Report No. FHWA/RD-82/042

PREDICTING TRAVEL VOLUMES FOR HOV PRIORITY TECHNIQUES

User's Guide
April 1982
Final Report

Prepared for

U.S. Department of Transportation

Federal Highway Administration

Offices of Research & Development
Traffic Systems Division
Washington, D.C. 20590

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FOREWORD

This User's Guide will be of interest to planners and engineers who are responsible for planning, designing and operating restricted lanes for carpools and buses on freeway facilities. A simple-to-use forecasting technique is presented to predict changes in modal volumes from implementing bus only lanes and/or carpool-bus lanes and for changing from bus only to bus and carpool and for changing the definition of the required passengers in a carpool to be qualified to use the priority lane. Data on modal volumes, travel times, and geometrics are required. Calculations can be made with a hand-held calculator. Example applications are presented to show how to use the work sheets which are provided in the report.

This report is from a contractual effort as part of FCP Project 2D, "Priority Techniques for High Occupancy Vehicles." A technical report was also prepared on this contract which reviews past forecasting models and describes the research for developing the demand and supply relationships used in the forecasting model.

Copies of this report are being distributed to provide two copies to each regional office, two copies to each division office, two copies to each State highway agency and one copy to each Metropolitan Planning Organization (MPO) for urban areas with populations over 500,000. The division, State, and MPO copies are being sent directly to each division office.

Charles F. Scheffey
Director, Office of Research

NOTICE

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16. Abstract

This report is a user's guide for a quick-response, low-cost procedure that can be used to forecast travel demand and supply impacts of implementing four different types of priority techniques for high occupancy vehicles (HOV) on freeways. The procedure involves performing a straightforward set of calculations using a hand-held calculator and a set of worksheets that is provided in the report. Input data requirements consist of modal volumes, travel times or speeds, and roadway geometrics and capacity. Example applications of the forecasting procedure are provided in the report. The model parameters were developed using data from existing HOV projects. An accompanying report (FHWA/RD-82-043) presents the results of much of the research, data and other information used to develop and test the models incorporated in the worksheets presented in this report.

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PREFACE

The work performed during the course of this study is presented in two reports. The first is a "User's Guide" that provides a step-by-step description explaining how the model and worksheets are used to forecast travel volumes. Example applications are also presented. The second report is a "Technical Supplement" that provides a complete documentation of all work tasks conducted. In particular, this report presents much of the underlying data and other information used in the model estimation and testing phases of the study.

Professor Adolf D. May of the University of California at Berkeley contributed important input at various points throughout the course of this study. Finally, the authors would like to thank the many individuals and agencies who cooperated with our requests for information on HOV projects that have been implemented throughout the United States.

FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion, and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements that affect the quality of the human environment. The goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge and technology of materials properties, using available natural materials, improving structural foundation materials, recycling highway materials, converting industrial wastes into useful highway products, developing extender or substitute materials for those in short supply, and developing more rapid and reliable testing procedures. The goals are lower highway construction costs and extended maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural and hydraulic designs, fabrication processes, and construction techniques to provide safe, efficient highways at reasonable costs.

6. Improved Technology for Highway Construction

This category is concerned with the research, development, and implementation of highway construction technology to increase productivity, reduce energy consumption, conserve dwindling resources, and reduce costs while improving the quality and methods of construction.

7. Improved Technology for Highway Maintenance

This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

0. Other New Studies

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (HRD-3), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

TABLE OF CONTENTS

LIST OF FIGURES

1

INTRODUCTION

PURPOSE OF REPORT

This User's Guide describes a simple-to-use procedure for forecasting changes in modal volumes that result from implementing various high occupancy vehicle (HOV) techniques on freeways. The procedure is both easy to learn and easy to apply. Because it is designed to provide "quick response" results, data requirements are minimal and should be readily available to most planning agencies. The accuracy of the results should be interpreted as commensurate with the resources required to use the approach. That is, the predicted volumes should be considered as sketch planning-level responses that, if conditions warrant, would be subjected to additional and possibly more refined analyses. However, test applications of the prediction procedures described in this report have in many instances yielded results far beyond the accuracy typically associated with sketch planning techniques.

Basically, the prediction procedure involves using various relationships to forecast demand volumes, and with the aid of supply relationships, obtaining equilibrium travel flows on the general purpose freeway and HOV lane(s). The demand model relationships have been developed through a quantitative analysis of before-and-after data from a number of actual HOV facilities located across the United States. Therefore, as with all models developed in this fashion, they are most applicable when they are used to predict travel flows due to the implementation of similar HOV strategies, and are likely to be less reliable when employed beyond the range of data used to estimate the models.

The initial data requirements, along with the necessary demand and supply relationships, have been incorporated into a series of worksheets. A blank set of the worksheets is contained in Appendix A. The worksheets can be used to forecast peak hour travel volumes in the a.m. peak direction for four basic types of freeway, high occupancy vehicle strategies. The HOV strategies and HOV sites that were used to estimate the model parameters are:

1) Dedicate new or existing freeway lane(s) for HOV buses only:

   - San Bernardino (CA)-I;
   - U.S. 101 (CA)-I;
   - Southeast Expressway (MA) (1971); and
   - I-495, Lincoln Tunnel (NJ).

2) Dedicate new or existing freeway lane(s) for HOV buses and carpools:

   - Banfield Freeway (OR)-I;
   - I-95 Miami (FL)-I; and
   - Southeast Expressway (MA) (1977).

3) Allow carpools onto existing bus-only HOV lane(s):

   - Shirley Highway (VA);
   - San Bernardino (CA)-II; and
   - U.S. 101 (CA)-II.

4) Change the definition of carpools on existing bus and carpool HOV lane(s):

   - Banfield Freeway (OR)-II; and
   - I-95 Miami (FL)-II.

The procedures described in this User's Guide can be used to predict peak hour flows for: 1) automobiles on the general purpose lanes; 2) carpools that are already on or that will be allowed to use the HOV lane or lanes; and 3) bus passengers on the HOV lane(s). Since the demand relationships used in the worksheets were developed by using data on actual before-and-after travel volumes, the models forecast the net change in volumes due to mode shifts, time-of-day changes, trip generation, and route diversion effects. Consequently, the models provide more information on anticipated travel volumes than could be obtained through the use of either conventional or state-of-the-art mode split models only. (The "Technical Supplement" report provides additional information on the characteristics of this and other forecasting models.)

A supply model patterned after speed-flow relationships presented in the recently revised Highway Capacity Manual (TRB Circular Number 212) and elsewhere is used in an iterative fashion with the predicted demand volumes to reach equilibrium travel volumes. The supply model is used to determine equilibrium speeds on the general purpose lanes if it is possible for free-flow conditions to exist on the general purpose lanes in the after period. An examination of existing HOV facilities revealed that free-flow conditions are sometimes possible when buses and carpools are allowed to use the HOV facility and a general purpose lane is not taken away. Under all other circumstances, forced-flow conditions continued to prevail in the after period.

REPORT OUTLINE

The remainder of this report is divided into three chapters and one appendix. Chapter 2 presents a general overview of the approach used to forecast travel volumes. Included in the chapter is a description of the types of HOV strategies that can be evaluated, the travel modes that are explicitly considered, the data measures that are required, and a summary description of each of the seven worksheets. Chapter 3 explains in a detailed, step-by-step manner how the worksheets are to be used to forecast volumes and supply changes. The procedures are further illustrated by using as an example application data from the Shirley Highway. Additional example applications of the forecasting procedures using data from actual HOV projects are presented in Chapter 4. Appendix A contains a blank set of worksheets that can be reproduced as needed.

2

OVERVIEW OF THE PREDICTION APPROACH

APPLICABLE HOV TREATMENTS

The HOV alternatives that can be analyzed with the forecasting procedures presented in this User's Guide can be classified into four distinct groups based on the modes allowed onto the HOV lanes in the before and after periods. (Of course, in many cases, no HOV lane will exist in the before period. The after period is assumed to represent conditions present about one year after the HOV lane opens.)

The four HOV alternatives that can be evaluated are:

	Before Period	After Period
1.	No HOV lane	Bus-Only HOV lane(s)
2.	No HOV lane	Bus and Carpool HOV lane(s)
3.	Bus-Only HOV lane(s)	Bus and Carpool HOV lane(s)
4.	Bus and Carpool HOV lane(s)	Bus and Revised Definition of Carpools

Notice that the HOV strategies are not classified according to whether the HOV lane is formed by "adding a lane" or "taking away a lane." The predicted modal volumes, however, will differ depending on whether a general purpose lane is taken away or not.

All of the existing HOV sites that were used in developing the relationships embedded in the forecasting approach share some common characteristics that help define the type of HOV treatments that can best be analyzed with the procedures presented herein. First, the HOV lanes operate on (or adjacent to) major radial freeways leading into a central city or central business district. Thus, the proposed HOV corridor/lane should have similar characteristics (i.e., the approach may not yield reliable results for HOV lanes on surface arterials or HOV lanes on circumferential freeways). Second, the HOV lanes ranged from 2.5 to 9 miles in length. Third, all sites experienced force-flow or severe capacity constraint conditions on the general purpose lanes in the before period during the morning peak hour. It appears, however, that the benefits would be slight (or even negative) if an HOV lane were instituted in a corridor that operated under relatively free-flow conditions during the morning peak hour.

Finally, among the HOV sites used in model estimation, many network conditions and alternative links (e.g., parallel freeways/arterials) exist, allowing different route diversion effects. The models and relationships that were developed reflect the average of these conditions. If a corridor being analyzed is especially atypical with respect to alternative routes, the models may not capture the full effects due to these alternative or competing links.

DEFINITIONS OF PEAK HOUR TRAVEL VOLUMES

Five modes are used in the worksheets and throughout this report:

1. Nonpriority Automobiles -- the volume of automobiles traveling in the peak hour on the general purpose lanes in either the before or after time periods;

2. Priority Eligible Automobiles -- the volume of automobiles traveling in the peak hour on the general purpose lanes in the before period that will be eligible to use the HOV lane(s) in the after period;

3. Carpools on HOV Lane(s) -- the volume of automobiles traveling in the peak hour on the HOV lanes in the before period that will continue to be allowed on the HOV lanes in the after period;

4. Priority Eligible Buses -- the number of buses/passengers traveling in the peak hour on the general purpose lanes that will be eligible to use the HOV lane(s) in the after period; and

5. Buses on HOV Lanes(s) -- the number of buses/passengers traveling in the peak hours on the HOV lane(s) in the before period that will continue to use the HOV lane(s) in the after period.

The "before" values of these volumes are entered as BASELINE DATA conditions in the first worksheet. The calculations performed in subsequent worksheets provide the "after" values for these volumes. The worksheets are discussed fully in Chapter 3.

DATA REQUIREMENTS

Given the selection of a particular corridor and freeway for which it is desired to analyze the change in travel volumes resulting from implementing a particular HOV strategy, the following four types of data are required.

PEAK HOUR VOLUMES -

In the before period, a.m. peak hour volumes are required for the following modes (see definitions above): 1) nonpriority automobiles; 2) priority eligible automobiles (note that for bus-only HOV strategies, this volume will be zero); 3) carpools on HOV lanes (if no carpool/HOV lane exists, this volume will be zero); and 4) the number of buses and passengers either eligible to move onto the HOV lane or already on the HOV lane. (Note that this is an either/or situation.) These volumes are measured at a screen line located within the boundaries of the beginning and endpoint of the proposed (or existing) HOV lane(s). This screen line is also the reference point for all other measurements. Consequently, this line will indicate the location of the forecasted volumes.

Of the four peak hour volumes that may be required for a particular analysis, the one likely to be the least readily available is the volume of priority-eligible automobiles. Typically, permanent or temporary counting stations will provide good data on the total number of vehicles traveling inbound in the morning peak hour. However, if the proposed strategy being analyzed is to allow 3+ person carpools onto an existing or new HOV lane, the volume of 3+ person carpools is needed along with the combined volumes of one- and two-person carpools. If these volumes by auto occupancy are not immediately available, one could, as a first-cut approximation, use systemwide auto occupancy proportions obtained from ridesharing studies (or even Census data), or more accurately conduct a special vehicle occupancy count during the morning peak commuting period.

PEAK HOUR TRAVEL TIMES -

For each travel mode that is pertinent to the HOV strategy being evaluated, an estimate of average door-to-door travel time is required. As indicated above, this estimate is determined for vehicles passing the screen line. Since travel times "saved" or reduced by using or not using the HOV lane are calculated as a proportion of these total door-to-door travel times, small errors in the latter will not introduce large errors in the proportion's input to the model. Therefore, it is not necessary that they be determined precisely. They can be obtained from the output of existing UTPS programs or by using information on average trip lengths and route sections having different average travel speeds.

AVERAGE PEAK HOUR TRAVEL SPEEDS -

Average peak hour travel speeds are required for vehicles on the general purpose lanes and, if they are present in the before period, vehicles on the HOV lane(s). The speeds are those required to travel either the length of the HOV lane(s) or the length of the general purpose lanes adjacent to the existing or proposed HOV lane(s). These speeds should be estimated more precisely than the total travel time data since they are used to estimate travel times, and changes in travel times, over the (typically) shorter section of the freeway bounded by the HOV lane. If not already available from secondary sources, these speeds could be determined through actual measurement (e.g., by using a floating car travel time study).

EXISTING FREEWAY SUPPLY AND CAPACITY -

The number of lanes and capacity must be specified for both the existing general purpose freeway lanes, and if they exist, for the HOV lane(s). The capacity, if not readily known, can be computed using the step-by-step computation procedure given in the recent Interim Materials on Highway Capacity (see TRB Circular Number 212, pp. 171-185).

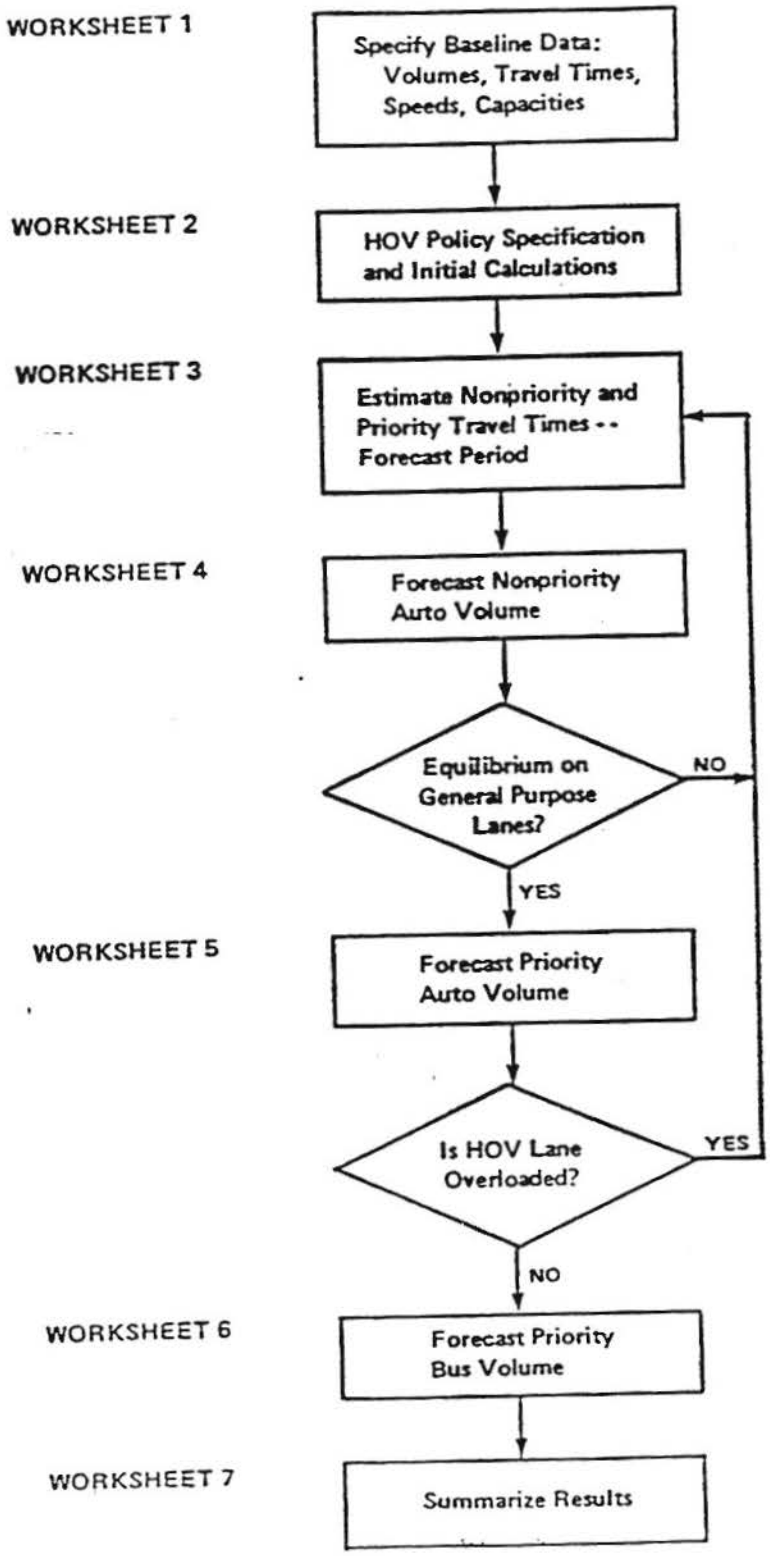
For the forecasting procedures presented herein, capacity is defined as the maximum number of vehicles moving by a particular point in a given one-hour period. Thus, if empirical data should yield peak hour travel volumes that are higher than those determined through a formal application of the capacity manual calculations, the higher value should be used as the measure of capacity.

OVERVIEW OF WORKSHEETS FOR PREDICTION

The procedures for predicting travel volumes resulting from any one of the four types of HOV strategies discussed above are based on the results of the several models developed in this study. These models, which are described more fully in the "Technical Supplement" report, have been incorporated into a set of seven worksheets that are used in a sequential and, if necessary, iterative fashion to reach equilibrium. The flow chart in Figure 1 highlights the major activities for each worksheet. The following material summarizes the purpose of each worksheet.

Figure 1

ACTIVITIES UNDERTAKEN IN EACH WORKSHEET



First, baseline travel data consisting of before volumes, travel times, speeds, and capacity (as defined above) are assembled and listed on Worksheet 1. Next, the proposed HOV strategy to be evaluated is defined on Worksheet 2. This consists of specifying the modes that will be allowed to use the HOV lane(s), the length of the HOV lane(s), and the proposed capacity of the general purpose and HOV lanes.

With the information presently specified, various initial calculations are performed using Worksheet 2 to disaggregate the baseline travel time data into two components -- travel time on and off the freeway section bordered by (or adjacent to) the HOV lane(s). Worksheet 3 is used next to derive initial estimates of travel time changes, and therefore "after" travel times, that will be needed to forecast demand volumes in subsequent worksheets. The before and after travel times now known for each mode are input to a demand equation contained on Worksheet 4 to estimate the after peak hour volume of nonpriority automobiles. If it has been assumed that free-flow travel conditions are possible, a check is made to determine if the initial estimated travel times (and thus speeds) are in close agreement with the model's estimated volume (and thus travel speed and times). If these equilibrium conditions are not satisfied, revised or updated estimates of travel time are computed and the procedure is repeated.

When equilibrium volumes are obtained on the general purpose lanes, Worksheet 5 is used to forecast the volume of carpools (including priority eligible autos and existing HOV carpools) that will use the HOV lane(s). If carpools are not allowed on the HOV lane(s), this worksheet is not used. However, if this worksheet is used, the predicted volume of carpools on the HOV lane is compared to the capacity of the HOV lane(s) to determine whether the initial estimate of speed is valid. This check also determines whether the volume of carpools will exceed the HOV lane capacity, indicating that a more restrictive HOV strategy should be evaluated.

Worksheet 6 is used to predict the volume of priority bus users. A similar equilibration procedure is not employed, since bus volumes on the HOV lanes are not likely to exceed HOV capacity. (If necessary, however, the analyst can perform a simple test patterned after those used for nonpriority and priority eligible automobiles.) Finally, Worksheet 7 summarizes the forecasted peak hour travel volumes, speeds, and times that have been obtained from the previous worksheets.

TIME AND COST REQUIREMENTS

The time required to use the worksheets to predict travel volumes resulting from different freeway-based HOV strategies is extremely modest, being much less than nearly all other modeling approaches available to forecast volume changes due to implementing HOV strategies. (See the "Technical Supplement" report for information that compares resource requirements for alternative forecasting procedures.)

Indeed, the most time-intensive aspect of the entire process is completing Worksheet 1 on the specification of baseline data conditions. This task can be completed in a few hours if the data are available "off the shelf," or could range up to a matter of days otherwise. The remaining worksheets can be completed in less than one hour, once the basic procedure is known. Computers or special programmable calculators are not required. Rather, a simple hand-held calculator, with a power to the X key (i.e., y^x) is all that is necessary.

Because Worksheets 2 through 7 can be completed so quickly, it may be preferable, if one or two key items of baseline data are not readily available, to assume alternative (high/low) default values and work through the subsequent calculations. If these initial tests show that the results are not sensitive to the assumptions, the time that would have been devoted to securing better estimates of the data items in question can be saved.

3

HOW TO USE THE WORKSHEETS

This chapter explains step-by-step how the worksheets are used to forecast travel volumes (and thus the change in travel volumes) resulting from implementing any one of four different HOV strategies. To help one understand how each worksheet is used, an example application is given using actual data from the Shirley Highway. This particular example will analyze the introduction (on December 10, 1973) of 4+ person carpools onto the previously existing bus-only HOV lanes. Chapter 4 will present additional examples demonstrating how the worksheets can be used to evaluate other HOV strategies.

WORKSHEET 1: BASELINE DATA

Worksheet 1 is used to record data on existing (or before period) travel volumes and supply conditions. Peak hour travel volumes (in the a.m. inbound direction only) are required for up to 4 principal modes: nonpriority automobiles, priority eligible automobiles (or carpools), carpools on (existing) HOV lanes, and number of buses and bus passengers either eligible to use the HOV lanes or already on HOV lanes. As shown on Worksheet 1, a space is provided to record each volume. If a particular volume is not applicable, use 0 (zero), N/A, or NPA/NPL (no priority auto/no priority lane) as the situation dictates.

Each volume is also labeled with a unique symbol or variable name. For example, the peak hour volume for nonpriority automobiles is labeled as V_o^{npa}. The subscript "o" refers to the before/initial time period. A subscript "1" would refer to the after or forecasted time period. These variable names are subsequently used in other worksheets in place of the actual variable title in order to save space.

In the Shirley Highway example, the total peak hour auto volume on the three general purpose lanes was 5,091 VPH. Of this volume, 4,896 VPH were comprised of vehicles with 3 persons or less while 195 VPH were 4+ person carpools. There were, of course, no carpools on the two existing bus-only HOV lanes. There were 176 buses per hour (BPH) on the HOV lanes (B_0^{HOV}); consequently, the number of buses on the general purpose lanes that would be eligible to use the HOV lanes (i.e, B_0^{Peb}) is zero (or N/A).

The number of peak hour bus users on the Shirley Highway was 7,900 passengers per hour (PPH), which results in the computed average (bus) load factor of 44.8 passengers per bus (PPB). No information is available on the volume of trucks using the general purpose lanes.

Average door-to-door travel time of individuals using the general purpose lanes was determined to be 56.2 minutes. Consequently, this is entered for both nonpriority and priority eligible automobiles. With no carpools on the HOV lanes, an N/A is entered for T_0^{HOV}. Because of the significantly higher speeds on the HOV lanes, average travel time for bus users (T_0^b) was determined to be 37.5 minutes.

Over the 9-mile length of HOV roadway that carpools will be allowed to use, buses currently operate at an average speed of 55.5 mph. Vehicles traveling on the general purpose lanes parallel to the 9-mile HOV section average 19.0 mph. in the before period.

The capacity of the 3 general purpose lanes is estimated at 5,880 VPH while on the 2 HOV lanes, the capacity is determined to be 2,000 VPH. (As a general rule, a bus-only HOV lane can be assumed to have a capacity of 875-1,000 BPH while a bus and carpool lane has a capacity of about 1,500 VPH.)

WORKSHEET 2: HOV POLICY SPECIFICATION AND INITIAL CALCULATIONS

Worksheet 2 is used to specify the particular HOV alternative to be examined and to translate the information tabulated up to this point into specific data formats required by later worksheets.

Shirley Highway Example

WORKSHEET 1: BASELINE DATA

Specification of Initial/Before Data

VOLUMES (PEAK-HOUR)

- Automobiles, nonpriority V_o^{npa} = 4896 VPH
- Automobiles, priority eligible V_o^{pa} = 195 VPH
- Carpools on HOV lane(s) V_o^{HOV} = 0 VPH
- Buses, priority eligible B_o^{peb} = N/A BPH
- Buses on HOV lane(s) B_o^{HOV} = 176 BPH
- Bus Passengers (HOV or priority eligible) V_o^b = 7900 PPH
- Bus Load Factor L_o^b = 44.8 PPB
- Trucks V_o^T = N/A VPH

TOTAL TRAVEL TIME (PEAK-HOUR)

- Automobiles, nonpriority T_o^{npa} = 56.2 Min.
- Automobiles, priority eligible T_o^{pa} = 56.2 Min.
- Carpools on HOV lane(s) T_o^{HOV} = N/A Min.
- Buses (HOV or priority eligible) T_o^b = 37.5 Min.

SPEEDS (AVERAGE PEAK HOUR)

- General Purpose Lane(s) S_o^{GP} = 19.0 MPH
- HOV Lane(s) - Carpools S_o^C = N/A MPH
- HOV Lane(s) - Buses S_o^B = 55.5 MPH

EXISTING SUPPLY/CAPACITY

- No. of General Purpose Lanes L_o^{GP} = 3
- No. of HOV Lanes L_o^{HOV} = 2
- Capacity, general purpose lanes C_o^{GP} = 5880 VPH
- Capacity, HOV Lanes C_o^{HOV} = 2000 VPH

The HOV alternatives are specified by checking the bus-only or combined bus and carpool boxes. In the latter instance, the carpool size allowed on the HOV lanes is also indicated. The proposed (or after) supply conditions are noted by listing the length of the HOV lanes in miles, as well as the proposed number of lanes and capacity of the general purpose and HOV section of the facility. If the number of the buses that will operate during the peak hour is determined through an exogenous policy decision, it is entered here as B_1HOV. However, this space is left blank if bus service requirements are to be based on the forecasts derived from the travel time savings due to implementing the HOV facility.

In the Shirley Highway example, there is no change in the configuration or number of general purpose and HOV lanes. Therefore, the capacity of the general purpose lanes remains unchanged, while the capacity of the HOV lanes increases, since more vehicles can operate on a bus/carpool lane compared to a bus-only HOV lane.

As a general rule, if the number of buses on the general purpose lanes that become eligible to move over to the HOV lanes is less than 100, it is not necessary to revise the capacity for the general purpose lanes.
The next section of the worksheet is used to disaggregate total travel time in the before period into travel time on the general purpose freeway lanes bounded by the HOV roadway section and the travel time that is spent off this roadway section (i.e., all the "remaining" travel time). If the HOV lane exists in the before period, similar calculations are performed for the existing HOV bus mode.

WORKSHEET 3: ESTIMATE TRAVEL TIMES -- FORECAST PERIOD

BUSES ON HOV LANES

Total travel times for buses and carpools (if any) on the HOV lane(s) and for nonpriority autos on the general purpose lanes are determined by using Worksheet 3. If buses are already on an HOV lane, then the after bus travel time is set equal to the before bus travel time. This assumes that travel speeds on the HOV lane, as an initial starting point, will not decrease if carpools are allowed access.

If an HOV lane does not exist in the before period, bus travel times are computed using an assumed average free-flow speed of 50 mph. -- unless other data indicate a different value should be used. (Except for the Lincoln Tunnel and Southeast Expressway (1977) sites, the average bus speed on all other HOV lanes examined was approximately 50 mph. As an example of "other data," the Lincoln Tunnel contraflow bus lane had a posted speed limit of 35 mph.)

WORKSHEET 2: HOV POLICY AND INITIAL CALCULATIONS

(check one)

HOV Alternative: ☐ Bus Only
☒ Bus and Carpool (Carpool Size: 4+)

HOV Length: 9.0 Miles

PROPOSED SUPPLY/CAPACITY

• No. of General Purpose Lanes	L_1^{GP} =	3	
• No. of HOV Lanes	L_1^{HOV} =	2	
• Capacity, general purpose lanes	C_1^{GP} =	5880	VPH
• Capacity, HOV lanes	C_1^{HOV} =	2500	VPH
• Buses per Hour (if exogenously determined)	B_1^{HOV} =	N/A	BPH

EXISTING TRAVEL TIMES -- OVER HIGHWAY BOUNDED BY HOV LANES*

• Automobiles, nonpriority	t_o^{npa} =	28.4	Min.
• Automobiles, priority eligible	t_o^{pa} =	28.4	Min.
• Buses (HOV or priority eligible)	t_o^{b} =	9.7	Min.

EXISTING TRAVEL TIMES -- OFF HIGHWAY BOUNDED BY HOV LANES

• Automobiles, nonpriority	$T_o^{npa} - t_o^{npa}$ =	t_{off}^{npa} =	27.8	Min.
• Automobiles, priority eligible	$T_o^{pa} - t_o^{pa}$ =	t_{off}^{pa} =	27.8	Min.
• Buses (HOV or priority eligible)	$T_o^{b} - t_o^{b}$ =	t_{off}^{b} =	27.8	Min.

---

*Formula: Vehicles on general purpose lanes (Before Period)

$$t_o^{\cdot} = \frac{\overset{\text{HOV Length}}{\boxed{9}}}{\underset{S_o^{GP}}{\boxed{19}}} \times 60 = \underline{28.4} \text{ Minutes}$$

*Formula: Vehicles on HOV lanes (Before Period)

$$t_o^{\cdot} = \frac{\overset{\text{HOV Length}}{\boxed{9}}}{\underset{S_o^{B}}{\boxed{55.5}}} \times 60 = \underline{9.7} \text{ Minutes}$$

AUTOS ON HOV LANES

Total travel time for automobiles/carpools that are eligible to use the HOV lane are based on either the travel times of carpools already on the HOV lane(s), or travel speeds of buses already on the HOV lane(s), or are determined by using an estimated free-flow speed equal to that used for buses eligible to use the HOV lane (i.e., 50 mph., unless data indicate otherwise).

AUTOS ON GENERAL PURPOSE LANES

Travel time for autos on the general purpose lanes is determined contingent upon the change in capacity on the general purpose lanes and/or the type of vehicles allowed onto the HOV lanes. If capacity on the general purpose lanes is reduced (e.g., by taking away a lane for HOV use) or if only buses are allowed on the HOV lane, the travel time for nonpriority autos in the after period is assumed to equal travel time in the before period. In effect, this is equivalent to stating that forced-flow conditions will continue. (This finding was observed for all sites that met either one of the two conditions given above.)

Alternatively, if the capacity is not reduced on the general purpose lanes and if carpools are allowed to use the HOV lane(s), it is possible that the general purpose lanes could operate under either free-flow or forced-flow conditions. Unless other information indicates otherwise, travel times will be computed initially, based on free-flow speeds. Free-flow speeds are computed using a speed and volume/capacity relationship. The "Technical Supplement" report presents additional information on the derivation and characteristics of this relationship.

The last computation to be performed is to calculate what has been labeled on the worksheet as an "eligibility factor." This variable basically represents that share of the general purpose freeway demand that is eligible to move to the HOV lanes normalized by the change in general purpose freeway supply. This variable is extremely important in accounting for site-to-site differences in the composition of traffic by different vehicle mixes (e.g., buses, 3+ person carpools, etc.) that may be eligible to use the HOV lane(s). In addition, it is one of the principal factors used to account for differences between "add-a-lane" and "take-away-a-lane" HOV projects. See the "Technical Supplement" report for additional information on this variable.

Since buses were already on the HOV lanes in the Shirley Highway example, bus travel time in the after period is set equal to bus travel time in the before period (i.e., 37.5 minutes). Because carpools were not on the HOV lanes in the before period, travel time for priority eligible autos in the after period ($T_1{}^{Pa}$) is computed based on the before speed of the HOV buses (i.e., $S_0{}^{B}$). Travel time off the HOV roadway section (T^{Pa}_{off}) is assumed to remain unchanged.

WORKSHEET 3: ESTIMATE TRAVEL TIMES -- FORECAST PERIOD

BUSES ON OR ELIGIBLE TO USE HOV LANES

Check one

☒ Buses already on HOV, use:

$T_1^b = T_o^b =$ 37.5 Minutes

☐ Buses will be eligible to use HOV, use:

$$T_1^b = \underbrace{\boxed{}}_{t_{off}^b} + \frac{\boxed{}\ \text{HOV Length}}{\boxed{}\ \text{Estimated Speed}^*} \times 60 = \underline{\qquad}\ \text{Minutes}$$

AUTOS ON OR ELIGIBLE TO USE HOV LANES

Check one

☐ Autos already on HOV, use:

$T_1^{pa} = T_o^{HOV} =$ ______ Minutes

☒ Autos will be eligible to use HOV, use:

$$T_1^{pa} = \underbrace{\boxed{27.8}}_{t_{off}^{pa}} + \frac{\boxed{9}\ \text{HOV Length}}{\boxed{55.5}\ S_o^B \text{ or Estimated Speed}^*} \times 60 = \underline{37.5}\ \text{Minutes}$$

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*If estimating speed, use 50 MPH unless other data indicates otherwise

Continued

WORKSHEET 3 (Continued)

AUTOS ON GENERAL PURPOSE LANES

Check one

1. ☐ Capacity Reduction or Bus Only HOV Lane

$$T_1^{npa} = T_0^{npa} = \underline{\qquad} \text{ Minutes (i.e, force-flow continues)}$$

2. ☒ Capacity Same and Carpools Granted Priority

· Assume free-flow initially unless data indicates otherwise

ESTIMATE FREE-FLOW SPEEDS AND TRAVEL TIMES

$$S_1^{GP} = \cfrac{60}{1.0 + \left[\cfrac{\underset{V_0^{npa}}{\boxed{4896}} + \underset{V_0^{pa}}{\boxed{195}}}{\underset{C_1^{GP}}{\boxed{5880}}}\right]^{15}} = \underline{53.8} \text{ MPH}$$

$$\boxed{\text{Check: If } S_1^{GP} > S_0^{C,B}, \text{ Set } S_1^{GP} = S_0^{C,B} = \underline{\qquad} \text{ MPH}}$$

$$T_1^{npa} = \underset{t_{off}^{npa}}{\boxed{27.8}} + \left[\cfrac{\underset{\text{HOV Length}}{\boxed{9}}}{\underset{S_1^{GP}}{\boxed{53.8}}} \times 60\right] = \underline{37.8} \text{ Minutes}$$

COMPUTE "ELIGIBILITY FACTOR"

$$\text{EFCTR} = \cfrac{\underset{L_1^{GP}}{\boxed{3}}}{\underset{L_0^{GP}}{\boxed{3}}} \times \left[\cfrac{\underset{V_0^{npa}}{\boxed{4896}} + \underset{V_0^{pa}}{\boxed{195}} + 2.0 \times \underset{B_0^{Pcb}}{\boxed{0}}}{\underset{V_0^{npa}}{\boxed{4896}}}\right] = \underline{1.04}$$

Because capacity of the general purpose lanes did not change while 4+ person carpools were allowed onto the HOV lane, travel times for nonpriority autos are initially computed based on free-flow travel speeds. (This assumption will be tested at the end of Worksheet 4.)

WORKSHEET 4: FORECAST NONPRIORITY AUTO VOLUME

The initial forecast of nonpriority auto volume is computed simply by filling in the appropriate before and after travel times (in the boxes provided) for the modes indicated along with the value of the eligibility factor (EFCTR). The variables T_1Pa2 and $T_1Pa3/4$ represent the total travel time in the after period for 2-person and 3+/4+ person carpools, respectively, that are traveling as priority autos (Pa) on the HOV lanes. Consequently, if carpools are not allowed on the HOV lanes, both the third and fourth terms in the equation (i.e., those containing T_1Pa2 and T_1Pa3) take on a value of zero. If only 3+ or 4+ vehicles are allowed onto the HOV lane, only the third term containing T_1Pa2 takes on a value of zero. In summary, the third and fourth terms are used depending on whether 2+ and/or 3+/4+ carpools are allowed onto the HOV facility.

In the Shirley Highway example, the boxes are filled in with their appropriate values obtained from previous worksheets. Since 2-person carpools are not allowed onto the HOV lanes, X's are placed in the boxes for T_0Pa2 and T_1Pa2, resulting in a value of 0 for the third term in the equation. When the calculations are completed, a forecasted nonpriority auto volume of 6,734 VPH is computed. Since Box 2 was checked on Worksheet 3 (indicating free-flow conditions), a check is made next to determine whether the speed resulting from the forecasted volume is approximately equal to the initially estimated speed. As shown on the bottom of Worksheet 4, the forecasted V/C ratio is greater than 1.0 implying forced-flow conditions or a speed much less than that initially assumed. Consequently, a revised nonpriority travel time is computed based on the before, forced-flow, nonpriority auto travel time (i.e., 56.2 minutes), and a new estimated volume of 5,045 is computed. This represents a V/C ratio less than 1, which is consistent with the forced flow speed that was assumed.

WORKSHEET 5: FORECAST PRIORITY AUTO VOLUME

This worksheet is used to forecast the total peak hour volume of carpools (consisting of priority eligible automobiles and, if applicable, carpools already on the HOV lane) that will use the HOV lane(s) in the after period. Depending on the HOV strategy being analyzed and whether some carpools are already on the HOV facility, either or both Equations A and B may be used.

WORKSHEET 4: FORECAST NONPRIORITY AUTO VOLUME

$$\Delta_{npa} = -0.916 - 1.053\left[\frac{\overset{T_1^{npa}}{\boxed{37.8}}}{\underset{T_0^{npa}}{\boxed{562}}} - 1.\right] + 1.190\left[\frac{\overset{T_1^{pa2}}{\boxed{X}}}{\underset{T_0^{pa2}}{\boxed{X}}} - 1.\right] +$$

$$+ 0.122\left[\frac{\overset{T_1^{pa3/4}}{\boxed{37.5}}}{\underset{T_0^{pa3/4}}{\boxed{562}}} - 1.\right] + 0.278\left[\frac{\overset{T_1^{b}}{\boxed{37.5}}}{\underset{T_0^{b}}{\boxed{37.5}}} - 1.\right] + 0.949\overset{EFCTR}{\boxed{1.04}} = .375$$

$\Delta_{npa} =$ + 0.375

$$V_1^{npa} = \left[1.0 + \overset{\Delta_{npa}}{\boxed{0.375}}\right] \times \overset{V_0^{npa}}{\boxed{4896}} = \underline{6734} \text{ VPH}$$

EVALUATE RESULTS

Check one

☐ If force-flow conditions, proceed to Worksheet 5

☒ If Box 2 checked, Validate Service Level Assumptions

COMPUTE VOLUME/CAPACITY RATIO-- FORECAST PERIOD

$$\frac{V_1^{npa}}{C_1^{npa}} = \frac{\boxed{6734}}{\boxed{5880}} = \underline{1.15}$$

Continued

WORKSHEET 4 (Continued)

DETERMINE WHICH CONDITION APPLIES

Check one

☐ If $V_1^{npa}/C_1^{GP} < 1$; then,

Compute $S_1^{GP'} = \dfrac{60}{1 + \left(\underbrace{\boxed{}}_{V_1^{npa}/C_1^{GP}}\right)^{15}}$ = ______ MPH

Check one

☐ If $S_1^{GP'} = S_1^{GP}$, Equilibration achieved, Go to Worksheet 5

☐ If $S_1^{GP'} \neq S_1^{GP}$, Repeat with $S_1^{GP'}$, Go to Worksheet 3, P.2.

☒ If $V_1^{npa}/C_1^{GP} \geq 1$; then,

Repeat analysis with T_1^{npa} based on force-flow conditions

$\therefore$ $T_1^{npa} = T_0^{npa}$ = 56.2 Minutes, Redo Worksheet 4

WORKSHEET 4: FORECAST NONPRIORITY AUTO VOLUME

$$\Delta_{npa} = -0.916 \quad -1.053\left[\frac{\overset{T_1^{npa}}{\boxed{562}}}{\underset{T_0^{npa}}{\boxed{562}}} - 1.\right] + 1.190\left[\frac{\overset{T_1^{pa2}}{\boxed{X}}}{\underset{T_0^{pa2}}{\boxed{X}}} - 1.\right] +$$

$$+\,0.122\left[\frac{\overset{T_1^{pa3/4}}{\boxed{37.5}}}{\underset{T_0^{pa3/4}}{\boxed{562}}} - 1.\right] + 0.278\left[\frac{\overset{T_1^{b}}{\boxed{37.5}}}{\underset{T_0^{b}}{\boxed{37.5}}} - 1.\right] + 0.949\,\overset{EFCTR}{\boxed{1.04}} = 0.03$$

$\Delta_{npa} =$ +0.03

$$V_1^{npa} = \left[1.0 + \overset{\Delta_{npa}}{\boxed{0.03}}\right] \times \overset{V_0^{npa}}{\boxed{4896}} = \underline{5045}\ \text{VPH}$$

EVALUATE RESULTS

Check one

☒ If force-flow conditions, proceed to Worksheet 5

☐ If Box 2 checked, Validate Service Level Assumptions

COMPUTE VOLUME/CAPACITY RATIO-- FORECAST PERIOD

$$\frac{V_1^{npa}}{C_1^{npa}} = \frac{\boxed{}}{\boxed{}} = \underline{\qquad\qquad}$$

Continued

Equation A is used if 3+ or 4+ person carpools are to be allowed onto the HOV lane, or if they are already on the HOV lane(s), while Equation B is used if 2+ person carpools are to be allowed onto the HOV lane(s). (It is not likely that an HOV strategy will be examined when 2+ person carpools are already on the HOV facility. Moreover, this scenario was not represented in any of the existing HOV sites.)

Once the after priority auto volume is computed (V_1^{Pa}), it is added to the revised volume of existing carpools already on the HOV lane, if any, (which is estimated using the results of Equation A), to arrive at the total volume of carpools on the HOV lane(s) in the after period (V_1^{HOV}). A check is made to determine whether this volume is less than capacity. For V/C ratios of about 0.8 or less, the initial congestion-free, travel speed assumptions can be considered valid. However, for V/C ratios between 0.8 and 0.95 lower service levels exist with the implication that speeds on the HOV lane(s) will decrease. Thus, a revised, lower speed on the HOV lane(s) should be computed (resulting in a higher travel time for priority autos), and Worksheets 4 and 5 should be repeated with these new travel time values. V/C ratios that continue to equal or exceed 1 imply that the HOV strategy being tested will lead to oversaturated conditions on the HOV lanes and a breakdown in travel speeds. Consequently, a more stringent definition of carpool eligibility should be evaluated.

In the case of the Shirley Highway, Equation A is used since 4+ person carpools are to be allowed onto the HOV lane(s). A peak hour carpool volume of 654 VPH is estimated, resulting in an acceptable V/C ratio on the HOV lane(s) of 0.34.

WORKSHEET 6: FORECAST PRIORITY BUS VOLUME

This worksheet is used to forecast the a.m. peak hour volume of bus passengers on the HOV lane(s). Four different equations can be used to determine the percent change in volume (labeled as Δ) depending on the type of HOV strategy being evaluated. Equation A is used if only buses are allowed on the HOV lane(s) and bus supply is determined endogenously. If bus supply is established exogenously (e.g., through a policy that headways will be at a certain minimum), and only buses use the HOV lane(s), then Equation B is used.

Equation C is used if buses and either 3+ or 4+ person carpools are allowed onto the HOV lane(s), while if buses and 2+ person carpools use the HOV lane(s), Equation D is used. The number of buses required to serve the forecasted demand is simply determined by using the existing average load factor (L_0B) from Worksheet 1.

Check one or both

A. ☒ For existing carpools or priority autos with 3+ or 4+ persons:

$$\Delta_{Pa^*} = -0.203 - 7.7\left[\frac{\overset{T_1^{Pa}}{\boxed{37.5}}}{\underset{T_0^{Pa^*}}{\boxed{56.2}}} - 1.\right] + 4.8\left[\frac{\overset{T_1^{b}}{\boxed{37.5}}}{\underset{T_0^{b}}{\boxed{37.5}}} - 1.\right] = \underline{+2.35}$$

*For existing carpools, substitute "HOV" for "Pa."

B. ☐ For priority autos with 2 persons allowed onto HOV lane(s):

$$\Delta_{Pa} = -0.203 - 6.7\left[\frac{\overset{T_1^{Pa}}{\boxed{}}}{\underset{T_0^{Pa}}{\boxed{}}} - 1.\right] + 4.8\left[\frac{\overset{T_1^{b}}{\boxed{}}}{\underset{T_0^{b}}{\boxed{}}} - 1.\right] = \underline{\qquad}$$

COMPUTE PRIORITY AUTO VOLUME

$$V_1^{Pa} = \left[1.0 + \overset{\Delta_{Pa}}{\boxed{2.35}}\right] \times \overset{V_0^{Pa}}{\boxed{195}} = \underline{654}\ \text{VPH}$$

COMPUTE TOTAL CARPOOLS ON HOV LANE

$$V_1^{HOV} = \overset{V_1^{Pa}}{\boxed{654}} + \left[\left(1.0 + \overset{\Delta_{HOV}}{\boxed{0}}\right) \times \overset{V_0^{HOV}}{\boxed{0}}\right] = \underline{654}\ \text{VPH}$$

CHECK SERVICE LEVEL ASSUMPTIONS

$$V/C_{HOV} = \frac{\overset{V_1^{HOV}}{\boxed{654}} + \overset{B_{0,1}^{HOV}}{\boxed{176}}}{\underset{C_1^{HOV}}{\boxed{2500}}} = \underline{0.33}$$

Check one

☒ If $V/C_{HOV} \leq 0.80$, then initial speed assumptions (S_1^{HOV}) are valid.

☐ If $V/C_{HOV} > 0.80$, repeat analysis with $S_1^{HOV'} = \dfrac{60}{1 + [V/C_{HOV}]^{15}}$

Check: If $S_1^{HOV'} < S_1^{CP}$, set $S_1^{HOV'} = S_1^{CP} = \underline{\qquad}$ MPH

NOTE: If V/C_{HOV} remains > 0.95, HOV strategy may not be appropriate.

Since 4+ person carpools are allowed onto the HOV lane(s) in the Shirley Highway example, Equation C is used to estimate the volume of bus passengers. (Note that bus travel times are not used in this equation. This is the result of the model estimation phase, which revealed that when carpools are allowed on an HOV lane, the explanatory power of the carpool travel time variables greatly dominated the effects due to bus travel time changes. See the "Technical Supplement" report for further details on this point. Completing Worksheet 6 indicates that bus volume will increase by 8.2 percent to 8,550 PPH. With a load factor of 44.8, about 191 buses will be required.

WORKSHEET 7: SUMMARY RESULTS

Worksheet 7 is used to summarize in one place the forecasted equilibrium volumes, travel times, and travel speeds determined from previous worksheets.

Below is a summary of the predicted and actual peak hour travel volumes for the Shirley Highway example:

	Actual Volumes		Predicted Volumes
Mode	Before	After	
Nonpriority Auto	4,896	5,126	5,045 VPH
HOV Carpool	195	758	654 VPH
HOV Bus	7,900	8,756	8,550 PPH

WORKSHEET 6: FORECAST PRIORITY BUS VOLUME

A. ☐ Bus Only on HOV Lane (bus supply determined endogenously)

$$\Delta_b = -1.404 \left[\frac{\boxed{}\ T_1^b}{\boxed{}\ T_0^b} - 1. \right] = \_\_\_\_\_\_$$

B. ☐ Bus Only on HOV Lane (bus supply determined exogenously)

$$\Delta_b = -0.308 \left[\frac{\boxed{}\ T_1^b}{\boxed{}\ T_0^b} - 1. \right] + 0.422 \left[\frac{\boxed{}\ B_1^{HOV}}{\boxed{}\ B_0^{Peb}} - 1. \right] = \_\_\_\_\_\_$$

C. ☒ Buses and 3^+ or 4^+ Person Carpools on HOV Lane.

$$\Delta_b = +0.227 + 0.435 \left[\frac{\boxed{37.5}\ T_1^{Pa}}{\boxed{56.2}\ T_0^{Pa}} - 1. \right] = \underline{+0.082}$$

D. ☐ Buses and 2^+ Person Carpools on HOV Lane

$$\Delta_b = +0.227 + 1.710 \left[\frac{\boxed{}\ T_1^{Pa}}{\boxed{}\ T_0^{Pa}} - 1. \right] = \_\_\_\_\_\_$$

COMPUTE PRIORITY BUS VOLUME

$$V_1^b = \left[1.0 + \underset{\Delta_b}{\boxed{0.082}} \right] \times \underset{V_0^b}{\boxed{7900}} = \underline{8550}\ \text{PPH}$$

$$B_1^{HOV} = \frac{\boxed{8550}\ V_1^b}{\boxed{44.8}\ L_0^B} = \underline{191}\ \text{BPH}$$ (Unless Exogenously Determined)

WORKSHEET 7: SUMMARY RESULTS

VOLUMES (PEAK-HOUR)

• Automobiles, nonpriority	V_1^{npa}	= 5045	VPH
• Carpools on HOV Lane(s)	V_1^{HOV}	= 654	VPH
• Buses on HOV Lane(s)	B_1^{HOV}	= 191	BPH
• Bus Passengers on HOV Lane(s)	V_1^{b}	= 8550	PPH

TOTAL TRAVEL TIME (PEAK-HOUR)

• Automobiles, nonpriority	T_1^{npa}	= 56.2	Min.
• Carpools on HOV Lane(s)	T_1^{pa}	= 37.5	Min.
• Buses on HOV Lane(s)	T_1^{b}	= 37.5	Min.

SPEEDS (AVERAGE PEAK HOUR)

• General Purpose Lane(s)	S_1^{GP}	= 19.0	MPH
• HOV Lane(s)	S_1^{HOV}	= 55.5	MPH

4

ADDITIONAL EXAMPLE APPLICATIONS

CHANGING DEFINITION OF CARPOOLS

The example presented below illustrates how the worksheets can be used to evaluate an HOV strategy that allows carpools with a lower vehicle occupancy level to use an existing bus/carpool HOV lane. The example uses actual data from the Banfield Freeway concurrent flow HOV lane project. In this particular instance, carpools with 2 persons were allowed (beginning February 12, 1979) to use the then-existing bus and 3+ person carpool lane. The worksheets presented on the following pages use data describing only before travel volumes and conditions to predict after volumes and travel time.

Worksheet 1 has been completed based on information obtained from the Oregon Department of Transportation. The variable V_0HOV indicates there were 178 carpools with occupancies of 3 or more persons on the HOV lanes in the before period. The number of 2-person carpools traveling on the general purpose lanes (v_0^Pa) during the a.m. peak hour was 530 VPH. If 2-person carpools are allowed onto the single HOV lane, the questions of main concern are: 1) will the HOV lane be overloaded with 2-person carpools resulting in breakdowns in traffic flow and reduced speeds?; 2) will passengers be diverted from the existing HOV bus mode?; and 3) what will be the new speeds and volume of vehicles remaining in the general purpose lanes?

The existing HOV lane length of 3.3 miles is listed on the top part of Worksheet 2. Capacities on the general purpose and HOV lane remain the same as in the before period. The "initial calculations" that are performed reveal that autos on the general purpose lanes (both nonpriority and priority eligible) require 6.0 minutes to travel a distance of 3.3 miles while vehicles on the HOV lane use only 4.2 minutes.

Initial travel time estimates for the after period are made using Worksheet 3. Since carpools will be allowed onto the HOV lane, travel times on the general purpose lanes are based on free-flow conditions (e.g., with a level of service of C or D). Using the formula provided, a speed (S_1GP) of 41.7 mph. is initially estimated.

Using the equations presented on Worksheet 4, a nonpriority auto volume (v_1npa) of 3,662 VPH is computed. This compares very favorably with the initial estimates of speed and V/C (i.e., 43.2 = 41.7 mph.). Thus, unless revisions are made later, it appears that the general purpose lanes will be able to operate at a service level of about D if 2-person carpools are allowed onto the HOV lanes.

Equation B on Worksheet 5 is used to forecast the volume of 2-person carpools since vehicles with 2+ persons will be allowed to use the HOV lanes. Equation A on Worksheet 5 is used to forecast the percent change (Δ_{HOV}) in volume of existing 3+ person carpools. The forecasted volume of 704 2-person carpools is combined with the revised volume of 142 3+ person carpools to arrive at a total 2+ person carpool volume of 846 VPH. A check against the HOV lane capacity indicates that free-flow speeds will continue to prevail on the HOV lane.

Lastly, Equation D on Worksheet 6 is used to estimate a bus passenger volume of 685 passengers per hour. This represents an increase of about 9 percent over the before volume, thereby indicating that allowing 2-person carpools on the HOV lane will not lead to a decrease in bus passengers. This result is obtained because the travel time "saved" (or reduced) by 2-person carpools is relatively small in this particular example.

Below is a summary of the predicted and actual peak hour travel volumes for the Banfield Freeway Phase II Project.

	Actual Volumes		
Mode	Before	After	Predicted Volume
Nonpriority Auto	3,161	3,793	3,662 VPH
HOV Carpool	708	1,180	846 VPH
HOV Bus	628	657	685 PPH

WORKSHEET 1: BASELINE DATA

Specification of Initial / Before Data

VOLUMES (PEAK-HOUR)

• Automobiles, nonpriority	V_o^{npa}	= 3161	VPH
• Automobiles, priority eligible	V_o^{pa}	= 530	VPH
• Carpools on HOV lane(s)	V_o^{HOV}	= 178	VPH
• Buses, priority eligible	B_o^{Peb}	= 0	BPH
• Buses on HOV lane(s)	B_o^{HOV}	= 20	BPH
• Bus Passengers (HOV or priority eligible)	V_o^{b}	= 628	PPH
• Bus Load Factor	L_o^{b}	= 31.4	PPB
• Trucks	V_o^{T}	= N/A	VPH

TOTAL TRAVEL TIME (PEAK-HOUR)

• Automobiles, nonpriority	T_o^{npa}	= 22.7	Min.
• Automobiles, priority eligible	T_o^{pa}	= 22.7	Min.
• Carpools on HOV lane(s)	T_o^{HOV}	= 20.9	Min.
• Buses (HOV or priority eligible)	T_o^{b}	= 20.9	Min.

SPEEDS (AVERAGE PEAK HOUR)

• General Purpose Lane(s)	S_o^{GP}	= 33	MPH
• HOV Lane(s) - Carpools	S_o^{C}	= 47	MPH
• HOV Lane(s) - Buses	S_o^{B}	= 47	MPH

EXISTING SUPPLY/CAPACITY

• No. of General Purpose Lanes	L_o^{GP}	= 2	
• No. of HOV Lanes	L_o^{HOV}	= 1	
• Capacity, general purpose lanes	C_o^{GP}	= 3900	VPH
• Capacity, HOV Lanes	C_o^{HOV}	= 1500	VPH

WORKSHEET 2: HOV POLICY AND INITIAL CALCULATIONS

(check one)

HOV Alternative: ☐ Bus Only
☒ Bus and Carpool (Carpool Size: 2^+)

HOV Length: 3.3 Miles

PROPOSED SUPPLY/CAPACITY

• No. of General Purpose Lanes	L_1^{GP} =	2	
• No. of HOV Lanes	L_1^{HOV} =	1	
• Capacity, general purpose lanes	C_1^{GP} =	3900	VPH
• Capacity, HOV lanes	C_1^{HOV} =	1500	VPH
• Buses per Hour (if exogenously determined)	B_1^{HOV} =	N/A	BPH

EXISTING TRAVEL TIMES -- OVER HIGHWAY BOUNDED BY HOV LANES*

• Automobiles, nonpriority	t_o^{npa} =	6.0	Min.
• Automobiles, priority eligible	t_o^{pa} =	6.0	Min.
• Buses (HOV or priority eligible)	t_o^{b} =	4.2	Min.

EXISTING TRAVEL TIMES -- OFF HIGHWAY BOUNDED BY HOV LANES

• Automobiles, nonpriority	$T_o^{npa} - t_o^{npa}$ =	t_{off}^{npa} =	16.7	Min.
• Automobiles, priority eligible	$T_o^{pa} - t_o^{pa}$ =	t_{off}^{pa} =	16.7	Min.
• Buses (HOV or priority eligible)	$T_o^{b} - t_o^{b}$ =	t_{off}^{b} =	16.7	Min.

---

*Formula: Vehicles on general purpose lanes (Before Period)

$$t_o = \frac{\overset{\text{HOV Length}}{\boxed{3.3}}}{\underset{S_o^{GP}}{\boxed{33}}} \times 60 = \underline{6.0} \text{ Minutes}$$

*Formula: Vehicles on HOV lanes (Before Period)

$$t_o = \frac{\overset{\text{HOV Length}}{\boxed{3.3}}}{\underset{S_o^{B}}{\boxed{47}}} \times 60 = \underline{4.2} \text{ Minutes}$$

WORKSHEET 3: ESTIMATE TRAVEL TIMES -- FORECAST PERIOD

BUSES ON OR ELIGIBLE TO USE HOV LANES

Check one

☒ Buses already on HOV, use:

$$T_1^b = T_0^b = \underline{\ 20.9\ } \text{ Minutes}$$

☐ Buses will be eligible to use HOV, use:

$$T_1^b = \underset{t_{off}^b}{\square} + \frac{\overset{\text{HOV Length}}{\square}}{\underset{\text{Estimated Speed}^*}{\square}} \times 60 = \underline{\qquad\quad} \text{ Minutes}$$

AUTOS ON OR ELIGIBLE TO USE HOV LANES

Check one

☒ Autos already on HOV, use:

$$T_1^{pa} = T_0^{HOV} = \underline{\ 20.9\ } \text{ Minutes}$$

☐ Autos will be eligible to use HOV, use:

$$T_1^{pa} = \underset{t_{off}^{pa}}{\square} + \frac{\overset{\text{HOV Length}}{\square}}{\underset{S_0^B \text{ or Estimated Speed}^*}{\square}} \times 60 = \underline{\qquad\quad} \text{ Minutes}$$

---

*If estimating speed, use 50 MPH unless other data indicates otherwise

Continued

WORKSHEET 3 (continued)

AUTOS ON GENERAL PURPOSE LANES

Check one

1. ☐ Capacity Reduction or Bus Only HOV Lane

$$T_1^{npa} = T_0^{npa} = \_\_\_\_\_\_ \text{ Minutes (i.e, force-flow continues)}$$

2. ☒ Capacity Same and Carpools Granted Priority

   · Assume free-flow initially unless data indicates otherwise

ESTIMATE FREE-FLOW SPEEDS AND TRAVEL TIMES

$$S_1^{GP} = \frac{60}{1.0 + \left[\dfrac{\underset{V_0^{npa}}{\boxed{3161}} + \underset{V_0^{pa}}{\boxed{530}}}{\underset{C_1^{GP}}{\boxed{3900}}}\right]^{15}} = \underline{41.7} \text{ MPH}$$

$$\boxed{\text{Check: If } S_1^{GP} > S_0^{c,B}, \text{ Set } S_1^{GP} = S_0^{c,B} = \_\_\_\_\_\_ \text{ MPH}}$$

$$T_1^{npa} = \underset{t_{off}^{npa}}{\boxed{16.7}} + \left[\frac{\underset{\text{HOV Length}}{\boxed{3.3}}}{\underset{S_1^{GP}}{\boxed{41.7}}} \times 60\right] = \underline{21.4} \text{ Minutes}$$

COMPUTE "ELIGIBILITY FACTOR"

$$\text{EFCTR} = \frac{\underset{L_1^{GP}}{\boxed{2}}}{\underset{L_0^{GP}}{\boxed{2}}} \times \left[\frac{\underset{V_0^{npa}}{\boxed{3161}} + \underset{V_0^{pa}}{\boxed{530}} + 2.0 \times \underset{B_0^{peb}}{\boxed{0}}}{\underset{V_0^{npa}}{\boxed{3161}}}\right] = \underline{1.168}$$

WORKSHEET 4: FORECAST NONPRIORITY AUTO VOLUME

$$\Delta_{npa} = -0.916 - 1.053\left[\frac{\overset{T_1^{npa}}{\boxed{21.4}}}{\underset{T_0^{npa}}{\boxed{22.7}}} - 1.\right] + 1.190\left[\frac{\overset{T_1^{pa2}}{\boxed{20.9}}}{\underset{T_0^{pa2}}{\boxed{22.7}}} - 1.\right] +$$

$$+ 0.122\left[\frac{\overset{T_1^{pa3/4}}{\boxed{20.9}}}{\underset{T_0^{pa3/4}}{\boxed{20.9}}} - 1.\right] + 0.278\left[\frac{\overset{T_1^{b}}{\boxed{20.9}}}{\underset{T_0^{b}}{\boxed{20.9}}} - 1.\right] + 0.949\,\overset{EFCTR}{\boxed{1.168}} = 0.158$$

$\Delta_{npa} =$ +0.158

$$V_1^{npa} = \left[1.0 + \overset{\Delta_{npa}}{\boxed{.158}}\right] \times \overset{V_0^{npa}}{\boxed{3161}} = \underline{3662} \text{ VPH}$$

EVALUATE RESULTS

check one

☐ If force-flow conditions, proceed to Worksheet 5

☒ If Box 2 checked, Validate Service Level Assumptions

COMPUTE VOLUME/CAPACITY RATIO-- FORECAST PERIOD

$$\frac{V_1^{npa}}{C_1^{npa}} = \frac{\boxed{3662}}{\boxed{3900}} = \underline{0.94}$$

Continued

WORKSHEET 4 (Continued)

DETERMINE WHICH CONDITION APPLIES

Check one

☒ If $V_1^{npa}/C_1^{GP} < 1$; then,

Compute $S_1^{GP'} = \dfrac{60}{1 + \left(\underbrace{\boxed{.94}}_{V_1^{npa}/C_1^{GP}} \right)^{15}} = \underline{43.2}$ MPH

Check one

☒ If $S_1^{GP'} \approx S_1^{GP}$, Equilibration achieved, Go to Worksheet 5

☐ If $S_1^{GP'} \neq S_1^{GP}$, Repeat with $S_1^{GP'}$, Go to Worksheet 3, P.2

☐ If $V_1^{npa}/C_1^{GP} \geq 1$; then,

Repeat analysis with T_1^{npa} based on force-flow conditions

$\therefore T_1^{npa} = T_0^{npa} =$ ______ Minutes, Redo Worksheet 4

WORKSHEET 5: FORECAST PRIORITY AUTO VOLUME

Check one or both

A. ☒ For existing carpools or priority autos with 3+ or 4+ persons:

$$\Delta_{\cancel{Pa}^{*}\,HOV} = -0.203 \; -7.7\left[\frac{\overset{T_1^{Pa}}{\boxed{20.9}}}{\underset{T_0^{\cancel{Pa}\,HOV}}{\boxed{20.9}}} - 1.\right] + 4.8\left[\frac{\overset{T_1^{b}}{\boxed{20.9}}}{\underset{T_0^{b}}{\boxed{20.9}}} - 1.\right] = \underline{-.203}$$

*For existing carpools, substitute "HOV" for "Pa"

B. ☒ For priority autos with 2 persons allowed onto HOV lane(s):

$$\Delta_{Pa} = -0.203 - 6.7\left[\frac{\overset{T_1^{Pa}}{\boxed{20.9}}}{\underset{T_0^{Pa}}{\boxed{22.7}}} - 1.\right] + 4.8\left[\frac{\overset{T_1^{b}}{\boxed{20.9}}}{\underset{T_0^{b}}{\boxed{20.9}}} - 1.\right] = \underline{+0.329}$$

COMPUTE PRIORITY AUTO VOLUME

$$V_1^{Pa} = \left[1.0 + \overset{\Delta_{Pa}}{\boxed{.329}}\right] \times \overset{V_0^{Pa}}{\boxed{530}} = \underline{704} \text{ VPH}$$

COMPUTE TOTAL CARPOOLS ON HOV LANE

$$V_1^{HOV} = \overset{V_1^{Pa}}{\boxed{704}} + \left[\left(1.0 + \overset{\Delta_{HOV}}{\boxed{-.203}}\right) \times \overset{V_0^{HOV}}{\boxed{178}}\right] = \underline{846} \text{ VPH}$$

CHECK SERVICE LEVEL ASSUMPTIONS

$$V/C_{HOV} = \frac{\overset{V_1^{HOV}}{\boxed{846}} + \overset{B_{0,1}^{HOV}}{\boxed{20}}}{\underset{C_1^{HOV}}{\boxed{1500}}} = \underline{0.58}$$

Check one

☒ If $V/C_{HOV} \leq 0.80$, then initial speed assumptions (S_1^{HOV}) are valid.

☐ If $V/C_{HOV} > 0.80$, repeat analysis with $S_1^{HOV'} = \dfrac{60}{1 + [V/C_{HOV}]^{15}}$

Check: If $S_1^{HOV'} < S_1^{GP}$, set $S_1^{HOV'} = S_1^{GP} =$ ______ MPH

NOTE: If V/C_{HOV} remains > 0.95, HOV strategy may not be appropriate.

WORKSHEET 6: FORECAST PRIORITY BUS VOLUME

A. ☐ Bus Only on HOV Lane (bus supply determined endogenously)

$$\Delta_b = -1.404 \left[\frac{\boxed{}\ T_1^b}{\boxed{}\ T_0^b} - 1. \right] = \underline{\qquad\qquad}$$

B. ☐ Bus Only on HOV Lane (bus supply determined exogenously)

$$\Delta_b = -0.308 \left[\frac{\boxed{}\ T_1^b}{\boxed{}\ T_0^b} - 1. \right] + 0.422 \left[\frac{\boxed{}\ B_1^{HOV}}{\boxed{}\ B_0^{Peb}} - 1. \right] = \underline{\qquad\qquad}$$

C. ☐ Buses and 3^+ or 4^+ Person Carpools on HOV Lane

$$\Delta_b = +0.227 + 0.435 \left[\frac{\boxed{}\ T_1^{Pa}}{\boxed{}\ T_0^{Pa}} - 1. \right] = \underline{\qquad\qquad}$$

D. ☒ Buses and 2^+ Person Carpools on HOV Lane

$$\Delta_b = +0.227 + 1.710 \left[\frac{\boxed{20.9}\ T_1^{Pa}}{\boxed{22.7}\ T_0^{Pa}} - 1. \right] = \underline{+0.09}$$

COMPUTE PRIORITY BUS VOLUME

$$V_1^b = \left[1.0 + \underset{\Delta_b}{\boxed{.09}} \right] \times \underset{V_0^b}{\boxed{628}} = \underline{685} \text{ PPH}$$

$$B_1^{HOV} = \frac{\boxed{685}\ V_1^b}{\boxed{31.4}\ L_0^B} = \underline{22} \text{ BPH}$$ (Unless Exogenously Determined)

WORKSHEET 7: SUMMARY RESULTS

VOLUMES (PEAK-HOUR)

- Automobiles, nonpriority — V_1^{npa} = 3662 VPH
- Carpools on HOV Lane(s) — V_1^{HOV} = 846 VPH
- Buses on HOV Lane(s) — B_1^{HOV} = 22 BPH
- Bus Passengers on HOV Lane(s) — V_1^{b} = 685 PPH

TOTAL TRAVEL TIME (PEAK-HOUR)

- Automobiles, nonpriority — T_1^{npa} = 21.4 Min.
- Carpools on HOV Lane(s) — T_1^{pa} = 20.9 Min.
- Buses on HOV Lane(s) — T_1^{b} = 20.9 Min.

SPEEDS (AVERAGE PEAK HOUR)

- General Purpose Lane(s) — S_1^{GP} = 41.7 MPH
- HOV Lane(s) — S_1^{HOV} = 47.0 MPH

TAKE AWAY A LANE

This example uses data from the Southeast Expressway (MA) HOV experiment to illustrate the use of the worksheets when a general purpose lane is "taken away" to be used by HOV vehicles. In particular, on May 4, 1977, the inside lane of a four-lane freeway (3 regular lanes and 1 breakdown lane) was converted into an HOV ("diamond") lane to be used by buses and 3+ person carpools. (Strict enforcement of the lane did not begin until October 1977, however.)

On the worksheets presented here for this example, the reduction in capacity due to eliminating one general purpose lane is recorded on Worksheet 2 under "proposed capacity" (i.e., C_1^{GP} = 5,300, compared to an existing capacity of 7,000 VPH). The reduction in capacity is also captured in the computation of the eligibility factor on Worksheet 3. Since a lane is taken out of service, travel speeds will continue to operate under the forced-flow conditions (i.e., service level F).

The remaining worksheets are completed in a relatively straightforward fashion. The reader should be able to follow the logic of the remaining calculations that are presented. (The "Technical Supplement" report presents additional information on the development of the models used in the worksheets and compares forecasts obtained with the worksheets to actual before-and-after data for other HOV sites.)

Below is a summary of the predicted and actual peak hour travel volumes for the Southeast Expressway HOV Lane Project.

Mode	Actual Volumes Before	Actual Volumes After	Predicted Volume
Nonpriority Auto	5,504	4,306	3,909 VPH
HOV Carpool	388	641	737 VPH
HOV Bus	2,000	2,124	2,124 PPH

WORKSHEET 1: BASELINE DATA

Specification of Initial/Before Data

VOLUMES (PEAK-HOUR)

• Automobiles, nonpriority	V_o^{npa}	=	5504	VPH
• Automobiles, priority eligible	V_o^{pa}	=	388	VPH
• Carpools on HOV lane(s)	V_o^{HOV}	=	0	VPH
• Buses, priority eligible	B_o^{Peb}	=	50	BPH
• Buses on HOV lane(s)	B_o^{HOV}	=	N/A	BPH
• Bus Passengers (HOV or priority eligible)	V_o^{b}	=	2000	PPH
• Bus Load Factor	L_o^{b}	=	40.	PPB
• Trucks	V_o^{T}	=	N/A	VPH

TOTAL TRAVEL TIME (PEAK-HOUR)

• Automobiles, nonpriority	T_o^{npa}	=	35.	Min.
• Automobiles, priority eligible	T_o^{pa}	=	35.	Min.
• Carpools on HOV lane(s)	T_o^{HOV}	=	N/A	Min.
• Buses (HOV or priority eligible)	T_o^{b}	=	35.	Min.

SPEEDS (AVERAGE PEAK HOUR)

• General Purpose Lane(s)	S_o^{GP}	=	21.	MPH
• HOV Lane(s) - Carpools	S_o^{C}	=	NPL	MPH
• HOV Lane(s) - Buses	S_o^{B}	=	NPL	MPH

EXISTING SUPPLY/CAPACITY

• No. of General Purpose Lanes	L_o^{GP}	=	4	
• No. of HOV Lanes	L_o^{HOV}	=	0	
• Capacity, general purpose lanes	C_o^{GP}	=	7000	VPH
• Capacity, HOV Lanes	C_o^{HOV}	=	0	VPH

WORKSHEET 2: HOV POLICY AND INITIAL CALCULATIONS

(check one)

HOV Alternative: ☐ Bus Only
☒ Bus and Carpool (Carpool Size: 3^{+})

HOV Length: 8.0 Miles

PROPOSED SUPPLY/CAPACITY

- No. of General Purpose Lanes L_1^{GP} = 3
- No. of HOV Lanes L_1^{HOV} = 1
- Capacity, general purpose lanes C_1^{GP} = 5300 VPH
- Capacity, HOV lanes C_1^{HOV} = 1500 VPH
- Buses per Hour (if exogenously determined) B_1^{HOV} = N/A BPH

EXISTING TRAVEL TIMES -- OVER HIGHWAY BOUNDED BY HOV LANES*

- Automobiles, nonpriority t_o^{npa} = 22.9 Min.
- Automobiles, priority eligible t_o^{pa} = 22.9 Min.
- Buses (HOV or priority eligible) t_o^{b} = 22.9 Min.

EXISTING TRAVEL TIMES -- OFF HIGHWAY BOUNDED BY HOV LANES

- Automobiles, nonpriority $T_o^{npa} - t_o^{npa} = t_{off}^{npa}$ = 12.1 Min.
- Automobiles, priority eligible $T_o^{pa} - t_o^{pa} = t_{off}^{pa}$ = 12.1 Min.
- Buses (HOV or priority eligible) $T_o^{b} - t_o^{b} = t_{off}^{b}$ = 12.1 Min.

---

*Formula: Vehicles on general purpose lanes (Before Period)

$$t_o^{\cdot} = \frac{\overset{\text{HOV Length}}{\boxed{8}}}{\underset{S_o^{GP}}{\boxed{21}}} \times 60 = \underline{22.9} \text{ Minutes}$$

*Formula: Vehicles on HOV lanes (Before Period)

$$t_o^{\cdot} = \frac{\overset{\text{HOV Length}}{\boxed{}}}{\underset{S_o^{B}}{\boxed{}}} \times 60 = \underline{} \text{ Minutes}$$

WORKSHEET 3: ESTIMATE TRAVEL TIMES -- FORECAST PERIOD

BUSES ON OR ELIGIBLE TO USE HOV LANES

Check one

☐ Buses already on HOV, use:

$$T_1^b = T_0^b = \underline{\qquad} \text{ Minutes}$$

☒ Buses will be eligible to use HOV, use:

$$T_1^b = \underbrace{\boxed{12.1}}_{t_{off}^b} + \frac{\overbrace{\boxed{8}}^{\text{HOV Length}}}{\underbrace{\boxed{50}}_{\text{Estimated Speed}^*}} \times 60 = \underline{21.7} \text{ Minutes}$$

AUTOS ON OR ELIGIBLE TO USE HOV LANES

Check one

☐ Autos already on HOV, use:

$$T_1^{pa} = T_0^{HOV} = \underline{\qquad} \text{ Minutes}$$

☒ Autos will be eligible to use HOV, use:

$$T_1^{pa} = \underbrace{\boxed{12.1}}_{t_{off}^{pa}} + \frac{\overbrace{\boxed{8}}^{\text{HOV Length}}}{\underbrace{\boxed{50}}_{S_0^B \text{ or Estimated Speed}^*}} \times 60 = \underline{21.7} \text{ Minutes}$$

---

*If estimating speed, use 50 MPH unless other data indicates otherwise

Continued

WORKSHEET 3 (Continued)

AUTOS ON GENERAL PURPOSE LANES

Check one

1. ☒ Capacity Reduction or Bus Only HOV Lane

$$T_1^{npa} = T_0^{npa} = \underline{\ 35.0\ } \text{ Minutes (i.e., force-flow continues)}$$

2. ☐ Capacity Same and Carpools Granted Priority

· Assume free-flow initially unless data indicates otherwise

ESTIMATE FREE-FLOW SPEEDS AND TRAVEL TIMES

$$S_1^{GP} = \frac{60}{1.0 + \left[\dfrac{\underset{V_0^{npa}}{\boxed{}} + \underset{V_0^{pa}}{\boxed{}}}{\underset{C_1^{GP}}{\boxed{}}} \right]^{15}} = \underline{\qquad} \text{ MPH}$$

$$\boxed{\text{Check: If } S_1^{GP} > S_0^{C,B}, \text{ Set } S_1^{GP} = S_0^{C,B} = \underline{\qquad} \text{ MPH}}$$

$$T_1^{npa} = \underset{t_{off}^{npa}}{\boxed{}} + \left[\frac{\underset{\text{HOV Length}}{\boxed{}}}{\underset{S_1^{GP}}{\boxed{}}} \times 60 \right] = \underline{\qquad} \text{ Minutes}$$

COMPUTE "ELIGIBILITY FACTOR"

$$EFCTR = \frac{\underset{L_1^{GP}}{\boxed{3}}}{\underset{L_0^{GP}}{\boxed{4}}} \times \left[\frac{\underset{V_0^{npa}}{\boxed{5504}} + \underset{V_0^{pa}}{\boxed{388}} + 2.0 \times \underset{B_0^{Peb}}{\boxed{50}}}{\underset{V_0^{npa}}{\boxed{5504}}} \right] = \underline{\ 0.82\ }$$

WORKSHEET 4: FORECAST NONPRIORITY AUTO VOLUME

$$\Delta_{npa} = -0.916 - 1.053\left[\frac{\overset{T_1^{npa}}{\boxed{35.}}}{\underset{T_0^{npa}}{\boxed{35.}}} - 1.\right] + 1.190\left[\frac{\overset{T_1^{pa2}}{\boxed{X}}}{\underset{T_0^{pa2}}{\boxed{X}}} - 1.\right] +$$

$$+ 0.122\left[\frac{\overset{T_1^{pa3/4}}{\boxed{21.7}}}{\underset{T_0^{pa3/4}}{\boxed{35.0}}} - 1.\right] + 0.278\left[\frac{\overset{T_1^{b}}{\boxed{21.7}}}{\underset{T_0^{b}}{\boxed{35.0}}} - 1.\right] + 0.949 \overset{EFCTR}{\boxed{0.82}} = -0.29$$

$\Delta_{npa} = \underline{-0.29}$ ← .046

$$V_1^{npa} = \left[1.0 + \overset{\Delta_{npa}}{\boxed{-.29}}\right] \times \overset{V_0^{npa}}{\boxed{5504}} = \underline{3909} \text{ VPH}$$

EVALUATE RESULTS

☒ If force-flow conditions, proceed to Worksheet 5

☐ If Box 2 checked, Validate Service Level Assumptions

COMPUTE VOLUME/CAPACITY RATIO-- FORECAST PERIOD

$$\frac{V_1^{npa}}{C_1^{npa}} = \frac{\boxed{}}{\boxed{}} = \underline{}$$

Continued

WORKSHEET 4 (Continued)

DETERMINE WHICH CONDITION APPLIES

Check one

☐ If $V_1^{npa}/C_1^{GP} < 1$; then,

Compute $S_1^{GP'} = \dfrac{60}{1 + \left(\boxed{}\right)^{15}} = \_\_\_\_\_$ MPH, where the box holds V_1^{npa}/C_1^{GP}

Check one

☐ If $S_1^{GP'} = S_1^{GP}$, Equilibration achieved, Go to Worksheet 5

☐ If $S_1^{GP'} \neq S_1^{GP}$, Repeat with $S_1^{GP'}$, Go to Worksheet 3, P.2

☐ If $V_1^{npa}/C_1^{GP} \geq 1$; then,

Repeat analysis with T_1^{npa} based on force-flow conditions

$\therefore\ T_1^{npa} = T_0^{npa} = \_\_\_\_\_$ Minutes, Redo Worksheet 4

WORKSHEET 5: FORECAST PRIORITY AUTO VOLUME

check one or both

A. ☒ For existing Carpools or priority autos with 3+ or 4+ persons:

$$\Delta_{Pa^*} = -0.203 - 7.7\left[\frac{\overset{T_1^{Pa}}{\boxed{21.7}}}{\underset{T_0^{Pa*}}{\boxed{35}}} - 1.\right] + 4.8\left[\frac{\overset{T_1^{b}}{\boxed{21.7}}}{\underset{T_0^{b}}{\boxed{35}}} - 1.\right] = \underline{+0.90}$$

*For existing carpools, substitute "HOV" for "Pa."

B. ☐ For priority autos with 2 persons allowed onto HOV lane(s):

$$\Delta_{Pa} = -0.203 - 6.7\left[\frac{\overset{T_1^{Pa}}{\boxed{}}}{\underset{T_0^{Pa}}{\boxed{}}} - 1.\right] + 4.8\left[\frac{\overset{T_1^{b}}{\boxed{}}}{\underset{T_0^{b}}{\boxed{}}} - 1.\right] = \underline{}$$

COMPUTE PRIORITY AUTO VOLUME

$$V_1^{Pa} = \left[1.0 + \overset{\Delta_{Pa}}{\boxed{0.90}}\right] \times \overset{V_0^{Pa}}{\boxed{388}} = \underline{737} \text{ VPH}$$

COMPUTE TOTAL CARPOOLS ON HOV LANE

$$V_1^{HOV} = \overset{V_1^{Pa}}{\boxed{737}} + \left[\left(1.0 + \overset{\Delta_{HOV}}{\boxed{0}}\right) \times \overset{V_0^{HOV}}{\boxed{0}}\right] = \underline{737} \text{ VPH}$$

CHECK SERVICE LEVEL ASSUMPTIONS

$$V/C_{HOV} = \frac{\overset{V_1^{HOV}}{\boxed{737}} + \overset{B_{o,1}^{HOV}}{\boxed{50}}}{\underset{C_1^{HOV}}{\boxed{1500}}} = \underline{0.52}$$

Check one

☒ If $V/C_{HOV} \leq 0.80$, then initial speed assumptions (S_1^{HOV}) are valid.

☐ If $V/C_{HOV} > 0.80$, repeat analysis with $S_1^{HOV'} = \dfrac{60}{1 + [V/C_{HOV}]^{15}}$

Check: If $S_1^{HOV'} < S_1^{GP}$, set $S_1^{HOV'} = S_1^{GP} =$ ____ MPH

NOTE: If V/C_{HOV} remains > 0.95, HOV strategy may not be appropriate.

WORKSHEET 6: FORECAST PRIORITY BUS VOLUME

A. ☐ Bus Only on HOV Lane (bus supply determined endogenously)

$$\Delta_b = -1.404 \left[\frac{\overset{T_1^b}{\boxed{}}}{\underset{T_0^b}{\boxed{}}} - 1. \right] = \_\_\_\_\_\_$$

B. ☐ Bus Only on HOV Lane (bus supply determined exogenously)

$$\Delta_b = -0.308 \left[\frac{\overset{T_1^b}{\boxed{}}}{\underset{T_0^b}{\boxed{}}} - 1. \right] + 0.422 \left[\frac{\overset{B_1^{HOV}}{\boxed{}}}{\underset{B_0^{Peb}}{\boxed{}}} - 1. \right] = \_\_\_\_\_\_$$

C. ☒ Buses and 3^+ or 4^+ Person Carpools on HOV Lane

$$\Delta_b = +0.227 + 0.435 \left[\frac{\overset{T_1^{Pa}}{\boxed{21.7}}}{\underset{T_0^{Pa}}{\boxed{35.}}} - 1. \right] = \underline{+0.062}$$

D. ☐ Buses and 2^+ Person Carpools on HOV Lane

$$\Delta_b = +0.227 + 1.710 \left[\frac{\overset{T_1^{Pa}}{\boxed{}}}{\underset{T_0^{Pa}}{\boxed{}}} - 1. \right] = \_\_\_\_\_\_$$

COMPUTE PRIORITY BUS VOLUME

$$V_1^b = \left[1.0 + \overset{\Delta_b}{\boxed{.062}} \right] \times \overset{V_0^b}{\boxed{2000}} = \underline{2124} \text{ PPH}$$

$$B_1^{HOV} = \frac{\overset{V_1^b}{\boxed{2124}}}{\underset{L_0^B}{\boxed{40}}} = \underline{53} \text{ BPH}$$ (Unless Exogenously Determined)

WORKSHEET 7: SUMMARY RESULTS

VOLUMES (PEAK-HOUR)

• Automobiles, nonpriority	V_1^{npa}	= 3909	VPH
• Carpools on HOV Lane(s)	V_1^{HOV}	= 737	VPH
• Buses on HOV Lane(s)	B_1^{HOV}	= 53	BPH
• Bus Passengers on HOV Lane(s)	V_1^{b}	= 2124	PPH

TOTAL TRAVEL TIME (PEAK-HOUR)

• Automobiles, nonpriority	T_1^{npa}	= 35.	Min.
• Carpools on HOV Lane(s)	T_1^{pa}	= 21.7	Min.
• Buses on HOV Lane(s)	T_1^{b}	= 21.7	Min.

SPEEDS (AVERAGE PEAK HOUR)

• General Purpose Lane(s)	S_1^{GP}	= 21	MPH
• HOV Lane(s)	S_1^{HOV}	= 50	MPH

Appendix A

BLANK WORKSHEETS

WORKSHEET 1: BASELINE DATA

Specification of Initial/Before Data

VOLUMES (PEAK-HOUR)

• Automobiles, nonpriority	V_o^{NPA}	= ______	VPH
• Automobiles, priority eligible	V_o^{PA}	= ______	VPH
• Carpools on HOV lane(s)	V_o^{HOV}	= ______	VPH
• Buses, priority eligible	B_o^{PEB}	= ______	BPH
• Buses on HOV lane(s)	B_o^{HOV}	= ______	BPH
• Bus Passengers (HOV or priority eligible)	V_o^{b}	= ______	PPH
• Bus Load Factor	L_o^{b}	= ______	PPB
• Trucks	V_o^{T}	= ______	VPH

TOTAL TRAVEL TIME (PEAK-HOUR)

• Automobiles, nonpriority	T_o^{NPA}	= ______	Min.
• Automobiles, priority eligible	T_o^{PA}	= ______	Min.
• Carpools on HOV lane(s)	T_o^{HOV}	= ______	Min.
• Buses (HOV or priority eligible)	T_o^{b}	= ______	Min.

SPEEDS (AVERAGE PEAK HOUR)

• General Purpose Lane(s)	S_o^{GP}	= ______	MPH
• HOV Lane(s) - Carpools	S_o^{C}	= ______	MPH
• HOV Lane(s) - Buses	S_o^{B}	= ______	MPH

EXISTING SUPPLY/CAPACITY

• No. of General Purpose Lanes	L_o^{GP}	= ______	
• No. of HOV Lanes	L_o^{HOV}	= ______	
• Capacity, general purpose lanes	C_o^{GP}	= ______	VPH
• Capacity, HOV Lanes	C_o^{HOV}	= ______	VPH

WORKSHEET 2: HOV POLICY AND INITIAL CALCULATIONS

(check one)

HOV Alternative: ☐ Bus Only
☐ Bus and Carpool (Carpool Size: ____)

HOV Length: ______ Miles

PROPOSED SUPPLY/CAPACITY

- No. of General Purpose Lanes L_1^{GP} = ________
- No. of HOV Lanes L_1^{HOV} = ________
- Capacity, general purpose lanes C_1^{GP} = ________ VPH
- Capacity, HOV lanes C_1^{HOV} = ________ VPH
- Buses per Hour (if exogenously determined) B_1^{HOV} = ________ BPH

EXISTING TRAVEL TIMES -- OVER HIGHWAY BOUNDED BY HOV LANES*

- Automobiles, nonpriority t_o^{npa} = ________ Min.
- Automobiles, priority eligible t_o^{pa} = ________ Min.
- Buses (HOV or priority eligible) t_o^{b} = ________ Min.

EXISTING TRAVEL TIMES -- OFF HIGHWAY BOUNDED BY HOV LANES

- Automobiles, nonpriority $T_o^{npa} - t_o^{npa} = t_{off}^{npa}$ = ________ Min.
- Automobiles, priority eligible $T_o^{pa} - t_o^{pa} = t_{off}^{pa}$ = ________ Min.
- Buses (HOV or priority eligible) $T_o^{b} - t_o^{b} = t_{off}^{b}$ = ________ Min.

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*Formula: Vehicles on general purpose lanes (Before Period)

$$t_o^{\cdot} = \frac{\overset{\text{HOV Length}}{\boxed{}}}{\underset{S_o^{GP}}{\boxed{}}} \times 60 = \_\_\_\_\_\_ \text{ Minutes}$$

*Formula: Vehicles on HOV lanes (Before Period)

$$t_o^{\cdot} = \frac{\overset{\text{HOV Length}}{\boxed{}}}{\underset{S_o^{B}}{\boxed{}}} \times 60 = \_\_\_\_\_\_ \text{ Minutes}$$

WORKSHEET 3: ESTIMATE TRAVEL TIMES -- FORECAST PERIOD

BUSES ON OR ELIGIBLE TO USE HOV LANES

Check one

☐ Buses already on HOV, use:

$T_1^b = T_0^b =$ ______ Minutes

☐ Buses will be eligible to use HOV, use:

$$T_1^b = \underbrace{\boxed{}}_{t_{off}^b} + \frac{\overbrace{\boxed{}}^{\text{HOV Length}}}{\underbrace{\boxed{}}_{\text{Estimated Speed}^*}} \times 60 = \text{\_\_\_\_\_\_ Minutes}$$

AUTOS ON OR ELIGIBLE TO USE HOV LANES

Check one

☐ Autos already on HOV, use:

$T_1^{pa} = T_0^{HOV} =$ ______ Minutes

☐ Autos will be eligible to use HOV, use:

$$T_1^{pa} = \underbrace{\boxed{}}_{t_{off}^{pa}} + \frac{\overbrace{\boxed{}}^{\text{HOV Length}}}{\underbrace{\boxed{}}_{S_0^B \text{ or Estimated Speed}^*}} \times 60 = \text{\_\_\_\_\_\_ Minutes}$$

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*If estimating speed, use 50 MPH unless other data indicates otherwise

Continued

WORKSHEET 3 (Continued)

AUTOS ON GENERAL PURPOSE LANES

Check one

1. $\square$ Capacity Reduction or Bus Only HOV Lane

$$T_1^{npa} = T_0^{npa} = \_\_\_\_\_\_ \text{ Minutes (i.e, force-flow continues)}$$

2. $\square$ Capacity Same and Carpools Granted Priority

· Assume free-flow initially unless data indicates otherwise

ESTIMATE FREE-FLOW SPEEDS AND TRAVEL TIMES

$$S_1^{GP} = \frac{60}{1.0 + \left[\dfrac{\underset{V_0^{npa}}{\square} + \underset{V_0^{pa}}{\square}}{\underset{C_1^{GP}}{\square}}\right]^{15}} = \_\_\_\_\_\_ \text{ MPH}$$

$$\boxed{\text{Check: If } S_1^{GP} > S_0^{C,B}, \text{ Set } S_1^{GP} = S_0^{C,B} = \_\_\_\_\_\_ \text{ MPH}}$$

$$T_1^{npa} = \underset{t_{off}^{npa}}{\square} + \left[\frac{\underset{\text{HOV Length}}{\square}}{\underset{S_1^{GP}}{\square}} \times 60\right] = \_\_\_\_\_\_ \text{ Minutes}$$

COMPUTE "ELIGIBILITY FACTOR"

$$\text{EFCTR} = \frac{\underset{L_1^{GP}}{\square}}{\underset{L_0^{GP}}{\square}} \times \left[\frac{\underset{V_0^{npa}}{\square} + \underset{V_0^{pa}}{\square} + 2.0 \times \underset{B_0^{Pcb}}{\square}}{\underset{V_0^{npa}}{\square}}\right] = \_\_\_\_\_\_$$

WORKSHEET 4: FORECAST NONPRIORITY AUTO VOLUME

$$\Delta_{npa} = -0.916 - 1.053\left[\frac{\overset{T_1^{npa}}{\boxed{\quad}}\ G30}{\underset{T_0^{npa}}{\boxed{\quad}}\ D16} - 1.\right] + 1.190\left[\frac{\overset{T_1^{pa2}}{\boxed{\quad}}\ G30}{\underset{T_0^{pa2}}{\boxed{\quad}}\ D17} - 1.\right] +$$

$$+ 0.122\left[\frac{\overset{T_1^{pa3/4}}{\boxed{\quad}}\ G30}{\underset{T_0^{pa3/4}}{\boxed{\quad}}\ D17} - 1.\right] + 0.278\left[\frac{\overset{T_1^{b}}{\boxed{\quad}}\ G27}{\underset{T_0^{b}}{\boxed{\quad}}\ D19} - 1.\right] + 0.949\ \underset{G38}{\overset{EFCTR}{\boxed{\quad}}} =$$

$\Delta_{npa} =$ ________

$$V_1^{npa} = \left[1.0 + \overset{\Delta_{npa}}{\boxed{\quad}}\right] \times \overset{V_0^{npa}}{\boxed{\quad}} = \_\_\_\_\_\_\_\_ \text{ VPH}$$

EVALUATE RESULTS

Check one

- ☐ If force-flow conditions, proceed to Worksheet 5
- ☐ If Box 2 checked, Validate Service Level Assumptions

COMPUTE VOLUME/CAPACITY RATIO-- FORECAST PERIOD

$$\frac{V_1^{npa}}{C_1^{npa}} = \frac{\boxed{\quad}}{\boxed{\quad}} = \_\_\_\_\_\_\_\_$$

Continued

WORKSHEET 4 (Continued)

DETERMINE WHICH CONDITION APPLIES

Check one

☐ If $V_1^{npa}/C_1^{GP} < 1$; then,

Compute $S_1^{GP'} = \dfrac{60}{1 + \left(\underbrace{\boxed{\quad}}_{V_1^{npa}/C_1^{GP}}\right)^{15}} =$ _____ MPH

Check one

☐ If $S_1^{GP'} \approx S_1^{GP}$, Equilibration achieved, Go to Worksheet 5

☐ If $S_1^{GP'} \not\approx S_1^{GP}$, Repeat with $S_1^{GP'}$, Go to Worksheet 3, P.2

☐ If $V_1^{npa}/C_1^{GP} \geq 1$; then,

Repeat analysis with T_1^{npa} based on force-flow conditions

$\therefore\ T_1^{npa} = T_0^{npa} =$ _____ Minutes, Redo Worksheet 4

WORKSHEET 5: FORECAST PRIORITY AUTO VOLUME

Check one or both

A. ☐ For existing carpools or priority autos with 3+ or 4+ persons:

$$\Delta_{pa^*} = -0.203 - 7.7\left[\frac{\overset{T_1^{pa}}{\boxed{}}}{\underset{T_0^{pa*}}{\boxed{}}} - 1.\right] + 4.8\left[\frac{\overset{T_1^{b}}{\boxed{}}}{\underset{T_0^{b}}{\boxed{}}} - 1.\right] = \_\_\_\_\_$$

*For existing carpools, substitute "HOV" for "pa"

B. ☐ For priority autos with 2 persons allowed onto HOV lane(s):

$$\Delta_{pa} = -0.203 - 6.7\left[\frac{\overset{T_1^{pa}}{\boxed{}}}{\underset{T_0^{pa}}{\boxed{}}} - 1.\right] + 4.8\left[\frac{\overset{T_1^{b}}{\boxed{}}}{\underset{T_0^{b}}{\boxed{}}} - 1.\right] = \_\_\_\_\_$$

COMPUTE PRIORITY AUTO VOLUME

$$V_1^{pa} = \left[1.0 + \overset{\Delta_{pa}}{\boxed{}}\right] \times \overset{V_0^{pa}}{\boxed{}} = \_\_\_\_\_ \text{ VPH}$$

COMPUTE TOTAL CARPOOLS ON HOV LANE

$$V_1^{HOV} = \overset{V_1^{pa}}{\boxed{}} + \left[\left(1.0 + \overset{\Delta_{HOV}}{\boxed{}}\right) \times \overset{V_0^{HOV}}{\boxed{}}\right] = \_\_\_\_\_ \text{ VPH}$$

CHECK SERVICE LEVEL ASSUMPTIONS

$$V/C_{HOV} = \frac{\overset{V_1^{HOV}}{\boxed{}} + \overset{B_{0,1}^{HOV}}{\boxed{}}}{\underset{C_1^{HOV}}{\boxed{}}} = \_\_\_\_\_$$

Check one

☐ If $V/C_{HOV} \leq 0.80$, then initial speed assumptions (S_1^{HOV}) are valid.

☐ If $V/C_{HOV} > 0.80$, repeat analysis with $S_1^{HOV'} = \dfrac{60}{1 + [V/C_{HOV}]^{15}}$

Check: If $S_1^{HOV'} < S_1^{CP}$, set $S_1^{HOV'} = S_1^{CP} =$ _____ MPH

<u>NOTE</u>: If V/C_{HOV} remains > 0.95, HOV strategy may not be appropriate.

WORKSHEET 6: FORECAST PRIORITY BUS VOLUME

A. ☐ Bus Only on HOV Lane (bus supply determined endogenously)

$$\Delta_b = -1.404\left[\frac{\overset{T_1^b}{\boxed{}}}{\underset{T_0^b}{\boxed{}}} - 1\right] = \underline{\hspace{2cm}}$$

B. ☐ Bus Only on HOV Lane (bus supply determined exogenously)

$$\Delta_b = -0.308\left[\frac{\overset{T_1^b}{\boxed{}}}{\underset{T_0^b}{\boxed{}}} - 1.\right] + 0.422\left[\frac{\overset{B_1^{HOV}}{\boxed{}}}{\underset{B_0^{Peb}}{\boxed{}}} - 1.\right] = \underline{\hspace{2cm}}$$

C. ☐ Buses and 3^+ or 4^+ Person Carpools on HOV Lane

$$\Delta_b = +0.227 + 0.435\left[\frac{\overset{T_1^{Pa}}{\boxed{}}}{\underset{T_0^{Pa}}{\boxed{}}} - 1.\right] = \underline{\hspace{2cm}}$$

D. ☐ Buses and 2^+ Person Carpools on HOV Lane

$$\Delta_b = +0.227 + 1.710\left[\frac{\overset{T_1^{Pa}}{\boxed{}}}{\underset{T_0^{Pa}}{\boxed{}}} - 1.\right] = \underline{\hspace{2cm}}$$

<u>COMPUTE PRIORITY BUS VOLUME</u>

$$V_1^b = \left[1.0 + \overset{\Delta_b}{\boxed{}}\right] \times \overset{V_0^b}{\boxed{}} = \underline{\hspace{2cm}} \text{ PPH}$$

$$B_1^{HOV} = \frac{\overset{V_1^b}{\boxed{}}}{\underset{L_0^B}{\boxed{}}} = \underline{\hspace{2cm}} \text{ BPH} \quad \text{(Unless Exogenously Determined)}$$

WORKSHEET 7: SUMMARY RESULTS

VOLUMES (PEAK-HOUR)

• Automobiles, nonpriority	V_1^{npa}	= ________	VPH
• Carpools on HOV Lane(s)	V_1^{HOV}	= ________	VPH
• Buses on HOV Lane(s)	B_1^{HOV}	= ________	BPH
• Bus Passengers on HOV Lane(s)	V_1^{b}	= ________	PPH

TOTAL TRAVEL TIME (PEAK-HOUR)

• Automobiles, nonpriority	T_1^{npa}	= ________	Min.
• Carpools on HOV Lane(s)	T_1^{Pa}	= ________	Min.
• Buses on HOV Lane(s)	T_1^{b}	= ________	Min.

SPEEDS (AVERAGE PEAK HOUR)

• General Purpose Lane(s)	S_1^{GP}	= ________	MPH
• HOV Lane(s)	S_1^{HOV}	= ________	MPH

*U.S. GOVERNMENT PRINTING OFFICE: 1992 161-425/20552 1-3

Worksheet for "Predicting Travel Volumes for HOV Priority Treatments"
Based on Charles River Associates, April, 1982 Report

Worksheet #1
Initial/Before Data

V-o-npa	7230
V-o-pa	240
V-o-hov	0
B-o-peb	30
B-o-hov	0
V-o-b	1500
L-o-b	50
V-o-T	0
T-o-npa	60
T-o-pa	60
T-o-hov	
T-o-b	60
S-o-gp	14
S-o-c	
S-o-b	
L-o-gp	4
L-o-hov	0
C-o-gp	7800
C-o-hov	0

Worksheet #2
HOV Policy

Defn	3
HOV Lgth	8.99
L-1-gp	4
L-1-hov	1
C-1-gp	7800
C-1-hov	1500
B-1-hov	35
t-0-npa	38.5
t-0-pa	38.5
t-o-b	38.5
t-off-npa	21.5
t-off-pa	21.5
t-off-b	21.5

Worksheet #3
Travel Times

	T-1-b		
	Est Spd	50	
	T-1-b	32.3	
	T-1-pa		
	Est Spd	50	
	T-1-pa	32.3	
ForcdFlo	T-1-npa	60	31
FreeFlo	S-1-gp	30.6	
	adjstd	19.5	33
	T-1-npa	49.1	34

ChooseForcdFlo(G31)orFreeFlo(G34)

T-1-npa	49.1	36
S-1-gp	20	
EFCTR	1.04	

Worksheet #4
NPA Volume

DLTA-npa	0.078
V-1-npa	7795

If ForcdFlo Goto Wksht 5

Check v/c 0.999
If >1,Redo from F36
w. ForcdFlo

Chk S1gp 30.1

If about 20
Goto 5, If not redo
from G33

Worksheet #5
Priority Auto Volume

DLTA-pa	1.138
V-1-pa	513
Check v/c	0.365

If >.8 reduce speed to
60 and repeat

If v/c>.95 HOV Defn too high

Worksheet #6: Not Incorporated

Worksheet #7
Summary Results

1. Volumes (Peak Hour)

Autos, Nonpriority	7795
Carpools on HOV Lane	513
Buses on HOV Lane	35

2. Total Travel Time on Highway (min

Autos, Nonpriority	27.7
HOV Lane	10.8

3. Speeds (mph)

Genl Purpose Lanes	19.5
HOV Lane	50

Variable Definitions

* = Calculated by spreadsheet

1. Baseline (Initial/Before) Data

Peak Hour Volumes:

V-o-npa	Autos, nonpriority, vph
V-o-pa	Autos, priority eligible, vph
V-o-hov	Carpools on existing HOV Lane, vph
B-o-peb	Buses, priority eligible, bph
B-o-hov	Buses on existing HOV Lane, bph
V-o-b	Bus Passengers per hour, pph
L-o-b	Bus Load Factor, ppb
V-o-T	Trucks, vph

Total Ave Travel Time, door to door, peak hour:

T-o-npa	Autos, nonpriority, min.
T-o-pa	Autos, priority eligible, min.
T-o-hov	Carpools on existing HOV lane, min.
T-o-b	Buses, min.

Speeds, average peak hour:

S-o-gp	Gen'l purpose lanes, mph
S-o-c	Existing HOV lane, carpools, mph
S-o-b	Existing HOV lanes, buses, mph

Existing supply/capacity:

L-o-gp	Number of gen'l purpose lanes
L-o-hov	Number of HOV lanes
C-o-gp	Capacity, gen'l purpose lanes, vph
C-o-hov	Capacity, HOV lanes, vph

2. HOV Policy and Initial Calculations

Defn	Proposed carpool definition (people/veh)
HOV Lgth	Length of proposed HOV lane

Proposed supply/capacity:

L-1-gp	Number of gen'l purpose lanes
L-1-hov	Number of HOV lanes
C-1-gp	Capacity of gen'l purpose lanes,vph
C-1-hov	Capacity of HOV lanes, vph
B-1-hov	Buses/hr if exogenously determined

Existing Travel Times over hwy bounded by HOV lanes:

t-o-npa	* Autos, nonpriority, min.
t-o-pa	* Autos, priority eligible, min.
t-o-b	* Buses, min.

Existing Travel Times off hwy bounded by HOV lanes:

t-off-npa	* Autos, nonpriority, min.
t-off-pa	* Autos, priority eligible, min.
t-off-b	* Buses, min.

3. Travel Time Estimates for forecast period

Buses and autos on or eligible to use HOV lanes:

T-1-b	* Buses, min.
T-1-pa	* Autos (carpools), min.
Est Spd	Suggests 50 mph in absense of better data

Autos on general purpose lanes:

T-1-npa	* Autos, nonpriority, min.
S-1-gp	* Speed in gen'l purpose lanes
EFCTR	* "Eligibility Factor"

4. Forecast of Nonpriority auto volume

DLTA-npa	* Parameter calculated by spreadsheet
V-1-npa	* Nonpriority auto forecast, vph

5. Forecast of Priority Auto volume

DLTA-pa	* Parameter calculated by spreadsheet
V-1-pa	* Priority auto volume in HOV lane (= carpools in HOV lane when L-o-hov=0)