed outside the home were relatively unaffected by household size.

Recognizing the importance of single-household carpools, some researchers have isolated those Carpools and treated them separately. Teal (1987), for example recognized three types of carpoolers:

1. Household Carpoolers, who commute together with at least one other worker from the same household (42% of 1977-78 NPTS total);
2. External Carpoolers, who share transportation with unrelated individuals and who either share driving responsibilities or who always drive (36% of 1977-78 NPTS total); and
3. Carpool Riders, who commute with other unrelated workers but who only ride and never provide a vehicle (27% of 1977-78 NPTS total).

External Carpools tend to carry more people than household Carpools. Teal (1987) found that only 5% of all household Carpools had more than two members, while 39% of cat-pools formed outside the household had three or more members.

Household Income. Research findings differ with respect to the impact of household income on carpooling tendencies. A recent Orange County Marketing Study (McKever, et al., 1991) found no significant correlation between household income and carpooling tendencies. Ulberg (1994) noted that Seattle surveys showed a greater propensity to carpool among higher income households, but suggested that this finding reflected the presence of more wage earners in larger households. In his earlier nationwide study of NPTS data, Teal (1987) found that carpoolers tended to have lower incomes than drive-alone commuters. This was particularly true of carpoolers who rode with members of other households and never provided a vehicle. Teal also concocted a variable composed of the ratio of drive-alone commuting costs to income, which he called the Commuting Cost to Income (CCTI) burden, and which proved to be positively correlated with the decision to carpool. The CCTI ratio for all carpoolers was 4.4%, as compared with 2.5% for commuters who drive alone.

In examining the most recent NPTS data, Ferguson (1995) found that "...carpooling declines with income at lower income levels, but is largely unrelated to income at higher income levels." For household incomes below $30,000 per year, the lower the income level the greater the likelihood of ridesharing. Workers living in households with family incomes of $30,000 or more showed virtually no change in their tendency to rideshare as income increased. This is consistent with the earlier findings of Teal (1987), who reported that the propensity to carpool increased by a factor of 2 to 3 when the ratio of drive-alone commuting costs exceeded 5% of the average family income per worker. Workers living in higher income households in which commuting costs constituted a lower proportion of the family budget tended to base their commuting choice on factors other than cost.

Vehicle Availability. As would be expected, vehicle availability correlates well with the decision to drive alone rather than carpool. In reviewing research on the influence of socioeconomic characteristics on mode choice, Ulberg (1994) notes that "...one theme runs through the literature. The most important characteristic is automobile accessibility in a household." Teal (1987) found that "among households with fewer vehicles than workers, 38% of all household commuters are carpoolers, compared with only 15% when the Vehicle per Worker (VPW) ratio is at least one.

In his survey of the 1990 NPTS data, Ferguson (1995) also found that carpooling is sensitive to the number of vehicles in the household. Table 3- tabulates the percentage of carpooling found in households with different numbers of vehicles. It shows that commuters in households with no vehicles are almost twice as likely to carpool as those in households with four or more vehicles. For households with two or more vehicles, however (which accounted for 80% of the sampled households), the mode of travel to work was far less sensitive to the number of vehicles in the household.

Table 3-1. Impact of Vehicle Ownership on Carpooling

INCIDENCE OF CARPOOLING AS A FUNCTION OF HOUSEHOLD VEHICLES

Number of Household Vehicles	0	1	2	3	4+	All Households
Percent Carpooling to Work	26.5%	23.4%	14.9%	13.8%	13.5%	16.3%

Source: Ferguson, 1995

3.2.4 Individual Demographics

Most past researchers (Dobson and Tischer, 1977; Teal, 1987; and Ulberg, 1994, for example) have found little evidence that individual demographics can be used to explain carpooling tendencies. They have argued that carpoolers are much the same as drive-alones in terms of such characteristics as age, gender, and education. In a thorough early review of ridesharing research, Kostyniuk (1982) wrote that "There is agreement in the literature that any existing relationships between demographic and work-trip ridesharing behavior are very weak." More recently, in examining 1990 NPTS data, Ferguson (1995) found slight but significant differences between the demographic characteristics of carpoolers and solo drivers. While his findings may be helpful in separating markets and targeting advertising campaigns, the relationships do not appear to be sufficiently strong to affect the current mode choice modeling effort.

Age Teal (1987) and Ulberg (1994) found no evidence that age affected Carpool choices. While Ferguson (1995) found that workers under 25 and over 65 were somewhat more likely to be carpoolers, he noted that the relationship between age and carpooling, although statistically significant, was not very powerful.

Gender. Several researchers (Dobson and Tischer, 1977, Teal , 1987, Strgar-Roscoe-Fausch, 1987) have found that female and/or clerical workers are more likely to carpool than male and/or professional and managerial workers. Teal (1987) also found that married females were more likely to Carpool than unmarried females or married or unmarried males. Ferguson (1995) found that the 1990 NPTS data showed that 14.0% of working males carpooled, as compared with 19.1% of working females. He found, however, that "...male workers are almost 50% more likely than female workers to Carpool with non-household members."

Education. Teal (1987) argued that there was no relationship between carpooling and education. Ulberg (1995) found carpoolers responding to Seattle surveys to have lower education levels than solo drivers. Ferguson (1995) found that "...Education is one of the few demographic variables to show any systematic relationship with the composition of carpools." In reviewing 1990 NPTS data, he found that commuters with no high school diploma were twice as likely to Carpool, bicycle, or walk to work. As education increased above the high school level, the propensity to Carpool with strangers declined steadily. Whereas 28% of commuters with no high school diploma carpooled and 17% of those who had only a high school diploma shared rides to work, the percentage of carpooling dropped to 14% for commuters with some college experience and to 11% for commuters who had attended graduate school.

3.2.5 Attitudes and Perceptions

Attitudinal Research. Several researchers (Horowitz and Sheth, 1977, Henley, et al., 1981, and Ulberg, 1995) have explored the attitudes of carpooler and non-carpoolers through survey questions designed to elicit psychological perceptions of travel modes and document cognitive preferences for different modal attributes. Horowitz and Sheth (1977) for example, in a psycho-social analysis of ridesharers, identified primary differences between ridesharers and solo drivers in their perceptions of the convenience, reliability, comfort, and time savings of the two modes. These studies sometimes belabor the obvious. Kostyniuk, for instance, reviews a semantic differential analysis that showed that "...poolers liked to drive with others, whereas solo drivers did not, and poolers perceived a real cost savings whereas nonpoolers felt that the amount of savings was not worthwhile." While attitudinal preferences are undoubtedly important in modal choice, isolating these preferences for predictive purposes requires a survey capability which is beyond the scope of the current modeling effort.

Anti-Carpooling Disposition. Nearly every series of focus group discussions or market-oriented interviews which has addressed the issue of carpooling has identified a hard core of solo drivers who will not carpool under any circumstances. Members of this group have a variety of reasons for their stance, including the need for a car before, during or after work, variable working hours, a short commute trip, or a lack of suitable Carpool matches. The size of this hard core may vary, but it seems safe to estimate that at least one-third of the current crop of solo drivers in Southern California could not be induced to Carpool under any circumstances. [1] This attitude, or more accurately, this set of circumstances, places an effective upper limit on the benefits which may be expected from any new HOV facility.

It is important to recognize that the upper limit on the number of drive-alones who might be induced to Carpool through the addition of an HOV lane to a corridor can represent a relatively small proportion of

1 In a recent survey of Riverside County commuters, who reported average commute times of over one hour, 35% said they would not Carpool under any circumstances (DKS, June 1990).

current corridor drivers. A survey conducted in advance of HOV lanes on the Long Island Expressway (Bloch, et al., 1994) found that only twenty percent of existing expressway users were willing to consider carpooling as an option. Market research conducted prior to the opening of I-394 in Minneapolis determined that only ten percent of existing corridor users would consider switching to carpooling or busing when the Express Lanes were complete (Strgar-Roscoe-Fausch, Inc., 1986). Females under the age of 35 represented the most likely target for this mode shift.

3.2.6 Trip End Characteristics

Employment Density. Teal (1987) found a higher percentage of carpooling among auto users in SMSAs which favor transit trips – those with dense populations and concentrated employment patterns. These lead to high employment densities and higher parking charges. As noted earlier (Section 3.2.2), drivers who have to pay for parking are more likely to carpool than those who park for free, and employment density is a useful surrogate for parking costs.

A Melbourne study (Richardson and Young, 1981) investigating the relative dispersion of individual origins and destinations at either end of the work trip found that most of those Carpools that are found among non-household members are work-based. Richardson defined the work-end radius of the commute trip as the maximum straight-line distance between the driver's place of work and any passenger's work place. The home-end radius was similarly defined in terms of the maximum straight-line distance from the driver's home to the home of any one of his passengers. Armed with these definitions, the investigating team found that 70% of those Carpools formed outside a single household had a zero work-end radius (i.e. carpoolers all work at the same place). By way of contrast, only 12% of those non-home-based external carpools have a zero home-end-radius. This indicates that external Carpools tend to be formed by commuters who work together (or near one another) rather than by those who live near one another. The average work-end radius in Melbourne was found to be 1.1 km for external Carpools, considerably lower than the corresponding home-end radius of 5.2 km.

Employer Incentives. At the work end of the trip, employers may offer such ridesharing incentives as subsidized parking, special parking privileges or a transportation allowance for carpoolers. Alternatively, employers may allow carpoolers to use company-owned vehicles or install a program of flexible working hours which makes it easier for employees to work out carpooling arrangements. Recent surveys show that relatively few carpoolers are exposed to these programs. In Houston, only 15% to 20% of employers offer any sort of carpooling incentive (TTI, 1989). A recent Bay Area survey (Billheimer, June 1990) also found few employers offering incentives. The most-used incentives in the Bay Area were special parking privileges, which were offered by 11.7% of employers, and parking subsidies, which were offered by 8.5% of employers.

3.3 SUMMARY

Commuter interviews undertaken before and after the installation of specific HOV lanes and as part of broader nationwide surveys such as the National Personal Transportation Study all showed that the variable with the most consistent impact on carpooling choices are travel time and trip length. Carpooling tendencies increase significantly with both these variables.

Since an estimated 59% of all work-related carpools are formed within a single household, household size and vehicle availability are also important predictors of carpooling tendencies. The need to pay for parking at the workplace also influences carpooling choices, although less than ten percent of all commuters are faced with this requirement.

Three-person carpools are much more likely to be formed outside the home than two-person carpools. As a result, size is not the only difference between carpools using 3+ HOV lanes and those using 2+ lanes. The Carpools will differ markedly in both composition and ease of formation, factors which must be considered in predicting HOV demand.

While households with very low incomes show a higher propensity to Carpool, this factor has little impact on carpool formation once household income exceeds $30,000 per year. Individual demographics also serve as relatively weak predictors of ridesharing tendencies, although females tend to be more likely to share rides than males, particularly in household-based car-pools, and, the tendency to car-pool seems to be inversely related to one's education level.

In summary, then, the tendency to car-pool:

- increases with travel time;
- increases with trip length;
- increases with household size;
- increases as income drops below $30,000 per year;
- increases as parking charges are levied at the workplace;
- is only weakly related to age; and
- decreases with one's education level.

It is important to recognize that a large proportion of drive-alones either cannot or will not rideshare, and that the maximum proportion of solo drivers who might be induced to shift to car-pooling through the addition of an HOV lane to a corridor could be as low as twenty percent of these drivers. While such a shift could effectively double the number of carpoolers in many corridors, surveys suggest that greater inroads into the population of solo drivers aren't likely.

4. EXISTING METHODS

4.1 APPROACH

The literature review included technical reports, periodicals, computer models, and software documentation. The review began with a search of the National Technical Information Service (NTIS) and Transportation Research Information System (TRIS) data bases, as well as computerized files of newsletters, journals, business news sources and newspaper articles maintained by Dialog Information Service. Key words used in the search process included high occupancy vehicle lanes, reserved lanes, ramp metering, evaluation, assessment, demand, forecasting, prediction, mode shift. as well as various permutations and combinations of these words. In addition, members of the consulting team scoured the library shelves of their own firms and conducted a bibliographic search of the subject categories at the Institute for Transportation Studies (ITS) Library at the University of California at Berkeley.

Abstracts of reports and articles identified through the initial search process were reviewed and copies of promising references were obtained. Typically, a review of these reports would yield citations leading to other relevant references. Two survey articles which were particularly useful in this regard were a state-of-the-art review of demand analysis for ridesharing from Transportation Research Record 876 (Kostyniuk, 1982)' and a literature review undertaken by Charles River Associates (CRA) in developing an early demand prediction model (CRA, 1982). The reference list assembled in this fashion was submitted for the review of the consulting team and members of a Steering Committee of state DOT representatives, MPO members, university researchers, practitioners and federal transportation officials assembled under the supervision of FHWA. This process led to the identification and review of over seventy references listed in the bibliography of this report.

4.2 REGIONWIDE LOGIT MODELS

4.2.1 OVERVIEW

The most prevalent approach to the regionwide estimation of HOV lane mode shares entails the use of disaggregate logit models embedded in the traditional four-step transportation planning process of (1) trip generation; (2) trip distribution; (3) mode split; and (4) traffic assignment. Typically these disaggregate models have been respecitied to handle carpool modes as well as transit and solo driving, either simultaneously or sequentially in "nested' formats which separate auto and transit ridership before addressing carpool mode shares.

'A reference list appears in Appendix C, organized alphabetically by author. In-text references to this list give the author's name and the year of publication (e.g., Kostyniuk, 1982). When the same author has more than one reference in the same year, the month of publication is included to identify the specific work.

4.2.1.1 Model Definition

Mathematical Formulation. The conventional multinomial logit formulation for mode share estimation can be represented as:

$$P_i = \frac{\exp(U_i)}{\sum_j \exp(U_j)} \qquad \text{(Equation 4.1)}$$

where:

P_i = probability of choosing mode i;

j = modes 1 to "n"; and

U_i = $U_i (S, X_i)$ = the utility to an individual of mode i as a function of transportation level of service variables and an individual's socioeconomic characteristics.

Additional details on the logit model may be found in Horowitz, et al. (1986), and the model's use in predicting HOV demand is well-treated in the Charles River Associates Report "Predicting Travel Volumes for HOV Priority Techniques" (Charles River Associates, 1982).

Model Input. The logit model formulation can accommodate a wide variety of input parameters in estimating the utility U_i of individual modes. Parameters used as explanatory variables in mode-share models have included the trip characteristics, tripmaker attributes, and trip-end descriptors listed below.

Table 4-1. HOV Mode Split Explanatory Variables

TRIP CHARACTERISTICS	TRIPMAKER ATTRIBUTES	TRIP-END DESCRIPTORS
TRAVEL TIME	HOUSEHOLD INCOME	EMPLOYMENT DENSITY
Waiting time	WORKERS/HOUSEHOLD	EMPLOYER INCENTIVES
Carpool pick-up time	AUTO AVAILABILITY	Subsidized Parking
Line-haul time	NEED FOR CAR BEFORE	Special Parking
Distribution time	DURING OR AFTER WORK	Privilege
TRIP DISTANCE	HOUSEHOLD SIZE	Flexible Hours
TRAVEL COST	LENGTH OF RESIDENCE	Transportation
Parking charges		Allowance
Gasoline costs		
Tolls		
HOV TIME SAVINGS		

4.2.1.2 Model Features

Nested Models. While Equation 4.1 implies a simultaneous selection process in which all modes compete for travelers at the same time, some regional logit models (Barton Aschman, 1986; Southern California Association of Governments, 1986) use a sequential or nested approach. These models first make the split between auto and transit, and then use submodels to divide auto users into drive-alone and two- or three-person carpools. This "nested" approach appears to replicate real choice procedures better than models in which carpools of various sizes and solo autos compete directly with transit for a fixed number of travelers.

Pivot Point Models. The pivot point, or incremental logit, model is a simple adaptation of the multinomial logit model that generally improves accuracy by predicting changes in existing travel behavior. The data input requirements consist of information on existing mode shares and changes in transportation service characteristics. Parody (Charles River Associates, 1982) notes that the incremental approach, in which model coefficients are used to pivot about existing mode shares, "...reduces data requirements and eliminates the need for detailed socioeconomic and level of service data for each household or traffic analysis zone." He further observes that "in general, the model coefficients from nearly any multimodal mode choice logit model can be reformulated into a pivot point model."

The basic form of the pivot point logit model is:

$$P_i' = \frac{P_i \exp(\Delta U_i)}{\sum_j P_j \exp(\Delta U_j)} \qquad \text{(Equation 4.2)}$$

where:

P_i' = new share of mode i;

P_i = original share of mode i;

j = all available modes; and

ΔU_i = change in utility for mode i

4.2.2 EXAMPLES

Table 4-2 lists the key features of a number of regionwide logit models designed for use in various urban areas. The table identifies the area, lists a reference describing the model in detail, documents the modes accepted by the model (in sequential stages for nested models), and lists the input variables used as a basis for modeling mode selection.

4.2.2.1 Input Data Needs

All of the models in Table 4-2 are multinomial logit formulations designed for use in a traditional regional urban transportation planning system (UTPS) network. As such, they require node-link representations of each of the networks represented in the mode choice model. At a minimum, this includes:

- Highway network time and distance files;
- HOV network time and distance files;
- Transit network time and distance files; and
- Zonal data reflecting model parameters (i.e. parking costs; household income; auto occupy tables; auto ownership; workers/household; HOV lane access; transit availability; transit fares).

Table 4-2. Summary of Selected Regionwide Logit Models

Model/Area	Reference	Mode Split Process		Model type	Variables	
		First Stage	Second Stage		Trip Descriptors	Socio-Economic
Metropolitan Washington COG	Barton Aschman, 1986 Ecosometrics	Drive Alone Transit Pool	Pool (2) Pool (3) Pool (4+)	Nested Multinomial Logit	Time, Cost, HOV Savings	Household Auto Ownership
Southern California Association of Governments	SCAG, 1986 Barton Aschman, 1987	Transit Auto	Walk Access Drive Access Pool Access Drive Alone Pool (2) Pool (3+)	Nested Multinomial Logit	Time, Cost, Income	Auto/House Drivers/HH Workers/HH Income
Network Performance Evaluation Model	Carnegie Mellon, Oak Ridge, Janson, et. al. 1987	Auto (1 or 2) Transit Pool (2) Pool (3+)		Multinomial Logit Iterative Assignment	Time, Cost	Income Zonal Land Area
San Francisco Metropolitan Transportation Commission	Kollo, 1987 Pulvis, 1988	Drive Alone Transit Pool (2) Pool (3+)		Multinomial Logit	Time, Cost	Autos/HH Workers/HH Employment Density Income
North Central Texas COG	NCTCOG, 1990	Drive Alone Pool (2) Pool (3+) Transit (walk) Transit (Drive)		Multinomial Logit	Time, Cost	CBD Attraction Autos/Person Choice/No Choice quadrants

The model also requires home-based work (HBW) trip tables linking all origin destination zones, as well as base-period traffic counts and transit ridership data for calibration and validation purposes.

The development of these regionwide models can require substantial commitments of time and resources. TTI (1988) estimates that the development of a workable regionwide model can require ". . .18-24 months of intensive effort." Most MPOs large enough to consider HOV lanes have already invested the effort in developing regionwide network models, although not all of them have incorporated existing or potential HOV networks into the models.

4.2.2.2 Typical Procedures

Mode Split. The regional UTPS approach to HOV demand estimation can be represented by any of the models listed in Table 4-2. In the nested model developed for the Southern California Association of Governments (SCAG, 1986), these models are used to separate modal shares. After a binary mode choice model estimates transit and auto shares, a disaggregate mode choice model developed by Cambridge Systematics (CSI, 1993) splits the auto share into shared-ride and drive-alone trips. Finally, a third mode choice model, developed by Barton Aschman Associates (Barton Aschman, 1987) splits the shared-ride trips into carpools of two persons and carpools involving three or more persons.

Supply/Demand Interaction. Travel time is an important component of the mode-share models embedded in the UTPS procedure. Accurate predictions of travel time, however, must reflect anticipated conditions of congestion on freeways, HOV lanes and arterials, which in turn are affec ted by modal choices. Traditional regionwide planting models may require several successive iterations of the traffic assignment and mode split procedures before the predicted mode shares accurately reflect congestion conditions on HOV facilities and adjacent mixed-flow lanes. For example, the SCAG model described above typically requires fifteen iterations before equilibrium is achieved.

4.2.3 CRITICAL ASSESSMENT

4.2.3.1 Advantages

Regionwide logit models are mathematically tractable and widely used in regional planning, so that their use is well understood in the planning community. Since the models incorporate a regionwide network, they are particularly useful in representing the network impacts of HOV lanes, such as the diversion of carpool and solo driver trips from parallel routes.

4.2.3.2 Disadvantages

Data Requirements. The use of regionwide network models require extensive data input and model calibration. This can be a cumbersome process when the issue at hand deals with the impact of HOV lanes on a limited number of corridors.

Recalibration. Regionwide models require extensive recalibration from location to location. TTI (1988) cautions that ". . .these models generally are not directly transferable from one urban area to another," and Galbraith and Hensher (1984) found it ". . .very difficult to define criteria that would enable a model to be transferred to another area," Recalibration is not only a geographic issue. Bedoe and Miller (1995) found that a model calibrated for use in Toronto using 1964 data performed very poorly in replicating 1986 travel patterns and concluded that ".. .model parameters had not remained stable over time." Thus recalibration was necessary to ensure temporal transferability as well.

Speed and Delay Estimation. Traditional regionwide network models have limited ability to estimate the operational impacts of HOV facilities on speed, average delays, and traffic queues. As highway networks become more and more congested, regionwide models are less and less successful in estimating travel times and delays. In particular, they fail to replicate the manner in which congestion queues transmit delays throughout the system. As a result, they are ill-equipped to represent the travel-time advantages provided by HOV lanes that are crucial in influencing shifts to ridesharing modes.

Validation. As a practical matter, regionwide logit models have historically not performed well in replicating the impact of HOV facilities on actual mode choices. A JHK report (JHK, 1994) observes that ". . .in the application of travel demand models, there are frequently considerable discrepancies between HOV model estimates and observed roadway counts of multi-occupant vehicles." TTI (1988) further cautions that "regional mode-choice models in general, and regional mode-choice models with components in particular, have not performed well in terms of their ability to predict mode shares." In view of the fact that most regional models of HOV use were not originally designed to handle trip-dependent changes in travel time and have been carved out of traditional logit models developed with only two modes (transit and auto) in mind and calibrated to match overall corridor flows, it is hardly surprising that they have not performed well in representing the impact of HOV lanes on mode share.

4.2.3.3 Summary

Although regional logit models are used widely to analyze the network-wide impacts of alternative systems, they do not seem to be flexible enough to focus on the corridor-specific impacts of HOV facilities. Existing regionwide models tend to be data-intensive and require extensive recalibration to accommodate transfers both from location to location and from one time frame to another. They are ill-equipped to represent the operational impacts of HOV lanes on travel times and have historically not performed well in predicting the impact of these lanes on modal shifts.

4.3 CORRIDOR MODELS

4.3.1 OVERVIEW

4.3.1.1 Model Formulation

Many attempts to model HOV demand have focused on a single corridor, usually ignoring impacts of HOV facilities in the broader regionwide network and sometimes glossing over the interdependencies between mode choice and travel times on HOV facilities and adjacent mixed-flow lanes. While some of these models use the multinomial logit formulation described in connection with regionwide network models, others use quick-response regression relationships in which HOV lane usage is computed as a function of travel time savings (for example, Mann, 1983, Parody, 1984, or Wesemann, 1987) or some other measure of congestion.

Corridor models can also differ markedly with respect to their field of vision within the corridor. For example, such models can include parallel routes, limit their field of vision to a single freeway (or arterial), or focus on a single point along a freeway segment.

Parallel Route Models include two or more parallel routes and typically model the interactions between these routes in an attempt to replicate the spatial responses, or diversion, which occurs when drivers switch routes.

Single Route Models ignore parallel routes to focus on a single route within the corridor. This narrower focus usually precludes the consideration of spatial response to proposed changes (i.e. diversion from parallel routes), simplifying the modeling approach at the expense of more robust results.

Critical Point Models focus on a single point along a route (usually the most congested point) and compute the traffic performance along the entire route as a function of the congestion at that point. These approaches greatly reduce data input requirements and simplify modeling efforts at the expense of overall performance data.

4.3.1.2 Demand Models vs. Supply Models

Corridor Demand Models. Some corridor models of HOV demand (i.e. Mann, 1983 and Wesemann, 1987) ignore the interaction between mode choice and travel time, accepting the travel time differential between HOV lanes and mixed-flow traffic as a given input variable and using it to compute the demand for carpools in the corridor. Other models (i.e. Small, 1977 and Talvitie, 1978) treat the interaction between demand and travel time explicitly by iterating between demand model results and travel time models until convergence is obtained.

Traffic Flow Simulations. In recent years, a number of macroscopic simulations of freeway conditions have been developed as an aid for studying the detailed impacts of design alternatives on speed, delays, and traffic queues in a specific corridor. Examples of these simulation models include FREQ (May, 1991) and FREFLO (FHWA, 1992). These models typically take the demand for access to HOV lanes and mixed flow lanes within a specific time frame as an input variable in simulating the propagation of traffic queues and congestion delays from one section of the freeway to another. Although these models focus on the elaborate delineation of freeway operations data, they can be used iteratively with corridor demand models (Scapinakis, et al., 1991) or with regionwide network models (JHK, 1994) in computing the impact of HOV lanes on mode choices.

4.3.1.3 Section Contents

This section reviews both corridor demand models designed to predict mode share as a function of freeway operations and supply models designed to predict freeway speeds and delays as a function of external demand, as well as attempts to combine both sets of models in a unified approach.

4.3.2 DEMAND MODELS

Table 4-3 lists the key features of a number of demand models designed to estimate the mode split among solo drivers, carpoolers, and transit users in a transportation corridor. The table identifies the corridor location, lists references describing the model in detail, documents the modes accepted by the model, and documents the input variables used as a basis for modeling mode split. The models are listed in approximate chronological order.

4.3.2.1 Logit Models

A number of investigators have applied the logit model formulation described earlier (See Equations 4.1 and 4.2) in estimating the impact of HOV lanes on mode choice within a single corridor. Cambridge Systematics (1977) used a pivot point logit model in estimating the effects of Carpool incentives for the Department of Energy. Coworkers from the Institute of Transportation Studies at the University of California in Berkeley (Kruger, et al., 1977) developed a disaggregate mode choice model designed to explore the implications of priority treatments by splitting corridor trips among four competing modes. The four modes were (1) noncarpooling auto; (2) Carpool (either 2+ or 3+ occupants); (3) bus with walk access; and (4) bus with auto access (park-and-ride). At the same time, Small (1977) combined a similar disaggregate model with a simple traffic flow model and Cilliers, May and Cooper (1978) incorporated the methodology into the FREQ traffic flow simulation. The results of these disaggregate modeling procedures suggested that increases in carpooling were almost directly proportional to the travel time differences between carpooling and solo driving afforded by priority treatments.

Talvitie (1978) developed a similar dissagregate model for the I-580 corridor in San Francisco that uses a logit model as the first stage in a three-stage process of (1) predicting demand; (2) calculating level-of-service parameters; and (3) equilibrating between demand and level-of-service estimates. While this model explicitly considers the interaction between demand and supply on both freeways and parallel arterials in the travel corridor, the author acknowledges that the supply model used is too insensitive to changes in highway capacity.

Table 4-3. Summary of Selected Corridor Demand Models

Model	Reference	Mode Split Method	Model Type	Variables: Trip Descriptors	Variables: Socio-Economic
Cambridge Systematics	CSI, 1977	Drive Alone Transit Carpool	Multinomial Logit, Pivot Point	Change in Travel Time and Cost by Mode	Location, Income, Auto Availability
UC. Berkeley	Kruger, et. al., 1977 Small, 1977 Cilliers, 1978	Non-Carpool Carpool (2+ or 3+) Bus (walk) Bus (Drive)	Multinomial Logit	Time and Cost Walk and Wait Time Bus Transfers	Income, Age, Length of Residence, No. of Children
I-580, San Francisco	Talvitite, 1978	Drive Alone Shared Ride Bus Bart	Multinomial Logit	Access Time Line Haul Time	Household Characteristics
Metropolitan Washington COG	Mann, 1983	Car Occupancy Distributions	Regression Nomograph	HOV Time Savings	None
Charles Rivers Associates	Parody CRA, 1984	Drive Alone Pool (2) Pool (3+) Transit	Pivot Point Regression	Change in Travel Time by Mode	None
Orange County	Wesemann, 1987	HOV Formation (% of Base)	Pivot Point Table Look-up	HOV Time Savings Trip Length	None
Texas Transitway	TTI, 1988	Drive Alone Transit Pool	Trip Table	Modal Time	Destination Attractions
Riverside County	DKS, 1990	Drive Alone Pool	Nonlinear Function	HOV Time Savings	Hard Core Drive Alone
Dallas	Poe, et. al. TTI, 1994	HOV Lane Use as a % of ADT	Regression	Congestion Level (ADT/Lane)	None

4.3.2.2 Regression Models and Trip Tables

A number of investigators (Mann, 1983, Parody, 1984, Poe, et al., 1994) have used linear regression relationships to model the effects of HOV lanes on mode share. In most cases, these models have used the travel time savings in the HOV lane as an independent variable to predict carpooling tendencies. These models mimic the relationships of the more complex logit formulations, which also showed mode share to be a nearly linear function of travel time differences.

Mann (1983). Mann reports on a technique developed to predict the use of carpools on HOV lanes in the Washington, D.C. region. The technique was developed by the Metropolitan Washington Council of Governments/Transportation Planning Board (COG/TPB) and uses a regression analysis in conjunction with nomographs designed to translate data on average vehicle occupancies into estimates of individual occupancy rates to predict the impact of HOV lanes on zone-to-zone auto occupancy rates. The regression relationships are plotted below in Figure 4-l.

As shown, the model uses data from ten existing HOV facilities to develop optimistic and pessimistic estimates of the impact of HOV time savings on car occupancy statistics. The author himself indicates that one drawback of the model is the limited number of data sets then available to support HOV demand estimates.

Another drawback lies in the fact that the model mixes data from HOV lanes requiring two or more persons (Los Angeles ramps, Honolulu freeways, Miami I-95) with lanes requiring three or more occupants (Shirley Highway, Santa Monica Diamond Lanes, El Monte Busway, and the San Francisco/Oakland Bay Bridge). Subsequent research (see, for example, Ulberg, 1994) suggests that the mechanism for Carpool formation differs greatly when occupancy requirements are raised from two to three persons.

Parody (1984). After undertaking a thorough review of existing techniques for predicting travel volumes on HOV facilities (Charles River Associates, 1982), Parody (1984) developed a set of demand and supply models based, respectively, on regression relationships and speed-volume relationships. The demand models were estimated using a consistent set of before-and-after empirical data from seven HOV facilities (Shirley Highway, El Monte Busway, U.S. 101, Banfield Freeway, Miami I-95, Boston's Southwest Expressway, and the Lincoln Tunnel). Five of these facilities were observed before and after the introduction of different priority requirements, providing additional pairs of observations.

The demand model formulation that produced the most favorable results for all modes is listed below:

$$\frac{V_1^m - V_0^m}{V_0^m} = a_0 + \sum_i a_i \frac{(T_1^i - T_0^i)}{T_0^i} \qquad \text{(Equation 4.3)}$$

where:

V^m_0	=	peak hour before volume for mode m;
V^m_1	=	peak hour after volume for mode m;
T^i_0	=	before travel times for modes i to m;
T^i_1	=	after travel times for modes i to m;
$a_{o,i}$	=	calibration coefficients.

Supply models were developed using traditional speed-volume relationships from the Bureau of Public Roads and combined with the demand models through a set of worksheets that predicted equilibrium flows of non-carpooling vehicles on general purpose freeway lanes and carpools and buses on HOV lanes.

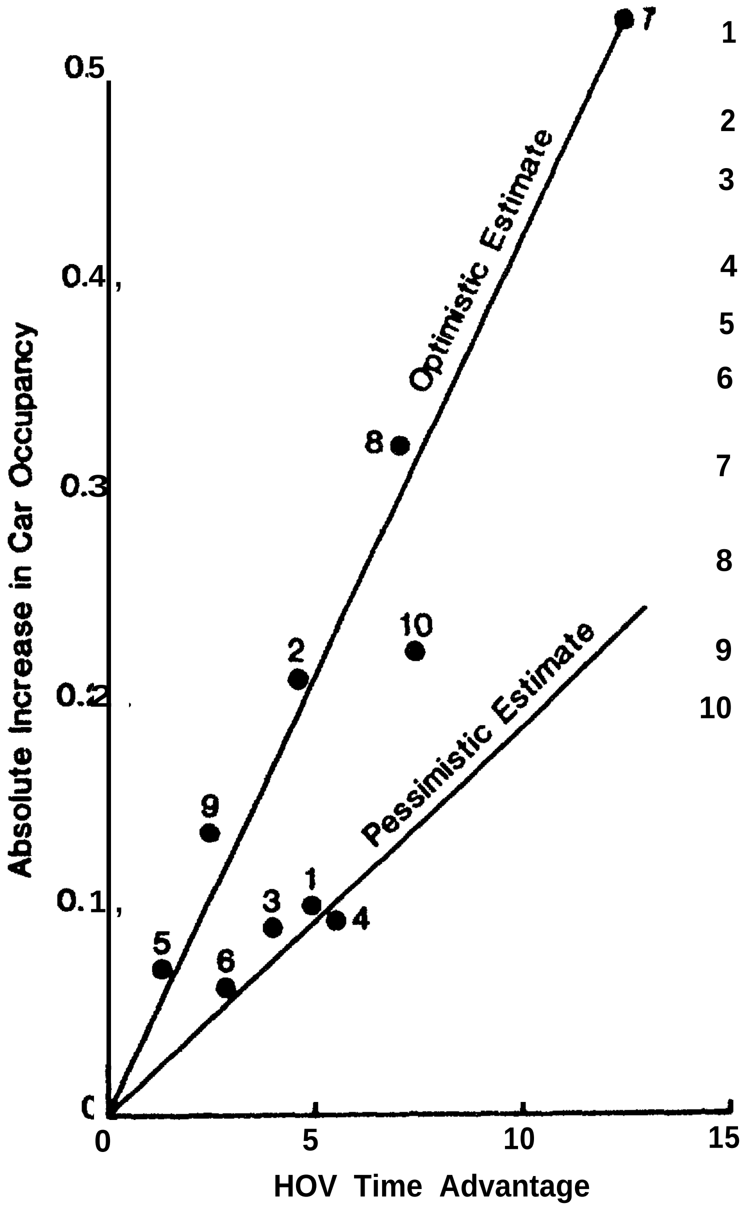
Parody characterizes this approach as a "quick-response" sketch planning techniques that could be subjected to additional and possibly more refined analyses. As in the case of Mann (1983), the data set used to calibrate the model is somewhat sparse, consisting of only twelve-before-after pairs. However, test applications of these procedures on the original data set yielded favorable results, producing average errors of less than four percent for the non-priority auto and bus modes, and less than fourteen percent for the carpool mode. Subsequent applications of the model to more recently developed HOV lanes (Billheimer, May 1990) also showed that the model performed credibly in predicting HOV lane usage.

Orange County. A simpler procedure for estimating demand on HOV lanes was developed by Wesemann (1987) for use in Orange County, California. The procedure reflects rates observed on facilities similar to those planned for Orange County and is summarized below in Table 4-4.

Table 4-4. Orange County HOV Lane Patronage Factors
Factors Used In Estimating Transitway Person Trip Usage For Transitways And Commuter Lanes In Orange County, California

Category of Travel TimeSavings	% of Existing Trips Shifting to Transitways: Trips 7 Miles Or Less in Length	Trips Greater Than 7 Miles In Length	% Increase in HOV Formation For Trips Using Transitways
Less than 5 minutes	No Shift	No Shift	No Increase
5-9 Minutes	No Shift	65-75%	20-30%
10-14 Minutes	No Shift	75-85%	30-40%
15 Minutes or Greater	No Shift	85-95%	40-50%

Source: Wesemann (1988)



1 San Francisco Oakland-Bay Bridge Approach
2 Honolulu-Moanaloa Freeway
3 Los Angelos-Santa Monica Freeway
4 Miami-I 95
5 Portland-Banfield Freeway
6 Average of 56 Los Angeles ramps
7 Washington, DC-Shirley Highway
8 Los Angeles-San Bernardino express lanes
9 Honolulu-Kalanianaole Highway
10 Miami-South Dixie Highway

Source: Mann 1983

Figure 4-1
Impact of HOV Facility based on Washington COG/TPB Model.

This demand model segments responses by trip length and is based entirely on the amount of time saved by the HOV facility. The model predicts no increase in HOV formation until travel time savings exceed five minutes. This flies in the face of experience on many HOV lanes in Northern and Southern California, which have experienced significant increases in carpool usage in response to travel time savings of two to four minutes. (Billheimer, May 1990). Carpooling on Los Angeles Route 91, for example, increased over 70 percent in response to an average savings of three minutes, while carpooling on Santa Clara Route 101 increased by 30% in response to a similar change. One possible reason why relatively minor savings in commute time have produced seemingly disproportionate mode shifts is that drivers tend to overestimate the time to be saved through the use of HOV lanes.

Texas Transitways. An alternative approach to HOV demand estimation developed by Texas Transportation Institute (TTI, 1988) uses trip tables which focus on employment centers served by specific HOV lanes. This technique was based on experience from Houston's Katy (I-10W) Transitway and entail the following steps:

Step 1: Define Transitway Marketing: Area by identifying the major activity centers served by a transitway;

Step 2: Compile Trip Tables. Census tracts where trips to the identified activity centers are likely to originate are identified, and Census Journey-to-Work files are used to estimate the number of person trips between each origin and the defined destinations.

Step 3: Estimate Carpool Mode Splits: Carpool mode splits for the identified activity centers are estimated using historical data. As a guide for this process, TTI offers the Katy Transitway information shown below is Table 4-5:

Table 4-5. Katy Transitway Characteristics

Activity Center	Trip Length (miles)	Total Employment	Square Feet Office Space (millions)	Employees/ Million sq. ft.	2+ Carpool Mode-Split
Downtown	13	178.300	51.8	3440	20%
City Post Oak	9	78.100	25.3	3090	25%
Greenway Plaza	13	34.200	12.1	2800	24%
Texas Medical Center	19	49.700	9.8	5100	15%

Source: TTI (1988).

This procedure suggests that for large activity centers with employment densities in the range of 3,000 to 3,500 employees per million square feet of office space and trip lengths in excess of ten miles, mode splits of 20-25% could be used in sketch planning applications. The exception to the rule is the Texas Medical Center, whose 24-hour a day, seven-day-a-week operation were not judged by the TTI authors to be "...particularly conducive to ridesharing arrangements."

Step 4: Assign Carpool Vehicle Trips to Transitway. Once the mode split is accomplished, trips are assigned to the transitway manually. This procedure provides results for peak-period demands for 2+ carpools. If analyses using other occupancy requirements and/or time periods are needed, TTI offers the following conversion factors based on Houston experience:

- To convert vehicle movement to person movement, multiply by 2.2.
- To convert from peak-period to peak-hour, multiply by 0.50.
- To convert from 2+ Carpool demand to 3+ carpool demand, multiply by 0.20.
- To convert unauthorized Carpool demand to authorized Carpool demand (i.e. if carpooling requires special identification or training), multiply by 0.60.

As presented, this approach relies exclusively on information from a single source, and demands some independent judgment on the part of the user, who must decide, at a minimum, which activity centers are “particularly conducive to ridesharing.” It is possible that the method’s application range could be broadened by analyzing and incorporating data from other locations, but this step remains to be taken.

Dallas Poe, et al. (1994) developed a simple regression model for use in developing preliminary planning estimates of future demand for HOV facilities in Dallas. HOV traffic was established through the use of a regression equation relating HOV ridership, expressed as a percentage of average daily traffic (ADT) levels, to overall corridor congestion, estimated as a function of ADT levels per lane. A graph of this regression relationship appears in Figure 4-2.

The regression relationship shown in Figure 4-2, suitably adjusted to reflect local conditions, and iterated until HOV ridership and congestion conditions are in balance, enables planners to develop preliminary projections of HOV ridership for various combinations of future traffic levels and alternative freeway designs. While this approach is simple, coherent, and logical, it uses fairly crude estimates of HOV ridership and congestion that are based on ADT measurements and are heavily tied to Houston data. The authors note that the Houston data are adequate for cities with similar land use patterns and densities. In most cases, however, planners will need to adjust the regression equations to reflect local conditions, traffic directionality, and the percentage of ADT occurring during the peak period.

4.3.3 SUPPLY MODELS

As drivers shift to Carpools and begin to use HOV lanes, the level of service on adjacent mixed flow lanes is affected. Significant shifts can improve flow in adjacent lanes, reducing the travel time savings available in the HOV lanes, and therefore lowering the incentive to use these lanes. While some models of HOV demand ignore the interaction, others have gone to great lengths to replicate levels of service in both HOV and mixed-flow lanes. Because the estimation of HOV travel time savings is crucial to the prediction of HOV mode shares, this section reviews the model and methodologies used to predict the impact of traffic flows on average traffic speeds.

4.3.3.1 Travel Time Estimation

Recent research shows that freeway speeds are comparatively insensitive to traffic flows until the flows reach capacity. When the volumes exceed capacity, then the average travel speed is determined by the extent of queuing at various bottlenecks along the freeway.

The BPR Curve. Regional planning models (e.g. UTPS, TRANPLAN, MINUTP, etc.) all incorporate a relatively simple speed-flow relationship originally developed by the Bureau of Public Roads (BPR) This curve uses the volume/capacity ratio to reduce the initial free-flow speed to a congested speed. The same curve is often applied to both arterials and freeways and is employed in queuing (v/c > 1) and non-queuing (v/c < 1) situations. This simplification tends to over-estimate speeds for arterials and for queuing situations.

The standard equation for the BPR curve is:

$$\text{Congested Speed} = [\text{Free Flow Speed}] / [1+0.15 * (v/c)^4]$$

where v/c = Volume/Capacity Ratio

Highway Capacity Manual Curve. The 1985 and 1994 Highway Capacity Manuals (HCM) also use the volume/capacity ratio to estimate freeway speeds. Figure 4-11 compares freeway speeds as a function of the volume/capacity ratio for both the 1985 and 1994 Highway Capacity Manuals and the BPR curve. As can be seen, the BPR curve falls between the 1985 and 1994 HCM curves. The greatest discrepancy between the BPR and HCM curves occur at the point at which volume equals capacity. Since most HOV lanes are installed on freeways operating under conditions of congestion, the estimation of speed-flow relationships in this range is of key importance in modeling HOV impacts.

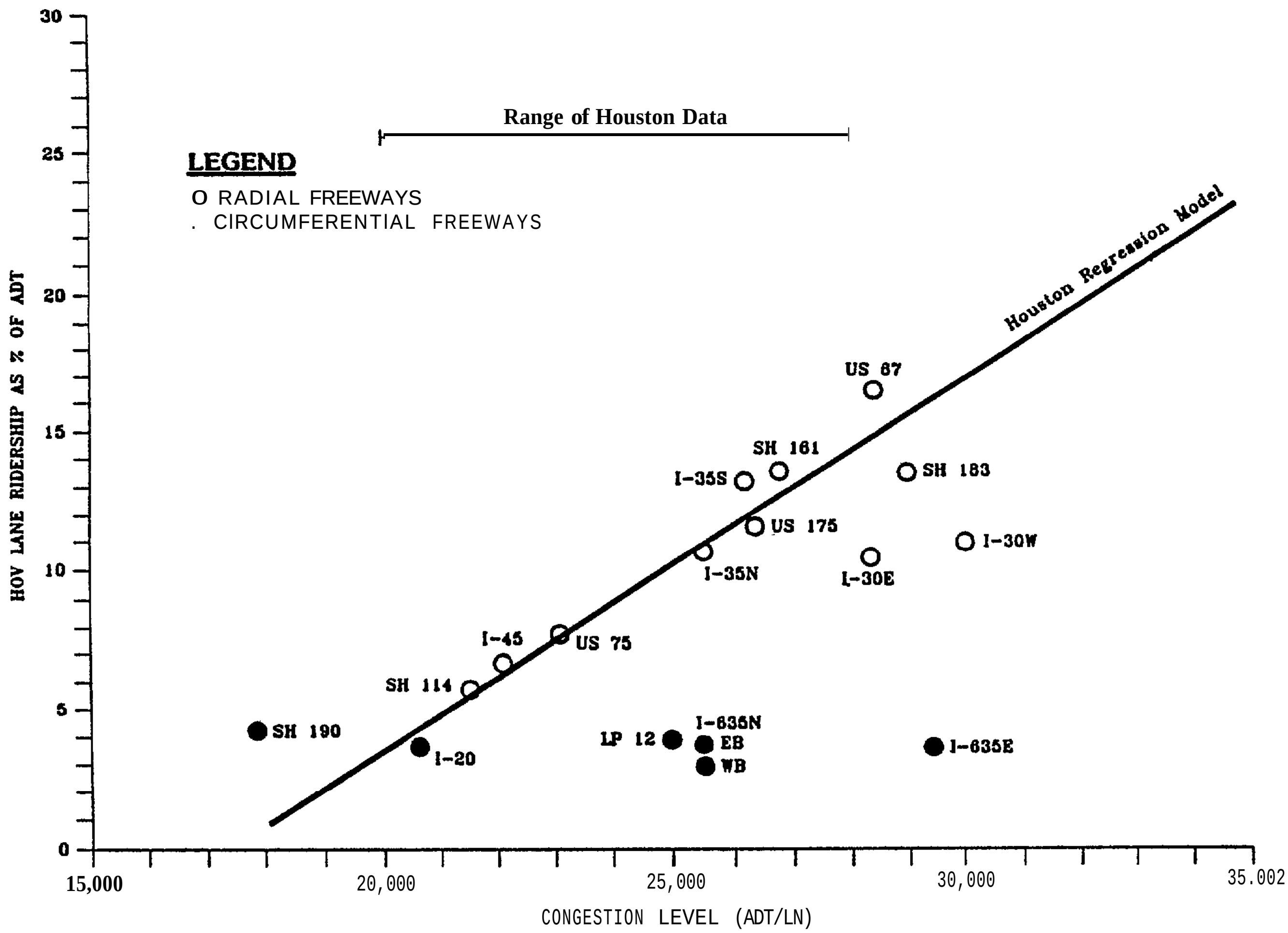


Figure 4-2
Houston Regression Model Relationship
Between HOV Ridership and Congestion Levels.

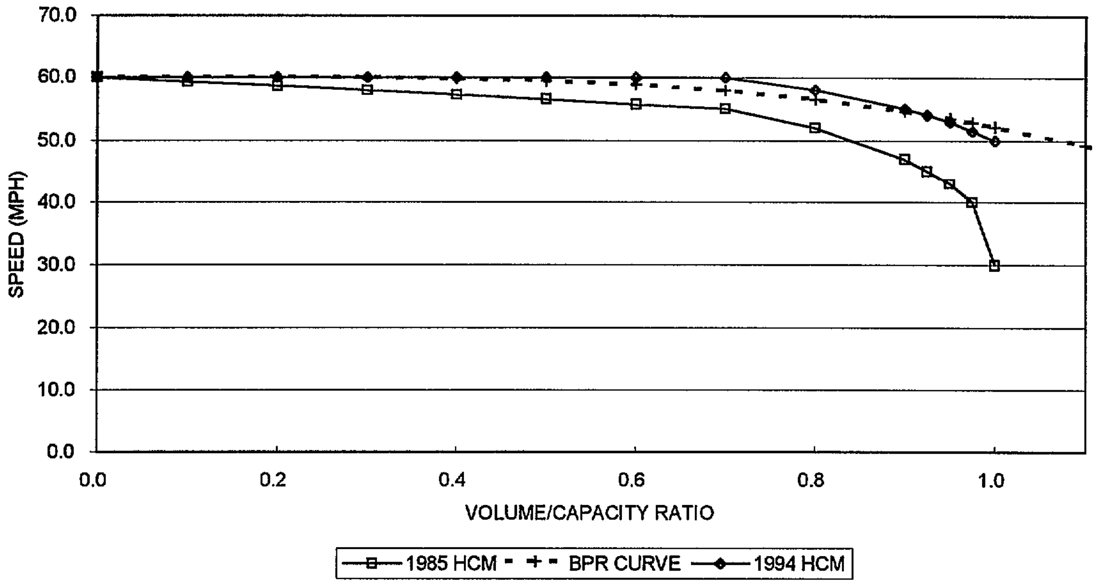


Figure 4-3. The BPR and HCM Speed Flow Curves

Because of the importance of understanding speed-flow relationships under conditions of congestion, many researchers have attempted to model those conditions in some detail. The following subsection describes several simulation models developed to replicate freeway flows as traffic volumes approach and exceed capacity.

4.3.3.2 Freeway Simulation Models

FREQ. FREQ is a macroscopic simulation model capable of modeling HOV lanes, adjacent freeway lanes and HOV ramp bypass facilities. The first version of FREQ was developed in 1970 by Adolf D. May and others at the University of California at Berkeley. The model has evolved through a number of modifications to produce the current parallel versions FREQ 11 PL (where PL signifies priority lanes) and FREQ 11 PE (where PE signifies priority entry). These models are discussed in some detail in Scapinakis (1991) and May, et al. (1991).

FREQ simulates traffic flow on a mainline freeway by dividing the freeway into subsections and the study time period into discrete time slices. The on ramp and mainline demands or service during each time slice are loaded into each subsection. If demand exceeds capacity, a queue is generated and the queue propagated upstream into later time slices. Downstream mainline demands are reduced according to the discharge capacity of each bottleneck subsection.

The use of the FREQ model in simulating HOV lanes has been well documented (Bacon, et al., 1994). FREQ 11 PL simulates an HOV facility by treating the facility as if it had been split into two separate roadways (HOV lanes and mixed-flow lanes) and analyzing each facility separately. Speed-flow curves and capacity restraints for HOV lanes differ from those used for mixed-flow facilities. The model has been modified through the addition of modules capable of analyzing both modal splits and spatial shifts, and is capable of simulating the following four situations:

- (Day – 1) Before implementation of the HOV lane.
- (Day + 1) Immediately after implementation of the HOV lane.
- (Middle term) After implementation of the HOV lane with spatial response.
- (Middle term) After implementation of the HOV lane with modal response.

FREQ simulates spatial responses to HOV lanes by modeling a representative arterial running parallel to the freeway. As carpoolers shift from the mixed-flow lane to the newly created HOV lane, travel times improve on the mixed-flow lane, inducing some vehicles to shift from the parallel arterial (which can represent the capacity of a number of roadways) to the freeway.

The model can also simulate modal shifts, which are assumed to occur after spatial shifts. Modal shifts are predicted using a multinomial logit model (Cilliers, 1978) calibrated with data from San Francisco. (If desired, the user can recalibrate the model using elasticities from another locale). The modal shift is accomplished through an iterative process in which a small number of vehicles are shifted from the mixed-flow lanes to the HOV lane. Travel times are recalculated, and the process continues until the travel time savings no longer induce mode shift.

The FREQ model has been in use for a number of years and is widely accepted as a useful tool for simulating mainline freeway sections. The model's unique features is its ability to simulate, at a macroscopic level, congested traffic flow conditions under alternative operating scenarios. Because of the heavy data input requirements and the complex set of calculations needed to replicate traffic queues and the promulgation of shock waves, however, the model itself is not likely to be part of a quick-response demand estimating procedure. It could, however, be part of a multi-level screening process in which more complex procedures are used to compute impacts too complex to be estimated through the use of quick-response techniques.

FREFLO. FREFLO is a macroscopic simulation model that represents traffic on a freeway in terms of aggregate measures of traffic flow, density, and speed. FREFLO is part of FHWA's TRAF system of models (FHWA, 1991) and is capable of modeling both HOV and mixed-flow lanes. This simulation models freeways as a series of sections which traffic attempts to enter. The capacity of each section determines the traffic flow that can be passed on to the next section within a specific time frame.

4.3.3.3 Arterial Simulation Models

The simulation of speed on arterial roadways is sensitive not only to volume/capacity ratios but also to signal timing and the spacing of intersections.

Macroscopic Simulations. Macroscopic simulations of arterial traffic flow apply deterministic relationships to individual roadway sections. Representative models include:

TRANSYT-7F, a model developed by the FHWA, that simulates given non-dynamic traffic flows in a signalized surface street network and optimizes signal timing parameters.

SATURN, a surface street simulation model that combines an operational evaluation of traffic signalization parameters with a traffic assignment technique. SATURN was developed at the Institute for Transportation Studies, University of Leeds.

CONTRAM, a surface street network simulation model that evaluates and optimizes traffic signalization. CONTRAM was developed by the British Transport and Road Research Laboratory.

Microscopic Simulations. Microscopic models simulate the movement of individual vehicles, based on theories of car-following and lane-changing. Typically, vehicles enter a transportation network using a statistical distribution of arrivals (a stochastic process) and are tracked through the network on a second-by-second basis. Representative models in this category are:

FRESIM, a model developed by the FHWA for simulation of freeway traffic operations.

NETSIM, a model developed by the FHWA for optimization of traffic signal timing in a surface street network.

INTEGRATION, a model that was developed to evaluate and optimize the operation of integrated freeway/signalized arterial networks during recurring and non-recurring congestion.

The INTEGRATION model can be used to represent an entire freeway corridor, along with numerous parallel arterials. Bacon, et al. (1994) describe the processes needed to model HOV lanes using the

INTEGRATION simulation. While the model successfully simulated an existing real-world condition, the authors noted that the coding process needed to represent an entire freeway corridor was "...quite data and labor intensive." Because INTEGRATION is a hybrid macroscopic and microscopic model moreover, the simulation time needed to model a test corridor was much longer than that consumed by the macroscopic model FREQ.

4.3.4 COMBINED APPROACHES

Modelers have found various ways of integrating supply and demand estimates to develop predictions of the impact of HOV lanes on mode choice. The most common approach iterates the application of mode shift equations and level-of-service estimates until the two estimates converge. This is the approach taken in most regionwide network models and by several analysts modeling corridor impacts (i.e., Small, 1977 and Talvitie, 1978). Some modelers have combined different approaches in an attempt to improve the accuracy and/or simplicity of HOV lane demand estimates. JHK and Associates, for example, combined traditional regionwide planning models with a freeway simulation to improve the level-of-service estimates available in the regional network. (JHK, 1994). In another combined approach, investigators at U.C. Berkeley developed a three-tiered HOV lane evaluation in which the analytic complexity increases in each of the three tiers (Scapinakis, 1991).

4.3.4.1 CALINK

Because traditional regional planning models typical use the BPR curve in estimating traffic flow levels, they have a limited capability for estimating the impacts of mode shifts on such important measures of traffic operations as speed, average, delays, and traffic queues. For this reason, these traditional models are ill-equipped to represent the travel time differences between carpools and single-occupant vehicles that are introduced by HOV facilities. In an attempt to remedy this defect, JHK & Associates undertook a project for CALTRANS (JHK, 1994) in which a freeway simulation model, FREQ (May, et al., 1991) was linked with a traditional planning model. The resulting analytical tool, called CALINK, executes the planning and simulation activities iteratively. Estimates of mode split and assigned traffic volumes produced by the planning model are introduced to the simulation model to produce revised estimates of freeway speeds and ramp delays. The revised travel time information is then introduced to the planning model for use in a new mode split and assignment. The process is repeated until the travel speeds and volumes converge from iteration to iteration.

4.3.4.2 Three- Tiered Screening Procedure

Investigators at U.C. Berkeley (Scapinakis, 1991) have suggested a three-tiered analytic methodology to help screen promising sites for HOV facilities. The three tiers proceed from a simple qualitative evaluation of many candidate sites (Level 1) to a relatively simple analytical model (Level 2) that can be used to identify the most promising candidates. These candidates are subjected to a detailed analysis using the FREQ freeway simulation.

<u>Tier One</u>. The first tier of the process entails a qualitative evaluation performed by professionals familiar with the candidate sites. These professionals exercise their judgment in answering a series of thirteen questions on a scoring sheet devised as an initial screening device. The scoring sheet with its thirteen questions appears in Figure 4-4.

<u>Tier Two</u>. In this tier, simple analytical models are used to address short- and medium-term operational issues. In the first phase of this analysis, a series of nomographs are used to evaluate the number of vehicles in priority and non-priority lanes immediately after implementation (before any demand response occurs). A sample nomograph used to assess lane conversion options in Seattle appears in Figure 4-5. In the second phase of this tier, the mode split model developed by Parody is used to predict the demand shifts likely to occur in the medium term.

Tier Three. The third tier entails a comprehensive evaluation of those surviving candidates using the FREQ computer simulation. Because the evaluation requires considerable resources, the authors recommend that it be limited to small numbers of candidate sites.

4.3.5 CRITICAL ASSESSMENT

4.3.5.1 Demand Models

Advantages The corridor demand models reviewed in this paper represent simple, transparent approaches that are easy to understand and apply. Data requirements are minimal, and at least one model, that of Parody (1984), appears to perform well in replicating overall demand measurements on existing HOV lanes (Billheimer, May, 1990).

Disadvantages. Even the best of existing corridor models have been calibrated on limited data sets, either because relatively few HOV lanes were in operation at the time they were developed (as in the case of the Mann and Parody models) or because the modelers had a narrow regional focus (as in the case of the TTI models). The geographic transferability of these models is not well understood, and none are equipped to deal with spatial and temporal shifts in trip making. Those models that are based on regression relationships tie their predictions to a single explanatory variable.

Individual models have specific drawbacks which have been covered in the discussion of those models. For example, Mann (1983) mixes two-person and three-person carpool lanes indiscriminately in developing his model, while Poe, et al. (1994) base their projections on a crude measure of congestion (ADT/lane) that is not easily transferred outside its Houston base of reference.

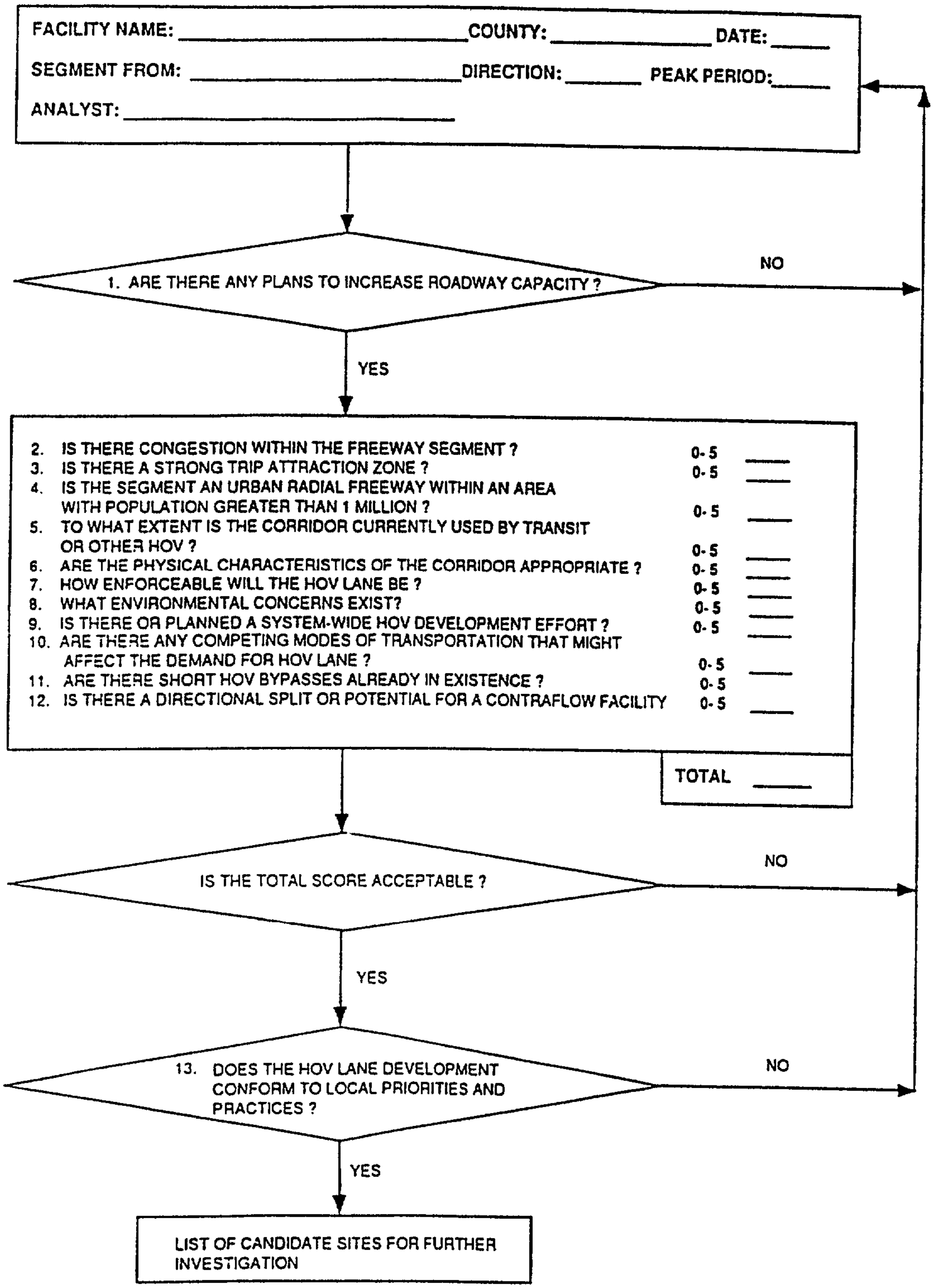
4.3.5.2 Supply Models

Advantages. Even the simplest speed/volume curves provide a useful mechanism for incorporating the feedback relationship between Carpool formation and traffic conditions in demand prediction.

Disadvantages. The iterative procedures needed to model the feedback between Carpool formation and travel times in adjacent mixed-flow lanes can be cumbersome. Simple speed-volume curves can forecast vastly different speeds under congested conditions, the only conditions in which HOV lanes are likely to be effective. While more complex simulations can address the impact of carpool formation and spatial and temporal shifts on travel times under congested conditions, these simulations require more data and resources than are appropriate for the current modeling effort. In short, simplified supply models do not replicate congestion conditions well, and those models which do replicate congestion adequately are not simple.

4.3.5.3 Summary

Simple corridor-based regression models, updated to reflect current HOV lane experience, represent a promising means of predicting the overall number of carpools attracted to a new HOV lane. Some mechanism needs to be found for coupling these models with level-of-service estimates and addressing issues of spatial and temporal diversion in a manner consistent with a quick-response modeling effort.



Source: Scapinakis, 1991.

Figure 4-4 The Scoring Sheet Used in the Tier One Evaluation.

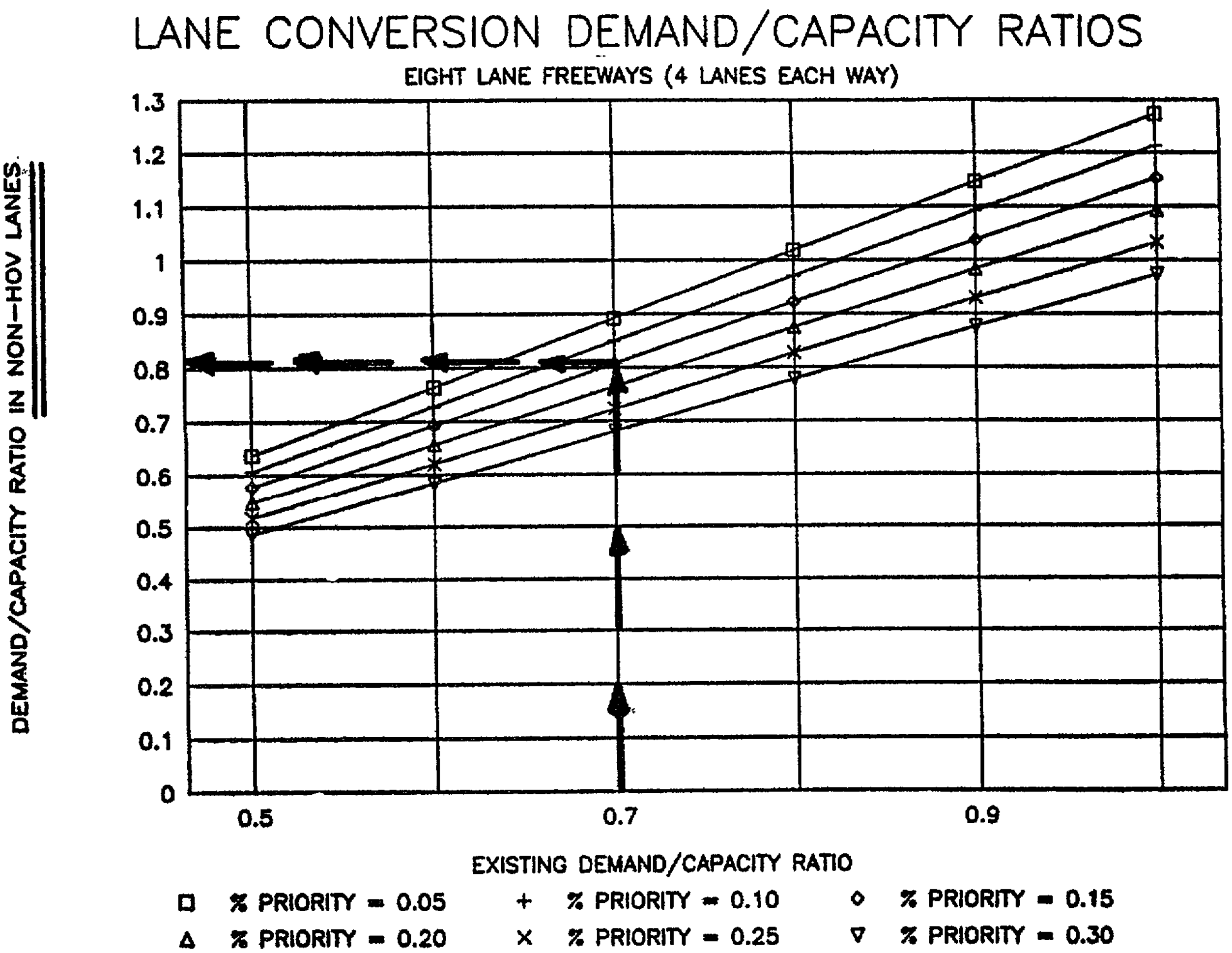


Figure 4-5 Seattle Nomograph for HOV Lane Conversions.

5. NEEDS ANALYSIS

This chapter presents a needs assessment by defining alternative approaches, methodologies, and computer analysis tools that are being used to predict HOV lane demand and by evaluating each of these methodologies in terms of its ability to satisfy analytical goals and objectives. The results of the user survey conducted for the methodology development task is also summarized. The purpose of the needs analysis effort is to assist in defining as clearly as possible the most desirable characteristics of the HOV methodology, and to prioritize the significance of various analysis objectives.

A summary of the needs assessment is presented in Table 5.1. Each of the analysis goals and objectives was assigned a row in Table 5.1 and is defined in Section 5.1. Each of the existing HOV methodology categories was assigned a column in Table 5.1 and is presented in Section 5.2. A (-) sign in Table 5.1 means that, based on the project team's evaluation, the particular methodology does not address the corresponding analysis goal at all, or it addresses it in a poor fashion. A (+) sign in Table 5.1 means that the specific analysis goal is addressed by the corresponding methodology in a satisfactory way. A (0) sign in Table 5.1 means that the methodology is neutral in addressing the analytical goal.

5.1 Analysis Goals

There are several analysis goals and objectives for methodologies and the software models to predict HOV facility demand. Each of these goals was assigned a row in Table 5.1 and is described below.

5.1.1 HOV Facility Analysis Environment

HOV methodologies and software tools have varying degrees of analytical capabilities with respect to the HOV facility analysis environment, including:

- Analyze freeway congestion including mixed-flow and HOV lanes;
- Analyze arterial congestion including mixed-flow and HOV lanes;
- Model on-ramp entry control bypass (HOV bypass);
- Perform analysis at the corridor level;
- Perform analysis at the network level; and
- Perform analysis at the transportation system level.

HOV methodologies and software models are capable of analyzing freeway and arterial congestion including mixed-flow and HOV lanes. A (-) sign in the "freeway" and "arterial" rows in Table 5.1 means that the particular existing methodology does not address this requirement at all, or it addresses it in a poor fashion. A (+) sign in Table 5.1 means that freeway or arterial congestion is addressed by the corresponding methodology in a satisfactory way and that it incorporates the effect of queuing and delays onto congestion,

ISTEA and federal/state clean air legislation have reinforced the importance of traffic management and control of the existing highway capacity as an alternative to physical capacity improvements through new construction. In response to this strategy, an increasing number of urban freeways are ramp-metered. Even though the interaction of HOV lanes and ramp metering is often perceived as antagonistic, the provision of ramp meter HOV bypass lanes clearly reinstates the capability for a beneficial synergy between ramp metering and HOV lanes. A (-) sign in this row of Table 5.1 means that the corresponding methodology does not have the capability to model ramp meter HOV bypass lanes.

Table 5.1 Existing HOV Methodologies vs. Project Objectives

	EXISTING HOV METHODOLOGIES				
Analytical Goals	**Sketch Planning Methodologies**	**Macroscopic Simulation Models**	**Microscopic Simulation Models**	**Regional Models**	**Simulation/ Regional Model Linkage**
Traffic Operational Characteristics					
1. Freeway	0	+	+	0	+
2. HOV Bypass		+	0	-/0	+
3. Arterial		+	+	0	+
4. Corridor	-	0	+	+	+
5. Network	-		+	+	+
6. System				+	+
Traveler Response					
7. Temporal Diversion			0		+
8. Mode Shift	0/+	+		+	+
9. Route Diversion	-	+/0	+	+	+
10. Total Diversion					
11. Short-term Demand	+	+	+	+	+
12. Long-term Demand				+	+
13. HOV Support Systems	-/0				
Measures of Performance					
14. Emissions Analysis		0	0	0	+
15. Accurate Speed Estimation		0/+	+	0	0/+
Software Operational Characteristics					
16. Quick Method	+	0			
17. Current Use By DOT	+	0	-	0	
18. Operational Status	+	+	-/0	+	0/-
19. Hardware Requirements	+	+	+	+	+
20. Data Reauirements	+	0/+		0/-	

Note: (+): The specific analysis objective is generally addressed by the corresponding methodology.
(-) The particular methodology does not generally address the specific analysis objective.
(0): Neutral

Existing HOV methodologies are generally applicable to corridor, network, and system level HOV demand analysis. Definitions for corridor, network, and system level analysis are as follows:

- **Corridor** level analysis would include the freeway (with HOV and mixed-flow lanes) and parallel arterials.
- **Network** level analysis would include the whole network of highways and streets impacted by the HOV lane. Typically, this includes a grid of freeways, arterials, and local streets in the general vicinity of the HOV lane.
- **System** level analysis would include the impacted network as well as address the interaction of the HOV lane with all transportation modes (including SOV, HOV2, HOV3, HOV4+, passenger rail, and other modes).

5.1.2 Traveler Response

In terms of traveler response to traffic congestion, HOV methodologies and software are capable of estimating and representing:

- Temporal diversion;
- Mode shift;
- Route diversion;
- Total diversion;
- Short-term person/vehicle HOV demand;
- Long-term person/vehicle HOV demand; and
- The impact of HOV support systems.

In response to a new HOV lane, travelers can change their time of travel (temporal diversion), can use a different mode of transportation (mode shift), can select a different route (route diversion), or completely cancel or create a new trip (induced/suppressed demand). A (+) or (-) in the corresponding rows of Table 5.1, respectively represent how well or badly the corresponding methodology can model temporal, mode, route, or total diversion.

Short-term demand is the vehicle- or person-demand for the HOV lane shortly after it has opened for operation. Typically, estimation of short-term demand is based on forecasts of volumes, speeds, and travel times, and on achieving an equilibrium between travel times in the priority and non-priority lanes. Short-term demand estimation does not take into account factors such as trip length, route diversion, mode shift, temporal diversion, and total diversion. In contrast, estimation of long-term demand for HOV lanes takes into account the effects of trip length, alternative routes, transportation modes, times of travel, and overall congestion onto the demand for the HOV lane. A (+) in a cell of Table 5.1 means that the corresponding methodology provides the capability of estimating short- or long-term HOV demand.

The last analysis objective in this category reflects the ability of a particular methodology to analyze the impact of HOV lane support systems (such as Park-&-Ride facilities, rideshare programs, etc.) onto the demand for the HOV lane. A (+) or (-) in this row of Table 5.1, respectively represent how well or badly the corresponding methodology can model the impact of HOV lane support systems.

5.1.3 Measures of Performance

In reviewing analytical capabilities of existing HOV analysis methodologies, two measures of performance have emerged as critical in the prediction of HOV facility demand:

- Impact of HOV facilities on vehicular emissions; and
- Accuracy in travel speed estimation.

The Clean Air Act Amendments (CAAA) of 1990 and (to a lesser extent) the Intermodal Surface Transportation Efficiency Act (ISTEA) of 199 1 place great emphasis on modeling to provide accurate accountability towards meeting air quality goals and deadlines that, if not met, could lead to highway funds being withheld. HOV lanes will only be feasible if it can be shown that their implementation will not further impair air quality in specific areas. The ability of existing HOV models to predict and evaluate the impact of HOV lanes on air quality relates to the following issues:

- Ability to interface with emission rate models (e.g. DTIM) and emissions dispersion models (e.g. EMFAC and MOBILE);
- Ability to accurately predict traffic volumes and speeds since travel speeds are the most important determinant of mobile source emission models; generally, the detailed representation of capacity and flow provided by simulation models results in more accurate speed estimates than those of travel demand models;
- Ability to accurately model the effects of traffic congestion since emissions at low, congested speeds are different from emissions at uncongested speeds; this also relates to the ability to estimate vehicle flow profiles (vehicle operating mode) since emissions during vehicle acceleration are different from emissions during vehicle cruise or idle mode; and
- Ability to model the regional and system-wide impacts of HOV lanes on air quality. California experience shows that when HOV lanes were evaluated only at the corridor level, emissions increased when compared to the no-build scenario; however, when network-wide analysis was performed and regional modal and spatial shift was taken into account, HOV lanes showed air quality benefits.

A (-) sign in Table 5.1 signifies that the corresponding methodology has limited abilities to predict and evaluate the impact of HOV lanes on vehicular emissions.

HOV methodological procedures generally predict and evaluate the impact of an HOV facility on person demand, vehicle demand, auto occupancy, congestion, delay, and air quality. Accuracy in travel speed estimation is critical to the prediction and evaluation of all the above performance measures. A (+) sign in Table 5.1 means that the corresponding methodology is producing relatively accurate speed estimates.

5.1.4 Operational Characteristics

This section discusses the level of effort and operational characteristics associated with the implementation of HOV methodologies and software. These attributes include:

- Quick response method/level of effort;
- Current use of methodology by State DOTs;
- Operational status;
- Hardware requirements; and
- Data requirements.

The project scope of work calls for a methodology to "obtain quick analysis of HOV lane demand and operations". A (+) sign in Table 5.1 signifies that the corresponding methodology is a relatively quick response method for HOV analysis, while a (-) sign means that the methodology has a more labor-intensive implementation.

The second analysis objective in this category evaluates if a particular methodology is currently used by State Departments of Transportation (DOT). A (-) sign indicates that the specific methodology is generally not used by State DOTs.

The third analysis objective evaluates the operational status of each methodology including development status, proprietary status, and analysts' experience with use. A (-) in Table 5.1 indicates that the particular methodology is not fully operational (e.g.: not 100% debugged, not user-friendly, etc.).

The project scope of work calls for development of a "microcomputer model". This project objective evaluates the operating environment and hardware requirements (microcomputer, mainframe, etc.) for each methodology. A (+) in Table 5.1 means that the corresponding methodology currently operates in a microcomputer.

The last analysis objective in this section evaluates the amount of data required by each particular methodology. A (+) sign in Table 5.1 indicates that relatively few data are required for HOV demand analysis.

5.2 Existing HOV Methodologies

Several methodologies exist for predicting HOV facility demand, for evaluating traffic operations at HOV lanes, and for assessing impacts of HOV lanes. For the purpose of this needs analysis, the HOV methodologies/models were grouped into the following categories:

- Sketch planning methodologies;
- Macroscopic simulation models;
- Microscopic simulation models;
- Regional transportation planning models; and
- Linked regional planning/simulation models.

Each of the HOV demand methodology types shown above were assigned a column in Table 5.1 and representative models are briefly described in the remainder of this section.

5.2.1 Sketch Planning Methodologies

Sketch planning methodologies produce general order-of-magnitude estimates of HOV facility demand. Representative models in this category include:

- The methodology developed by Charles River Associates (CRA) for the FHWA ("Predicting Travel Volumes for HOV Priority Techniques – Technical Report and Final Report," 1982), otherwise known as the "Parody" method;
- The Pivot Point method developed by Cambridge Systematics ("HOV Support Facilities and Programs" for MTC – San Francisco Bay Area, 1990);
- The TDM model developed by COMSIS Corporation for the FHWA/FTA is used to evaluate HOV lanes as one of the TDM policies ("Congestion Management System Alternatives" – Maricopa Association of Governments, 1994); and
- The "TCM Tools" methodology developed by JHK & Associates ("Evaluate TDM/TSM Effectiveness" – Pima Association of Governments, 1993).

5.2.2 Macroscopic Simulation Models

Macroscopic simulation models are based on deterministic relationships developed through research on highway capacity and traffic flow. The simulation for a macroscopic model takes place on a section-by-section basis rather than tracking individual vehicles. The main representative models in this category are:

- CORFLO, a family of surface street and freeway models developed by the FHWA, including FREFLO, NETFLO 1, NETFLO2, and TRAFFIC.
- FREQ, a model developed by the Institute of Transportation Studies at the University of California at Berkeley, that simulates corridor traffic operations including one freeway and one parallel arterial.
- TRANSYT-7F, a model developed by the FHWA, that simulates given non-dynamic traffic flows in a signalized surface street network and optimizes signal timing parameters.

- SATURN, a surface street simulation model that combines an operational evaluation of traffic signalization parameters with a traffic assignment technique. SATURN was developed at the Institute for Transportation Studies, University of Leeds.
- CONTRAM, a surface street network simulation model that evaluates and optimizes traffic signalization. CONTRAM was developed by the British Transport and Road Research Laboratory.

5.2.3 Microscopic Simulation Models

Microscopic simulation models simulate the movement of individual vehicles, based on theories of car-following and lane-changing. Typically, vehicles enter a transportation network using a statistical distribution of arrivals (a stochastic process) and are tracked through the network on a second-by-second basis. Representative models in this category are:

- FRESIM, a model developed by the FHWA for simulation of freeway traffic operations.
- NETSIM, a model developed by the FHWA for optimization of traffic signal timing in a surface street network.
- INTEGRATION, a model that was developed to evaluate and optimize the operation.of integrated freeway/signalized arterial networks during recurring and non-recurring congestion.

5.2.4 Regional Travel Demand Models

Regional travel demand models follow a four-step modeling process including trip generation, trip distribution, mode choice and trip assignment. The four-step process can be implemented with a variety of software packages that follow the same overall guidelines for modeling practices but differ in the specific options or parameters that may be invoked for a particular module. The main regional travel demand software packages are UTPS, TRANPLAN, MINUTP, and EMME/2.

The mode choice element of regional travel demand models typically provides estimates of transit trips, single-occupant vehicle (SOV), and high-occupancy vehicle (HOV) trips. The most common application of the mode choice model is a logit model with numerous variables, including but not limited to:

- Transit and highway level-of-service (travel time and cost);
- Socioeconomic characteristics of the traveler (such as income); and
- Characteristics of household trip origins and destinations (such as autos per household, workers per household, parking charges, and access travel time).

Predicting HOV facility demand and assessment of impacts of HOV lanes requires specific analytical capabilities, such as the consideration of mode choice and major route choice and the representation of traffic flow in the highway network. These attributes are presently found only in the structure and orientation of regional travel demand models. Regional models, however, have only limited capability to accurately estimate changes in operational characteristics (such as speed, delay, and queuing) resulting from implementation of HOV lanes.

A typical problem with HOV demand modeling is that HOV assignments usually reflect only home-based work trips (excluding other trip purposes). This results in underestimation of HOV lane flows and correspondingly overestimation of mixed-flow lane flows. Another typical problem with HOV supply modeling is that in most regional models, the HOV assignment algorithm produces an all-or-nothing allocation that assigns all eligible vehicles to HOV lanes whenever the speed differential favors the HOV lane. In reality, proportionally more eligible vehicles are likely to use the HOV lane as the HOV speed advantage increases.

5.2.5 Linked Regional/Simulation Models

Accurate estimation of mode shift between HOV, SOV, and transit modes requires accurate estimates of travel times and speeds experienced by each travel mode. Criticism against regional model forecasts concentrates on the inadequate treatment of specific traffic operational characteristics, and the inaccuracy of travel speed and traffic volume estimates. These inadequacies generally occur because of poor representation of the dynamic nature of traffic in regional modeling. Estimation of realistic travel speeds requires realistic representation of queuing, congestion levels, congestion dissipation, and traffic diversion in space and in time.

To address regional model deficiencies, there are several efforts under way to link regional models with simulation models. This linkage uses the best characteristics of the two model systems: Simulation models provide accurate travel time and speed estimation for mixed-flow and HOV lanes. The regional model uses these speed estimates to perform route assignment and mode choice. This linkage iterates until convergence is achieved. This approach enhances travel demand forecasting by introducing accurate traffic operations analysis to travel demand modeling. In parallel, this approach enhances traffic operations analysis by introducing assignment and mode choice to freeway simulation modeling.

The linked planning/simulation model approach is currently used in several projects sponsored by various state and federal agencies. Examples of these projects include:

- "Travel Demand and Simulation Modeling" by Caltrans Headquarters; this project developed a model framework that integrates a regional travel demand model (MINUTP, TRANPLAN, or SYSTEM II) with a freeway simulation model (FREQ) and with an emissions model;
- "IVHS Benefits Assessment Framework" by the Volpe National Transportation Systems Center and the FHWA; in this project an analytical tool was developed that links a regional travel demand model with freeway and arterial macroscopic simulation models (FREQ and TRANSYT-7F, respectively), and with emissions, fuel consumption, and safety impact assessment models; and
- "Feasibility and Demonstration of Network Simulation Techniques for Estimation of Emissions in a Large Urban Area" by the California Air Resources Board; this project examined the feasibility of linking a microscopic freeway simulation model (FRESIM) with a travel demand model.

5.3 User Survey

The purpose of this section is to summarize the results of the user survey conducted for the methodology development task of the Federal Highway Administration Project #42-10-4172, Predicting the Demand for High Occupancy Vehicle (HOV) Lanes. The user survey is part of the methodology development task that will provide a set of "quick response" procedures for predicting and evaluating the impacts of HOV lanes on person demand, vehicle demand, auto occupancy, congestion, delay, and air quality.

The results of the user survey are summarized according to the following sections.

- Section 5.3.1 – Purpose and Approach;
- Section 5.3.2 – Critical HOV Impacts;
- Section 5.3.3 – Current Methodologies/Models;
- Section 5.3.4 – HOV Modeling Approach;
- Section 5.3.5 – Data Availability; and
- Section 5.3.6 – HOV Support Facilities.

5.3.1 Purpose and Approach

5.3.1.1 Purpose

The user survey was conducted to identify the existing methodologies being used by the technical planning community for predicting, analyzing, and evaluating travel demand for HOV lanes and to assess the needs of the potential model users. Another objective of this survey was to obtain technical staff opinions and input regarding possible approaches for modeling HOV facility demand. In addition, data availability information was collected for both model inputs and HOV support facilities.

5.3.1.2 Approach

One of the objectives of the project is to formulate a methodology which can be applied by planners and engineers with limited or no access to or experience with regional travel demand modeling. Nine agencies were selected for this user survey:

- California State Department of Transportation – District 4 (San Francisco, California);
- California State Department of Transportation – District 7 (Los Angeles, California);
- Minnesota Department of Transportation (Minneapolis, Minnesota);
- New Jersey Department of Transportation (Trenton, New Jersey);
- Texas State Department of Highways and Public Transportation (SDHPT) and Metropolitan Transit Authority of Harris County (Houston, Texas);
- Virginia Department of Transportation (Richmond, Virginia);
- Washington State Department of Transportation (Seattle, Washington);
- Santa Clara County (San Jose, California); and
- Snohomish County (Seattle, Washington).

Fifteen telephone surveys were conducted during the months of April and May, 1995. In some cases, more than one user was surveyed during one telephone call. The following sections present the results of the user survey.

5.3.2 Critical HOV Impacts

The new HOV methodology will guide users through a procedure which will predict and evaluate the impact of an HOV facility on person and vehicle demand, auto occupancy, congestion, delay, and air quality. To help determine the extent to which some of these performance measures might be evaluated in the new methodology and model the users were asked which of the following HOV facility impacts are most critical for their agency:

- Person demand;
- Vehicle demand;
- Auto occupancy;
- Congestion;
- Delay; and
- Air quality.

Table 5.2 presents the agencies' responses to which of the HOV facility impacts were most critical. A (J) in a cell of Table 5.2 means that one of the representatives of that agency identified the HOV facility impact as critical. Most of those surveyed responded that all of the HOV facility impacts under question are important; the level of importance depends on the situation (or project) under consideration. The impacts which tended to be most critical were vehicle demand, congestion, person demand, and air quality. Other HOV facility impacts or outputs which were mentioned as desired for inclusion in the methodology and model were cost, noise, transit usage, mode split and trip distribution.

Table 5.2 Most Critical HOV Impacts

Agency	Person Demand	Vehicle Demand	Auto Occupancy	Congestion	Delay	Air Quality
Caltrans - District 4 (San Francisco)	✓	✓	✓	✓	✓	✓
Caltrans - District 7 (Los Angeles)	✓	✓	✓	✓	✓	✓
Minnesota Department of Transportation	✓	✓		✓	✓	
New Jersey Department of Transportation	✓	✓			✓	✓
Texas (SDHPT) and Metropolitan Transit Authority of Harris County (Metro)	✓	✓	✓	✓		✓
Virginia Department of Transportation		✓	✓			✓
Washington State DOT and Snohomish and King Counties	✓	✓	✓	✓		
Santa Clara County, California		✓		✓		✓

Table 5.3 Methodologies/Models Used

Agency	Methodologies/Models
Caltrans - District 4 (San Francisco)	MINUTP EMME/2 FREQ
Caltrans - District 7 (Los Angeles)	UTPS DTIM
Minnesota Department of Transportation	FREQ FRESIM TRAVEL TRANPLAN EMME/2
New Jersey Department of Transportation	FREQ MINUTP TRANPLAN
Texas State Department of Highways and Public Transportation (SDHPT) and Metropolitan Transit Authority of Harris County (Metro)	Charles River's Pivot-Point Method FREQ TRANPLAN Texas Transportation Institute (TTI) Method Dallas/Fort Worth Regional Model (UTPS) MOBILE
Virginia Department of Transportation	Cambridge Systematics Pivot Point Method MINUTP
Washington State Department of Transportation and Snohomish and King Counties	Charles River's Pivot-Point Method University of Washington Method FREQ FRESIM TRANSYT-7F EMME/2 UTPS
Santa Clara County, California	TRANPLAN DTIM2

5.3.3 Current Methodologies/Models

Table 5.3 identifies existing methodologies or models used by the agencies represented in the user survey to predict, analyze, and/or evaluate travel demand for HOV lanes. Three of the agencies stated that they use sketch planning methodologies (pivot-point), four agencies identified use of macroscopic simulation models (FREQ and TRANSYT-7F), microscopic simulation models (FRESIM) were mentioned for two agencies, and all of the agencies use regional travel demand models for some type of evaluation of HOV facilities. The regional travel demand models being used by the agencies include TRANPLAN, MINUTP, EMME/2 and UTPS or UTPS-based models. Approximately half of the agencies represented in the survey use some sort of post-processors for enhancing speeds and emissions estimates, operational analysis, or for re-estimating mode choice and distribution.

The users were also asked about their experience using the various existing methodologies and models, specifically the level of effort involved and any key advantages or weaknesses. On average, the individuals surveyed have been using the existing methodologies and models for over seven years.

5.3.3.1 Level of Effort for Existing Methodologies/Models

With respect to regional travel demand models, most of the users stated that once the model was operational, the level of effort was minimal. However, the network coding and calibration efforts required to get the model running is time consuming, demanding of personnel, and data intensive. According to the users surveyed, the macroscopic and microscopic simulation models tended to be fairly data intensive, but necessary for the outputs desired.

5.3.3.2 Advantages of Existing Methodologies/Models

Some of the advantages of existing methodologies and models identified by the users include:

Macroscopic Simulation Models – calibration capabilities, capable of day-l and longer time period evaluations, readily available, and operational analysis capabilities; and

- **Travel Demand Models –** better emissions estimates, mode choice by zones, select-link analysis, all trips fully accountable (origin/destination capabilities), LOS analysis, diversions for travel time savings, integrated with transit, method/model well understood, and confidence in results.

5.3.3.3 Weaknesses of Existing Methodologies/Models

The disadvantages or weaknesses of the existing methodologies and models, as specified by the model users, include:

- Lack of flexibility for geometrics (start and end of HOV lane, right-side HOV facilities, exclusive on- and off-ramps, grade, expanding or constricting number of lanes, HOV merging and weaving, extending or shortening HOV facilities, and general condition changes);
- Inability to evaluate temporal diversion;
- Only evaluates work trips;
- Only produces HOV trips for those with a time savings of greater than five minutes;
- All or nothing assignment assumption for HOV analysis leading to overestimation of HOV lane volumes;
- Time period analysis constraints;
- Too many assumptions required (leap-of-faith);
- Extensive network coding, calibration, and data collection required for travel demand models; and
- Slow/time-consuming to run model.

5.3.4 HOV Modeling Approach

The following list identifies some of the issues which the model users would like to have addressed in a new model for predicting and evaluating HOV facility demand.

- Simple, user friendly, flexible, consistent with existing models and methodologies, better confidence in results, and outputs understandable to a lay person;
- Right-side HOV analysis, weaving effects (in-and-out of HOV lanes), speed differential, violation rates, ramp-metering and HOV bypass lanes, signal preemption strategies, eligibility considerations (2+ versus 3+), various effects of lane conversions (mixed flow to HOV), extending or shortening HOV lanes, access considerations (limited access versus continuous access), exclusive on- and off-ramps, and effects of various HOV facility terminations (merging/bottlenecks);
- Location considerations such as urban versus suburban and/or radial versus circumferential highways;
- Transit usage and performance, and evaluation of the various modes using the HOV facility (transit, Carpool, Vanpool, and motorcycles);
- Benefit/cost analysis, project costs (construction, operation, and congestion), and HOV project prioritization (or at a minimum outputs which could be used for prioritization efforts);
- Capture non-work trips as well as work trips;
- Impacts of peak spreading, toll facilities, Carpool incentives, congestion pricing, HOV buy-in programs (selling HOV lane use to SOV vehicles), and technology (ITS);
- Allow for "what-if" scenarios;
- Better origin-destination analysis capabilities;
- Actual utilization of HOV lane by HOV vehicles (not all HOV vehicles use the HOV facility);
- Better temporal diversion and mode shift estimation;
- Capability to design their own speed versus demand-to-capacity (d/c) curves, but default curves should also be available; and
- Capability of outputting schematics, maps, and/or graphs of facility geometrics and model outputs (e.g., queuing, air quality, congestion, and speed/flow).

Users were also surveyed on what the relationship should be of a new HOV model to an existing regional travel demand model if a regional travel demand model is available for the project study area. Most of the users stated that there should be a link or interface between the two models and that the results should be consistent. Most of the users also believed that if a regional model is available for the HOV project study area, the regional model should be used (but not necessarily required) for HOV analysis, especially for significant decisions such as major investment studies.

5.3.5 Data Availability

General data availability was investigated for several potential model inputs. The potential inputs included:

- Existing HOV and mixed-flow lane(s) demand and counts for freeways;
- Existing HOV and mixed-flow lane(s) demand and counts for on- and off-ramps;
- Existing HOV and mixed-flow lane(s) demand and counts for HOV arterial facilities;
- HOV demand growth estimates for future analysis periods;
- Existing HOV and mixed flow lane(s) occupancy distribution and breakdown options;

- Existing average speeds;
- HOV and mixed-flow lane capacity;
- Number of HOV and mixed-flow lanes;
- Length of facilities;
- Availability of parallel capacity (corridor characteristics); and
- Average speeds on parallel facilities.

Table 5.4 presents the availability of input data for each of the agencies. A (+) means that the data is readily available, a (+/-) means the data is somewhat available, and a (-) means the data is not available.

Most of the input data was readily or somewhat available. The potential inputs which tended to have less data availability included arterial counts (where an HOV facility on an arterial roadway is to be evaluated), HOV demand growth estimates, occupancy, average speeds, and information on parallel facilities.

5.3.6 HOV Support Facilities

The users were also surveyed on the data availability of several HOV support facilities, including:

- Ramp-metering;
- Park-and-ride facilities;
- Carpool/vanpool parking;
- Rideshare programs;
- Public information/marketing programs;
- Automated traffic management systems;
- Transit and/or intermodal stations;
- HOV bypass lanes;
- Exclusive HOV facility on- and off-ramps (skyways); and
- Quantity and type of bus services.

Table 5.5 presents the data availability for various HOV support facilities by agency. A (+) means that the data is readily available, a (+/-) means the data is somewhat available, and a (-) means the data is not available. Overall, most of the agencies surveyed stated that all of the HOV support facilities data or information is available or somewhat available.

Table 5.4 Input Data Availability

Agency	Freeway Demand	Ramp Demand	Arterial Demand	Demand Growth	Vehicle Occup.	Average Speeds	Lane Capacity	No. of Lanes	Facility Length	Parallel Capacity	Parallel Speeds
Caltrans - District 4 (San Francisco)	+	+/-	+/-	+	+	+/-	+/-	+	+/-	-	-
Caltrans - District 7 (Los Angeles)	+	+/-	+/-	+/-	+/-	+	+	+	+	+/-	+/-
Minnesota DOT	+/-	+/-	+/-	+/-	+/-	+	+/-	+	+	+/-	
New Jersey DOT	+/-	+/-	+/-	+/-		+/-	+	+	+	+/-	
Texas (SDHPT) and Metro	+	+/-	+		+/-	+	+	+	+	+	+/-
Virginia DOT	+	+/-	+/-		+/-		+	+	+	+	
Washington State DOT/Snohomish	+	+	+/-	+/-	+/-	+	+	+	+	+	-
Santa Clara County, California	+	+	+/-	+/-	+/-	+/-	+	+	+	+	+/-

Note: **(+):** Input data are available.
(+/-): Input data are somewhat available.
(-): Input data are not available.

Table 5.5 Availability of HOV Support Facilities

Agency	Ramp Metering	Park-&-Ride Facilities	Carpool/ Vanpool Parking	Rideshare Programs	Public Info/ Mkting	Automated Traffic Mgmt	Transit/ Intermodal Stations	Bypass Lanes	Skyways	Bus Services
Caltrans - District 4 (San Francisco)	+/-	+	+/-	+	+/-	+/-	+	+/-		+
Caltrans - District 7 (Los Angeles)	+	+	+/-	+	+/-	+/-	+	+	+/-	+
Minnesota DOT	+	+	+	+	+	+	+/-	+/-	+/-	+
New Jersey DOT	+/-	+	+/-	+/-	+/-	+/-	+	+/-	n/a	+
Texas (SDHPT) and Metro	+/-	+	+/-	+	+/-	+/-	+	n/a	+	+
Virginia DOT	+/-	+	+/-	+	+/-	+-I-	+	n/a	+	+
Washington State DOT/Snohomish	+	+	+/-	+	-l-	+	+/-	+	+	+
Santa Clara County, California	+	+		+/-	+/-	+-/-	+/-	+	n/a	+

Note: (+): Data are available.
(+/-): Data are somewhat available.
(-): Data are not available.
n/a: Not applicable (either the facility does not exist or the user is unsure if the data is available).

6. RECOMMENDED MODELING APPROACH

This chapter provides an overview of the HOV modeling approach for predicting HOV facility demand and resulting HOV and mixed-flow lane(s) performance. The approach design is based upon contract objectives (and constraints) as well as on input received from the Steering Committee augmented through research team deliberations,

6.1 Data for Model Development and Testing

The purpose of the new HOV model is to provide a "quick response" methodology for predicting and evaluating the impacts of HOV lanes on person and vehicle demand, auto occupancy, congestion, delay, emissions, and fuel consumption. The new HOV model methodology uses travel time differences (HOV versus non-HOV, and before versus after) as the "stimulus" in the demand estimation, and the differences in vehicle volumes (HOV versus non-HOV, and before versus after) as the "response" to be predicted by the methodology.

Table 6.1 contains a summary of the data collected for use in the model development and framework. The key elements used in the model development include HOV lane(s) eligibility, facility length (study section length), violation rate, action type (add lane, lane conversion, etc.), travel times, vehicle volumes, and person volumes. A description of the data collection effort including detailed summaries for each of the HOV facilities is presented in Appendix D.

6.2 HOV Modeling Approach

The analysis of project objectives and needs, the user requirements survey, and the availability of HOV facility data have helped to define the most desirable characteristics of the HOV model methodology. The intent of the new approach is to provide for a quick-response tool for predicting HOV and mixed-flow lane(s) demand and traffic performance, with limited impact estimation capabilities. In this sense, the HOV model can be considered as a screening tool used to evaluate peak period directional roadway sections. The new approach can be used to estimate traffic performance and impacts in the short-term (six months to one year after opening day) and long-term (after one or more years in operation).

The iterative HOV demand/supply estimation process consists of several steps and iterations as shown in Figure 6.1. The model involves seven individual modules including:

- **Input Module –** Accepts and edits the input data;
- **Allocation Module –** Distributes traffic to the HOV and mixed-flow lanes (occurs three times in the process);
- **Supply Module –** Predicts travel times for the HOV and mixed-flow lanes;
- **Total Response Module –** Predicts the total response by vehicle type;
- **Equilibration Module – Checks closing criterion;**
- **Spatial and Modal Response Module –** Allocates total response into spatial and modal components; and
- **Output Module –** Computes measures of performance including vehicle and person volumes, travel times, vehicle and person miles of travel, vehicle and person hours of travel, vehicle and person delay, air quality/emissions, and fuel consumption.

Table 6.1 Summary of Data

NO.	Location	Date	Eligible	Roadway Classification	No. of HOV Lanes	No. of MF Lanes	Facility Length (miles)	Time (Peak Hour Peak Period)	violation Rate (%)	Action Type
1	U.S. 12/I-394 - Minneapolis	11/85	2	Arterial	1	2	4.0	PH	5.0	Construct new HOV lane
2	I-10 Katy - Houston	8/86	2	Freeway	1	3	6.4	PH	5.0	Convert 3+ (pre-authorized) to 2+ (unauthorized)
2	I-10 Katy - Houston	8/86	2	Freeway	1	3	6.4	PP	5.0	Convert 3+ (pre-authorized) to 2+ (unauthorized)
3	I-10 Katy - Houston	6/87	2	Freeway	1	3	11.4	PH	5.0	Extend lane 5 miles
3	I-10 Katy - Houston	6/87	2	Freeway	1	3	11.4	PP	5.0	Extend lane 5 miles
4	I-10 Katy - Houston	10/88	3	Freeway	1	3	11.4	PH	5.0	Convert from 2+ to 3+
4	I-10 Katy - Houston	10/88	3	Freeway	1	3	11.4	PP	5.0	Convert from 2+ to 3+
5	I-10 Katy - Houston	l/90	3	Freeway	1	4	12.6	PH	5.0	Extend lane 1.5 miles
5	I-10 Katy - Houston	l/90	3	Freeway	1	4	12.6	PP	5.0	Extend lane 1.5 miles
6	I-45N North Fwy - Houston	6/90	2	Freeway	1	4	13.5	PH	1.7	Convert 3+ (pre-authorized) to 2+ (unauthorized)
7	U.S. 290 NW Fwy - Houston	8/88	2	Freeway	1	3	9.5	PH	3.6	Construct new HOV lane
7	U.S. 290 NW Fwy - Houston	8/88	2	Freeway	1	3	9.5	PP	3.6	Construct new HOV lane
8	I-15 - San Diego	10/88	2	Freeway	2	4	8.0	PH		Construct new HOV lane
8	I-15 - San Diego	10/88	2	Freeway	2	4	8.0	PP		Construct new HOV lane
9	I-90 - Seattle	11/93	2	Freeway	1	3	6.2	PP	4.6	Convert 3.7 mi to HOV and add 2.5 mi HOV lane
10	I-5 - Seattle	7/91	2	Freeway	1	3	7.7	PH	22.0	Convert from 3+ to 2+
11	I-5 - Seattle	9/81		Ramp		1	6.0	PP	3.0	Install ramp meters with HOV bypass
12	I-5 - Seattle	8/83	3	Freeway	1	3-4	5.6	PP	19.0	Construct new HOV lane
13	U.S. 101 - San Jose	4/93	2	Freeway	1	3	6.0	PH	5.2	Add SOV and HOV lane (HOV lane gap closure)
13	U.S. 101 - San Jose	4/93	2	Freeway	1	3	6.0	PP	5.2	Add SOV and HOV lane (HOV lane gap closure)
14	U.S. 101 - San Jose	11/86	2	Freeway	1	3	2.8	PI-I	24.3	Add new HOV lane
14	U.S. 101 - San Jose	11/86	2	Freeway	1	3	2.8	PP	13.0	Add new HOV lane
15	I-280 - San Jose	11/90	2	Freeway	1	3	10.7	PH	9.2	Add new HOV lane
15	I-280 - San Jose	11/90	2	Freeway	1	3	10.7	PP	9.2	Add new HOV lane
16	128th/Airport Rd - Seattle	l/93	2	Arterial	1	l-2	3.3	PH		Add new HOV lane
17	S.R. 237 - San Jose	10/84	2	Arterial	1	2	5.9	PP	9.0	Add new HOV lane
18	San Tomas Expwy - San Jose	11/82	2	Arterial	1	3	4.9	PP	5.0	Add new HOV lane
19	Santa Monica Diamond Lanes	3/76	3	Freeway	1	3	12.0	PP	12.6	Convert lane to HOV
20	San Bernardino Express Busway	11/76	3	Freeway	1	4	11.0	PP	8.8	Allow carpools to use exclusive busway
21	Route 101 - Marin County	6/76	3	Freeway	1	3	3.7	PH	21.5	Convert bus only lane to carpool lane
22	Route 91- Los Angeles	6/85	2	Freeway	1	4	8.0	PH	7.8	Convert median to carpool lane
23	l-210 - Los Angeles	10/93	2	Freeway	1	5	17.0	PH	2.8	Add new HOV lane
24	Route 91- Los Angeles	3/93	2	Freeway	1	4	10.5	PH	2.3	Convert median to carpool lane
25	Route 55 - Orange County	11/85	2	Freeway	1	3	11.0	PH	12.0	Convert median to carpool lane
26	Route 101 - Corte Madera	10/88	2	Freeway	1	3	3.7	PP	11.0	Convert 3+ to 2+
27	Route 101- San Rafael	10/88	2	Freeway	1	3	3.0	PP	10.0	Convert 3+ to 2+

Table 6.1 Summary of Data (continued)

		Average Travel Time (minutes)				Person-Volumes				Vehicle-Volumes			
NO.	Location	HOV Before	MF Before	HOV After	MF After	HOV Before	Non-HOV Before	HOV After	Non-HOV After	HOV Before	Non-HOV Before	HOV After	Non-HOV After
1	U.S. 12/I-394 - Minneapolis	14.0	14.0	7.8	**11.0**	1814	3719	2581	3594	**281**	3719	656	3594
2	I-10 Katy - Houston	12.6	15.0	8.1	15.0	2905	3811	4795	3474	720	3811	1625	3474
2	I-10 Katy - Houston	10.2	11.0	7.9	11.0	6920	11418	9430	11335	1785	11418	3330	11335
3	I-10 Katy - Houston	20.0	26.0	14.2	26.0	4795	3474	4920	4084	1625	3474	1671	4084
3	I-10 Katy - Houston	15.9	19.0	13.8	19.0	9430	11335	11260	12654	3330	11335	3940	12654
4	I-10 Katy - Houston	13.3	22.9	13.2	25.6	2300	6674	3310	6346	361	5374	531	5596
4	I-10 Katy - Houston	13.8	17.9	12.9	18.6	5060	18854	6941	19302	840	15754	1300	17102
5	I-10 Katy - Houston	16.4	28.8	15.3	28.3	3310	6346	3760	6921	531	5496	631	5891
5	I-10 Katy - Houston	15.0	22.0	14.8	22.0	6941	19302	7811	20399	1300	17102	1590	17599
6	I-45N North Fwy - Houston	17.9	19.0	15.4	19.0	4280	7220	6030	6350	700	7220	1380	6350
7	U S. 290 NW Fwy - Houston	20.0	20.0	14.4	18.0	1320	4880	3006	5064	490	4880	1226	5064
7	U.S. 290 NW Fwy - Houston	14.1	14.1	11.5	12.0	3520	13930	6460	14890	1365	13930	2510	14890
8	I-15 - San Diego	18.0	18.0	8.6	11.0	4910	8601	7845	11266	1749	8601	3047	11266
8	I-15 -San Diego	14.0	14.0	8.7	10.0	10194	23084	13240	27504	3707	23084	4788	27504
9	I-90 - Seattle	6.6	6.6	6.4	6.4	3615	9675	4067	8815	2195	9675	2633	8815
10	I-5 - Seattle	7.4	8.0	6.0	6.2	5440	4561	6580	4761	1439	4561	1939	4761
11	I-5 -Seattle												
12	I-5 - Seattle	8.0	8.0	6.0	7.0								
13	U.S. 101 - San Jose	19.0	19.0	7.0	14.0	1815	3895	3580	3745	511	3895	1582	3745
13	U.S. 101 - San Jose	15.0	15.0	7.0	14.0	3062	7233	6478	7269	1227	7233	3079	7269
14	U.S. 101 - San Jose	11.0	11.0	4.4	7.0	1288	5112	1936	5224	581	5112	836	5224
14	U.S. 101 -San Jose	9.0	9.0	3.9	5.0	3920	14880	5635	15165	1820	14880	2635	15165
15	I-280 - San Jose	26.0	26.0	13.1	20.0	1130	5780	1832	6588	340	5780	732	6588
15	I-280 - San Jose	22.0	22.0	14.1	16.0	3152	15518	7204	18926	1297	15518	3060	18926
16	128th/Airport Rd - Seattle	8.0	8.0	7.0	8.0								
17	S.R. 237 - San Jose	11.0	11.0	6.0	7.5	2534	6566	4625	8575	1034	6566	2025	8575
18	San Tomas Expwy - San Jose	9.0	9.0	7.5	9.0	1528	7301	2659	7773	741	7296	1297	7766
19	Santa Monica Diamond Lanes	15.7	15.7	15.5	20.5	2055	28151	4456	22659	492	25270	883	19985
20	San Bernardino Express Busway	17.4	19.0	13.2	20.0	7460	30600	10810	31748	840	26800	1886	27808
21	Route 101 - Marin County	3.9	3.9	3.6	3.9	5155	6229	5620	7590	450	5120	500	5400
22	Route 91- Los Angeles	26.0	26.0	10.1	13.5	2314	6926	3751	6833	1015	6926	1645	6833
23	I-210 - Los Angeles	40.5	40.5	23.9	28.6	4023	9922	4555	8755	1875	9922	2218	8755
24	Route 91- Los Angeles	25.2	25.2	11.7	14.5	2657	6437	4648	6934	1205	6437	2075	6934
25	Route 55 - Orange County	32.0	32.0	16.3	29.0	1999	5079	3196	5666	921	5079	1484	5666
26	Route 101 - Corte Madera	5.4	5.8	4.35	4.4	11650	11460	12125	11870	2460	11460	2885	11870
27	Route 101- San Rafael	9.1	10.9	6.6	11.1	8240	12490	8950	13040	2080	12490	2620	13040

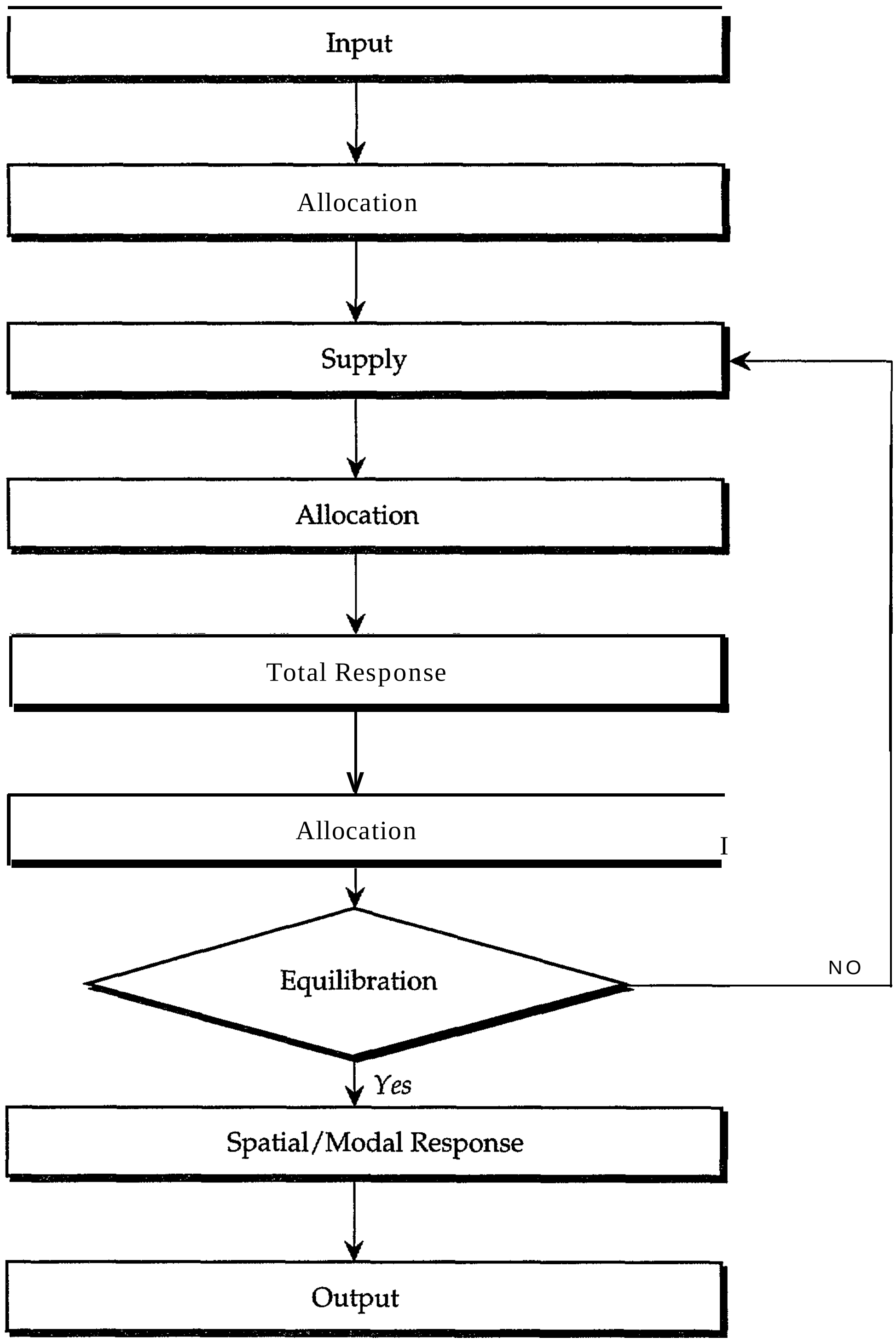


Figure 6.1 HOV Model Structure

6.3 Methodology

The following sections describe each of the modules which formulate the HOV methodology approach. The description of each module includes the purpose, key inputs, the methodology approach, and outputs

6.3.1 Input and Background Calculations Module

The purpose of the input module is to accept and edit the input data. This first step involves identifying the HOV study section and the critical sub-section, inputting demand and supply data, and performing background calculations to adapt the data to the model structure.

The HOV model methodology takes into consideration the controlling or critical sub-section of a directional peak period HOV study section. The critical sub-section is identified as having the highest demand-to-capacity ratio over the study section length. The remainder of the HOV study section should have a fairly uniform demand and capacity profile over its length. Since the HOV model evaluates the impacts of HOV lane(s) for a single direction of travel, each direction of the proposed facility must be analyzed separately.

A summary list of data inputs required by the user is presented in Table 6.2. Inputs marked with the symbol (1) represent the data required for the model. The remaining data inputs are optional since default values are provided by the methodology. The data inputs have been separated into three categories: project description inputs; current demand and travel characteristics; and arterial HOV facility inputs. Project description inputs include proposed design characteristics, facility geometrics, and model parameters. Data inputs such as travel speed, traffic volumes, and occupancy rates are included under current demand and travel characteristics. The inputs listed under arterial HOV facility inputs are only required for users who want to assess an HOV lane on an arterial facility. Table 6.2 also identifies the inputs which are only required for specific analysis options; for example, lane width is only required if the user selects the 1994 HCM based option for calculating running time. Table 6.3 contains the default values for the data inputs.

Table 6.4 presents the model calibration ranges for data inputs and computations for the HOV model methodology. The ranges typically contain a minimum and maximum value, and may further be divided into eligibility type. If any of the input or output values do not fall within these minimum and/or maximum ranges, a warning is issued to inform the user that the value is outside of the model's calibrated range.

Figure 6.2 contains a flow diagram for the input module framework. The user has four options for inputting data into the HOV model: a batch file; an input module for users with minimum data; an input module for users with complex data sets; or the data editor routine. The ASCII batch file method is completely non-interactive. The other three forms are interactive for novice or experience users. The minimum data set routine takes the user though a series of detailed questions to input the data. The complete data set routine involves inputting the data using a series of spreadsheet screens. The complex data set routine offers more flexibility and detail for inputting the data.

Depending on the availability of data, the existing volumes can be input in several different forms. Existing demand (volumes) is requested by vehicle and lane type. If a critical sub-section is specified by the user, data are required for both the critical sub-section and the remainder of the study section. For users with very limited data (minimum data set routine), the HOV model methodology contains a process for deriving traffic volumes by auto occupancy category based on the total directional volume and the average vehicle occupancy for the entire facility. The auto occupancy categories used throughout the HOV model framework include:

- Single occupant vehicles (SOV);
- Two-occupant vehicles (HOV2);

Table 6.2 Summary List of Inputs

Project Description Inputs

- User novice or experienced(1)
- FREQ based or 1994 HCM based running time calculation option(1)
- EMFAC or MOBILE 5 air quality calculation option(1)
- Roadway type
- Proposed HOV lane eligibility(1)
- Action type(1)
- Proposed HOV lane barrier availability(‘)
- Length of the study section and/or critical sub-section”)
- Existing and proposed number of lanes for the study section and/or critical sub-section”)
- Capacity per lane for the study section and/or at the critical sub-section
- Length of peak period
- Distance from traveled way to obstruction (1994 HCM based option only)
- Obstruction on one or both sides (1994 HCM based option only)
- Lane width (1994 HCM based option only)
- Type of terrain (1994 HCM based option only)
- Peaking characteristics
- Existing and estimated ramp meter delay
- Violation rate
- Stop criterion
- Average annual temperature (EMFAC option only)(1)
- Trip table allocation percentages (spatial and modal response)
- Analysis period

Current Demand and Travel Characteristics

- Travel direction(1)
- Existing peak period vehicle speed for the study section(1)
- Free-flow speed or posted speed limit
- Existing peak period average speed on parallel roadways(1)
- Traffic stream type (1994 HCM based option only)
- Percentage of trucks which are gas versus diesel
- Percentage of total vehicles which are recreational vehicles (1994 HCM based option only)
- Occupancy rate(s) and/or distributions by vehicle type(1)
- Existing peak period demand (volume) for study section and/or critical sub-section(1)
- Maximum percentage of peak period HOV eligible vehicles in the HOV lane(s)
- Peak hour factor (1994 HCM based option only)

Arterial HOV Facility Inputs (only necessary if proposed facility is an arterial)

- Number of traffic signals over the length of the study section(1)
- Percentage of turns which are from exclusive lanes
- Quality of signal progression
- Average cycle length
- Average effective green time

Note: (1) Required data inputs.

Table 6.3 Input Data Default Values

Data Inputs	Default Values
Project Description Inputs	
Roadway type	Freeway
Capacity per lane for the study section and/or at the critical sub-section	
HOV lane on a 6+ or 4-lane freeway or multi-lane highway	1600 vph
HOV lane on an arterial (saturation flow rate)	1300 vph
Mixed-flow lane on a 6+ lane freeway	2300 vph
Mixed-flow lane on a 4-lane freeway or multi-lane highway	2200 vph
Mixed-flow lane on an arterial (saturation flow rate)	1900 vph
Length of peak period	3 hours
Distance from traveled way to obstruction (1994 HCM based option only)	6 feet
Obstruction on one or both sides (1994 HCM based option only)	Both sides
Lane width (1994 HCM based option only)	12 feet
Type of terrain (1994 HCM based option only)	Level
Peaking characteristics	
Number of sub-periods	4
Length of sub-periods as a portion of the peak period	l/6, l/3, l/3, 1/6
Flow rates as a percentage of peak hour volume	I I%, 45%, 32%, 12%
HOV lane on a 6+ or 4-lane freeway or multi-lane highway	1600 vph
Existing and estimated average ramp meter delay	
No ramp metering	0
With ramp metering	1 minute
Violation rate	0%
Stop criterion	1%
Trip table allocation percentages (spatial and modal response)	
Facility	
-- Non-HOV to non-HOV	75%
-- Non-HOV to HOV	27%
-- Non-HOV to bus	10%
-- HOV to non-HOV	9%
-- HOV to HOV	37%
-- HOV to bus	35%
-- Bus to non-HOV	1%
-- Bus to HOV	12%
-- Bus to bus	50%
Parallel Facilities	
-- Non-HOV to non-HOV	**13%**
-- Non-HOV to HOV	12%
-- Non-HOV to bus	1%
-- HOV fo non-HOV	1%
-- HOV to HOV	8%
-- HOV to bus	1%
-- Bus to non-HOV	1%
-- Bus to HOV	4%
-- Bus to bus	3%

Table 6.3 Input Data Default Values (continued)

Data Inputs	Default Values
- **Analysis** period	Short-term
Current Demand and Travel Characteristics	
• Free-flow speed or posted speed limit	
– Freeway	60 mph
– Arterial	35 mph
• Average vehicle occupancy	1.25
• Average vehicle occupancy for vehicles with 3 or more persons	3.4
• Average vehicle occupancy for buses	34
• Traffic stream type **(1994** HCM based option only)	Commuter
• Percentage of total vehicle volume which are	
– Trucks	5%
– Buses	0.5%
– Motorcycles	0.8%
– Recreational vehicles (1994 HCM based option only)	0%
- Percentage of total trucks on the facility which are	
– Gas trucks	**70%**
– Diesel trucks	**30%**
. Maximum percent peak period HOV eligible vehicles in the HOV lane(s)	
– 2+ eligibility	**80%**
– 3+ eligibility	**90%**
• Peak hour factor (1994 HCM based option only)	**0.85**
Arterial HOV Facility Inputs (only necessary if proposed facility is an arterial)	
• Percentage of turns which are from exclusive lanes	12%
• Quality of signal progression	**4**
• Average cycle length	120 seconds
• Average effective green time	**54** seconds

Table 6.4 Model Calibration Ranges

Data Inputs and Computations	Minimum	Maximum
(TTAHOVL-TTAMF)/TTAMF	-0.67	0.02
Percent HOV eligible vehicles in the HOV lane(s)		
• 2+ eligibility	22.4%	77.2%
• 3+ eligibility	75.6%	89.9%
Length of study section (FREQ option only)	5 miles	20 miles
Free-flow speed for freeways	55 mph	65 mph
D/C	---	1.25
Number of sub-periods for peaking characteristics	---	4
Percent HOV change (growth)		
• 2+ eligibility	17%	151%
• 3+ eligibility	11%	125%
(TTAH-TTBH)/TTBH		
• 2+ eligibility	-0.533	-0.030
• 3+ eligibility	-0.241	-0.013
(TTAS-TTAH)/TTBS (3+ eligibility only)	0.077	0.038
Percent non-HOV change (growth)		
• 2+ eligibility	-12%	22%
• 3+ eligibility	-21%	9%
(TTAS-TTBS)/TTBS		
• 2+ eligibility	-0.286	0.018
• 3+ eligibility	0.000	0.303
Length of study section		
• 2+ eligibility	3.0 miles	13.5 miles
• 3+ eligibility	3.7 miles	12.6 miles
Stop criterion	---	10%
Average annual temperature (EMFAC option only)	55°F	95°F
Lane width (1994 HCM option only)	10 feet	---
Average effective green time per cycle (g/cycle)	0.20	0.70

Where: TTAHOVL = Estimated (future) peak period travel time for vehicles in the HOV lane(s)
TTAMF = Estimated (future) peak period travel time for vehicles in the mixed-flow lane(s)
TTAH = Estimated (future) peak period HOV eligible vehicle travel time
TTBH = Existing (before) peak period HOV eligible vehicle travel time
TTAS = Estimated (future) peak period non-HOV eligible vehicle travel time
TTBS = Existing (before) peak period non-HOV eligible vehicle travel time

Purpose: To ***Accept and*** Edit ***Input*** Data

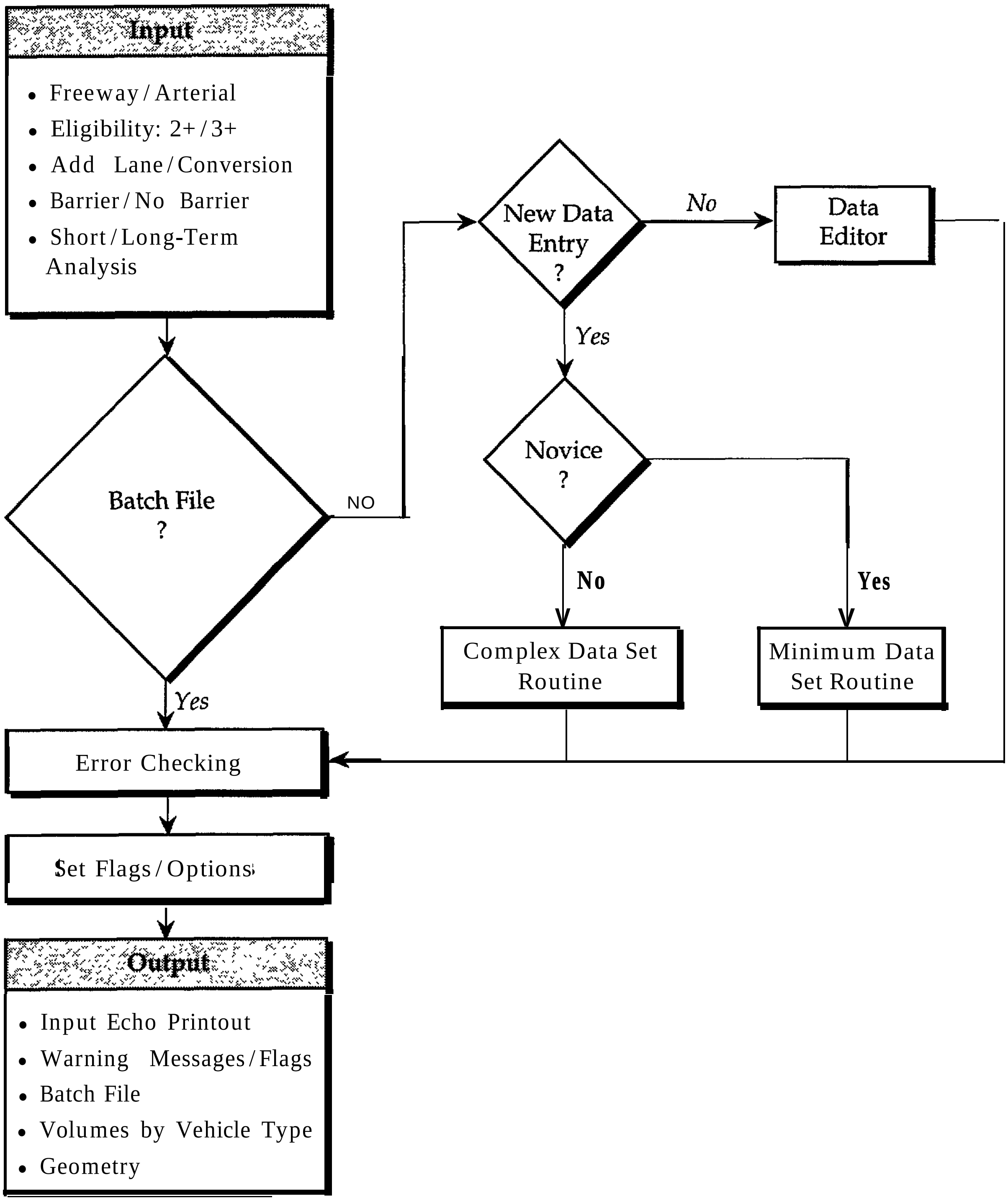


Figure 6.2 Input Module

- Three-or more occupant vehicles (HOV3+);
- Trucks;
- Buses; and
- Motorcycles.

Since trucks, buses, and motorcycles are typically only a small portion of the total traffic volume, average percentage values were calculated from the project data set to be used as defaults. Using the available data sets, percent flows (volumes) versus average vehicle occupancies (AVO) were plotted for each vehicle type. Figure 6.3 shows the lines fitted to the regression equations developed for the SOV and HOV2 vehicle types. Note that the percentage of HOV3+ vehicles is the remaining percentage out of the sum of SOV and HOV2. The equations developed to determine the percentage of SOVs and HOV2s in the total traffic stream based on AVO take the following form:

$$\% \ SOV = [(-0.80 * \text{Average Vehicle Occupancy}) + 1.80] * 100$$

$$\% \ HOV2 = [(0.667 * \text{Average Vehicle Occupancy}) - 0.667] * 100$$

The input and background calculations module distributes the existing (or before) vehicle volumes according to the proposed HOV lane(s) eligibility (HOV eligible or non-HOV eligible). It is assumed that for2+ eligibility, all vehicles carrying two or more persons, buses, and motorcycles are considered HOV eligible. For3+ facilities, all vehicles with three or more persons, buses, and motorcycles are HOV eligible.

The demand model's parameters were estimated based upon actual observations of short-term impacts (six-months to one year); there was minimal data available for long-term impacts. Therefore, if the user is interested in conducting a long-term analysis of the HOV facility (longer than one year), the following equation is applied to the existing volumes input or calculated in this module.

$$\text{Long - term volume} = \text{Existing volume} * \left(1 + \frac{\% \ \text{Growth}}{100}\right)^{\text{Number of analysis years}}$$

6.3.2 Allocation Module

The purpose of the allocation module is to allocate the HOV and non-HOV eligible vehicles into the HOV and mixed-flow lane(s). The allocation module framework is presented in Figure 6.4. The necessary inputs for the allocation module include:

- HOV lane(s) eligibility;
- HOV lane(s) barrier availability;
- Violation rate;
- Maximum percentage of peak period HOV eligible vehicles in the HOV lane(s) for the study section;
- Existing (before) peak period travel times for the HOV and mixed-flow lane(s); and
- Existing (before) peak period HOV eligible and non-HOV eligible vehicle volumes.

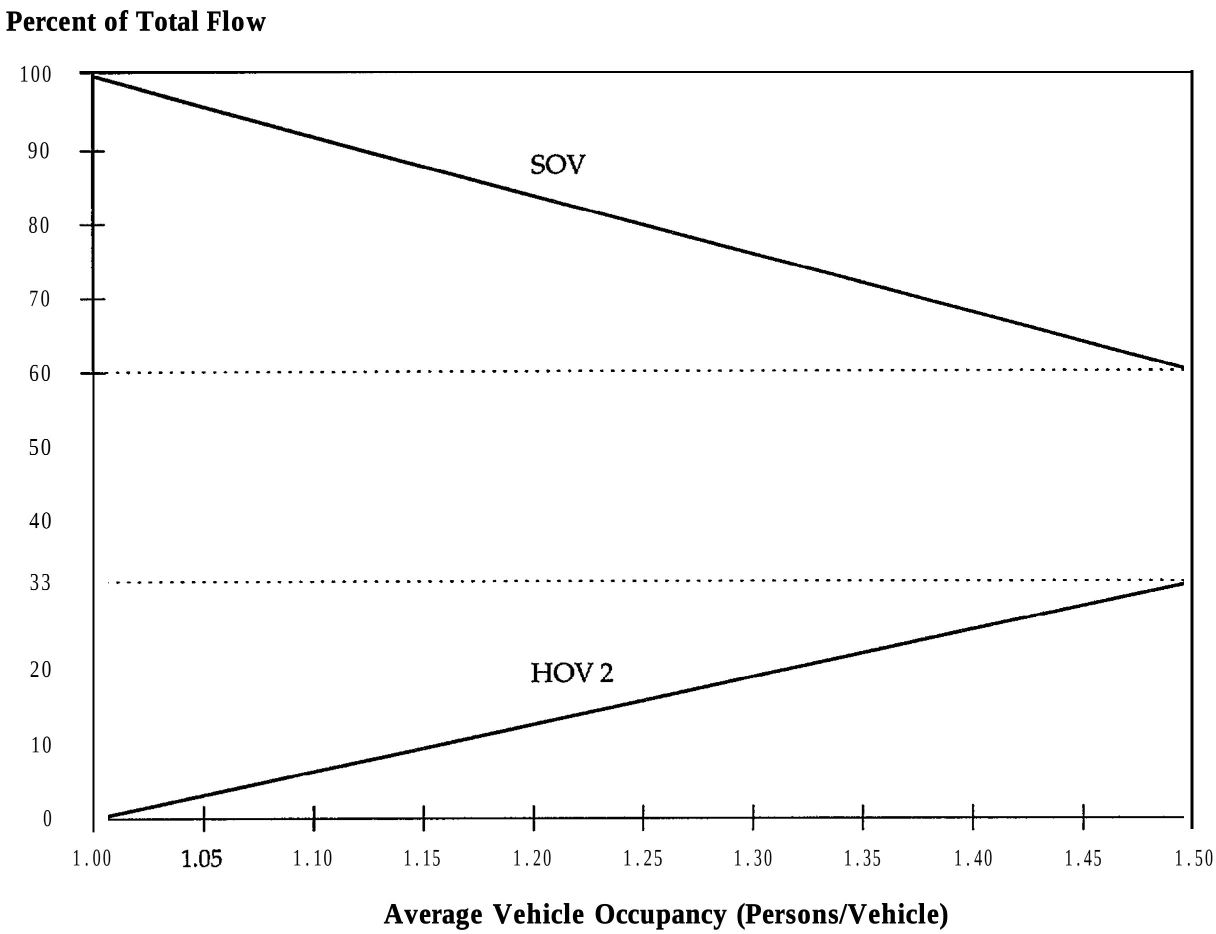


Figure 6.3 Percent Flow vs. Average Vehicle Occupancy (AVO)

Purpose: To Allocate ***Traffic to HOV and Mixed-Flow Lane(s)***

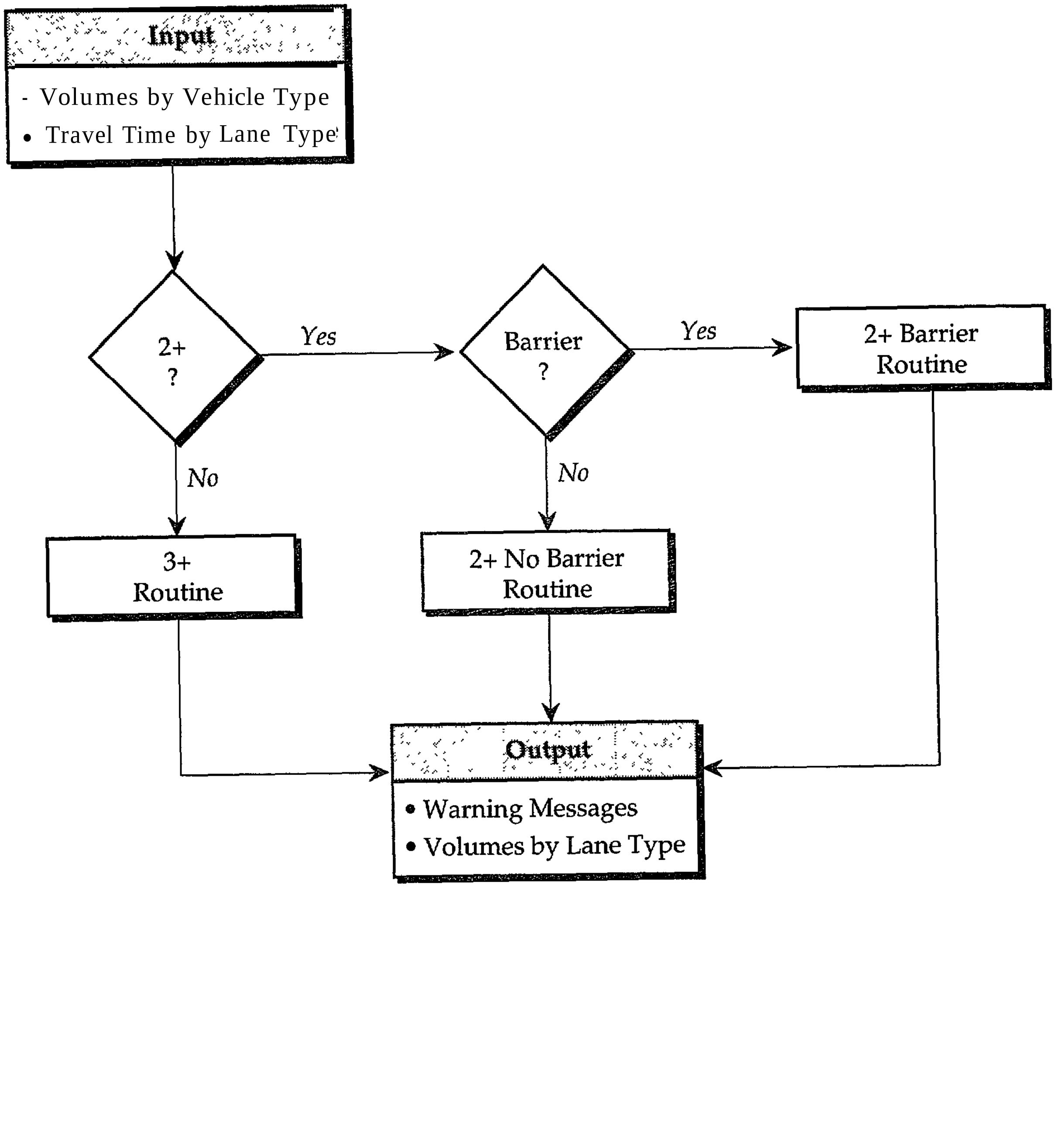


Figure 6.4 Allocation Module

As visible from Figure 6.4, the vehicle volumes are distributed into the HOV and mixed-flow lane(s) using one of three routines depending upon HOV lane(s) eligibility and barrier availability. The three routines include the 2+ barrier routine, the 2+ no-barrier routine, and the 3+ routine (based upon actual data, there is no differentiation between barrier and no-barrier for the 3+ eligibility routine). A barrier-separated HOV facility is defined as a facility separated from the mixed-flow lanes by a stripe or barrier that limits access. Using the available data sets, the percent HOV eligible vehicles in the HOV lane(s) were plotted against the percent differential in travel times between the HOV and mixed-flow lane(s) for each of the three cases. Regression equations were developed from these plots for estimating the percent of HOV eligible vehicles in the HOV lane(s). Figures 6.5 to 6.7 present the plots for each of the three routines. The equations for estimating the percentage of HOV eligible vehicles in the HOV lane are as follows:

- For 2+ eligibility and barrier-separated HOV facilities:

$$\%\,HOVs\ in\ the\ HOV\ lane = \left[0.352 - (1.053) * \left(\frac{TTAHOVL - TTAMF}{TTAMF}\right)\right] * 100$$

Where: TTAHOVL = Estimated (future) HOV lane(s) travel time
TTAMF = Estimated (future) mixed-flow lane(s) travel time
Maximum = 80% or user override
Minimum = 0%

- For 2+ eligibility and no-barrier facilities:

$$\%\,HOVs\ in\ the\ HOV\ lane = \left[0.439 - (0.389) * \frac{(TTAHOVL - TTAMF)}{TTAMF}\right] * 100$$

Where: TTAHOVL = Estimated (future) HOV lane(s) travel time
TTAMF = Estimated (future) mixed-flow lane(s) travel time
Maximum = 80% or user override
Minimum = 0%

- For all 3+ eligible facilities:

$$\%\,HOVs\ in\ the\ HOV\ lane = \left[0.503 - (0.882) * \frac{(TTAHOVL - TTAMF)}{TTAMF}\right] * 100$$

Where: TTAHOVL = Estimated (future) HOV lane(s) travel time
TTAMF = Estimated (future) mixed-flow lane(s) travel time
Maximum = 90% or user override
Minimum = 0%

As evident in the statements following the equations, the user has the capability of overriding the maximum percentage of HOV eligible vehicles using the HOV lane(s).

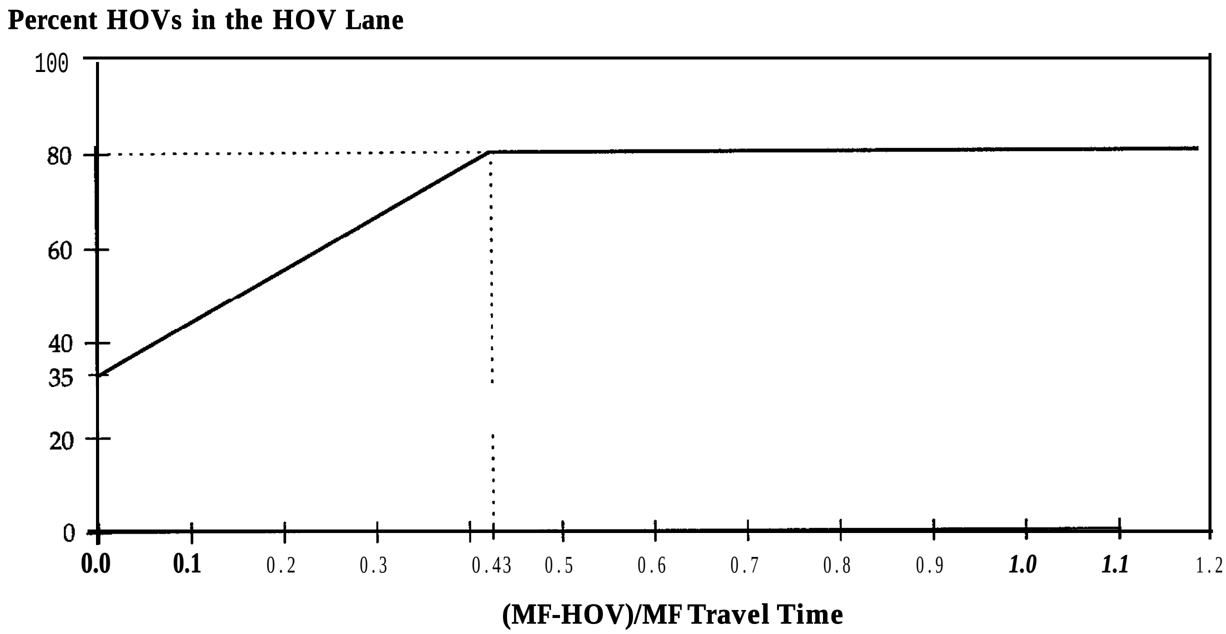


Figure 6.5 HOV 2+/Barrier Allocation Routine

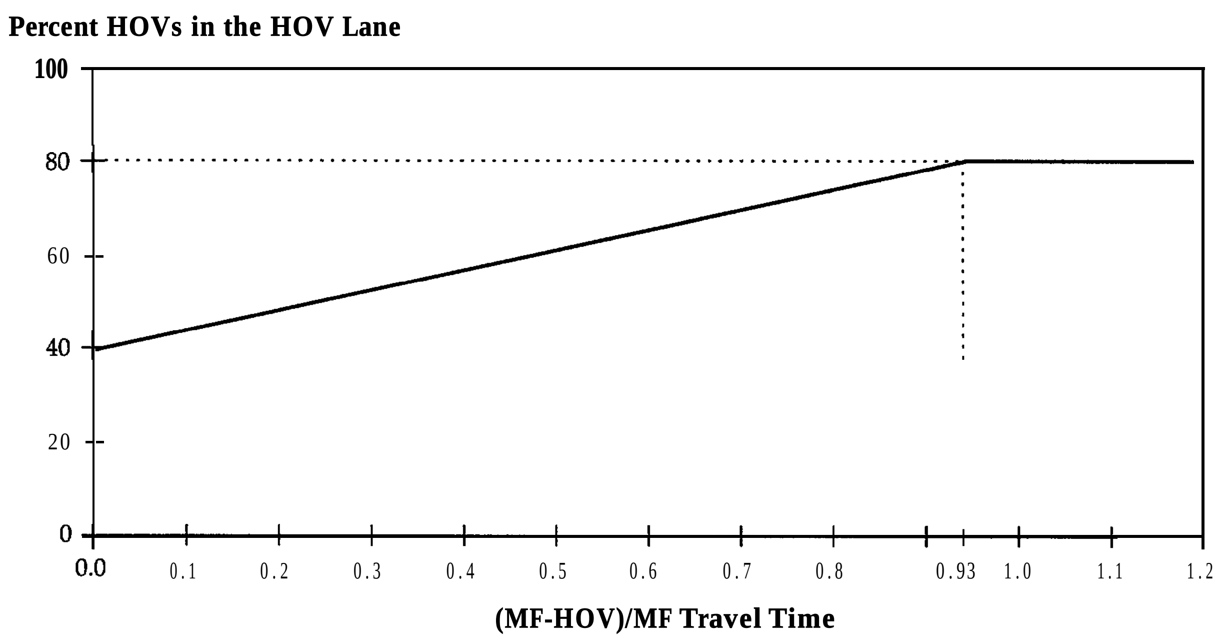


Figure 6.6 HOV 2+/No Barrier Allocation Routine

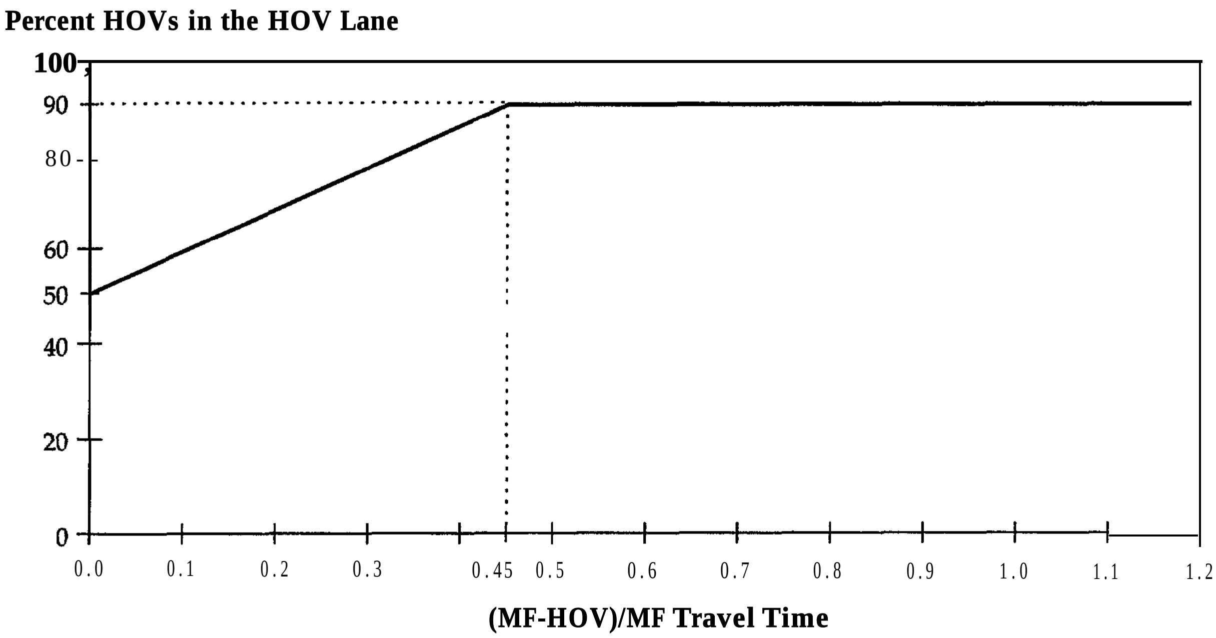


Figure 6.7 HOV 3+ Allocation Routine

The model then estimates the violators in the HOV lane(s) using the following equation and the violation rate input by the user.

$$\begin{bmatrix} \text{Estimated violators} \\ \text{in the HOV lane(s)} \end{bmatrix} = \begin{bmatrix} \text{Estimated HOVs in the} \\ \text{HOV lane(s) volume} \end{bmatrix} * \begin{bmatrix} \dfrac{\text{Violation rate}}{100} \end{bmatrix}$$

The sum of the HOV eligible vehicles in the HOV lane(s) and the violators is the estimated peak period HOV lane(s) volume. The estimated mixed-flow lane(s) volume is the non-HOV eligible vehicle volume minus the violators in the HOV lane(s) plus the HOV eligible vehicles in the mixed-flow lane(s).

The allocation module is used in three steps within the general model framework as shown in Figure 6.1. Initially it is used to allocate the existing vehicle volumes into each lane type for existing travel times. Using the travel times estimated within the supply module, the volumes are then reallocated for estimating HOV and non-HOV eligible vehicle travel times within the total response module. Finally, the module estimates the HOV and non-HOV eligible total response which must be allocated into the HOV and mixed-flow lane(s) for use in the equilibration, spatial and modal response, and output modules.

6.3.3 Supply Module

The supply module computes the travel times for the HOV and mixed-flow lane(s). Within this module, the travel time computation is different for proposed HOV facilities on a freeway versus an arterial. The inputs to the supply module include:

- Running time calculation option (FREQ or 1994 HCM based);
- Roadway type;
- Length of study section and critical sub-section;
- Length of peak period and peaking characteristics;
- Existing and proposed average ramp meter delay;
- Existing and proposed number of lanes for the study section and/or at critical sub-section;
- Capacity per lane for the study section and/or at the critical sub-section (saturation flow rate for arterials);
- Free-flow speed;
- Existing travel time;
- Peak hour factor (1994 HCM option only);
- Obstructions and distance from obstruction to traveled way (1994 HCM option only);
- Lane width (1994 HCM option only);
- Traffic stream type (1994 HCM option only);
- Percentage of total vehicles which are trucks (1994 HCM option only);
- Percentage of total vehicles which are recreational vehicles (1994 HCM option only);
- Type of terrain (1994 HCM option only);
- Existing and estimated peak period demand (volumes) by lane type for the study section and/or at the critical sub-section;

- Percentage of turns which are from exclusive lanes (for arterials □■●⊠◑▭
- Quality of signal progression (for arterials only);
- Average cycle length (for arterials only);
- Average effective green time (for arterials only);
- Average number of signals per mile (for arterials only); and
- Average signal spacing (for arterials only).

Figure 6.8 presents the structure for the supply module. The supply module computes travel times for the HOV and mixed-flow lane(s) using the basic computation:

[Travel Time] = [Running Time] + [Queue Delay] + [Ramp Meter Delay] + [Travel Time Calibration Value]

For proposed HOV facilities on freeways or arterials, demand to capacity ratios are computed for the critical sub-section and the remainder of the study section to determine if there will be a queue delay. If the demand to capacity ratio (D/C) is greater than one then the queuing delay must be added to the running time, ramp meter delay, and calibration value.

The running time is computed differently for freeways and arterials. Separate computations of running time are performed for the critical sub-section and the remainder of the study section. The total running time for the study section is obtained by summing the two values. There are two alternative procedures used to compute running time for freeways. The options include a FREQ based computation and a 1994 Highway Capacity Manual (HCM) based approach.

The FREQ based running time computation routine is identified in Figure 6.9. This procedure was developed based on supply curves estimated using a series of parametric simulations using the macroscopic simulation model FREQ. The FREQ model was used to estimate the directional freeway study section speed as a function of the freeway critical sub-section demand to capacity ratio. Based upon the D/C and the free-flow speed, the running time in minutes per mile can be estimated and multiplied by the length of the study section to obtain the running time.

The 1994 HCM based option computes the running time according to the equations shown in Figure 6.10 The estimated volume is converted to an ideal volume which is then used to look-up the speed in Figure 3-2 of the HCM. The BPR curve-type equation contained in Figure 6.10 was fitted to the curve in Figure 3-2 of the HCM. The speed obtained from this equation is then multiplied by the section length to obtain the running time.

The methodology for estimating running time for arterial HOV facilities is based upon the techniques described in the arterials chapter of the 1994 HCM. The arterial travel time estimation procedure uses the HCM arterial speed computation routine as presented in Figure 6.11. The running time per mile is estimated based upon the free-flow speed and the average distance between signals computed in the input module. Next the intersection approach delay is computed according to equation 2 in Figure 6.11 The arterial running time is a function of the section length, the average number of signals per mile, the running time between signals, and the average intersection approach delay, and is computed as follows:

Purpose: To Predict Travel Time

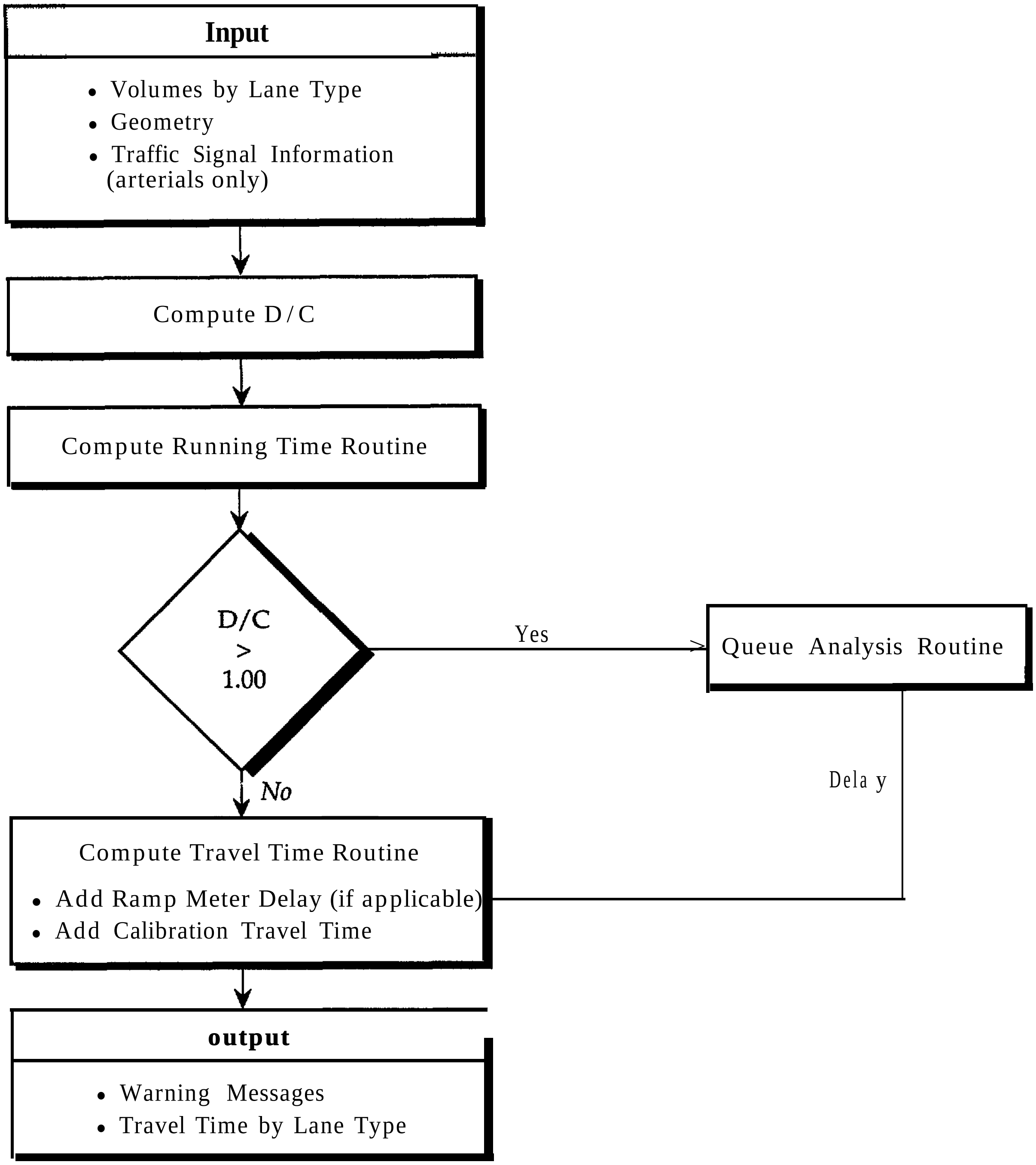
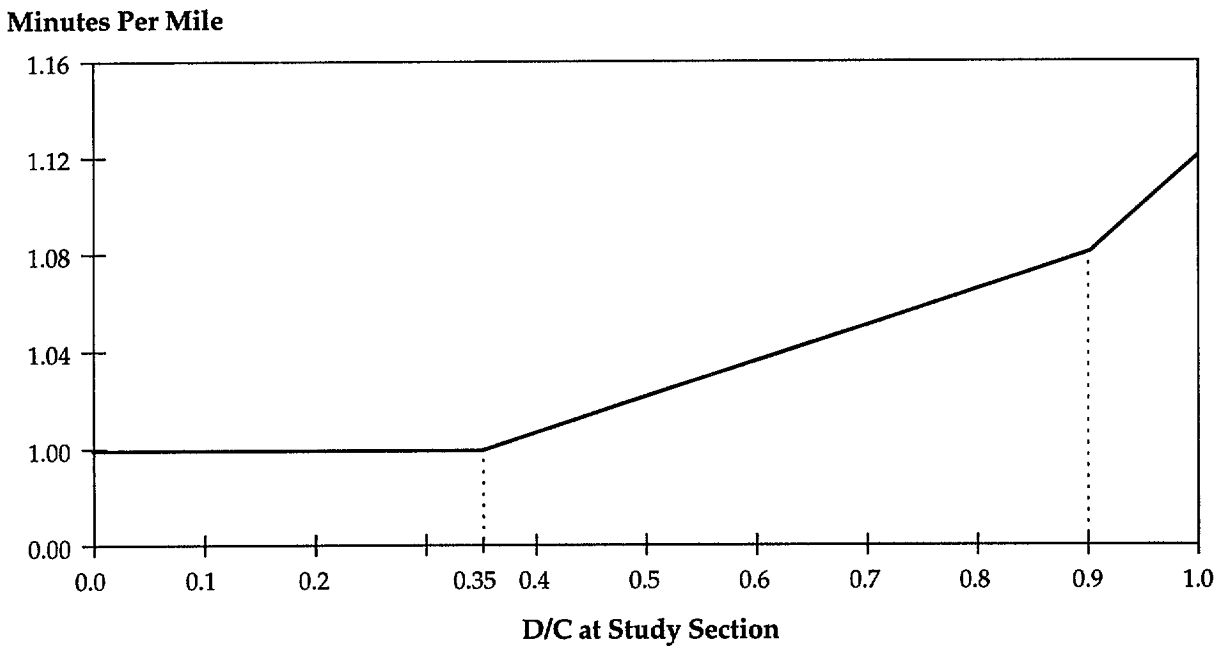


Figure 6.8 Supply Module



If: Dss/C ≤ 0.35

$$\text{Running Time} = \frac{\text{Section length} \cdot 60}{\text{Free - flow speed}}$$

If: 0.35 < Dss/C ≤ 0.90

$$\text{Running Time} = \left[(0.1497 \cdot \text{Dss/C}) + 0.9467 + (\frac{60}{\text{Free - flow speed}} - 1)\right] * \text{ Section length}$$

If: 0.90 < Dss/C < 1.00

$$\text{Running Time} = \left[(0.3497 \cdot \text{Dss/C}) + 0.7667 + (\frac{60}{\text{Free - flow speed}} - 1)\right] * \text{ Section length}$$

Figure 6.9
Freeway Running Time Computation Routine - FREQ Based

(1)

$$v_{ideal} = \frac{v_{predicted}}{PHF * f_{width} * f_{heavy\ vehicles} * f_{population}}$$

Where:

v_{ideal}	=	Ideal flow rate to compute speed
$v_{predicted}$	=	Predicted volume (vph)
PHF	=	Peak hour factor
f_{width}	=	Lane width and lateral clearance adjustment factor
$f_{heavy\ vehicles}$	=	Adjustment factor for effect of heavy vehicles
$f_{population}$	=	Driver population adjustment factor

(2)

$$s = \frac{s_f}{1 + a(v/c)^b}$$

Where:

s	=	Predicted mean speed (mph)
s_f	=	Free-flow speed (mph)
v	=	Minimum of v_{ideal} or capacity
c	=	Capacity
a	=	$0.16 + \frac{s_f - 70}{250}$
b	=	$4 + \frac{70 - s_f}{2.5}$

Source: 1994 Highway Capacity Manual

Figure 6.10
Freeway Running Time Computation Routine - 1994 HCM Based

(1)

$$\text{Running time per mile} = \frac{3600}{s_f - a * \exp^{(b*dist)}}$$

Where:

s_f = Free-flow speed (mph)

dist = Average distance between signals (miles)

$$a = 18 + \frac{s_f - 70}{250}$$

$$b = \frac{s_f - 25}{5} - 9$$

(2)

$$D = 1.3 * (d_u * DF + d_i)$$

Where:

d_u = Approach uniform delay (sec/veh)

$$= (0.38) * C * \frac{[1 - (G/C)]^2}{[1 - (G/C) * Min(X, 1.0)]}$$

d_i = Approach incremental delay (sec/veh)

$$= 173 * X^2 * \left\{(X-1) + \sqrt{(X-1)^2 + m * (X/C)}\right\}$$

DF = Delay adjustment factor

C = Cycle length (sec)

G = Effective green time for the lane group (sec)

G/C = Green ratio for the subject group

X = Volume/capacity ratio for the subject lane group (if v/c > 1.00, use 1.00)

v = Volume per hour

c = Capacity for the through lane group (vph)

m = Calibration term for incremental delay

D = Approach total delay

Source: 1994 Highway Capacity Manual

Figure 6.11 Arterial Running Time Computation Routine

The arterial running time estimate using this procedure is only valid for volume to capacity ratios (v/c) less than or equal to 1.00. Therefore, if v/c is greater than 1.00, the running time estimated using this process is added to the additional time estimated in the queue analysis routine.

The queue analysis routine is used when the demand to capacity ratio is greater than 1.00. If the demand to capacity ratio is less than 1.00, then the queue delay equals zero. The queue analysis routine is used for both freeway and arterial facilities and is computed separately for the critical sub-section and the remainder of the study section. As shown in Figure 6.12, the queue analysis routine requires data on peaking characteristics to determine the duration of the queue, when the queue occurs, and when the queue clears to estimate the total delay. The graphs in Figure 6.12 show the accumulated volume and queue versus time through the sub-periods. The figure also identifies the model's default values for the peaking characteristics.

Data checks are necessary to verify that the queue will clear during the analysis period. The queue first occurs within the sub-period where the demand rate (V) is greater than the capacity. Next, the sub-period where the queue clears is determined, checking to see if the queue builds again in another period. Total and mean delay are then computed using lane(s) capacities and sub-period lengths and volume rates, using the following equations:

$$Estimated\ total\ delay = \frac{1}{2}\left[\sum_{i}^{k}(V_i - C_i) * \left[P_i^2 + P_i * \frac{\sum_{j}^{k} P_j * (V_j - C_j)}{C_{k+1} - V_{k+1}}\right]\right] + R$$

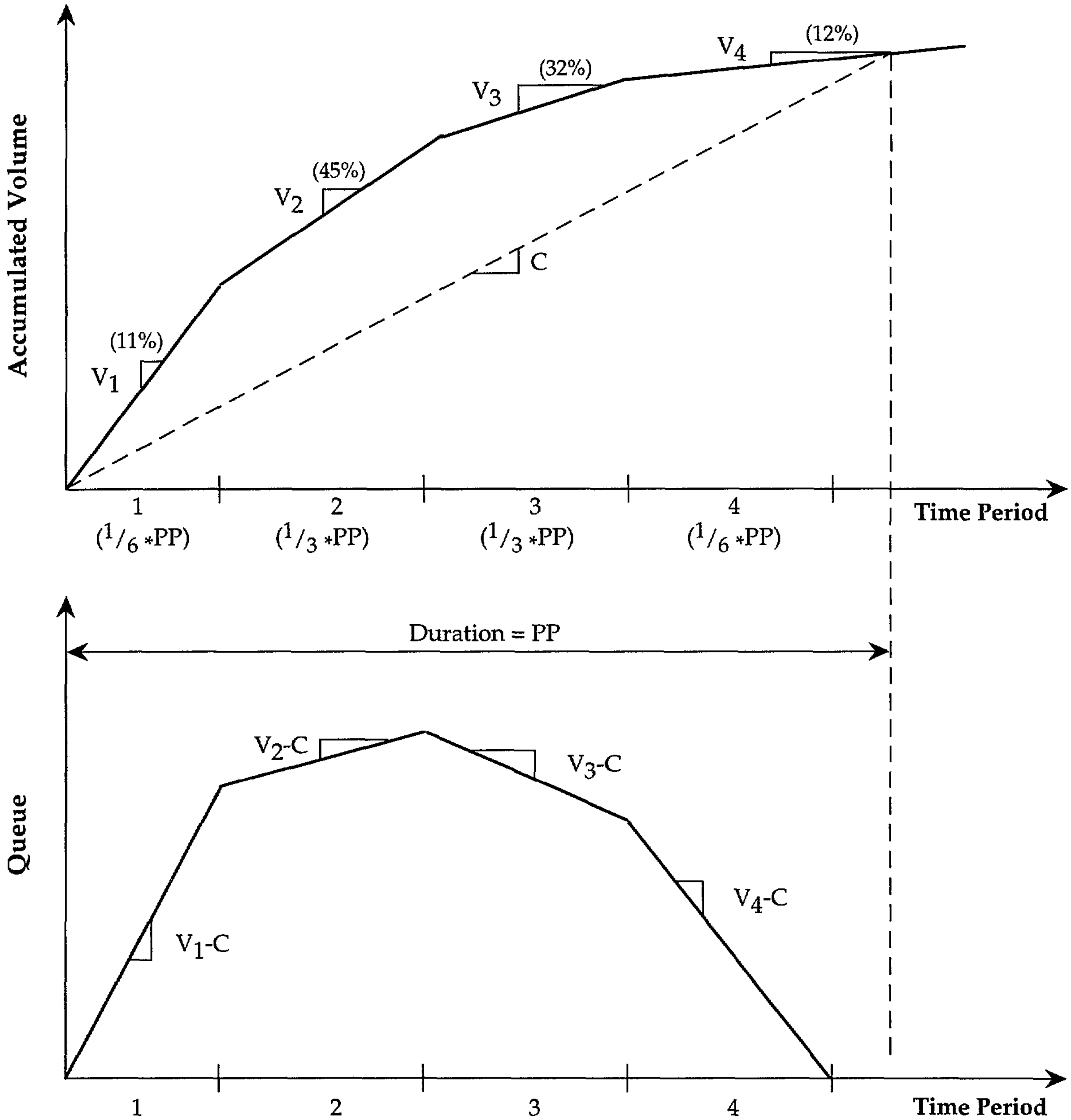
Where: i=j= Number of sub-periods;
P = Length of sub-period in hours;
V = Demand rate;
C = Capacity;

Case	k	R
A	1	0
B	2	$(V_1 - C_1) * P_1 * P_2$
C	3	$[(V_1 - C_1) * P_1 * (P_2 + P_3)] + [(V_2 - C_2) * P_2 * P_3]$

Case A = Queue clears in second sub-period;
Case B = Queue clears in second sub-period; and
Case C = Queue clears in fourth sub-period.

$$Estimated\ queuing\ delay = \frac{60 * [Estimated\ total\ delay]}{[Estimated\ volume]}$$

If the facility has either existing or proposed ramp metering, the user has the option of including ramp meter delay in the travel time computation routine. The user needs to input ramp meter delay, in minutes, for the HOV eligible and non-HOV eligible vehicles. Since the model was not calibrated for ramp metering specifically, a warning is issued to the user to that effect. Also, if there is no ramp metering in the existing (before) case, but there is ramp metering proposed for the future facility, a warning is issued to the user that there will be origin and destination discrepancies since ramp metering tends to favor longer trips.



Where:
( ) = Default values
V = Demand rate (percentage of peak)
C = Capacity
PP = Duration of peak period

Figure 6.12 Queue Analysis Routine (Dcss/C>1.0)

The existing ramp meter delay input by the user is directly input into the travel time calculation. Ideally, for the estimated (future) travel time computation, the estimated user input ramp meter delay should be adjusted after each run of the model. To do this, the estimated demand (volume) output from the total response model and distributed through the allocation module could be input into FREQ and run. The average ramp delay from the FREQ run could then be used as the input in the HOV model. The procedure would be complete when the average ramp delay output from FREQ is approximately equal to the ramp meter delay input by the user.

The travel time calibration term adjusts the forecasted travel times to account for differences between estimated travel time and the observed travel time (user input). The existing travel time is estimated using the supply module routine described above. This travel time estimation uses existing roadway geometrics and demand input by the user. If the estimated travel time is significantly different from observed travel time (greater than 20%), the user must adjust the input capacity values and/or peaking characteristics to more closely reflect input travel times. This difference between the model's estimated existing travel time and the travel time input by the user is added to the running time, queue delay, and ramp meter delay in each iteration to compute total travel times.

6.3.4 Total Response Module

In this step, the HOV model estimates total traveler response to the proposed HOV facility. Several variables influence the demand for HOV facilities including travel time savings in the HOV lane, trip length, household size, vehicle availability, rideshare programs, parking costs, etc. HOV demand models typically express the demand for an HOV facility (dependent variable) as a function of several tangible explanatory variables.

Because the total response model's parameters are estimated based on actual observations, all carpool formation factors and traveler responses to the HOV lane are assumed to be accounted for within the data used for model estimation. Thus, HOV demand models are typically forecasting the total response to the HOV lane which aggregates spatial, temporal, and modal responses. An implicit assumption in the estimation of the HOV model (and a guide in the selection of observation sites) was that apart from the HOV lane, no other major changes have occurred in the locations used in the statistical estimation of the model.

Based on the HOV literature review, HOV lane travel time savings emerged as the primary determinant of HOV demand. Consequently, the total response model was developed to predict total response to the HOV facility based on travel time savings in the HOV lane relative to the existing (before) traffic conditions and relative to mixed-flow lane traffic performance. The total response estimation procedure was developed using before/after and HOV/non-HOV observations from existing HOV facilities around the United States.

Prior to the total response module, the allocation module uses the estimated travel times by lane type to distribute the HOV eligible vehicles into the HOV and mixed-flow lane(s) as described previously. This input is necessary to compute travel times by vehicle type (HOV eligible or non-HOV eligible vehicles) through weighted averages of volumes. The other necessary inputs include:

- Eligibility type;
- Existing average peak period speeds by lane type;
- Length of study section;
- Existing peak period volumes for the study section by eligibility type;
- Estimated peak period travel times by lane type; and
- Estimated peak period HOV eligible vehicle volumes for the study section by lane type.

The total response module framework is shown in Figure 6.13. Separate model parameters were estimated for facilities with different occupancy requirements (2+ and 3+) and are applicable to the following design and occupancy scenarios:

- Add one HOV lane;
- Add two HOV lanes;
- Extending an HOV lane;
- Convert mixed-flow lane to HOV lane;
- Convert occupancy requirement from 3+ to 2+; and
- Convert occupancy requirement from 2+ to 3+.

The model equations for predicting total response are shown in Figure 6.14. These equations were developed by regressing the percent change in vehicle volumes versus the percent change in travel times from the available data sets. The methodology for estimating total response for 2+ eligibility (HOV and non-HOV eligible) and non-HOV eligible in HOV 3+ facilities use dependent variables that describe percent change in travel times from before to after the HOV facility is implemented. The first equation in Figure 6.14 shows an increment of 0.13 which means that a new or converted HOV 2+ facility will generate a minimum of 13 percent growth in HOVs even in the case of no travel time benefit for HOVs from before to after. This growth is probably due to HOVs diverting from parallel facilities onto the new HOV facility. Total response to HOV 3+ facilities is a function of both before/after and HOV/non-HOV travel times. Figures 6.15 and 6.16 contain the plots and corresponding regression equations for the 2+ eligibility models for HOV and non-HOV vehicles, respectively. Each of the observation points used for the development of the model equations is shown and is labeled according to location, barrier availability, and action type.

The percent HOV and non-HOV volume changes computed through this procedure are applied to the existing HOV eligible and non-HOV eligible vehicle volumes to obtain forecasted volumes by vehicle type. Figure 6.17 presents a comparison of results of the total response model to results from other existing models that are used to predict HOV demand. The new methodology, for similar travel time benefits, estimates HOV 2+ total response close to the mid-to-low range of the other models. This is probably reflecting the reduced car-pool mode shares observed in the 1990 Census. The HOV 3+ total response estimate is greater than for HOV 2+, and is in the mid-to-high range of other HOV model estimates since travel time benefits of 3+ HOV lanes are typically greater than travel time benefits of 2+ HOV lanes.

Purpose: To Predict Total Response

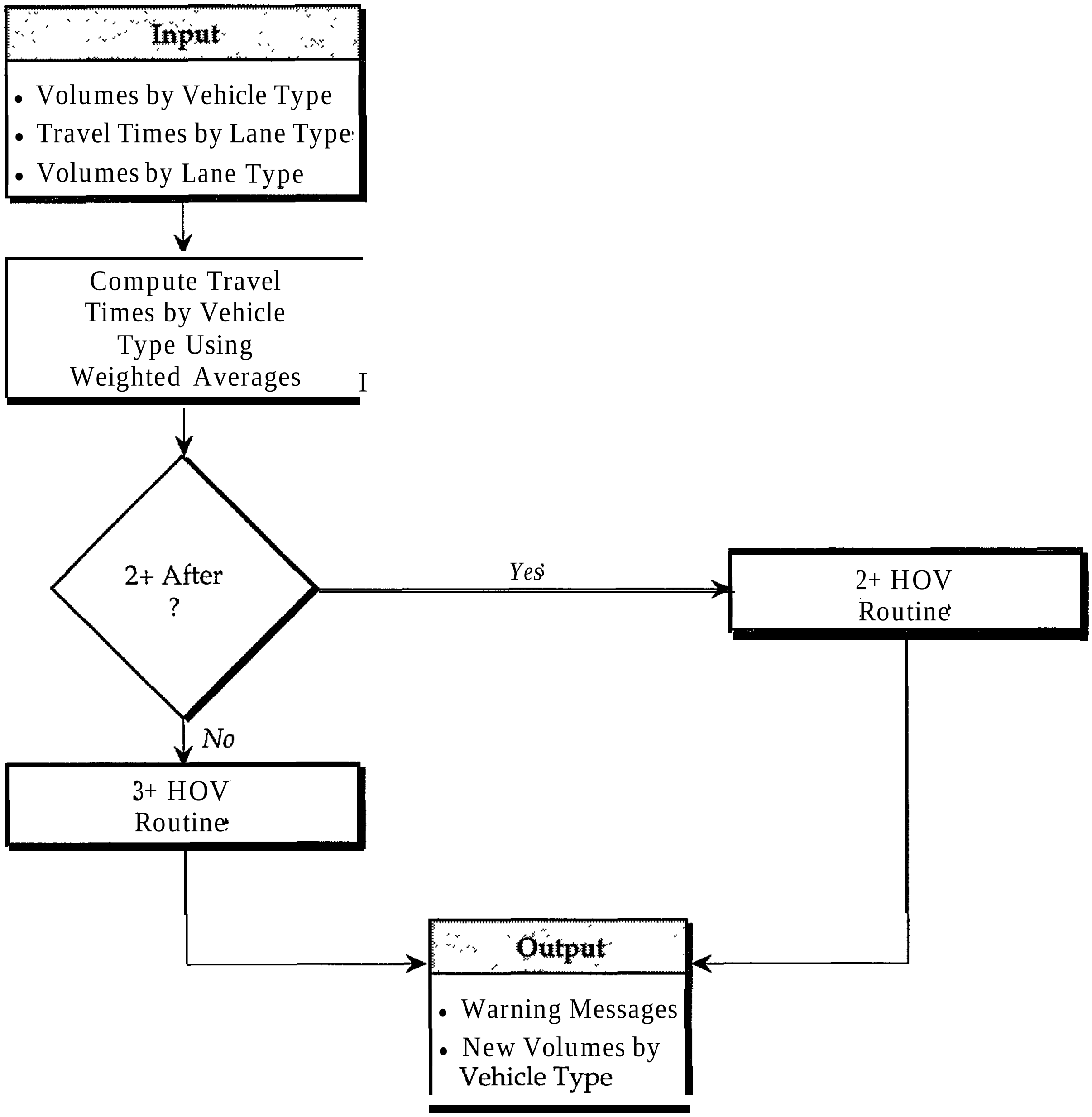


Figure 6.13 Total Response Module

- $Percent\ HOV\ 2{+}\ Change = 0.13 + 2.11 * \left[\frac{(After - Before)\ Travel\ Time\ for\ HOV\ 2+}{Before\ Travel\ Time\ for\ HOV\ 2+}\right]$
  - T-statistic: (0.50) (2.21)
  - F-statistic = 4.91

- $Percent\ Non\text{-}HOV\ 2{+}\ Change = 0.48 * \left[\frac{(After - Before)\ Travel\ Time\ for\ Non - HOV\ 2+}{Before\ Travel\ Time\ for\ Non - HOV\ 2+}\right]$
  - T-statistic: (3.24)
  - F-statistic = 6.80

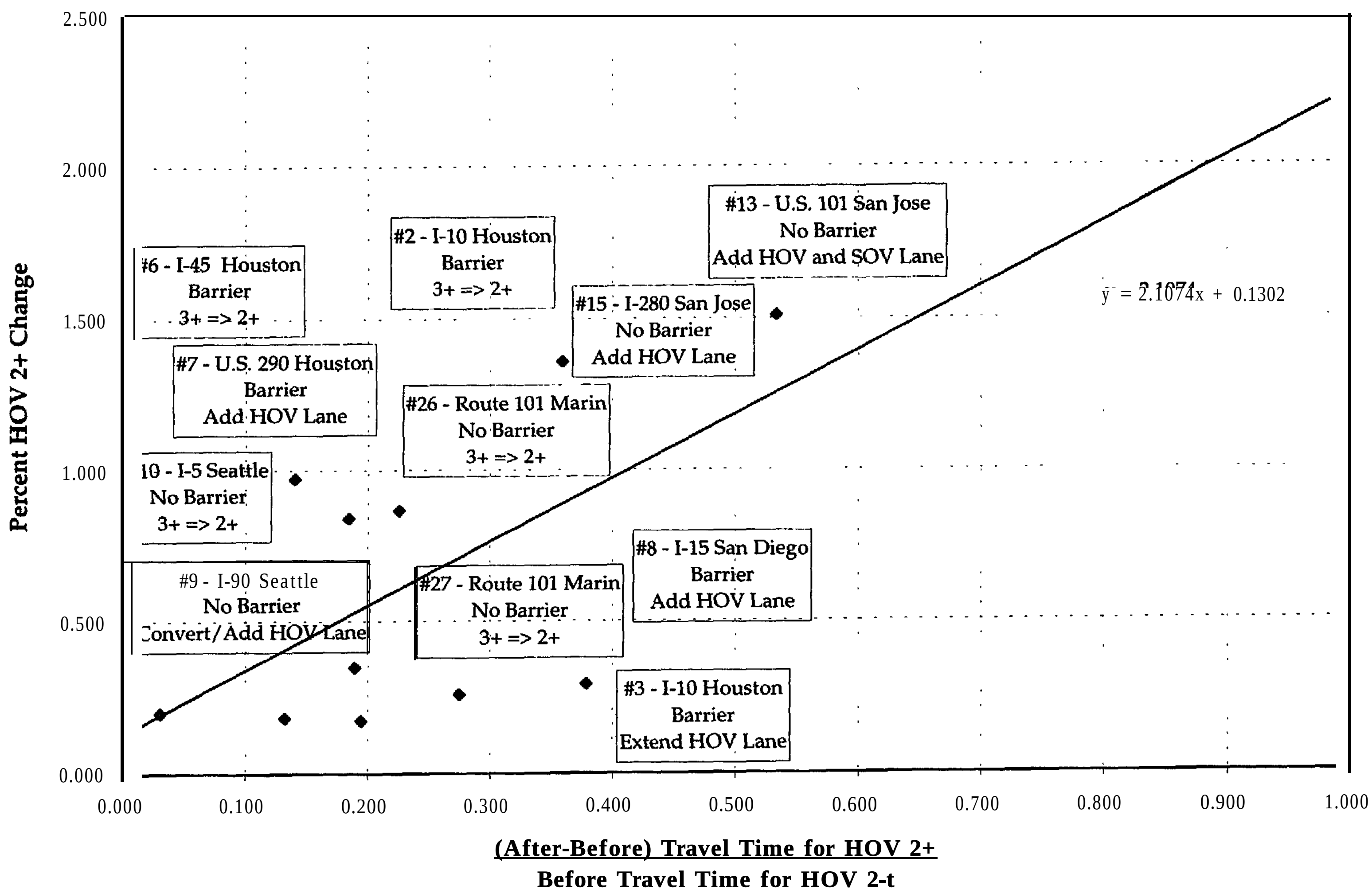
- $Percent\ HOV\ 3{+}\ Change = 2.72 * \left[\frac{(After - Before)\ Travel\ Time\ for\ HOV\ 3+}{Before\ Travel\ Time\ for\ HOV\ 3+}\right] +$
  - T-statistic: (1.84)

  $$1.41 * \left[\frac{[(Non - HOV3+) - (HOV\ 3+)]\ After\ Travel\ Time}{Before\ Travel\ Time\ for\ Non - HOV\ 3+}\right]$$
  - T-statistic: (2.42)
  - F-statistic = 3.92

- $Percent\ Non\text{-}HOV\ 3{+}\ Change = 0.07 + 0.89 * \left[\frac{(After - Before)\ Travel\ Time\ for\ Non - HOV\ 3+}{Before\ Travel\ Time\ for\ Non - HOV\ 3+}\right]$
  - T-statistic: (3.23) (-5.70)
  - F-statistic = 32.54

Figure 6.14 Models for Prediction of Total Response

Figure 6.15 Total HOV Eligible Vehicle Response to a 2+ HOV Facility



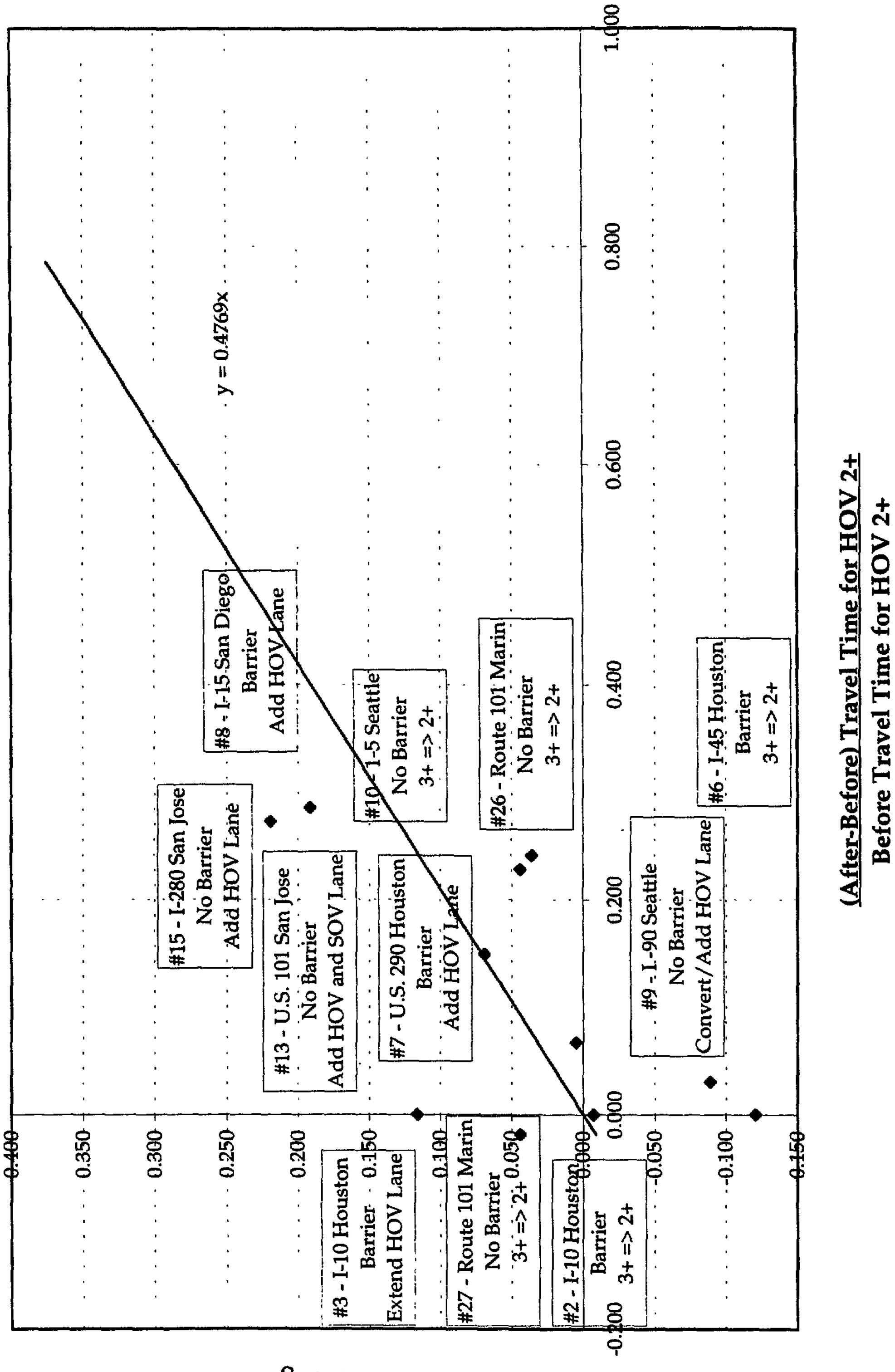


Figure 6.16 Total Non-HOV Eligible Vehicle Response to a 2+ HOV Facility

Figure 6.17 Comparison of Total Response Model to Other HOV Models

		Travel Time Differential (Minutes)		
Model	**Year**	**Before/After**	**HOV/SOV**	**Total HOV Response (Growth)**
Comsis	**1994**	5	---	40%
Shoemaker/Sullivan	1994	---	12	120%
Wesemann (Orange County)	1987	5-9	---	20-30 %
Parody/CRA	1982	**6**	---	**90-230%**
New HOV 2+ Model	**1995**	**6**	**---**	**62-92%**
New HOV 3+ Model	1995	**6**	**6**	**95-155%**

6.3.5 Equilibration Module

Because the estimation of HOV travel time savings is crucial in the prediction of HOV mode shares, and HOV mode shares in turn influence travel times in HOV and mixed-flow lanes, the new HOV model includes an iterative mechanism to couple HOV and mixed-flow total response estimates with traffic performance estimates. Figure 6.18 contains the framework for the equilibration module.

The equilibration module procedure is the same for both freeway and arterial facilities. The data inputs include estimated demand for the study section and iteration closing (stop) criterion. The user is given the flexibility to define a closing criterion that will terminate the loop and proceed with the next step. The closing criterion is expressed in terms of the percent change in vehicle volume by lane type from the previous iteration.

$$\begin{pmatrix}\text{Closing factor} \\ \text{\% difference between} \\ \text{consecutive itera tions}\end{pmatrix} = \left| \frac{\begin{bmatrix}\text{Estimated volume} \\ \text{for current iteration}\end{bmatrix} - \begin{bmatrix}\text{Estimated volume} \\ \text{for previous iteration}\end{bmatrix}}{[\text{Estimated volume for previous iteration}]} \right|$$

The criterion must be satisfied (computed percent difference is less than the closing criterion input by the user, or default) for two consecutive iterations before the mode1 proceeds to the next step. If the criterion is not satisfied for both the HOV and mixed-flow lane(s), a weighted average is computed to advance convergence using the following procedure:

$$\left[V_{i+1}\right] = \left(\frac{i-1}{i}\right)V_{i-1} + \left(\frac{1}{i}\right)V_i$$

Where: V = Traffic volume (demand); and
i = Iteration number.

These adjusted vehicle volumes are then used to proceed within the iterative process as inputs into the supply module (see Figure 6.1 – Genera1 Model Structure). If the closing criterion is satisfied then the mode1 proceeds to the spatial and modal response module.

Purpose: To Find Equilibrium

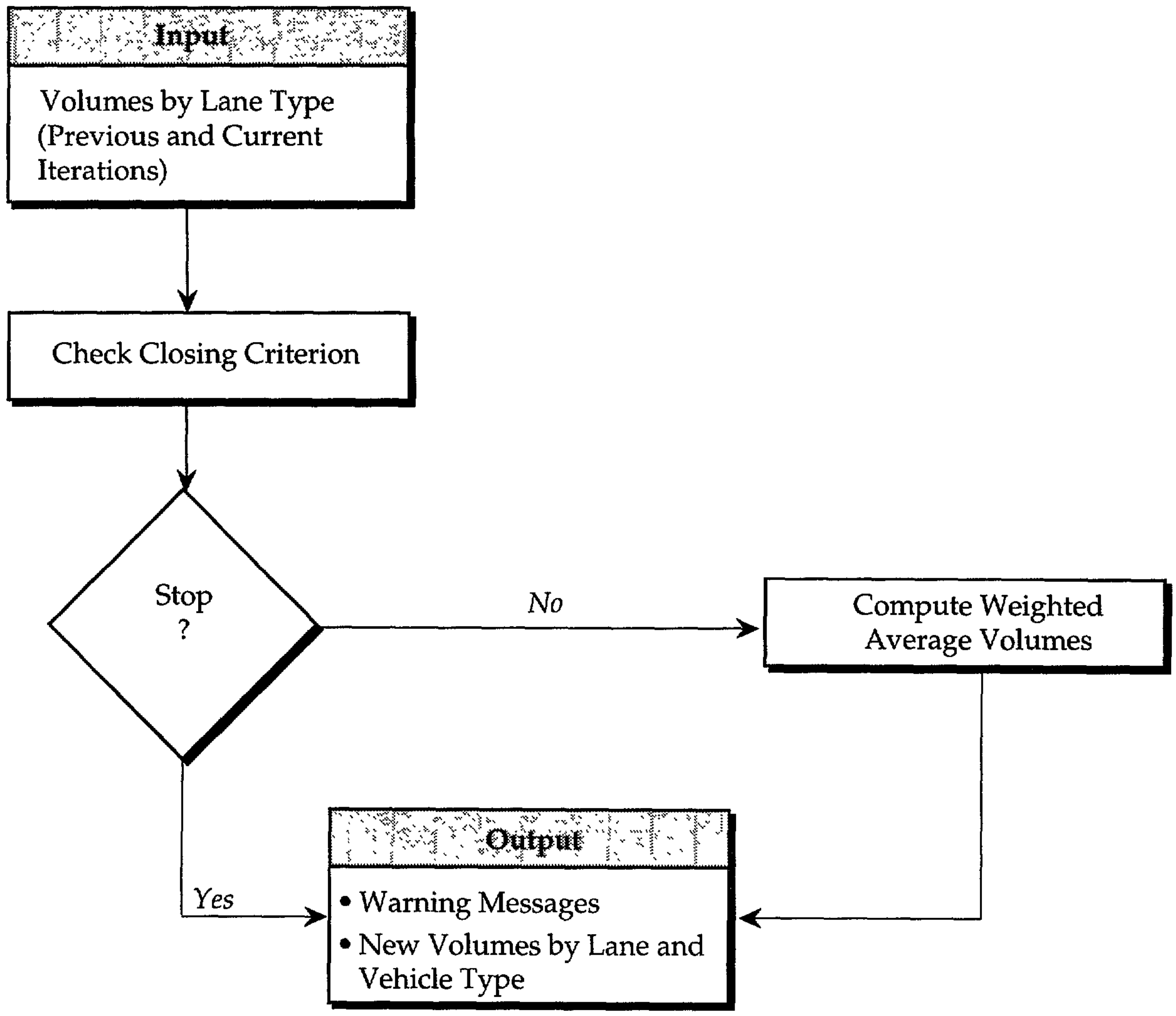


Figure 6.18 Equilibration Module

6.3.6 Spatial and Modal Response Module

The HOV model methodology estimates the total traveler response to the HOV facility including travelers that came from or go to parallel facilities and other modes. Since the model methodology is applied to the peak period, it is assumed that the estimated total response to the HOV facility includes only spatial and modal components but no temporal response. The model addresses the shift between the proposed facility and the parallel route(s) for non-HOV eligible vehicles, HOV eligible vehicles, and buses. The purpose of this module, is to produce a quick estimate of the allocation of the forecasted new HOV demand into spatial and modal components. An overview of the module's framework is contained in Figure 6.19.

Based upon the data available, the model estimates the percentage of HOV lane demand that came from or diverts to another route. The inputs to the spatial and modal response module are:

- Existing peak period vehicle volume by vehicle type;
- Average vehicle occupancies by vehicle type;
- Estimated peak period vehicle volume by vehicle type;
- Spatial and modal response trip table allocation percentages;
- Violation rate; and
- Percent of HOVs in the HOV lane(s).

The module estimates the spatial and model response using a trip distribution type methodology that allocates the estimated trips by their existing mode of travel. A trip matrix is developed which distributes the existing non-HOV, HOV, and bus trips to the estimated (after) non-HOV, HOV, and bus trips on both the facility and the parallel route(s). Table 6.5 presents the spatial and modal trip matrix.

Table 6.5 Spatial and Modal Response Trip Matrix

			After						
			Facility			Parallel Facilities			
			Non-HOV	HOV	Bus	Non-HOV	HOV	Bus	Total
Before	Facility	Non-HOV							
		HOV							
		BUS							
	Parallel Facilities	Non-HOV				0	0	0	
		HOV				0	0	0	
		Bus				0	0	0	
		Total							

The vehicle trips input by the user and estimated in the total response module are converted to person trips using the average vehicle occupancies (AVO) by vehicle type input by the user or the default values. The existing (before) person trip volumes by mode for the facility are input into the row totals. The estimated (after) person trip volumes by mode are input into the column totals. Since there is no information on the trips which remain on the parallel facilities and the methodology needs not to predict them, the cells shown in Table 6.5 with a "0" represent those trips which are on the parallel facilities in both the before and after scenarios.

Purpose: **To *Allocate Response into Spatial and Modal Components***

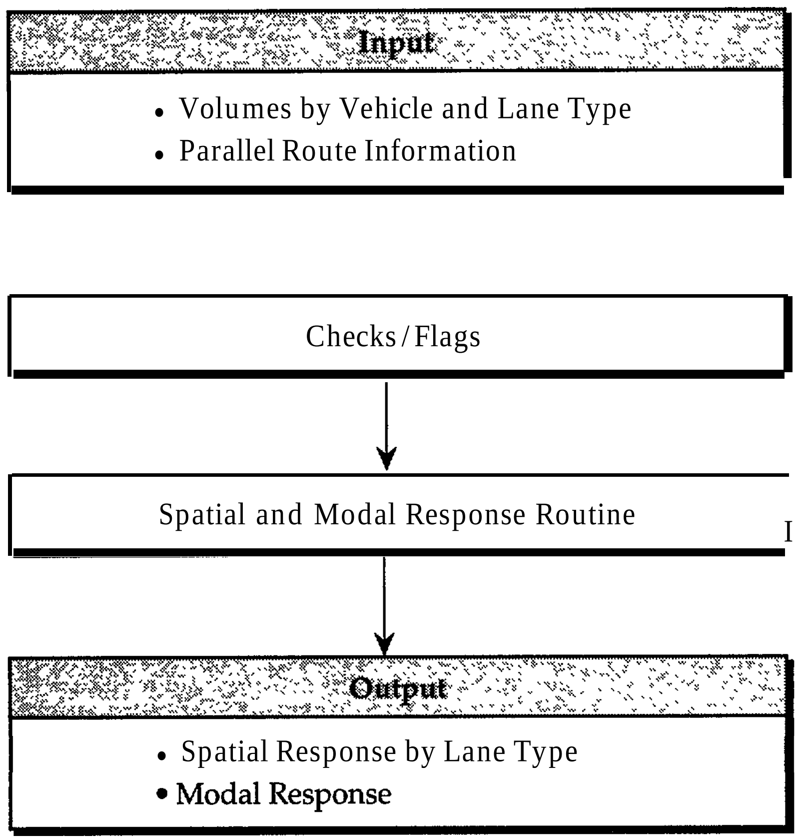


Figure 6.19 Spatial and Modal Response Module

The row and column totals are then be distributed within the trip matrix. The row and column totals for the parallel facilities are then estimated based on the following assumptions:

- If the estimated (after) person trips is greater than the existing (before), the difference is from the parallel facility, and the number of trips going from the facility to the parallel route(s) is zero (see Table 6.6 for the default distribution percentages). If the existing (before) person trips is greater than the estimated (after), the difference went to the parallel facility, with zero trips coming from the parallel route(s) and going to the proposed HOV facility. Table 6.7 presents the default allocation percentages for diversion away from the proposed HOV facility. The estimated (after) parallel facility person trips are distributed among the existing (before) modes using the existing (before) mode split for the proposed facility.
- Total trips going to or coming from the parallel facilities are distributed according to the mode split on the proposed facility. The greater of the existing (before) or the estimated (after) HOV mode split is used.

Table 6.6 Spatial and Modal Trip Table Allocation Percentages for Diversion to the HOV Facility

			After		
			Non-HOV	**HOV**	**Bus**
Before	Facility	Non-HOV	**75%**	**27%**	10%
		HOV	**9%**	**37%**	**35%**
		Bus	1%	**12%**	**50%**
	Parallel Facilities	Non-HOV	13%	**12%**	1%
		HOV	1%	**8%**	1%
		Bus	1%	4%	**3%**
		Total	100%	100%	100%

Table 6.7 Spatial and Modal Trip Table Allocation Percentages for Diversion Away From the HOV Facility

			After						
			Facility			Parallel Facilities			
			Non-HOV	**HOV**	**Bus**	**Non-HOV**	**HOV**	**Bus**	**Total**
Before	Facility	Non-HOV	**75%**	**9%**	1 %	13%	1%	1%	100%
		HOV	**27%**	**37%**	**12%**	**12%**	**8%**	**4%**	100%
		Bus	10%	**35%**	**50%**	1%	1%	3%	100%

The user has the option of overriding these values. The HOV percentages contained in Table 6.6 are based on the Houston North Freeway Survey (1990) and are similar to the results from a Minneapolis survey conducted in 1989.

The estimated trip table is then revised so that the sum of cell values add up to the correct before row totals. A FRATAR row and column factoring process is used until the cell entries sum to the desired row and column totals.

The closing criterion for the FRATAR factoring process is 1% of 1 .00 (ratio of current value over previous iteration value).

Once the closing criterion for the FRATAR factoring process is satisfied, the resulting person trip table is converted back to vehicles using the average vehicle occupancy values by mode. The resulting vehicle trips are then distributed by lane type according to the percentage of HOV eligible vehicles in the HOV lane computed in the allocation module.

6.3.7 Output Module

In this step the model computes, summarizes, and reports final measures of performance as shown in Figure 6.20. Figure 6.2 1 presents an overview of the output module structure. The measures of performance estimated within the model framework include:

- Vehicle and person volumes;
- Travel time;
- Vehicle and person miles of travel;
- Vehicle and person hours of travel;
- Vehicle and person delay;
- Air quality/emissions; and
- Fuel consumption.

Each of these measures is estimated by lane type (HOV and mixed-flow lane(s)) and by analysis period (existing, short-term and/or long-term) in either English or metric units. In addition, spatial response by lane type is evaluated for the air quality/emissions and fuel consumption performance measures to provide a means to effectively assess the net effect of the proposed HOV facility.

The inputs required for the output module include:

- Air quality calculation option (EMFAC or MOBILE 5a);
- Average speed on parallel roadways;
- Analysis period;
- Average annual temperature (EMFAC option only);
- Percentage of total vehicles which are trucks (gas versus diesel), buses, and motorcycles;
- Average vehicle occupancy for HOV3+ and buses;

Vehicle Volumes	Before			Short-Term			Long-Term		
	HOV Lane(s)	Mixed-Flow Lanes	Total	HOV Lane(s)	Mixed-Flow Lanes	Total	HOV Lane(s)	Mixed-Flow Lanes	Total
SOVs									
HOV 2									
HOV 3+									
Buses									
Trucks									
Motorcycles									
Total									

Person Volumes	Before			Short-Term			Long-Term		
	HOV Lane(s)	Mixed-Flow Lanes	Total	HOV Lane(s)	Mixed-Flow Lanes	Total	HOV Lane(s)	Mixed-Flow Lanes	Total
SOVs									
HOV 2									
HOV 3+									
Buses									
Trucks									
Motorcycles									
Total									
AVO									

Measure of Performance	Before			Short-Term			Long-Term			Spatial Response			Net Effect	
	HOV Lane(s)	Mixed-Flow Lanes	Total	HOV Lane(s)	Mixed-Flow Lanes	Total	HOV Lane(s)	Mixed-Flow Lanes	Total	HOV Lane(s)	Flow Lanes	Total	Short-Term to Existing	Long-Term to Existing
Vehicle Volume														
Person Volume														
Travel Time (mun)														
VMT														
PMT														
VHT														
PHT														
Vehicle Delay (hrs)														
Person Delay (hrs)														
HC (kg)														
CO (kg)														
NOx (kg)														
Fuel (gallons)														

Figure 6.20 Output Tabulations

Purpose: To *Compute Outputs*

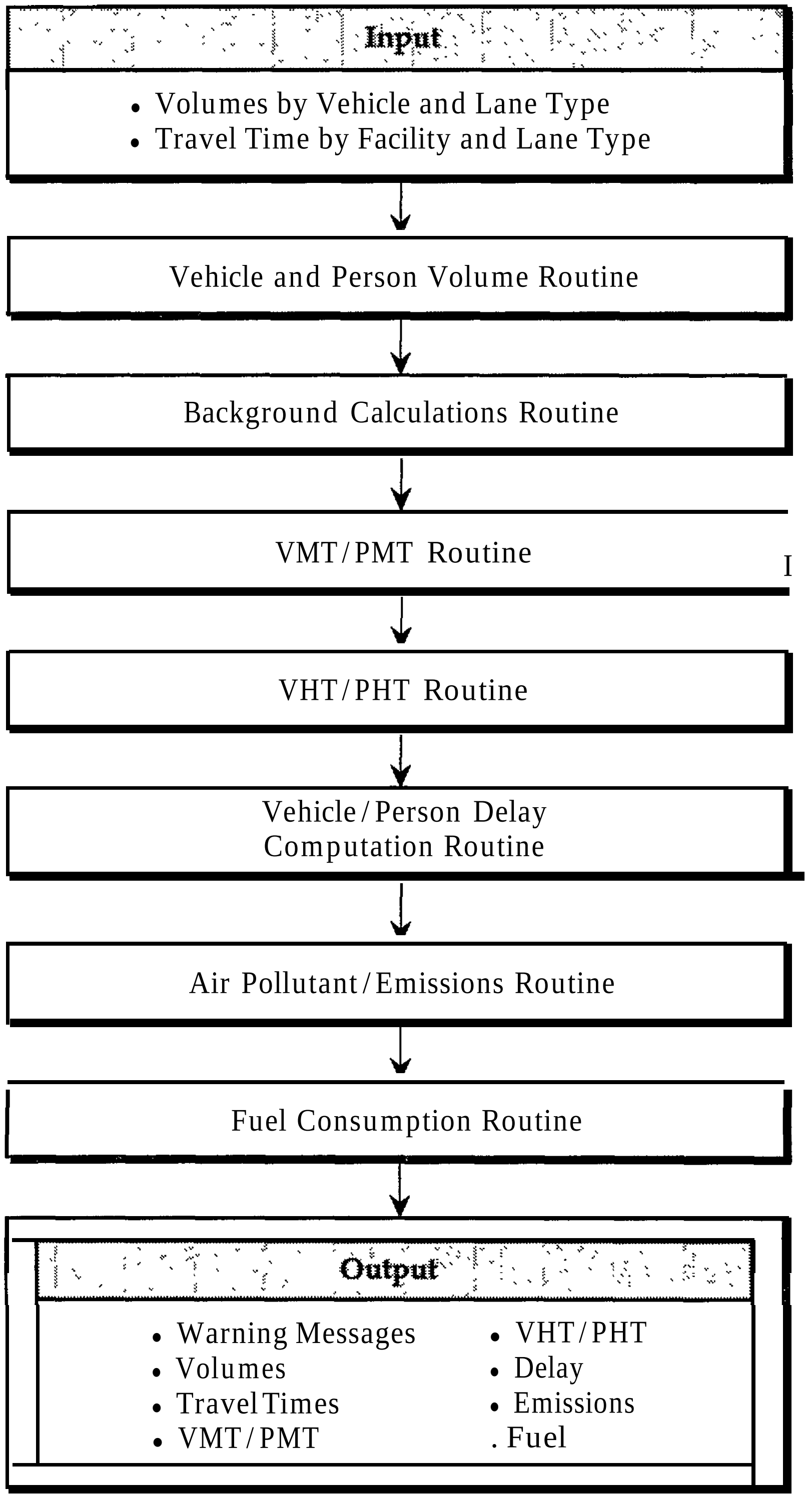


Figure 6.21 Output Module

Existing and estimated (future) peak period vehicle volumes by lane and vehicle type;

- Length of study section;
- Free-flow speed;
- Existing and estimated (future) peak period travel times by lane type;
- Percentage of HOV eligible vehicle volume in the HOV lane(s); and
- Estimated peak period spatial and modal response.

Vehicle volumes estimated by the total response model are first allocated by vehicle and lane type according to the input (or default) percentages of trucks, buses, and motorcycles. SOV, HOV2, and HOV3+ volumes by lane type are then determined according to the equations in Figure 6.22. The procedure for distributing the total volumes by lane type is different for 2+ versus 3+ eligibility. The 0.86 and 0.88 factors shown in the equations are percentages estimated from actual data collected and utilized in the total response model.

Occupancy rates for computing person volumes are based upon the following values:

Table 6.8 Occupancy Rates by Vehicle Type

Vehicle Type	Occupancy (Persons per Vehicle)
SOV	1
HOV2	2
HOV3 +	User input or default (3.4)
Truck	1
Bus	User input or default (32)
Motorcycle	1

Impacts are estimated as follows:

- Vehicle miles of travel (VMT) is computed by lane type and for the total study section, as shown in **the** following equation:

$$VMT = [Vehicle\ volume] * [Length\ of\ study\ section]$$

- Person miles of travel (PMT) is computed by multiplying the estimated VMT by the average vehicle occupancy.
- Vehicle hours of travel (VHT) by lane type and for the total study section is estimated according to the following equation:

$$WIT = [Vehicle\ volume] * \frac{[Travel\ \ time]}{60}$$

The 60 value in this equation converts the travel time from minutes to hours.

For 2+ eligibility

- $\left[Total\ SOV\ volume\right] = \left[Non - HOV\ eligible\ vehicle\ volume\right] - \left[Total\ truck\ volume\right]$

- $\left[SOV\ volume\ in\ the\ HOV\ lane(s)\right] = \left[HOV\ lane(s)\ volume\right] - \dfrac{\left[HOV\ lane(s)\ volume\right]}{\left[1 + \dfrac{Violation\ rate}{100}\right]}$

- $\begin{bmatrix} SOV\ volume\ in\ the \\ mixed - flow\ lane(s) \end{bmatrix} = \left[Total\ SOV\ volume\right] - \left[SOV\ volume\ in\ the\ HOV\ lane(s)\right]$

- $\left[Total\ HOV2\ volume\right] = \left[\begin{bmatrix} HOV\ eligible \\ vehicle\ volume \end{bmatrix} - \begin{bmatrix} Total\ bus \\ volume \end{bmatrix} - \begin{bmatrix} Total\ motorcycle \\ volume \end{bmatrix}\right] * 0.88$

- $\left[HOV2\ volume\ in\ the\ HOV\ lane(s)\right] = \left[Total\ HOV2\ volume\right] * \left[\dfrac{\%\ HOVs\ in\ the\ HOV\ lane(s)}{100}\right]$

- $\begin{bmatrix} HOV2\ volume\ in\ the \\ mixed - flow\ lane(s) \end{bmatrix} = \left[Total\ HOV2\ volume\right] - \left[HOV2\ volume\ in\ the\ HOV\ lane(s)\right]$

- $\begin{bmatrix} Total \\ HOV3+ \\ volume \end{bmatrix} = \begin{bmatrix} Total \\ volume \end{bmatrix} - \begin{bmatrix} Total \\ truck \\ volume \end{bmatrix} - \begin{bmatrix} Total \\ bus \\ volume \end{bmatrix} - \begin{bmatrix} Total \\ motorcycle \\ volume \end{bmatrix} - \begin{bmatrix} Total \\ SOV \\ volume \end{bmatrix} - \begin{bmatrix} Total \\ HOV2 \\ volume \end{bmatrix}$

- $\begin{bmatrix} HOV3+volume\ in \\ the\ HOV\ lane(s) \end{bmatrix} = \begin{bmatrix} HOV\ lane(s) \\ volume \end{bmatrix} - \begin{bmatrix} Truck\ volume\ in \\ the\ HOV\ lane(s) \end{bmatrix} - \begin{bmatrix} Bus\ volume\ in \\ the\ HOV\ lane(s) \end{bmatrix} - \begin{bmatrix} Motorcycle\ volume \\ in\ the\ HOV\ lane(s) \end{bmatrix} - \begin{bmatrix} SOV\ volume\ in \\ the\ HOV\ lane(s) \end{bmatrix} - \begin{bmatrix} HOV2\ volume\ in \\ the\ HOV\ lane(s) \end{bmatrix}$

- $\begin{bmatrix} HOV3+volume\ in\ the \\ mixed - flow\ lane(s) \end{bmatrix} = \left[Total\ HOV3+volume\right] - \left[HOV3+volume\ in\ the\ HOV\ lane(s)\right]$

Figure 6.22
Equations for Distribution of Volumes by Vehicle and Lane Types

For 3+ eligibility

- $$\left[\text{Total SOV volume}\right] = \left[\left[\text{Non - HOV eligible vehicle volume}\right] - \left[\text{Total truck volume}\right]\right] * 0.86$$

- $$\left[\text{SOV volume for the HOV lane(s)}\right] = \left[\left[\text{HOV lane(s) volume}\right] - \frac{\left[\text{HOV lane(s) volume}\right]}{\left[1 + \frac{\text{Violation rate}}{100}\right]}\right] * 0.86$$

  $$\begin{bmatrix}\text{SOV volume in the}\\ \text{mixed - flow lane(s)}\end{bmatrix} = \left[\text{Total SOV volume}\right] - \left[\text{SOV volume in the HOV lane(s)}\right]$$

- $$\left[\text{Total HOV2 volume}\right] = \begin{bmatrix}\text{Non - HOV eligible}\\ \text{vehicle volume}\end{bmatrix} - \left[\text{Total truck volume}\right] - \left[\text{Total SOV volume}\right]$$

- $$\begin{bmatrix}\text{HOV2 volume in}\\ \text{the HOV lane(s)}\end{bmatrix} = \left[\left[\text{HOV lane(s) volume}\right] - \frac{\left[\text{HOV lane(s) volume}\right]}{\left[1 + \frac{\text{Violation rate}}{100}\right]}\right] - \begin{bmatrix}\text{SOV volume in}\\ \text{the HOV lane(s)}\end{bmatrix}$$

- $$\begin{bmatrix}\text{HOV2 volume in the}\\ \text{mixed - flow lane(s)}\end{bmatrix} = \left[\text{Total HOV2 volume}\right] - \left[\text{HOV2 volume in the HOV lane(s)}\right]$$

- $$\begin{bmatrix}\text{Total}\\ \text{HOV3 +}\\ \text{volume}\end{bmatrix} = \begin{bmatrix}\text{Total}\\ \text{volume}\end{bmatrix} - \begin{bmatrix}\text{Total}\\ \text{truck}\\ \text{volume}\end{bmatrix} - \begin{bmatrix}\text{Total}\\ \text{bus}\\ \text{volume}\end{bmatrix} - \begin{bmatrix}\text{Total}\\ \text{motorcycle}\\ \text{volume}\end{bmatrix} - \begin{bmatrix}\text{Total}\\ \text{SOV}\\ \text{volume}\end{bmatrix} - \begin{bmatrix}\text{Total}\\ \text{HOV2}\\ \text{volume}\end{bmatrix}$$

- $$\begin{bmatrix}\text{HOV3 + volume in}\\ \text{the HOV lane(s)}\end{bmatrix} = \begin{bmatrix}\text{HOV lane(s)}\\ \text{volume}\end{bmatrix} - \begin{bmatrix}\text{Truck volume in}\\ \text{the HOV lane(s)}\end{bmatrix} - \begin{bmatrix}\text{Bus volume in}\\ \text{the HOV lane(s)}\end{bmatrix} - \begin{bmatrix}\text{Motorcycle volume}\\ \text{in the HOV lane(s)}\end{bmatrix} - \begin{bmatrix}\text{SOV volume in}\\ \text{the HOV lane(s)}\end{bmatrix} - \begin{bmatrix}\text{HOV2 volume in}\\ \text{the HOV lane(s)}\end{bmatrix}$$

- $$\begin{bmatrix}\text{HOV3 + volume in the}\\ \text{mixed - flow lane(s)}\end{bmatrix} = \left[\text{Total HOV3 + volume}\right] - \left[\text{HOV3 + volume in the HOV lane(s)}\right]$$

Figure 6.22 (continued)
Equations for Distribution of Volumes by Vehicle and Lane Types

- Person hours of travel (PHT) is estimated similar to PMT, by multiplying VHT by average vehicle occupancy.

The output module then computes vehicle hours of delay which is measured as the difference between the estimated travel time from the model and the free-flow speed travel time. Vehicle hours of delay is calculated as follows:

$$\textit{Vehicle hours of delay} = VHT * \frac{VMT}{\textit{Free - flow speed}}$$

- Person hours of delay is the vehicle hours of delay times the average vehicle occupancy.

Emissions impacts are estimated by lane type, for the total study section, and for spatial shift through one of two options. The user has the option of using EMFAC or MOBILE 5a emission rates. The emission rates included within both options are in grams per mile and include hydrocarbons (HC), carbon monoxide (CO), and nitrous oxides (NO_X). The EMFAC option emission rates are based on travel speeds; existing (19 95) versus long-term analyses (2010); various ambient temperatures (55°F to 95°F); and separate vehicle types (autos, gas trucks, and diesel trucks). Interpolation may be required for analysis years or temperatures which fall between the values available. The MOBILE 5a option includes separate emission rates based on speed and vehicle type (autos versus trucks/buses). The emission rates for both EMFAC and MOBILE 5a are shown in Appendix E.

The methodology for computing the emissions assumes that there are no trucks in the HOV lane(s). Emissions are computed in kilograms based upon the following equations:

$$\left[\textit{HOV lane(s) emissions}\right] = \frac{\left[\left[\textit{HOV lane(s) VMT}\right] * \left[\textit{Emission rate for autos}\right]\right]}{1000}$$

$$\begin{bmatrix}\textit{Mixed - flow} \\ \textit{lane(s) emissions}\end{bmatrix} = \frac{\left[\textit{Length of study section}\right] * \left[\left[\begin{pmatrix}\textit{Autos in the mixed -} \\ \textit{flow lane(s) volume}\end{pmatrix} * \begin{pmatrix}\textit{Emission rate} \\ \textit{for autos}\end{pmatrix}\right] + \left[\begin{pmatrix}\textit{Total gas} \\ \textit{truck volume}\end{pmatrix} * \begin{pmatrix}\textit{Emission rate} \\ \textit{for gas trucks}\end{pmatrix}\right] + \left[\begin{pmatrix}\textit{Total diesel} \\ \textit{truck volume}\end{pmatrix} * \begin{pmatrix}\textit{Emission rate} \\ \textit{for diesel trucks}\end{pmatrix}\right]\right]}{1000}$$

$$\begin{bmatrix}\textit{Emissions for} \\ \textit{spatial responders}\end{bmatrix} = \frac{\left[\left[\textit{Spatial response}\right] * \left[\textit{Emission rate for autos}\right]\right]}{1000}$$

If vehicles divert from parallel facilities to the proposed HOV facility, a reduction in emissions can be taken after implementation of the new HOV facility. If vehicles divert away from the proposed HOV facility, some of the decrease in demand on the facility went to parallel roadways. Therefore, the emissions for spatial responders should be added to the after case to reflect the shift of autos now traveling at parallel facility speeds.

Fuel consumption is estimated similar to emissions. Fuel consumption rate tables, in gallons per mile, are provided in Appendix F. Fuel consumption rates are based upon facility type (freeway or arterial), vehicle type (autos, gas trucks, and diesel trucks), and travel speeds. Fuel consumption values are computed for HOV lane(s), mixed-flow lane(s), the total facility, and for spatial response.

6.4 Implementation

The research results of this report have been implemented in a software product known as Quick-HOV, which provides an analysis and planning tool for HOV facilities based on the model developed herein. The Quick-HOV software model is designed to provide a quick analysis of HOV lane demand and operations.

The program is designed to evaluate the impacts of:

1. Constructing new HOV lane(s)
2. Extending existing HOV lane(s)
3. Changing the eligibility requirements of existing HOV lane(s).

The program is a "quick response" method that evaluates the impacts of HOV lanes for a single direction of travel over a single peak period for arterials and freeways. To analyze both directions of travel, the model is simply run again for the opposite travel direction. The procedures allow the user to predict and evaluate the impacts of HOV lanes on person demand, vehicle demand, auto occupancy, congestion, delay, and air quality. The program produces detailed tabulations of vehicles, persons, vehicle-miles traveled (VMT), vehicles-hours traveled (VHT), delay, delay per vehicle, fuel consumption, and air pollutants. The detailed tabulations show the number of persons or vehicles by vehicle type for the HOV lane(s) and the mixed-flow lane(s) for the before, opening day, short range, and long range conditions. A summary table aggregates these values for all vehicles on the entire study section.

6.4.1 Program Input Data

The program allows two modes of input. The data can be entered interactively or as an ASCII batch file. The interactive form allows the user to provide a minimum set of data or a more complex set of data. The program uses defaults to create a complete data set from the minimum data set.

Regardless of the input mode, the user needs to provide a project description and the project demand data. The project description includes

General Facility Data

- Facility Type
- Length
- Number of Through Lanes
- Capacity/Lane (vphpl)
- Free-Flow Speed
- Average Peak Period Travel Time (optional)
- Barrier-separated?
- HOV Lane Eligibility by vehicle type

Arterial Facility Data

- Lane Width
- Shoulder Width
- Terrain Type
- Ramps per mile
- Barrier Entry/Exits per mile
- Percent RVs
- Signals Per Mile
- Cycle Length (sec)
- Green/Cycle
- Quality of Progression
- Exclusive Left Turn Lanes?
- Percent Turns from Exclusive Lanes

The facility data is supplied for both the HOV lane(s) and the mixed-flow lane(s). The data for the study section can be divided into a critical subsection and the rest of the study section. These data are needed for both the existing and the proposed conditions. The critical subsection is the portion of the study section that has the highest demand to capacity ratio and functions as the "controlling" subsection. The user does not have to specify a critical subsection, if the demand or capacity across the study section does not differ by more than ten percent.

The user must also provide the existing demand data for the study section. The demand data can be entered as a summary demand data set or a complete demand data set. The complete data set includes the demand by vehicle type for each lane type in the critical subsection and the rest of the study section. The demand data also includes information on the following:

Length of peak period

Ramp meter delay by vehicle type

Mean trip length by vehicle type

6.4.2 Summary of Model Components

The Quick-HOV model is a "quick response" tool for predicting order-of-magnitude HOV and mixed-flow demand and traffic performance. The Quick-HOV software can be considered a screening tool used to evaluate traffic performance and impacts on opening day, short-term (six months to a year) and long term (after one or more years).

The model is divided into seven distinct modules. Each module is briefly described below.

Input Module	Accepts and edits data
Lane Allocation Module	Allocates vehicles to the HOV and mixed-flow lanes.
Travel Time Module	Calculates the travel time for the HOV and mixed-flow lanes.
Weighted Travel Time Module	Calculates the average weighted travel time by vehicle type.
Response (Demand) Module	Determines the growth in HOV and mixed-flow traffic due to the travel time savings of the proposed HOV project.
Equilibration Module	Checks closing criteria
Output Module	Calculates the measures of performance for the proposed HOV project.

6.4.3 Hardware Requirements

Minimum computer hardware needed to run the Quick-HOV program includes the following:

- An IBM-compatible micro-computer with at least a 386/486 microprocessor
- MS-DOS version 3.0 or later
- At least 0.5 Mb of hard disk space for the program files.

The software is a stand-alone MS-DOS™ program which runs either in the MS-DOS™ mode or under the Windows™ environment. All input and output files are stored on the hard disk in ASCII format, which allows interfacing with other traffic analysis software.

APPENDIX A. DATA SETS

	1					
Action:	Construct 4.0 miles HOV lane					
Name	U.S. 12/I-394					
Metro Area	Minneapolis					
State	MN					
HOV Facility:	Reversible median lane at 5 signals					
HOV Length (mi)	4					
HOV Lanes Each Direction						
Hours of Operation:	6-9 AM EB, 3-7PM WB					
Elgibility:	2+					
HOV Open Date:	11/19/85					
Street Type	Arterial					
Mixed Flow Lanes Each Dir.	2					
Free-Flow Speed (mph):	39					
Peak Hour:	7:00 - 8:00 AM		VEHICLES			
Direction:	EB					
Data:	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	ALL	HOV	OTHER	TOTAL	After - Before	
Date:	5/84	5/86	5/86	5/86	Diff.	%
Max. Time (min)	14	6	11	10	-4	-28.6%
Ave. Time (min)	14	6	11	10	-4	-28.6%
1 occ Vol	3603	21	3457	3478	-125	-3.5%
2 occ Vol	100	345	165	510	410	410.0%
3 occ Vol	80	43	22	65	-15	-18.8%
4+ occ Vol	60	22	10	32	-28	-46.7%
Bus Vol	27	9	26	35	8	29.6%
Truck Vol	116	?	116	116	0	0.0%
Cycle Vol	14	?	14	14	0	0.0%
Subtotal HOV's	281	419	237	656	375	133.5%
Subtotal Other	3719	21	3573	3594	-125	-3.4%
Total Vol:	4000	440	3810	4250	250	6.3%
Peak Period:	6:00 - 9:00 AM					
Direction:	EB					
Data:	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	ALL	HOV	OTHER	TOTAL	After - Before	
Date:	5/84	5/86	5/86	5/86	Diff.	%
Max. Time (min)				0	0	ERR
Ave. Time (min)				0	0	ERR
1 occ Vol					0	ERR
2 occ Vol					0	ERR
3 occ Vol					0	ERR
4+ occ Vol					0	ERR
Bus Vol					0	ERR
Truck Vol					0	ERR
Cycle Vol					0	-100.0%
Subtotal HOV's	610	0	0	0	-610	ERR
Subtotal Other	0	0	0	0	0	41.0%
Total Vol:	610	0	860	860	250	ERR

Data Set Number:	1				Persons	
Action:	Construct 4.0 miles HOV lane					
Name	U.S. 12/I-394					
City	Minneapolis					
State	MN					
HOV Facility:	Reversible median lane at 5 signals					
Length (mi)	4					
No. of Lanes	1					
Hours of Operation:	6-9 AM EB, 3-7PM WB					
Elgibility:	2+					
HOV Open Date:	11/19/85					
Street Type	Arterial		Source: pg 14, Phase III Report			
No. of Lanes Each Direction	2					
Free-Flow Speed (mph):	39					
Peak Hour:	7:00 - 8:00 AM			PERSONS		
Direction:	EB					
Data:	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	ALL	HOV	OTHER	TOTAL	After - Before	
Date:	5/84	5/86	5/86	5/86	Diff.	%
Max. Time (min)						
Ave. Time (min)	14	6	11	17	3	21.4%
1 occ Pers	3603	21	3457	3478	-125	-3.5%
2 occ Pers	200	690	330	1020	820	410.0%
3 occ Pers	240	129	66	195	-45	-18.8%
4+ occ Pers	360	132	60	192	-168	-46.7%
Bus Pers	1000	300	860	1160	160	16.0%
Truck Pers	116 ?		116	116	0	0.0%
Cycle Pers	14 ?		14	14	0	0.0%
Subtotal HOV's	1814	1251	1330	2581	767	42.3%
Subtotal Other	3719	21	3573	3594	-125	-3.4%
Total Persons:	5533	1272	4903	6175	642	11.6%
Auto Occupancy:	1.15	2.26	1.07	1.2	0.05	4.3%
Peak Period:	6:00 - 9:00 AM					
Direction:	EB					
Data:	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	ALL	HOV	OTHER	TOTAL	After - Before	
Date:	5/84	5/86	5/86	5/86	Diff.	%
Max. Time (min)	14	6	11	7	-7	-50.0%
Ave. Time (min)	9	6	a	7	-2	-22.2%
1 occ Pers					0	ERR
2 occ Pers					0	ERR
3 occ Pers					0	ERR
4+ occ Pers					0	ERR
Bus Pers		880	340	1220	1220	ERR
Truck Pers					0	ERR
Cycle Pers					0	ERR
Subtotal HOV's	0	880	340	1220	1220	ERR
Subtotal Other	0	0	0	0	0	ERR
Total Persons:	0	880	340	1220	1220	
Auto Occupancy:	0	ERR	ERR	ERR	ERR	ERR

	2							
Action:	Convert 3+Pre-Authorized to 2+ Unauthorized							
Name	I-IO Katy Transitway							
Metro Area	Houston							
State	TX							
HOV Facility:	Reversible median lane							
HOV Length (mi)	6.4							
HOV Lanes Each Direction	1							
Hours of Operation:	5AM-Noon EB, 2-9PM WB							
Elgibility:	2+							
HOV Open Date:	8/11/86							
Street Type	Freeway							
Mixed Flow Lanes Each Dir.	4							
Free-Flow Speed (mph):	55							
Peak Hour:	6:45-7:45 AM					VEHICLES		
Direction:	WB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/86	4/86	4/86	4/87	4/87	4/87	Diff.	%
Max. Time (min)	7	17	17	7	17	14	-3	-17.6%
Ave. Time (min)	7	15	15	7	15	13	-2	-13.3%
1 occ Vol	11	3800	3811	74	3400	3474	-337	-8.8%
2 occ Vol	75	450	525	1150	200	1350	825	157.1%
3 occ Vol	90	45	135	200	15	215	80	59.3%
4+ occ Vol	25	?	25	25	?	25	0	0.0%
Bus Vol	25	10	35	25	10	35	0	0.0%
Truck Vol	?	?	O ?		?	0	0	ERR
Cycle Vol	?	?	O ?		?	0	0	ERR
Subtotal HOV's	215	505	720	1400	225	1625	905	125.7%
Subtotal Other	11	3800	3811	74	3400	3474	-337	-8.8%
Total Vol:	226	4305	4531	1474	3625	5099	568	12.5%
Peak Period:	6:00 - 9:30 AM							
Direction:	WB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	ALL	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/86	4/86	4/86	4/87	4/87	4/87	Diff.	%
Max. Time (min)	7	17	17	7	17	15	-2	-11.8%
Ave. Time (min)	7	11	11	7	11	10	-1	-9.1%
1 occ Vol	18	11400	11418	135	11200	11335	-83	-0.7%
2 occ Vol	90	1300	1390	2200	700	2900	1510	108.6%
3 occ Vol	110	130	240	240	50	290	50	20.8%
4+ occ Vol	65	?	65	60	?	60	-5	-7.7%
Bus Vol	80	10	90	70	10	80	-10	-11.1%
Truck Vol	?	?	O ?		?	0	0	ERR
Cycle Vol	?	?	O ?		?	0	0	ERR
Subtotal HOV's	345	1440	1785	2570	760	3330	1545	86.6%
Subtotal Other	18	11400	11418	135	11200	11335	-83	-0.7%
Total Vol:	363	12840	13203	2705	11960	14665	1462	11.1%

Data Set Number:	2					Persons		
Action:	Convert 3+Pre-Authorized to 2+ Unauthorized							
Name	I-IO Katy Transitway							
City	Houston							
State	TX							
HOV Facility:	Reversible median lane							
Length (mi)	6.4							
No. of Lanes								
Hours of Operation:	5AM-Noon EB, 2-9PM WB							
Elgibility:	2+							
HOV Open Date:	8/11/86							
Street Type	Freeway							
No. of Lanes Each Direction	4							
Free-Flow Speed (mph):	55							
Peak Hour:	6:45-7:45 AM		PERSONS			PERSONS		
Direction:	WB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	ALL	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/86	4/86	4/86	4/87	4/87	4/87	Diff.	%
Max. Time (min)	7	17	17	7	17	14	-3	-17.6%
Ave. Time (min)	7	15	15	7	15	13	-2	-13.3%
1 occ Pers	11	3800	3811	74	3400	3474	-337	-8.8%
2 occ Pers	150	900	1050	2300	400	2700	1650	157.1%
3 occ Pers	270	135	405	600	45	645	240	59.3%
4+ occ Pers	150	0	150	150	0	150	0	0.0%
Bus Pers	929	371	1300	929	371	1300	0	0.0%
Truck Pers	?	?	O ?		?	0	0	ERR
Cycle Pers	?	?	O ?		?	0	0	ERR
Subtotal HOV's	1499	1406	2905	3979	816	479s	1890	65.1%
Subtotal Other	11	3800	3811	74	3400	3474	-337	-8.8%
Total Persons:	1510	5206	6716	4053	4216	8269	1553	23.1%
Auto Occupancy:	2.89	1.13	1.2	2.16	1.06	1.38	0.18	15.0%
Peak Period:	6:00 - 9:30 AM							
Direction:	WB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	ALL	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/86	4/86	4/86	4/87	4/87	4/87	Diff.	%
Max. Time (min)	7	17	17	7	17	15	-2	-11.8%
Ave. Time (min)	7	11	11	7	11	10	-1	-9.1%
1 occ Pers	18	11400	11418	135	11200	11335	-83	-0.7%
2 occ Pers	180	2600	2780	4400	1400	5800	3020	108.6%
3 occ Pers	330	390	720	720	150	870	150	20.8%
4+ occ Pers	390	0	390	360	0	360	-30	-7.7%
Bus Pers	2133	267	2400	2100	300	2400	0	0.0%
Truck Pers	?	?	O?		?	0	0	ERR
Cycle Pers	?	?	O?		?	0	0	ERR
Subtotal HOV's	3033	3257	6290	7580	1850	9430	3140	49.9%
Subtotal Other	18	11400	11418	135	11200	11335	-83	-0.7%
Total Persons:	3051	14657	17708	7715	13050	20765	3057	17.3%
Auto Occupancy:	3.24	1.12	1.17	2.13	1.07	1.26	0.09	7.7%

	3
Action:	Extend Lane 5 miles
Name	I-10 Katy Transitway
Metro Area	Houston
State	TX
HOV Facility:	Reversible median lane
HOV Length (mi)	11.4
HOV Lanes Each Direction	1
Hours of Operation:	5AM-Noon EB, 2-9PM WB
Elgibility:	2+
HOV Open Date:	6/29/87
Street Type	Freeway
Mixed Flow Lanes Each Dir.	4
Free-Flow Speed (mph):	57

Peak Hour:	6:45-7:45 AM					VEHICLES		
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/87	4/87	4/87	4/88	4/88	4/88	Diff.	%
Max. Time (min)	20	30	27	12	30	25	-2	-7.4%
Ave. Time (min)	19	26	24	12	26	22	-2	-8.3%
1 occ Vol	74	3400	3474	84	4000	4084	610	17.6%
2 occ Vol	1150	200	1350	1110	200	1310	-40	-3.0%
3 occ Vol	200	15	215	240	60	300	85	39.5%
4+ occ Vol	25	?	25	25	?	25	0	0.0%
Bus Vol	25	10	35	35	1	36	1	2.9%
Truck Vol	?	?	O ?		?	0	0	ERR
Cycle Vol	?	?	O ?		?	0	0	ERR
Subtotal HOV's	1400	225	1625	1410	261	1671	46	2.8%
Subtotal Other	74	3400	3474	84	4000	4084	610	17.6%
Total Vol:	1474	3625	5099	1494	4261	5755	656	12.9%

Peak Period:	6:00 - 9:30 AM							
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/87	4/87	4/87	4/88	4/88	4/88	Diff.	%
Max. Time (min)	20	30	28	12	30	27	-1	-3.6%
Ave. Time (min)	15	19	18	12	19	18	0	0.0%
1 occ Vol	135	11200	11335	154	12500	12654	1319	11.6%
2 occ Vol	2200	700	2900	2300	800	3100	200	6.9%
3 occ Vol	240	50	290	500	200	700	410	141.4%
4+ occ Vol	60	?	60	60	?	60	0	0.0%
Bus Vol	70	10	80	70	10	80	0	0.0%
Truck Vol	?	?	O ?		?	0	0	ERR
Cycle Vol	?	?	O ?		?	0	0	ERR
Subtotal HOV's	2570	760	3330	2930	1010	3940	610	18.3%
Subtotal Other	135	11200	11335	154	12500	12654	1319	11.6%
Total Vol:	2705	11960	14665	3084	13510	16594	1929	13.2%

Data Set Number:	3				Persons			
Action:	Extend Lane 5 miles							
Name	I-IO Katy Transitway							
City	Houston							
State	TX							
HOV Facility:	Reversible median lane							
Length (mi)	11.4							
No. of Lanes	1							
Hours of Operation:	5AM-Noon EB, 2-9PM WB							
Elgibility:	2+							
HOV Open Date:	6/29/87							
Street Type	Freeway							
No. of Lanes Each Direction	4							
Free-Flow Speed (mph):	57							
Peak Hour:	6:45-7:45 AM		PERSONS			PERSONS		
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/87	4/87	4/87	4/88	4/88	4/88	Diff.	%
Max. Time (min)	20	30	27	12	30	25	-2	-7.4%
Ave. Time (min)	19	26	24	12	26	22	-2	-8.3%
1 occ Pers	74	3400	3474	84	4000	4084	610	17.6%
2 occ Pers	2300	400	2700	2220	400	2620	-80	-3.0%
3 occ Pers	600	45	645	720	180	900	255	39.5%
4+ occ Pers	150	0	150	150	0	150	0	0.0%
Bus Pers	929	371	1300	1215	35	1250	-50	-3.8%
Truck Pers	?	?	O?		?	0	0	ERR
Cycle Pers	?	?	O?		?	0	0	ERR
Subtotal HOV's	3979	816	479s	4305	615	4920	125	2.6%
Subtotal Other	74	3400	3474	84	4000	4084	610	17.6%
Total Persons:	4053	4216	8269	4389	4615	9004	735	8.9%
Auto Occupancy:	2.16	1.06	1.38	2.18	1.08	1.36	-0.02	-1.4%
Peak Period:								
Direction:								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/87	4/87	4/87	4/88	4/88	4/88	Diff.	%
Max. Time (min)	20	30	28	12	30	27	-1	-3.6%
Ave. Time (min)	15	19	18	12	19	18	0	0.0%
1 occ Pers	135	11200	11335	154	12500	12654	1319	11.6%
2 occ Pers	4400	1400	5800	4600	1600	6200	400	6.9%
3 occ Pers	720	150	870	1500	600	2100	1230	141.4%
4+ occ Pers	360	0	360	360	0	360	0	0.0%
Bus Pers	2100	300	2400	2275	325	2600	200	8.3%
Truck Pers	?	?	O?		?	0	0	ERR
Cycle Pers	?	?	O?		?	0	0	ERR
Subtotal HOV's	7580	1850	9430	8735	2525	11260	1830	19.4%
Subtotal Other	135	11200	11335	154	12500	12654	1319	11.6%
Total Persons:	7715	13050	20765	8889	15025	23914	3149	15.2%
Auto Occupancy:	2.13	1.07	1.26	2.19	1.09	1.29	0.03	2.4%

	4
Action:	Convert from 2+ to 3+
Name	I-IO Katy Transitway
Metro Area	Houston
State	TX
HOV Facility:	Reversible median lane
HOV Length (mi)	11.4
HOV Lanes Each Direction	
Hours of Operation:	5AM-Noon EB, 2-9PM WB
Elgibility:	3+
HOV Open Date:	10/17/88
Street Type	Freeway
Mixed Flow Lanes Each Dir.	4
Free-Flow Speed (mph):	57

Peak Hour:	6:45-7:45 AM					VEHICLES		
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/88	4/88	4/88	4/89	4/89	4/89	Diff.	%
Max. Time (min)	12	30	25	12	30	27	2	8.0%
Ave. Time (min)	12	26	22	12	26	24	2	9.1%
1 occ Vol	74	4000	4074	46	4600	4646	572	14.0%
2 occ Vol	1100	200	1300	400	450	850	-450	-34.6%
3 occ Vol	240	60	300	420	50	470	170	56.7%
4+ occ Vol	25	?	25	25	?	25	0	0.0%
Bus Vol	35	1	36	35	1	36	0	0.0%
Truck Vol	?	?	O?		?	0	0	ERR
Cycle Vol	?	?	O?		?	0	0	ERR
Subtotal HOV's	1400	261	1661	880	501	1381	-280	-16.9%
Subtotal Other	74	4000	4074	46	4600	4646	572	14.0%
Total Vol:	1474	4261	5735	926	5101	6027	292	5.1%

Peak Period:	6:00 - 9:30 AM							
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/88	4/88	4/88	4/89	4/89	4/89	Diff.	%
Max. Time (min)	12	30	27	12	30	28	1	3.7%
Ave. Time (min)	12	19	18	12	19	18	0	0.0%
1 occ Vol	154	12500	12654	102	14800	14902	2248	17.8%
2 occ Vol	2300	800	3100	800	1400	2200	-900	-29.0%
3 occ Vol	500	200	700	1000	160	1160	460	65.7%
4+ occ Vol	60	?	60	60	?	60	0	0.0%
Bus Vol	70	10	80	70	10	80	0	0.0%
Truck Vol	?	?	O?		?	0	0	ERR
Cycle Vol	?	?	O?		?	0	0	ERR
Subtotal HOV's	2930	1010	3940	1930	1570	3500	-440	-11.2%
Subtotal Other	154	12500	12654	102	14800	14902	2248	17.8%
Total Vol:	3084	13510	16594	2032	16370	18402	1808	10.9%

Data Set Number:	4				Persons			
Action:	Convert from 2+ to 3+							
Name	I-IO Katy Transitway							
City	Houston							
State	TX							
HOV Facility:	Reversible median lane							
Length (mi)	11.4							
No. of Lanes								
Hours of Operation:	5AM-Noon EB, 2-9PM WB							
Elgibility:	3+							
HOV Open Date:	10/17/88							
Street Type	Freeway							
No. of Lanes Each Direction	4							
Free-Flow Speed (mph):	57							
Peak Hour:	6:45-7:45 AM	PERSONS			PERSONS			
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/88	4/88	4/88	4/89	4/89	4/89	Diff.	%
Max. Time (min)	12	30	25	12	30	27	2	8.0%
Ave. Time (min)	12	26	22	12	26	24	2	9.1%
1 occ Pers	74	4000	4074	46	4600	4646	572	14.0%
2 occ Pers	2200	400	2600	800	900	1700	-900	-34.6%
3 occ Pers	720	180	900	1260	150	1410	510	56.7%
4+ occ Pers	150	0	150	150	0	150	0	0.0%
Bus Pers	1215	35	1250	1701	49	1750	500	40.0%
Truck Pers	?	?	O?		?	0	0	ERR
Cycle Pers	?	?	O?		?	0	0	ERR
Subtotal HOV's	4285	615	4900	3911	1099	5010	110	2.2%
Subtotal Other	74	4000	4074	46	4600	4646	572	14.0%
Total Persons:	4359	4615	8974	3957	5699	9656	682	7.6%
Auto Occupancy:	2.18	1.08	1.36	2.53	1.11	1.32	-0.04	-2.9%
Peak Period:								
Direction:								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/88	4/88	4/88	4/89	4/89	4/89	Diff.	%
Max. Time (min)	12	30	27	12	30	28	1	3.7%
Ave. Time (min)	12	19	18	12	19	18	0	0.0%
1 occ Pers	154	12500	12654	102	14800	14902	2248	17.8%
2 occ Pers	4600	1600	6200	1600	2800	4400	-1800	-29.0%
3 occ Pers	1500	600	2100	3000	480	3480	1380	65.7%
4+ occ Pers	360	0	360	360	0	360,	0	0.0%
Bus Pers	2275	325	2600	2713	388	3101	501	19.3%
Truck Pers	?	?	O?		?	0	0	ERR
Cycle Pers	?	?	O?		?	0	0	ERR
Subtotal HOV's	8735	2525	11260	7673	3668	11341	81	0.7%
Subtotal Other	154	12500	12654	102	14800	14902	2248	17.8%
Total Persons:	8889	15025	23914	7775	18468	26243	2329	9.7%
Auto Occupancy:	2.19	1.09	1.29	2.58	1.11	1.26	-0.03	-2.3%

5

Action: Extend Lane 1.5 miles
Name I-10 Katy Transitway
Metro Area Houston
State TX
HOV Facility: Reversible median lane
HOV Length (mi) 12.6
HOV Lanes Each Direction
Hours of Operation: 5AM-Noon EB, 2-9PM WB
Elgibility: 3+
HOV Open Date: l/9/90
Street Type Freeway
Mixed Flow Lanes Each Dir. 4
Free-Flow Speed (mph): 54

Peak Hour:	6:45-7:45 AM					VEHICLES		
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/89	4/89	4/89	4/90	4/90	4/90	Diff.	%
Max. Time (min)	15	34	31	14	34	30	-1	-3.2%
Ave. Time (min)	15	30	28	14	30	27	-1	-3.6%
1 occ Vol	46	4600	4646 ?		4800	4800	154	3.3%
2 occ Vol	400	450	850	580	450	1030	180	21.2%
3 occ Vol	420	50	470	520	50	570	100	21.3%
4+ occ Vol	25 ?		25	25 ?		25	0	0.0%
Bus Vol	35	1	36	35	1	36	0	0.0%
Truck Vol	?	?	O?		?	0	0	ERR
Cycle Vol	?	?	O?		?	0	0	ERR
Subtotal HOV's	880	501	1381	1160	501	1661	280	20.3%
Subtotal Other	46	4600	4646	0	4800	4800	154	3.3%
Total Vol:	926	5101	6027	1160	5301	6461	434	7.2%

Peak Period:	6:00 - 9:30 AM							
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/89	4/89	4/89	4/90	4/90	4/90	Diff.	%
Max. Time (min)	15	34	32	14	34	31	-1	-3.1%
Ave. Time (min)	14	22	21	14	22	21	0	0.0%
1 occ Vol	102	14800	14902 ?		14650	14650	-252	-1.7%
2 occ Vol	800	1400	2200	1400	1400	2800	600	27.3%
3 occ Vol	1000	160	1160	1300	150	1450	290	25.0%
4+ occ Vol	60 ?		60	60 ?		60	0	0.0%
Bus Vol	70	10	80	70	10	80	0	0.0%
Truck Vol	?	?	O?		?	0	0	ERR
Cycle Vol	?	?	D ?		?	0	0	ERR
Subtotal HOV's	1930	1570	3500	2830	1560	4390	890	25.4%
Subtotal Other	102	14800	14902	0	14650	14650	-252	-1.7%
Total Vol:	2032	16370	18402	2830	16210	19040	638	3.5%

Data Set Number:	5				Persons				
Action:	Extend Lane 1.5 miles								
Name	I-IO Katy Transitway								
City	Houston								
State	TX								
HOV Facility:	Reversible median lane								
Length (mi)	12.6								
No. of Lanes									
Hours of Operation:	5AM-Noon EB, 2-9PM WB								
Elgibility:	3+								
HOV Open Date:	1/9/90								
Street Type	Freeway								
No. of Lanes Each Direction	4								
Free-Flow Speed (mph):	54								
Peak Hour:	6:45-7:45 AM		PERSONS			PERSONS			
Direction:	EB								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference		
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before		
Date:	4/89	4/89	4/89	4/90	4/90	4/90	Diff.	%	
Max. Time (min)	15	34	31	14	34	30	-1	-3.2%	
Ave. Time (min)	15	30	28	14	30	27	-1	-3.6%	
1 occ Pers	46	4600	4646 ?		4800	4800	154	3.3%	
2 occ Pers	800	900	1700	1160	900	2060	360	21.2%	
3 occ Pers	1260	150	1410	1560	150	1710	300	21.3%	
4+ occ Pers	150	0	150	150	0	150	0	0.0%	
Bus Pers	1701	49	1750	1847	53	1900	150	8.6%	
Truck Pers	?	?	O?		?	0	0	ERR	
Cycle Pers	?	?	O?		?	0	0	ERR	
Subtotal HOV's	3911	1099	5010	4717	1103	5820	810	16.2%	
Subtotal Other	46	4600	4646	0	4800	4800	154	3.3%	
Total Persons:	3957	5699	9656	4717	5903	10620	964	10.0%	
Auto Occupancy:	2.53	1.11	1.32	2.55	1.1	1.36	0.04	3.0%	
Peak Period:									
Direction:									
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference		
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before		
Date:	4/89	4/89	4/89	4/90	4/90	4/90	Diff.	%	
Max. Time (min)	15	34	32	14	34	31	-1	-3.1%	
Ave. Time (min)	14	22	21	14	22	21	0	0.0%	
1 occ Pers	102	14800	14902 ?		14650	14650	-252	-1.7%	
2 occ Pers	1600	2800	4400	2800	2800	5600	1200	27.3%	
3 occ Pers	3000	480	3480	3900	450	4350	870	25.0%	
4+ occ Pers	360	0	360	360	0	360	0	0.0%	
Bus Pers	2713	388	3101	2713	388	3101	0	0.0%	
Truck Pers	?	?	O?		?	0	0	ERR	
Cycle Pers	?	?	O?		?	0	0	ERR	
Subtotal HOV's	7673	3668	11341	9773	3638	13411	2070	18.3%	
Subtotal Other	102	14800	14902	0	14650	14650	-252	-1.7%	
Total Persons:	7775	18468	26243	9773	18288	28061	1818	6.9%	
Auto Occupancy:	2.58	1.11	1.26	2.56	1.1	1.32	0.06	4.8%	

	6
Action:	Convert 3+Pre-Authorized to 2+ Unauthorized
Name	I-45N North Fwy
Metro Area	Houston
State	TX
HOV Facility:	Reversible median lane
HOV Length (mi)	13.5
HOV Lanes Each Direction	1
Hours of Operation:	5AM-Noon SB, 2-9PM NB
Elgibility:	2+
HOV Open Date:	6/26/90
Street Type	Freeway
Mixed Flow Lanes Each Dir.	4
Free-Flow Speed (mph):	62

Peak Hour:	7:00-8:00 AM					VEHICLES		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	5/90	5/90	5/90	5/91	5/91	5/91	Diff.	%
Max. Time (min)	13	22	ERR	13	22	21	ERR	ERR
Ave. Time (min)	13	19	ERR	13	19	18	ERR	ERR
1 occ Vol	?	?	?	?	6350	6350	6350	ERR
2 occ Vol	?	?	?	650	465	1115	1115	ERR
3 occ Vol	?	?	?	60	45	105	105	ERR
4+ occ Vol	50	?	?	50	25	75	75	ERR
Bus Vol	70	?	?	70	15	85	85	ERR
Truck Vol	?	?	?	?	?	0	0	ERR
Cycle Vol	?	?	?	?	?	0	0	ERR
Subtotal HOV's	?	?	700	830	550	1380	680	97.1%
Subtotal Other	?	?	7720	0	6350	6350	-1370	-17.7%
Total Vol:	?	?	8420	830	6900	7730	-690	-8.2%

Peak Period:	6:00 - 8:45 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	5/90	5/90	5/90	5/91	5/91	5/91	Diff.	%
Max. Time (min)	13	22	22	13	22	22	0	0.0%
Ave. Time (min)	13	17	17	13	17	17	0	0.0%
1 occ Vol	?	?	O?		?	0	0	ERR
2 occ Vol	?	?	O?		?	0	0	ERR
3 occ Vol	?	?	O?		?	0	0	ERR
4+ occ Vol	?	?	O?		?	0	0	ERR
Bus Vol	?	?	O?		?	0	0	ERR
Truck Vol	?	?	O?		?	0	0	ERR
Cycle Vol	?	?	O?		?	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	22500	22500	0	21000	21000	-1500	-6.7%

Data Set Number:	6	Persons
Action:	Convert 3+Pre-Authorized to 2+ Unauthorized	
Name	I-45N North Fwy	
City	Houston	
State	TX	
HOV Facility:	Reversible median lane	
Length (mi)	13.5	
No. of Lanes	1	
Hours of Operation:	5AM-Noon SB, 2-9PM NB	
Elgibility:	2+	
HOV Open Date:	6/26/90	
Street Type	Freeway	
No. of Lanes Each Direction	4	
Free-Flow Speed (mph):	62	

Peak Hour:	7:00-8:00 AM		PERSONS			PERSONS		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	5/90	5/90	5/90	5/91	5/91	5/91	Diff.	%
Max. Time (min)	13	22	ERR	13	22	21	ERR	ERR
Ave. Time (min)	13	19	ERR	13	19	18	ERR	ERR
1 occ Pers	?	?	?	?	6350	6350	6350	ERR
2 occ Pers	?	?	?	1300	930	2230	2230	ERR
3 occ Pers	?	?	?	180	135	315	315	ERR
4+ occ Pers	500	?	?	400	150	550	550	ERR
Bus Pers	2400	?	?	2600	335	2935	2935	ERR
Truck Pers	?	?	?	?	?	0	0	ERR
Cycle Pers	?	?	?	?	?	0	0	ERR
Subtotal HOV's	?	?	4280	4480	1550	6030	1750	40.9%
Subtotal Other	?	?	7220	0	6350	6350	-870	-12.0%
Total Persons:	?	?	11500	4480	7900	12380	880	7.7%
Auto Occupancy:	34.29	ERR	1.37	2.47	1.1	1.24	-0.13	-9.5%

Peak Period:								
Direction:								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	5/90	5/90	5/90	5/91	5/91	5/91	Diff.	%
Max. Time (min)	13	22	22	13	22	22	0	0.0%
Ave. Time (min)	13	17	17	13	17	17	0	0.0%
1 occ Pers	?	?	O?		?	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	800	0	800	500	0	500	-300	-37.5%
Bus Pers	4900	ERR	ERR	4700	ERR	ERR	ERR	ERR
Truck Pers	?	?	O?		?	0	0	ERR
Cycle Pers	?	?	O?		?	0	0	ERR
Subtotal HOV's	5700	ERR	ERR	5200	ERR	ERR	ERR	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	5700	25000	30700	5200	23000	28200	-2500	-8.1%
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR

	7							
Action:	Construct 9.5 mile HOV Lane							
Name	U.S. 290 Northwest Fwy							
Metro Area	Houston							
State	TX							
HOV Facility:	Reversible median lane							
HOV Length (mi)	9.5							
HOV Lanes Each Direction	1							
Hours of Operation:	4AM-IPM SB, 2-IOPM NB							
Elgibility:	2+							
HOV Open Date:	8/29/88							
Street Type	Freeway							
Mixed Flow Lanes Each Dir.	3							
Free-Flow Speed (mph):	50							
Peak Hour:	7:00-8:00 AM					VEHICLES		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/88	4/88	4/88	4/89	4/89	4/89	Diff.	%
Max. Time (min)	?	20	ERR	11.4	19	18	ERR	ERR
Ave. Time (min)	?	20	ERR	11.4	18	17	ERR	ERR
1 occ Vol	?	?	?	?	?	?	0	ERR
2 occ Vol	?	?	?	?	?	?	0	ERR
3 occ Vol	?	?	?	?	?	?	0	ERR
4+ occ Vol	?	?	?	?	?	?	0	ERR
Bus Vol	?	?	?	?	?	?	0	ERR
Truck Vol	?	?	?	?	?	?	0	ERR
Cycle Vol	?	?	?	?	?	?	0	ERR
Subtotal HOV's	?	?	490	666	560	1226	736	150.2%
Subtotal Other	?	?	4880	24	5040	5064	184	3.8%
Total Vol:	?	?	5370	690	5600	6290	920	17.1%
Peak Period:	6:00 - 9:30 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/88	4/88	4/88	4/89	4/89	4/89	Diff.	%
Max. Time (min)	?	20	ERR	11.4	19	19	ERR	ERR
Ave. Time (min)	?	14	ERR	11	12	12	ERR	ERR
1 occ Vol	?	?	?	?	?	?	?	ERR
2 occ Vol	?	?	?	?	?	?	?	ERR
3 occ Vol	?	?	?	?	?	?	?	ERR
4+ occ Vol	?	?	?	?	?	?	?	ERR
Bus Vol	?	?	?	?	?	?	?	ERR
Truck Vol	?	?	?	?	?	?	?	ERR
Cycle Vol	?	?	?	?	?	?	?	ERR
Subtotal HOV's	?	?	1365	1060	1450	2510	1145	83.9%
Subtotal Other	?	?	13930	40	14850	14890	960	6.9%
Total Vol:	?	?	15295	1100	16300	17400	2105	13.8%

Data Set Number:	7					Persons		
Action:	Construct 9.5 mile HOV Lane							
Name	U.S. 290 Northwest Fwy							
City	Houston							
State	TX							
HOV Facility:	Reversible median lane							
Length (mi)	9.5							
No. of Lanes	1							
Hours of Operation:	4AM-IPM SB, 2-IOPM NB							
Elgibility:	2+							
HOV Open Date:	8/29/88							
Street Type	Freeway							
No. of Lanes Each Direction	3							
Free-Flow Speed (mph):	50							
Peak Hour:	7:00-8:00 AM		PERSONS			PERSONS		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/88	4/88	4/88	4/89	4/89	4/89	Diff.	%
Max. Time (min)	?	20	ERR	11.4	19	18	ERR	ERR
Ave. Time (min)	?	20	ERR	11.4	18	17	ERR	ERR
1 occ Pers	?	?	?	?	?	?	?	ERR
2 occ Pers	?	?	?	?	?	?	?	ERR
3 occ Pers	?	?	?	?	?	?	?	ERR
4+ occ Pers	?	?	?	?	?	?	?	ERR
Bus Pers	?	?	?	?	?	?	?	ERR
Truck Pers	?	?	?	?	?	?	?	ERR
Cycle Pers	?	?	?	?	?	?	?	ERR
Subtotal HOV's	?	?	1320	1886	1120	3006	1686	127.7%
Subtotal Other	?	?	4880	24	5040	5064	184	3.8%
Total Persons:	?	?	6200	1910	6160	8070	1870	30.2%
Auto Occupancy:	ERR	ERR	1.15	2.77	1.1	1.28	0.13	11.3%
Peak Period:								
Direction:								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/88	4/88	4/88	4/89	4/89	4/89	Diff.	%
Max. Time (min)	?	20	ERR	11.4	19	19	ERR	ERR
Ave. Time (min)	?	14	ERR	11	12	12	ERR	ERR
1 occ Pers	?	?	?	?	?	?	?	ERR
2 occ Pers	?	?	?	?	?	?	?	ERR
3 occ Pers	?	?	?	?	?	?	?	ERR
4+ occ Pers	?	?	?	?	?	?	?	ERR
Bus Pers	?	?	?	?	?	?	?	ERR
Truck Pers	?	?	?	?	?	?	?	ERR
Cycle Pers	?	?	?	?	?	?	?	ERR
Subtotal HOV's	?	?	3520	3110	3350	6460	2940	83.5%
Subtotal Other	?	?	13930	40	14850	14890	960	6.9%
Total Persons:	?	?	17450	3150	18200	21350	3900	22.3%
Auto Occupancy:	ERR	ERR	1.14	2.86	1.12	1.23	0.09	7.9%

	8
Action:	Construct 8 mile HOV Lane
Name	I-15
Metro Area	San Diego
State	CA
HOV Facility:	Reversible median lane
HOV Length (mi)	8
HOV Lanes Each Direction	2
Hours of Operation:	6AM-9AM SB, 3-6:30PM NB
Elgibility:	2+
HOV Open Date:	i0/20/88
Street Type	Freeway
Nixed Flow Lanes Each Dir.	4
Free-Flow Speed (mph):	60

Peak Hour:	AM					VEHICLES		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	5/88	5/88	5/88	5/89	5/89	5/89	Diff.	%
Max. Time (min)		20	20	8	13	12	-8	-40.0%
Ave. Time (min)		18	18	8	11	IO	-8	-44.4%
1 occ Vol		8435	8435	39	10979	11018	2583	30.6%
2 occ Vol		1449	1449	2154	523	2677	1228	84.7%
3 occ Vol		188	188	239	17	256	68	36.2%
4+ occ Vol		?	0	0	?	0	0	ERR
Bus Vol		24	24	?	26	26	2	8.3%
Truck Vol		166	166	?	248	248	82	49.4%
Cycle Vol		88	88	55	33	88	0	0.0%
Subtotal HOV's	0	1749	1749	2448	599	3047	1298	74.2%
Subtotal Other	0	8601	8601	39	11227	11266	2665	31.0%
Total Vol:	0	10350	10350	2487	11826	14313	3963	38.3%

Peak Period:	6:00 - 9:00 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	5/88	5/88	5/88	5/89	5/89	5/89	Diff.	%
Max. Time (min)	0	20	20	8	13	13	-7	-35.0%
Ave. Time (min)		14	14	8	10	10	-4	-28.6%
1 occ Vol		22439	22439	49	26614	26663	4224	18.8%
2 occ Vol		3097	3097	2445	1555	4000	903	29.2%
3 occ Vol		369	369	335	64	399	30	8.1%
4+ occ Vol		0	0	100	0	100	100	ERR
Bus Vol		68	68	55	61	116	48	70.6%
Truck Vol		645	645	0	841	841	196	30.4%
Cycle Vol		173	173	80	93	173	0	0.0%
Subtotal HOV's	0	3707	3707	3015	1773	4788	1081	29.2%
Subtotal Other	0	23084	23084	49	27455	27504	4420	19.1%
Total Vol:	0	26791	26791	3064	29228	32292	5501	20.5%

Data Set Number:	8					Persons		
Action:	Construct 8 mile HOV Lane							
Name	I-15							
City	San Diego							
State	CA							
HOV Facility:	Reversible median lane							
Length (mi)	8							
No. of Lanes	2							
Hours of Operation:	6AM-9AM SB, 3-6:30PM NB							
Elgibility:	2+							
HOV Open Date:	10/20/88							
Street Type	Freeway							
No. of Lanes Each Direction	4							
Free-Flow Speed (mph):	60							
Peak Hour:	AM		PERSONS			PERSONS		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	5/88	5/88	5/88	5/89	5/89	5/89	Diff.	%
Max. Time (min)	0	20	20	8	13	12	-8	-40.0%
Ave. Time (min)	0	18	18	8	11	10	-8	-44.4%
1 occ Pers	0	8435	8435	39	10979	11018	2583	30.6%
2 occ Pers	0	2898	2898	4308	1046	5354	2456	84.7%
3 occ Pers	0	564	564	717	51	768	204	36.2%
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers		1360	1360	415	1220	1635	275	20.2%
Truck Pers	0	166	166	?	248	248	82	49.4%
Cycle Pers	0	88	88	55	33	88	0	0.0%
Subtotal HOV's	0	4910	4910	5495	2350	7845	2935	59.8%
Subtotal Other	0	8601	8601	39	11227	11266	2665	31.0%
Total Persons:	0	13511	13511	5534	13577	19111	5600	41.4%
Auto Occupancy:	ERR	1.18	1.18	2.08	1.05	1.23	0.05	4.2%
Peak Period:								
Direction:								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	5/88	5/88	5/88	5/89	5/89	5/89	Diff.	%
Max. Time (min)	0	20	20	8	13	13	-7	-35.0%
Ave. Time (min)	0	14	14	8	10	10	-4	-28.6%
1 occ Pers	0	22439	22439	49	26614	26663	4224	18.8%
2 occ Pers	0	6194	6194	4890	3110	8000	1806	29.2%
3 occ Pers	0	1107	1107	1005	192	1197	90	8.1%
4+ occ Pers	0	0	0	600	0	600	600	ERR
Bus Pers		2720	2720	830	2440	3270	550	20.2%
Truck Pers	0	645	645	0	841	841	196	30.4%
Cycle Pers	0	173	173	80	93	173	0	0.0%
Subtotal HOV's	0	10194	10194	7405	5835	13240	3046	29.9%
Subtotal Other	0	23084	23084	49	27455	27504	4420	19.1%
Total Persons:	0	33278	33278	7454	33290	40744	7466	22.4%
Auto Occupancy:	ERR	1.15	1.15	2.23	1.06	1.17	0.02	1.7%

Data Set Number:	9					Persons			
Action:	Convert 3.7 mi to HOV Lane, Add 2.5 mi HOV Lane								
Name	I-90								
City	Seattle								
State	WA								
HOV Facility:	Freeway, Concurrent								
Length (mi)	6.2								
No. of Lanes	1								
Hours of Operation:	0								
Elgibility:	2+								
HOV Open Date:	11/93								
Street Type	Freeway								
No. of Lanes Each Direction	3								
Free-Flow Speed (mph):	53								
Peak Hour:	AM		PERSONS			PERSONS			
Direction:	WB								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference		
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After-	Before	
Date:	11/93	11/93	11/93	6/94	6/94	6/94	Diff .	%	
Max. Time (min)	0	7	ERR	7	7	ERR	ERR	ERR	
Ave. Time (min)	0	7	ERR	7	7	ERR	ERR	ERR	
1 occ Pers	0	0	0	0	0	0	0	ERR	
2 occ Pers	0	0	0	0	0	0	0	ERR	
3 occ Pers	0	0	0	0	0	0	0	ERR	
4+ occ Pers	0	0	0	0	0	0	0	ERR	
Bus Pers			0			0	0	ERR	
Truck Pers	0	0	0	0	0	0	0	ERR	
Cycle Pers	0	0	0	0	0	0	0	ERR	
Subtotal HOV's	0	0	0	0	0	0	0	ERR	
Subtotal Other	0	0	0	0	0	0	0	ERR	
Total Persons:	0	0	0	0	0	0	0	ERR	
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	
Peak Period:									
Direction:									
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference		
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before		
Date:	11/93	11/93	11/93	6/94	6/94	6/94	Diff.	%	
Max. Time (min)	0	7	7	7	7	7	0	0.0%	
Ave. Time (min)	0	6.6	7	6.5	6.4	6	-1	-14.3%	
1 occ Pers	0	0	0	0	0	0	0	ERR	
2 occ Pers	0	0	0	0	0	0	0	ERR	
3 occ Pers	0	0	0	0	0	0	0	ERR	
4+ occ Pers	0	0	0	0	0	0	0	ERR	
Bus Pers			0			0	0	ERR	
Truck Pers	0	0	0	0	0	0	0	ERR	
Cycle Pers	0	0	0	0	0	0	0	ERR	
Subtotal HOV's	0	3615	3615	1294	2773	4067	452	12.5%	
Subtotal Other	0	9675	9675	28	8787	8815	-860	-8.9%	
Total Persons:	0	13290	13290	1322	11500	12822	-468	-3.5%	
Auto Occupancy:	ERR	1.12	1.12	2.14	1.06	1.12	0	0.0%	

	9
Action:	Convert 3.7 mi to HOV Lane, Add 2.5 mi HOV Lane
Name	I-90
Metro Area	Seattle
State	WA
HOV Facility:	Freeway, Concurrent
HOV Length (mi)	6.2
HOV Lanes Each Direction	1
Hours of Operation:	
Elgibility:	2+
HOV Open Date:	11/93
Street Type	Freeway
Mixed Flow Lanes Each Dir.	3
Free-Flow Speed (mph):	53

Peak Hour:	AM					VEHICLES		
Direction:	WB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	11/93	11/93	11/93	6/94	6/94	694	Diff.	%
Max. Time (min)		7	ERR	7	7	ERR	ERR	ERR
Ave. Time (min)		7	ERR	7	7	ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR

Peak Period:	7:00 - 10:00 AM							
Direction:	WB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	II/93	11/93	11/93	6/94	6/94	6/94	Diff.	%
Max. Time (min)	0	7	7	7	7	7	0	0.0%
Ave. Time (min)		6.6	7	6.5	6.4	6	-1	-14.3%
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	2195	2195	590	2043	2633	438	20.0%
Subtotal Other	0	9675	9675	28	8787	8815	860	-8.9%
Total Vol:	0	11870	11870	618	10830	11448	-422	-3.6%

	10							
Action:	Convert 3+ to 2+							
Name	1-5							
Metro Area	Seattle							
State	WA							
HOV Facility:	Freeway, Concurrent, with ramp meters							
HOV Length (mi)	7.7 SB							
HOV Lanes Each Direction	1							
Hours of Operation:								
Elgibility:	2+							
HOV Open Date:	7/29/91							
Street Type	Freeway							
Mixed Flow Lanes Each Dir.	3							
Free-Flow Speed (mph):	80							
Peak Hour:	7:00-8:OO AM					VEHICLES		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	9/90	9/90	9/90	9/91	9/91	9/91	Diff.	%
Max. Time (min)	6	8	8	6	6	6	-2	-25.0%
Ave. Time (min)	5.8	7.5	7	5.8	6.2	6	-1	-14.3%
1 occ Vol	0	4440	4440	220	4403	4623	183	4.1%
2 occ Vol	0	960	960	345	1062	1407	447	46.6%
3 occ Vol	300	0	300	376	0	376	76	25.3%
4+ occ Vol	?	?	?	?	?	?	0	ERR
Bus Vol	59	0	59	59	0	59	0	0.0%
Truck Vol	0	121	121	0	138	138	17	14-D%
Cycle Vol	41	79	120	41	56	97	-23	-19.2%
Subtotal HOV's	400	1039	1439	a21	1118	1939	500	34.7%
Subtotal Other	0	4561	4561	220	4541	4761	200	4.4%
Total Vol:	400	5600	6000	1041	5659	6700	700	11.7%
Peak Period:	6:00-9:00 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	9/90	9/90	9/90	9/91	9/91	9/91	Diff.	%
Max. Time (min)	6	8	ERR	6	6	ERR	ERR	ERR
Ave. Time (min)			ERR			ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR

Data Set Number:	10					Persons			
Action:	Convert 3+ to 2+								
Name	I-5								
City	Seattle								
State	WA								
HOV Facility:	Freeway, Concurrent, with ramp meters								
Length (mi)	7.7								
No. of Lanes									
Hours of Operation:	0								
Eligbility:	2+								
HOV Open Date:	7/29/91								
Street Type	Freeway								
No. of Lanes Each Direction	3								
Free-Flow Speed (mph):	80								
Peak Hour:	7:00-8:00 AM		PERSONS			PERSONS			
Direction:	SB								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference		
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before		
Date:	9/90	9/90	9/90	9/91	9/91	9/91	Diff.	%	
Max. Time (min)	6	8	8	6	6	6	-2	-25.0%	
Ave. Time (min)	5.8	7.5	7	5.8	6.2	6	-1	-14.3%	
1 occ Pers	0	4440	4440	220	4403	4623	183	4.1%	
2 occ Pers	0	1920	1920	690	2124	2814	894	46.6%	
3 occ Pers	900	0	900	1128	0	1128	228	25.3%	
4+ occ Pers	0	0	0	0	0	0	0	ERR	
Bus Pers	2500	?	2500	2500	?	2500	0	0.0%	
Truck Pers	0	121	121	0	138	138	17	14.0%	
Cycle Pers	41	79	120	41	56	97	-23	-19.2%	
Subtotal HOV's	3441	1999	5440	4359	2180	6539	1099	20.2%	
Subtotal Other	0	4561	4561	220	4541	4761	200	4.4%	
Total Persons:	3441	6560	10001	4579	6721	11300	1299	13.0%	
Auto Occupancy:	3	1.18	1.27	2.17	1.19	1.34	0.07	5.5%	
Peak Period:									
Direction:									
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference		
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before		
Date:	9/90	9/90	9/90	9/91	9/91	9/91	Diff.	%	
Max. Time (min)	6	8	ERR	6	6	ERR	ERR	ERR	
Ave. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR	
1 occ Pers	0	0	0	0	0	0	0	ERR	
2 occ Pers	0	0	0	0	0	0	0	ERR	
3 occ Pers	0	0	0	0	0	0	0	ERR	
4+ occ Pers	0	0	0	0	0	0	0	ERR	
Bus Pers			0			0	0	ERR	
Truck Pers	0	0	0	0	0	0	0	ERR	
Cycle Pers	0	0	0	0	0	0	0	ERR	
Subtotal HOV's	0	0	0	0	0	0	0	ERR	
Subtotal Other	0	0	0	0	0	0	0	ERR	
Total Persons:	0	0	0	0	0	0	0	ERR	
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	

	11							
Action:	Install Ramp Meters with HOV bypass							
Name	I-5							
Metro Area	Seattle							
State	WA							
HOV Facility:	HOV bypass Lanes at 6/13 SB meters							
HOV Length (mi)	6							
HOV Lanes Each Direction	n/a							
Hours of Operation:	?							
Elgibility:	?							
HOV Open Date:	9/30/81							
Street Type	fwy ramp							
Mixed Flow Lanes Each Dir	1							
Free-Flow Speed (mph):	ERR							
Peak Hour:	AM					VEHICLES		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	9/81	9/81	9/81	9/82	9/82	9/82	Diff.	%
Max. Time (min)			ERR			ERR	ERR	ERR
Ave. Time (min)			ERR			ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ VOl			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR
Peak Period:	6-8:30 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	9/81	9/81	9/81	9/82	9/82	9/82	Diff.	%
Max. Time (min)	0	0	0	0	0	0	0	ERR
Ave. Time (min)			0			0	0	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	20000	20000	653	15527	16180	-3820	-19.1%

Data Set Number:	11					Persons			
Action:	Install Ramp Meters with HOV bypass								
Name	1-5								
City	Seattle								
State	WA								
HOV Facility:	HOV bypass Lanes at 6/13 SB meters								
Length (mi)	6								
No. of Lanes	n/a								
Hours of Operation:	?								
Elgibility:	?								
HOV Open Date:	9/30/81								
Street Type	fwy ramp								
No. of Lanes Each Direction	1								
Free-Flow Speed (mph):	ERR								
Peak Hour:	AM		PERSONS			PERSONS			
Direction:	SB								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference		
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before		
Date:	9/81	9/81	9/81	9/82	9/82	9/82	Diff.	%	
Max. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR	
Ave. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR	
1 occ Pers	0	0	0	0	0	0	0	ERR	
2 occ Pers	0	0	0	0	0	0	0	ERR	
3 occ Pers	0	0	0	0	0	0	0	ERR	
4+ occ Pers	0	0	0	0	0	0	0	ERR	
Bus Pers			0			0	0	ERR	
Truck Pers	0	0	0	0	0	0	0	ERR	
Cycle Pers	0	0	0	0	0	0	0	ERR	
Subtotal HOV's	0	0	0	0	0	0	0	ERR	
Subtotal Other	0	0	0	0	0	0	0	ERR	
Total Persons:	0	0	0	0	0	0	0	ERR	
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	
Peak Period:									
Direction:									
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference		
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before		
Date:	9/81	9/81	9/81	9/82	9/82	9/82	Diff.	%	
Max. Time (min)	0	0	0	0	0	0	0	ERR	
Ave. Time (min)	0	0	0	0	0	0	0	ERR	
1 occ Pers	0	0	0	0	0	0	0	ERR	
2 occ Pers	0	0	0	0	0	0	0	ERR	
3 occ Pers	0	0	0	0	0	0	0	ERR	
4+ occ Pers	0	0	0	0	0	0	0	ERR	
Bus Pers			0			0	0	ERR	
Truck Pers	0	0	0	0	0	0	0	ERR	
Cycle Pers	0	0	0	0	0	0	0	ERR	
Subtotal HOV's	0	0	0	0	0	0	0	ERR	
Subtotal Other	0	0	0	0	0	0	0	ERR	
Total Persons:	0	0	0	0	0	0	0	ERR	
Auto Occupancy:	ERR	0	0	0	0	0	0	ERR	

12

Action:	Construct 5.6 mile HOV lane
Name	I-5
Metro Area	Seattle
State	WA
HOV Facility:	Freeway, Concurrent
HOV Length (mi)	5.6
HOV Lanes Each Direction	
Hours of Operation:	24 hours
Elgibility:	3+
HOV Open Date:	8/29/83
Street Type	Freeway
Mixed Flow Lanes Each Dir.	3 or 4
Free-Flow Speed (mph):	ERR

Peak Hour:	6:45-7:45 AM					VEHICLES		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	9/82	9/82	9/82	12/83	12/83	12/83	Diff.	%
Max. Time (min)		9	0	6	8	8	8	ERR
Ave. Time (min)			0			0	0	ERR
1 occ Vol			0	62		62	62	ERR
2 occ Vol			0	41		41	41	ERR
3 occ VOl			0	164		164	164	ERR
4+ occ Vol			0	69		69	69	ERR
Bus Vol			0	37		37	37	ERR
Truck Vol			0	?		0	0	ERR
Cycle Vol			0	37		37	37	ERR
Subtotal HOV's	0	0	0	348	0	348	348	ERR
Subtotal Other	0	0	0	62	0	62	62	ERR
Total Vol:	270	?	?	410	6000	6410	6410	ERR

Peak Period:	6-8:30 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	9/82	9/82	9/82	12/83	12/83	12/83	Diff.	%
Max. Time (min)	0	9	9	6	8	8	-1	-11.1%
Ave. Time (min)		8	8	6	7	7	-1	-12.5%
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	13400	13400	680	14700	15380	1980	14.8%

Data Set Number:	12				Persons			
Action:	Construct 5.6 mile HOV lane							
Name	I-5							
City	Seattle							
State	WA							
HOV Facility:	Freeway, Concurrent							
Length (mi)	5.6							
No. of Lanes	1							
Hours of Operation:	24 hours							
Elgibility:	3+							
HOV Open Date:	8/29/83							
Street Type	Freeway							
No. of Lanes Each Direction	3 or 4							
Free-Flow Speed (mph):	ERR							
Peak Hour:	6:45-7:45 AM	PERSONS			PERSONS			
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	9/82	9/82	9/82	12/83	12/83	12/83	Diff.	%
Max. Time (min)	0	9	0	6	8	8	8	ERR
Ave. Time (min)	0	0	0	?	?	?	0	ERR
1 occ Pers	0	0	0	62	?	62	62	ERR
2 occ Pers	0	0	0	82	?	82	82	ERR
3 occ Pers	0	0	0	492	?	492	492	ERR
4+ occ Pers	0	0	0	414	?	414	414	ERR
Bus Pers			0	1480	?	1480	1480	ERR
Truck Pers	0	0	0	?	?	?	0	ERR
Cycle Pers	0	0	0	37	?	37	37	ERR
Subtotal HOV's	0	0	0	2505	?	2505	2505	ERR
Subtotal Other	0	0	0	62	?	62	62	ERR
Total Persons:	0	0	0	2567	7200	9767	9767	ERR
Auto Occupancy:	0	ERR	ERR	3.13	1.2	1.3	ERR	ERR
Peak Period:								
Direction:								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	9/82	9/82	9/82	12/83	12/83	12/83	Diff.	%
Max. Time (min)	0	9	9	6	a	8	-1	-11.1%
Ave. Time (min)	0	8	8	6	7	7	-1	-12.5%
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers			0			0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	0	0	0	0	0	0	ERR

13

Action:	Add 6.0 miles SOV Lane + HOV Lane
Name	U.S. 101 - HOVL Gap Closure
Metro Area	San Jose
State	CA
HOV Facility:	Freeway, Concurrent, Left Side, Fully Accessible
HOV Length (mi)	6
HOV Lanes Each Direction	
Hours of Operation:	5-9 AM, 3-7 PM
Elgibility:	2+
HOV Open Date:	4/5/93
Street Type	Freeway
Mixed Flow Lanes Each Dir.	3
Free-Flow Speed (mph):	51

Peak Hour:	7-a AM					VEHICLES		
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	Before	Before	Before	12/93	12/93	12/93	Diff.	%
Max. Time (min)	28	28	28	7	27	20	-a	-28.6%
Ave. Time (min)	19	19	19	7	14	12	-7	-36.8%
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	511	0	0	1582	1071	209.6%
Subtotal Other	0	0	3895	0	0	3745	-150	-3.9%
Total Vol:	0	0	4406	1840	3487	5327	921	20.9%

Peak Period:	‘I-PAM							
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	Before	Before	Before	12/93	12/93	12/93	Diff.	%
Max. Time (min)	28	28	28	7	27	ERR	ERR	ERR
Ave. Time (min)	15	15	15	7	14	ERR	ERR	ERR
1 occ Vol			6931			6957	26	0.4%
2 occ Vol			1090			2610	1520	139.4%
3 occ Vol			112			351	239	213.4%
4+ occ Vol			0			2	2	ERR
Bus Vol			15			1	-14	-93.3%
Truck Vol			302			312	10	3.3%
Cycle Vol			10			115	105	1050.0%
Subtotal HOV's	0	0	1227	0	0	3079	1852	150.9%
Subtotal Other	0	0	7233	0	0	7269	36	0.5%
Total Vol:	0	0	8460	0	0	10348	1888	22.3%

Data Set Number:	13					Persons			
Action:	Add 6.0 miles SOV Lane + HOV Lane								
Name	U.S. 101 - HOVL Gap Closure								
City	San Jose								
State	CA								
HOV Facility:	Freeway, Concurrent, Left Side, Fully Accessible								
Length (mi)	6								
No. of Lanes									
Hours of Operation:	5-9 AM, 3-7 PM								
Elgibility:	2+								
HOV Open Date:	4/5/93								
Street Type	Freeway								
No. of Lanes Each Direction	3								
Free-Flow Speed (mph):	51								
Peak Hour:	7-8 AM		PERSONS			PERSONS			
Direction:	NB								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference		
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before		
Date:	Before	Before	Before	12/93	12/93	12/93	Diff.	%	
Max. Time (min)	28	28	28	7	27	20	-a	-28.6%	
Ave. Time (min)	19	19	19	7	14	12	-7	-36.8%	
1 occ Pers	0	0	0	0	0	0	0	ERR	
2 occ Pers	0	0	0	0	0	0	0	ERR	
3 occ Pers	0	0	0	0	0	0	0	ERR	
4+ occ Pers	0	0	0	0	0	0	0	ERR	
Bus Pers							0	ERR	
Truck Pers	0	0	0	0	0	0	0	ERR	
Cycle Pers	0	0	0	0	0	0	0	ERR	
Subtotal HOV's	0	0	0	0	0	0	0	ERR	
Subtotal Other	0	0	0	0	0	0	0	ERR	
Total Persons:	0	0	5710	3771	3554	7325	1615	28.3%	
Auto Occupancy:	ERR	ERR	1.3	2.05	1.02	1.38	0.08	6.2%	
Peak Period:	7-9AM								
Direction:	NB								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference		
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before		
Date:	Before	Before	Before	12/93	12/93	12/93	Diff.	%	
Max. Time (min)	28	28	28	7	27	ERR	ERR	ERR	
Ave. Time (min)	15	15	15	7	14	ERR	ERR	ERR	
1 occ Pers	0	0	693 1	0	0	6957	26	0.4%	
2 occ Pers	0	0	2180	0	0	5220	3040	139.4%	
3 occ Pers	0	0	336	0	0	1053	717	213.4%	
4+ occ Pers	0	0	0	0	0	20	20	ERR	
Bus Pers			536			70	-466	-86.9%	
Truck Pers	0	0	302	0	0	312	10	3.3%	
Cycle Pers	0	0	10	0	0	115	105	1050.0%	
Subtotal HOV's	0	0	3062	0	0	6478	3416	111.6%	
Subtotal Other	0	0	7233	0	0	7269	36	0.5%	
Total Persons:	0	0	10295	0	0	13747	3452	33.5%	
Auto Occupancy:	ERR	ERR	1.16	ERR	ERR	1.34	0.18	15.5%	

	14							
Action:	Add 2.8 mile HOV lane							
Name	U.S. 101 (Lawrence to Guadalupe)							
Metro Area	San Jose							
State	CA							
HOV Facility:	Freeway, Concurrent, Left Side, Fully Accessible							
HOV Length (mi)	2.8							
HOV Lanes Each Direction	1							
Hours of Operation:	5-9 AM, 3-7 PM							
Eligibility:	2+							
HOV Open Date:	11/10/86							
Street Type	Freeway							
Mixed Flow Lanes Each Dir.	3							
Free-Flow Speed (mph):	56							
Peak Hour:	AM					VEHICLES		
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	10/87	10/87	10/87	Diff.	%
Max. Time (min)	11	11	11	3	7	7	-4	-36.4%
Ave. Time (min)	11	11	11	3	7	7	-4	-36.4%
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	581	537	299	836	255	43.9%
Subtotal Other	0	0	5112	173	5051	5224	112	2.2%
Total Vol:	D	0	5700	710	5350	6060	360	6.3%
Peak Period:	6-9 AM							
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	10/87	10/87	10/87	Diff.	%
Max. Time (min)	11	11	11	3	7	7	-4	-36.4%
Ave. Time (min)	9	9	9	3	5	5	-4	-44.4%
1 occ Vol			14312	260	14158	14418	106	0.7%
2 occ Vol			1473	1206	983	2189	716	48.6%
3 occ Vol			220	100	105	205	-15	-6.8%
4+ occ Vol			2	5	4	9	7	350.0%
Bus Vol			8	9	9	18	10	125.0%
Truck Vol			568	0	747	747	179	31.5%
Cycle Vol			117	150	64	214	97	82.9%
Subtotal HOV's	0	0	1820	1470	1165	2635	815	44.8%
Subtotal Other	0	0	14880	260	14905	15165	285	1.9%
Total Vol:	0	0	16700	1730	16070	17800	1100	6.6%

Data Set Number:	14				Persons			
Action:	Add 2.8 mile HOV lane							
Name	U.S. 101 (Lawrence to Guadalupe)							
City	San Jose							
State	CA							
HOV Facility:	Freeway, Concurrent, Left Side, Fully Accessible							
Length (mi)	2.8							
No. of Lanes	1							
Hours of Operation:	S-9 AM, 3-7 PM							
Elgibility:	2+							
HOV Open Date:	11/1O/B6							
Street Type	Freeway							
No. of Lanes Each Direction	3							
Free-Flow Speed (mph):	56							

Peak Hour:	AM		PERSONS			PERSONS		
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	10/87	10/87	10/87	Diff.	%
Max. Time (min)	11	11	11	3	7	7	-4	-36.4%
Ave. Time (min)	11	11	11	3	7	7	-4	-36.4%
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers			0			0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	1228	0	0	1936	708	57.7%
Subtotal Other	0	0	5112	0	0	5224	112	2.2%
Total Persons:	D	0	6400	1360	5800	7160	760	11.9%
Auto Occupancy:	ERR	ERR	1.12	1.92	1.08	1.18	0.06	5.4%

Peak Period:	6-9AM							
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	10/87	10/87	10/87	Diff.	%
Max. Time (min)	11	11	11	3	7	7	-4	-36.4%
Ave. Time (min)	9	9	9	3	5	5	-4	-44.4%
1 occ Pers	0	0	14312	260	14158	14418	106	0.7%
2 occ Pers	0	D	2946	2412	1966	4378	1432	48.6%
3 occ Pers	0	0	660	300	315	615	-45	-6.8%
4+ occ Pers	0	0	12	30	24	54	42	350.0%
Bus Pers			185	187	187	374	189	102.2%
Truck Pers	0	0	568	0	747	747	179	31.5%
Cycle Pers	0	0	117	150	64	214	97	82.9%
Subtotal HOV's	0	0	3920	3079	2556	5635	1715	43.8%
Subtotal Other	0	0	14880	260	14905	15165	285	1.9%
Total Persons:	0	0	18800	3339	17461	20800	2000	10.6%
Auto Occupancy:	ERR	ERR	1.12	1.91	1.08	1.16	0.04	3.6%

	15							
Action:	Add 10.7 mile HOV Lane							
Name	I-280							
Metro Area	San Jose							
State	CA							
HOV Facility:	Freeway, Concurrent, Left Side, Fully Accessible							
HOV Length (mi)	10.7							
HOV Lanes Each Direction								
Hours of Operation:	5-9 AM, 3-7 PM							
Elgibility:	2+							
HOV Open Date:	11/21/90							
Street Type	Freeway							
Mixed Flow Lanes Each Dir.	3							
Free-Flow Speed (mph):	49							
Peak Hour:	7-8AM					VEHICLES		
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	11/91	11/91	11/91	Diff.	%
Max. Time (min)	27	27	27	13	22	21	-6	-22.2%
Ave. Time (min)	26	26	26	13	20	19	-7	-26.9%
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	340	717	15	732	392	115.3%
Subtotal Other	0	0	5780	73	6515	6588	808	14.0%
Total Vol:	0	0	6120	790	6530	7320	1200	19.6%
Peak Period:	6-9AM							
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	11/91	11/91	11/91	Diff.	%
Max. Time (min)	27	27	27	13	22	21	-6	-22.2%
Ave. Time (min)	22	22	22	13	16	16	-6	-27.3%
1 occ Vol			15358			18570	3212	20.9%
2 occ Vol			1165			2735	1570	134.8%
3 occ Vol			72			175	103	143.1%
4+ occ Vol			1			21	20	2000.0%
Bus Vol			10			25	15	150.0%
Truck Vol			160			356	196	122.5%
Cycle Vol			49			104	55	112.2%
Subtotal HOV's	0	0	1297	1943	1117	3060	1763	135.9%
Subtotal Other	0	0	15518	197	18729	18926	3408	22.0%
Total Vol:	0	0	16815	2140	19846	21986	5171	30.8%

Data Set Number:	15					Persons		
Action:	Add 10.7 mile HOV Lane							
Name	I-280							
City	San Jose							
State	CA							
HOV Facility:	Freeway, Concurrent, Left Side, Fully Accessible							
Length (mi)	10.7							
No. of Lanes								
Hours of Operation:	5-9 AM, 3-7 PM							
Elgibility:	2+							
HOV Open Date:	11/21/90							
Street Type	Freeway							
No. of Lanes Each Direction	3							
Free-Flow Speed (mph):	49							
Peak Hour:	7-8AM		PERSONS			PERSONS		
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	11/91	11/91	11/91	Diff.	%
Max. Time (min)	27	27	27	13	22	21	-6	-22.2%
Ave. Time (min)	26	26	26	13	20	19	-7	-26.9%
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers						0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	1130	D	0	1832	702	62.1%
Subtotal Other	0	0	5780	0	0	6588	808	14.0%
Total Persons:	0	0	6910	1510	6910	8420	1510	21.9%
Auto Occupancy:	ERR	ERR	1.13	1.91	1.06	1.15	0.02	1.8%
Peak Period:	6-9AM							
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	11/91	11/91	11/91	Diff.	%
Max. Time (min)	27	27	27	13	22	21	-6	-22.2%
Ave. Time (min)	22	22	22	13	16	16	-6	-27.3%
1 occ Pers	0	0	15358	0	0	18570	3212	20.9%
2 occ Pers	0	0	2330	0	0	5470	3140	134.8%
3 occ Pers	0	0	216	0	0	525	309	143.1%
4+ occ Pers	0	0	6	0	0	126	120	2000.0%
Bus Pers			551			979	428	77.7%
Truck Pers	0	0	160	0	0	356	196	122.5%
Cycle Pers	0	0	49	0	0	104	55	112.2%
Subtotal HOV's	0	0	3152	0	0	7204	4052	128.6%
Subtotal Other	0	0	15518	0	0	18926	3408	22.0%
Total Persons:	0	0	18670	0	0	26130	7460	40.0%
Auto Occupancy:	ERR	ERR	1.08	0	0	1.15	0.07	6.5%

	16
Action:	Add 3.3 mi. Arterial HOV Lane
Name	128th/Airport Road
Metro Area	Seattle
State	WA
HOV Facility:	Arterial, Concurrent, Right Side, Fully Accessible
HOV Length (mi)	3.3
HOV Lanes Each Direction	1
Hours of Operation:	PM Peak Hour
Elgibility:	2+
HOV Open Date:	Jan. 93
Street Type	Arterial
Mixed Flow Lanes Each Dir.	1/2
Free-Flow Speed (mph):	26

Peak Hour:	PM					VEHICLES		
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	4/90	4/90	4/90	Diff.	%
Max. Time (min)	8	8	8	7	8	ERR	ERR	ERR
Ave. Time (min)	8.4	8.4	8	7.5	8.5	ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	D	0	0	0	0	ERR
Total Vol:	0	0	1506	0	0	1375	-131	-8.7%

Peak Period:								
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	4/90	4/90	4/90	Diff.	%
Max. Time (min)	8	8	ERR	7	8	ERR	ERR	ERR
Ave. Time (min)			ERR			ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	D	0	0	0	0	ERR

Data Set Number:	16					Persons		
Action:	Add 3.3 mi. Arterial HOV Lane							
Name	128th/Airport Road							
City	Seattle							
State	WA							
HOV Facility:	Arterial, Concurrent, Right Side, Fully Accessible							
Length (mi)	3.3							
No. of Lanes	1							
Hours of Operation:	PM Peak Hour							
Elgibility:	2+							
HOV Open Date:	Jan. 93							
Street Type	Arterial							
No. of Lanes Each Direction	1/2							
Free-Flow Speed (mph):	26							
Peak Hour:	PM		PERSONS			PERSONS		
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	4/90	4/90	4/90	Diff.	%
Max. Time (min)	8	8	8	7	8	ERR	ERR	ERR
Ave. Time (min)	8.4	8.4	8	7.5	8.5	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers			0			0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	1920	0	0	2067	147	7.7%
Auto Occupancy:	ERR	ERR	1.27	ERR	ERR	1.5	0.23	18.1%
Peak Period:	0							
Direction:	EB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	4/90	4/90	4/90	Diff.	%
Max. Time (min)	8	8	ERR	7	8	ERR	ERR	ERR
Ave. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers			0			0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	D	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR

	17
Action:	Add 5.9 mi. Expressway HOV Lane
Name	State Route 237 - Santa Clara Co.
Metro Area	San Jose
State	CA
HOV Facility:	Expressway, Concurrent, Right Side, Full Accessible
HOV Length (mi)	5.9
HOV Lanes Each Direction	1
Hours of Operation:	5-9 AM WB, 3-7PM EB
Elgibility:	2+
HOV Open Date:	Oct. 1984
Street Type	Expressway
Mixed Flow Lanes Each Dir.	2
Free-Flow Speed [mph):	54

Peak Hour:	7-8 AM					VEHICLES		
Direction:	WB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	4/85	4/85	4/85	Diff.	%
Max. Time (min)	13	13	13	7	9	ERR	ERR	ERR
Ave. Time (min)	13	13	13	6.5	9	ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ VOl			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	D	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR
Peak Period:	6-9AM							
Direction:	WB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	4/85	4/85	4/85	Diff.	%
Max. Time (min)	13	13	13	7	9	ERR	ERR	ERR
Ave. Time (min)	10	10	10	6	7.5	ERR	ERR	ERR
1 occ Vol			6422			8427	2005	31.2%
2 occ Vol			790.4			1632.4	842	106.5%
3 occ Vol			98.8			243.8	145	146.8%
4+ occ VOl			7.6			10.6	3	39.5%
Bus Vol			22.8			21.2	-1.6	-7.0%
Truck Vol			144.4			148.4	4	2.8%
Cycle Vol			114			116.6	2.6	2.3%
Subtotal HOV's		0	1033.6	0	0	2024.6	991	95.9%
Subtotal Other		0	6566.4	0	0	8575.4	2009	30.6%
Total Vol:		0	7600	0	0	10600	3000	39.5%

Data Set Number:	17					Persons		
Action:	Add 5.9 mi. Expressway HOV Lane							
Name	State Route 237 - Santa Clara Co.							
City	San Jose							
State	CA							
HOV Facility:	Expressway, Concurrent, Right Side, Full Accessible							
Length (mi)	5.9							
No. of Lanes	1							
Hours of Operation:	5-9 AM WB, 3-7PM EB							
Elgibility:	2+							
HOV Open Date:	Oct. 1984							
Street Type	Expressway							
No. of Lanes Each Direction	2							
Free-Flow Speed (mph):	54							

Peak Hour:	7-8 AM		PERSONS			PERSONS		
Direction:	WB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	4/85	4/85	4/85	Diff.	%
Max. Time (min)	13	13	13	7	9	ERR	ERR	ERR
Ave. Time (min)	13	13	13	6.5	9	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers			0			0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR

Peak Period:	6-9AM							
Direction:	WB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	before	before	before	4/85	4/85	4/85	Diff.	%
Max. Time (min)	13	13	13	7	9	ERR	ERR	ERR
Ave. Time (min)	10	10	10	6	7.5	ERR	ERR	ERR
1 occ Pers	0	0	6422	0	0	8427	2005	31.2%
2 occ Pers	0	0	1580.8	0	0	3264.8	1684	106.5%
3 occ Pers	0	0	296.4	D	0	731.4	435	146.8%
4+ occ Pers	0	0	45.6	0	0	63.6	18	39.5%
Bus Pers			496.8			448.2	-48.6	-9.8%
Truck Pers	0	0	144.4	0	0	148.4	4	2.8%
Cycle Pers	0	0	114	0	0	116.6	2.6	2.3%
Subtotal HOV's	0	0	2533.6	0	0	4624.6	2091	82.5%
Subtotal Other	0	0	6566.4	0	0	8575.4	2009	30.6%
Total Persons:	0	0	9100	0	0	13200	4100	45.1%
Auto Occupancy:	ERR	ERR	1.14	ERR	ERR	1.21	0.07	6.1%

	18
Action:	Add 4.9 mi. Expressway HOV Lane
Name	San Tomas Expressway
Metro Area	San Jose
State	CA
HOV Facility:	Expressway, concurrent, right side, fully accessible
HOV Length (mi)	4.9
HOV Lanes Each Direction	1
Hours of Operation:	6-9 AM NB, 3-7 PM SB
Elgibility:	2+
HOV Open Date:	11/22/82
Street Type	Expressway
Mixed Flow Lanes Each Dir	3
Free-Flow Speed (mph):	42

Peak Hour:	AM					VEHICLES		
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	1982	1982	1982	1983	1983	1983	Diff.	%
Max. Time (min)	13	13	13	7	13	ERR	ERR	ERR
Ave. Time (min)	13	13	13	7	13	ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR

Peak Period:	6-9AM							
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	1982	1982	1982	1983	1983	1983	Diff.	%
Max. Time (min)	13	13	ERR	7	13	12	ERR	ERR
Ave. Time (min)	9	9	ERR	7	9	9	ERR	ERR
1 occ Vol			0	52		52	52	ERR
2 occ Vol			0	?		0	0	ERR
3 occ Vol			0	?		0	0	ERR
4+ occ Vol			0	?		0	0	ERR
Bus Vol			0	?		0	0	ERR
Truck Vol			0	?		0	0	ERR
Cycle Vol			0	?		0	0	ERR
Subtotal HOV's	0	0	741	997	300	1049	308	41.6%
Subtotal Other	0	0	7296	52	7714	8014	718	9.8%
Total Vol:	0	0	8037	1049	8014	9063	1026	12.8%

Data Set Number:	18	Persons
Action:	Add 4.9 mi. Expressway HOV Lane	
Name	San Tomas Expressway	
City	San Jose	
State	CA	
HOV Facility:	Expressway, concurrent, right side, fully accessible	
Length (mi)	4.9	
No. of Lanes	1	
Hours of Operation:	6-9 AM NB, 3-7 PM SB	
Elgibility:	2+	
HOV Open Date:	11/22/82	
Street Type	Expressway	
No. of Lanes Each Direction	3	
Free-Flow Speed (mph):	42	

Peak Hour:	AM		PERSONS			PERSONS		
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	1982	1982	1982	1983	1983	1983	Diff.	%
Max. Time (min)	13	13	13	7	13	ERR	ERR	ERR
Ave. Time (min)	13	13	13	7	13	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers			0			0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	D	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR

Peak Period:	6-9AM							
Direction:	NB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	1982	1982	1982	1983	1983	1983	Diff.	%
Max. Time (min)	13	13	ERR	7	13	12	ERR	ERR
Ave. Time (min)	9	9	ERR	7	9	9	ERR	ERR
1 occ Pers	0	?	0	?	?	0	0	ERR
2 occ Pers	0	?	0	?	?	0	0	ERR
3 occ Pers	0	?	0	?	?	0	0	ERR
4+ occ Pers	0	?	0	?	?	0	0	ERR
Bus Pers		?	0	?	?	0	0	ERR
Truck Pers	0	?	0	?	?	0	0	ERR
Cycle Pers	0	?	0	?	?	0	0	ERR
Subtotal HOV's	0	?	1528	?	?	2659	1131	74.0%
Subtotal Other	0	?	7301	?	?	7773	472	6.5%
Total Persons:	0	?	8829	?	?	10432	1603	18.2%
Auto Occupancy:	ERR	ERR	1.1	0	0	1.15	0.05	4.5%

	19							
Action:	Convert Mixed Flow Lane to 3+ HOV Lane							
Name	I-IO Santa Monica Freeway							
Metro Area	Los Angeles							
State	CA							
HOV Facility:	Freeway, concurrent							
HOV Length (mi)	12							
HOV Lanes Each Direction								
Hours of Operation:	6:00-10:00 AM, 3:00-7 PM							
Elgibi lity:	3+							
HOV Open Date:	3/15/76							
Street Type	Freeway							
Mixed Flow Lanes Each Dir.	3							
Free-Flow Speed (mph):	62							
Peak Hour:						VEHICLES		
Direction:								
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/75	10/75	10/75	6-8/76	6-8/76	6-8/76	Diff.	%
Max. Time (min)						ERR	ERR	ERR
Ave. Time (min)						ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR
Peak Period:	6:30-9:30 AM							
Direction:	Eastbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/75	10/75	10/75	6-8/76	6-8/76	6-8/76	Diff.	%
Max. Time (min)		18.1	18	14.7	26.6	26	8	0.444444
Ave. Time (min)		15.7	16	14.7	20.5	20	4	0.25
1 occ Vol		22389	22389	99	17213	17312	-5077	-0.22676
2 occ Vol		2881	2881	11	2662	2673	-208	-0.0722
3 occ Vol		427	427	635	105	740	313	0.733021
4+ occ Vol		47	47	71	12	83	36	0.765957
Bus Vol		18	18	60	0	60	42	2.333333
Truck Vol		?	0	?	?	0	0	ERR
Cycle Vol		?	0	?	?	0	0	ERR
Subtotal HOV's	0	3373	3373	777	2779	3556	183	0.054254
Subtotal Other	0	22389	22389	99	17213	17312	-5077	-0.22676
Total Vol:	0	25762	25762	876	19992	20868	-4894	-0.18997

Data Set Number:	19					Persons		
Action:	Convert Mixed Flow Lane to 3+ HOV Lane							
Name	I-IO Santa Monica Freeway							
City	Los Angeles							
State	CA							
HOV Facility:	Freeway, concurrent							
Length (mi)	12							
No. of Lanes								
Hours of Operation:	6:00-10:00 AM, 3:00-7 PM							
Elgibility:	3+							
HOV Open Date:	3/15/76							
Street Type	Freeway							
No. of Lanes Each Direction	3							
Free-Flow Speed (mph):	62							
Peak Hour:	0		PERSONS			PERSONS		
Direction:	0							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/75	10/75	10/75	6-8/76	6-8/76	6-8/76	Diff.	%
Max. Time (min)	0	0	0	0	0	ERR	ERR	ERR
Ave. Time (min)	0	0	0	0	0	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers			0			0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR
Peak Period:	6:30-9:30 AM							
Direction:	Eastbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/75	10/75	10/75	6-8/76	6-8/76	6-8/76	Diff.	%
Max. Time (min)	0	18.1	18	14.7	26.6	26	8	0.444444
Ave. Time (min)	0	15.7	16	14.7	20.5	20	4	0.25
1 occ Pers	0	22389	22389	99	17213	17312	-5077	-0.22676
2 occ Pers	0	5762	5762	22	5324	5346	-416	-0.0722
3 occ Pers	0	1281	1281	1905	315	2220	939	0.733021
4+ occ Pers	0	188	188	284	48	332	144	0.765957
Bus Pers	0	586	586	1905	0	1905	1319	2.250853
Truck Pers	0	?	? ?		?	0	0	ERR
Cycle Pers	0	?	? ?		?	0	0	ERR
Subtotal HOV's	0	7817	7817	4116	5687	9803	1986	0.254062
Subtotal Other	0	22389	22389	99	17213	17312	-5077	-0.22676
Total Persons:	0	30206	30206	4215	22900	27115	-3091	-0.10233
Auto Occupancy:	ERR	1.15	1.15	2.83	1.15	1.21	0.06	0.052174

	20
Action:	Convert Busway to 3+ HOV
Name	I-IO San Bernardino Freeway
Metro Area	Los Angeles County
State	CA
HOV Facility:	Freeway
HOV Length (mi)	11
HOV Lanes Each Direction	
Hours of Operation:	6:00-10:00 AM, 3:00-7 PM
Elgibility:	3+
HOV Open Date:	10/76
Street Type	Freeway
Mixed Flow Lanes Each Dir.	4
Free-Flow Speed (mph):	62 mph

Peak Hour:						VEHICLES		
Direction:	Westbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/86	10/86	10/86	11/77	11/77	11/77	Diff.	%
Max. Time (min)						ERR	ERR	ERR
Ave. Time (min)						ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR

Peak Period:	6:00-10:00 AM							
Direction:	Westbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/86	10/86	10/86	11/77	11/77	11/77	Diff.	%
Max. Time (min)	11	25	25	11	27.3	26	1	0.04
Ave. Time (min)	11	19	19	11	20	20	1	0.052632
1 occ Vol	0	23000	23000	68	23800	23868	868	0.037739
2 occ Vol	0	3800	3800	?	3940	3940	140	0.036842
3 occ Vol	0	560	560	1070	345	1415	855	1.526786
4+ occ Vol	0	110	110	190	115	305	195	1.772727
Bus Vol	170	?	170	166	?	166	-4	-0.02353
Truck Vol	0	?	0	?	?	0	0	ERR
Cycle Vol	0	?	0	?	?	0	0	ERR
Subtotal HOV's	170	4470	4640	1426	4400	5826	1186	0.255603
Subtotal Other	0	23000	23000	68	23800	23868	868	0.037739
Total Vol:	170	27470	27640	1494	28200	29694	2054	0.074313

Data Set Number:	20				Persons			
Action:	Convert Busway to 3+ HOV							
Name	I-IO San Bernardino Freeway							
City	Los Angeles County							
State	CA							
HOV Facility:	Freeway							
Length (mi)	11							
No. of Lanes	1							
Hours of Operation:	6:00-10:00 AM, 3:00-7 PM							
Elgibility:	3+							
HOV Open Date:	10176							
Street Type	Freeway							
No. of Lanes Each Direction	4							
Free-Flow Speed (mph):	62							
Peak Hour:	0		PERSONS			PERSONS		
Direction:	Westbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
'Date:	10/86	10/86	10/86	11/77	11/77	11/77	Diff.	%
Max. Time (min)	0	0	0	0	0	ERR	ERR	ERR
Ave. Time (min)	0	0	0	0	0	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers			0			0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR
Peak Period:	6:00-10:00 AM							
Direction:	Westbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/86	10/86	10/86	11/77	11/77	11/77	Diff.	%
Max. Time (min)	11	25	25	11	27.3	26	1	0.04
Ave. Time (min)	11	19	19	11	20	20	1	0.052632
1 occ Pers	0	23000	23000	68	23800	23868	868	0.037739
2 occ Pers	0	7600	7600	0	7880	7880	280	0.036842
3 occ Pers	0	1680	1680	3210	1035	4245	2565	1.526786
4+ occ Pers	0	550	550	950	575	1525	975	1.772727
Bus Pers	5230	0	5230	5040	0	5040	-190	-0.03633
Truck Pers	O?		O?	?		0	0	ERR
Cycle Pers	D ?		O?	?		0	0	ERR
Subtotal HOV's	5230	9830	15060	9200	9490	18690	3630	0.241036
Subtotal Other	0	23000	23000	68	23800	23868	868	0.037739
Total Persons:	5230	32830	38060	9268	33290	42558	4498	0.118182
Auto Occupancy:	ERR	1.2	1.2	3.18	1.18	1.27	0.07	0.058333

	21
Action:	Convert Busway to 3+ HOV
Name	U.S. 101 - Marin Freeway
Metro Area	Marin County
State	CA
HOV Facility:	left side concurrent flow lane
HOV Length (mi)	3.7
HOV Lanes Each Direction	
Hours of Operation:	6:30-8:30 AM SB, 4:00-7:00 PM NB
Elgibility:	3+
HOV Open Date:	6/16/76
Street Type	Freeway
Mixed Flow Lanes Each Dir.	3
Free-Flow Speed (mph):	62 mph

Peak Hour:	AM Peak Hour					VEHICLES		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	3/76	3/76	3/76	3/77	3177	3/77	Diff.	%
Max. Time (min)	3.6	4.6		3.6	4.6	5	5	ERR
Ave. Time (min)	3.6	3.9		3.6	3.9	4	4	ERR
1 occ Vol	0	4011	4011	?	4230	4230	219	0.0546
2 occ Vol	0	1109	1109	?	1170	1170	61	0.055005
3 occ Vol	0	315	315	360	?	360	45	0.142857
4+ occ Vol	0	35	35	40	?	40	5	0.142857
Bus Vol	100	?	100	100	?	100	0	0
Truck Vol	0	?	0	0	?	0	0	ERR
Cycle Vol	0	?	0	0	?	0	0	ERR
Subtotal HOV's	100	1459	1559	500	1170	1670	111	0.071199
Subtotal Other	0	4011	4011	0	4230	4230	219	0.0546
Total Vol:	100	5470	5570	500	5400	5900	330	0.059246

Peak Period:	6:30-8:30 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	3/76	3/76	3/76	3/77	3/77	3/77	Diff.	%
Max. Time (min)			ERR			ERR	ERR	ERR
Ave. Time (min)			ERR			ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR

Data Set Number:	21	Persons
Action:	Convert Busway to 3+ HOV	
Name	U.S. 101 - Marin Freeway	
City	Marin County	
State	CA	
HOV Facility:	left side concurrent flow lane	
Length (mi)	3.7	
No. of Lanes	1	
Hours of Operation:	6:30-8:30 AM SB, 4:00-7:00 PM NB	
Elgibility:	3+	
HOV Open Date:	6/16/76	
Street Type	Freeway	
No. of Lanes Each Direction	3	
Free-Flow Speed (mph):	62	

Peak Hour:	AM Peak Hour	PERSONS				PERSONS		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	3/76	3/76	3/76	3/77	3/77	3/77	Diff.	%
Max. Time (min)	3.6	4.6	0	3.6	4.6	5	5	ERR
Ave. Time (min)	3.6	3.9	0	3.6	3.9	4	4	ERR
1 occ Pers	0	4011	4011	?	4230	4230	219	0.0546
2 occ Pers	0	2218	2218	0	2340	2340	122	0.055005
3 occ Pers	0	945	945	1080	0	1080	135	0.142857
4+ occ Pers	0	210	210	240	0	240	30	0.142857
Bus Pers	4000	?	4000	4300	?	4300	300	0.075
Truck Pers	O?		0	D ?		0	0	ERR
Cycle Pers	O?		0	O?		0	D	ERR
Subtotal HOV's	4000	3373	7373	5620	2340	7960	587	0.079615
Subtotal Other	0	4011	4011	0	4230	4230	219	0.0546
Total Persons:	4000	7384	11384	5620	6570	12190	806	0.070801
Auto Occupancy:	ERR	1.35	1.35	3.3	1.22	1.36	0.01	0.007407

Peak Period:	6:30-8:30 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	3/76	3/76	3/76	3/77	3/77	3/77	Diff.	%
Max. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
Ave. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers	0	0	0	0	0	0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR

22

Action:	Add 2+ HOV Lane
Name	Route 91 - Los Angeles, Artesia Freeway
Metro Area	Los Angeles County
State	CA
HOV Facility:	Left side, concurrent flow lane, painted buffer
HOV Length (mi)	8
HOV Lanes Each Direction	1 - EB Only
Hours of Operation:	3-7PM originally, 2-7 PM after Jan. 86, 24 hrs a day after June 88
Elgibility:	2+ (3+ first two weeks)
HOV Open Date:	6/10/85
Street Type	Freeway
Mixed Flow Lanes Each Dir.	4
Free-Flow Speed (mph):	62 mph

Peak Hour:	AM Peak Hour					VEHICLES		
Direction:	Eastbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/85	4/85	4/85	4/86	4/86	4/86	Diff.	%
Max. Time (min)		28		9	16	15	15	ERR
Ave. Time (min)		26		8.5	13.5	13	13	ERR
1 occ Vol		6926	6926	56	6777	6833	-93	-0.01343
2 occ Vol		866	866	949	415	1364	498	0.575058
3 occ Vol		104	104	111	110	221	117	1.125
4+ occ Vol		45	45	50	10	60	15	0.333333
Bus Vol		?	0	?	?	0	0	ERR
Truck Vol		?	0	?	?	0	0	ERR
Cycle Vol		?	0	?	?	0	0	ERR
Subtotal HOV's	0	1015	1015	1110	535	1645	630	0.62069
Subtotal Other	0	6926	6926	56	6777	6833	-93	-0.01343
Total Vol:	0	7941	7941	1166	7312	8478	537	0.067624

Peak Period:	6:30-8:30 AM							
Direction:	Eastbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/85	4/85	4/85	4/86	4/86	4/86	Diff.	%
Max. Time (min)			ERR			ERR	ERR	ERR
Ave. Time (min)			ERR			ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR

Data Set Number:	22				Persons			
Action:	Add 2+ HOV Lane							
Name	Route 91 - Los Angeles, Artesia Freeway							
City	Los Angeles County							
State	CA							
HOV Facility:	Left side, concurrent flow lane, painted buffer							
Length (mi)	8							
No. of Lanes	1 EB Only							
Hours of Operation:	3-7PM originally, 2-7 PM after Jan. 86, 24 hrs a day after June 88							
Elgibility:	2+ (3+ first two weeks)							
HOV Open Date:	6/10/85							
Street Type	Freeway							
No. of Lanes Each Direction	4							
Free-Flow Speed (mph):	62							
Peak Hour:	AM Peak Hour	PERSONS			PERSONS			
Direction:	Eastbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/85	4/85	4/85	4/86	4/86	4/86	Diff.	%
Max. Time (min)	0	28	0	9	16	15	15	ERR
Ave. Time (min)	0	26	0	8.5	13.5	13	13	ERR
1 occ Pers	0	6926	6926	56	6777	6833	-93	-0.01343
2 occ Pers	0	1732	1732	1898	830	2728	996	0.575058
3 occ Pers	0	312	312	333	330	663	351	1.125
4+ occ Pers	0	270	270	300	60	360	90	0.333333
Bus Pers			0			0	0	ERR
Truck Pers	O?		O?	?		0	0	ERR
Cycle Pers	O?		O?	?		0	0	ERR
Subtotal HOV's	0	2314	2314	2531	1220	3751	1437	0.621003
Subtotal Other	0	6926	6926	56	6777	6833	-93	-0.01343
Total Persons:	0	9240	9240	2587	7997	10584	1344	0.145455
Auto Occupancy:	ERR	1.16	1.16	2.22	1.09	1.25	0.09	0.077586
Peak Period:	6:30-8:30 AM							
Direction:	Eastbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	4/85	4/85	4/85	4/86	4/86	4/86	Diff.	%
Max. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
Ave. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	D	ERR
Bus Pers	0	0	0	0	0	0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR

	23
Action:	Add 17 mile 2+ HOV Lane
Name	I-210 Foothill Freeway
Metro Area	Los Angeles County (Pasadena to Glendora)
State	CA
HOV Facility:	Left side, concurrent flow lane, painted buffer
HOV Length (mi)	17
HOV Lanes Each Direction	
Hours of Operation:	24 hours
Elgibility:	2+
HOV Open Date:	11193 through 1/94
Street Type	Freeway
Mixed Flow Lanes Each Dir.	5
Free-Flow Speed (mph):	60 mph
Peak Hour:	AM Peak Hour (6:30-7:30 AM) VEHICLES
Direction:	Westbound

Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	7/29/93	7/29/93	7/29/93	7/19/94	7/19/94	7/19/94	Diff.	%
Max. Time (min)		42		24.8	35.7	34	34	ERR
Ave. Time (min)		41		20.8	28.6	28	28	ERR
1 occ Vol		9922	9922	61	8694	8755	-1167	-0.11762
2 occ Vol		1665	1665	1237	810	2047	382	0.229429
3 occ Vol		189	189	76	38	114	-75	-0.39683
4+ occ Vol		21	21	8	4	12	-9	-0.42857
Bus Vol		?	0	?	?	0	0	ERR
Truck Vol		?	0	?	?	0	0	ERR
Cycle Vol		?	0	45	?	45	45	ERR
Subtotal HOV's	0	1875	1875	1366	852	2218	343	0.182933
Subtotal Other	0	9922	9922	61	8694	8755	-1167	-0.11762
Total Vol:	0	11797	11797	1427	9546	10973	-824	-0.06985

Peak Period:	6:30-8:30 AM
Direction:	Westbound

Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	7/29/93	7/29/93	7/29/93	7/19/94	7/19/94	7/19/94	Diff.	%
Max. Time (min)			ERR			ERR	ERR	ERR
Ave. Time (min)			ERR			ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's		0	0	0	0	0	0	ERR
Subtotal Other		0	0	0	0	0	0	ERR
Total Vol:		0	0	0	0	0	0	ERR

Data Set Number:	23					Persons		
Action:	Add 17 mile 2+ HOV Lane							
Name	I-210 Foothill Freeway							
City	Los Angeles County (Pasadena to Glendora)							
State	CA							
HOV Facility:	Left side, concurrent flow lane,painted buffer							
Length (mi)	17							
No. of Lanes	1							
Hours of Operation:	24 hours							
Elgibility:	2+							
HOV Open Date:	11/93 through 1/94							
Street Type	Freeway							
No. of Lanes Each Direction	5							
Free-Flow Speed (mph):	60							
Peak Hour:	AM Peak Hour (6:30PERSONS					PERSONS		
Direction:	Westbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	7/29/93	7/29/93	7/29/93	7/19/94	7/19/94	7/19/94	Diff.	%
Max. Time (min)	0	42	0	24.8	35.7	34	34	ERR
Ave. Time (min)	0	41	0	20.8	28.6	28	28	ERR
1 occ Pers	0	9922	9922	61	8694	8755	-1167	-0.11762
2 occ Pers	0	3330	3330	2474	1620	4094	764	0.229429
3 occ Pers	0	567	567	228	114	342	-225	-0.39683
4+ occ Pers	0	126	126	48	24	72	-54	-0.42857
Bus Pers			0			0	0	ERR
Truck Pers	O?		O?		?	0	0	ERR
Cycle Pers	O?		0	45	?	45	45	ERR
Subtotal HOV's	0	4023	4023	2795	1758	4553	530	0.131742
Subtotal Other	0	9922	9922	61	8694	8755	-1167	-0.11762
Total Persons:	0	13945	13945	2856	10452	13308	-637	-0.04568
Auto Occupancy:	ERR	1.18	1.18	2.03	1.09	1.21	0.03	0.025424
Peak Period:	6:30-8:30 AM							
Direction:	Westbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	7/29/93	7/29/93	7/29/93	7/19/94	7/19/94	7/19/94	Diff.	%
Max. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
Ave. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers	0	0	0	0	0	0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR

24

Action:	Add 2+ HOV Lane
Name	Route 91 - Los Angeles, Artesia Freeway
Metro Area	Los Angeles County
State	CA
HOV Facility:	Left side, concurrent flow lane, painted buffer
HOV Length (mi)	8
HOV Lanes Each Direction	1 - WB Only
Hours of Operation:	24 hours a day
Elgibility:	2+
HOV Open Date:	3/1/93
Street Type	Freeway
Mixed Flow Lanes Each Dir.	4
Free-Flow Speed (mph):	60 mph

Peak Hour: AM Peak Hour — VEHICLES

Direction: Eastbound

Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	3/93	3/93	3/93	9/93	9/93	9/93	Diff.	%
Max. Time (min)						0	0	ERR
Ave. Time (min)		25		10.5	14.5	14	14	ERR
1 occ Vol		6437	6437	37	6897	6934	497	0.07721
2 occ V0l		1015	1015	1241	500	1741	726	0.715271
3 occ Vol		171	171	181	67	248	77	0.450292
4+ occ Vol		19	19	21	8	29	10	0.526316
Bus Vol		?	0	12	?	12	12	ERR
Truck Vol		?	0	?	?	0	0	ERR
Cycle Vol		?	0	45	?	45	45	ERR
Subtotal HOV's	0	1205	1205	1500	575	2075	870	0.721992
Subtotal Other	0	6437	6437	37	6897	6934	497	0.07721
Total Vol:	0	7642	7642	1537	7472	9009	1367	0.17888

Peak Period: 6:30-8:30 AM

Direction: Eastbound

Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	3/93	3/93	3/93	9/93	9/93	9/93	Diff.	%
Max. Time (min)			ERR			ERR	ERR	ERR
Ave. Time (min)			ERR			ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR

Data Set Number:	24				Persons			
Action:	Add 2+ HOV Lane							
Name	Route 91 - Los Angeles, Artesia Freeway							
City	Los Angeles County							
State	CA							
HOV Facility:	Left side, concurrent flow lane, painted buffer							
Length (mi)	8							
No. of Lanes	1 - WB Only							
Hours of Operation:	24 hours a day							
Elgibility:	2+							
HOV Open Date:	3/1/93							
Street Type	Freeway							
No. of Lanes Each Direction	4							
Free-Flow Speed (mph):	60							
Peak Hour:	AM Peak Hour	PERSONS			PERSONS			
Direction:	Eastbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	3/93	3/93	3/93	9/93	9/93	9/93	Diff.	%
Max. Time (min)	0	0	0	0	0	0	0	ERR
Ave. Time (min)	0	25	0	10.5	14.5	14	14	ERR
1 occ Pers	0	6437	6437	37	6897	6934	497	0.07721
2 occ Pers	0	2030	2030	2482	1000	3482	1452	0.715271
3 occ Pers	0	513	513	543	201	744	231	0.450292
4+ occ Pers	0	114	114	180	48	228	114	1
Bus Pers		?	0	150	?	150	150	ERR
Truck Pers	0	?	0	?	?	0	0	ERR
Cycle Pers	0	?	0	45	?	45	45	ERR
Subtotal HOV's	0	2657	2657	3400	1249	4649	1992	0.749718
Subtotal Other	0	6437	6437	37	6897	6934	497	0.07721
Total Persons:	0	9094	9094	3437	8146	11583	2489	0.273697
Auto Occupancy:	ERR	1.19	1.19	2.19	1.09	1.27	0.08	0.067227
Peak Period:	6:30-8:30 AM							
Direction:	Eastbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	3/93	3/93	3/93	9/93	9/93	9/93	Diff.	%
Max. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
Ave. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers	0	0	0	0	0	0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR

25

Action:	Add 2+ HOV Lane
Name	Route 55 (Newport-Costa Mesa)
Metro Area	Orange County
State	CA
HOV Facility:	Left side, concurrent flow lane, painted buffer
HOV Length (mi)	11
HOV Lanes Each Direction	
Hours of Operation:	24 hours a day
Elgibility:	2+
HOV Open Date:	11/85
Street Type	Freeway
Mixed Flow Lanes Each Dir.	3
Free-Flow Speed (mph):	60 mph

Peak Hour:	7-8 AM Peak Hour				VEHICLES			
Direction:	Southbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/85	10/85	10/85	10/86	10/86	10/86	Diff.	%
Max. Time (min)		34.5		11.5	32	28	28	ERR
Ave. Time (min)		32		11.5	29	26	26	ERR
1 occ Vol		5079	5079	147	5519	5666	587	0.115574
2 occ Vol		825	825	954	311	1265	440	0.533333
3 occ Vol		53	53	62	20	82	29	0.54717
4+ occ Vol		30	30	50	?	50	20	0.666667
Bus Vol		3	3	7	?	7	4	1.333333
Truck Vol		?	0	?	?	0	0	ERR
Cycle Vol		10	10	80	?	80	70	7
Subtotal HOV's	0	921	921	1153	331	1484	563	0.611292
Subtotal Other	0	5079	5079	147	5519	5666	587	0.115574
Total Vol:	0	6000	6000	1300	5850	7150	1150	0.191667

Peak Period:	6:30-8:30 AM							
Direction:	Southbound							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/85	10/85	10/85	10/86	10/86	10/86	Diff.	%
Max. Time (min)			ERR			ERR	ERR	ERR
Ave. Time (min)			ERR			ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR

Data Set Number:	25	Persons
Action:	Add 2+ HOV Lane	
Name	Route 55 (Newport-Costa Mesa)	
City	Orange County	
State	CA	
HOV Facility:	Left side, concurrent flow lane, painted buffer	
Length (mi)	11	
No. of Lanes	1	
Hours of Operation:	24 hours a day	
Elgibility:	2+	
HOV Open Date:	11/85	
Street Type	Freeway	
No. of Lanes Each Direction	3	
Free-Flow Speed (mph):	60	

Peak Hour: 7-8 AM Peak Hour PERSONS PERSONS
Direction: Southbound

Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/85	10/85	10/85	10/86	10/86	10/86	Diff.	%
Max. Time (min)	0	34.5	0	11.5	32	28	28	ERR
Ave. Time (min)	0	32	0	11.5	29	26	26	ERR
1 occ Pers	0	5079	5079	147	5519	5666	587	0.115574
2 occ Pers	0	1650	1650	1908	622	2530	880	0.533333
3 occ Pers	0	159	159	186	60	246	87	0.54717
4+ occ Pers	0	120	120	200	0	200	80	0.666667
Bus Pers		60	60	140	?	140	80	1.333333
Truck Pers	0	?	0	?	?	0	0	ERR
Cycle Pers	0	10	10	80	?	80	70	7
Subtotal HOV's	0	1999	1999	2514	682	3196	1197	0.598799
Subtotal Other	0	5079	5079	147	5519	5666	587	0.115574
Total Persons:	0	7078	7078	2661	6201	8862	1784	0.252049
Auto Occupancy:	ERR	1.17	1.17	2.01	1.06	1.22	0.05	0.042735

Peak Period: 6:30-8:30 AM
Direction: Southbound

Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	10/85	10/85	10/85	10/86	10/86	10/86	Diff.	%
Max. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
Ave. Time (min)	0	0	ERR	0	0	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers	0	0	0	0	0	0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's	0	0	0	0	0	0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR

	26							
Action:	Convert 3+ to 2+							
Name	Route 101 - Corte Madera							
Metro Area	Marin County							
State	CA							
HOV Facility:	Freeway							
HOV Length (mi)	3.7							
HOV Lanes Each Direction	1							
Hours of Operation:	6:30-8:30 AM SB, 4:30-7 PM NB							
Elgibility:	2+							
HOV Open Date:	10/1/88							
Street Type	Freeway							
Mixed Flow Lanes Each Dir.	3							
Free-Flow Speed (mph):								
Peak Hour:	7-8 AM					VEHICLES		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:			0			0	Diff.	%
Max. Time (min)						ERR	ERR	ERR
Ave. Time (min)						ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's			0			0	0	ERR
Subtotal Other			0			0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR
Peak Period:	6:30-8:30 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	0	0	0	0	0	0	Diff.	%
Max. Time (min)	5.2	6.7	7	4.6	4.7	5	-2	-0.28571
Ave. Time (min)	4	5.8	6	4.3	4.4	4	-2	-0.33333
1 occ Vol	60	11310	11370	160	11540	11700	330	0.029024
2 occ Vol	30	1730	1760	940	1420	2360	600	0.340909
3 occ Vol	310	90	400	225	35	260	-140	-0.35
4+ occ Vol	40	5	45	30	45	75	30	0.666667
Bus Vol	140	50	190	160	10	170	-20	-0.10526
Truck Vol	0	90	90	0	170	170	80	0.888889
Cycle Vol	7	58	65	0	20	20	-45	-0.69231
Subtotal HOV's	527	1933	2460	1355	1530	2885	425	0.172764
Subtotal Other	60	11400	11460	160	11710	11870	410	0.035777
Total Vol:	587	13333	13920	1515	13240	14755	835	0.059986

Data Set Number:	26					Persons		
Action:	Convert 3+ to 2+							
Name	Route 101 - Corte Madera							
City	Marin County							
State	CA							
HOV Facility:	Freeway							
Length (mi)	3.7							
No. of Lanes	1							
Hours of Operation:	6:30-8:30 AM SB, 4:30-7 PM NB							
Elgibility:	2+							
HOV Open Date:	10/1/88							
Street Type	Freeway							
No. of Lanes Each Direction	3							
Free-Flow Speed (mph):	0							
Peak Hour:	7-8 AM		PERSONS			PERSONS		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	0	0	0	0	0	0	Diff.	%
Max. Time (min)	0	0	0	0	0	ERR	ERR	ERR
Ave. Time (min)	0	0	0	0	0	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers			0			0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's			0			0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR
Peak Period:	6:30-8:30 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	0	0	0	0	0	0	Diff.	%
Max. Time (min)	5.2	6.7	7	4.6	4.7	5	-2	-0.28571
Ave. Time (min)	4	5.8	6	4.3	4.4	4	-2	-0.33333
1 occ Pers	60	11310	11370	160	11540	11700	330	0.029024
2 occ Pers	60	3460	3520	1880	2840	4720	1200	0.340909
3 occ Pers	930	270	1200	675	105	780	-420	-0.35
4+ occ Pers	360	45	405	330	495	825	420	1.037037
Bus Pers	4760	1700	6460	5440	340	5780	-680	-0.10526
Truck Pers	0	90	90	0	170	170	80	0.888889
Cycle Pers	7	58	65	0	20	20	-45	-0.69231
Subtotal HOV's	6117	5533	11650	8325	3800	12125	475	0.040773
Subtotal Other	60	11400	11460	160	11710	11870	410	0.035777
Total Persons:	6177	16933	23110	8485	15510	23995	885	0.038295
Auto Occupancy:	3.2	1.15	1.22	2.25	1.15	1.25	0.03	0.02459

	27							
Action:	Convert 3+ to 2+							
Name	Route 101 - San Rafael							
Metro Area	Marin County							
State	CA							
HOV Facility:	Freeway							
HOV Length (mi)	3							
HOV Lanes Each Direction	1							
Hours of Operation:	6:30-8:30 AM SB, 4:30-7 PM NB							
Elgibility:	2+							
HOV Open Date:	10/1/88							
Street Type	Freeway							
Mixed Flow Lanes Each Dir.	3							
Free-Flow Speed (mph):								
Peak Hour:	7-8 AM					VEHICLES		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:		0	0		0	0	Diff.	%
Max. Time (min)						ERR	ERR	ERR
Ave. Time (min)						ERR	ERR	ERR
1 occ Vol			0			0	0	ERR
2 occ Vol			0			0	0	ERR
3 occ Vol			0			0	0	ERR
4+ occ Vol			0			0	0	ERR
Bus Vol			0			0	0	ERR
Truck Vol			0			0	0	ERR
Cycle Vol			0			0	0	ERR
Subtotal HOV's			0			0	0	ERR
Subtotal Other			0			0	0	ERR
Total Vol:	0	0	0	0	0	0	0	ERR
Peak Period:	6:30-8:30 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	0	0	0	0	0	0	Diff.	%
Max. Time (min)	5	12.5	12	4	13.3	12	0	0
Ave. Time (min)	3.3	10.9	11	3.7	11.1	10	-1	-0.09091
1 occ Vol	170	12060	12230	180	12620	12800	570	0.046607
2 occ Vol	60	1340	1400	1290	800	2090	690	0.492857
3 occ Vol	370	80	450	190	160	350	-100	-0.22222
4+ occ Vol	20	20	40	20	10	30	-10	-0.25
Bus Vol	50	50	100	80	20	100	0	0
Truck Vol	0	260	260	0	240	240	-20	-0.07692
Cycle Vol	0	90	90	0	50	50	-40	-0.44444
Subtotal HOV's	500	1580	2080	1580	1040	2620	540	0.259615
Subtotal Other	170	12320	12490	180	12860	13040	550	0.044035
Total Vol:	670	13900	14570	1760	13900	15660	1090	0.074811

Data Set Number:	27					Persons		
Action:	Convert 3+ to 2+							
Name	Route 101 - San Rafael							
City	Marin County							
State	CA							
HOV Facility:	Freeway							
Length (mi)	3							
No. of Lanes	1							
Hours of Operation:	6:30-8:30 AM SB, 4:30-7 PM NB							
Elgibility:	2+							
HOV Open Date:	10/1/88							
Street Type	Freeway							
No. of Lanes Each Direction	3							
Free-Flow Speed (mph):	0							
Peak Hour:	7-8 AM		PERSONS			PERSONS		
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	0	0	0	0	0	0	Diff.	%
Max. Time (min)	0	0	0	0	0	ERR	ERR	ERR
Ave. Time (min)	0	0	0	0	0	ERR	ERR	ERR
1 occ Pers	0	0	0	0	0	0	0	ERR
2 occ Pers	0	0	0	0	0	0	0	ERR
3 occ Pers	0	0	0	0	0	0	0	ERR
4+ occ Pers	0	0	0	0	0	0	0	ERR
Bus Pers			0			0	0	ERR
Truck Pers	0	0	0	0	0	0	0	ERR
Cycle Pers	0	0	0	0	0	0	0	ERR
Subtotal HOV's			0			0	0	ERR
Subtotal Other	0	0	0	0	0	0	0	ERR
Total Persons:	0	0	0	0	0	0	0	ERR
Auto Occupancy:	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR
Peak Period:	6:30-8:30 AM							
Direction:	SB							
Data:	BEFORE	BEFORE	BEFORE	AFTER	AFTER	AFTER	Difference	
Lanes:	HOV	OTHER	TOTAL	HOV	OTHER	TOTAL	After - Before	
Date:	0	0	0	0	0	0	Diff.	%
Max. Time (min)	5	12.5	12	4	13.3	12	0	0
Ave. Time (min)	3.3	10.9	11	3.7	11.1	10	-1	-0.09091
1 occ Pers	170	12060	12230	180	12620	12800	570	0.046607
2 occ Pers	120	2680	2800	2580	1600	4180	1380	0.492857
3 occ Pers	1110	240	1350	570	480	1050	-300	-0.22222
4+ occ Pers	200	200	400	180	90	270	-130	-0.325
Bus Pers	1800	1800	3600	2720	680	3400	-200	-0.05556
Truck Pers	0	260	260	0	240	240	-20	-0.07692
Cycle Pers	0	90	90	0	50	50	-40	-0.44444
Subtotal HOV's	3230	5010	8240	6050	2900	8950	710	0.086165
Subtotal Other	170	12320	12490	180	12860	13040	550	0.044035
Total Persons:	3400	17330	20730	6230	15760	21990	1260	0.060781
Auto Occupancy:	2.58	1.12	1.19	2.09	1.09	1.2	0.01	0.008403

APPENDIX B. TERMINOLOGY

This chapter introduces the terms that will be used in this report and describes the different HOV facility types that will be presented later in the report.

B.1 TERMS

This report uses several terms defined as follows:

HOV's:	High Occupancy Vehicles are motorized rubber-tired vehicles carrying 2 or more persons. This definition includes carpools, vanpools, taxis, and buses. This term may include single occupant motorcycles and scooters if local laws allow motorcycles to use the HOV lanes.
SOV's:	Single Occupant Vehicles are motorized, rubber-tired vehicles with only a driver. This term generally excludes single occupant motorcycles and scooters if they are allowed by local laws to use the HOV facility.
Mixed-Flow Lanes:	Lanes where both SOV's and HOV's are allowed to operate.
HOV Lanes:	Lanes where only HOV's with a minimum allowed number of persons per vehicle are allowed to operate. HOV lanes technically include lanes dedicated to the exclusive use of transit, however; there is already a great deal of published research on bus lanes and bus ways (see NCHRP 155, 'Bus Use of Highways': for example). Consequently, this report focuses on HOV lanes where Carpools, Vanpools, and transit buses share the facility together.
HOV Facility:	This term can include HOV lanes, exclusive bus-ways, and park and ride lots. However, this report will use this term primarily for HOV lanes only, since that is the focus of this research. Bus lanes, bus streets, and park and ride lots will generally be excluded from the usage of this term in this report, unless specifically identified in the text.
Facility:	This term will be used in this report to refer to a specific roadway, such as a freeway, an expressway, or an arterial street.
Corridor:	A corridor includes the facility in which the HOV lanes are located plus nearby parallel roadways (within one mile each side of the facility) that might offer alternative paths for HOV's and SOV's currently using the subject facility.
System:,	A system consists of an integrated network of HOV facilities within a single metropolitan area.
Network:	This report uses this term interchangeably with "system".
Quick Response:	Quick response, as defined in this report, is used to describe a general set of planning procedures that require a minimal amount of input data in order to produce approximate estimates of various performance measures such as speed, travel time, delay, and air pollutant emissions. The procedures may consist of

complex equations and default assumptions, but because they are implemented in a computer software program, they produce results in a short amount of time.

Regional Planning Models: This report uses the term, "regional planning models" to refer to the Urban Transportation Planning System (UTPS) 1 like model systems typically used by metropolitan planning organizations (MPO's) to forecast travel demand and determine its impacts on the regional transportation system.

Region: This term is used in this report to refer to a metropolitan area often including many different cities in a contiguous area.

B.2 TYPES OF HOV LANES

HOV facilities are operated on exclusive right-of-ways or shared right-of-ways with freeways, in separate rights-of-ways, on arterials. and at metered freeway entrance ramps or toll facilities. Although most of the available data on HOV facilities cover only the first two types, this report attempts to include both arterial and ramp and toll bypass HOV facilities where data is available. For the purposes of this study, HOV facilities were classified by type. Most freeway HOV facilities can be categorized into one of six types. These HOV facility types are defined below. For arterial facilities, the types of facilities vary widely and the definition provided is very general.

These definitions are taken from the ITE report on "The Effectiveness of High-Occupancy Vehicle Facilities"' and the U.S. Department of Transportation report entitled "A Description of High-Occupancy Vehicle Facilities in North America."[3] Both of these sources provide a good overview of HOV facilities.

Freeway HOV Facility Types

Freeway HOV facilities fall into four basic categories: Separated, Concurrent Flow, Contra-Flow, and Queue Bypass.

Separated Facilities

Separated facilities are separated from mixed-flow facilities by a barrier or they are placed in exclusive right-of-ways. They consist of busways, reversible one-way facilities, or two-way facilities

Busway - A roadway or lane(s) developed in a separate right-of-way for exclusive use by high-occupancy vehicles, These facilities are designated for bus use only and are typically two-lane, two-way facilities. Examples of busways are the University of Minnesota inter-campus busway in Minneapolis, the East and South Pathways in Pittsburgh, Pennsylvania, and the transitways in Ottawa, Canada.

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1 Urban Mass Transportation Administration. Urban Transportation Planning System - Reference Manual. Washington, D.C., 1976.

2 Institute of Transportation Engineers. "The Effectiveness of High-Occupancy Vehicle Facilities - An Informational Report." 1988.

3 Katherine F. Turnbull and James W. Hanks. A Description of High-Occupancy Vehicle Facilities in North America, Final Report, Prepared for the Office of Planning, Urban Mass Transportation Administration and the Texas State Department of Highways and Public Transportation, July 1990.

Barrier-Separated, Two-Way Facilities - A roadway or lane(s) developed within the freeway right-of-way that is physically separated from the general purpose freeway lanes for exclusive use by HOVs Most of these facilities are separated from the general purpose lanes with a concrete barrier. A few are separated with a wide painted buffer. Access and egress is limited to a few points along the corridor. These facilities are usually open to all types of HOV's and are two-way facilities. Example of barrier-separated, two-way facilities are the El Monte I-10 in Los Angeles, the I-25 in Denver, and the I-66 in northern Virginia.

Barrier-Separated, Reversible Facilities - A roadway or lane(s) developed within the freeway right-of-way that is physically separated from the general purpose freeway lanes for exclusive use by HOV's. Most of these facilities are separated from the general purpose lanes with a concrete barrier. A few are separated with a wide painted buffer. Access and egress points are typically three to five miles apart. The roadway or lanes are reversible corresponding to the peak direction of traffic. These facilities are usually open to all types of HOV' s. The Shirley Highway has barrier-separated, reversible flow lanes for HOV's. Other examples are the Katy, North, Northwest, and Gulf transitways in Houston, Texas and the I-15 freeway in San Diego, California.

Concurrent Flow Lanes

Concurrent flow lanes are generally separated from mixed flow lanes only by a painted stripe on the pavement. Concurrent flow lanes may be access limited (entry and exit is allowed only at specific points) or unlimited access (HOV's can enter and leave the lane at any place).

A Concurrent Flow Lane is not physically separated from the general purpose freeway lanes and is designated for use by HOV's for all or a portion of the day. These facilities are usually located on the inside lane or shoulder. Most HOV facilities in the U.S. and Canada are concurrent flow HOV lanes, including the I-5, I-90, and I-405 in Seattle, Washington, the I-95 in Miami, and US 101, I-280, and I-880 in the San Francisco Bay Area.

Contra-Flow Lanes

A Contra-flow Lane is a freeway lane in the off-peak direction of travel that is designated for use by HOV's traveling in the peak direction. The lane is separated from the off-peak direction general purpose travel lanes by some type of changeable treatment, such as plastic pylons or posts. These lanes are typically operated during the peak periods only. Examples of contra-flow facilities are Kalanianaole and Kahekili Highways in Honolulu, Hawaii, the Lincoln Tunnel between New Jersey and New York City, and the Long Island Expressway in New York.

Queue Bypass Lanes

A Queue Bypass is a lane or set of lanes used in conjunction with tolls or ramp metering that is for the exclusive use by HOV's to avoid the wait at the tolls or the ramp meter. Toll bypass facilities are used in the San Francisco Bay Area at the approaches to the Bay Bridge, the San Mateo Bridge, and the Dumbarton Bridge. Examples of ramp meter bypasses include over 250 entry ramps in Los Angeles and Orange Counties and various entry ramps in Seattle, Minneapolis, and San Diego.

Expressway and Arterial HOV Facilities

Expressway and arterial HOV facilities may consist of bus lanes, concurrent flow lanes, contra-flow lanes, or exclusive bus streets. This report does not focus on exclusive transit facilities, so bus lanes and bus streets are not discussed here.

Both expressways and arterials are controlled by traffic signals. Expressways operate at high speeds with little or no driveway access allowed to property fronting the expressway. Arterials operate at lower speeds, often have curbside parking, and allow numerous driveways between signals.

An expressway or an arterial HOV facility is a lane (or set of lanes) designated for the exclusive use of HOV's Arterial and expressway HOV lanes vary from reserved lanes for buses to lanes that operate similar to freeway HOV lanes. Typical arterials with HOV lanes have multiple points of access and egress and are signalized. Arterial and expressway facilities differ from freeway facilities in that they must deal with turning movements, signals, pedestrians, and driveways. Most arterial and expressway HOV facilities are concurrent flow. Examples are the Montague and San Tomas Expressways in Santa Clara County, California.

APPENDIX C. REFERENCES

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APPENDIX D. DATA COLLECTION

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Appendix D. DATA COLLECTION

This chapter describes: the selection of agencies and data sets for calibrating the new methodology, the HOV facilities operated by each agency, the availability of before/after studies, and the methods used to reduce each before/after study for use in the methodology development database.

D.1 DATA COLLECTION PROCEDURE

This section describes the procedures used to obtain data sets for developing and validating a methodology for predicting the demand for HOV lanes and their impacts on traffic congestion and air quality.

The data collection effort proceeded in four steps. First, the types of data necessary for developing and validating the methodology were determined based on the likely input, output, and desired sensitivities of the new methodology. Second, nine agencies, representative of HOV environments throughout the United States were selected for data collection. Third, “before and after” data was collected on the HOV facilities currently operated by each agency. Fourth, a single, coherent data set was then assembled based upon each “before and after” study.

Gaps in data were filled in where appropriate data could be obtained from other sources or by applying logical assumptions based upon the supplemental data sources. All data was converted into a consistent level of disaggregation and format for use in validation and methodology development.

Step One: Determination of Data Needs

The purpose of this project is to provide a “quick response” methodology for predicting and evaluating the impacts of HOV lanes on person demand, vehicle demand, auto occupancy, congestion, delay, and air quality. The methodology should be sensitive to parameters known to influence HOV demand (such as travel time and delay) and to user specified control parameters such as eligibility rules for HOV's. The methodology should be applicable to both freeway and arterial HOV lanes.

Consequently the ideal data set should provide “before and after” data on person demand, vehicle demand, auto occupancy, congestion, and delay’. The data sets should span different HOV lane facility types and facilities with different occupancy rules. The data sets should include both arterial and freeway HOV facilities.

A key requirement of the data sets is that the data sets provide data for both before and after the implementation of an HOV lane or a change in eligibility rules. This is crucial in order to be able to determine the impact of the installation of an HOV lane.

No new raw data collection was feasible as part of this study, because of the time schedule for the study. Valid after data must be gathered at least 6 months to one year after the opening of an HOV lane to allow time to measure the cumulative effects of an HOV lane on travel demand.

Pre-existing studies of existing HOV lanes had to be relied on in order to obtain the necessary “before and after” data for each facility.

Several agencies have extensive monitoring programs that measure speeds, volumes, and occupancies for existing HOV lanes. However, most of these monitoring programs were not implemented until “after” the HOV lane was already in place. Thus much of this extensive data was not of direct use to this study.

The needed “before and after” data falls into two broad groups - operations data and survey data (see Table D-l). Operations data typically includes traffic volume counts and vehicle occupancy counts for the HOV lane and the adjacent freeway lanes. The ideal data sets had vehicle volume counts by occupancy (1,2,3,4+) and by vehicle

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1 Air pollutant emissions can be predicted using standard emission models. It is beyond the scope of this study to obtain field data for validating the standard emission models.

type (car, motorcycle, truck, bus, van) for each lane type (HOV, and mixed flow); however, many studies only provided an overall average occupancy for the HOV lanes and the mixed flow lanes. Traveler survey data was useful for determining the influence of HOV lanes on the various aspects of total demand: mode shift, route shift, and time shift.

Table D-l. Desired Characteristics of Before/After Data Sets

Data Type	Before	After
Facility Description (Required)		
Location, Facility Type, Length, Number of Lanes (HOV and Mixed Flow)	√	√
Date HOV Lane Opened, Hours of Operation, Occupancy Requirements		√
Operations Data (Required)		
Vehicle Counts by occupancy type (1,2, 3,4+), vehicle type (auto, trucks, buses, vans, motorcycles), and lane type (HOV, mixed flow).	√	√
Travel Times (Average and Maximum for Peak Hour and Peak Period)(HOV lane and mixed flow lanes)	√	√
Traveler Surveys (Optional)		
Proportion of "after" SOV's and HOV's that shifted from other modes, other routes, other time oeriods		√

Before data should be collected preferably within one month of project opening, but can be as much as 18 months prior to opening. After data should be collected preferably no sooner than 6 months after project opening, but can be as much as 18 months later.

Step Two: Selection of Agencies

Nine agencies were selected for data collection based upon their geographic distribution, the HOV facilities they operate, and the availability of before/after data.

The specific criteria were:

1. Representative geographic distribution of the U.S. Since the methodology and software is being developed for use by agencies across the U.S., the nine agencies should cover several geographic areas. Although the majority of the existing HOV facilities are located in California, agencies were selected to represent several regions including the South, West Coast, East Coast, and Midwest.
2. Representative of several different types of HOV facilities. For maximum efficiency in data collection, the agencies selected should operate several different types of HOV facilities. Since concurrent flow facilities are the most popular facility type, they should be well-represented among the nine agencies. Barrier-separated and contra-flow HOV projects should be included. Agencies that operate different types of facilities were preferred. A special effort was made to include agencies that operate arterial HOV facilities.
3. Availability of before-and-after data. The last criteria, and the most crucial, is the availability of before-and-after data, preferably in a published report. A published report ensures consistency in data collection methodology for the before and after data collection efforts. Raw data taken from agency files is more difficult to control for consistency of methodology. In addition, routine data collection rarely includes occupancy or travel time measurements, except for the few agencies with extensive HOV monitoring programs. This specialized data has been historically collected only if an agency is conducting a specific "before and after" study. Monitoring programs in Houston, Seattle, and the San Francisco Bay Area are among the few programs to routinely collect the specialized data needed to evaluate the effectiveness of HOV lanes.

4. Cooperative Abilitv. All agencies contacted were sympathetic to the objectives of this project, however; some agencies did not have the personnel resources available to devote to internal searches of available HOV data.

The following nine agencies were selected for data collection based upon the above criteria:

1. Caltrans, District 4, San Francisco, California;
2. Caltrans, Districts 7 & 11, Los Angeles/San Diego, California;
3. Minnesota DOT, Minneapolis, Minnesota;
4. New Jersey DOT, Trenton, New Jersey;
5. Metropolitan Transit Authority of Harris County, Houston, Texas;
6. Virginia DOT, Richmond, Virginia;
7. Washington DOT, Seattle, Washington;
8. Santa Clara County, San Jose, California; and
9. Snohomish County, Seattle, Washington,

The nine agencies operate a combined total of 55 freeway and arterial HOV projects with a total of 586 lane-miles (943 lane-km). The selected agencies together operate 49% of the 1188 freeway HOV lane-miles (1,912 lane-km) in the United States and Canada. Many of the selected agencies collect and publish data on HOV lane usage annually, semi-annually, or quarterly. Most have conducted "before and after" studies for some of their HOV facilities.

Each of the agencies was contacted to determine the availability of before and after data for their HOV facilities. Table D-2 summarizes the types of data available in published "before-and-after" reports.

Caltrans District 11 (San Diego) and Houston Metro have the most comprehensive before and after data for their HOV facilities. Caltrans District 4 (San Francisco) and Santa Clara County collected mainly peak period data in their "before and after" studies. Minnesota DOT and Washington DOT gathered mainly peak hour data in their "before and after" studies.

It should be noted that Caltrans, Minnesota, and Washington currently have monitoring programs in place to gather much more extensive data than is cited here. These monitoring programs however often did not start early enough to provide "before" data for many HOV facilities. We have consequently sought published before and after studies by each agency that provide the "before" data for each facility.

Step Three: Collection Of Before/After Data

Each agency was requested to forward a copy of every available published "before and after" study for HOV facilities under their control. Some agencies no longer had available copies of "before/after" studies for projects which were opened over 20 years ago. In those cases, the University of California, Institute of Transportation Studies library and Systan Inc. files were searched for information on the older projects.

Minnesota DOT, the Texas Transportation Institute, and the California State University, San Diego (Caltrans District 11) had available to most extensive series of "before and after" studies for their HOV facility projects.

New Jersey DOT's "before and after" study of their I-80 facility is still in progress and could not yet be released at the date of publication of this report.

Agencies also provide copies of their monitoring program reports. The Texas Transportation Institute, Caltrans District 4, Washington Metro COG, and Washington State DOT provided extensive monitoring data.

The history of each HOV facility was then reviewed to determine which "changes" in facility operation or characteristics would be useful "actions" for inclusion in the methodology development database. Each action consists of a change in the length or operating rules (e.g. 2+ versus 3+ Carpools allowed).

It was particularly valuable when several "actions" could be identified on a single facility, because then the effects of different actions on the identical facility could be tested without interference caused by differences in driver types in different geographic areas. The Katy Transitway in Houston, and the I-5 freeway in Seattle were two particularly rich sources of multiple "actions" occurring on the same facility.

Several, otherwise excellent "before/after" studies were not eliminated because of potential distortions that could occur when multiple changes or "actions" occur within a short time period. A portion of the I-394 data set was not included in the database because the later portions of the HOV project occurred at the same time as freeway construction was proceeding. Some of the earlier studies of the Shirley Highway in Washington D.C. have not been included because of potential confusion of the effects of gasoline shortages in 1973 and 1979 with the impacts of the HOV facility.

It was not generally possible to "create" complete before/after data sets for a particular facility by combining different studies. Different studies gathered data at different geographic locations or for different time periods. It was particularly important that the travel time studies be conducted at about the same time as the volume counts. For this reason, travel time studies from one study were not combined with volume counts from another study to create a new data set.

A total of 27 "before/after" data sets out of a total 55 projects operated by the nine agencies have been identified and included in the methodology development database. The following chapter discusses the rationale for including or excluding each data set in the database.

Step 4: Data Reduction

The various "before/after" data sets identified in the previous step were reduced and consolidated into a single consistent database. This step involved converting percentages into volumes, translating travel time data into travel time differences, and tilling in gaps in the reported data based upon information available from related sources.

For example, vehicle occupancies were reported for the overall (HOV plus mixed flow) facility but not specifically for the HOV or mixed flow lanes in a few cases. This information plus information on violation rates, average vehicle occupancy by lane, and total lane volumes was then used to assign vehicles by occupancy type to each lane type.

In other cases, travel times were reported for a section of the freeway that was longer than the section in which the HOV lane was located. These times were converted to travel times for the shorter section of freeway with the HOV lane by assuming that all of the observed travel time difference between the HOV lane floating car run and the mixed flow lane floating car run was due to the HOV lane.

In some cases, only mean or only maximum travel time savings were reported and these had to be converted to the other measurement using an estimated ratio of mean to maximum travel times based on data collected on the Houston and San Francisco HOV facilities.

Table D-2. Available Before/After Data

	Caltrans Dist. 4 (SF)	Caltrans Dist. 7/12	Caltrans Dist. 11	Minnesota DOT	New Jersey DOT	Texas Metro	Virginia DOT	Washington State DOT	Santa Clara Co.	Washington Kings Co.
0. Individual Contacted Telephone #	Mr. David Seriani (510) 286-4653	Mr. Ron Klusza (213) 897-0788	Mr. Arian Abrishami (619) 688-3206	Mr. Mark Dierling (612) 341-7372	Ms. Barbara Fischer (609) 530-2468	Mr. Don Garrison (713) 802-5171	Mr. Kanathur Srikanth (703) 934-0608	Mr. Eldon Jacobson (206) 685-3187	Mr. Ananth Prasad (408) 494-1342	Mr. Mike Wong (206) 296-6506
Before and After Studies/Reports	US 101 Marin I-280 S.Clara S.Clara 237	I-10 LA I-210 LA LA 91 Orange 55	I-15 (San Diego)	I-394 (Minneapolis)	I-80[2] (Morris Co.)	I-10 Katy US 290 NW I-45 North	I-395[3] (North Virginia)	I-90 I-5	San Tomas	128th/Airport
Peak Hour Data	[4]									
Vehicle Counts	√	√	√	√		√		√		√
Person Counts	√	√	√	√		√		√		√
Veh. by Occupancy	√	√	√	√		√		√		
Max. SOV Times	√	√	√			[5]		√		
Ave. SOV Times	√	√	√	√				√		√
Peak Period Data		[6]								
Vehicle Counts	√	√	√			√	√		√	
Person Counts	√	√	√			√	√		√	
Veh. by Occupancy	√	√	√			√				
Max. SOV Times	√	√	√			√			√	
Ave. SOV Times	√	√	√			√			√	
Traveler Surveys	1990, 1995		√			√				

2 Study in progress. After study had not been released by September 6, 1995.

3 Excellent historical data available for HOV lanes only. Mixed flow lane data is limited. No travel time studies performed concurrent with volume counts,

4 Peak hour data available only for one of the U.S. 101 HOV projects. No peak period data available for this same project.

5 Only more recent travel time data (circa 199 1) is currently readily obtainable. Travel time for older projects estimated based upon 1991 data.

6 Peak period data available only for I-10 (El Monte and Santa Monica) projects. No peak hour data available for these two projects.

D.2 MINNESOTA DEPARTMENT OF TRANSPORTATION

The Minnesota Department of Transportation operates HOV facilities on two corridors in the Minneapolis-St. Paul area. These HOV lanes requires a vehicle occupancy of 2 or more persons. Table D-3 summarizes the facility characteristics for the HOV facilities in the Twin Cities region. The I-394 facility is described in greater detail in the Project Profiles.

Minnesota DOT operates the 8 HOV ramp meter bypasses on I-394 as well as 34 other HOV ramp meter bypasses in the Twin Cities Metro Area. These are part of a system of 367 ramp meters which are all operated by the Minnesota DOT's Traffic Management Center (TMC).[7]

The Minnesota Department of Transportation has collected data on I-394 since one year prior to the opening of the interim HOV lane in 1984 and continues to collect data periodically. Daily and monthly data has been collected since the interim facility opened in 1985.

A comprehensive traveler survey was conducted in October 1986. A telephone survey of persons regularly using I-394 during the peak periods for work was conducted of 403 households from January 2 1 to February 5, 1993. The survey included traveler profiles, trip profiles, and commuter attitudes.

A before/after report is not available for the I-35W HOV facility.

Contact: Mr. Mark Dierling
Minnesota Department of Transportation
Tel: (612) 341-7372

D.2.1 I-394 Traveler Surveys

Several traveler surveys (surveys of HOV drivers and non-HOV drivers) were conducted throughout the I-394 evaluation study. A comprehensive traveler survey was conducted in October 1986. The survey indicated that the growth in carpooling came from both modal and spatial shifts. The survey results showed that during the AM peak hour 25% of the carpoolers were previously carpoolers on Highway 12, 26% were carpoolers on other routes, 38% previously drove alone, and 11% were former bus riders. Route shifts (from various modes) accounted for almost 40% of all the new carpoolers on the facility (see Figure D-l).

In 1989, another survey of regular lane users, HOV lane users, and bus riders was conducted on April 5 and 12. A total of 6,173 surveys were distributed with a 1,802 surveys returned. The results of the April 1989 diversion survey showed that during the AM Peak hour 34% of the carpoolers were previous carpoolers on Highway 12, 11% were carpoolers on other routes, 39% previously drove alone, and 15% were former bus riders. The percentage of carpoolers from other routes fell from 26% in 1986 to 11% in 1989, representing the effects of the construction in 1989.

A telephone survey of persons regularly using I-394 during the peak periods for work was conducted of 403 households was conducted from January 21 to February 5, 1993. The survey included user profiles, trip profiles, and commuter attitudes. The survey results identify the current mode of travel along I-394 and the potential to change the modal distribution through direct questions. The survey does not ask about previous mode, but asks about the duration of the present mode, which gives some idea if the mode choice was related to the opening of the HOV lane.

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7 Mn/DOT Freeway Operations Program Status Report, January 1995.

Table D-3. Minnesota Freeway HOV Lane Characteristics

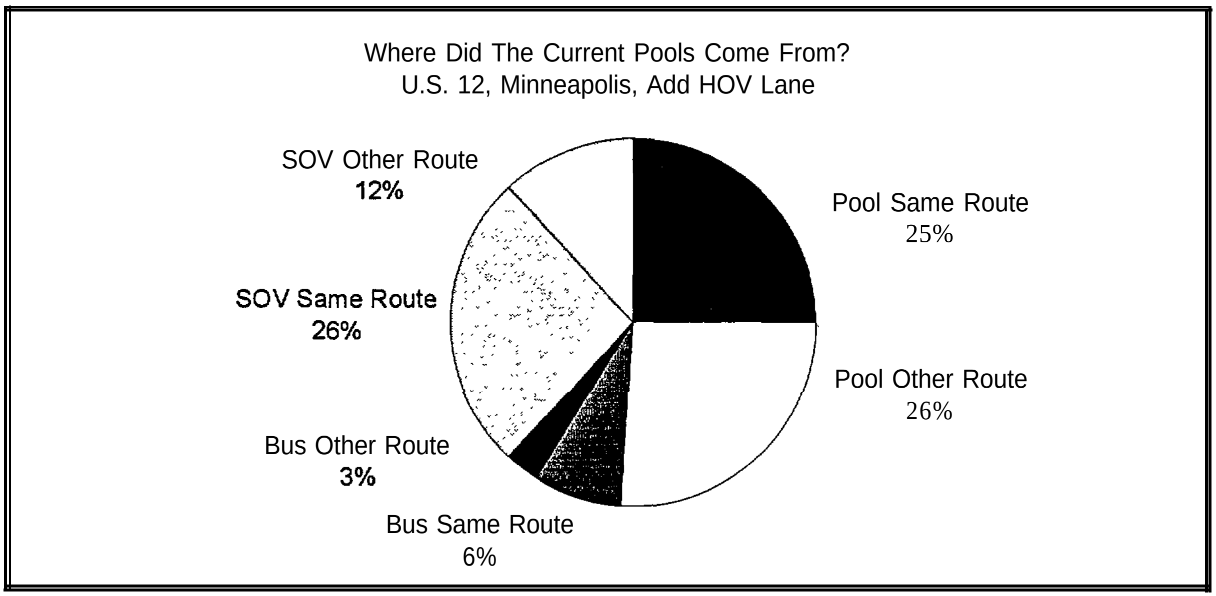
Characteristics	Minnesota DOT		
Corridor	I-394 Minneapolis		I-35W
Begin and End /Ramp Location	T.H. 101 to Hwy 100	Hwy 100 to I-94	T.H. 13 Bumsville to I-494 Bloomington
# of Directional HOV lanes	2	2	1
Length (mi.)	**8**	3	**6**
Date Operational	90	92	94
HOV Eligibility	2+	2+	2+
Hours of HOV Operation (weekdays only)	6-9 AM EB 2-6 PM WB	6-10:30am EB 2pm-midnight WB	6-9 AM, 3-6 PM both directions
Type of facility’	striped concurrent each dir.	barrier separated reversible lane	concurrent in each dir.
Ramp Metering	8 locations		none
Park-and-ride facilities	8 lots		?
Other support facilities/programs (rideshare program)	3 downtown garages, parking incentives, transit timed transfer stations		

Sources:

Allan Pint, Charleen Zimmer Joseph Kern, Leonard Palek. “Evaluation of the Minnesota I-394 HOV Transportation System”, TRB, 74th annual meeting, January 1995.

Glen Carlson, MnDOT, 1995.

Figure D-l Where I-394 Carpoolers Came From



8 All HOV lanes are on the left side unless otherwise noted.

D.2.2 I-394 HOV Facility - Minneapolis, Minnesota

The I-394 HOV lanes and freeway is located west of downtown Minneapolis. The HOV lanes are part of a system that includes transit facilities, park-and-ride lots, parking garages, and skyways. Table D-3 summarizes the characteristics for the I-394 HOV system.

I-394 was constructed on the alignment of US 12, an existing arterial, and extends 1 l-miles west from downtown Minneapolis. East of Highway 100, three miles of barrier separated reversible HOV lanes are located in the freewaymedian. Access and egress are limited to the ends of the 3-mile section at Highway 100 and I-94. West of Highway 100, eight miles of concurrent flow HOV lanes with unlimited access are in operation.

Project History

An interim HOV lane was opened to traffic on November 19, 1985. The interim project provided additional person-carrying capacity during the construction of I-394. The interim facility was a single reversible-flow lane in the median of US 12, a signalized arterial. A short section of left hand side concurrent flow lanes were used to carry the HOV facility under a railroad underpass.

The reversible median lane was replaced with temporary concurrent flow lanes during freeway construction. Construction lasted from April 1987 to October 1992.

The reversible HOV lane between downtown and T.H 100 was partially completed in November 1990. The entire HOV and freeway project was opened in October 1992.

Selection of Before/After Data Sets

Three distinct HOV facility changes or "actions" on the I-394 HOV facility can be identified as candidates for inclusion in the methodology development database:

1. Construction of Reversible Median Lane,
2. Construction of Interim HOV lanes during freeway construction,
3. Construction of Final HOV lanes T.H. 101 to I-94.

The latter two actions however occurred during the construction of the freeway and thus it is impossible to separate out the effects of the HOV lanes from the effects of the freeway construction. Consequently these last two actions have not been included in the methodology development data base.

Data Collection

The Minnesota Department of Transportation collected data one year prior to the opening of the interim HOV lane in 1984 and continues to collect data periodically. Daily and monthly HOV lane data has been collected since the interim facility opened in 1985. The 1984 baseline data was for Trunk Highway 12, which was a signalized arterial, and for parallel roadways. The data consist of vehicle volumes, Carpools in the corridor, bus ridership, auto occupancy, and travel times.

Minnesota DOT is in the final phase of a four-phase evaluation study of the I-394 facility. For Phase I, data was collected in 1986 during the first year of operation. Phase II covered the construction period from 1987 to 1992. The Phase II Report published in 1990 focused on the effectiveness of the interim lane. Phase III, the start-up period from 1993 to 1994, was recently completed. The final phase of the study covers stable operations over the next five years.

The Phase I, 1984 baseline data was collected for Trunk Highway 12, which was a signalized arterial, and for parallel roadways.

The Phase II evaluation consisted of continuous counts, biennial counts, and one-time counts. Volumes, transit boardings, and downtown garage counts were made on a continuous basis. Every six months data was collected on vehicle occupancy, travel time, transit peak loading, park-and-ride lot utilization, and traffic counts for the parallel facility, T.H. 55. One time data collection efforts included a telephone survey conducted in 1993, a license plate survey of park-and-ride users in May 1993, and vehicle occupancy and queue length counts at all I-394 on-ramps in August 1993.

The data collected for the Phase III evaluation consisted of continuous counts, biennial counts, and one-time counts. Volumes, transit boardings, and downtown garage counts were made on a continuous basis. Every six months data was collected on vehicle occupancy, travel time, transit peak loading, park-and-ride lot utilization, and traffic counts for the parallel facility, T.H. 55. One time data collection efforts included a telephone survey conducted in 1993, a license plate survey of park-and-ride users in May 1993, and vehicle occupancy and queue length counts at all I-394 on-ramps in August 1993.

Data is available for the AM peak hour, AM peak period, the PM peak hour, and PM peak period, in the peak and off-peak direction. The April 1984 data represents "before" conditions on the signalized arterial. May 1986 data represents operations of the interim facility. The vehicle counts and occupancy data is for all vehicles, including passenger automobiles, buses, and trucks. The data represent the peak load point of the facility. Once the facility was complete and the barrier-separated HOV lanes east of T.H. 100 were opened, data was collected on I-394 at Penn Avenue. Prior to 1992, the data was collected at a point just east of T.H. 100.

Data Reduction

One action was selected for inclusion in the methodology development database: Construction of the reversible HOV lane in the median in 1985, before freeway construction started.

Description: This data set shows the impacts of constructing a 4.0 mile (6.4 km) HOV lane. The HOV lane is a single reversible lane located in the median of a four lane (2 lanes each direction) signalized arterial. The signalized arterial (U.S. 12) was the last uncompleted section of the I-394 freeway. The average speed through this section can drop to 17 mph during the peak hour.

The HOV lane is split into two sections. The 3.0 mile (about 4.8 km) section of the median HOV lane moved through 4 traflic signals. The one mile section was located about one mile west of the three mile section. The one mile section had one traffic signal in the middle of it.

The median lane provided HOV's with their own exclusive lane for queuing at the signals. No turns were allowed into or out of the HOV median lane at any of the signals. Entry or exit was allowed only at the endpoint of each section of the HOV lane.

Ramp metering was not present during the periods of the before and after studies.

Travel Time Data: The available before and after travel time data was for a 7 mile long segment from I-494 to Penn Avenue that included the HOV lane.

The HOV travel time for the 4.0 mile HOV section was computed assuming that the HOV's moved at 55 mph on the freeway portions of the travel time run. The estimated HOV travel time on the non-HOV lane portions was subtracted from the total time to obtain the HOV travel time for the 4.0 mile section with the HOV lane.

The difference in travel times (SOV minus HOV) for the after case was then added to the HOV time to obtain the SOV (single occupant vehicles and other non-HOV-lane using vehicles) after time.

The "before" travel time was computed assuming that the arterial functioned as a bottleneck, thus allowing all traflic to travel at 55 mph on the freeway portions of the run.

Only average peak hour travel times were available. The maximum peak hour time was therefore assumed to be equal to the average peak hour travel time for SOV's. The HOV maximum and average travel times are assumed to be identical.

No peak period data was available.

Volume Counts: Before and after AM peak hour eastbound counts were obtained for May 1984 and May 1986 respectively.

Volume counts were not broken down by auto occupancy. The percentage breakdown by occupancy in the HOV lane was reported for the after survey. These percentages plus the reported persons per vehicle in the HOV and SOV lanes were used to derive an approximate distribution of vehicles by occupancy type.

Trucks and motorcycles were estimated for the before condition and for the after SOV lanes based upon 1986 "after" data and the split between motorcycles and trucks reported by a later 1993 data collection effort on I-394.

Bus passenger counts were obtained directly from the available reports.

The number of single occupant vehicles using the HOV lane was estimated based upon the reported "after" violation rate (5%).

No peak period data was available.

Table D-5 summarizes the results of the before/after study.

References

1. Allan Pint, Charlene Zimmer, Joseph Kern, and Leonard Palek. "Evaluation of the Minnesota I-394 HOV Transportation System," Preprint from Transportation Research Board 74th Annual Meeting, January 22-28, 1995.
2. Strgar-Roscoe-Fausch, Inc. I-394 User Assessment Survey, April 1993.
3. Strgar-Roscoe-Fausch, Inc. I-394 Interim HOV Lane: A Case Study, Phase I Report, Prepared for Minnesota Department of Transportation, October 1987.
4. Strgar-Roscoe-Fausch, Inc. I-394 Interim HOV Lane: A Case Study, Phase II Report, Prepared for Minnesota Department of Transportation, July 1990.
5. Strgar-Roscoe-Fausch, Inc. I-394 Case Study, April 1989 Survey Results, August 1990.
6. Strgar-Roscoe-Fausch, Inc. I-394 Phase III Evaluation Data Summary Report, Prepared for Minnesota Department of Transportation, September 1994.
7. Donald G. Capelle and Sharon Greene. "High-Occupancy Vehicle Lanes: An Incentive for Ridesharing?" ITE, District 6, 1988 Annual Meeting, Colorado Springs, July 1988, pp. 6-8.

Table D-4. I-394 Minneapolis HOW Facility History

Date	November 1985	1987 to 1992	October 1992
Action:	Construct 4 miles barrier separated, reversible HOV Lane in Median	Replace Expressway Signals with Freeway Interchanges. Construct Left-hand Side, Concurrent Flow HOV Lanes	Construct 2 lane barrier separated, reversible HO\ Facility in Median of Freeway
Included in Before/After Data Set?	YES	NO[9]	NO[10]
Corridor	us 12	T.H. 101 toT.H. 100	T.H. 100 to I-94
# of HOV lanes	1 lane reversible	1 lane in each direction	2 lanes reversible
# of general purpose lanes	2 lanes each direction	2 lanes in each direction	2 lanes in each direction
Length	3 miles - e/o T.H. 100 1 mile - Plvmouth Road	8 miles	3 miles
HOV Eligibility	2+	2+	
Hours of HOV Operation	6:00 to 9:00 am EB 2:00 to 7:00 pm WB	6:00 to 10:00 am EB 2:00 to 8:30 pm WB	6:00 to 10:00 am EB 2:00 to 8:30 pm WB
Type of facility	barrier-separated reversible, on signalized expressway	concurrent lanes on freeway	barrier separated reversible on freeway
Ramp Metering	no	8 ramp meters with HOV bypass lanes	
Park-and-ride facilities	6 park and ride lots	7 park and ride lots	
Other support facilities	1 downtown parking lot for registered carpools, public information program	Automated traffic management system, 3 downtown parking garages, skyways, 3 transit transfer stations, rideshare program, marketing program	
Bus Service	Addition of express bus service to downtown	Expanded express and timed-transfer local bus service	

9 The available "before and after" data for this action has not been included in the methodology development database because the HOV lane action occurred at about the same time as the replacement of signalized intersections with freeway interchanges. In addition, the freeway construction occurred over a four year period (April 1987 to October 1992) thus making the available "before" data a little too old to be reliable.

10 This action also occurred at same time as freeway construction, thus it has not been included in the methodology development database.

Table **D-5. Before/After Results for I-394, Minneapolis Expressway HOV Lanes**

Action: Construct 4 miles barrier separated, reversible HOV Lane in Expressway Median”		
	Peak Hour	Peak Period
HOV Lane Volume (After)	440	-
Change in Total Vehicles[12]	+6%	-
Change in Total Persons”	+12%	
Average Vehicle Occupancy[14]: Before: After:	1.38 1.45	- -
C h a in HOV Time”	Save 8 minutes	
Change in SOV Time[16]	Save 3 minutes	

11 Data is for morning peak period, eastbound direction. Before data gathered 18 months before opening, After data gathered 6 months after opening. Note that bus service was expanded (12/85), carpool matching efforts expanded (1986), and a free parking lot for carpools was constructed downtown (1 l/85) just prior to the HOV lane opening. All of these events occurred between the “before” study in May 1985 and the “after” study in May 1986, and probably influenced the results. Ramp metering was not present during the before or after studies.

l2 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as “After” minus “before”, divided by “before”.

13 Total persons in peak direction in all vehicles, in all lanes expressed as “After” minus “before”, divided by “before”.

l4 Total persons divided by total vehicles. Includes buses and vans.

15 Mean time savings for HOV lane vehicle expressed as “Before” minus “After.

l6 Mean time savings for mixed flow lane drivers expressed as “before” minus “after.

D.3 METRO - HOUSTON, TEXAS

Houston has HOV facilities operating on five of the city's freeways that are part of a planned 96-mile HOV network, Figure D-2 shows the existing and planned network of HOV lanes surrounding downtown Houston. The system is a joint effort between the Metropolitan Transit Authority of Harris County (METRO) and the Texas State Department of Highways and Public Transportation (SDHPT). METRO is responsible for the daily operations and enforcement on the HOV lanes, or transitways. Table D-6 summarizes the facility characteristics of the HOV lanes in the Houston system. The Houston transitways are one-lane reversible facilities located in the median of the freeway and separated from the mixed-flow traffic by concrete barriers. The HOV lanes are part of a larger system that includes transit centers, park-and-ride lots, and park-and-pool staging lots. Carpool incentives, parking incentives, and flexible work hours are all part of the trip reduction program.

The first HOV facility in Houston was the North Freeway (I-45) contra-flow lane for authorized 8+ passenger vanpools and buses in 1979. This facility introduced Houston drivers to the concept of HOV lanes. Due to its success, the current system was developed. The North Freeway Contra-flow lane was replaced by the barrier separated reversible North Transitway in November 1984.

The occupancy requirement has varied from buses and authorized 8+ passenger Vanpools to the existing 2+ person per vehicle. Over the years in response to the desire to increase the transitway usage, the occupancy requirements have been lowered and the authorization requirement was eliminated. When the Gulf and Northwest Transitways became operational in July and August 1988, the 2+ occupancy requirement was used. The North Transitway and the newer Southwest Transitway also require 2 or more persons per vehicle. The Katy Transitway is one of the only HOV facilities that has varying occupancy requirements.

The Katy Transitway opened in October 1984 to authorized 8+ person vanpool and buses, but the requirements changed over time. After dropping occupancy requirements to 2+ persons per vehicle, the operations of the Katy Transitway were negatively impacted. A.M. peak hour volumes reached 1,500 vehicles per hour and travel speeds dropped, travel times increased, and travel times were no longer as reliable. In response, the peak hour occupancy requirement was raised back to 3 + persons per vehicle during the A.M. peak period and subsequently, the PM peak period.

The Texas Transportation Institute (TTI) is in charge of preparing quarterly reports of HOV lane data. TTI has been monitoring the effects of allowing Carpools on the transitways since their inception. Combining transitway operations data with Carpool surveys, TTI has amassed a great deal of data on the transitways.

Comprehensive surveys have been performed by TTI for the Katy, Northwest and Gulf Freeway corridors. A limited amount of survey data is available for the North Freeway corridor. Surveys were conducted on the Katy Freeway every year since its opening from 1985 to 1989. The Northwest and Gulf Freeways were surveyed in 1988 and 1989. The North Freeway was surveyed once in 1986. TTI has summarized this data in a report.[17]

The purpose of the surveys was to determine the impacts of allowing Carpools on the transitways and to measure public sentiment towards HOV facilities. Survey questionnaires were distributed periodically to both HOV users and non-users from license plate numbers collected during the a.m. peak period on each of the facilities. The response rate ranged from 29% to 42% of the surveys mailed. The survey included personal characteristics, travel patterns and trip characteristics, and attitudes and impacts pertaining to transitways.

Contact: Mr. Dick McCasland, Texas Transportation Institute , Tel: (713) 686-2971

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17 Diane L. Bullard ***A summary of Survey Data from the Katy, North, Northwest and Gulf Transitways, April 198.5 Through October*** 1989. Texas Transportation Institute for the Texas State Department of Highways and Public Transportation, Research Report 484- 12, July 1990.

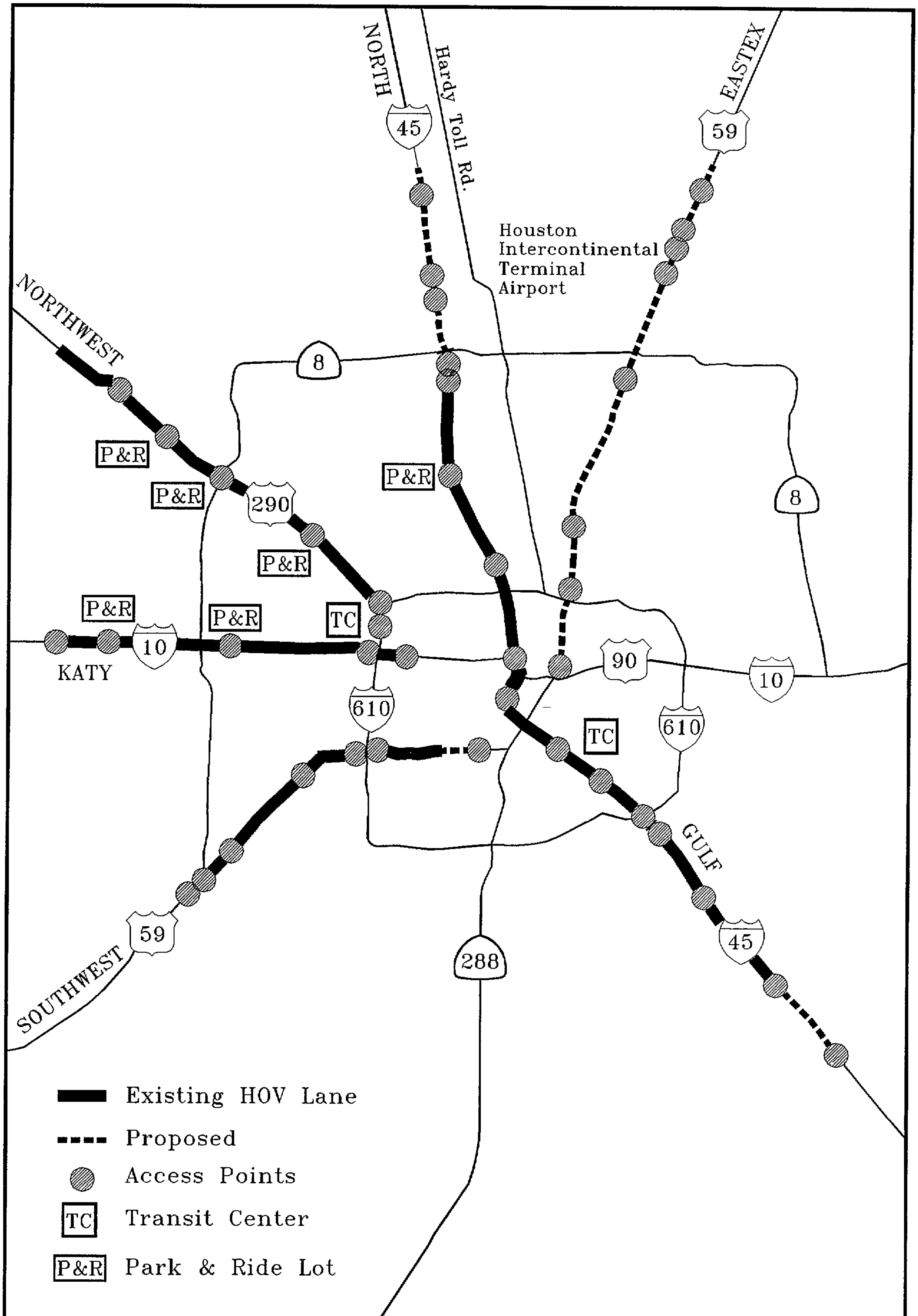

Figure D-2
HOV Facilities in the Houston Area

94044/figD-2 DWG 5-28-96

Table D-6. Houston Freeway HOV Characteristics

Characteristics	Texas - Houston				
Corridor	Katy I-10	North I-45	Northwest US290	Gulf I-45	Southwest us59
# of lanes	1	1	1	1	1
Length (mi.)	13	13.5	13.5	12.1	11.5
Date Operational	84/90	79/90	88	88/94	
HOV Eligibility	3+ peak hrs 2+ other	2+	2+	2+	2+
Hours of HOV Operation (weekday only)	5am-12noon 2-9pm	5am-12noon 2-9pm	5am-12noon 2-9pm	5am-12noon 2-9pm	5am-12noon 2-9pm
Type of facility (barrier sep. 2-way, reversible flow, concurrent, etc.)	barrier separated reversible	barrier separated reversible	barrier separated reversible	barrier separated reversible	barrier separated reversible
Park-and-ride facilities	3 lots (3,500+ spaces)	3 lots (3,500+ spaces)	3 lots (3,500+ spaces)	3 lots (3,500+ spaces)	3 lots (3,500+ spaces)
Ramp Metering	None	None	None	None	None
Other support facilities	park-and-pool staging lots	park-and-pool staging lots	park-and-pool staging lots	park-and-pool staging lots	park-and-pool staging lots
Bus Service	Express service	express service	express service	express service	express service

Sources:

1. Tumbull, Katherine. An Assessment of High-Occupancy Vehicle Facilities in North America: Executive Report, Texas Transportation Institute, August 1992, Table 1. General Characteristics of Operating HOV Facilities.
2. Fuhs, Charles. Inventory of Existing and Proposed High-Occupancy Vehicle Projects, June 1994.

D.3.1 Traveler Survey Results

Survey of transitways users and non-users were conducted from 1986 to 1990. Users included both bus patrons and carpool/vanpool users. Results of these surveys when compared to 1981 and 1984 data show an increase in actual and perceived use of the facility that is not at the expense of other transit modes. The survey included previous mode of travel, trip purposes, trip origin and destination, perceptions of utilization and attitudes towards the HOV lanes. From the results of the survey work, it was estimated that about 50% of the carpoolers have chosen to carpool or ride the bus since the opening of the HOV facility. A look at the results of the previous mode of travel indicate that carpoolers who previously drove alone increased from 40% in 1988 to 60% in 1990.

The following figures show the proportions of HOV drivers that came from other modes for the North and Northwest transitways. These two surveys were collected soon after the opening of the HOV lane in the Northwest Corridor or soon after the conversion of the North Transitway from 3+ to 2+ operation. Figure D-3 shows the previous modes of HOV drivers using the North Freeway in 1990. Figure D-4 shows the previous modes of HOV drivers using the Northwest Freeway in 1990.

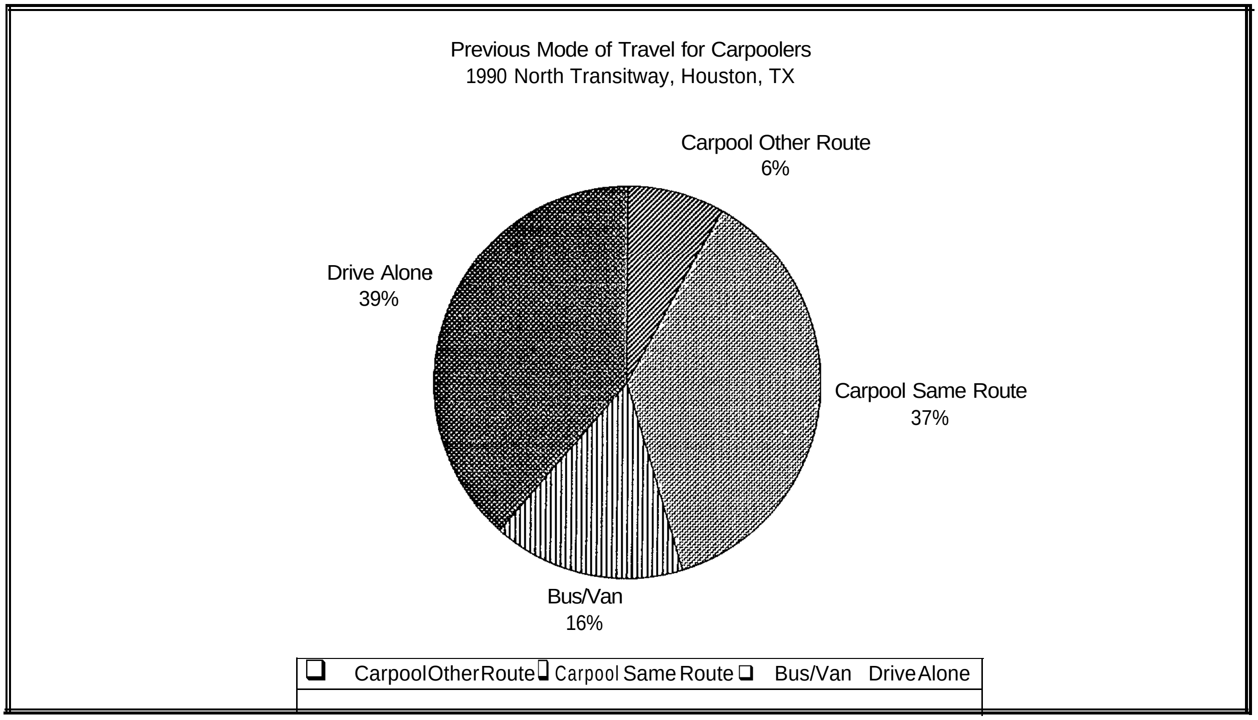

Figure D-3 Previous Mode of North Transitway Carpoolers.

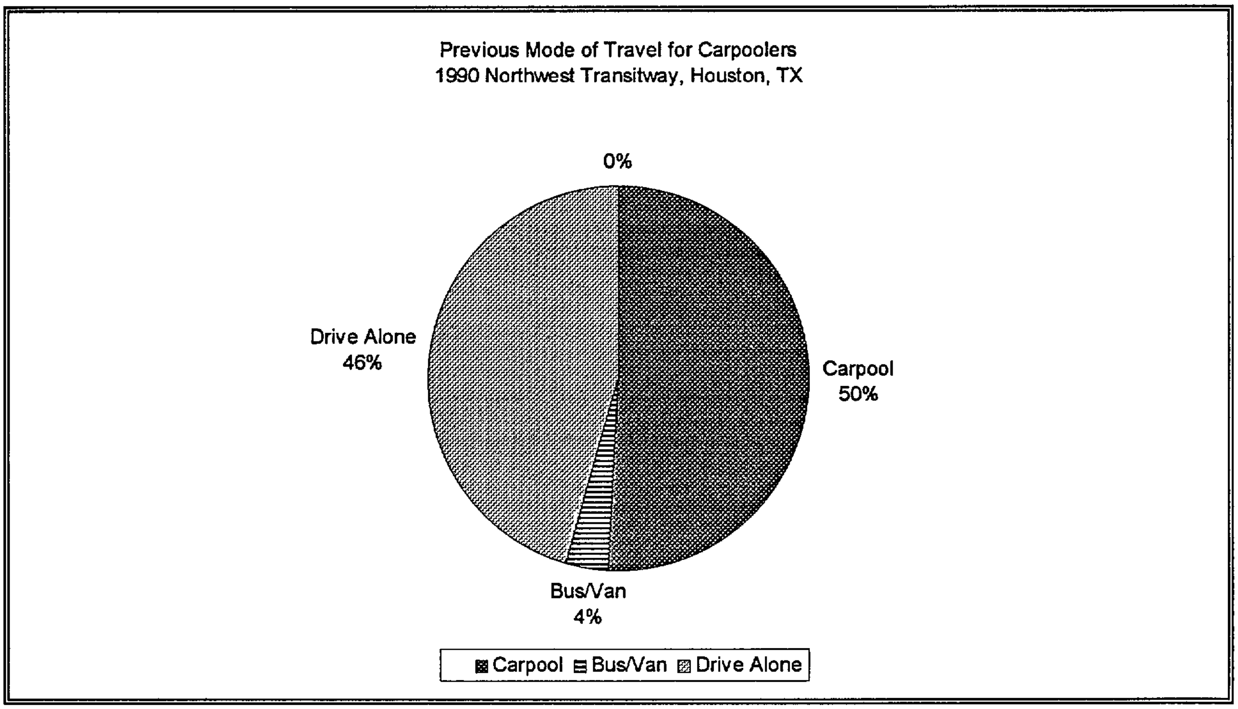

Figure D-4 Previous Mode of Northwest Transitway Carpoolers.

D.3.2 Katy Freeway (I-10 West) - Houston, Texas

The Katy Freeway HOV lane is a 13-mile, one-lane, barrier-separated, reversible facility on the west side of Houston. Access and egress are provided by both slip ramps and grade-separated, direct access ramps at five points along the corridor. Three park-and-ride lots and three park-and-pool lots are located in the corridor. The HOV lane was opened in stages between 1984 and 1990. The current hours of operation are from 5:00 am to 12:00 noon inbound and 2:00 pm to 9:00 pm outbound. The Katy transitway also operates during the weekend.

Project History

The Katy HOV facility opened in 1984 to buses and authorized vanpools exclusively (See Table D-7). Its initial length was 4.7 miles (7.6 km). In April 1985, the requirement was dropped to 4+ carpools with pre-authorization. The facility was extended another 1.7 miles (2.7 km) in May 1985. In December 1985, the requirement was dropped to 3+ carpools with prior authorization. The authorization requirement was dropped and the occupancy requirement was further reduced to 2+ in August 1986. The facility was extended another 5.1 miles (8.2 km) in June 1987. In response to a degradation in the travel times on the HOV lane, the requirement was changed in October 1988 back to 3 + occupancy during the peak morning commute period from 6:45 am to 8:15 am, while remaining at 2+ person during all other hours of operation. The facility was extended another 1.2 miles (1.9 km) in January 1990. In September 1991, the 3+ requirement was also imposed during the PM peak period from 5:00 to 6:00 pm. The Katy Transitway is the only HOV facility that changes occupancy requirements by time of day.

Selection of Before/After Data Sets

The above history suggests the following distinct HOV facility actions that could be candidates for inclusion in the methodology development database:

1. Construction of 4.7 mile Transitway October 29, 1984.

2. 4+ Carpools allowed (4/1/85).
3. HOV extended 1.7 miles (5/2/85.
4. 3+ carpools allowed (1 l/4/85).
5. 2+ carpools allowed, longer hours of operation (8/l l/86).
6. HOV extended 5.1 miles (6/29/87).
7. Longer hours of operation (7/25/88).
8. Only 3+ cat-pools allowed 6:45 AM to 815 AM, 2+ allowed other times (10/17/88).
9. HOV extended 1.2 miles (l/9/90).
10. Northwest Transit Center opens (4/l/90).
11. 3+ carpool hours changed to 6:45 AM to 8:00 AM (5/23/90).
12. Only 3+ carpools allowed 5:00 PM to 6:00 PM (9/16/91).

Actions # 5,6, 8, 9 were selected for before/after studies. Prior to action #5, every action related to a bus/Vanpool or pre-authorized HOV facility. These conditions are not comparable to the majority of the HOV facilities elsewhere in the country and therefore have not been included in the proposed new methodology database. Similarly, actions #7, 10, 11, and 12 have not been included in the before/after data set because of the lack of similar data elsewhere and the likelihood that the new methodology (being a quick response method) will not be sensitive to minor impacts caused by changes in hours of operation or the construction of a new transit center.

Data Collection

The Texas Transportation Institute (TTI) has conducted comprehensive before-and-after studies and continues to monitor the Katy and other transitways. Data includes person movements, vehicle counts, travel times, speeds, vehicle occupancy, Carpool volumes, travel behavior studies, bus service, park-and-ride utilization, and bus utilization. In the reports, the data are separated into HOV, non-HOV, and transit.

The volume counts are taken from trend line graphs of the person movements and vehicle utilization for the HOV lane and the freeway mainline.

Survey of transitways users and non-users were conducted from 1985 to 1990. Users included both bus patrons and carpool/vanpool users.

Data Reduction

Description: This data set consists of four before/after data sets showing:

A. The impacts of converting a 6.4 mile (10.3 km) median, reversible HOV lane from buses and pre-authorized 3+ carpools to 2+ carpools, with the Carpools no longer required to obtain a permit before using the lane.
B. The impacts of extending a median, reversible HOV lane (with 2+ carpools and buses allowed) by 5.0 miles (8.1 km).
C. The impacts of converting a 5.0 mile (8.1 km) long median, reversible HOV lane from 2+ carpools to 3+ Carpools.
D. The impacts of extending a median, reversible HOV lane (with 3+ carpools and buses allowed) by 1.2 miles (1.9 km).

The HOV lane is a single reversible lane located in the median of an eight lane (4 lanes each direction) freeway. The average speed over the length of the section can drop to as low as 23 mph during the peak period. Access to the HOV lane is limited to its starting and endpoints plus selected mid-points.

Travel Time Data: The earliest available travel time data was collected in 1991 for a 13 mile long segment. Travel time data was reported by 15 minute period for the entire peak period. No before and after data was available.

The SOV travel time was computed using the reported SOV average speed for 1991. Before and after SOV times were assumed to be unchanged.

The computation of before and after HOV travel times varied by action. The SOV travel times were assumed to be unaffected by each action.

Action "A" (Convert 3+ to 2+):	The HOV travel time for the HOV section was computed assuming that the HOV's moved at 55 mph. Before and after HOV times were assumed to be unchanged
Action "B" (Extend 5 miles):	The HOV travel time for the HOV lane section was computed assuming that the HOV's moved at 55 mph. Before HOV times were computed assuming that HOV's moved at the same speed as SOV's on the non-HOV lane section of the freeway.
Action "C" (Convert 2+ to 3+):	The HOV travel time for the HOV section was computed assuming that the HOV's moved at 55 mph. Before and after HOV times were assumed to be unchanged
Action "D" (Extend 1.2 miles):	The HOV travel time for the HOV lane section was computed assuming that the HOV's moved at 55 mph. Before HOV times were computed assuming that HOV's moved at the same speed as SOV's on the non-HOV lane section of the freeway.

The before/after results for each of the above four actions are shown in Table D-8, Table D-9, Table D-10, and Table D-11.

Volume Counts: Before and after AM peak hour eastbound counts were obtained for April 1986 and April 1987 respectively.

Volume counts were obtained from monthly graphs of total vehicle volumes, 2+ Carpools, 3+carpools, vans, and buses using the HOV lane and the mixed flow lanes. No truck or motorcycle data was reported. Bus passenger counts were obtained directly from the available reports. The number of single occupant vehicles using the HOV lane was reported be less than 5%, so this percentage was used to estimate the number of SOV's in the HOV lane.

Table D-7. Katy Freeway History and Characteristics

Date:	10/29/84	4/1/85	5/2/85	11/4/85	8/11/86	6/29/87	10/17/88	May 1990
Action:	Construct 4.7 miles	Allow 4+	Extend 1.7 miles	Allow 3+	Allow 2+	Extend 5.1 miles	Convert to Partial 3+	Extend 1.5 miles
Included in Before/After Data Set?	No	No	No	No	Yes	Yes	Yes	Yes
Limits	Post Oak to Gessner		Post Oak to West Belt			Post Oak to S.H. 6		S.H. 6 to Washington
# of HOV lanes	1 lane reversible							
# of general purpose lanes	3 lanes in each direction							
Length	4.7	4.7	6.4	6.4	6.4	11.5	11.5	13 miles
HOV Eligibility	Buses and vanpools	4 + carpool with authorization		3 + carpool with authorization	2 + carpool	2+ carpool	3 + (peak) and 2+ (other)	
Hours of HOV Operation	5:00 am to 12:00 noon 2:00 pm to 9:00 pm							
Type of facility	Barrier-separated, reversible							
Ramp Metering	None	None	None	None	None	None	None	None
Park-and-ride facilities	Addicks (1981)	West Belt 1,111 spaces (1984)	Kingsland 1,326 spaces (1985)				Addicks Expansion 1,155 spaces (1988)	
Other support facilities					3 "park-and-pool" staging lots			
Bus Service	Express service from park-and-ride lots and major collector routes, bus transfer centers, Northwest Transit Center (1990)							

Sources:

1. Diane L. Bullard. "Analysis of Carpool Survey Data from the Katy, Northwest, and Gulf Transitways in Houston, Texas," Transportation Research Record 1321, pp. 73-81.
2. Diane L. Bullard. A Summary of Survey Data for the Katy, North, Northwest, and Gulf Transitways, April 1985 through October 1989. Texas Transportation Institute, July 1990.
3. Montie G. Wade, Dennis Christiansen, and Daniel E. Morris. An Evaluation of the Houston High-Occupancy Vehicle Lane System. Texas Transportation Institute, Research Report 1146-5, August 1992. Appendix A.

Table D-8. Action "A", Katy Transitway Results

Action: Convert 3+ pre-authorized to 2+ unauthorized[18]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	1400	**2570**
Change in Total Vehicles"	+11%	+10%
Change in Total Persons[20]	+57%	**+41%**
Average Vehicle Occupant[21] : Before: After:	 1.48 **1.63**	 1.34 **1.42**
Change in HOV Time[22]	Save 8 minutes	Save 4 minutes
Change in SOV Time[23]	Save 0 minutes **(est.)**	Save 0 minutes (est.)

Table D-9. Action "B", Katy Transitway Results

Action: Extend HOV Facility 5.1 miles[24]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	1410	**2930**
Change in Total Vehicles	+13%	+13%
Change in Total Persons	**+9%**	**+15%**
Average Vehicle Occupancy: Before: After:	 1.63 **1.57**	 1.42 **1.45**
Change in HOV Time	Save 7 minutes	Save 3 minutes
Change in SOV Time	Save 0 minutes (est.)	Save 0 minutes (est.)

18 Data is for morning peak period (6:00 AM to 9:30 AM), eastbound direction. Before data gathered 4 months before opening, After data gathered 8 months after opening.

19 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

20 Total persons in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

21 Total persons divided by total vehicles. Includes buses and vans,

22 Mean time savings for HOV lane vehicle expressed as "Before" minus "After. Estimated from 1991 data.

23 Mean time savings for mixed flow lane drivers expressed as "before" minus "after. Estimated from 1991 data.

24 Data is for morning peak period (6:00 AM to 9:30 AM), eastbound direction. Before data gathered 3 months before opening, After data gathered 9 months after opening.

Table D-l 0. Action "C", Katy Transitway Results

Action: Convert 2+ to 3+ during peak of peak period[25]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	880	1930
Change in Total Vehicles[26]	+6%	+11%
Change in Total Persons[27]	+8%	+10%
Average Vehicle Occupant[28].		
Before:	1.57	1.45
After:	1.61	1.43
Change in HOV Time[29]	Lose 14 minutes	Lose 7 minutes
Change in SOV Time[30]	Save 0 minutes (est.)	Save 0 minutes (est.)

Table D-l 1. Action "D", Katy Transitway Results

Action: Extend HOV facility 1.5 miles (1.2 miles in eastbound direction, 1.5 miles in westbound direction)[31]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	1160	2830
Change in Total Vehicles	+8%	+4%
Change in Total Persons	+11%	+7%
Average Vehicle Occupancy		
Before:	1.61	1.43
After:	1.64	1.47
Change in HOV Time[32]	Save 1 minutes	Save 0 minutes
Change in SOV Time	Save 0 minutes (est.)	Save 0 minutes (est.)

25 Data is for morning peak period (6:00 AM to 9:00 AM), eastbound direction. Before data gathered 6 months before opening, After data gathered 6 months after opening.

26 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

27 Total persons in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

28 Total persons divided by total vehicles. Includes buses and vans.

29 Mean time savings for 2 person HOV vehicles expressed as "Before" minus "After. Estimated from 1991 data. Lost time reflects that 2 person HOV's now must use mixed flow lanes.

30 Mean time savings for mixed flow lane drivers expressed as "before" minus "after. Estimated from 1991 data.

31 Data is for morning peak period (6:00 AM to 9:30 AM), eastbound direction. Before data gathered 8 months before opening, After data gathered 4 months after opening.

32 Mean time savings for HOV lane vehicle expressed as "Before" minus "After. Estimated from 1991 data. Rounded to nearest whole minute.

D.3.3 North Freeway (I-45) - Houston, Texas

The North Freeway serves the rapidly growing northern Harris County and Montgomery County to the north of downtown Houston. The North Freeway HOV lane is a 13.5-mile barrier-separated, reversible facility in the median of I-45 North. The HOV lane can be accessed at six points along the corridor. The HOV lanes are in operation from 5:00 am to 12:00 noon inbound and 2:00 pm to 9:00 pm outbound. The current facility is restricted to vehicles with two or more persons. Four park-and-ride lots are located in the vicinity of the HOV facility.

Project History

The original HOV lane on I-45 North was a 9.1 mile (14.7 km) contraflow facility that opened in August 1979 (see Table D-12). The contraflow facility was intended as an interim improvement until the flows in the off-peak direction gained enough to offset the initial 70 to 30 directional split. Travel time savings of 15 minutes were realized on the contraflow facility. After one year of operation, the peak period passenger trips increased from 1,450 to 4,600.

The contraflow facility operated through-out construction of the transitway, from January to November 1984, when it was replaced by a 9.1 mile reversible flow lane in the median (the transitway).

Between June 1987 and June 1988 the freeway was widened from 3 to 4 mixed-flow lanes in each direction.

The transitway was extended 4.4 miles (7.1 km) in April 1990.

Two person Carpools were allowed on the transitway on June 26, 1990.

Plans call for extending the HOV lane further north to FM 1960. Once completed the North Freeway HOV lane will extend from downtown Houston to FM 1960 for a total of 19.7 miles.

Selection of Before/After Data Sets

The following actions were identified for this facility:

1. Construction of Contraflow lanes (8/29/79).
2. Replacement with reversible flow lane in median (1 l/23/84).
3. Extension of 4.4 miles (4/2/90).
4. 2+ carpools allowed (6/26/90).

All of these actions, except for the last action, applied when the transitway operated as abusway with Vanpools allowed. The last action, allowing 2+ Carpools, is equivalent to opening a new HOV lane in most other states. Consequently, only the last action of allowing 2+ Carpools will be included in the methodology development database.

Data Collection

The data collected for the North Freeway focuses on the barrier separated HOV facility. Limited data is available for the contraflow facility. Similar to the data for the Katy Freeway, the data for the North Freeway include person movements, vehicle counts, travel times, speeds, vehicle occupancy, Carpool volumes, travel behavior studies, bus service, park-and-rode utilization, and bus utilization.

The data collection effort did not include the contraflow and concurrent flow facilities that were in place prior to the construction of the barrier-separated, reversible flow lane in the median. Limited pre-contraflow "before" condition data is available since the data was not collected prior to the opening of the contraflow facility in 1979.

The volume counts are taken from trend line graphs of the person movements and vehicle utilization for the HOV lane and the freeway mainline. Both A.M. and P.M. peak hour and peak period data are available.

Data Reduction

Description: This data set shows the impacts of converting a 13.5 mile (2 1.7 km) median, reversible HOV lane from buses and pre-authorized 3+ carpools to 2+ car-pools, with the Carpools no longer required to obtain a permit before using the lane. The HOV lane is a single reversible lane located in the median of an eight lane (4 lanes each direction) freeway. The average speed over the length of the section can drop to as low as 37 mph during the peak period.

The conversion took effect June 26, 1990.

Access to the HOV lane is limited to its starting and endpoints plus few points in between.

Travel Time Data: The earliest available travel time data was collected in 1991 for a 13 mile long segment. Travel time data was reported by 15 minute period for the entire peak period. No before data was available.

The HOV travel time for the HOV section was computed assuming that the HOV's moved at 55 mph. Before and after HOV times were assumed to be unchanged.

The SOV travel time was computed using the reported SOV average speed for 199 1. Before and after SOV times were assumed to be unchanged.

Volume Counts: Before and after AM peak hour south-eastbound counts were obtained for May 1990 and May 1991 respectively.

Volume counts were obtained from monthly graphs of total vehicle volumes, 2+ Carpools, vans, and buses using the HOV lane. Only total vehicle and person volumes were available for the mixed flow lanes (no breakdown by occupancy). The split between 2, 3, and 4+ Carpools was estimated assuming 90% 2-person, 9% 3-person, and 1% 4+person (similar to the Katy freeway observations). No van data was reported.

No truck or motorcycle data was reported.

Bus passenger counts were obtained directly from the available reports.

The number of single occupant vehicles using the HOV lane was assumed to be 5% of the HOV volume.

Table D-13 summarizes the results of the before/after study.

Sources

1. Diane L. Bullard. "Analysis of Carpool Survey Data from the Katy, Northwest, and Gulf Transitways in Houston, Texas," Transportation Research Record 132 1, pp. 73-8 1.
2. Diane L. Bullard. A Summary of Survey Data for the Katy, North, Northwest, and Gulf Transitways, April 1985 through October 1989. Texas Transportation Institute, July 1990.
3. Hana M. Kuo. The North Freeway Transitway: Evaluation of the First Year of Barrier-Separated Operation. Texas Transportation Institute, Research Report 339-9, February 1987.
4. Montie G. Wade, Dennis Christiansen, and Daniel E. Morris. An Evaluation of the Houston High-Occupancy Vehicle Lane System. Texas Transportation Institute, Research Report 1146-5, August 1992. Appendix "B".

Table D-12. North Freeway HOV Facility History and Characteristics

Characteristic	North Freeway HOV System			
Date:	Aug 79	Nov 84	Apr 90	Jun 90
Action:	Construct Contra-flow Lane	Construct Reversible Lane	Extend 4.4 miles	Convert to 2+
Include in Before/After Data Set	No	No	No	Yes[33]
Corridor	Downtown to N. Shepherd Dr.	Downtown to N. Shepherd Dr.	Downtown to Beltway 8	Downtown to Beltway 8
# of HOV lanes	1	1	1	1
# of gen. purpose lanes		4 in each dir.	4 in each dir.	4 in each dir.
Length	9.6	9.6	13.5	13.5
HOV Eligibility	buses and 8+ vanpools only			2+ pools
Hours of HOV Operation	6 to 8:30 am 4 to 6:30 pm	6 to 8:30 am 4 to 6:30 pm	5 am to 12 noon 2 pm to 9 pm	5 am to 12 noon 2 pm to 9 pm
Type of facility	contraflow	barrier separated reversible	barrier separated reversible	barrier separated reversibl
Ramp Metering	yes, for off- peak dir. flow	None	None	None
Park-and-ride facilities	Champions (8/79 - 10/82) Greenspoint (8/79 - 11/79) Aldine Stad. (11/79 - 1/80) N. Shepherd (750 spaces) Kuykendahl (1,300 spaces)	N.Shepherd Expansion (1,605 total spaces) Spring (1,280 spaces) Kuykendahl Expansion (2,256 total spaces) Seton Lake (1,286 spaces)		Woodlands Expansion (1991)
Bus Service	Increase bus service	No dramatic increase in additional service		

33 All actions prior to conversion to 2+ operation excluded from database because they apply only to busway (with vans) operation. Bus patronage and frequency forecasting requires different methodology than for 2+ carpools.

Table D-13. North Transitway Results

Action: Convert to 2+ Carpool operation[34]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	830	-
Change in Total Vehicles[35]	-3%	%
Change in Total Persons[36]	+7%	- %
Average Vehicle Occupancy[37]: Before: After:	 1.45 1.60	
Change in HOV Time[38]	Save 6 minutes	Save 0 minutes
Change in SOV Time[39]	Save 0 minutes (est.)	Save 0 minutes (est.)

34 Data is for morning peak period (6:00 AM to 8:45 AM), southbound direction. Before data gathered 1 month before opening, After data gathered 11 months after opening.

35 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

36 Total persons in peak direction in all vehicles, in ail lanes expressed as "After" minus "before", divided by "before".

37 Total persons divided by total vehicles. Includes buses and vans.

38 Mean time savings for HOV lane vehicle expressed as "Before" minus "After. Estimated from 199 1 data. Rounded to nearest whole minute.

39 Mean time savings for mixed flow lane drivers expressed as "before" minus "after. Estimated from 1991 data.

D.3.4 Northwest Freeway (US 290) - Houston, Texas

The Northwest Freeway HOV lane is a 13.5-mile, one-lane, barrier-separated, reversible facility on the north side of Houston. The HOV lane was opened in 1988 to vehicles with two or more occupants. Access and egress are provided by both skip ramps and direct access ramps at six points along the corridor. The hours of operation are from 4:00 am to 1:00 pm inbound and 2:00 pm to 10:00 pm outbound.

Project History

The first 9.5 mile (15.3 km) segment of the transitway opened on August 29, 1988 (see Table D-14). The lane was extended 4 miles on February 6, 1990. It has always operated as a 2+ person carpool facility.

Selection of Before/After Data Sets

The opening of the new transitway in August 1988 was selected for inclusion in the methodology development database. The later extension of the transitway occurred within two months of the opening of the Northwest Transit Center which would have confused the results. Consequently this latter action was not included in the database.

Data Collection

The Texas Transportation Institute (TTI) has conducted comprehensive before-and-after studies and continues to monitor the Northwest and other transitways in Houston. Data includes person movements, vehicle counts, travel times, speeds, vehicle occupancy, car-pool volumes, travel behavior studies, bus service, park-and-ride utilization, and bus utilization. In the reports, the data are separated into HOV, non-HOV, and transit.

Vehicle count data is available for the Hempstead Highway which parallels the Northwest Freeway along the railroad tracks from downtown Houston. This is one of the parallel facilities for which data is collected.

The volume counts are taken from trend line graphs of the person movements and vehicle utilization for the HOV lane and the freeway mainline. Both A.M. and P.M. peak hour and peak period data are available.

Data Reduction

Description: This data set shows the impacts of constructing a 9.5 mile (15.3 km) median, reversible HOV lane (with 2+ carpools and buses allowed). The HOV lane is a single reversible lane located in the median of an six lane (3 lanes each direction) freeway. The average speed over the length of the section can drop to as low as 30 mph during the peak period.

Access to the HOV lane is limited to its starting and endpoints and a few other points.

Travel Time Data: The earliest available travel time data was collected in 1991 for a 13 mile long segment. Travel time data was reported by 15 minute period for the entire peak period. No before and after data was available.

The HOV travel time for the HOV lane section was computed assuming that the HOV's moved at 55 mph. Before HOV times were computed assuming that HOV's moved at the same speed as SOV's on the non-HOV lane section of the freeway.

The SOV travel time was computed using the reported SOV average speed for 199 1 Before and after SOV times were assumed to be unchanged.

Volume Counts: Before and after AM peak hour southbound counts were obtained for April 1989 and April 1990 respectively.

Volume counts were obtained from monthly graphs of total vehicle volumes, 2+ carpools, vans, and buses using the HOV lane. Only total vehicle and person volumes were available for the mixed flow lanes (no breakdown by occupancy). The split between 2, 3, and 4+ carpools was estimated assuming 90% 2-person, 9% 3-person, and 1% 4+person (similar to the Katy freeway observations). No van data was reported.

No truck or motorcycle data was reported.

Bus passenger counts were obtained directly from the available reports.

The number of single occupant vehicles using the HOV lane was assumed to be zero.

The results of the before/after study are summarized in Table D-15

Sources

1. Diane L. Bullard. "Analysis of Carpool Survey Data from the Katy, Northwest, and Gulf Transitways in Houston, Texas," Transportation Research Record 1321, pp. 73-81.
2. Diane L. Bullard. A Summary of Survey Data for the Katy, North, Northwest, and Gulf Transitways, April 1985 through October 1989. Texas Transportation Institute, July 1990.
3. Montie G. Wade, Dennis Christiansen, and Daniel E. Morris. An Evaluation of the Houston High-Occupancy Vehicle Lane System. Texas Transportation Institute, Research Report 1146-5, August 1992. Appendix "D".

Table D-14. Northwest Freeway HOV Facility History and Characteristics

Characteristic	Northwest Freeway HOV System	
Date:	8/29/88	2/6/90
Action:	Construct HOV lane	Extend HOV lane 4 miles
Included in Before/After Data Set?	Yes	No[40]
Limits:	Northwest Transit Center to Little York	Northwest Transit Center to FM 1960
# of HOV lanes	1	1
# of general purpose lanes	3 lanes in each direction	3 lanes in each direction
Length	9.5	13.5
HOV Eligibility	2+	2+
Hours of HOV Operation	4:00 am to I:00 pm inbound 2:00 pm to 10:00 pm outbound	4:00 am to 1:00 pm inbound 2:00 pm to 10:00 pm outbound
Type of facility	barrier separated reversible	barrier separated reversible
Ramp Metering	None	None
Park-and-ride facilities	Northwest Station (1984) W. Little York (1988) Pinemont (1989)	Northwest Station Modification (1990)
Bus Service	Northwest Transit Center opened 4/l/90	

[40] Excluded because transit center also opened within 2 months of HOV lane extension.

The HOV peak hour volume breakdown by occupancy was estimated based upon the mixed flow occupancy data, assuming that motorcycles, trucks, and buses in the lanes could be neglected. Single occupant vehicle use of the HOV lanes was also assumed to be negligible based upon the reported 1.5% violation rate.

The distribution of volumes by vehicle occupancy and vehicle type was assumed to be identical for the peak period and the peak hour. (However, the necessary data was reported by 15 minute period, should it be desirable to check this assumption)

Bus passenger counts were reported only on a daily basis for buses using the HOV lanes. This daily ridership was assumed to occur totally in the peak period. The peak period ridership was divided by 2 to obtain peak hour ridership. The ridership was then assigned to the HOV lanes and the mixed flow lanes in proportion to the number of buses using each facility.

The number of single occupant vehicles using the HOV lane was assumed to be zero.

Table D-19 summarizes the results of the before/after study.

Sources:

J.S. Supernak. Assessment of the Effectiveness of the Reversible Roadway for High Occupancy Vehicles on Interstate Route 15. San Diego State University, Department of Civil Engineering, San Diego, California, May 1991,

Part 2 - Volume/Occupancy Study,

Part 3 - Speed/Delay Study,

Part 6 - Bus Study.

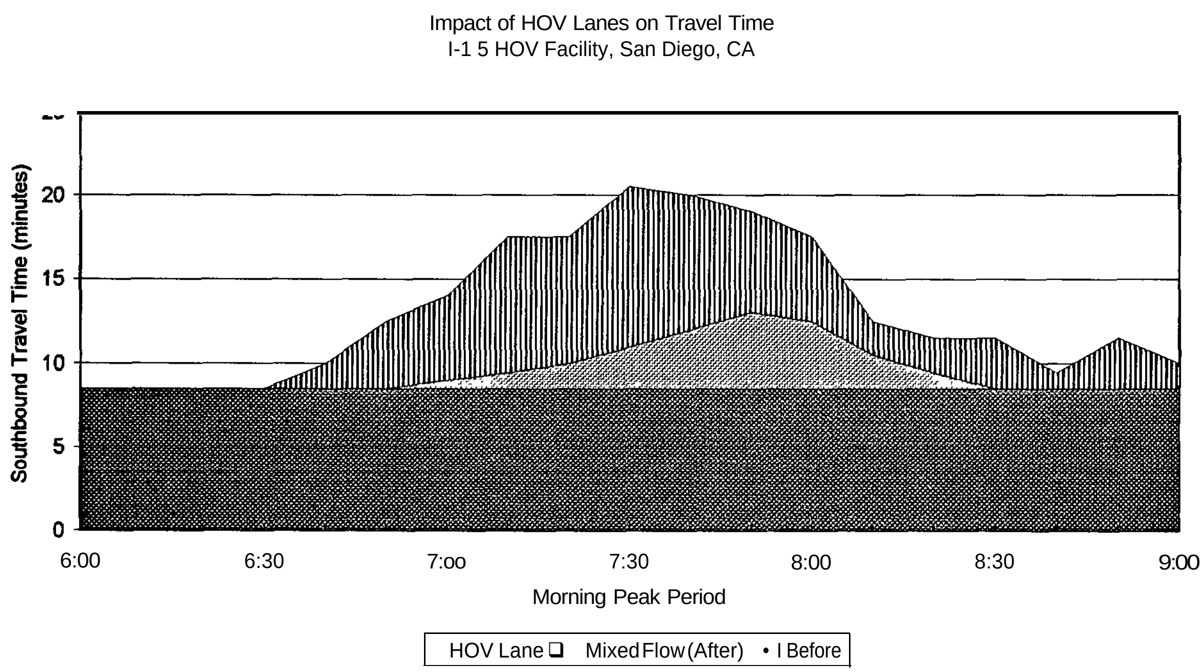

Figure D-5. Impact of HOV Lanes on Travel Time

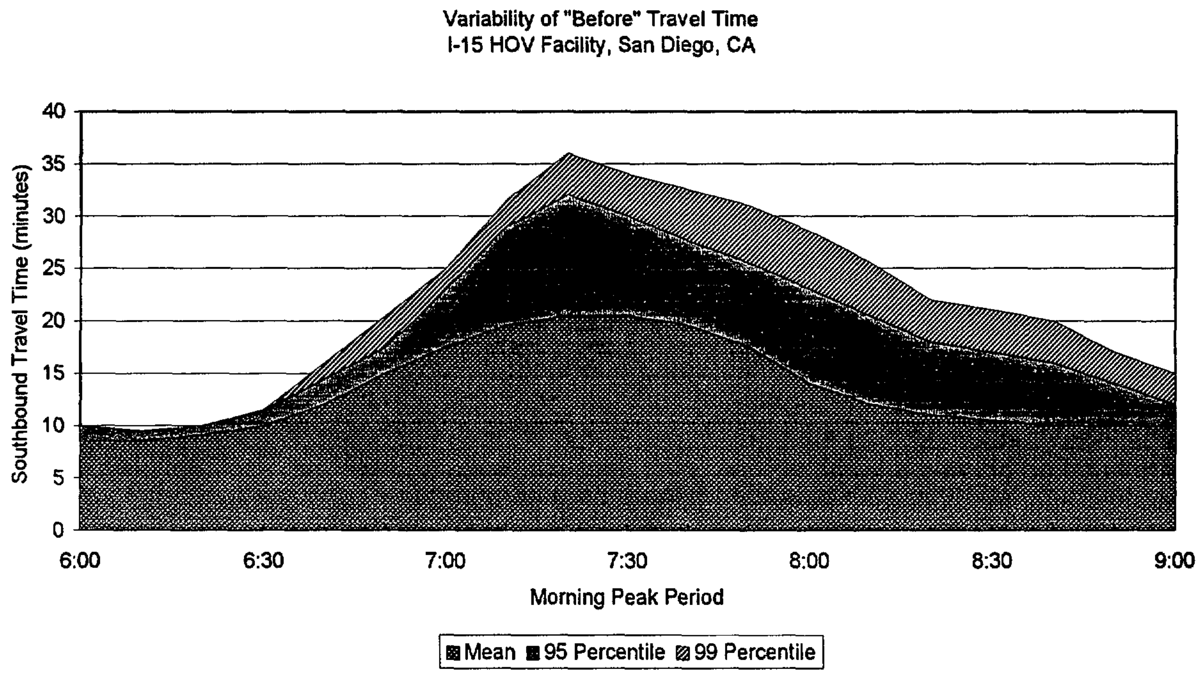

Figure D-6. Variability of "Before" Travel Time

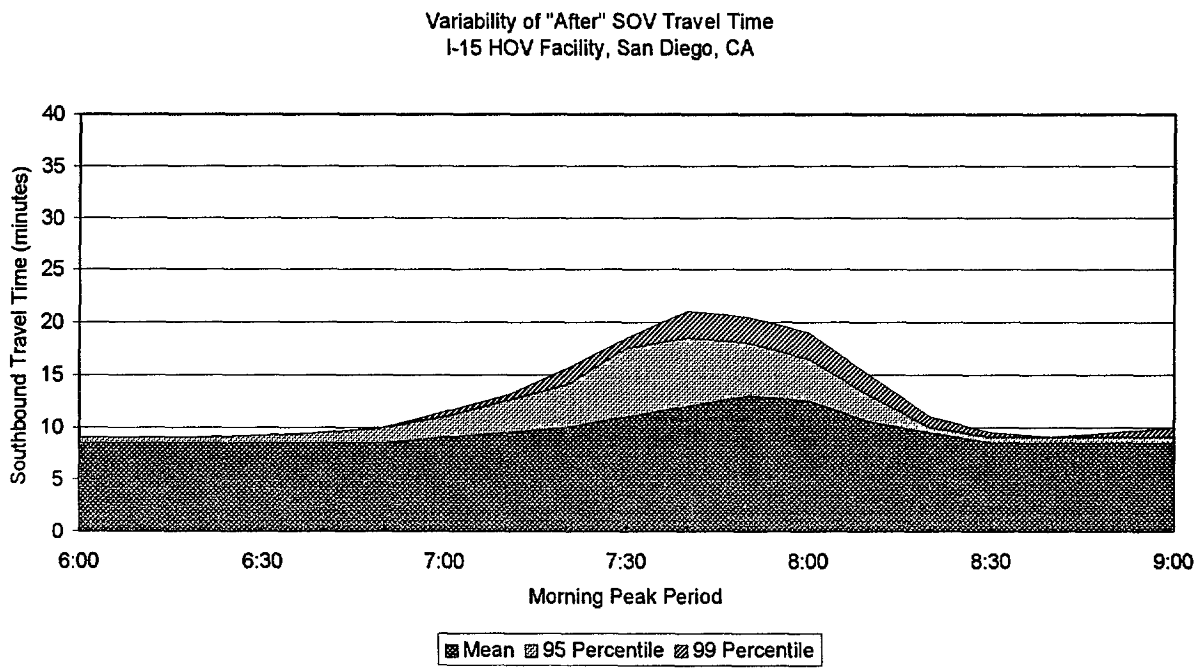

Figure D-7. Variability of "After" SOV Travel Time

Table D-15. Northwest Transitway Results

Action: Construct 9.5 mile reversible HOV lane[41]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	670	820
Change in Total Vehicles[42]	+16%	13%
Change in Total Persons[43]	+26%	16%
Average Vehicle Occupancy[44]: Before: After:	 1.17 1.27	 1.17 1.19
Change in HOV Time[45]	Save 4 minutes	Save 4 minutes
Change in SOV Time[46]	Save 0 minutes (est.)	Save 0 minutes (est.)

41 Data is for morning peak period (6:00 AM to 9:30 AM), southbound direction. Before data gathered 4 months before opening, After data gathered 8 months after opening.

42 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

43 Total persons in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

44 Total persons divided by total vehicles. Includes buses and vans.

45 Mean time savings for HOV lane vehicle expressed as "Before" minus "After. Estimated from 199 1 data. Rounded to nearest whole minute.

46 Mean time savings for mixed flow lane drivers expressed as "before" minus "after. Estimated from 1991 data.

D.4 CALTRANS - LOS ANGELES AND SAN D/EGO

Caltrans District 7, 12, and 11 are responsible for HOV facilities on state highways in Los Angeles County, Orange County, and San Diego County, respectively.

Caltrans District 7 has been operating HOV lanes since 1973 and currently operates 5 HOV facilities in Los Angeles area. The HOV facilities range from barrier separated lanes to concurrent freeway lanes. The facilities require 2 or more persons to be eligible for the HOV lanes. All facilities operate 24 hours for 7 days a week. Virtually all ramps in the Los Angeles metropolitan area have been metered.

Table D-16, Table D-17, and Table D-18 summarize the HOV facility characteristics for Districts 7, 11, and 12.

A rider match service program is provided by consultants or Orange County Transportation Association (OCTA).

The HOV Operations Branches of Districts 7, 11, and 12 are responsible for data collection. Vehicle counts and vehicle occupancy rates are available for both HOV lanes and mixed flow traffic.

Before/after study reports are available for I-2 10 and SR-9 1 HOV facilities. Unpublished before/after data is available for the I-210, I-405, Rte. 55, and Rte. 91. Additional before/after data is available for the I-10 Santa Monica and the I-10 El Monte facilities. No "before" data for I-105 (Century Freeway) exists since the facility opened with HOV lanes already in place.

An extensive before and after analysis was conducted by District 11 of the I-15 HOV facility in the San Diego Metropolitan Area. Several reports have been published on this facility.

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Table D-16. Caltrans District 7 - Freeway HOV Facilities

Characteristics	Caltrans District 7				
Corridor	I-10 El Monte	I-405 LA	SR91 LA	I-105 LA	I-210 LA
Begin and End	Alameda to Baldwin	Bellflower to SR605 (SB); SR110 to Century	SR110 to SR605	Century Fwy to SR605	Rte 134 to Sunflower
# of Directional HOV lanes	2	2	2	2	2
Length (lane-mi.)	23	24.6	18.9	33.2	37.0
Date Operational	73	93	85/93	93	93
HOV Eligibility	3+	2+	2+	2+	2+
Hours of HOV Operation	24 hours (7-day)	24 hours (7-day)	24 hours (7-day)	24 hours (7-day)	24 hours (7-day)
Type of facility	barrier/pylon separat-ed two-way	striped concurrent each dir.	striped concurrent each dir.	barrier separated two-way	striped concurrent each dir.

Table D-17. Caltrans District 11 Freeway HOV Facility Characteristics

Characteristics	Caltrans District 11			
Corridor	I-15	SR 163	SR 75	I-5
Begin and End	SR 163 to North City Parkway	"A" Street to I-5	Coronado Bridge Toll Plaza	U.S. Port of Entry from Mexico
# of Directional HOV lanes	2	1	1	4
Length (lane-mi.)	19.6	0.4	0.1	0.1
Date Operational	October 1988	December 1975	?	June 1991
HOV Eligibility	2+	Buses Only	2+	4+
Hours of HOV Operation	6-9 AM (S/B) 3-6 PM (N/B)	24 hours (7-day)	24 hours (7-day)	24 hours (Mon-Fri)
Type of facility	reversible, barrier separated	striped concurrent, one direction	striped concurrent, one direction	striped concurrent, one direction

Table D-18. Caltrans District 12 Freeway HOV Facility Characteristics

Characteristics	Caltrans District 12			
Corridor	Rte. 55	I-405	I-5	Rte. 57
Begin and End	Costa Mesa to Rte. 91	I-5 to LA Co.	I-405 to Rte. 55	I-5 to LA Co.
# of Directional HOV lanes	2	2	2	2
Length (lane-mi.)	24.6	48.0	18.0	23.8
Date Operational	November 1985	April 1990	October 1992	June 1992
HOV Eligibility	2+	2+	2+	2+
Hours of HOV Operation	24 hours	24 hours	24 hours	24 hours
Type of facility	left side concurrent, buffer separated	left side concurrent, buffer separated	left side concurrent, buffer separated	left side concurrent, buffer separated

Note: All facilities are left side unless otherwise noted.

Sources:

Charles Fuhs Inventory of Current and Proposed High-Occupancy Vehicle Projects in the U.S. and Canada, January 1995.

Caltrans, California Existing, HOV Lanes, May 26, 1994.

D.4.1 I-15 HOV Facility - San Diego, California

The I-l 5 HOV Facility in the San Diego Metropolitan Area is $3 1.5 million, eight mile long pair of reversible lanes constructed in the median of the I-15 freeway. The project was opened to traffic in October 1988.

The facility is accessible only at each end. There are 5 interchanges between the starting and end points of the facility that cannot access the HOV facility.

The lanes operate in the southbound direction during the morning commute between the hours of 6 AM and 9 AM. They operate in the northbound direction between 3 PM and 6 PM. Carpools (2+ persons) vanpools, buses and motorcycles are allowed to use the facility during these hours. The facility is closed during the remainder of the day.

Project History

No changes have been made in length or operating hours since the facility's opening. Ramp metering was not present at the time of the before/after studies, but ramp metering has since been installed.

Selection of Before/After Data Set

The opening of the facility was selected for the methodology development database.

Data Collection

All date was obtained from the California State University reports written by Dr. Janusz C. Supemak.

Data Reduction

Description: This data set shows the impacts of constructing an 8.0 mile (12.9 km) median, reversible pair of HOV lanes (with 2+ carpools and buses allowed). The HOV facility consists of 2 reversible lanes located in the median of an eight lane (4 lanes each direction) freeway. The average speed of the mixed flow lanes, over the length of the section, can drop to as low as 24 mph during the peak period.

The HOV facility opened October 20, 1988. Access to the HOV lane is limited to its starting and endpoints.

Travel Time Data: Before and after travel time is reported by 10 minute interval for the AM peak period. No corrections were required.

Figure D-5 shows the impact of adding an HOV lane on the peak period travel times for the mixed flow lanes. There is a significant reduction in both average delay and peak delay.

Figure D-6, and Figure D-7 show how adding an HOV lane not only reduces the average travel time and peak travel time on mixed flow lanes on a given day, but also significantly reduces the likelihood of larger delays over several days. The 99 percentile travel times (99% of the floating car runs over several days are below the 99 percentile value) for mixed flow lanes drops significantly after the addition of the HOV lane.

Volume Counts: Before and after AM peak hour eastbound counts were obtained for May 1988 and May 1989 respectively. Later data for 1990 is also available but not reported here.

Volume counts were obtained for HOV's and SOV's for both the HOV lanes and for the mixed flow lanes. These counts however did not break down the volumes by occupancy nor by vehicle type (motorcycle, truck, bus, etc.). AM peak period traffic counts classified by occupancy and vehicle type are provided in an appendix for the mixed flow lanes, but not the HOV lanes.

D.4.2 I-210 Pasadena

The I-210 Foothill Freeway HOV facility is an 18.5 mile long (29.6 km) pair of left side concurrent flow HOV lanes between State Route 134 in Pasadena and Sunflower Avenue in Glendora.

Project History

The project opened in stages between November 1993 and January 1994. Ramp metering was present before and after the project opening.

Data Collection

Before/After dam for this facility was obtained from Caltrans District 7 offices and Systan files. The before study was conducted in July 29, 1993, approximately 5 months before the project was completed and fully opened. The after study was conducted in July 19, 1994, about 7 months after the project was fully opened. Data is available only for the peak hour.

Data Reduction

Description The data set shows the impacts of constructing 18.5 miles (29.6 km) of HOV lanes in each direction. The HOV lanes are located on the left side in each direction and are separated from the mixed flow lanes by a 2 to 3 foot (60 to 90 cm) striped buffer.

Travel Time Data: The data shows a significant reduction in travel times for both the HOV lanes and the mixed flow lanes.

Volume Counts: Vehicle and passenger volumes are reported by vehicle occupancy (SOV, 2, and 3+) and for motorcycles. Count data is not reported separately for buses, vans, trucks. Motorcycle volumes were not reported for the before condition. The breakdown between 3 person HOV and 4+ HOV was estimated based upon the number of persons reported for 3+ HOV's.

D.4.3 Route 91 Los Angeles

The Route 91 Artesia Freeway HOV facility is an 10.5 mile long (16.8 km) left side concurrent flow HOV lane in the westbound direction between I-l 10 in Gardena and I-605 in Bellflower., and an 8 miles (12.8 km) long eastbound concurrent flow lane between Central Avenue in Compton and I-605 in Bellflower.

Project History

The eastbound lane opened in June 10, 1985. The westbound lane opened in March 1, 1993. Ramp metering was present before and after the project opening.

Data Collection

Before/After data for this facility was obtained from Caltrans District 7 offices and Systan files.

The before study for the eastbound lane was conducted in April 1985, approximately 2 months before the project was opened. The after study was conducted in April 1986, about 10 months after the project was opened. Data is available only for the peak hour.

Data Reduction

Description: The data set shows the impacts of two separate actions: the construction of an 8 mile (12.8 km) long HOV lane in the eastbound direction, and a 10.5 mile (16.8 km) long HOV lane in the westbound direction eight

Table D-19. I-15 San Diego HOV Results

Action: Construct 8.0 mile reversible pair of HOV lanes[47]		
	Peak Hour	**Peak Period**
HOV Lane Volume (After)	**2448**	**4786**
Change in Total Vehicles[48]	**+38%**	**+11%**
Change in Total Persons[49]	**+41%**	**+19%**
Average Vehicle Occupancy[50]:		
Before:	1.31	1.22
After:	1.34	1.31
Change in HOV Time[51]	Save 10 minutes	Save 6 minutes
Change in SOV Time[52]	Save 7 minutes	Save 4 minutes

47 Data is for morning peak period (6:00 AM to 9:00 AM), southbound direction. Before data gathered 5 months before opening, After data gathered 7 months after opening.

48 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

49 Total persons in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

50 Total persons divided by total vehicles. Includes buses and vans.

51 Mean time savings for HOV lane expressed as "Before" minus "After. Rounded to nearest whole minute.

52 Mean time savings for mixed flow lane drivers expressed as "before" minus "after.

years later. The HOV lanes are located on the left side in each direction and are separated from the mixed flow lanes by a 2 foot (60 cm) striped buffer.

Travel Time Data: The data shows a significant reduction in travel times for both the HOV lanes and the mixed flow lanes.

Volume Counts: The westbound vehicle and passenger volumes are reported by vehicle occupancy (SOV, 2, and 3+) and for motorcycles. Bus and 4+ HOV count data is reported for the HOV lane but not the mixed flow lanes, and not for the 'before" condition. Count data is not reported separately for trucks. Motorcycle volumes were not reported for the before condition. The breakdown between 3 person HOV and 4+ HOV for the before condition was estimated based upon the number of persons reported for 3+ HOV's.

The eastbound count data is reported only for SOV's and HOV's. there is no further subcategorization of the HOV's by occupancy type. Truck, bus, and motorcycle volumes were not reported.

D.4.4 Route 55 Orange County

The -210 Foothill Freeway HOV facility is an 18.5 mile long (29.6 km) pair of left side concurrent flow HOV lanes between State Route 134 in Pasadena and Sunflower Avenue in Glendora.

Project History

The project opened in stages between November 1993 and January 1994. Ramp metering was present before and after the project opening.

Data Collection

Before/After data for this facility was obtained from Caltrans District 7 offices and Systan files. The before study was conducted in July 29, 1993, approximately 5 months before the project was completed and fully opened. The after study was conducted in July 19, 1994, about 7 months after the project was fully opened. Data is available only for the peak hour.

Data Reduction

Description The data set shows the impacts of constructing 18.5 miles (29.6 km) of HOV lanes in each direction. The HOV lanes arc located on the left side in each direction and are separated from the mixed flow lanes by a 2 to 3 foot striped buffer.

Travel Time Data: The data shows a significant reduction in travel times for both the HOV lanes and the mixed flow lanes.

Volume Counts: Vehicle and passenger volumes are reported by vehicle occupancy (SOV, 2, and 3+) and for motorcycles. Count data is not reported separately for buses, vans, trucks. Motorcycle volumes were not reported for the before condition. The breakdown between 3 person HOV and 4+ HOV was estimated based upon the number of persons reported for 3+ HOV's.

D.4.5 I-10 Santa Monica

The I-10 Santa Monica Freeway HOV facility was a 12.0 mile long (19.2 km) pair of concurrent flow HOV lanes formed by converting two existing mixed flow lanes (one in each direction) in the City of Los Angeles. This project is not listed in the table of Caltrans District 7 HOV projects because it is no longer active.

Project History

The project opened March 15, 1976. The increased congestion caused by the lane conversion was very controversial and resulted in the reconversion of the HOV lanes back to mixed flow use about a year after the original conversion. Ramp metering was present before and after the project opening.

Data Collection

Before/After data for this facility was obtained from Caltrans District 7 offices and Systan files. The before study was conducted October 1975, approximately 5 months before the project opened. The after study data was collected over a three month period between June and August 1976. Data is available only for the peak period.

Data Reduction

Description The data set shows the impacts of converting one mixed flow lane in each direction to an HOV lane.

Travel Time Data: The data shows an increase in travel times for SOV's and a decrease for HOVs.

Volume Counts: Vehicle and passenger volumes are reported by vehicle occupancy only for SOV+2HOV, 3+ HOV and bus. Count data is not reported separately for vans, and trucks. The breakdown between 1 person, 2 person, 3 person and 4+ person vehicles was estimated based upon the number of persons reported for 3+ HOV's and "non-3+ HOV's".

D.4.6 I-10 El Monte

The I-10 San Bernardino Freeway (El Monte Busway) HOV facility is an 11 mile long (17.6 km) partially separated HOV/Busway facility between I-605 and Downtown Los Angeles.

Project History

The project opened originally as a busway Three plus HOV's were allowed to use the busway in October 1976. Ramp metering was present before and after the project opening.

Data Collection

Before/After data for this facility was obtained from Caltrans District 7 offices and Systan files. The before study was conducted in October 1976, the same month the facility was opened to Carpools. The after study was conducted in November 1, 1977, about 13 months after the project was opened to Carpools. Data is available only for the peak period.

Data Reduction

Description: The data set shows the impacts of opening a 11 mile (17.6 km) long busway to Carpools.

Travel Time Data: The data shows a reduction in travel times for HOV's and a slight increase in travel times for the mixed flow lanes that may be due to general increase in mixed flow volumes over the year.

Volume Counts: Vehicle and passenger volumes are reported by vehicle occupancy (SOV, 2, and 3+) and for buses. Count data is not reported separately for motorcycles, vans, trucks. The breakdown between 3 person HOV and 4+ HOV was estimated based upon the number of persons reported for 3+ HOV's.

D.5 WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

The Washington State Department of Transportation currently operates 62 lane-miles (100 lane-km) of HOV lanes on three interstate highways and six state routes in the Seattle metropolitan area. The HOV system in the Seattle area is shown in Figure D-8. Seattle also has HOV lanes on a few arterial streets and HOV bypass lanes at some metered freeway ramps.

The HOV lanes are part of a larger HOV system including park-and-ride lots, transit centers, transit service improvements, rideshare programs, and TDM programs. The Washington State Department of Transportation has a policy for the freeway HOV system of improving the capability of freeway corridors to move more people by increasing the number of persons per vehicle, providing travel time savings and reliability for HOV's, and providing safe travel options for HOV's and mixed-flow traffic.

Most of the HOV lanes in the Seattle area are concurrent flow facilities allowing continuous access and egress that operate on a 24-hour basis. The HOV lanes, which may use the inside lane, outside lane, or shoulder, are delineated from the general purpose lanes by a painted line, pavement markings and signing. The occupancy requirement varies between 2 + and 3 + occupants per vehicle. WSDOT operates queue bypass facilities on SR 509 from SW Cloverdale to the 1st Avenue South Bridge and on SR 526 for buses.

WSDOT currently operates HOV lanes on the I-5, I-405, I-90, and SR 522 freeways. Additional HOV lanes are operated by WSDOT and/or the City of Seattle on SR 167 NB, SR 99 NB, SR 520 WB, and SR 509 NB (See Table D-20).

Starting in July 1991, WSDOT has been monitoring HOV lane operations in the Seattle area. The report, HOV Monitoring and Evaluation Tool: Final Technical Report, established the method for collecting data for monitoring and evaluating the impact of the HOV lanes in the Seattle area, To establish a baseline from which to evaluate impacts, vehicle occupancy data and travel time data are collected by observers positioned at various mainline and ramp locations throughout the HOV system. Data is collected for both the HOV and the general purpose lanes. Surveys were sent to vehicle owners who drive the HOV corridors to measure public perception. Additional data sources include the WSDOT accident data bank, METRO's HERO program for voluntarily reporting HOV violations, and transit ridership data.

Since many HOV lanes were in operation prior to the start of this study, "before" data is not available for many of the HOV lanes in the Seattle area. To insure that data is available in the future, the objective of the HOV Evaluation and Monitoring program is to provide baseline data for analyzing HOV lane performance and development in the Puget Sound region. This study collected data before opening of the extension of the I-5 HOV lane from Mercer St. to Yesler in 1993 and after the facility was opened several months. "Before" data was also collected for the conversion of the general purpose westbound lane on I-90 to an HOV lane.

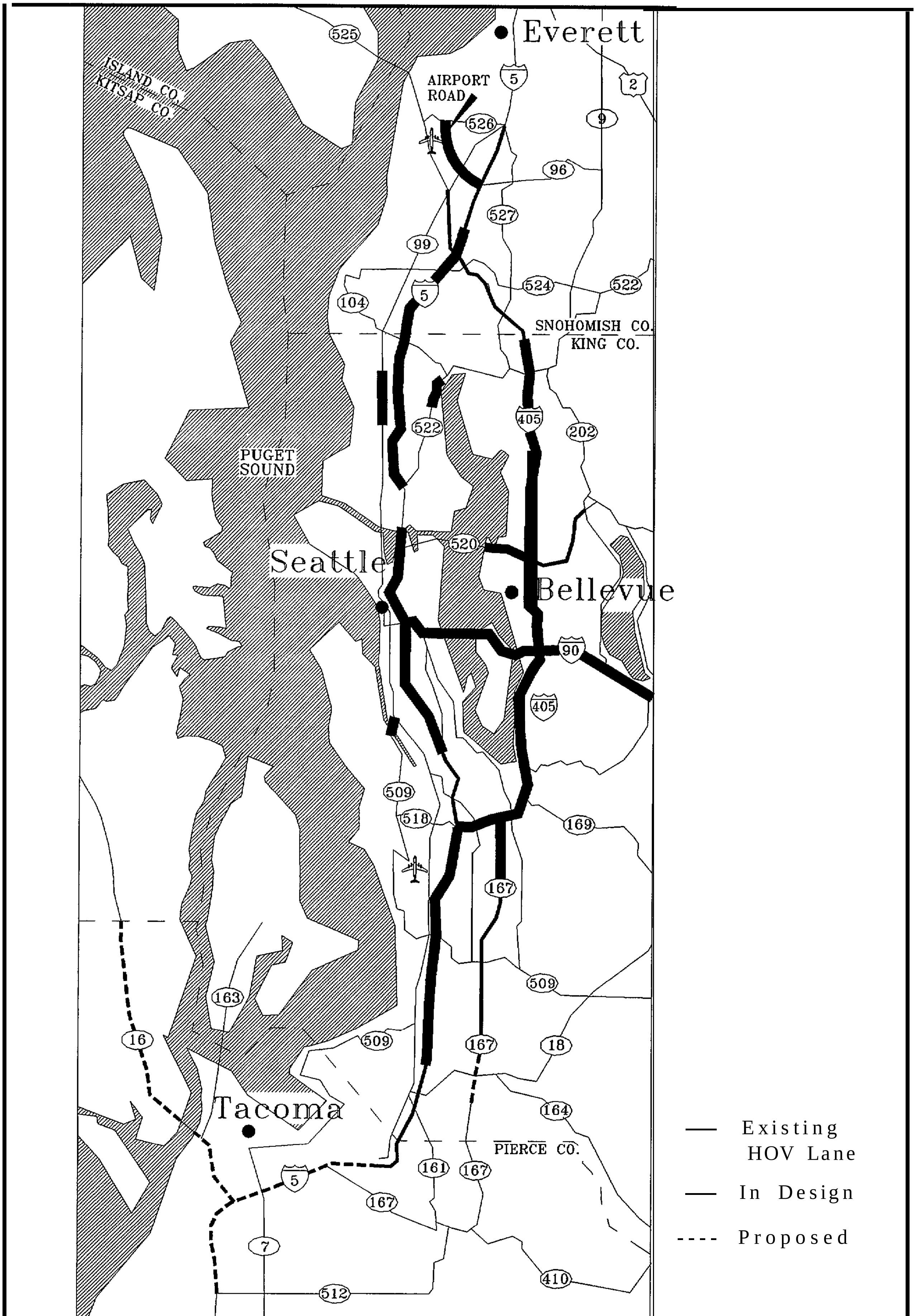

Figure D-8
HOV Facilities in the Seattle Area

Several existing HOV corridors in the Puget Sound region were identified and segmented for the initial study. Other HOV corridors will be added as the HOV lane system continues to develop. The following corridors are under observation at this stage of monitoring:

- I-5 North from Northgate to the King/Snohomish County line at SW. 236th Street,
- I-5 Downtown form Downtown Seattle at Lakeview Boulevard E. to S. 144th Street,
- I-5 South from the Southcenter Hill at S. 178th Street to S. 272nd Street,
- I-90 from the Mount Baker Tunnel at 23rd Ave S. to Bellevue Way,
- I-405 from Southcenter at Tukwila Parkway north to Kirkland/Redmond at SR 908, and
- SR 520 from Medina at Hunt's Point to Bellevue/Kirkland at SR 908.
- Also, additional outlying sites.

Data was collected from July 1, 1992 through July 5, 1993. After August 1993, the decision was made to discontinue collecting travel time data, except under special circumstances. Vehicle occupancy data is to be collected on an on-going basis.

This data is compiled into a report to be published annually with quarterly updates and is made available to WSDOT and MPOs. The data includes vehicle occupancy data for 41 locations on the HOV system and travel time data collected through license plate data from 2 1 locations. The data from the public opinion survey includes demographic data, domestic conditions, commute mode, and perceived importance and effectiveness of the HOV lanes.

As the HOV system in the Puget Sound region continues to develop, Washington State DOT has moved towards system-level studies to try to better integrate HOV lanes into more efficient system operations. Each HOV lane is not studied in isolation and the synergistic effects *among* the HOV lanes and support facilities are studied.

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Table D-20. Washington State DOT HOW Facilities

Characteristics	Washington State DOT HOV System								
Corridor	I-90 (central)	I-5 (central)	I-90 (west)	I-5 (north)	I-90 (east)	I-5 (south)	I-405	SR 167	SR 520
Limits	Rainier Ave. to East Mercer Island	Lake City Way to express lane entrance NB, Roanake to Cherry SB	5th Ave to Rainier Ave	Exp. Ln Entrance to 236th St. SW	East Mercer Island to Issaquah	Federal Way to Tukwila	Tukwila Pkwy (I-5) to NE 160th St.	North Kent to I-405	108th NE to 76th
# of HOV lanes	2	2	1 WB 1 EB	2	1 WB 1 EB	2	2	2	1 WB
Length	6.2	2.6 SB/1.6 NB	1.5	7.4 SB/4.3 NB	7.3 WB 7.1 EB	4 SB 10 NB	8.1 SB/8.6 NB	2	2.3
Date Operational	1992	70/85/87	2/92	83/91/93	1973/1994	1991/1994	1986/90/94	1988/1994	1973
HOV Eligibility	2+	2+	2+	2+	2+	2+	2+	2+	3+
Hours of HOV Operation	24 hours	5 to 11 am SB 12 to 4 pm NB	24 hours	24 hours	24 hours	24 hours	24 hours	24 hours	24 hours
Type of facility	barrier separated reversible	barrier separated reversible Express Lanes with mixed-flow	barrier separated two-way	concurrent	concurrent GP lane conversion	concurrent	concurrent, part rightside	concurrent	concurrent shoulder
Ramp Metering	50 at various locations								
Park-and-ride facilities	49 permanent (major) lots and 41 leased lots. Total capacity is 16,300 spaces								
Other support facilities	Direct access ramps		connects to bus tunnel						
Bus Service	Yes	Yes	Yes	Yes	Yes				

All HOV lanes are on the left side unless otherwise noted.

Sources:

Jacobson, Eldon L., 1995.

Turnbull, Katherine. An Assessment of High-Occupancy Vehicle Facilities in North America: Executive Report, Texas Transportation Institute, August 1992, Table 1. General Characteristics of Operating HOV Facilities.

Fuhs, Charles. Inventory of Existing and Proposed High-Occupancy Vehicle Projects, June 1994.

D.5.1 Traveler Surveys

Several surveys on travel behavior have been conducted in the Seattle metropolitan area. The Puget Sound Council of Governments (PSCOG), the Municipality of Metropolitan Seattle (METRO), and the Washington State Transportation Center (TRAC) have conducted surveys.

PSCOG Survey

The PSCOG Transportation Panel Survey contacted 5,152 households in the Puget Sound area through random-digit dialing from September to December of 1989. Of the households contacted, 33%, or 1,680 respondents, completed two-day travel diaries. In February and March of 1990, each respondent was sent an attitudes and values survey to measure cognitive and affective perceptions towards mode choice. The respondents were surveyed again in the fall of 1990 for travel diary information and the fall of 1991 for attitudinal data. This survey captures the dynamic aspects of mode choice since it collected data at more than one point in time. The PSCOG survey data supports the importance of the perception of modes and modal accessibility in mode choice.

METRO Surveys

METRO sponsored two studies which surveyed employees and residents in the north King County and urban Snohomish County area. The employee survey was an evaluation of Transportation Demand Management (TDM) /Transportation Systems Management (TSM) strategies of 23 businesses employing 50 or more employees who elected to participate. The survey, while biased toward white collar employees with higher than average incomes, looked at employee mode choice and the effectiveness of commuter programs. The report summarizing the results of the survey was published in December 1989.[53]

METRO's market segmentation study was conducted by Gilmore Research Group. The survey was a random-digit telephone survey of 3,586 residents of north King County and urban Snohomish County. Six times as many respondents lived in Snohomish county as compared to King county. The telephone survey included household characteristics, mode choice, trip characteristics, and attitudes toward mode choice.[54]

I-405 Survey

An operational analysis of the I-405 HOV facilities was conducted by the Washington State Transportation Center (TRAC). A public opinion survey was conducted as part of the study. The data collection included demographics, mode choice, and constraints to mode choice; attitudes about and perceptions of different modes; and attitudes about HOV lane issues and operations. The attitudes and perceptions of different modes was taken directly from the Puget Sound Council of Governments Transportation Panel Survey. The survey was administered in April and May 1990 at driver licensing offices in Bellevue, Kirkland, and Renton by TRAC and WSDOT.

This method proved to have a very high rate of response at 87%, or 1,545 of the 1,775 surveys handed out. The survey results were analyzed comparing SOV to carpool, SOV to bus riders, and carpoolers to bus riders. The findings covered such areas as mode usage, carpool characteristics, and reasons for driving alone. One interesting finding was that the majority of the Carpools comprised of co-workers and not spouses or children. The list of statistically significant variables included education, occupation, household income, average number of workers per household, and average number of household vehicles. One problem with this study is that the sample does not represent the typical commute population, but a subset of young, professionals with middle to upper middle incomes.

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53 Laurie McCutcheon *Marketing Commuter Programs: Surveys of North King County and Urban Snohomish County Employees.* Municipality of Metropolitan Seattle, December 1989.

54 Gilmore Research Group. *1989 North King County and Urban Snohomish County Transportation Market Segmentation* Study, *Volumes* I *and* II. Prepared for the Municipality of Metropolitan Seattle, August 1989.

D.5.2 I-90 - Seattle, Washington

I-90 is a six lane (3 lanes in each direction) freeway between I-405 and downtown Seattle. East of I-405, I-90 widens to eight lanes. This project converted one of the extra lanes in each direction to HOV use. Thus I-90 was converted to a six mixed-flow lane freeway from East Bellevue Way (near I-405) and Issaquah (near State Route 900) with a right-side concurrent flow HOV lane in each direction.

The project is 10 kilometers long (6.2 miles). The HOV lanes are open to 2+ carpools. There was no congestion in this section of I-90 before the conversion, and there was no congestion within the seven months after completion of the HOV lane conversion. The project was opened in November 1993. Ramp metering was not present on this section of I-90 during the before and after studies.

Selection of Before/After Data Set

The project opening was selected as the action for the methodology development database. This project is of interest precisely because there was no congestion before or after its opening. This project shows if there is an "inherent" effect of an HOV lane on HOV usage that is unrelated to time savings.

Data Collection

All data was taken from the Washington State Transportation Center's report on the I-90 lane conversion, dated February 1995. The before data set was gathered the same month in which the conversion was opened to traffic. The after data set was gathered 7 months after the project opening date.

Data Reduction

Description: This data set shows the impacts of converting 3.7 miles (6.0 km) of an existing mixed flow lane to HOV use and constructing an additional 2.5 mile (4.0 km) shoulder HOV lane. The HOV facility consists of a concurrent flow lane on each side of a six lane freeway (3 lanes plus HOV lane in each direction). The average speed over the length of the section never dropped below 53 mph during the peak period.

Travel Time Data: Travel times were computed from the reported before and after average speeds for the 3 hour morning peak period. Since the before and alter average speeds are both above 55 mph, no congestion appears to be present. Thus the maximum travel time is assumed to be equal to the average travel time for the peak period. Before and after travel times differed by 0.2 of a minute.

Volume Counts: Before and after AM peak period westbound counts were obtained for Fall 1993 and Summer 1994 respectively. Count data was reported by lane, but not by occupancy type or vehicle type. The HOV lane violation rate was reported to be 5%.

No peak hour data was reported. Table D-2 1 shows the results.

Sources:

- Soon Gwan Kim, Jodi Koehne, Fred Mannering, I-90 Lane Conversion Evaluation, Washington State Transportation Center, Seattle, Washington, February 1995.

Table D-21. I-90 HOV Results

Action: Convert 3.7 miles of mixed flow lanes to HOV lane, add 2.5 miles of HOV lane[55]		
	Peak Hour	Peak Period
HOV Lane Volume (After)		618
Change in Total Vehicles[56]	-%	-4%
Change in Total Persons[57]	-%	-4%
Average Vehicle Occupancy[58]: Before: After:		1.12 1.12
Change in HOV Time[59]	Save 0 minutes	Save 0 minutes
Change in SOV Time[60]	Save 0 minutes	Save 0 minutes

55 Data is for morning peak period (7:00 AM to 10:00 AM), westbound direction. Before data gathered same month of opening, After data gathered 7 months after opening

56 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

57 Total persons in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

58 Total persons divided by total vehicles. Includes buses and vans,

59 Mean tune savings for HOV lane expressed as "Before" minus "After. Rounded to nearest whole minute.

60 Mean time savings for mixed flow lane drivers expressed as "before" minus "after.

D.5.3 I-5 North - Seattle, Washington

The I-5 North HOV lanes are concurrent flow lanes located to the north of downtown Seattle extending 7.7 miles in the southbound direction and 7.2 miles in the northbound direction. The project limits extend from NE Northgate Way on the south to 236th Street Southwest on the north. The HOV lanes are a left-hand side, concurrent flow facility that operates for 24 hours a day. Table D-22 summarizes the characteristics of the I-5 North HOV facility.

This section of the I-5 freeway is ramp metered during the peak periods.

Project History

Ramp meters with HOV bypass lanes were first installed on this section of I-5 on September 30, 1981. Thirteen southbound and five northbound on-ramps were metered between the limits of NE 45th Street on the south and 44th Avenue on the north. HOV bypass lanes were installed at 6 of the 13 metered southbound on-ramps. An HOV bypass lane was also installed at one of the five metered northbound on-ramps. The southbound meters operate during the AM peak period (6-9 AM). The northbound meters operated during the PM peak period (3:30-6:30 PM).

The HOV lanes were installed in August 29, 1983 and opened to 3+ occupancy vehicles.

The occupancy requirement for the I-5 North HOV lanes was lowered to 2+ persons per vehicle in July 1991 as part of a demonstration project.

Selection of Before/After Data Sets

Three actions can be identified from the project history:

A. Installation of Ramp Metering with HOV Bypass Lanes.

B. Construction of HOV Lanes.

C. Conversion from 3+ to 2+ Operation.

Data Collection

Three sets different reports were used to evaluate the three actions. The "FLOW" reports by WDOT provided data on the effects of ramp metering. The "HOV" reports by WDOT provided data on the impacts of the HOV lanes. The "I-5 North HOV Lane" report by TRAC provided data on the impacts of converting from 3+ to 2+ operation.

The "FLOW' study was conducted in 1983. This report provides data on the traffic flow impacts of ramp metering for the 2 year period prior to the construction of the HOV lane on the I-5 freeway mainline. Data is provided on ramp delays, meter violations, and volumes for the AM peak period in the southbound direction. Before volumes were gathered in September 199 1. After volume counts are available for March and September 1982 and 1983. Mainline freeway travel times are shown by 15 minute period for 1981, 1982, and 1983 for both the AM (6:30-8:30 AM) and PM (4:00-6:00 PM) peak periods. Accident data is also provided.

The ramp meters reduced southbound AM peak delay on the freeway mainline from 5 minutes to 2 minutes. Freeway mainline congestion was reduced but not eliminated by the ramp meters.

Two "HOV" reports provide data for 3 months and 20 months after the opening of the I-5 HOV lanes. AM and PM peak hour vehicle and person volumes for the HOV lanes only are reported for two-weeks, three-months, and twenty-months after project opening. The percentage of vehicles by occupancy and vehicle type are also reported. Before (1982) and after (1983) freeway mainline volumes and travel times are reported by 15 minute periods for the southbound AM peak period (6:30-8:30 AM) and the northbound PM Peak period (4-6 PM). Violation and accident data are also briefly summarized.

The I-5 North demonstration project was conducted to determine how the change in vehicle occupancy requirements affects the objectives of the HOV program, specifically, person throughput, vehicle occupancies, travel time savings and reliability, and safety. The data collection activities included:

- Vehicle occupancy counts for both HOV and general purpose lanes
- Travel time surveys using license plate methodology for both HOV and general purpose lanes
- Utilization levels and lane vehicle volumes from loop detectors
- Accident data from State Patrol
- Calls for the HERO program from Seattle Metro (violations)
- Bus ridership and park-and-ride lot utilization rates from Community Transit
- Surveys of transit riders, carpoolers, and motorists conducted by Community Transit evaluating HOV lanes in the Seattle area.

The demonstration project was conducted by University of Washington with the Texas Transportation Institute. The evaluation of the demonstration project was based on meeting the objectives established by the WSDOT HOV policy. The impacts of the occupancy requirement change were assessed for the HOV lane and the general purpose lanes. Public perception was also measured through surveys of bus riders, carpoolers, and motorist.

Vehicle occupancy data was collected for the I-5 North in 1989 and 1990 as part of the WSDOT Vehicle Occupancy Monitoring Project, again in July 199 1, four days prior to the start of the demonstration, and the over the first five months of the demonstration project. All counts were made at 145th Street.

The low response rate from the survey of carpoolers and general purpose motorist did not provide statistically valid results.

Travel time data was collected using the license plate methodology rather than a floating car. License plates were recorded at 236th Street and 117th Street. The difference in PM peak hour travel time was minimal. Travel time in the HOV lane was 7.5 minutes while that in the mixed-flow lanes was 7.98 minutes.

Vehicle occupancies were measured at 145th Street. The report contains average occupancy, total person throughput, and percentages of 2 person Carpools, 3 person car-pools, and single occupant vehicles.

Counts were from loop detectors embedded in the pavement that are part of the on-going WSDOT monitoring program. AM peak hour and peak period counts were collected at 3 locations. PM Peak hour and peak period counts were collected at 2 locations.

Three different groups were surveyed. The surveys focused on the impacts of the change in occupancy and the general attitude toward HOV lanes. An on-board survey of transit riders was conducted on November 2 1, 1991 with 926 surveys (71%) completed and returned. Carpoolers and motorists had much lower response rates of 10% (57 completed surveys) and 30% (160 completed surveys). The data, though not statistically significant, showed the mode shift due to the change in occupancy. The completed carpool surveys showed the following general trends: 15 of 57 (26%) carpool were formed in the last 6 months, 12 of the 15 formerly drove alone, and 2 of the 15 previously rode the bus. The attitude toward the occupancy change was one of strong support from motorists and carpoolers, while only 39% of the bus riders favored the change.

The demonstration project showed that the occupancy requirement change negatively impacts the operation of the HOV based on the policy objectives. However, the public perception surveys supported the change overall. As a result, despite the lower performance based on the policy objectives, the WSDOT elected to maintain the lower occupancy requirement of 2+ persons per vehicle due to the strong public support for it and the fear of public opposition if returned to the 3+ requirement.

Data Reduction

Data reduction varied by action.

Action "A": Install Ramp Metering:

This data set shows the impacts of installing ramp metering on 13 out of 15 southbound on-ramps over a 6 mile section of a freeway without an HOV lane. Six of the 13 on-ramps with meters have HOV bypass lanes. The HOV facility consists of HOV bypass lanes at 6 southbound on-ramps on a six lane freeway (3 lanes in each direction). The bypass lanes are limited to 3+ carpools and are operated from 6:30 AM to 8:30 AM each weekday. (There are also 5 metered northbound ramps during the PM peak period with one ramp having an HOV bypass lane.)

Ramp metering and the HOV bypass lanes were opened on September 30, 198 1.

Travel Time Data: The maximum ramp delay for non-HOV's was reported to be 8 minutes. The average delay was reported to be 2 to 3 minutes. HOV's had no delay.

Volume Counts: Before and after AM peak period (6:00-8:30 AM) southbound on-ramp volume counts were obtained for September 198 1 and September 1982 respectively. The reported volumes do not distinguish between HOV bypass lane volumes and other lane volumes. The ramp meters and HOV bypass lanes caused a 19% net reduction in AM peak period vehicle volumes using the metered ramps (See Appendix "A" for results).

It is reported that 9% of the on-ramp volumes used the HOV bypass lanes and that one-third of the bypass lane users are violators (less than 3+ Carpools).

Sources:

- S.M. Betts, L.N. Jacobson, H.J. Mieras, T.D. Pickman, PLOW, A Two Year Evaluation, Washington State Department of Transportation, District No. 1. Traffic Systems Management Center, Seattle, Washington, December 1983.

Action "B": Construct HOV Lanes:

This data set shows the impacts of constructing a concurrent flow, left-hand side HOV lane on a freeway. The HOV facility consists 5.6 miles (9.0 km) southbound and 4.0 miles (6.4 km) northbound of concurrent flow, left-hand side HOV lanes on a six/eight lane freeway (3 or 4 lanes in each direction). Ramp metering with HOV bypass lanes (see previous project description) was already in place prior to the HOV lane construction.

The HOV lanes were opened on August 29, 1983. Ramp metering with HOV bypasses (see Action "A") were present both before and after the lane construction.

<u>Travel Time Data</u>: Mixed flow lane travel times were reported by 15 minute time period over the 6:30 to 8:30 AM peak period for a 11.2 mile segment of the freeway. These times were converted to equivalent times for a 5.6 mile run for the mixed flow lanes by proportioning the time for the shorter distance traveled (in effect assuming the average speed over the larger length was the same for the shorter length).

The HOV lane times were computed assuming free flow travel at 55 mph.

<u>Volume Counts</u>: Before and after AM peak period (6:00-8:30 AM) southbound volume counts were obtained for September 1982 and September 1983 respectively. The reported volumes are not segregated by occupancy nor vehicle type.

It is reported that 25% of the HOV lane volumes were violators (less than 3+ carpools).

The before/after results are summarized in Table D-23.

Sources:

- S.M. Betts, L.N. Jacobson, H.J. Mieras, T.D. Rickman, FLOW, A Two Year Evaluation, Washington State Department of Transportation, District No. 1, Traffic Systems Management Center, Seattle, Washington, December 1983.
- S.M. Betts, L.N. Jacobson, T.D. Rickman, HOV, High Occupancy Vehicle Lanes, Three Month Report, Washington State Department of Transportation, District No. 1, Traffic Systems Management Center, Seattle, Washington, December 1983.
- K.C. Henry, M.J. Jacobs, A Twenty Month Report, HOV, High Occupancy Vehicle Lanes, Washington State Department of Transportation, District No. 1, Traffic Systems Management Center, Seattle, Washington, May 1985.

Action "C": Conversion from 3+ to 2+:

This data set shows the impacts of converting 7.7 miles (12.4 km) of an existing, left-hand side, concurrent flow HOV lane from 3+ to 2+ carpools. The HOV facility consists of a left-hand lane, concurrent flow lane on each side of a six lane freeway (3 lanes plus HOV lane in each direction). Ramp metering with HOV bypass lanes at half the on-ramps was also in place at the time. The average speed over the length of the section never dropped below 55 mph during the peak period.

The HOV conversion occurred on July 29, 1991. Ramp metering with HOV bypasses (see Action "A") were present both before and after the conversion.

<u>Travel Time Data</u>: Average travel times were reported for the peak hour only. The maximum times are assumed to be the same as the mean travel times during the peak hour.

<u>Volume Counts</u>: Before and after AM peak hour southbound volume counts were obtained for September 1990 and September 1991 respectively for the HOV lane and the mixed flow lanes,

The volume by occupancy type (SOV,2,3+pool) was estimated based upon graphs showing the percent of before and after traffic across all lanes for the before and after condition. A 10% violation rate was assumed. The vehicles were then distributed by occupancy type and between the HOV lane and the mixed flow lanes to match the observed percentages and total volume by lane type. Motorcycle and truck volumes were estimated based upon an assumed percentage of the total volumes (This was necessary in order to achieve the total reported lane volumes).

No peak period data was reported.

The before/after study results are summarized in Table D-24.

Sources:

- Cy Ulberg, Gary Farnsworth, Graciela Etchert, Katherine Tumbull, Russell H. Henk, and David L. Schrank. I-5 North High-Occupancy Vehicle Lane 2 + Occupancy Requirement Demonstration Evaluation, Washington State Department of Transportation (TRAC) with Texas Transportation Institute (TTI), February 1992.

Table D-22. I-5 North HOV Facility

Characteristic	I-5 North HOV System
Limits	HOV Lanes: NE Northgate Way to 236th Street SW Meters: NE 45th Street to 44th Avenue West (in 1981)
# of HOV lanes	1 in each direction
# of general purpose lanes	3 in each direction
Length	7.7 miles SB 6.2 miles NB
Date Operational	1983
HOV Eligibility	3+ (changed to 2+ July 1991)
Hours of HOV Operation	24-hours
Type of facility	concurrent
Ramp Metering	yes
Park-and-ride facilities	yes
Other support facilities	Transit centers, rideshare and TDM programs
Bus Service	Service improvements

Table D-23. Action "B" I-5 Seattle Results

Action: Construct 5.6 miles HOV lanes[61]		
	Peak Hour	Peak Period
HOV Lane Volume (After)		680
Change in Total Vehicles[62]		+15%
Change in Total Persons[63]	-	-
Average Vehicle Occ.[64] Before: After:		 - -
Change in HOV Time[65]	-	Save 2 minutes
Change in SOV Time[66]	-	Save 1 minutes

Table D-24. Action "C" I-5 Seattle Results

Action: Convert from 3+ to 2+ Occupancy Requirement[67]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	1,000	-
Change in Total Vehicles	+12%	-
Change in Total Persons	+16%	-
Average Vehicle Occupancy: Before: After:	 1.25 1.30	 - -
Change in HOV Time	Save 2 minutes	-
Change in SOV Time	Save 2 minutes	-

61 Data is for Morning Peak Period (6:00 AM to 8:30 AM) southbound direction. Before data gathered 12 months before opening, After data gathered 3 months after opening.

62 Total vehicles in peak direction, expressed as "After" minus "before", divided by "before".

63 Total persons in peak direction expressed as "After" minus "before", divided by "before".

64 Total persons divided by total vehicles. Includes buses and vans.

65 Mean time savings for HOV lane: "Before" minus "After. Rounded to nearest whole minute.

66 Mean time savings for mixed flow lane drivers expressed as "before" minus "after.

67 Data is for morning peak period (6:00 AM to 9:00 AM), southbound direction. Before data gathered 11 months before opening, After data gathered 2 months after opening.

D.6 CALTRANS - DISTRICT 4 - SAN FRANCISCO

Caltrans District 4 has been operating HOV lanes since 1970. There are currently 20 HOV facilities in operation totaling 158 lane-miles (254 lane-km) of freeway and expressway lanes in the San Francisco Bay Area. An additional 10 projects totaling 178 miles (286 km) are anticipated to be opened by the year 2000. These facilities are shown in Figure D-9. The types of facilities range from concurrent freeway lanes to toll bypass lanes on the bridge toll approaches. Caltrans also operates one HOV facility on an arterial street that is part of the state highway system. In general, the facilities require 2 or more persons to be eligible for the HOV lanes, with the exception of several bridge toll bypass facilities. Hours of operation differ depending upon the peak period of the facility. Table D-25 and Table D-26 summarize the HOV facility characteristics for Caltrans District 4.

The Highway Operations Branch of District 4 is responsible for the data collection on all of the HOV facilities under its jurisdiction. HOV facility operations data is summarized annually in the "Annual HOVL Report." The report published by Caltrans District 4 covers all HOV lanes under their jurisdiction since 1988. The report includes the peak period and peak hour vehicle and person volumes for the HOV lane and the adjacent mixed-flow lanes, the vehicle occupancy rates, the violation rates, and travel times. The report also contains some general information on the HOV facilities such as the date opened, the HOV lane eligibility, the hours of operation, the length of facility, and the milepost location. This report provides annual facility data for the HOV lanes in the Bay Area.

The data for HOV lanes are collected twice a year by observers during peak hours. To ensure that the data collected represents a "typical" non-incident weekday, the data collection is canceled and rescheduled if an incident occurs during the data collection. Each travel lane is monitored by an individual observer who records the vehicle occupancy count in 15-minute intervals. The HOV facility data includes the vehicle counts for both HOV lane and adjacent general-purpose lanes in 15-minute intervals from loop detectors, person counts by individual vehicle in 15-minute intervals, and travel speeds from floating car surveys. The most recent two years of data are saved in a Macintosh-based Excel format. Earlier data are available in hardcopy from the district offices.

Four "before-and-after" reports are available for selected routes. The reports are for US 101 (2 segments), I-280, and SR 237. The "before-and-after" reports summarize the evaluation of traffic volumes, vehicle occupancy rates, travel time savings, and travel speed for before-and-after conditions. The after condition covers the first year of operation for the HOV facility. Additional "before-and-after" raw data are available, but have not been analyzed or published in report format.

D.6.l San Francisco Bay Area HOV/SOV Driver Surveys

Two major HOV/SOV driver surveys have been conducted in the San Francisco Bay Area. One was conducted in 1990 at six HOV locations throughout the Bay Area. The other was conducted in 1995 also at six HOV lane locations (two of these locations the same as for the previous study).

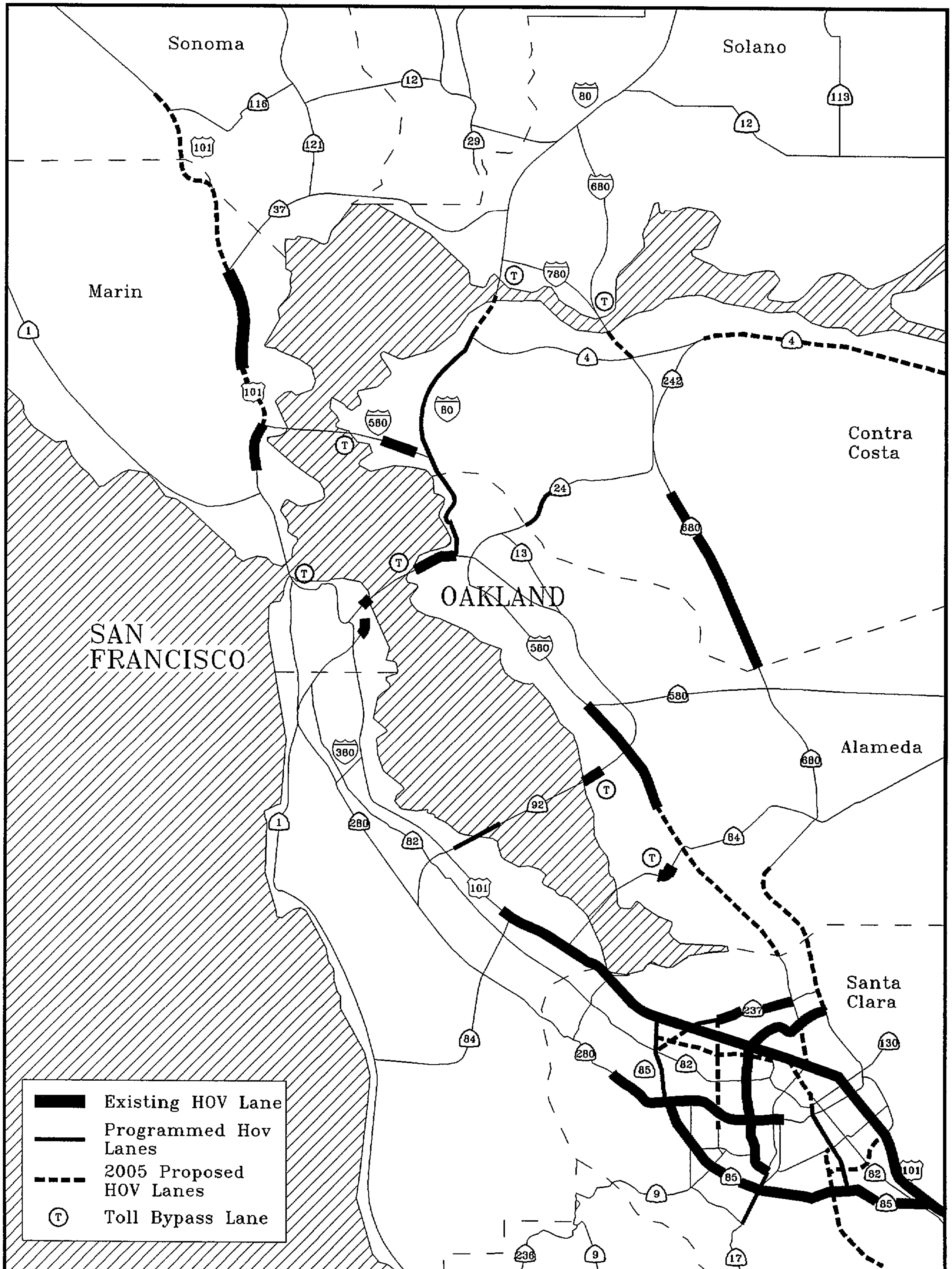

Figure D-9
HOV Facilities Operated by Caltrans and Santa Clara County in the San Francisco Bay Area

94044 FIGD-9 DWG 5-28-96

Table D-25. Caltrans District 4 HOV Facilities

Characteristics	Caltrans District 4									
Corridor	US 101 Marin	US 101 Marin	US 101 SCL/SM	US 101 SCL	I-880	I-280	I-680	I-580	SR 237	SR 85
Begin and End	Richardson to Greenbrae	N. San Pedro to Rte 37	Whipple to Guadalupe	Guadalupe to Bernal	Rte238 to Whipple	Magdalena to Leland	I-580 to Rudgear	Marine to Central	I-880 to Mathilda	SR237 to I-101 Gilroy
# of Directional HOV lanes	2	2	2	2	2	2	2	2	2	2
Length (mi.)	3.7	6.1	18.5	13.2	7.3	11.2	10.4	5.1	6	22.2
Date Operational	74	86/87	86/91	90/93	91	90	94	89	84	90/94
HOV Eligibility	bus only to 2+	2+	2+	2+	2+	2+	2+	2+	2+	2+
Hours of HOV Operation (weekdays only)	6:30-8:30am SB 4:30-7pm NB	6:30-8:30am SB 4:30-7pm NB	5-9am 3-7pm	5-9am 3-7pm	5-9am 3-7pm	5-9am 3-7pm	6-9am 3-6pm	7-8am 5-6pm	5-9am WB 3-7pm EB	5-9am 3-7pm
Type of facility (barrier sep. 2-way, reversible flow, concurrent, etc.)	striped concurrent each dir.	striped concurrent each dir.	striped concurrent each dir.	striped concurrent each dir.	striped concurrent each dir.	striped concurrent each dir.	striped concurrent each dir.	striped concurrent each dir.	striped concurrent each dir. arterial (right lane)	striped concurrent each dir.
Ramp Metering (# of location, HOV bypass)	None	None	Yes	6 NB locations	None	1 NB and 3 SB locations	None	None	None	8 NB and 4 SB locations

All HOV lanes are on the left side unless otherwise noted.

Source: Caltrans - District 4. Annual HOVL Report, December 1994.

Table D-26. Caltrans 04 Bridge Toll and Ramp HOV Bypass Facilities

Characteristics	Caltrans District 4									
Type of HOV Facility	HOV Toll Plaza							Ramp HOV Bypass		
Corridor	I-80	SR84	SR92	I-80	SR160	I-580	I-680	SR85 SCL	US101 SCL	I-280 SCL
Name of Bridge /Ramp Locations	Bay Bridge	Dumbarton Bridge	San Mateo Bridge	Carquinez Bridge	Antioch Bridge	San Rafael Bridge	Martinez Bridge	SCL Co.	SCL Co.	SCL Co.
# of Directional HOV lanes or # of Ramp Locations	4 WB only	1 WB only	1 WB only	1 EB only	1 NB only	1 WB only	1 NB only	12 locations NB(8) & SB(4)	6 locations for NB	4 locations NB(1) & SB(3)
Length (mi.)	3.9	1.8	2	approach only	approach only	approach only	approach only	N/A	N/A	N/A
Date Operational	70	82/89	89	91	91	89	91	94	80/82/91/92	77/80/93
HOV Eligibility	3+	2+	2+	3+	3+	3+	3+	2+	2+	2+
Hours of HOV Operation (weekdays only)	5-10am WB 3-6pm WB	5-10am WB 3-6pm WB	5-10am WB 3-6pm WB	5-10am EB 3-7pm EB	5-10am NB 3-7pm NB	5-10am WB 3-6pm WB	5-10am NB 3-7pm NB	24 hours	varies by locations	varies by locations
Type of facility2 (barrier sep. 2-way, reversible flow, concurrent, etc.)	concurrent pylon separated in WB only.	striped concurrent in WB only.	striped concurrent in WB only.	striped concurrent in EB only.	striped concurrent in NB only.	striped concurrent WB only.	striped concurrent in NB only.	striped concurrent on-ramp lane.	striped concurrent on-ramp lane.	striped concurrent on-ramp lane.

Contact:

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Tel: (510) 286-5140

Fax: (510) 286-4561

Sources:

Caltrans - District 4, Highway Operations Branch, Annual HOVL Report - Overall Volumes and HOVL Violation History, reports available from 1990 to 1994.

1990 HOV Survey

The "San Francisco Bay Area HOV Lane User Study"[68] describes the survey of HOV drivers identified from videotapes at eight locations on six HOV lanes throughout the Bay Area. HOV lanes were videotaped at the following locations:

- San Tomas Expressway
- Bay Bridge Toll Approach WB
- Sterling on-ramp to Bay Bridge EB
- US 101 Santa Clara SB
- US 101 Santa Clara NB
- Dumbarton Bridge Toll Approach WB
- US 101 Marin - Corte Madera
- US 101 Marin - San Rafael

The 11,401 license plates videotaped and identified yielded 998 completed surveys. The surveys were administered over the telephone in late 1989 and early 1990. The purpose of the survey was to measure carpool attitudes and identify factors that influence Carpool formation. Due to the Loma Prieta earthquake, the survey included pre- and post-earthquake travel patterns in addition to the originally planned questions on carpool formation, demographics, and HOV lane perceptions and attitudes.

The key survey results were as follows:

- The average trip length for carpools was 25 miles.
- Drivers perceived travel time savings to be more than double the average savings recorded during the peak hour and four times that recorded during the peak period.
- Casual car-pooling amounted to about 36% of the Carpools on the Bay Bridge.
- More than half (54%) of the car-pools were formed through household members. Another 29% were formed with co-workers.
- About 22% of carpoolers pay for parking. The average cost for parking (among those paying) was $118 per month.
- Transit was found to be a significant source of carpoolers only on the Bay Bridge and US 10 1 in Corte Madera.

[68] John W. Billheimer. San Francisco Bay Area HOV Lane User Studs. Final Report, June 1990

1995 HOV Survey

The 1995 survey[69] was conducted at six HOV lane facilities:

U.S. 101, Marin County;

I-680, Contra Costa County;

I-880, Alameda County;

State Route 237, Santa Clara County;

U.S. 101, Santa Clara County; and

I-280, Santa Clara County.

The same video-taping and postcard mailout survey procedure was used as in the 1990 survey. A total of 77,925 vehicles were videotaped in the six corridors during the morning peak period. Eighteen percent of these vehicles were eliminated from the sample because they were trucks, commercial vehicles, out-of-state vehicles, or had unreadable license plates. Another 6% of the total sample was eliminated due to invalid plates or out of area residences for the vehicle owners. Survey forms were sent to 59,473 vehicle owners. Completed surveys were received from 28% (16,855) of the total mailed out.

The salient results of the survey are as follows (Note that only vehicle owners were surveyed. The results do not necessarily account for vehicle drivers or vehicle passengers):

- Home to Work trips accounted for 86% of the morning peak trips in the sample. Business related trips accounted for an additional 4% of the sample. School commute trips accounted for another 3%.
- Carpoolers (2+ persons) accounted for 13% of the vehicles traveling in the study corridors during the morning peak period.
- The average trip length is 28 miles for carpoolers, 27 miles for non-carpoolers.
- 56% of Carpools were formed with other household members. 3 1% of the carpoolers pool with co-workers.
- The average pool driver/vehicle owner has been pooling 3 years. This is not the same as average duration of a given pool.
- HOV lanes that had been in place for longer than 5 years were cited by 34% of poolers as being a primary incentive for pooling. Only 8% of HOV drivers identified HOV lanes as a primary incentive if the lanes had been opened within the last 6 months.
- Cost savings was the second most often cited reason for pooling.
- HOV lanes caused 22% of the solo drivers and 57% of the Carpool drivers to change their behavior.
- Eleven percent of the respondents identifying themselves as primarily solo drivers changed their driving time because of the HOV lanes. Four percent of the solo drivers chose to carpool regularly or occasionally while 3% changed their route. The remaining 5% made other unspecified changes. (The percents add up to greater than 22% because multiple responses were allowed.)
- Less than half (43%) of the respondents identifying themselves as carpoolers were unaffected by the HOV lanes. About 35% had previously used another mode. About 17% changed

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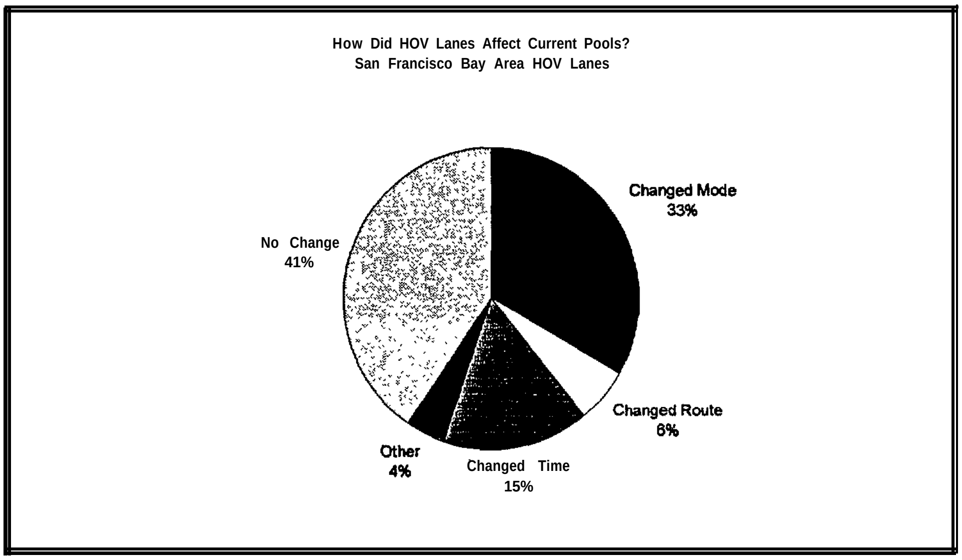
69 Billheimer, John W., Origin/Destination Surveys in Six Bay Area Corridors, for Caltrans District 04, by Systan Inc., Los Altos, CA, March 1995.

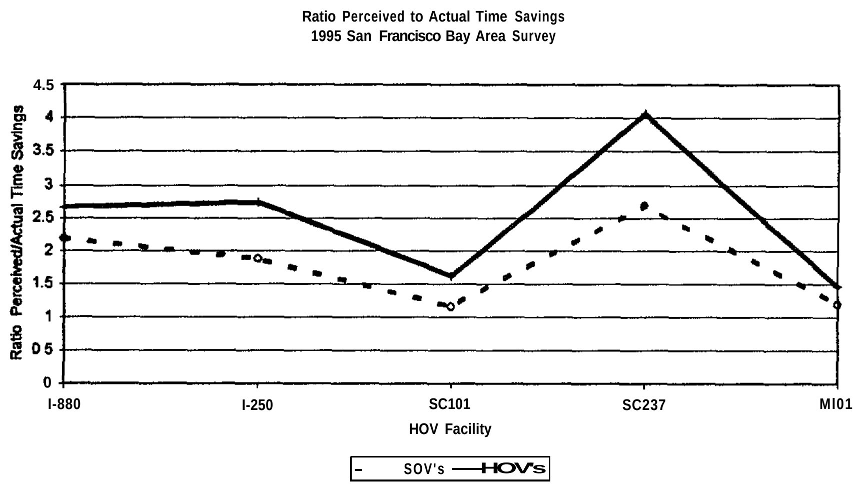
their driving time and 6% changed their route. The remaining 5% made other unspecified changes. (The percents add up to greater than 57% because multiple responses were allowed.) (See Figure D-10).

Figure D-10 Impact of HOV lanes on Carpoolers



- HOV drivers tend to perceive the benefits of HOV lanes much more optimistically than do SOV drivers. SOV drivers however also tend to over estimate the actual time savings of HOV lanes by a factor of two. HOV drivers tend to over estimate the time savings by a factor of almost three (see Figure D-l 1)

Figure D-l 1 Ratio of Perceived to Actual Time Savings of HOV Lanes



D.6.2 I-280 HOV Facility - Santa Clara County, California

An 11.2~mile section of I-280 from Magdalena Avenue in Cupertino to Leland Avenue in San Jose was widened from 6 lanes to 8 lanes in November/December 1990 (see Table D-27). The two additional lanes were designated as left-hand side, concurrent flow HOV lanes during the AM and PM peak periods. The northbound HOV lane is 10.7 miles (17.2 km) long. The southbound HOV lane is 11.2 miles (18.0 km) long. Buses, vanpools, motorcycles, and 2+ person carpools may use the HOV lanes during the peak periods. The HOV lanes are open to all vehicles during the rest of the day.

Data Collection

The Highway Operations Branch of Caltrans District 4 collected "before" data prior to the opening of the HOV lanes on I-280. The "after" data was collected after several months of operation in 199 1. The 'before-and-after" data contain vehicle counts by lane for HOV lane and general-purpose lane, person counts by lane for HOV lane and general-purpose lanes, violation vehicle counts on HOV lane, and travel speeds for HOV lane and general-purpose lanes. No specific dates are given for the before and after surveys.

Data reported includes:

- Speed profiles for peak hour for AM and PM both directions.
- Travel times for AM and PM Peak periods both directions.
- Vehicle occupancy for AM and PM peak period both directions.
- Vehicle counts for total of all lanes during peak period or lane by lane for peak hour.

The counts were taken at a midway point on the facility between Lawrence Expressway and Wolfe Road.

Data Reduction

Description: This data set shows the impacts of adding a concurrent flow, left-hand side HOV lane for 10.7 miles (17.2 km) in the northbound direction on a 6 lane freeway. The HOV lanes were opened to traffic on November 2 1, 1990 (northbound) and December 1, 1990 (southbound). Ramp metering with HOV bypasses was present before and after the addition of the HOV lane.

Travel Time Data: The maximum travel times for the mixed flow lanes were read directly from the peak period travel time profiles for the northbound direction, morning peak period. The means were obtained graphically from the profiles.

Volume Counts: Peak period volume counts by occupancy type and vehicle type were obtained directly from the tabulations in the report. The data was not broken down by lane type. Peak hour volumes by lane type (but not by occupancy type) were read from the bar graphs contained in the report.

The before/after study results are summarized in Table D-28.

Sources

1. Caltrans - District 4, Highway Operations Branch. Route 280 - Magdalena Avenue to Leland Avenue, HOVL Evaluation Report, November 199 1.

Table D-27. I-280 Santa Clara HOV Facility

Characteristics	I-208 HOV System
Begin and End	Magdalena Avenue to Leland Avenue
# of HOV lanes	1 lane in each direction
# of general purpose lanes	3 lanes in each direction
Length (mi.)	11.2 miles
Date Operational	November 1990 (NB), December 1990 (SB)
HOV Eligibility	2+
Hours of HOV Operation (weekdays only)	5:00 to 9:00 am, 3:00 to 7:00 pm
Type of facility	concurrent
Ramp Metering	6 HOV meter bypass lanes

Table D-28. I-280 HOV Lane Results

Action:
Construct 10.7 mile HOV lane[70]

	Peak Hour	Peak Period
HOV Lane Volume (After)	1840	
Change in Total Vehicles[71]	+15%	+3 1%
Change in Total Persons[72]	+22%	+40%
Average Vehicle Occ.[73]: Before:	1.13	1.11
After:	1.20	1.19
Change in HOV Time[74]	Save 13 minutes	Save 9 minutes
Change in SOV Time[75]	Save 5 minutes	Save 6 minutes

70 Data is for morning peak period (7:00 AM to 9:00 AM), northbound direction. Report is unclear on dates of data collection.

71 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

72 Total persons in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

73 Total persons divided by total vehicles. Includes buses and vans.

74 Mean time savings for HOV lane expressed as "Before" minus "After. Rounded to nearest whole minute.

75 Mean time savings for mixed flow lane drivers expressed as "before" minus "after.

D.6.3 US-101 (Lawrence to Guadalupe) HOV Facility - Santa Clara County, California

The section of US 101 between Lawrence Expressway and Guadalupe Parkway was widened from 6 lanes to 8 lanes in November 1986. The two added lanes were designated as HOV lanes located in the freeway median. The HOV lanes were opened in November 1986. The HOV lanes are restricted to buses, vanpools, and 2 or more persons during peak hours: 5-9 AM, and 3-7 PM (See Table D-29).

The HOV lanes consist of 2.83 mile concurrent flow HOV lane in the northbound direction, and a 3.18 mile concurrent flow lane in the southbound direction.

The peak flow directions are northbound in the morning and southbound in the afternoon.

Data Collection

The Highway Operations Branch of Caltrans District 4 collected "before" data prior to the opening of the HOV lanes on US-101. Two sets of "after" data were collected: One, in 1987 between Lawrence Expwy and Guadalupe Parkway, and the second set, in 1993 between Guadalupe Parkway and I-280/I-680/US101 interchange. The "first" "after" data set is reported here.

The first set of "after" data was collected in 1988 after a few months of operation. The "before-and-after" data contain vehicle counts by lane for HOV lane and general-purpose lane, person counts by lane for HOV lane and general-purpose lanes, violation vehicle counts on HOV lane, and travel speeds for HOV lane and general-purpose lanes. No specific dates are given for the before and after surveys.

The counts were taken at a point approximately midway between the endpoints of the project.

Data Reduction

Description: This data set shows the impacts of adding a concurrent flow, left-hand side HOV lane for 2.8 miles (4.5 km) in the northbound direction on a 6 lane freeway. The HOV lanes were opened to traffic on November 7, 1986 (northbound) and November 10, 1986 (southbound). Ramp metering with HOV bypasses was present before and after the addition of the HOV lane.

Travel Time Data: The maximum travel times for the mixed flow lanes were read directly from the peak period travel time profiles for the northbound direction, morning peak period. The means were obtained graphically from the profiles.

Volume Counts: Peak period volume counts by occupancy type and vehicle type were obtained directly from the tabulations in the report. This data was not broken down by lane type but total peak period volumes by lane type were obtainable from the bar graphs. Peak hour volumes by lane type (but not by occupancy type) were read from the bar graphs contained in the report.

The results are summarized in Table D-30.

Source

1. Caltrans - District 4, Highway Operations Branch, SCL-101 Commuter Lane -Lawrence Expressway to Guadalupe Parkway Preliminary Evaluation Report, June 1988.

Table D-29. US 101 Guadalupe to Lawrence HOV Facility

Characteristics	US 101 HOV System
Begin and End of Section	Lawrence Expwy to Guadalupe Parkway
# of HOV lanes	1 lane in each direction
# of general purpose lanes	3 lanes in each direction
Length (mi.)	2.83 (N-B), 3.18 (SB)
Date Operational	November 1986
HOV Eligibility	**2+**
Hours of HOV Operation (weekdays only)	5:00 to 9:00 am, 3:00 to 7:00 pm
Type of facility	concurrent
Ramp Metering	3 HOV bypass lanes

Table D-30. US 101 Guadalupe to Lawrence HOV Lane Results

Table 29 Before/After Results for US 101 HOV (Guadalupe-Lawrence), San Jose, Ca.		
Action: Construct 2.8 mile HOV lane[76]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	710	1730
Change in Total Vehicles[77]	+6%	+7%
Change in Total Persons[78]	+12%	+11%
Average Vehicle Occ.[79]: Before: After:	 1.12 1.18	 1.13 1.17
Change in HOV Time[80]	Save 8 minutes	Save 6 minutes
Change in SOV Time[81]	Save 4 minutes	Save 3 minutes

76 Data is for morning peak period (6:00 AM to 9:00 AM), northbound direction. Report is unclear on dates of data collection.

77 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

78 Total persons in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

79 Total persons divided by total vehicles. Includes buses and vans.

80 Mean time savings for HOV lane expressed as "Before" minus "After. Rounded to nearest whole minute.

81 Mean time savings for mixed flow lane drivers expressed as "before" minus "after.

D.6.4 U.S. 101 (Guadalupe to I-680) - Santa Clara County, California

The section of US-10 1 between Guadalupe Parkway and I-280/I-680/US 101 interchange was widened from 4/6 lanes to 8 lanes for its entire length. The effect was to add one lane in each direction to the six lane sections for the HOV lanes and to add two lanes (one HOV, one mixed flow) to the existing four lane sections of the freeway (see Table D-3 1).

The HOV lanes and the added mixed flow lane sections were opened to operation in February and April of 1993. The HOV lanes are restricted to buses, vanpools, and 2 or more persons during peak hours. This facility is a 5.8 miles of concurrent flow lanes for both directions.

This project was an HOV lane gap closure project. Prior to this widening project, HOV lane facilities on US-101 were separated into two facilities to the north and to the south of this section. This gap section consequently usually experienced congestion during the peak hours.

Data Collection

The Highway Operations Branch of Caltrans District 4 collected "before" data prior to the opening of the HOV lanes on US 10 1. Unfortunately, no dates are given for these studies. The "before-and-after" data contain vehicle counts by each lane for HOV lane and general-purpose lane, person counts by each lane for HOV lane and general-purpose lanes, violation vehicle counts on HOV lane, and travel speeds for HOV lane and general-purpose lanes.

Data Reduction

Description: This data set shows the impacts of adding a concurrent flow, left-hand side HOV lane for 6.0 miles (9.7 km) in the northbound direction on a 6 lane freeway. The last section of the HOV lanes was opened to traffic on April 5, 1993. Ramp metering with HOV bypasses was present before and after the addition of the HOV lane,

Travel Time Data: The maximum travel times for the mixed flow lanes were read directly from the peak period travel time profiles for the northbound direction, morning peak period. The means were obtained graphically from the profiles.

Volume Counts: Peak period volume counts by occupancy type and vehicle type were obtained directly from the tabulations in the report. This data was not broken down by lane type. Peak hour volumes by lane type (but not by occupancy type) were read from the bar graphs contained in the report. The peak period violation rate was 5% of the HOV lane volume.

The results are summarized in Table D-32.

Source

1. H. David Seriani, Caltrans - District 4, Highway Operations Branch, SCL-Route 10 1 HOVL Gap Closure (Route 280/680/101 Interchange to Guadalupe Parkway Preliminary HOVL Evaluation Report, December 1993.

Table D-31. US 101 HOV Lane, I-680 to Guadalupe

Characteristics	
# of HOV lanes	1 lane in each direction
# of general purpose lanes	3 lanes in each direction
Length (mi.)	11.2 miles
Date Operational	April 1993
HOV Eligibility	2+
Hours of HOV Operation (weekdays only)	5:00 to 9:00 am, 3:00 to 7:00 pm
Type of facility	concurrent
Ramp Metering	2 HOV bypass lanes

Table D-32. US 101 Results, I-680 to Guadalupe

Action: Construct 6.0 mile HOV lane[82]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	1840	-
Change in Total Vehicles[83]	+21%	+22%
Change in Total Persons[84]	+28%	+34%
Average Vehicle Occ.[85]: Before: After:	1.30 1.38	1.16 1.33
Change in HOV Time[86]	Save 12 minutes	Save 8 minutes
Change in SOV Time[87]	Save 5 minutes	Save 1 minutes

82 Data is for morning peak period (7:00 AM to 9:00 AM), northbound direction. Report is unclear on dates of data collection.

83 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

84 Total person8 in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

85 Total persons divided by total vehicles. Includes buses and vans.

86 Mean time savings for HOV lane expressed as "Before" minus "After. Rounded to nearest whole minute.

87 Mean time savings for mixed flow lane drivers expressed as "before" minus "after.

D.6.5 SR237 HOV Facility - Santa Clara County, California

This project is a pair of 6.0 mile long right-hand side, concurrent flow HOV lanes (one in each direction) that were added to the shoulders of a four lane (2-lanes in each direction) expressway. Signals are spaced one to two miles apart. Free-Flow speeds exceed 55 mph. No access is allowed to the expressway between the signalized intersections. The HOV lanes opened October 1984 (see Table D-33).

The peak direction of flow is westbound in the morning and eastbound in the afternoon. Congestion is severe in the peak directions at many of the signalized intersections.

Data Collection

The Highway Operations Branch of Caltrans District 4 collected “before” data prior to the opening of the HOV lanes on SR237. The “after” data was collected approximately six months after the start of operation. Unfortunately, no dates are given for these studies. AM and PM peak period vehicle and person volumes are reported. The vehicle counts are stratified by occupancy and vehicle type. The total peak period volumes are also stratified between the HOV lane and mixed flow lanes. Violation rates are reported for each peak period over 5 days. Travel time data is reported for five “before” floating car runs (made over a 10 month period) and four “after” floating car runs (made over a 3 month period).

Data Reduction

Description: This data set shows the impacts of adding a concurrent flow, right-hand side HOV lane for 5.9 miles (9.5 km) in the westbound direction on a 4 lane expressway with signals every one to two miles. This portion of SR-237 was not a freeway at the time of the HOV lane project. No ramp metering was present.

Travel Time Data: The maximum travel times for the mixed flow lanes were read directly from the peak period travel time profiles for the westbound direction, morning peak period. The means were obtained graphically from the profiles.

Volume Counts: Peak period volume counts by occupancy type and vehicle type were obtained directly from the tabulations in the report. This data was not broken down by lane type. Peak hour volumes by lane type (but not by occupancy type) were read from the bar graphs contained in the report. The violation rate was 9% of the HOV lane volume.

Table D-34 summarizes the results of the before/after study.

Source

1. Caltrans - District 4, Highway Operations Branch, SCL 237 Commuter Lane - Summary of Data Collected During the First Six Months of Operation, May 1985.

Table D-33. SR-237 Expressway HOV Lane

Characteristics	SR237 HOV System
Begin and End	I-880 to Magdalena Avenue
# of HOV lanes	1 shoulder lane in each direction
# of general purpose lanes	2 lanes in each direction
Length (mi.)	6 miles
Date Operational	October 1984
HOV Eligibility	2+
Hours of HOV Operation (weekdays only)	5:00 to 9:00 am (WB), 3:00 to 7:00 pm (EB)
Type of facility	concurrent

The HOV lane is the rightmost lane. A portion of it runs on a permissive shoulder which reverts to regular shoulder use at off-peak hours.

Table D-34. SR-237 HOV Lane Results

Action: Construct 5.9 mile HOV lane[88]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	957	-
Change in Total Vehicles[89]	-	+39%
Change in Total Person[90]	-	+45%
Average Vehicle Occ.[91] : Before: After:	- -	1.20 1.25
Change in HOV Time[92]	Save 6 minutes	Save 4 minutes
Change in SOV Time[93]	Save 4 minutes	Save 3 minutes

88 Data is for morning peak period (6:00 AM to 900 AM), westbound direction. Report is unclear on dates of data collection.

89 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

90 Total persons in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

91 Total persons divided by total vehicles. Includes buses and vans.

92 Mean time savings for HOV lane expressed as "Before" minus "After. Rounded to nearest whole minute.

93 Mean tune savings for mixed flow lane drivers expressed as "before" minus "after.

D.6.6 US 101 Marin HOV Facility

The US 10 1 Marin HOV facility consists of two HOV lane sections on the US 10 1 freeway that are separated by about 3 miles. The northerly section extending from North San Pedro Road in San Rafael to Route 37 in Novato is about 6.1 miles (.8 km) long. The southerly section, extending from Richardson Boulevard in Saucelito to Sir Francis Drake Boulevard in Greenbrae (or Larkspur) is about 3.7 miles (5.9 km) long.

The US 101 freeway in Marin is unique in that there are literally no parallel arterials or freeways for traffic to divert to in this corridor. The nearest parallel road is State Highway One which winds along the Pacific Coast.

Project History

The project opened originally as bus lanes in the southerly, 3.7 mile long section of US 10 1. Three-plus HOV's were allowed to use the bus lanes on June 16, 1976. The northerly, 6.1 mile long, HOV lane section was opened in August 20, 1986 for 3+ HOVs Two-plus HOV's were allowed to use both northerly and southerly sections of the HOV lanes on October 1, 1988. Ramp metering was not and is not present in this corridor.

Data Collection

Action "A". Conversion from Bus to 3+ HOV: The Before/After data for this action was obtained from Caltrans District 4 offices and Systan files. The before study was conducted in March 1976, about 3 months before the conversion. The after study was conducted in March 1977, about 9 months after the conversion. Data is available only for the peak hour. The before/after data apply only to the southerly, 3.7 mile long HOV lane section of US 101 in Marin County.

Action "B". Conversion from 3+ HOV to 2+ HOV: The Before/After data for this action was obtained from a before/after study by Caltrans[94]. The before data was collected in September 13-28, 1988. The after data was collected in November 1988, December 1988, February 1989, and March 1989. Data is available for the AM and PM peak hours and peak periods. The data reported in this chapter for this action is only for the southerly, 3.7 mile long, section of the HOV lanes on US 101. Only the AM peak period data is reported here.

Data Reduction

Description: The data set shows the impacts of two actions: converting a bus lane to 3+HOV's, and converting the same HOV lanes from 3+ to 2+.

Travel Time Data: The data shows a reduction in travel times for HOV's and no change in travel times for the mixed flow lanes for the conversion from bus lanes to 3+ HOV's The conversion from 3+ to 2+ HOV resulted in a slight increase in travel times for 3+ HOV's and a more significant reduction in travel time for SOV's and 2 person carpools.

Volume Counts:

> Action "A", Conversion from bus to 3+ HOV: Vehicle volumes by occupancy type were estimated for SOV and 2 person car-pools based on the reported passenger volumes. The split in vehicle volumes between 3 person HOV's and 4+ HOV's was estimated based upon the reported passenger volumes for 3+ HOVs. Truck and motorcycle volumes were not available. Bus volumes for the mixed flow lanes were not available.

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94 W R Shoemaker, Marin 10 1,2+ HOV Lane Occupancy Trial Period, October 1988 - March 1989, Operational Evaluation, Caltrans District 4, Highway Operations Branch, Oakland, CA, July 1989.

Action "B", Conversion from 3+ to 2+ HOV: All vehicle data was available by occupancy type. No conversion or splitting of the data was required.

D.7 SANTA CLARA COUNTY, CALIFORNIA

Santa Clara County has been operating HOV lanes, or "commuter-lanes" on signalized arterial streets since 1982. They are currently operating HOV facilities on the San Tomas Expressway and the Montague Expressway and HOV queue bypass lanes on the newly opened Central Expressway. The HOV lane facilities on the San Tomas and Montague Expressways are implemented on the right most lane. The eligibility of all HOV facilities is 2 or more persons per vehicle. These HOV lanes are in operation only during the peak hours, otherwise they carry mixed flow traffic Table D-35 illustrates some general information for HOV lane facilities under Santa Clara County's jurisdiction. Santa Clara County is currently constructing an additional HOV lane on the Lawrence Expressway. It is anticipated that this new HOV facility will be open in early 1997.

The arterial HOV facilities in Santa Clara County are part of the Santa Clara County Commuter Lane network. The County's Transportation 2000 Plan includes a 140-mile network of commuter lanes on freeways and expressways. About 17 lane miles of concurrent flow arterial HOV lanes are operational during the peak period only.

The Traffic and Electrical Operations is responsible for the data collection for HOV facilities. In general, the data is prepared on a semi-annual base by observers. The data collection are conducted during peak hours in the spring and fall when school is in session, Both mechanical and manual counts are used for collecting HOV lane data. The loop detectors mechanically counts 24-hour traffic volumes. Manual counts are made for the vehicle occupancy and percentage of HOV lane usage. The data contain 24-hour through traffic counts by direction only, peak hour vehicle counts for HOV and general-purpose lanes, percentage of HOV lane usage (HOV lane vs. general-purpose lanes), vehicle occupancy for HOV lane and general-purpose lanes. and average travel time and travel speeds. The HOV facility data is available in both hardcopy and IBM-based Lotus files. Dam older than two years old is not retained.

The annual "Commuter Lane Report" includes data for the San Tomas Expressway and Montague Expressway. The data for HOV queue bypass lanes on Central Expressway is not yet available since the bypass opened in 1994.

Adequate before and after data was found for the San Tomas Expressway commuter lanes in the "Commuter Lane Performance Evaluation" prepared by Systan in 1989. The available "before" data for the other HOV projects was less satisfactory and could not be included in the methodology database.

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D.7.1 San Tomas Expressway - Santa Clara County, California

The San Tomas Expressway is a 6 lane expressway with shoulder and curb lane HOV lanes. The HOV lanes are right-hand side, concurrent flow lanes extending for 6.5 miles. The northbound lane is open 6 AM to 9 AM weekdays. The southbound lane is open 3 PM to 7 PM weekdays. The HOV lanes are restricted to 2+ occupant vehicles plus motorcycles.

The first 4.9 mile (7.9 km) stage of the project opened November 22. 1982. The second 1.6 mile (2.6 km) stage of the project opened on April 1984. The first stage of this project was selected for the methodology development database. The lack of 1984 data precluded the incorporation of the second stage of this project in the methodology database.

Table D-35. Santa Clara County Expressway HOV Facilities

Characteristics	Santa Clara County		
Corridor	**San Tomas Expwy (commuter lane)**	**Montague Expwy (commuter lane)**	**Central Expressway (ramp queue bypass)**
Begin and End/Ramp Locations	**Walsh to Budd**	**US101 to I-680**	**Bowers, Scott**
# of Directional HOV lanes	**2**	**2**	**1 on-ramp**
Length (mi.)	**6.5**	**4.5**	**N/A**
Date Operational	**82/84**	**83/90**	**94**
HOV Eligibility	**2+**	**2+**	**2+**
Hours of HOV Operation (weekdays only)	6-9am NB 3-7pm SB	6-9am WB 3 -7pm EB	
Type of facility	striped concurrent (rightmost lane)	striped concurrent (rightmost lane)	striped concurrent on-ramp lanes

All HOV lanes are on the left side unless otherwise noted.

Source: County of Santa Clara, Roads & Airports Department, 1993 Commuter Lane Report, 1993.

Data Collection

Vehicle counts and passenger counts are available for the peak direction of the AM and PM peak periods on the San Tomas Expressway for the years 1982, 1983, 1985, 1986, 1987, and 1988. Violation rates are available for 1985, 1986, 1987, and 1988. Time savings data is available for 1983, 1985, 1986, 1987, and **1988.**

The vehicle counts are not stratified by occupancy type or vehicle type, but are stratified by lane type (HOV lane vs. other lanes).

Data Reduction

Description: This data set shows the impacts of adding a concurrent flow, right-hand side HOV lane for 4.9 miles (7.9 km) in the northbound direction on a 6 lane signalized expressway.

Travel Time Data: The maximum and mean travel time savings for the HOV lanes were read directly from the project data summary tabulations. The HOV time savings were converted to actual travel times assuming that the average speed in the HOV lanes was 45 mph (72 kph). The mixed flow lane travel times for the before condition were not reported, so they were assumed to be the same as the after travel times.

Volume Counts: Peak period volume counts by HOV lane and the other lanes were obtained directly from the tabulations in the report. This data was not broken down by vehicle type or occupancy type. Peak hour volumes were not reported. The AM peak period violation rate was 5% of the HOV lane volume in 1985.

Table D-36 summarizes the results of the before/after study.

Source

Systan Inc., Santa Clara County Commuter Lane Performance Evaluation, Final Report, Santa Clara County Transportation Agency, San Jose, California, March 1, 1989.

Table D-36. San Tomas Expressway Results

Action: Construct 4.9 mile HOV lane[95]		
	Peak Hour	Peak Period
HOV Lane Volume (After)	-	1049
Change in Total Vehicles[96]	-	+13%
Change in Total Persons[97]	-	+18%
Average Vehicle Occ.[98]:		
Before:	-	1.10
After:	-	1.15
Change in HOV Time[99]	-	Save 2 minutes
Change in SOV Time[100]	-	Save 0 minutes (est.)

95 Data is for morning peak period (6:00 AM to 9:00 AM), northbound direction. Report is unclear on dates of data collection.

96 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

97 Total persons in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

98 Total persons divided by total vehicles. Includes buses and vans.

99 Mean time savings for HOV lane expressed as "Before" minus "After. Rounded to nearest whole minute.

100 No data. Assumed to be zero.

D.8 SNOHOMISH AND KING COUNTIES, WASHINGTON

The Puget Sound region is one of the few areas in the U.S. to have implemented a HOV lane on an arterial street since the 1980's. Snohomish and King Counties are part of the Puget Sound region. Long range plans in the region would extend the HOV network to all freeways and many of the major arterial streets. The existing HOV facilities in the area are listed below:

1. Downtown Seattle - Right parking lanes on Second and Forth Avenues, one-way streets, are use for buses only during AM and PM peak periods. Both of HOV bus lanes are about one mile in length. Another facility located on Fifth Avenue is a contra-flow lane operating in the PM peak period.
2. SR99 - Outside northbound right lane between the Seattle city limits at N. 145th Street and N. 120th Street is required 3 or more persons, and right turning vehicle to be eligible for the facility. This HOV facility is about 1.5 mile in length and operates for 24-hour a day.
3. University of Washington - Eastbound on NE Pacific Street outside lane is required 2 or more to be eligible for the facility.
4. SR522 - Northbound parking strip between NE 130th Street and city limits at NE 145th Street, about 1 mile in length, is reserved for 3 or more and buses during the PM peak period. Southbound shoulder between Kenmore and the Seattle city limits at NE 145th Street is reserved for buses only for 24-hour a day.
5. Airport Road/128th Street - Northbound outside lane between 4th Avenue and SR99, 1 mile in length, is operating in the AM peak hours. Southbound outside lane between SR526 and 4th Avenue, 3.3 miles in length, is operating in the PM peak hours. Both of these directional HOV lanes were implemented in January 1993 in Snohomish County, and required 2 or more to be eligible for the facilities.

The University of Washington has done a great deal of work on arterial HOV facilities. A number of arterial studies have been conducted or are underway in the Puget Sound region.

A "before and after" study has been published for the Snohomish County Public Works on the Airport Road HOV Program. Public Works collected data prior to construction and 3-months, 6-months, and 1 year following construction and continues to collect the data, including vehicle volumes, occupancy, and speeds.

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D.8.1 Airport Rd./128th St. SW, Seattle, Washington

The Airport Road/l28th Street SW corridor consists of a 3.4 mile (5.5 km) long, four lane wide, divided, signalized arterial street. A 3.3 mile (5.3 km) long eastbound HOV lane and a 1 mile (1.6 km) shoulder HOV lane were added in January 1993. The lanes occupy the curb lane. Approximately 11 signals are in place along the length of this corridor. Two plus person vehicles are eligible to use the HOV lanes during each peak hour.

Data Collection

Vehicle counts and passenger counts are available for the eastbound direction during the PM peak hour for "before", 3 months after, 6 months after, and one year after opening of the eastbound HOV lane. Violation rates are not reported. Average HOV lane and mixed flow lane vehicle speeds are reported for the same periods.

The vehicle counts are not stratified by occupancy type, vehicle type, or lane type (HOV lane vs. other lanes).

Data Reduction

Description: This data set shows the impacts of adding a concurrent flow, right-hand side HOV lane for 3.3 miles (5.3 km) in the eastbound direction on a 4 lane, divided, signalized arterial.

Travel Time Data: The mean peak hour travel times for the HOV lanes and the mixed flow lanes were computed based on the reported mean speeds and the length of the HOV lane. Maximum travel times were not reported and were consequently assumed to be the same as the mean peak hour times.

Volume Counts: Peak hour vehicle and person volume counts were obtained from the bar graphs in the report. This data was not broken down by vehicle type, occupancy type, or lane type. Peak period volumes were not reported. Violation rates were not reported.

The before/after study results are summarized in Table D-37.

Source

Owen Carter, James Bloodgood, "Snohomish County Public Works Airport Road HOV Program", Compendium of Technical Papers, Institute of Transportation Engineers, 47th District 6 Annual Meeting, Portland, Oregon, July, 1994.

Table D-37. Airport Road HOV Lanes Results

Action: Construct 3.3 mile arterial HOV lane[101]		
	Peak Hour	Peak Period
HOV Lane Volume (After)		
'Change in Total Vehicles[102]	-9%	-
Change in Total Persons[103]	+8%	-
Average Vehicle Occ. [104]: Before: After:	 1.27 1.50	 - -
Change in HOV Time[105]	Save 1 minute	-
Change in SOV Time [106]	Save 0 minutes	-

101 Data is for evening peak hour only, eastbound direction. After data is for one year after opening.

102 Total vehicles (sum of HOV lane plus mixed flow lanes) in peak direction, expressed as "After" minus "before", divided by "before".

103 Total persons in peak direction in all vehicles, in all lanes expressed as "After" minus "before", divided by "before".

104 Total persons divided by total vehicles. Includes buses and vans.

105 Mean time savings for HOV lane expressed as "Before" minus "After. Rounded to nearest whole minute.

106 No data. Assumed to be zero.

D.9 VIRGINIA DEPARTMENT OF TRANSPORTATION

The Virginia Department of Transportation has been operating HOV lane since 1969 and currently operates 5 HOV facilities in the Northern Virginia area. Types of HOV facilities range from barrier-separated reversible lanes to barrier-separated two-way lanes to concurrent freeway lanes. Except for a section of the I-66 corridor, the HOV lanes require 3 or more persons per vehicle to be eligible. Hours of operation vary by route. Table D-38 shows general information on HOV facilities for the northern Virginia area.

The opening of the Shirley Highway to buses in 1969 was the first use of an HOV facility on a freeway in the U.S. Since opening, the occupancy requirement and operating hours have changed a number of times. Several studies have been conducted on the Shirley Highway since its inception as an "express-bus-on-freeway" demonstration. This data is currently being processed by the team and is not reported in this . The Virginia DOT has plans to conduct a "before-and-after" study on the conversion of the I-66 HOV project from 39 to 2+ in the near future.

The Virginia Vanpool Association (VVPA) plays an active role in the promotion and support of Vanpools in the northern Virginia/Washington. D.C. metropolitan arca. They have conducted several surveys of vanpool drivers and riders.[107]

The Metropolitan Washington Council of Governments has been conducting Metro core cordon counts since 1974. These counts were initially annual studies. They have been conducted every two to three years since 1981. The cordon counts include vehicle and passenger counts for the morning and evening peak periods of both the mixed flow and HOV lanes on the Shirley Highway and I-66. The monitoring data does not include travel time or speed measurements.

The Metropolitan Washington Council of Governments has also conducted surveys of Vanpool drivers and carpoolers including a "1987 Survey and Evaluation of Ride Finders Ridesharing Network" and a 1989 survey of Vanpool drivers which found their main concern to be HOV lanes over parking, insurance, costs, and riders.

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D.9.1 Shirley Highway (I-395) - Washington, D.C./Northern Virginia

The first use of a HOV facility on a freeway in the United States was the five miles of bus-only lanes on the Shirley Highway which opened in 1969 The facility provides access to Washington, D.C. from the southwest. The HOV facility is a barrier-separated, reversible, two-lane facility located in the median of the freeway (see Table D-39 for project history).

Park-and-ride lots and direct access ramps are located along the corridor. Metrorail Yellow Line opened in 1983

Several studies were conducted when the Shirley Highway first opened to buses in 1969.

As part of the Express-Bus-on-Freeway Demonstration Project. several reports were written about the Shirley Highway. The demonstration project was sponsored by the U.S. DOT and comprised of three

[107] Lew W. Pratsch. "Vanpools an HOV lanes: Major Keys to Reduce Traffic Congestion," 4th National Conference on High Occupancy Vehicle Facilities, April 11, 1990.

elements - 1 l-miles of HOV lanes, new buses in express service, and park-and-ride lots. Data collected included vehicle volumes and person trip counts at 8 stations along a screenline to cover changes in the corridor and not just the Shirley Highway. Bus data included adherence to schedules, number of passengers, costs, and travel times. Actual and perceived travel times were collected for buses and autos. Surveys of auto and bus commuters and park-and-ride users were conducted.

For the Shirley Highway Operations Study conducted in 1976, vehicle volumes were collected manually and by machine at approximately 50 locations to supplement existing counts. Speeds and travel times were collected for the mainline study section.

Data Collection

The majority of published before/after studies for the Shirley Highway HOV Facility were made when the facility operated as an exclusive bus facility.

Vehicle counts and passenger counts for the HOV lanes are available by vehicle type for the AM peak period for 1979, 1980, 1981, 1983, 1985, 1987, 1990, and 1993. This data is available in the most recent Metro Core Cordon Report published by the Metropolitan Washington Council of Governments. Similar historical data is available for the mixed flow lanes, but must be obtained from each year's report.

Total vehicle volumes during the morning peak period (6-9 AM) in the HOV lanes increased from 4608 to 6593 between 1987 and 1990. Passenger volumes increased from 30,717 to 37,610. The HOV lanes were converted from 4+ HOV to 3+ HOV in January 1989.

Unfortunately, none of the cordon reports provide travel time data collected simultaneously with the volume counts.

Sources

1. Gerald K. Miller and Keith M. Goodman. The Shirley Highway Express-Bus-on-Freeway Demonstration Project / First Year Results, Interim Report 2, UMTA, November 1972.
2. James T. McQueen, Richard F. Yates, and Gerald K. Miller. The Shirley Highway Express-Bus-on-Freeway Demonstration Project / Second Year Results, Interim Report 4, UMTA, November 1973.
3. JHK Associates. Shirley Highway Operations Study, August 1976.
4. Jon Williams, 1993 Metro Core Cordon Count of Vehicles and Passenger Volumes, Metropolitan Washington Council of Governments, Washington D.C., May 1994.

Table D-38. Northern Virginia HOV Facilities

Characteristics	Northern Virginia DOT			
Corridor	I-395 Shirley	I-66	I-66	I-95 (interim)
Begin and End	Capitol Beltway to Potomac River	Capitol Beltway to Potomac River	Outside Beltway	
# of Directional HOV lanes	2	2 to 3	2	2
Length (mi.)	11	9.6	7	5
Date Operational	69/75	82		
HOV Eligibility	3+	3+	2+	3+
Hours of HOV Operation (weekdays only)	6-9am NB 3:30-6pm SB	6:30-9am EB 4-6:30pm WB	N/A	6-9am 3:30-6pm
Type of facility	barrier separated reversible lane	barrier separated two-way	striped concurrent each dir.	striped concurrent each dir.
Ramp Metering	Yes	Yes	Yes	

Sources:

Tumbull, Katherine. An Assessment of High-Occupancy Vehicle Facilities in North America: Executive Report, Texas Transportation Institute, August 1992, Table 1. General Characteristics of Operating HOV Facilities.

Fuhs, Charles. Inventory of Current and Proposed High-Occupancy Vehicle Projects in the U.S. and Canada, January 1995.

Table D-39. Shirley Highway HOV Facility History

Characteristic	Shirley Highway HOV System			
Corridor				Springfield I/C to 14th St. Bridge
# of HOV lanes	2			
# of general purpose lanes	3 in each direction			
Length	5 miles			11 miles
Date Operational	1969	Dec 1973	Jan 1989	July 1991
HOV Eligibility	buses only	4 +	3 +	2 +
Hours of HOV Operation	11:00 pm to 11:00 am inbound 1:00 pm to 8:00 pm outbound		6:00 am to 9:00 am inbound 3:30 pm to 6:00 pm outbound	
Type of facility	barrier-separated, reversible			
Ramp Metering				
Park-and-ride facilities	yes			
Other support facilities				
Bus Service		New express buses		

D.10 NEW JERSEY DEPARTMENT OF TRANSPORTATION

The New Jersey State Department of Transportation began operating its first HOV lane facility in March 1994. This new HOV lane facility is located on the I-80 corridor in Morris County and provides a concurrent lane in the eastbound and westbound directions. Two or more persons per vehicle are required to be eligible for the HOV lanes, which only operate during peak hours in the peak direction. Table D-40 provides a summary of the facility characteristics of the I-80 HOV lanes. This spring the New Jersey DOT will begin construction of another HOV lane facility on I-287 corridor and a queue bypass within the I-80/I-287 interchange.

The Bureau of Transportation Data Development (BTDD) is maintaining the data collection through the state. Most of data collection are contracted out with consultants. The pre-HOV data ("before" data) on the I-80 corridor is available which contains vehicle counts in 15-minute interval by types of vehicle, vehicle occupancy, and average travel speed.

A before-and-after report for the newly implemented HOV facility on I-80 is not available at this time, but is expected to be available for distribution soon.

Although a user survey for the HOV facility has not been conducted in I-80 corridor, the New Jersey DOT is planning on conducting a HOV lane user survey in the future.

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D.10.1 I-80 HOV Facility - Morris County, New Jersey

Initially, in 1991. the section of I-80 was under construction to provide an additional general purpose lane in both eastbound and westbound. At the meantime, the feasibility study of providing HOV facility along I-80 began. In 1992, the committee who reviewed the feasibility study concluded that HOV lanes could be operated on I-80. The HOV lanes extend from Route 15 to Beverwcy Road of the east, and are approximately 10.5 miles. The section on I-80 within the limits of the HOV lanes consists of 4 lanes (HOV lanes located in the median) in each direction, with an exception of the eastern portion. The HOV facility was opened to operation in March 1994, and was restricted for buses, Vanpools, and 2 or more persons during peak periods. It should be noted that existing 6 park-and-ride lots are located close to the western limits of HOV lanes where the commuter trip origins are. Table D-4 1 summarizes the HOV facility information for I-80 corridor.

As mentioned in the agency profile. the Bureau of Transportation Data Development (BTDD) is maintaining HOV lanes' data. The data collection effort was conducted by several consultants. The "before" data of I-80 corridor are available in 1989, 1991, and 1994. The "after" data was collected after the opening of operation in 1994.

The "before-and-after" data consists of vehicle counts by each lane for HOV lane and general-purpose lane, person counts by each lane for HOV lane and general-purpose lanes, violation vehicle counts on HOV lane, and travel speeds for HOV lane and general-purpose lanes. Prior to the HOV lane operations, a phone survey of motorists and executive interviews were performed to obtain attitudinal data for I-80 HOV lane facility. Although the "after" data has been collected, it will not be released until March 1995. Table 41 shows the "before" data and comparisons for I-80 HOV lane facility.

References:

1. Barbara L. Fischer. Lane Conversion Strategy for the I-80 High-Occupancy Vehicle Lanes in New Jersey, June 1994.

2. State of New Jersey, Bureau of Transportation Data Development. I-80 HOV Lane, Data Collection/Monitoring Program, December 1993.

3. New Jersey Department of Transportation - Office of Region II Design. I-80 HOV Lane Evaluation Plan - Revised Draft, March 1994.

4. Parsons Brinckerhoff Quade & Douglas, Inc., and Pacific Rim Resources, Route I-80 High Occupancy Vehicle Lane Feasibility Study, January, 1992.

Table D-40. I-80 New Jersey HOV Lanes

Characteristics	**New Jersey DOT**
Corridor	**I-80** **Morris County**
Begin and End	**Mt. Home to Beverwyck**
# of Directional HOV lanes	**2**
Length (mi.)	**10.5**
Date Operational	**94**
HOV Eligibility	**2+**
Hours of HOV Operation (weekdays only)	**6-9am EB** 3-7pm WB
Type of facility	striped concurrent each dir.
Parallel roadway facilities	Rte 46 & Rte 10

All HOV lanes are on the left side unless otherwise noted.

Table D41. I-80 New Jersey HOV Lane Results

Date	# of Lanes		AM Peak Hour - Peak Direction (Eastbound) Counts						Occupancy (pers./veh.)		Travel Time [1] (min.)	
	HOV Lane	non-HOV	Bus		HOV Lane		non-HOV Lanes		HOV Lane	non-HOV	HOV Lane	non-HOV
			veh.	pers.	veh.	pers.	veh.	pers.				
1993	n.a.	3			n.a.	n.a.	4,680	5,124	**n.a.**	**1.1**	n.a.	n.a.
1994	1	3			n.a.	n.a.	n.a.	n.a.	**n.a.**	**n.a.**	n.a.	n.a.

1 Travel time not available. Average travel speed is 21.99 mph for eastbound direction during AM peak.

2 After data not yet available at time of printing. A "before-and-after" report is anticipated to be released in March 1995.

APPENDIX E. VEHICLE EMISSION RATES

VEHICLE EMISSION RATES

A total of twelve vehicle emission rate tables are embedded in the FREQ10 model. The user may select the desired table by specifying the year (1990, 1995, or 2010) and the temperature (55, 65, 85, or 95 degrees Fahrenheit). The default table is for the year 1990 and for a temperature of 65 degrees. The following tables show the actual values that are incorporated within the program.

Emission Rates for California Vehicles, 1990.
(Hot Stabilized Conditions, Ambient Temperature = 55^{o}F).

Vehicle Class	Gross per mile for average travel speeds (in mph) of:														OLE
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Auto6	4.54	2.40	1.67	1.30	1.06	0.89	0.75	0.65	0.57	0.52	0.47	0.54	0.77	1.00	0.38
Gas trucks	9.67	5.74	3.93	2.90	2.25	1.81	1.50	1.29	1.14	1.05	0.91	1.12	1.56	2.01	0.81
Diesel trucks	8.24	6.47	5.19	4.26	3.57	3.06	2.66	2.40	2.20	2.06	1.97	1.93	1.93	1.93	0.69
Carbon Monoxide															
Autos	50.91	26.04	17.82	13.52	10.86	9.03	7.72	6.76	6.06	5.52	5.04	9.70	22.19	34.67	i.24
Gas trucks	113.27	70.02	49.05	37.40	29.59	24.57	21.30	19.54	10.77	18.93	19.94	25.76	38.91	52.07	9.44
Diesel trucks	38.80	26.75	19.30	14.58	11.52	9.53	8.25	7.48	7.09	7.03	7.30	7.94	9.03	10.12	3.23
Nitrous Oxide															
Autos	1.43	1.30	1.19	1.11	1.06	1.02	1.00	0.99	1.01	1.17	1.54	1.91	2.27	2.64	0.12
Gas trucks	3.31	3.24	3.21	3.21	3.23	3.26	3.31	3.36	3.44	3.66	4.11	4.52	4.95	5.39	0.28
Diesel trucks	26.53	22.02	18.92	16.86	15.56	14.88	14.74	15.13	16.09	17.74	20.26	23.97	29.38	34.80	2.21

Emission Rates for California Vehicles, 1995.
(Hot Stabilized Conditions, Ambient Temperature = 55°F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	2.55	1.32	0.90	0.69	0.56	0.47	0.40	0.34	0.30	0.27	0.25	0.32	0.55	0.77	0.21
Gas trucks	6.67	3.93	2.68	1.97	1.52	1.22	1.01	0.86	0.76	0.69	0.65	0.74	1.02	1.31	0.56
Diesel trucks	6.91	5.43	4.36	3.57	3.00	2.57	2.25	2.02	1.85	1.73	1.65	1.62	1.62	1.62	0.58
Carbon Monoxide															
Autos	25.56	15.75	11.58	8.87	7.10	5.89	5.03	4.40	3.92	3.54	3.22	6.22	14.21	22.21	2.13
Gas trucks	67.88	43.37	31.07	23.35	18.45	15.30	13.31	12.13	11.61	11.65	12.23	15.94	24.36	32.78	5.66
Diesel trucks	37.02	25.53	18.42	13.91	11.00	9.09	7.87	7.13	6.76	6.71	6.97	7.57	8.61	9.65	3.09
Nitrous Oxides															
Autos	1.04	0.93	0.85	0.78	0.73	0.69	0.66	0.64	0.63	0.71	0.94	1.16	1.39	1.61	0.09
Gas trucks	3.11	3.05	3.02	3.01	3.02	3.05	3.08	3.13	3.19	3.38	3.75	4.12	4.49	4.86	0.26
Diesel trucks	21.28	17.65	15.17	13.52	12.47	11.93	11.82	12.13	12.90	14.22	16.24	19.22	23.56	27.90	1.77

Emission Rates for California Vehicles, 2010.
(Hot Stabilized Conditions, Ambient Temperature = 55F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	0.96	0.49	0.34	0.25	0.20	0.17	0.14	0.12	0.10	0.09	0.08	0.11	0.18	0.26	0.08
Gas trucks	4.26	2.53	1.72	1.25	0.95	0.75	0.62	0.53	0.46	0.42	0.39	0.44	0.59	0.74	0.35
Diesel trucks	6.22	4.88	3.92	3.21	2.70	2.31	2.03	1.81	1.66	1.56	1.49	1.46	1.46	1.46	0.52
Carbon Monoxide															
Autos	6.51	4.64	4.01	3.15	2.52	2.10	1.80	1.57	1.40	1.26	1.15	2.26	5.12	7.99	0.54
Gas trucks	31.50	21.37	15.97	12.08	9.54	7.92	6.89	6.26	5.94	5.91	6.16	8.25	13.05	17.86	2.62
Diesel trucks	35.08	24.19	17.45	13.18	10.42	8.62	7.47	6.76	6.41	6.36	6.60	7.18	8.16	9.15	2.92
Nitrous Oxides															
Autos	0.72	0.64	0.57	0.52	0.48	0.44	0.41	0.39	0.38	0.42	0.55	0.68	0.82	0.95	0.06
Gas trucks	2.94	2.90	2.88	2.88	2.90	2.93	2.97	3.02	3.08	3.24	3.55	3.86	4.17	4.48	0.25
Diesel trucks	18.30	15.18	13.05	11.63	10.73	10.26	10.17	10.44	11.10	12.23	13.97	16.53	20.27	24.00	1.53

Emission Rates for California Vehicles, 1990.
(Hot Stabilized Conditions, Ambient Temperature = 65°F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	4.28	2.33	1.64	1.29	1.05	0.87	0.73	0.61	0.52	0.47	0.43	0.55	0.93	1.31	0.36
Gas trucks	9.08	5.42	3.72	2.75	2.14	1.71	1.42	1.21	1.06	0.97	0.91	1.03	1.44	1.84	0.76
Diesel trucks	8.24	6.47	5.19	4.26	3.57	3.06	2.68	2.40	2.20	2.06	1.97	1.93	1.93	1.93	0.69
Carbon Monoxide															
Autos	44.06	22.54	15.42	11.70	9.39	7.82	6.68	5.85	5.24	4.78	4.36	8.40	19.20	30.00	3.67
Gas trucks	105.76	66.40	46.72	35.02	27.69	22.99	20.02	18.31	17.61	17.80	18.80	24.07	35.83	47.59	8.81
Diesel trucks	38.80	26.75	19.30	14.58	11.52	9.53	8.25	7.48	7.09	7.03	7.30	7.94	9.03	10.12	3.23
Nitrous Oxides															
Autos	1.34	1.21	1.11	1.04	0.99	0.95	0.93	0.93	0.94	1.09	1.44	1.78	2.13	2.47	0.11
Gas trucks	3.12	3.07	3.04	3.04	3.06	3.10	3.14	3.20	3.27	3.48	3.88	4.29	4.69	5.09	0.26
Diesel trucks	26.53	22.02	18.92	16.86	15.56	14.88	14.74	15.13	16.09	17.74	20.26	23.97	29.38	34.80	2.21

Emission Rates for California Vehicles, 1995.
(Hot Stabilized Conditions, Ambient Temperature = 65°F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	2.41	1.27	0.88	0.68	0.55	0.46	0.38	0.32	0.28	0.25	0.23	0.29	0.50	0.70	0.20
Gas trucks	6.23	3.69	2.52	1.85	1.43	1.14	0.94	0.80	0.71	0.64	0.60	0.68	0.94	1.20	0.52
Diesel trucks	6.91	5.43	4.36	3.57	3.00	2.57	2.25	2.02	1.85	1.73	1.65	1.62	1.62	1.62	0.58
Carbon Monoxide															
Autos	24.49	13.61	10.00	7.66	6.13	5.09	4.34	3.80	3.38	3.06	2.78	5.37	12.27	19.18	2.04
Gas trucks	62.86	40.26	28.79	21.61	17.06	14.15	12.31	11.24	10.77	10.83	11.41	14.73	22.19	29.64	5.24
Diesel trucks	37.02	25.33	18.42	13.91	11.00	9.09	7.87	7.13	6.76	6.71	6.97	7.57	8.61	9.65	3.09
Nitrous Oxides															
Autos	0.97	0.87	0.79	0.73	0.68	0.64	0.61	0.59	0.58	0.67	0.87	1.08	1.29	1.50	0.08
Gas trucks	2.94	2.88	2.86	2.85	2.86	2.88	2.92	2.97	3.03	3.20	3.55	3.89	4.24	4.58	0.24
Diesel trucks	21.28	17.65	15.17	13.52	12.47	11.93	11.82	12.13	12.90	14.22	16.24	19.22	23.56	27.90	1.77

Emission Rates for California Vehicles, 2010.
(Hot Stabilized Conditions, Ambient Temperature = 65°F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	0.92	0.49	0.34	0.26	0.20	0.17	0.14	0.11	0.09	0.08	0.08	0.10	0.17	0.24	0.08
Gas trucks	3.97	2.36	1.61	1.17	0.89	0.71	0.58	0.49	0.43	0.39	0.36	0.41	0.54	0.68	0.33
Diesel trucks	6.22	4.88	3.92	3.21	2.70	2.31	2.03	1.81	1.66	1.56	1.49	1.46	1.46	1.46	0.52
Carbon Monoxide															
Autos	5.63	4.01	3.47	2.72	2.18	1.82	1.56	1.36	1.21	1.09	0.99	1.93	4.42	6.91	0.47
Gas trucks	28.65	19.41	14.47	10.93	8.63	7.17	6.23	5.67	5.39	5.37	5.61	7.46	11.68	15.90	2.39
Diesel trucks	35.08	24.19	17.45	13.18	10.42	8.62	7.47	6.76	6.41	6.36	6.60	7.18	8.16	9.15	2.92
Nitrous Oxides															
Autos	0.68	0.60	0.54	0.49	0.45	0.42	0.39	0.37	0.35	0.40	0.52	0.65	0.77	0.90	0.06
Gas trucks	2.78	2.74	2.72	2.72	2.74	2.76	2.80	2.85	2.91	3.06	3.35	3.65	3.94	4.23	0.23
Diesel trucks	18.30	15.18	13.05	11.63	10.73	10.26	10.17	10.44	11.10	12.23	13.97	16.53	20.27	24.00	1.53

Emission Rates for California Vehicles, 1990.
(Hot Stabilized Conditions, Ambient Temperature = 85°F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	4.40	2.48	1.79	1.41	1.15	0.95	0.78	0.64	0.51	0.45	0.41	0.53	0.89	1.26	0.37
Gas trucks	9.49	5.74	3.96	2.94	2.27	1.82	1.50	1.26	1.10	0.99	0.93	2.00	2.43	2.85	0.79
Diesel trucks	8.24	6.47	5.19	4.26	3.57	3.06	2.68	2.40	2.20	2.06	1.97	1.93	1.93	1.93	0.69
Carbon Monoxide															
Autos	44.85	22.96	15.72	11.93	9.58	7.97	6.81	5.96	5.34	4.87	4.44	8.56	19.57	30.59	3.74
Gas trucks	122.52	77.47	54.49	40.79	32.22	26.74	23.31	21.35	20.58	20.85	22.13	27.94	40.66	53.37	10.21
Diesel trucks	38.80	26.75	19.30	14.58	11.52	9.53	8.25	7.48	7.09	7.03	7.30	7.94	9.03	10.12	3.23
Nitrous Oxides															
Autos	1.25	1.13	1.04	0.97	0.92	0.89	0.87	0.87	0.88	1.02	1.34	1.67	1.99	2.31	0.10
Gas trucks	3.24	3.21	3.21	3.22	3.26	3.31	3.37	3.44	3.53	3.74	4.13	4.52	4.91	5.30	0.27
Diesel trucks	26.53	22.02	18.92	16.86	15.56	14.88	14.74	15.13	16.09	17.74	20.26	23.97	29.38	34.80	2.21

Emission Rates for California Vehicles, 1995.
(Hot Stabilized Conditions, Ambient Temperature = 85°F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	2.50	1.37	0.97	0.75	0.61	0.50	0.41	0.33	0.27	0.24	0.22	0.29	0.48	0.68	0.21
Gas trucks	6.61	3.96	2.72	2.00	1.54	1.23	1.01	0.85	0.74	0.67	0.63	0.70	0.96	1.22	0.55
Diesel trucks	6.91	5.43	4.36	3.57	3.00	2.57	2.25	2.02	1.85	1.73	1.65	1.62	1.62	1.62	0.58
Carbon Monoxide															
Autos	25.35	14.12	10.39	7.96	6.37	5.29	4.52	3.95	3.52	3.18	2.89	5.58	12.76	19.94	2.11
Gas trucks	73.43	47.25	33.71	25.27	19.94	16.54	14.40	13.17	12.65	12.76	13.50	17.19	25.32	33.44	6.12
Diesel trucks	37.02	25.53	18.42	13.91	11.00	9.09	7.87	7.13	6.76	6.71	6.97	7.57	8.61	9.65	3.09
Nitrous Oxides	0.90	0.81	0.74	0.68	0.63	0.60	0.57	0.55	0.54	0.62	0.82	1.01	1.21	1.40	0.08
Autos	3.10	3.07	3.06	3.08	3.10	3.14	3.20	3.26	3.33	3.52	3.86	4.20	4.54	4.88	0.26
Gas trucks	21.28	17.65	15.17	13.52	12.47	11.93	11.82	12.13	12.90	14.22	16.24	19.22	23.56	27.90	1.77
Diesel trucks															

Table 10.4: Emission Rates for California Vehicles, 2010.
(Hot Stabilized Conditions, Ambient Temperature = 85°F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	0.99	0.54	0.38	0.29	0.23	0.19	0.15	0.11	0.09	0.08	0.08	0.10	0.17	0.24	0.08
Gas trucks	4.34	2.61	1.78	1.30	0.99	0.78	0.64	0.53	0.47	0.42	0.40	0.44	0.58	0.72	0.36
Diesel trucks	6.22	4.88	3.92	3.21	2.70	2.31	2.03	1.81	1.66	1.56	1.49	1.46	1.46	1.46	0.52
Carbon Monoxide															
Autos	5.98	4.26	3.69	2.90	2.32	1.93	1.66	1.45	1.29	1.16	1.05	2.06	4.71	7.35	0.50
Gas trucks	33.72	22.80	16.90	12.75	10.06	8.35	7.27	6.62	6.31	6.31	6.62	8.69	13.34	17.99	2.81
Diesel trucks	35.08	24.19	17.45	13.18	10.42	8.62	7.46	6.76	6.41	6.36	6.60	7.18	8.16	9.15	2.92
Nitrous Oxides															
Autos	0.64	0.57	0.51	0.46	0.43	0.40	0.37	0.35	0.33	0.37	0.49	0.61	0.73	0.85	0.05
Gas trucks	3.00	2.98	2.98	3.00	3.03	3.08	3.14	3.20	3.27	3.44	3.73	4.03	4.32	4.62	0.25
Diesel trucks	18.30	15.18	13.05	11.63	10.73	10.26	10.17	10.44	11.10	12.23	13.97	16.53	20.27	24.00	1.53

Emission Rates for California Vehicles, 1990.
(Hot Stabilized Conditions, Ambient Temperature = 95°F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	4.82	2.77	2.02	1.60	1.31	1.07	0.87	0.70	0.55	0.48	0.43	0.56	0.95	1.33	0.40
Gas trucks	10.57	6.42	4.44	3.29	2.54	2.03	1.67	1.40	1.21	1.10	1.03	1.15	1.57	1.99	0.88
Diesel trucks	8.24	6.47	5.19	4.26	3.57	3.06	2.68	2.40	2.20	2.06	1.97	1.93	1.93	1.93	0.69
Carbon Monoxide															
Autos	52.76	27.04	18.53	14.06	11.29	9.39	8.03	7.03	6.30	5.74	5.23	10.09	23.07	36.05	4.40
Gas trucks	151.97	96.37	67.79	50.72	40.05	33.24	28.98	26.56	25.62	25.99	27.63	34.70	50.07	65.43	12.66
Diesel trucks	38.80	26.75	19.30	14.58	11.52	9.53	8.25	7.48	7.09	7.03	7.30	7.94	9.03	10.12	3.23
Nitrous Oxides															
Autos	1.25	1.13	1.04	0.97	0.92	0.89	0.87	0.87	0.88	1.02	1.34	1.67	1.99	2.31	0.10
Gas trucks	3.59	3.58	3.60	3.63	3.68	3.75	3.83	3.92	4.02	4.25	4.66	5.07	5.48	5.89	0.30
Diesel trucks	26.53	22.02	18.92	16.86	15.56	14.88	14.74	15.13	16.09	17.74	20.26	23.97	29.38	34.80	2.21

Emission Rates for California Vehicles, 1995.
(Hot Stabilized Conditions, Ambient Temperature = 95°F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	2.73	1.51	1.07	0.84	0.68	0.55	0.45	0.36	0.30	0.26	0.24	0.31	0.52	0.73	0.23
Gas trucks	7.50	4.52	3.11	2.28	1.75	1.35	1.14	0.96	0.84	0.76	0.71	0.79	1.07	1.35	0.63
Diesel trucks	6.91	5.43	4.36	3.57	3.00	2.57	2.25	2.02	1.85	1.73	1.65	1.62	1.62	1.62	0.58
Carbon Monoxide															
Autos	30.36	16.95	12.50	9.58	7.66	6.37	5.44	4.75	4.23	3.83	3.47	6.72	15.36	24.01	2.53
Gas trucks	92.52	59.68	42.57	31.90	25.16	20.87	18.18	16.63	15.99	16.15	17.12	21.68	31.65	41.62	7.71
Diesel trucks	37.02	25.53	18.42	13.91	11.00	9.09	7.87	7.13	6.76	6.71	6.97	7.57	8.61	9.65	3.09
Nitrous Oxides															
Autos	0.90	0.81	0.74	0.68	0.63	0.60	0.57	0.55	0.54	0.62	0.82	1.01	1.21	1.40	0.08
Gas trucks	3.51	3.50	3.51	3.54	3.59	3.66	3.73	3.81	3.90	4.11	4.47	4.83	5.19	5.56	0.29
Diesel trucks	21.28	17.65	15.17	13.52	12.47	11.93	11.82	12.13	12.90	14.22	16.24	19.22	23.56	27.90	1.77

Emission Rates for California Vehicles, 2010.
(Hot Stabilized Conditions, Ambient Temperature = 95°F).

Vehicle Class	Grams per mile for average travel speeds (in mph) of:														IDLE (Grams /Min)
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	
Hydrocarbons															
Autos	1.09	0.61	0.43	0.33	0.26	0.21	0.16	0.13	0.10	0.10	0.08	0.11	0.18	0.26	0.09
Gas trucks	5.11	3.10	2.12	1.54	1.17	0.92	0.75	0.63	0.55	0.50	0.47	0.51	0.66	0.82	0.43
Diesel trucks	6.22	4.88	3.92	3.21	2.70	2.31	2.03	1.81	1.66	1.56	1.49	1.46	1.46	1.46	0.52
Carbon Monoxide															
Autos	7.36	5.24	4.54	3.57	2.85	2.38	2.04	1.78	1.58	1.43	1.30	2.53	5.79	9.04	0.61
Gas trucks	43.56	29.44	21.77	16.41	12.95	10.75	9.36	8.53	8.14	8.15	8.57	11.18	17.00	22.83	3.63
Diesel trucks	35.08	24.19	17.45	13.18	10.42	8.62	7.47	6.76	6.41	6.36	6.60	7.18	8.16	9.15	2.92
Nitrous Oxides															
Autos	0.64	0.57	0.51	0.46	0.43	0.40	0.37	0.35	0.33	0.37	0.49	0.61	0.73	0.85	0.05
Gas trucks	3.46	3.47	3.49	3.54	3.59	3.66	3.74	3.83	3.93	4.12	4.43	4.75	5.07	5.39	0.29
Diesel trucks	18.30	15.18	13.05	11.63	10.73	10.26	10.17	10.44	11.10	12.23	13.97	16.53	20.27	24.00	1.53

Emission Rates from MOBILE 5a

Emission Rates for 1995 (in grams per mile)

	Hydrocarbons		Carbon Monoxide		Nitrous Oxides	
Speed	Autos	Trucks'	Autos	Trucks[a]	Autos	Trucks[a]
2.5	6.77	10.57	103.68	122.26	**1.87**	17.79
5.0	3.61	8.73	54.96	98.13	**1.52**	16.19
7.5	2.53	7.29	38.43	79.84	1.41	14.87
10.0	1.98	6.15	30.16	65.81	1.35	13.78
12.5	1.66	5.25	25.22	54.97	1.31	12.89
15.0	1.44	4.52	21.94	46.53	1.29	12.16
17.5	1.29	3.93	19.60	39.92	1.27	11.57
20.0	1.17	3.45	17.77	34.69	1.27	11.10
22.5	1.06	3.05	16.05	30.55	1.29	10.73
25.0	0.97	2.72	14.66	27.27	1.30	10.47
27.5	0.89	2.46	13.52	24.66	1.31	10.28
30.0	0.83	2.23	12.56	22.59	1.32	10.17
32.5	0.78	2.05	11.75	20.98	1.33	10.14
35.0	0.73	1.89	11.06	19.74	1.34	10.18
37.7	0.70	1.76	10.46	18.82	1.35	10.28
40.0	0.66	1.65	9.94	18.18	1.36	10.47
42.5	0.63	1.55	9.49	17.79	1.37	10.74
45.0	0.61	1.48	9.10	17.65	1.37	11.08
47.5	0.58	1.42	8.75	17.74	1.38	11.53
50.0	0.58	1.37	8.68	18.07	1.49	12.07
52.5	0.58	1.34	8.68	18.66	1.62	12.74
55.0	0.58	1.31	8.68	19.52	1.76	13.54
57.5	0.67	1.30	11.96	20.70	1.89	14.50
60.0	0.75	1.29	15.25	22.25	2.03	15.66
62.5	0.84	1.29	18.53	24.23	2.16	17.05
65.0	0.92	1.31	21.82	26.74	2.30	18.72

Note: **a** = Includes trucks and buses

APPENDIX F. FUEL CONSUMPTION RATES

FUEL CONSUMPTION RATES

The following two fuel consumption rate tables for 1980 vehicles were in previous FREQ models. The 1980 grade correction factors that were embedded in the older version have been updated to 1990 factors and cannot be overridden by the user. Thus, if the user wishes to enter the 1980 fuel rates as user-supplied rates to be able to compare output from older versions of the program care must be taken to assure that the grade in each subsection is zero.

1980 Fuel Consumption Rates on Freeways.

Vehicle Class	Gallons per mile for average travel speeds (in mph) ets														IDLE (gals/ hour)
	S	10	15	20	25	30	35	40	45	50	55	60	65	70	
Autos .	.185	.131	.086	.061	.049	.044	.054	.048	.049	.052	.054	.057	.061	.065	.540
Gas trucks	.210	.144	.099	.077	.074	.072	.080	.088	.097	.107	.118	.129	.140	.151	.650
Diesel trucks	.696	.489	.297	.185	.131	.119	.112	.122	.136	.153	,170	.187	.204	.221	.450

1980 Fuel Consumption Rates on Arterials.

Vehicle Class	Gallons per mile for average travel speeds (in mph) at:							
	5	10	15	20	25	30	35	40
Autos	.144	.091	.073	.064	.059	.056	,053	.051
Gas trucks	.275	.174	.140	.123	.113	.106	.101	.097
Diesel trucks	.383	.241	.194	.171	.157	.147	.140	