An Evaluation of the Cost Effectiveness of HOV Lanes

Technical Report

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AN EVALUATION OF THE COST EFFECTIVENESS OF HOV LANES

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16. ABSTRACT

The cost effectiveness of high occupancy vehicle (HOV) lanes was analyzed by comparing the costs and benefits of existing HOV lanes with the hypothetical alternatives of doing nothing or adding a lane for general traffic. Three specific sites in the Seattle area were studied. A life-cycle costing approach was used.

The main result of the study was that (for the three locations studied) the construction of HOV lanes was the most cost effective alternative. The "marginal net present value" of each of the projects was positive (on the order of $50 to $600 per commuter per year, depending on the specific comparison). The "marginal benefit/cost ratio" was greater than six for all cases.

Using extreme values for the elements of the model had little impact on the outcome of the study. Using extreme values for any factor, one at a time, did not come close to reversing any of the findings. Reversing the general finding of the study required extreme values for virtually all of the factors. It is extremely unlikely that all the elements of the model were distorted in a direction to cause this outcome.

These findings showed that the three projects under consideration are very cost effective and should remain in place as HOV lanes. In fact, the investment of additional funds to improve the operation of these lanes could clearly be justified economically.

The methodology developed for this study was incorporated into an easy-to-use computer program that assesses the cost-effectiveness of the construction of HOV lanes in other locations. In order to save the costs of extensive data collection the sensitivity analysis approach developed in this study proved to be a valuable tool in the analysis of sites for HOV lanes. Instead of collecting extensive data to precisely quantify the cost-effectiveness of potential HOV lanes, this method can be used to determine which factors can significantly affect the outcome.

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AN EVALUATION OF THE COST EFFECTIVENESS OF HOV LANES

This technical report accompanies a final report on "An Evaluation of the Cost Effectiveness of HOV Lanes," prepared to document activities carried out under task order Y3399-7 by the Washington State Transportation Center for the Washington State Department of Transportation. An overview of the project and interpretation of the findings from that project may be found in the final report. This report is designed to provide detail on the activities of the project and of the analysis presented in the final report.

This report is divided into five main sections. The first is a literature review conducted to provide background for the cost analysis and forecasting the usage of HOV lanes. The second is the original study design and methodology proposed for the project. It has been subsequently revised to take into account the comments received during a review of that task and difficulties encountered in the final analysis stages. The actual methodology employed in the project is described in general in the final report. Some of the details may be found in the third, fourth and fifth sections of this technical report.

The third section of this report contains details of some of the computations used in the cost model. Specifically, it describes:

1) the method used to assign traffic to the freeway and parallel arterials,

2) the assignment of time penalties to trips required to travel outside the preferred time period,

3) the computation of speeds and volumes,

4) forecasts of shifts to HOV's, and

5) details of the outcomes of the cost analysis.

The fourth section describes details of the sensitivity analysis. The last section describes the computer programs used to run the cost model and gives instructions for their use.

SECTION 1

LITERATURE REVIEW

INTRODUCTION

For the last twenty years, there has been a great deal of interest in the development of methods to improve the efficiency of the existing highway system. One of these methods is the use of high occupancy vehicle (HOV) lanes. This section describes literature concerning HOV lanes that was reviewed for this project.

The provision of lanes for the exclusive use of buses, vanpools and/or carpools is seen as a way to achieve several objectives. A recent study (Southworth and Westbrook, 1985) culled the following objectives from a national survey of HOV projects:

> 1. To improve traffic flow by encouraging the use of shared ride vehicles (i.e. HOV's), and thereby creating more space on the highways during the peak commuting hours.
>
> 2. To reduce energy consumption through reduced vehicle miles of daily commuter travel.
>
> 3. To reduce air pollution (hydrocarbons, carbon monoxide, nitrogen oxides, sulphur and particulates) through reduced vehicle miles of daily commuter travel.
>
> 4. To reduce the cost of transportation to the commuter through the encouragement of shared ride and hence shared cost, modes of travel.
>
> 5. To remove or reduce the need for new highway construction or highway repair by reducing the volume of traffic that is responsible for road surface damage.

The focus of this study is the evaluation of HOV lanes. However, it is important to recognize that other types of transportation system management (TSM) actions support the efficient use of HOV lanes (e. g. Mounce, 1983). These other TSM actions could include ramp metering (with or without HOV bypass), park and ride lots, park and pool lots, ridematching programs, promotion of flexible working hours and the development of incentives to promote ridesharing activities. All these programs exist in the Seattle-King County area and contribute to the level of effectiveness of HOV lanes.

History of HOV lanes

The idea for HOV lanes was probably born decades ago. One of the first published articles on the subject (Institute of Traffic Engineers Technical Committee 3-D, 1959) was confined to bus lanes on urban streets. The article describes warrants approved by the committee for such lanes. Two articles (Morin and Reagan, 1969) and (Turner, 1970) refer to an earlier paper by Cherniak (1963) as the origin of the idea for HOV lanes on major highways. In a study of bus riders by Zell (1964), a one year experiment with an exclusive bus lane on the San Francisco-Oakland Bay Bridge was analyzed. The main intent of the paper was to assess the effect of the exclusive lane on bus patronage, but the paper concluded with an assessment of the efficacy of exclusive lanes for decreasing congestion. The study found that, even though bus patronage increased during the existence of the exclusive lane, the added passengers could not be attributed to the HOV facility. The paper further asserted that the overall vehicle-carrying capacity of the bridge was reduced by the introduction of the lane. A response by Karl Moscowitz, published with the paper, points out that the lane was successful in increasing the person-carrying capacity of the bridge.

Turner (1970) quotes a 1964 statement by Edward Holmes in "Transit and Federal Highways" as follows:

> The Bureau of Public Roads takes the position that such reservation (bus lane) is reasonable if the usage by bus passengers exceeds the number of persons that would normally be found in the same period in passenger cars . . .

It is clear that the concept of HOV lanes was well-known, although not widely accepted, by the early 1960's. The Turner paper also quotes Joseph Barnett, Chief of the Urban Road Division of the Public Roads Administration as early as 1947 making statements suggesting that since the most efficient use of highway lanes is by buses, exclusive lanes may be advantageous.

Regardless when the idea originated or who originated it, by the end of the 1960's it was well established and the first major projects were in the planning and implementation stage. Morin and Reagan (1969) supported the concept of taking a lane from highways for buses and carpools. Their paper analyzed the conditions under which their primary output measure (delay of persons) could be minimized. The Turner paper concentrated on the advantages that were expected to accrue from an exclusive bus lane (and later carpool and vanpool lane) on Shirley Highway in the Washington, D. C. area.

The Shirley Highway exclusive bus lane opened partially in 1969. The exclusive bus lane in the approach to the Lincoln Tunnel on I-495 in New Jersey opened in 1971. The first stage of the exclusive bus lane (later to include cars and vans) on the San Bernardino Freeway in the Los Angeles area opened in 1973. In 1974 and 1975, several HOV lane projects opened, including;

US 101 north of San Francisco,

Banfield Freeway in Portland, Oregon,

Moanalua Freeway in Honolulu,

I-95 in Miami, Florida, and

Long Island Expressway.

Since that time, several HOV lane projects on freeways have been initiated and several have been abandoned. The most recent national survey (Southworth and Westbrook, 1985) describes 17 projects currently in operation and three that have been abandoned since 1980. Previous surveys (Fisher and Simkowitz, 1978; Spielberg, et. al., 1980) contain descriptions of projects that are currently in operation as well as those that were abandoned before 1980.

Limits of this review

The onset of HOV lane projects in the early 1970's initiated a series of publications on the subject that has continued to the present. Early publications tended to be more descriptive than evaluative. This literature review concentrates on publications that are more evaluative, since the objective of the overall project is to evaluate the cost efficiency of HOV lanes.

Early evaluations tended to concentrate on a common set of measures of efficiency (MOE's), including average speed, person throughput, vehicle throughput, number of accidents and compliance rate. Only recently have publications begun to address the question of overall cost efficiency. This review concentrates on the latter type of study.

__Supporting documents__

A good general description of HOV lanes, including options for deployment and supporting HOV actions, is contained in a manual prepared for a course sponsored by the Federal Highway Administration (Samdahl, et. al., 1981). The document contains eight chapters with the following titles:

Introduction to HOV treatments,

Preliminary Planning,

Impact Analysis,

Physical Design,

Operations and Maintenance,

Enforcement,

Marketing Plan, and

Continuing Evaluation and Planning.

It also contains a comprehensive bibliography covering the years before 1981.

This literature review included an examination of some more recently written general descriptions of HOV lanes (Leyshon and Cunneen, 1982; Booth and Waksman, 1985; Boyle, 1985; Capelle and Robinson, 1985; Christiansen, 1985; and Roper, 1986). These articles don't discuss innovations in the physical implementation of HOV lanes, but they do draw on past experience to discuss the conditions under which HOV lanes are warranted. This aspect of these articles will be covered later.

The reader should consult a recent survey of HOV projects by Southworth and Westbrook (1985) for an up-to-date bibliography of __specific__ project descriptions. References that were reviewed for this project include the following:

California - (Sweet, 1976; Glazer and Crain, 1979; Gordon and Muretta, 1983; and Santa Clara Transit District Board, 1986)

Connecticut - (Artimovich, 1976)

Florida - (Harland, Bartholomew and Associates, Inc., 1984)

Hawaii - (Baluch, 1976; and Deuser, 1976)

Massachusetts - (Hatzi, 1976)

Minnesota - (Bather-Ringrose-Wolsfeld, Inc., 1975)

Oregon - (Bothman, 1976; and Oregon Department of Transportation, 1978)

Texas - (Kuo, et. al., 1984)

Washington - (Betts, Jacobson, Mieras and Rickman, 1984; Betts, Jacobson and Rickman, 1984; Henery and Jacobs, 1984; and Washington State Department of Transportation, 1985)

Washington, D. C. - (Mueller Associates, Inc., 1984)

A comprehensive analysis of enforcement of HOV lanes may be found in a report written for Caltrans and the California State Highway Patrol (Billheimer, 1981).

COST ANALYSIS

Much of the past research on HOV lanes has concentrated on identifying characteristics associated with "successful" HOV projects (e. g. Bly, Webster and Oldfield, 1978). Two "rules of thumb" have emerged from that research (Lomax and Morris, 1985):

1. priority lanes should provide a savings of one minute per mile of HOV lane treatment, and

2. a minimum overall savings of five to ten minutes is desirable.

However, as was discussed above, there generally are multiple criteria that govern the locations and times that HOV lane projects are considered likely to be effective. Other variables must be considered in any study of the cost effectiveness of HOV lanes.

Since the implementation of HOV lanes has occurred primarily in the last ten or twelve years, the experience to draw on is fairly limited. Although projects were initiated primarily in places where the use of the general lanes of traffic had reached capacity during the peak period, the highway facilities in the corridor surrounding the HOV project had not been completely saturated. In some cases, there had been little observed spread of the peak period. In virtually all cases where an HOV lane was added to the highway, the HOV lane has yet to be used to capacity. In other words, the full impact of HOV lanes has not yet been tested. However, some evaluation has been performed on most projects. The evaluations can be separated into two types, standard evaluations based on a series of MOE's and evaluations that attempt to convert the impacts of the projects to dollars and to assess the projects' cost efficiency.

Standard evaluations

Standard evaluations include measurements of improvements in person-carrying capacity, travel time savings, mode shifts, environmental effects, safety, enforcement and public opinion. Some examples of these studies include the evaluations of projects in Los Angeles (Gordon and Muretta, 1983), Orange County (Greene and Barasch, 1986), Florida (Harland, Bartholomew and Associates, Inc., 1984), Texas (Kuo and Mounce, 1984; and Kuo, Peterson and Mounce, 1984), Boston (Simkowitz, 1978) and Seattle (Betts, Jacobson and Rickman, 1984; and Washington State Department of Transportation, 1985). Courage, et. al. (1978) assessed the impact of changing the minimum occupancy requirements for an HOV lane on the person-moving performance of the facility. Zahavi and Roth (1980) suggest that, in the assessment of the impact of an HOV project, a useful measure of mobility is the total distance traveled per day by all travellers.

These types of evaluations generally provide a comprehensive set of data to assess the efficacy of a project, but they don't provide guidelines to measure the relative importance of each MOE. Polus and Tomecki (1986) suggest that measures of MOE's be combined by assigning specific weights to each variable and that an overall measure of level of service be developed from a linear combination of the MOE's. The weights would be provided by a panel of experts and decision-makers involved with the project. However, the paper doesn't cover the problem of getting a diverse group of people to agree on the weights.

Cost effectiveness studies

One widely-accepted way of combining multiple measures in an evaluation is to convert the measures into dollars. For instance, travel time savings can be converted to money if an agreed-upon value for time can be determined. Operating costs are probably less controversial and can be used in the comparison of alternatives. Other impacts are more difficult to convert to dollars. These include environmental benefits, improvements to the regional economy and safety.

The difficulty of converting all the impacts of an HOV project to dollars has not prevented attempts to do so. McKinsey and Company, Inc. of Dallas developed the Highway Economic Evaluation Model (HEEM) that has been used by the Texas State Department of Highways to evaluate highway projects. The model (discussed in Buffington and McFarland, 1975; and Buffington, McFarland and Rollins, 1979) makes assumptions about unit costs and evaluates highway projects in terms of a benefit/cost ratio, called an economic measure (EM). The EM for any project is the ratio of the present value of the estimated user benefits to the estimated construction costs. User benefits include time savings, vehicle operating cost savings and accident cost savings.

Memmott and Buffington (1982) discussed the applicability of HEEM to the assessment of HOV projects. They conclude that the model would be useful with some modifications. Their paper suggests that assumptions concerning truck volumes, occupancy rates, vehicle types, value of time and vehicle operating costs should be updated and refined to reflect values for a particular time and a particular corridor. Since HEEM uses a rather primitive algorithm for allocating traffic to various facilities in a corridor, the paper also recommends a more sophisticated marginal cost allocation method. The basic assumption of this method is that each individual seeks to minimize travel costs according to their perception of the situation.

Other approaches have been used to measure the cost effectiveness of HOV projects. The range of cost types is often limited. Previous studies generally take into account only travel time and vehicle operating costs (e. g. Cromwell, et. al., 1977). Hirsh (1975) assessed the impact of bus priority treatments on bus operating costs. A more recent study compared the costs of vanpooling, carpooling and driving alone (Bailey, 1982). It employed a sophisticated assessment of a variety of costs as perceived by the commuter to measure differences in commuting costs. It did not, however, attempt to evaluate the implementation of a specific HOV project.

Sources are available for obtaining unit costs, when local information in difficult to find (e. g. AASHTO, 1977; and Fisher and Viton, 1974). A body of literature exists discussing the methods for assessing the value of time to be used in cost estimation (e. g. Thomas and Thompson, 1971).

FORECASTING METHODOLOGY

The great difficulty in assessing the cost effectiveness of an HOV project over its life is to forecast what will happen in the future. We need to answer three questions in order to assess the future cost effectiveness of an HOV lane:

1) How do we know how much and when the demand for highway use will occur?

2) If we did know how much highway use will occur, how can we determine how it will be distributed?

3) When we know where and how much traffic there will be, how do we determine the speeds and other operating characteristics under those conditions?

A complete discussion of these questions is outside the scope of this study. However, some consideration is in order to plan a study of the cost effectiveness of HOV lanes.

A paper prepared for the Transportation Research Board (Shoemaker, 1983) suggests that estimates of energy usage can fluctuate greatly depending upon our assumptions about future volumes of traffic and its average speed. The same caution can be applied to estimates of cost efficiency.

The first question involves forecasts of employment and population growth both in terms of number and distribution. These forecasts are partly a result of land use policy and partly a result of national and international economic and demographic trends whose determination is outside the scope of this project.

The second question deals with the distribution of forecasts of travel demand. Many of the studies reviewed here mention the importance of taking a corridor approach in evaluating the impact on highway facilities of a growth in demand. However, none of the cost effectiveness studies reviewed above, with the possible exception of the HEEM, takes the corridor approach into account. In fact, most of the evaluations use existing data exclusively. They don't employ forecasts of the future demand and supply at all.

Several types of methods exist for the analysis and forecasting of HOV lane usage, from large scale, main frame computer models requiring large amounts of data, to sketch-level planning methods that rely primarily on graphic aids, worksheets and hand-held calculators. The models can be classified into four categories. The category determines the types and amount of data required, and the degree to which the above criteria are satisfied. These four categories are: 1) multinomial logit models, 2) pivot point logit models, 3) micro-level demand and supply models and 4) sketch-planning models. Following are descriptions of each of these types of models.

Multinomial logit models

The Urban Transportation Planning System (UTPS) model, ULOGIT (UTPS Reference Manual, 1984), is an example of a model which employs a multinomial logit formulation to predict mode choice. A similar, but less complex model, called the Quick Response System (QRS), employs the same logit formulation as UTPS (Roskin, 1984). Other examples include an economic simulation for priority lanes on urban radial freeways (Small, 1977) and a corridor-level planning model (Talvitie, 1978). In this type of model, the probability of choosing a particular mode is dependent on utility to an individual of each mode as a function of transportation supply and the individual's socioeconomic characteristics. When the travel demand between two analysis zones is known, this type of model predicts what modes travelers will choose. Some models, for example UTPS and Emme 2 (Babin, Florian, James-Lefebvre and Spiess, 1982), predict specific travel paths. Models like Small's and Talvitie's apply to single corridors or specific roadway links.

In order to calculate the probability of modal choice, the user of the model must specify the characteristics of the transportation links in the study corridor. This includes highway capacities, speeds and which modes are allowed on which facilities. Total travel demand between zones must be determined. In addition, the user must specify the socioeconomic characteristics of the travelers between the zones and how those socioeconomic characteristics are associated with the utilities they place on various costs of the trip (in and out-of-vehicle time, parking costs, vehicle operating costs, etc.). In short, these models require a great deal of data, probably involving origin and destination (O&D) surveys and home interview surveys to study socioeconomic characteristics. The models tend to be expensive and time-consuming to run, thus not satisfying the third criterion listed above.

These models can forecast spatial distribution of trips by mode if the transportation network and analysis zones are defined at a fine enough level. However, even though this type of model can account for mode choice in the whole corridor with some degree of reliability, there is some doubt that they do a good job in accounting for the specific travel paths employed. The method does not specifically account for shifts in time of travel.

Because of the large data requirements, the expense in operating the models and the insensitivity to travel demand on specific highway facilities, this class of models is not appropriate for the HOV cost effectiveness study.

Pivot point logit models

These models are similar to the first type of model except that they predict shifts in mode choice rather than mode choice in general. Therefore, they require only information on existing modal shares and changes in transportation supply characteristics. A good example of this type of model was developed by Cambridge Systematics, Inc. (Ben-Akiva and Atherton, 1977) for the U. S. Department of Energy. The QRS model also contains this option.

By using information about existing mode shares, data requirements are reduced and the need for detailed socioeconomic and transportation supply data for each highway facility or analysis zone is avoided. The model works best when the population is divided into a number of market segments and the changes in transportation level-of-service variables is specified for each segment.

One drawback of this model, as with all multinomial logit models, is that the coefficients that represent the utility of various aspects of transportation supply are determined at one point in time from cross-sectional data collected at some particular geographic location. There is no guarantee that these coefficients are the same in all places or that they will be the same in the future.

Another drawback is similar to problems with the first type of model. The analysis of travel behavior on specific highway facilities is weak. It is possible to recompute travel times and speeds based on modal shifts, and, in an iterative process, calculate new modal shifts. However, the model does not lend itself readily to analysis of travel path choices. A third drawback is that temporal shifts in travel are not explicitly taken into account in this type of model.

The pivot point logit model is an improvement over the first type of model for use in the HOV cost effectiveness study because it is less expensive and less time-consuming to use. However, it still requires a fairly large amount of data and suffers from several methodological weaknesses that don't satisfy the criterion set out above.

Micro-level demand and supply models

A third type of model is similar to the pivot point logit model, but attempts to explicitly account for travel behavior on specific highway facilities. The FREQ models (Imoda and May, 1985), developed at the University of California at Berkeley, typify this type of model. They employ a multinomial logit formulation to predict modal shift, but they also treat actions on specific highway facilities in detail.

The models use highway geometries to calculate capacities and speeds. They treat highway facilities separately as mainline and arterials (one arterial represents all alternative parallel routes to the mainline). Each of these facilities is divided into segments and defined in detail. The impact of changes in the facilities is analyzed in segments defined by the user.

Travel demand relationships are analyzed similarly to the pivot point logit model, but only changes in travel time are considered. Spatial choice (choice of freeway or arterial) is modeled fairly simply. When the mainline fills to capacity, the excess is fed (by the model) on to the arterial. The impact on arterial travel speed is recomputed and an iterative process is used to achieve equilibrium.

Temporal shift is simulated in FREQ models by keeping track of the vehicles that cannot be accommodated by the capacity of the mainline and arterial. These vehicles are assigned to a later time slice. The result is that trips are spread out to fill the facilities to their capacity.

FREQ operates basically like the pivot point logit model, but simulates, at a micro-level, the traffic flow on the facilities of interest. The model solves, to some extent, the weaknesses of the two previous types of models by explicitly taking highway facilities and temporal shifts into account. It does this, however, at the expense of simplicity. The data requirements of the model are fairly significant and the running of the model can be expensive.

In addition, the FREQ models, since they employ a multinomial logit formulation, require coefficients to represent the impact of various travel costs on mode choice. The elasticities in the model are based on a survey of 161 people in the San Francisco Bay Area in 1972. Users of the model have the choice of supplying their own elasticities, but the accuracy of the model in predicting modal shift is highly dependent on the choice of these elasticities.

Sketch-planning models

The three models described above have applications in the planning of HOV lanes. However, for the purposes of this project, they are inadequate, either because they would be too expensive and time-consuming to make several runs or they do not adequately simulate the behavior we are particularly interested in. A more promising approach to forecasting for this project is to use a sketch-level planning method employing a small number of assumptions that can be tested using sensitivity analysis.

One example of this type of model is the Community Aggregate Planning Model (CAPM) (Ryan, 1979). However, CAPM uses average auto occupancy as an input, rather than predicting mode split. A good example of a sketch-planning model that is used to predict mode split is the regression model developed by Charles Rivers Associates (Parody, 1982) for the Federal Highway Administration. This model is a pivot point model, but does not employ the logit formulation. In other words, it starts with a relatively simple description of the initial conditions, adds a simple description of the proposed change to the highway facility and predicts the travelers' responses to the change. The predictions are based on a regression analysis of 25 previous HOV projects carried out on freeways in the United States.

In using this approach, the prediction basically represents the <u>average</u> of what happened in other projects. This includes all of the temporal shifts (shifts in time), spatial shifts (shifts to parallel arterials) and all of the modal shifts. The model is very simple to use and requires only a minimum of initial data. It was designed to be used with a series of seven worksheets and a hand calculator. For this project, the worksheets have been computerized to facilitate the sensitivity analysis and the consideration of different future scenarios.

The input data requirements are as follows:

- existing numbers of automobiles, non-priority and priority-eligible
- number of existing buses and bus passengers
- current travel times and speeds
- current number of lanes and capacity
- future number of lanes and capacity
- HOV definitions and allowed lanes

The program predicts future volumes and speeds for all kinds of vehicles. The program represents what would happen within one year of the introduction of an HOV facility. By itself, it cannot be used for long term projections and it does not supply information about travel volumes on parallel arterials or changes in the length of the peak hour. However, the CRA regression model can form the basis for these kinds of forecasts. The following section outlines the plan for HOV travel forecasting based on the model to be used in this project.

SUMMARY AND CONCLUSIONS

The literature on HOV lanes is limited primarily because of the relatively short time that such facilities have been in place. The majority of it tends to be descriptive, rather than evaluative. The evaluative literature is incomplete in being able to guide a study of the cost effectiveness of HOV lanes. The incompleteness is in three areas: 1) range of types of costs covered, 2) corridor level analysis and 3) use of life cycle costing.

The current research project is designed to overcome some of the shortcomings in the literature. Previous cost analyses have concentrated on the costs of travel time, vehicle operating expense and costs for building and maintaining the HOV lanes. This study will attempt to quantify such things as support for regional development, safety and impact on other facilities.

This research will also consider the corridor level in the analysis of the impact of HOV lanes. In order to do so, it will be necessary to predict (or at least to account for) the shift of travel to other roads and highways. Shifts in mode and time of travel will also be taken into account.

The methodology for life cycle costing is well known. The problem in this study will be to forecast costs and benefits of an HOV lane project for a time frame of reasonable length. This will require estimates of future demand and estimates of travellers' responses to HOV improvements. The project will employ some form of modeling as described in the previous section.

The literature reviewed here will be useful, especially since it contains evaluations of several specific HOV projects that have been implemented in the last 15 years. These evaluations are a guide to the types of MOE's that should be considered in the evaluation of any HOV project. In addition, much of the work on unit costs and cost methodology has already been done, so that this research project can concentrate on the measurement of some of the more difficult-to-quantify variables. The existence of a range of modeling tools means that there will be a choice in approach and level of investment required.

SECTION 2

DETAILED STUDY DESIGN AND WORK PLAN

The purpose of this section is to outline, in detail, the originally proposed approach to evaluating the cost effectiveness of HOV lanes in the Puget Sound region. The section begins with a description of the general approach to the evaluation. Following that is a series of descriptions of the proposed methodologies for estimating the individual cost components in the evaluation. This section does not contain a complete specification of the values for assumptions going into the cost model, but it does specify how they will be determined (during the data collection and analysis phases). A third part of this section discusses the forecasting of shifts to higher occupancy modes induced by the implementation of HOV lanes. A fourth part describes the use of sensitivity analysis to determine the effects of the ranges in assumptions employed in the cost estimations.

GENERAL APPROACH

In general, the method to evaluate the cost effectiveness of HOV lanes compares the initial investment and annual operating costs of HOV lanes with the savings associated with HOV lanes by using differences in net present value. In order to do this, three alternatives will be considered:

1) do-nothing - the freeway segment without any additional lanes
2) add-a-general-lane - adding one lane to the freeway segment that can be used by any vehicle
3) add-an-HOV-lane - adding one lane to the freeway segment that can be used only by buses, vanpools and carpools (carpool definitions may vary)

Two freeway segments will be used as examples in this study to illustrate the use of the methodology. They were selected to represent a range of types of HOV lanes and to provide the opportunity to evaluate existing implementations. They are a) the lanes for buses and 3+ carpools on I-5 north of Northgate and b) the lane for buses and 2+ carpools on I-405 south of I-90.

HOV lanes will be evaluated by examining the differences between alternatives (1) and (3) and between alternatives (2) and (3). Costs will be analyzed for a twenty year time span. The analysis will deal with differences rather than total costs. For example, the initial design and construction investment for HOV lanes will be used in the comparison of (1) and (3), rather than using the total costs associated with the freeway segment. Savings (if any) will be differences in costs between alternatives. Since the full capacities of freeways are rarely used outside the peak and shoulder of the peak hours (hereafter referred to as the peak period), the analysis will be confined to those hours. The initial investment and the operating costs for additional lanes will be "charged" only to the peak and shoulder of the peak hours.

The first step will be to determine the cost differences per person-mile for each alternative for each year of the twenty year time period. This will be done by examining three years, 1986, 1996 and 2006. The costs for years in between will be determined by interpolation.

The next step will be to estimate total cost differences. This will be done using the same number of total person-trips for each alternative. They will, however, be distributed in two different ways. The first way will assume equal peak hour lengths during the peak period, thereby leading to different levels of congestion and speed for the three alternatives. The second way will assume equal levels of congestion in the general traffic lanes, resulting in different length peak hours and associated time penalties.

Finally, the cost differences will be brought back to the current year using a range of discount rates. The total discounted cost differences will be compared with the differences in the initial investments to determine if the net present value of HOV lanes is greater or less than the net present value of the two other alternatives.

INDIVIDUAL COST COMPONENTS

A wide range of individual cost components will be considered in this evaluation. The methods for estimating them draw heavily from two sources: 1) a recently completed study of the cost effectiveness of park-and-ride lots (Rutherford and Wellander, 1985) and 2) a 12-year old study of travel costs conducted at the University of California at Berkeley (Keeler and Small, 1975)

Highway Costs

The cost of highway construction and maintenance is a significant part of the cost of any trip. In the Rutherford and Wellander study, the highway cost was about 10% of the total cost for all trips made by people previous to using the park-and-ride lots. That was probably a conservative estimate. In this study, the total costs of an HOV lane or an extra general lane are considered separately and used as the basis for comparison with the savings associated with their existence.

Construction costs. The difference in construction cost (including design, land acquisition, etc.) between the HOV alternative (3) and the do-nothing alternative (1) will be determined from WSDOT records of construction costs. Even though the design and construction occurred over multiple years in both cases, for simplicity, the costs will be brought up to the present year using the Washington State Highways Construction Cost Index (Washington State Department of Transportation, 1960-1985). All costs associated with building the HOV lanes will be assigned to 1986.

The difference in construction cost between the add-a-general lane alternative (2) and the HOV alternative (3) will be estimated from the previous cost difference by subtracting specific costs that were associated with making the extra lane into an HOV lane. Again, the construction cost will be assumed in 1986.

In the Rutherford and Wellander study, only 59% of total construction costs were used for passenger vehicles, based on a study (United States Department of Transportation, 1982) which allocated construction cost between passenger vehicles (autos, pick-ups, passenger vans and buses) and non-passenger vehicles (freight trucks, delivery vans, maintenance and enforcement vehicles). For this study, in the add-a-general lane alternative, this factor will also be used. However, since HOV lanes are available almost exclusively to passenger vehicles, all construction costs for HOV lanes will be used.

Maintenance costs. The difference in maintenance costs between alternatives (1) and (3) will be determined from WSDOT records of maintenance costs for the entire freeway segments in the study. The cost for the HOV lanes will be estimated by dividing the total cost by the number of lanes and adding in specific costs for maintaining signage and lane marking for the HOV lane. Keeler and Small found that there was a negligible savings due to economies of scale when number of freeway lanes was taken into account. The difference between alternatives (2) and (3) will use only those costs specifically attributable to signage and lane marking costs. The factor accounting for passenger-only use in construction costs will also be applied to the maintenance costs.

Cost allocation. Allocation of highway costs should be based on the number of vehicles, not the number of persons. If average auto occupancy increases, then the highway cost is shared among fewer vehicles and is allocated to person-trips in different proportions, depending on the number of people in vehicles. In addition, the distribution of vehicles by time of day will vary by alternative and will result in a different allocation of highway costs to each part of the day. These differences will be included in this evaluation.

In the Rutherford and Wellander study, four methods were considered for allocating highway costs:

1) system average - total system construction costs are converted to lane-mile costs and divided by the average annual traffic volume per lane to result in the cost per mile per vehicle for any time of day

2) segment average - segment construction costs are converted to lane-mile costs for each segment and divided by the average annual traffic volume per lane for the segment to give a cost per mile per vehicle

3) peak period - this method goes one step further from the segment average cost and distributes costs to different hours of the day according to the traffic volumes during those hours of the day

4) Keeler-Small method - the cost is distributed according to the theory of optimal highway pricing and investment

The study used the peak period method as the primary estimation tool. The first two methods were insensitive to time of day and thus didn't take into account the fact that highway size is related primarily to peak traffic volumes. The fourth method is based on economic theory that assumes that users pay a toll that is equivalent to the marginal cost of their use. In fact, such a toll is not charged, so that it is unlikely that the use of the highway will ever adjust itself to the optimum levels. The result is that the theoretical cost of the peak period is probably too high.

The peak period method involves the determination of the number of lanes required during each time period assuming some set capacity per lane (say, 1700 vehicles). Two lanes in each direction is assumed to be the minimum number required, no matter what the traffic volume is. The cost of the initial two lanes is greater than the others because of the initial design, right-of-way purchase and other start-up costs.

A further set of assumptions were required to determine the costs that should be assigned to buses. Larger vehicles not only take up more space, but they require stronger materials and construction methods. Based on a comparison of the percentage of costs for highway construction assigned to buses in the USDOT cost allocation study and the percentage of bus travel on highways, Rutherford and Wellander assumed that bus highway costs were 2.49 times higher than auto highway costs.

Enforcement Costs

The success of HOV lanes depends to a large extent on the ability to enforce the car occupancy aspect of their definition. The ability to enforce the restrictions depends partly on the physical configuration of the lanes. There must be places for patrol officers to monitor the traffic and to safely pull violators over. The success of enforcement also depends on the financial commitment to it. Where there is little violation, there is little reason to commit a major amount of resources. However, where the incentives to violate are strong, a substantial commitment to enforcement costs may be required.

Currently, HOV enforcement costs consist of two types: 1) the time and equipment used by the Washington State Patrol to monitor the lanes and 2) the HERO program. The HERO program uses a phone number to which citizens can call and report violators. Violators receive a series of warnings, although no fine is assessed unless the violation is witnessed by a member of the state patrol. The costs for this program are shared between Metro and the Washington State Patrol.

The costs for enforcement will be estimated by using information from last year. The percentage of time devoted to HOV lane enforcement compared with other patrol activities will be estimated through interviews with patrol officers. The cost will include Washington State Patrol overhead costs as well as direct costs. Line item budget information from Metro will be used to estimate the costs of the HERO program.

HOV enforcement costs will be added to both differences under assessment (alternatives 1 versus 3 and alternatives 2 versus 3). We assume that enforcement costs for alternatives 1 and 2 are the same.

Travel Time

Savings in travel time are the most important potential benefits from the introduction of HOV lanes. Not only will higher speeds on the HOV lanes lead to time savings for people using the lanes, but other travelers can benefit from improved speeds if there is a significant shift in average auto occupancy and a corresponding reduction in vehicle traffic. On the other hand, people traveling in carpools, vanpools and buses incur extra time costs due to the nature of those travel modes. The extra travel time for these modes will be accounted for using average collection times.

Another travel time cost to be assessed in this project is due to the impact of extended peak hours because of congestion. A longer peak hour means that travelers have to plan to leave earlier to arrive at a specific time. This is most important in the morning peak hour, but also has some influence on schedules during the afternoon peak hour. The time penalty assigned when the peak hour is extended will be assumed to be half of the length of the extension.

Since travel time will be one of the major savings due to HOV lanes, the values assumed for travel time are critical. Previous studies have identified a large range of values. For in-vehicle time, the range is usually between one-fourth and one-half of the average hourly wage rate (Stopher, 1976). For out-of-vehicle time, the value ranges from 1 to 4.5 times that of the value of in-vehicle time (Southworth, 1976). As in the Rutherford and Wellander study, this study will assume a middle range of one-third of the commuter's hourly wage rate for in-vehicle time and 2.5 times that value for out-of-vehicle time. In the sensitivity analysis, the full range of values will be examined.

Auto Operating Costs

The Rutherford and Wellander study used estimates of operating costs from three sources: the Federal Highways Administration (FHWA, 1984), the American Automobile Association (AAA, 1982), and the Hertz Corporation (Hertz, 1982 and 1983). The FHWA study did not include finance charges, so they were added in assuming a 3-year loan and interest rates current at the time. The AAA estimates included depreciation costs based on a four year or 60,000 mile life. However, they didn't include costs for parts, accessories or repairs. The Hertz costs were based on full maintenance for five years and insurance costs that included youthful drivers. They were by far the highest costs.

The cost of owning a car includes depreciation, finance charges, registration and title fees, and scheduled maintenance and are incurred regardless of how far the vehicle travels. Operating costs, including repairs, maintenance, gasoline, oil, and tires, are assumed to be proportional to the amount the car is driven. Both fixed and variable costs will be estimated using the three sources listed above.

Accident costs may differ by alternative. There is conflicting evidence about the influence of HOV lanes on accident rates. The differences in travel speeds in different lanes (assuming no barriers) can lead to more accidents. However, this is mitigated to some extent by the fact that there is little lane changing between the HOV lane and general traffic lanes. In addition, to the extent that the HOV lanes reduce congestion, accident rates may be lower. The relationship between HOV lanes and accidents is unclear and impossible to quantify at this point. Therefore, the costs of accidents will be assumed to be equal for all vehicles and depend only on distance traveled. A further assumption will be made that insurance rates account for all the costs of accidents.

Parking costs can be a major part of the total cost of an automobile trip. The difference in parking cost between carpoolers and non-carpoolers is large, due to a greater number of people sharing the costs and the existence of parking incentives for carpoolers. In this study, parking costs will be derived from average daily parking costs provided by the Puget Sound Council of Governments.

Transit Costs

Transit costs will be estimated using a route cost model developed by Metro Transit. The model is a traditional method which allocates costs in two dimensions. One dimension is cost categories, consisting of variable, semi-variable and fixed costs. Fixed costs (mostly administrative) are incurred regardless of the amount of service. Variable costs vary proportionally with the amount of bus service provided. Semi-variable costs are somewhere in between and reflect the fact that some costs are step functions (such as adding a supervisor each time the labor pool increases by a certain amount).

In the second dimension, costs are classified by type of resource. Some costs are primarily a function of hours of service (e. g. driver's pay). Others depend on miles driven (e. g. fuel). The number of vehicles is the critical determinant of other costs, such as capital investment. This method will be used to assess agency costs for providing transit service. Transit fares will be allocated to each person-trip based on the current fare structure.

Congestion Costs

Congestion causes several different kinds of additional costs for highway travel. The Rutherford and Wellander study considered four kinds: travel time, auto operating costs, accidents and environmental costs. The congestion costs were separated from the basic costs for those items. In this study, the congestion costs will also be separately estimated and included in estimates of the total cost differences.

In order to estimate the cost in travel time due to congestion, two methods will be employed. In the first method, with the length of the peak hours assumed to be the same, increased congestion will lead to slower travel speeds and correspondingly longer travel times. The differential costs in travel times will be assessed using the method described above under "Travel Time Costs." In the second method, the peak hour will be extended to equalize the congestion on the mainlines for two alternatives and a penalty will be assigned to the longer peak hours to account for the fact that people have to schedule their travel times less efficiently than they might otherwise.

The Rutherford and Wellander study cites three ways to estimate the additional auto operating cost due to congestion. One source (Roth, 1967) indicates that the costs vary proportionally with travel time. In other words, if congestion causes a 10% reduction in travel speed, there is a corresponding increase in the operating cost per mile of 10%. Another source (Curry and Anderson, 1972) indicates a substantially lower cost associated with slower travel speeds, a 1.4% change with a 10% decrease in travel speed. This study will employ these estimates as the extremes for the impact of congestion on auto operating costs and select a mid-point value as the basic assumption.

Accident rates are greater when there is congestion. The variance in travel speeds in stop-and-go conditions is usually blamed for this fact (Winfrey and Zellner, 1971). The Curry and Anderson study estimates that the cost of accidents increases about 13% with a change in speed from 50 to 45 mph. This result will be used to estimate the impact of congestion on accident costs.

Environmental costs for the addition of each vehicle-mile were estimated in the Rutherford and Wellander study to vary between 1.04 and 20.0 cents. The lower figure, adjusted for inflation will be used in this study.

<u>Development Opportunities</u>

Additional freeway capacity means that a greater number of work trips can be supported in a given corridor. This means that the region encompassing the corridor can have a larger population and employment base. The additional population and employment can be estimated from the increased capacity of the travel corridor. The question is how to assign a value to the increased potential for population and employment.

One way is to estimate the additional tax revenues that the population and employment centers can generate. However, the additional population and employment will require additional services paid for out of the additional tax revenues. It could be argued that the additional tax revenues will equal the additional requirements. Using tax revenues alone misrepresents the impact of greater development.

One could argue that increased development improves the standard of living for everyone. A statistical study could be performed to relate average income with different levels of development in different regions. Again, this would not account for the extra costs incurred by individuals for living in more highly developed areas. Prices are generally higher where there is more development.

While it is tempting to try to quantify the economic impact of additional development, it is extremely difficult to agree on what costs and benefits to include. Since it seems likely that the costs and benefits of additional development will probably cancel each other out, this study will not attempt to quantify the results of the additional development possibilities. However, the extra capacity will be quantified in terms of person-trips and additional employees and population the region could support.

FORECASTING PLAN

The purpose of this section of the report is to outline a recommended approach to forecast shifts from SOV usage to higher occupancy modes. The principal criteria in evaluating different approaches were:

1. The forecasting methodology should include the ability to analyze the distribution of travel in the corridor.
2. The method should be able to account for shifts in time as well as location.
3. The method should be relatively inexpensive and easy to use, in order to allow for testing many different scenarios.
4. The method should be able to forecast travel demand for all three alternatives under consideration: do-nothing, added general purpose lane and added HOV lane.

5. The method should be available and proven in other applications.

The resulting method for forecasting HOV lane usage will be programmed or adapted for use on a microcomputer, for two reasons. First, the sensitivity analysis in the HOV cost effectiveness study will require several runs. A computer model will reduce time and associated costs. Secondly, one of the products of the study is a computer program that can be used as a planning tool in the assessment of the probable efficacy of future HOV lanes under consideration.

A combination of the models reviewed in the first section of this report will be used to forecast travel behavior in the HOV lane cost effectiveness study. The method relies on the simple methods of the CRA sketch-level planning model to predict modal shift and simplified versions of the micro-level demand and supply models to predict spatial and temporal shifts. Overall corridor travel demand will come from UTPS output from the Puget Sound Council of Governments (PSCOG).

The number of assumptions used in this method is small and they are straight-forward and understandable. Questions concerning the effect of the assumptions on final outcomes in the cost effectiveness analysis will be explored with a sensitivity analysis. This document doesn't specifically cover which assumptions will be tested in this way or how they will be tested. Those issues will be covered in a subsequent report describing the detailed study plan. This document covers the methodology assuming that a particular set of assumptions have been adopted.

The proposed forecasting method employs several steps that are illustrated in the flow diagram in Figure 1. Following is a description of those steps.

Future travel demand

Travel demand at future times will be based on forecasts prepared by the PSCOG assuming the planned HOV facilities. A screenline in the study corridors will be chosen to represent the travel demand for those corridors. Peak hour person-trip travel demand will be used as the basis for this analysis.

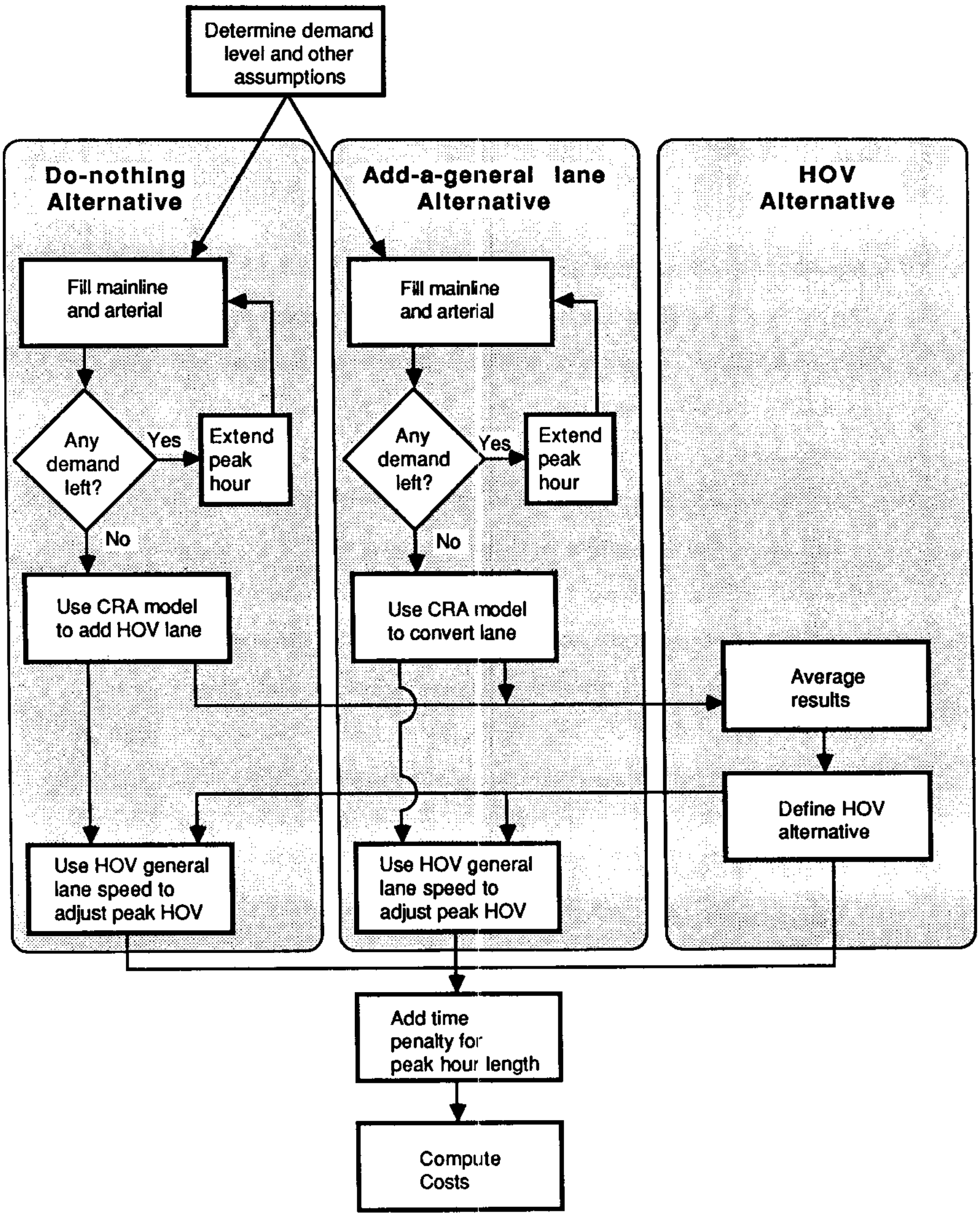

Figure 1. Forecast Method.

Determination of base number of priority-eligible vehicles

Since the do-nothing case will be used as the base case in the analysis, the percentage of vehicles that is eligible to use the HOV lanes will be the percentage that existed on I-5 north and I-405 south before the implementation of the HOV lanes. That percentage, along with predicted bus passenger volumes will be used to estimate the numbers of non-priority and priority eligible vehicles traveling through the screenlines. The same percentage will be used for the do-nothing and add-a-general lane cases.

Determine base number of bus passengers

The number of bus passengers will be derived from estimates developed in the multi-corridor planning efforts by Metro and the PSCOG.

Determine highway capacities

Freeway capacities will be determined for the do-nothing and both add-a-lane cases at the chosen screenlines. The Washington State Department of Transportation (WSDOT) will provide empirical estimates based on the largest volumes carried. Screenlines will be chosen partially to reflect the most restrictive parts of the freeway systems being studied.

Capacities of the parallel arterials will be provided by the Engineering Departments of the Cities of Seattle and Bellevue and King County. They will be added together and treated as one (similar to the FREQ models).

Determine peak hour spread for non-HOV alternatives

For both the do-nothing and the add-a-general lane case, the person-trip capacity will be calculated using the above percentages of priority-eligible vehicles and bus passengers and the highway capacities. The peak-hour travel demand will be spread or contracted to fill the corridor to capacity (this is a simplified version of the method employed in the FREQ models).

Estimate impact of HOV lane

The CRA regression model will be used to estimate the modal shift from a) adding an HOV lane to the do-nothing case and b) converting a lane from the add-a-general lane case. In the (a) case, the extra person-trips on the mainline will be assumed to come equally from the arterial and from the shoulders of the peak. In the (b) case, the reduced person trips will be assigned to the shoulder of the peak (the arterial capacity will be included in the assignment). The results of these two approaches will be averaged and taken as the modal shift resulting from the existence of an HOV lane.

Adjust do-nothing and add-a-general lane cases

A further adjustment to the peak-hour length for the do-nothing and add-a-general lane case will be accomplished by assuming that travel speeds in those two cases would be the same as the travel speeds on the general purpose lane in the add-an-HOV lane case. The vehicle volumes will be adjusted to reflect the same travel speeds and the peak hour will be lengthened to reflect that adjustment.

Estimating total impacts of the HOV lanes

This method will result in three estimates of volume, mode choice and speeds for the two corridors under study and estimates of the length of the total peak period required to accommodate all the traffic. The impact of the longer peak hour will be estimated by adding an extra penalty to the total travel time, under the assumption that a longer peak hour means that people have to leave home earlier to arrive at their destination at a given time.

SENSITIVITY ANALYSIS

Throughout the development of the forecasts of transportation demand and in the cost estimates from those forecasts, ranges of values must be assumed. A nominal value can be specified, but the lack of confidence in those nominal values means that we must assess the impact of the assumptions.

A major feature of this study will be a sensitivity analysis to test the importance of each assumption. This section of the report covers the method employed in the sensitivity analysis and the variables to be analyzed.

Method

The sensitivity of each of the assumptions will be tested using elasticities. Elasticities are measures of the impact of a difference in one variable on another. The elasticity is the percentage change in one variable caused by a difference of one percent in another variable. For instance, if the elasticity of gasoline price with respect to transit ridership were .32, it means that a 10% increase in gasoline price would lead to a 3.2% increase in transit ridership.

In this sensitivity analysis, this concept will be used to test the relative error that is introduced in the evaluation of the cost effectiveness of HOV lanes by an error in one of the assumptions. The basic measure of cost effectiveness will be the differences in the net present values between the HOV lane alternative and each of the other two alternatives. The elasticity will represent the change in those differences that results from changing the assumption under question. For instance, if the elasticity for the value of in-vehicle travel time with respect to net present value differences is .08, it means that a change of 10% in the assumption about the value of travel time leads to a .8% increase in the difference in net present value.

Since most of the assumptions in this study affect total costs or savings in all of the alternatives, differences in net present values are not expected to be greatly affected by having a range for assumptions, even though the total cost estimates for each of the alternatives could be quite different. All of the forecasting and cost estimates will be programmed for a microcomputer, so the effects of different assumptions will be relatively easy and quick to calculate.

In some cases, it may be possible that there are interactions among the assumptions. That is, a change in one assumption may multiply the effect of a change in some other assumption. The possibility of these interactions can be relatively easily tested through the use of the computer program.

Variables

The following variables involve assumptions that will be tested in the sensitivity analysis:

- travel demand growth
- initial auto occupancy

- initial auto speeds
- regression coefficients in the CRA model
- bus and bus passenger volumes
- lane capacities
- speed/volume relationships
- discount rates
- construction costs
- maintenance costs
- enforcement costs
- value of in-vehicle travel time
- value of out-of-vehicle travel time
- collection time for carpools and vanpools
- impact of extended peak hour
- allocation of highway costs
- fixed auto operating costs
- variable auto operating costs
- transit operating costs
- transit fares
- additional auto operating costs due to congestion
- additional travel time costs due to congestion
- additional accident costs due to congestion
- additional environmental costs due to congestion

In addition to an assessment of the elasticities of each of the assumptions, the potential contribution of each of the variables to the basic evaluation measure will be assessed. For each assumption, there is an associated range of possible and reasonable values. The difference in net present values of the alternatives will be computed using the extreme values of each assumption. Any single assumption range that could cause a reversal in the outcome of the study will be further investigated.

If no single assumption can reverse the outcome of the study, an additional test will be performed. Extreme values will be used for as many assumptions as required until the outcome of the evaluation is reversed. This will be the final test of robustness of the findings.

SECTION 3

DETAILED DESCRIPTION OF SELECTED COMPONENTS OF THE COST MODEL

The cost model used to analyze the cost effectiveness of HOV lanes is a fairly complex one involving the estimation and forecasting of modal choice, temporal choice and route choice as well as computing the costs and benefits of each alternative. The final report for this project contains an overview of the model and describes its general operation. Many of the components of the model are fairly straight-forward. A copy of the FORTRAN computer code is available in an appendix to this report. The simpler computations should be obvious from the code.

There are, however, a few components to the model which are not obvious. These will be described in this section of the report. They include:

1) the method used to assign traffic to the freeway and parallel arterials,

2) the assignment of time penalties to trips required to travel outside the preferred time period,

3) the computation of speeds and volumes, and

4) forecasts of shifts to HOV's.

In addition, this section contains a complete description of the outcomes of the cost analysis on the three facilities that were studied.

ROUTE CHOICES

The cost model analyses all the traffic in a corridor. In order to do this, it takes into account the fact that some traffic travels on arterials that are parallel to the freeway that is under study.

The basic method the model uses to assign traffic is to optimize travel route choices so that the total travel time for the corridor for all modes is a minimum. The justification for this approach is that most travelers are free to make different choices of route on a day-to-day basis. If only a small percentage of the travelers move back and forth between the freeway and parallel arterials each day in response to the level of congestion and try to minimize their travel time, the effect will be to approach an optimal distribution for all travelers. Of the three kinds of choices that people can make (modal, temporal and route), route choice is the least constrained. It would be difficult to argue that choices in mode or time of travel are made to optimize the total system.

The cost model uses an iterative process to find the optimum distribution of traffic. Figure 2 describes the process. At each iteration, total travel time is computed for three possible distributions (A, B, and C), equally separated from each other (distance D). If the central value (B) for the distributions has the minimum (Fig. 2a) total time compared with the other two values, the increment between the values is halved and the next iteration is performed (Fig. 2b). If one of the extreme values is the minimum (Fig. 2c), the set of three is shifted to make that the central one and the total times are computed again without changing the increment (Fig. 2d). This process continues until the increment D reaches a very small value.

TIME PENALTIES FOR DISPLACEMENTS

The cost model accounts for the spread of the peak period by counting the number of people that are not able to travel during the times they want and assigning them a time penalty. The length of the penalty is dependent on the number of people displaced and the remaining capacity of the shoulder hours and hours outside the peak period.

The computation of this penalty is illustrated in Figure 3. The initial demands (Fig. 3a) are determined by the percentage of people that are assumed to prefer to travel in the peak hour. The excess in the peak hour are assumed to shift to the shoulder hours. It is further assumed that the shifts tend to be from people who prefer to travel in the edges of the peak hour (Fig. 3b). The shifts are assumed to be to times as close to the peak hour as possible, given the demand in the shoulder hours (Fig. 3c). The time penalty is the difference between the median times for the vehicle trips as shown in Figure 3c. One can see that the minimum time penalty is zero as the excess approaches zero. When the excess is very large, the time penalty approaches 45 minutes.

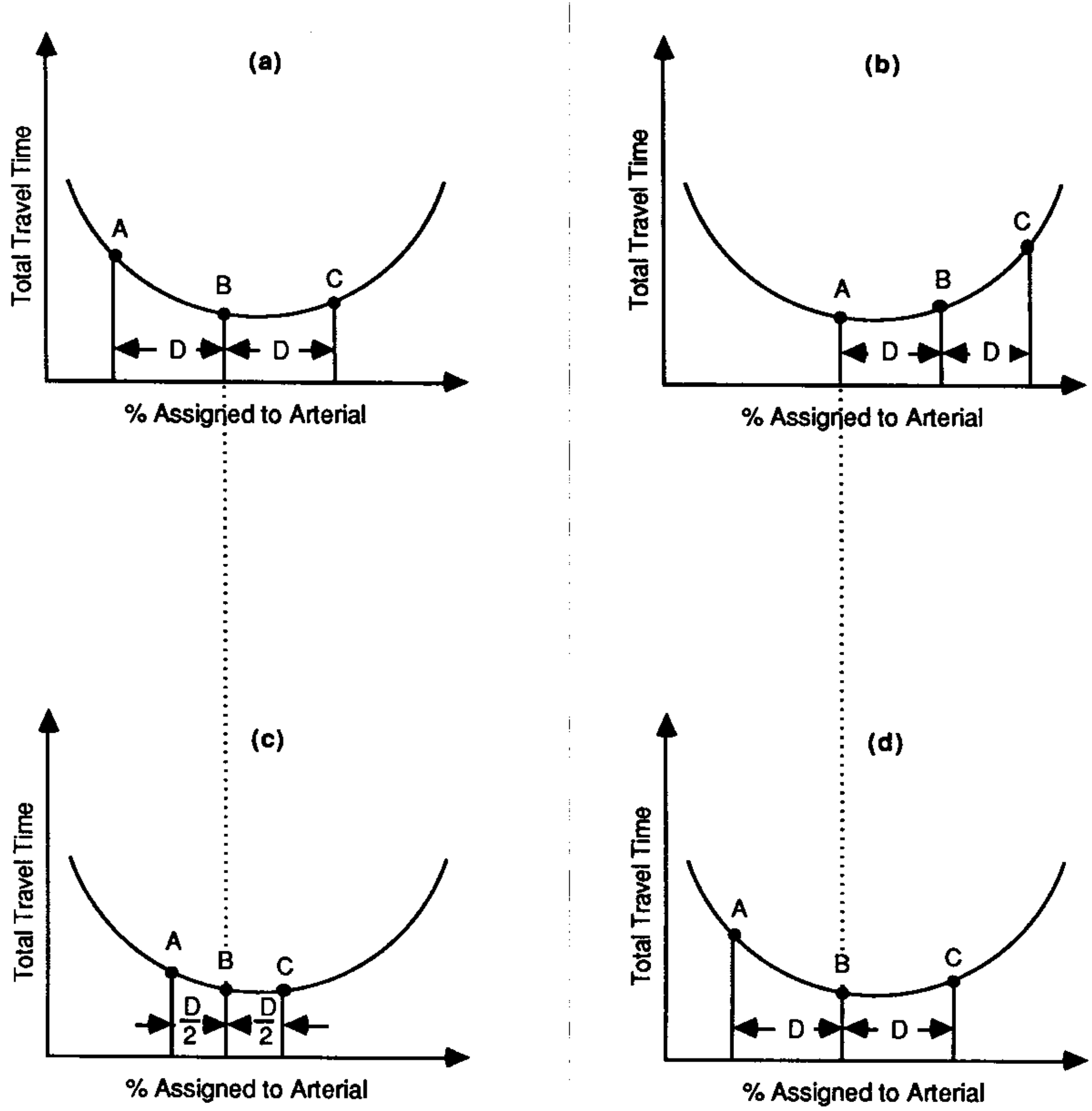

Figure 2. Optimization of Route Distribution.

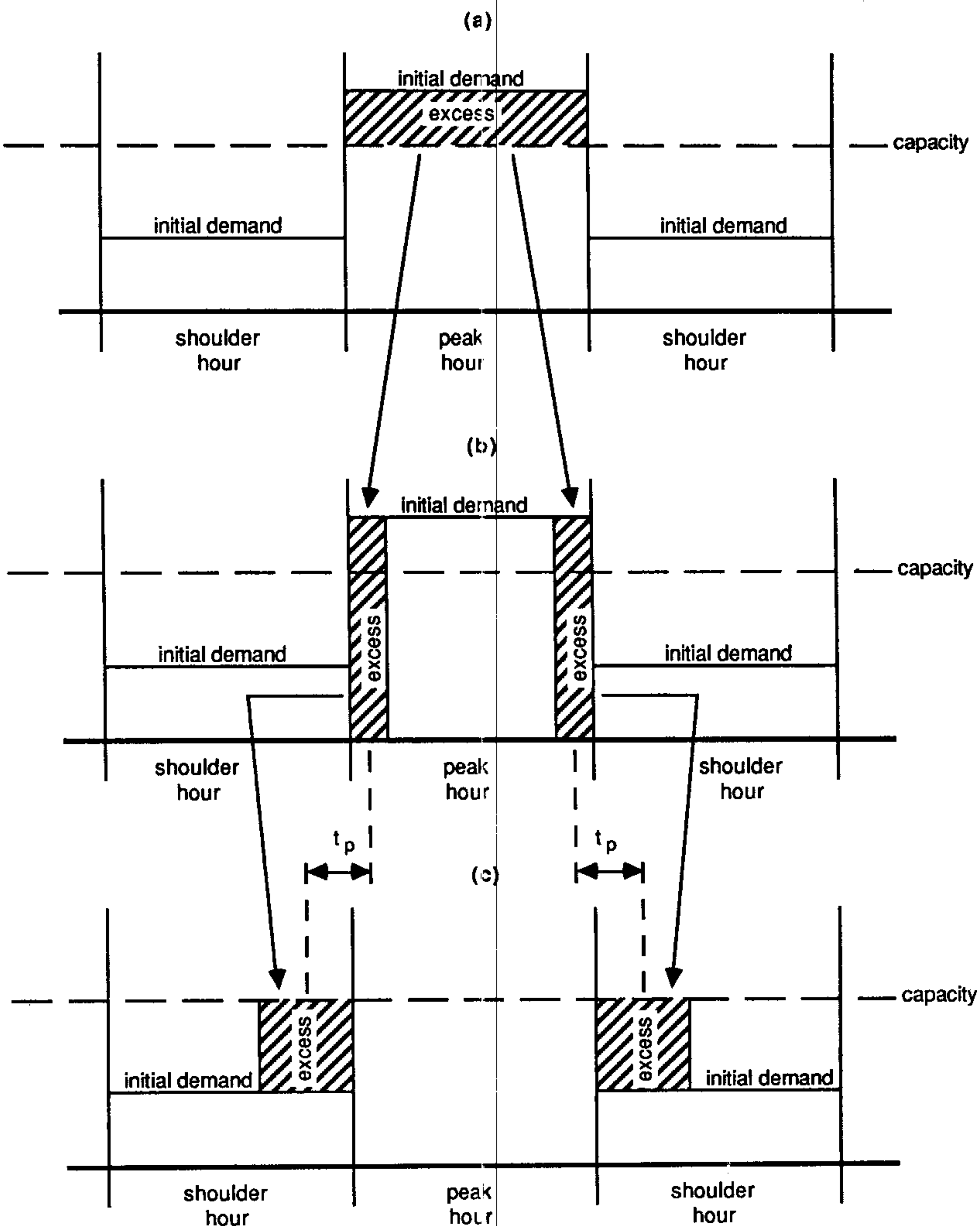

Figure 3. Computation of Time Penalty (t_p) for Vehicles Displaced Outside Peak Hour.

Two complications are considered in the analysis. One is that the peak capacity is dependent to some extent on the excess demand during that hour (see the next section) and does not necessarily equal the capacity in the shoulder hours. Secondly, in some scenarios, the demand in the shoulders exceeds the capacity. In that case, a maximum time penalty of 45 minutes is assigned to the displaced vehicles.

Figure 4 illustrates the computation of the time penalty for vehicles that are displaced outside the peak period. The off-peak demand was determined from an analysis of current traffic levels of the facilities being studied.

COMPUTATION OF SPEEDS AND VOLUMES

The computation of speeds and volumes is based directly on the Rutherford and Wellander study of park and ride lots. Figure 5 shows the speed-flow curve developed in that study using data from I-5 north of downtown Seattle. The equations used to represent this curve are:

for lane volumes < = 1500 vehicles per hour (vph),

$$s = 58 - .002q$$

for lane volumes > 1500 and < 1800 vph

$$s = 79.876 - .0166q$$

for lane volumes > = 1800 and < = 1873 vph,

$$s = 40.07 + (2518.62 - 1.344q)^{1/2}$$

Where:

s = average traffic speed in miles per hour

q = traffic flow in vehicles per lane hour

Speed computation for demand less than capacity

The above equations were generalized to use a variable maximum flow instead of 1873 vph and a variable maximum speed instead of 58 miles per hour. The resulting equations were:

for lane volumes < = q_1,

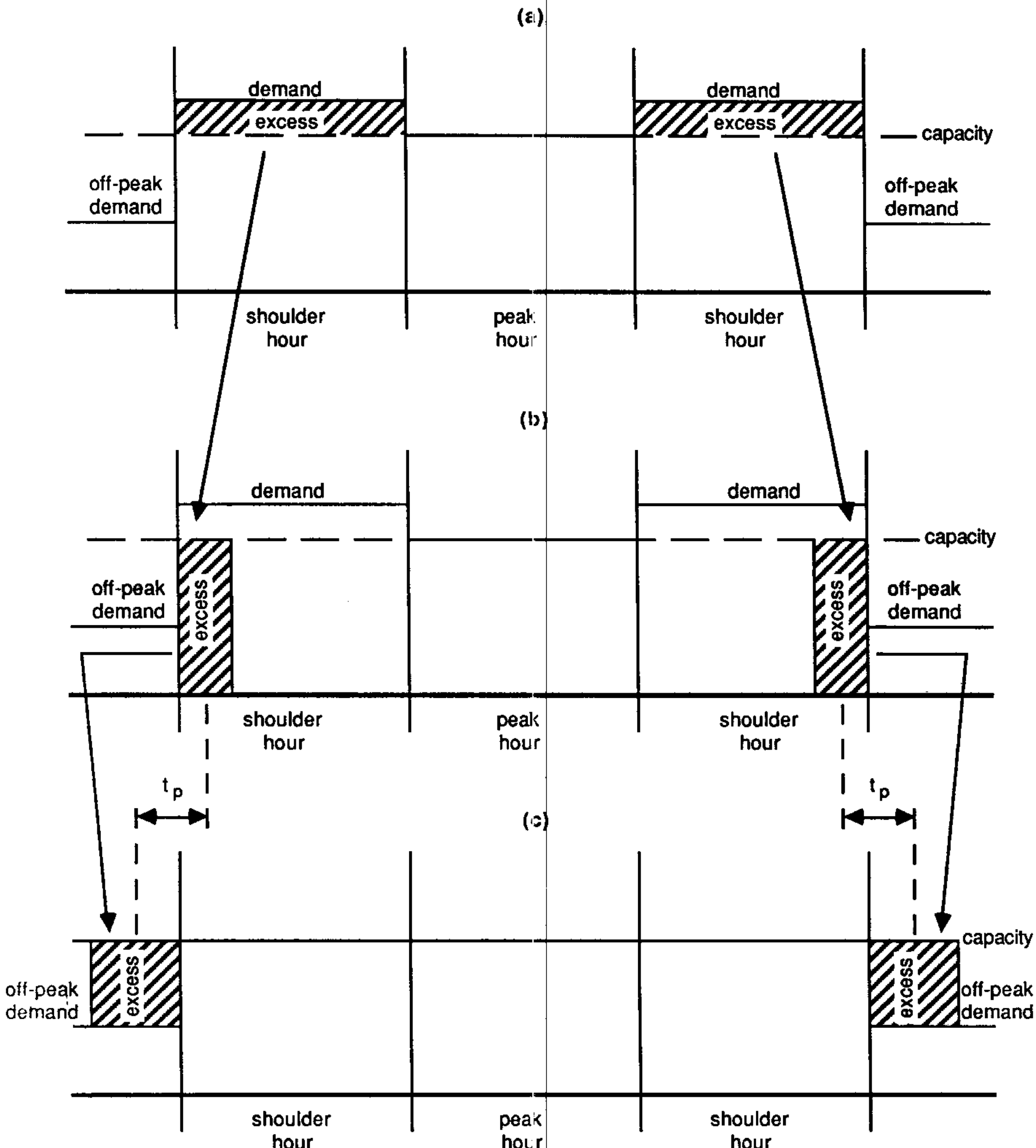

Figure 4. Computation of Time Penalty (t_p) for Vehicles Displaced Outside Peak Period.

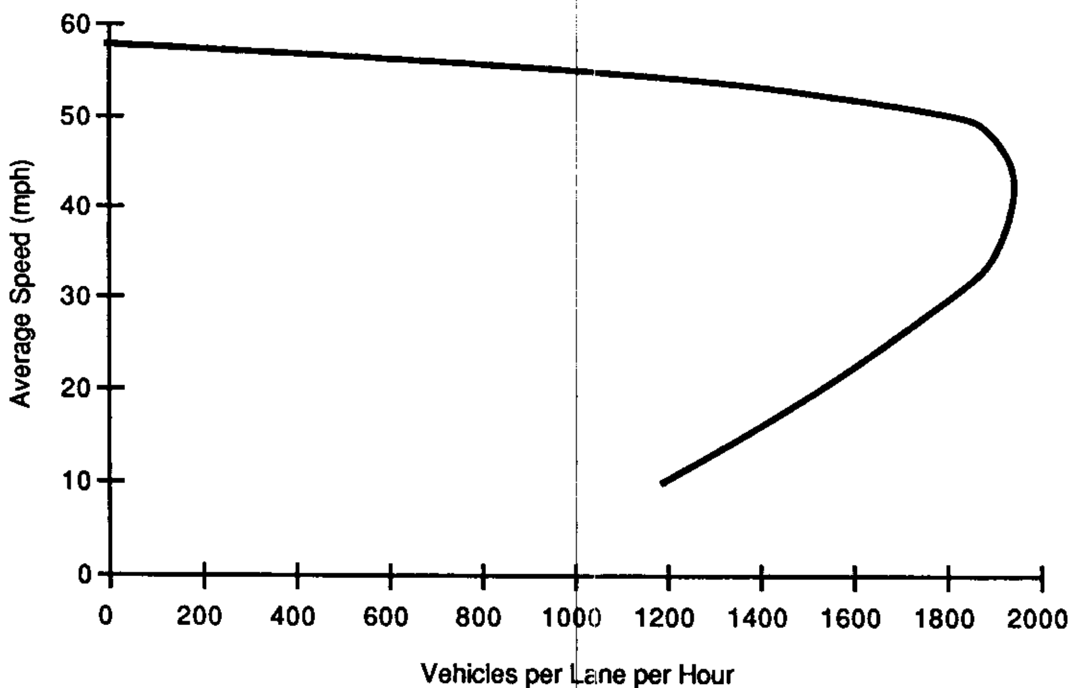

Figure 5. Speed-Flow Curve for I-5 North.

$$s = q_{max} (1 - .06462 r_{vol})$$

for lane volumes > q_1 and < q_2,

$$s = q_{max} (1.3793 - .5385 r_{vol})$$

for lane volumes >= q_2 and <= q_{max}

$$s = q_{max} (.69086 + .86157 (1 - r_{vol})^{1/2})$$

where:

q_1 = first flow cutoff ($.8004 q_{max}$)

q_2 = second flow cutoff ($.9605 q_{max}$)

q_{max} = maximum flow possible

r_{vol} = demand to capacity ratio

The equations were used when demand was less than capacity.

Speed computation for demand greater than capacity

When the lane demand is greater than the capacity, a lower limit for the volume is computed based on the lower part of the speed-flow curve using the equation:

$$q_{min} = q_{max} (.357 + 1.8614 r_{speed} - 1.3472 r_{speed}^2)$$

where:

q_{min} = the flow possible at the minimum speed

r_{speed} = ratio of the minimum speed to maximum speed

It was assumed that q_{min} represents the flow when the demand is 1.5 times the maximum capacity (assumptions varying between 1.1 and 2.0 were tested, showing little difference in outcome). The actual flow used is computed using a linear interpolation between q_{min} and q_{max} based on demand to capacity ratio (r_{vol}). The actual flow used is constrained to be between q_{min} and q_{max}. After these steps, the speed is computed using the equation:

$$s = q_{max} (.69086 - .86157 (1 - r_{vol})^{1/2})$$

based on the lower part of the speed-flow curve.

FORECASTING SHIFTS TO HOV'S

The shifts to HOV's were computed based on the Parody model. The Parody model allows a wide range of HOV facilities to be analyzed, including taking away a lane, introduction of bus lanes only and changing the definition of carpools. In this, study, however, only one type of shift was of interest: adding an HOV lane that would be available to carpools, vanpools and buses. The only alternatives necessary were two different definitions of carpools. This simplification allowed using only a small part of the Parody model in the cost analysis.

Equations for computing the priority automobile volume and the priority bus volumes are described in worksheets 5 and 6 of the Parody model (Parody, 1982). For carpools defined as three or more persons, the proportional shift introduced when an HOV lane is added given as:

$$d_{pa} = -.203 - 7.7(r_{ttime} - 1) + 4.8(r_{ttime} - 1)$$

where:

r_{ttime} = the ratio of total travel time for priority-eligible autos before and after the introduction of the HOV lanes

d_{pa} = the proportional shift for priority autos

For two person carpools, the equation is:

$$d_{pa} = -.203 - 6.7(r_{ttime} - 1) + 4.8(r_{ttime} - 1)$$

For buses and three or more person carpools, the equation is:

$$d_b = .227 + .435(r_{ttime} - 1)$$

where:

d_b = the proportional shift for buses

For buses and two person carpools, the equation is:

$$d_b = .227 + 1.71(r_{ttime} - 1)$$

The proportional increases are applied directly to the volumes in the "do nothing" alternative to arrive at the volumes for the "add an HOV lane" alternative. The coefficient for the priority automobiles is used to forecast increases in vanpools. If the proportional change for buses is less than zero, no change is assumed.

COST ANALYSIS OUTCOMES

The outcomes for the cost analyses of the three alternatives are shown in Tables 1, 2 and 3. In all cases, there was a net savings from the implementation of HOV lanes and the marginal benefit to cost ratio was always greater than six. Each facility has different characteristics, however, and some interpretation is appropriate.

I-5 north of Northgate

This corridor is a highly used and congested corridor. By the year 2000 there will be significant congestion under all alternatives. The "add an HOV lane" alternative came out so positively primarily because it led to a significant shift to HOV usage and offered much faster travel times to people using HOV lanes than either of the other alternatives did. For a relatively small investment, significant savings in time and other personal costs resulted.

SR 520 east of the Evergreen Point Bridge

This project did not accommodate the volumes of HOV's that the other alternatives did, nor did the HOV's travel as fast. However, for a very low cost, capacity was added over the "do nothing" alternative and all traffic traveled at higher speeds. If the HOV lane had been made available to all traffic, the small additional capacity may have come close to matching the HOV lane's ability to improve speeds, but it would not have lead to a shift in mode from SOV's to higher occupancy vehicles. The overall savings from the HOV lane is substantial, especially considering the modest investment required.

I-405 south of I-90

The HOV lanes on I-405 clearly were more cost effective than the "do nothing" alternative. However, the net savings over the "add a general lane" alternative were muted to some extent by the apparent ability of the "add a general lane" alternative to move people faster than the "add an HOV

HOV Cost Model
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I-5 north of Northgate

	Do Nothing 1985	Do Nothing 2000	Add Mixed Lane 1985	Add Mixed Lane 2000	Add HOV Lane 1985	Add HOV Lane 2000
Person-trips	45100	54800	45100	54800	45100	54800
SOV's	30383	37106	30383	37106	29165	35546
2-pers. carpools	4713	5727	4713	5727	4713	5727
3-pers.carpools	317	385	317	385	458	603
Vanpools	24	29	24	29	35	45
Buses	89	104	89	104	103	119
Carpool definition	1	1	1	1	3	3
% preferring peak	.45	.45	.45	.45	.45	.45
capacity - gen	1873	1873	1873	1873	1873	1873
HOV	0	0	0	0	1873	1873
art	500	500	500	500	500	500
# peak veh. - gen	7399	7095	9153	9037	7354	7266
HOV	0	0	0	0	268	345
art	7985	8340	6834	8339	7891	8340
# shoulder veh. - gen	10382	14404	11187	15783	8988	12145
HOV	0	0	0	0	328	422
art	9760	13511	8352	10192	9645	13522
peak speeds - gen	34.5	28.6	47.6	30.7	46.8	31.4
HOV	.0	.0	.0	.0	57.5	51.4
art	21.8	14.3	23.7	20.2	22.0	14.3
shoulder speeds - gen	55.4	49.9	55.8	53.7	55.8	54.7
HOV	.0	.0	.0	.0	57.7	57.6
art	24.1	23.7	24.2	24.0	24.1	23.7
length	5.1	5.1	5.1	5.1	5.1	5.1
# gen.purp.lanes	4.0	4.0	5.0	5.0	4.0	4.0
# HOV lanes	0	0	0	0	1	1
# arterial lanes	17	17	17	17	17	17
access time	11.5	11.5	11.5	11.5	11.5	11.5
carpool formation	.7	.7	.7	.7	.7	.7
vanpool formation	2.0	2.0	2.0	2.0	2.0	2.0
bus access	10.3	9.8	10.3	9.8	10.3	9.8
min. freeway speed	25	25	25	25	25	25
min. arterial speed	12	12	12	12	12	12
Travel time (minutes)						
Peak SOV	23.04	27.97	20.71	23.94	21.86	27.46
carpool	23.74	28.67	21.41	24.64	17.53	18.15
vanpool	25.04	29.97	22.71	25.94	18.83	19.45
bus	33.34	37.77	31.01	33.74	27.13	27.25
Shoulder SOV	20.51	20.91	20.05	19.96	20.72	20.95
carpool	21.21	21.61	20.75	20.66	17.51	17.51
vanpool	22.51	22.91	22.05	21.96	18.81	18.81
bus	30.81	30.71	30.35	29.76	27.11	26.61
Average SOV	21.60	23.42	20.34	21.55	21.23	23.41
carpool	22.30	24.12	21.04	22.25	17.51	17.80
vanpool	23.60	25.42	22.34	23.55	18.81	19.10
bus	31.90	33.22	30.64	31.35	27.11	26.90

Table 1

Cost Model Outcomes for I-5 Alternative

HOV Cost Model (cont.)
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I-5 north of Northgate

	Do Nothing 1985	Do Nothing 2000	Add Mixed Lane 1985	Add Mixed Lane 2000	Add HOV Lane 1985	Add HOV Lane 2000
Displacements						
peak freeway	602	2580	0	2132	0	1469
peak arterial	0	1493	0	0	0	1498
shoulder freeway	0	0	0	0	0	0
shoulder arterial	0	0	0	0	0	0
Summary Statistics						
% on arterials	.499	.504	.427	.427	.518	.530
average trip time	22.80	27.10	21.43	23.66	20.92	23.51
Total Trip Length						
average	10.0	12.0	10.0	12.0	10.0	12.0
SOV	9.7	11.7	9.7	11.7	9.6	11.7
2-pers. carpool	12.0	14.0	12.0	14.0	12.0	14.0
3-pers. carpool	13.0	14.0	13.0	14.0	13.0	14.0
vanpools	20.0	22.0	20.0	22.0	20.0	22.0
buses	12.0	12.0	12.0	12.0	12.0	12.0
Total Vehicle Miles (1000's)						
cars	354.19	518.96	354.19	518.96	343.50	503.05
vanpools	.48	.64	.48	.64	.69	1.00
buses	1.07	1.25	1.07	1.25	1.24	1.43
Maximum Speeds						
freeway	58.0	58.0	58.0	58.0	58.0	58.0
HOV	58.0	58.0	58.0	58.0	58.0	58.0
arterial	25.0	25.0	25.0	25.0	25.0	25.0
HOV differential	.0	.0	.0	.0	20.0	20.0
TOTAL COSTS	341.47	460.57	335.68	440.35	327.65	431.29

COST PARAMETERS

Parking costs ($'s/day)	
SOV	3.71
carpool	3.00
vanpool	.00
Operating costs	
car ($/mi.)	.23
van ($/mi.)	.42
bus ($/mi.)	1.31
bus ($/hr.)	24.83
bus ($/trip)	82.17

Annual costs ($1,000's)	
Maint. cost	48
Extra HOV maint.	10
Enforcement	105

Miscellaneous	
Value of time ($)	7.00
Discount rate (%)	4.0
Lane construction	9202
Extra HOV cost	920
Oper. cost elas.	.50
Bus fare	.80
Peak Factor	2.00

Net Savings ($1,000,000's)	total	time	personal	agency	marg b/c
HOV - Do Nothing	146.1	121.7	42.4	-18.1	9.08
HOV - Add Gen'l Lane	56.4	10.9	54.2	-8.7	7.50

Table 1 (continued)

Cost Model Outcomes for I-5 Alternative

HOV Cost Model
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I-405 south of I-90

	Do Nothing 1985	Do Nothing 2000	Add Mixed Lane 1985	Add Mixed Lane 2000	Add HOV Lane 1985	Add HOV Lane 2000
Person-trips	13900	15900	13900	15900	13900	15900
SOV's	11078	12623	11078	12623	10054	11287
2-pers. carpools	542	620	542	620	838	1005
3-pers.carpools	207	237	207	237	320	384
Vanpools	11	13	11	13	17	21
Buses	21	25	21	25	21	25
Carpool definition	1	1	1	1	2	2
% preferring peak	.45	.45	.45	.45	.45	.45
capacity - gen	1873	1873	1873	1873	1873	1873
HOV	0	0	0	0	1873	1873
art	500	500	500	500	500	500
# peak veh. - gen	3558	3452	5337	5598	3692	3610
HOV	0	0	0	0	538	646
art	493	473	0	485	479	490
# shoulder veh. - gen	7068	7316	6522	6842	5297	6380
HOV	0	0	0	0	658	789
art	739	984	0	593	586	807
peak speeds - gen	28.9	26.1	50.3	43.2	34.1	30.5
HOV	.0	.0	.0	.0	54.1	50.5
art	14.8	12.3	25.0	21.0	21.6	14.2
shoulder speeds - gen	50.5	32.4	55.8	55.7	55.4	53.4
HOV	.0	.0	.0	.0	57.3	57.2
art	23.8	14.6	25.0	24.0	24.1	23.6
length	5.6	5.6	5.6	5.6	5.6	5.6
# gen.purp.lanes	2.0	2.0	3.0	3.0	2.0	2.0
# HOV lanes	0	0	0	0	1	1
# arterial lanes	1	1	1	1	1	1
access time	11.5	11.5	11.5	11.5	11.5	11.5
carpool formation	.7	.7	.7	.7	.7	.7
vanpool formation	2.0	2.0	2.0	2.0	2.0	2.0
bus access	10.3	9.8	10.3	9.8	10.3	9.8
min. freeway speed	25	25	25	25	25	25
min. arterial speed	12	12	12	12	12	12
Travel time (minutes)						
Peak SOV	24.49	26.12	18.17	19.95	22.02	24.01
carpool	25.19	26.82	18.87	20.65	18.42	18.85
vanpool	26.49	28.12	20.17	21.95	19.72	20.15
bus	34.79	35.92	28.47	29.75	28.02	27.95
Shoulder SOV	18.86	23.37	17.52	18.16	18.36	18.68
carpool	19.56	24.07	18.22	18.86	18.06	18.07
vanpool	20.86	25.37	19.52	20.16	19.36	19.37
bus	29.16	33.17	27.82	27.96	27.66	27.17
Average SOV	20.78	24.26	17.81	18.97	19.88	20.62
carpool	21.48	24.96	18.51	19.67	18.22	18.42
vanpool	22.78	26.26	19.81	20.97	19.52	19.72
bus	31.08	34.06	28.11	28.77	27.82	27.52

Table 2

Cost Model Outcomes for I-405 Alternative

HOV Cost Model (cont.)
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I-405 south of I-90

	Do Nothing 1985	Do Nothing 2000	Add Mixed Lane 1985	Add Mixed Lane 2000	Add HOV Lane 1985	Add HOV Lane 2000
Displacements						
peak freeway	1224	1909	0	0	353	886
peak arterial	61	249	0	0	0	94
shoulder freeway	0	1146	0	0	0	0
shoulder arterial	0	147	0	0	0	0
Summary Statistics						
% on arterials	.104	.119	.000	.080	.106	.115
average trip time	25.61	32.81	18.62	19.76	20.33	22.42
Total Trip Length						
average	10.0	12.0	10.0	12.0	10.0	12.0
SOV	9.9	11.9	9.9	11.9	9.8	11.8
2-pers. carpool	12.0	14.0	12.0	14.0	12.0	14.0
3-pers. carpool	13.0	14.0	13.0	14.0	13.0	14.0
vanpools	20.0	22.0	20.0	22.0	20.0	22.0
buses	12.0	12.0	12.0	12.0	12.0	12.0
Total Vehicle Miles (1000's)						
cars	118.34	161.91	118.34	161.91	112.24	152.36
vanpools	.22	.29	.22	.29	.34	.46
buses	.25	.30	.25	.30	.25	.30
Maximum Speeds						
freeway	58.0	58.0	58.0	58.0	58.0	58.0
HOV	58.0	58.0	58.0	58.0	58.0	58.0
arterial	25.0	25.0	25.0	25.0	25.0	25.0
HOV differential	.0	.0	.0	.0	20.0	20.0
TOTAL COSTS	113.08	144.22	103.49	126.14	101.62	124.92

COST PARAMETERS

Parking costs ($'s/day)		Annual costs ($1,000's)		Miscellaneous	
SOV	3.71	Maint. cost	45	Value of time ($)	7.00
carpool	3.00	Extra HOV maint.	10	Discount rate (%)	4.0
vanpool	.00	Enforcement	115	Lane construction	10067
Operating costs				Extra HOV cost	1007
car ($/mi.)	.23			Oper. cost elas.	.50
van ($/mi.)	.42			Bus fare	.80
bus ($/mi.)	1.31			Peak Factor	3.50
bus ($/hr.)	24.83				
bus ($/trip)	82.17				

Net Savings ($1,000,000's)	total	time	personal	agency	marg b/c
HOV - Do Nothing	180.1	180.0	12.9	-12.8	15.12
HOV - Add Gen'l Lane	14.8	-48.7	66.1	-2.6	6.69

Table 2 (continued)

Cost Model Outcomes for I-405 Alternative

HOV Cost Model
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SR520 east of Evergreen Point Bridge

	Do Nothing 1985	Do Nothing 2000	Add Mixed Lane 1985	Add Mixed Lane 2000	Add HOV Lane 1985	Add HOV Lane 2000
Person-trips	17200	21300	17200	21300	17200	21300
SOV's	10448	14950	10448	14950	9381	13763
2-pers. carpools	900	1115	900	1115	900	1115
3-pers.carpools	293	362	293	362	405	579
Vanpools	7	9	7	9	10	14
Buses	87	63	87	63	102	72
Carpool definition	1	1	1	1	3	3
% preferring peak	.45	.45	.45	.45	.45	.45
capacity - gen	1873	1873	1873	1873	1873	1873
HOV	0	0	0	0	900	900
art	500	500	500	500	500	500
# peak veh. - gen	3646	3405	4298	3980	3676	3468
HOV	0	0	0	0	232	299
art	982	940	983	962	951	949
# shoulder veh. - gen	5907	7118	5253	8438	4493	7354
HOV	0	0	0	0	284	366
art	1201	1928	1202	1964	1162	1975
peak speeds - gen	31.9	25.0	42.5	26.3	46.9	26.5
HOV	.0	.0	.0	.0	44.2	41.5
art	20.1	12.0	20.1	13.1	21.7	12.4
shoulder speeds - gen	55.0	28.9	55.7	32.9	55.8	33.3
HOV	.0	.0	.0	.0	44.5	44.4
art	24.0	13.2	24.0	20.1	24.1	14.9
length	2.7	2.7	2.7	2.7	2.7	2.7
# gen.purp.lanes	2.0	2.0	2.3	2.3	2.0	2.0
# HOV lanes	0	0	0	0	1	1
# arterial lanes	2	2	2	2	2	2
access time	11.5	11.5	11.5	11.5	11.5	11.5
carpool formation	.7	.7	.7	.7	.7	.7
vanpool formation	2.0	2.0	2.0	2.0	2.0	2.0
bus access	10.3	9.8	10.3	9.8	10.3	9.8
min. freeway speed	25	25	25	25	25	25
min. arterial speed	12	12	12	12	12	12
Travel time (minutes)						
Peak SOV	17.21	19.50	16.10	18.87	15.78	19.11
carpool	17.91	20.20	16.80	19.57	15.86	16.11
vanpool	19.21	21.50	18.10	20.87	17.16	17.41
bus	27.51	29.30	26.40	28.67	25.46	25.21
Shoulder SOV	15.08	18.53	15.12	17.01	15.19	17.64
carpool	15.78	19.23	15.82	17.71	15.84	15.85
vanpool	17.08	20.53	17.12	19.01	17.14	17.15
bus	25.38	28.33	25.42	26.81	25.44	24.95
Average SOV	15.92	18.85	15.56	17.61	15.46	16.74
carpool	16.62	19.55	16.26	18.31	15.85	15.96
vanpool	17.92	20.85	17.56	19.61	17.15	17.26
bus	26.22	28.65	25.86	27.41	25.45	25.06

Table 3

Cost Model Outcomes for SR520 Alternative

HOV Cost Model (cont.)
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SR520 east of Evergreen Point Bridge

	Do Nothing 1985	Do Nothing 2000	Add Mixed Lane 1985	Add Mixed Lane 2000	Add HOV Lane 1985	Add HOV Lane 2000
Displacements						
peak freeway	653	2424	0	2127	0	1805
peak arterial	0	655	0	355	0	473
shoulder freeway	0	2432	0	1154	0	896
shoulder arterial	0	677	0	0	0	236
Summary Statistics						
% on arterials	.186	.215	.186	.177	.205	.212
average trip time	19.14	32.84	18.03	25.25	18.20	23.53
Total Trip Length						
average	10.0	12.0	10.0	12.0	10.0	12.0
SOV	9.7	11.8	9.7	11.8	9.7	11.8
2-pers. carpool	12.0	14.0	12.0	14.0	12.0	14.0
3-pers. carpool	13.0	14.0	13.0	14.0	13.0	14.0
vanpools	20.0	22.0	20.0	22.0	20.0	22.0
buses	12.0	12.0	12.0	12.0	12.0	12.0
Total Vehicle Miles (1000's)						
cars	116.31	197.24	116.31	197.24	106.75	185.65
vanpools	.14	.20	.14	.20	.19	.32
buses	1.04	.76	1.04	.76	1.22	.87
Maximum Speeds						
freeway	58.0	58.0	58.0	58.0	58.0	58.0
HOV	45.0	45.0	45.0	45.0	45.0	45.0
arterial	25.0	25.0	25.0	25.0	25.0	25.0
HOV differential	.0	.0	.0	.0	15.0	15.0
TOTAL COSTS	117.47	190.58	115.47	172.97	111.76	163.26

COST PARAMETERS

Parking costs ($'s/day)		Annual costs ($1,000's)		Miscellaneous	
SOV	3.71	Maint. cost	25	Value of time ($)	7.00
carpool	3.00	Extra HOV maint.	5	Discount rate (%)	4.0
vanpool	.00	Enforcement	60	Lane construction	2385
Operating costs				Extra HOV cost	239
car ($/mi.)	.23			Oper. cost elas.	.50
van ($/mi.)	.42			Bus fare	.80
bus ($/mi.)	1.31			Peak Factor	1.28
bus ($/hr.)	24.83				
bus ($/trip)	82.17				

Net Savings ($1,000,000's)	total	time	personal	agency	marg b/c
HOV - Do Nothing	78.7	65.0	20.9	-7.2	11.99
HOV - Add Gen'l Lane	31.0	10.9	24.7	-4.5	7.83

Table 3 (continued)

Cost Model Outcomes for SR520 Alternative lane" alternative. If the HOV lane on I-405 were available to general traffic, the capacity of the facility would be 50% greater than the "do nothing" alternative. According to this analysis, that section of highway would be running fairly smoothly in the year 2000. The caveat in this result, however, is that the demand assumed in the year 2000 was based on a lower capacity facility. It is probable that higher demand would not allow the highway to operate as fast as this analysis shows.

Even if general traffic were able to operate as fast as the analysis showed, there would be little incentive for people to shift to higher occupancy vehicles. That result was reflected in the overall net savings shown for the "add an HOV lane" alternative over the "add a general lane" alternative. The personal savings from ride sharing outweighed the (questionable) advantage that the general traffic lane had over the HOV lane in travel speeds.

SECTION 4

OUTCOME OF THE SENSITIVITY ANALYSIS

The sensitivity analysis was performed on the I-5 case in order to determine which assumptions were most critical in affecting the outcome of the study. Tables 4 and 5 show the outcome of that analysis. Each table lists all the assumptions that go into the cost analysis and which extreme value is associated with the worst outcome for the "add an HOV lane" alternative. Also shown are the net present values and marginal benefit to cost ratios for the worst case. They are listed in order of the average impact they have on the percentage shift in the two cost effectiveness indicators. It can readily be seen that for the majority of the assumptions the extreme ends of the ranges have negligible effects on the outcomes.

A further test was conducting by adding on extreme values for each assumption consecutively. Tables 6 and 7 show the results as each extreme value is added. It can be seen that it took 38 assumptions for the comparison with the "add a general lane" case to be reversed and 26 assumptions to reverse the outcome of the comparison with the "do nothing" alternative.

The consecutive addition of worst case assumptions did not always make the outcomes worse. This was due to the fact that there is great deal of interaction among the assumptions. For instance, assuming a higher freeway capacity and higher maximum speeds on the freeway, each taken separately, reduces the relative cost effectiveness of HOV lanes because it means less congestion. HOV lanes do not look as good when there is less congestion. If, however, the model uses a higher assumption for freeway lane capacity, and a higher maximum speed assumption is employed, the HOV lanes may actually look better, in a situation in which the differential speed between the HOV lane and the general traffic lane is a constraint.

Table 4
Sensitivity Analysis for Comparison with "Add a General Lane"

Assumption	Worst case	Net pres. value	Benefit cost rat.	Crit.
freeway capacity	10% more	40.1	5.07	43.4
discount rate	10% per year	34.5	6.96	39.5
min. arterial speed	3 mph less	44.3	6.05	28.9
min. freeway speed	5 mph more	47.2	6.05	25.3
carpool formation time	3 min. more	46.5	6.14	25.2
1985 person-trips	10% fewer	48.4	6.07	23.8
growth in 3+ carpools	50% less	47.1	6.41	22.0
arterial capacity	15% more	50.2	6.10	21.7
% preferring peak	0.38	52.6	6.19	18.7
freeway max. speed	5 mph more	49.5	6.47	18.4
SOV parking cost	20% less	49.2	6.67	16.9
arterial max. speed	3 mph more	50.4	6.72	14.9
value of time	$3 per hour	50.2	6.78	14.6
HOV lane max. speed	5 mph less	50.6	6.76	14.3
length	10% less	52.4	6.84	11.3
peak factor	10% less	50.5	7.27	10.9
extra HOV construction	20% of lane cost	55.5	6.78	9.7
2000 person-trips	25% less growth	53.6	6.89	9.5
overall access time	15% more	53.2	6.93	9.5
bus trip cost	10% more	55.6	6.85	8.8
auto operating cost	10% less	53.7	7.20	6.2
2000 3+ carpools	40% less growth	54.1	7.23	5.4
bus access time	3 min. more	53.8	7.30	5.3
HOV differential speed	5 mph less	54.4	7.22	5.1
average trip length	10% less	54.2	7.25	5.1
oper. cost elasticity	0.25	54.2	7.25	5.1
HOV lane enforcement	25% more	56.0	7.21	3.9
bus fare	10% less	56.4	7.24	3.5
2000 buses	10% fewer	54.5	7.56	3.5
1985 3+ carpools	15% fewer	55.2	7.36	2.8
2000 2 pers. carpools	40% less growth	55.3	7.38	2.5
growth in vanpools	50% less	55.4	7.39	2.3
HOV parking cost	20% more	55.6	7.41	1.9
bus mileage cost	10% more	56.2	7.37	1.8
bus trip length	10% more	56.3	7.37	1.7
1985 2 pers. carpools	15% fewer	55.6	7.46	1.5
2000 vanpools	40% less growth	55.9	7.45	1.1
growth in buses	50% less	56.1	7.44	1.0
extra HOV lane maint.	50% more	56.3	7.44	0.8
1985 vanpools	15% fewer	56.1	7.46	0.8
vanpool formation time	3 min. more	56.1	7.46	0.8
HOV lane capacity	10% less	56.3	7.49	0.2
vanpool trip length	10% more	56.3	7.49	0.2
van operating cost	10% more	56.3	7.49	0.2
2 p. pool trip length	10% more	56.4	7.50	0.0
bus hourly cost	10% more	56.4	7.50	0.0
lane construction cost	10% more	56.4	7.50	0.0
3+ carpool trip length	10% more	56.4	7.50	0.0
lane maintenance cost	2.5 times nominal	56.4	7.50	0.0

Table 5
Sensitivity Analysis for Comparison with "Do Nothing"

Assumption	[illegible]	Net pres. value	Benefit cost rat.	[illegible]
value of time	$3 per hour	76.5	5.23	63.8
discount rate	10% per year	80.3	6.31	54.4
% preferring peak	0.38	94.0	5.79	50.8
arterial capacity	15% more	117.5	7.11	29.2
freeway capacity	10% more	119.6	7.22	27.4
2000 person-trips	25% less growth	126.0	7.82	19.5
min. freeway speed	5 mph more	133.8	8.15	13.3
1985 person-trips	10% fewer	134.8	8.11	13.2
peak factor	10% less	130.2	8.44	13.0
carpool formation time	3 min. more	136.2	8.38	10.3
length	10% less	136.6	8.42	9.8
growth in 3+ carpools	50% less	136.6	8.56	8.7
arterial max. speed	3 mph more	137.7	8.56	8.1
min. arterial speed	3 mph more	139.0	8.62	7.0
SOV parking cost	20% less	138.9	8.69	6.5
freeway max. speed	5 mph more	141.1	8.65	5.8
HOV lane max. speed	5 mph less	140.3	8.72	5.6
lane maintenance cost	2.5 times nominal	145.1	8.62	5.1
extra HOV construction	20% of lane cost	145.2	8.64	4.9
lane construction cost	10% more	145.2	8.64	4.9
bus trip cost	10% less	145.3	8.69	4.3
overall access time	15% more	142.8	8.78	4.0
oper. cost elasticity	0.75	142.4	8.88	3.4
2000 3+ carpools	40% less growth	143.8	8.95	2.1
HOV differential speed	5 mph less	144.0	8.95	2.0
average trip length	10% less	143.9	8.96	2.0
bus access time	3 min. more	143.5	9.00	2.0
HOV lane enforcement	25% more	145.7	8.91	1.9
2000 buses	10% fewer	143.6	9.11	1.7
bus fare	10% less	146.1	8.93	1.7
auto operating cost	10% less	144.6	9.00	1.4
2000 2 pers. carpools	40% less growth	144.6	9.01	1.3
1985 3+ carpools	15% fewer	144.8	9.01	1.2
growth in vanpools	50% less	145.2	9.03	0.8
bus mileage cost	10% more	145.9	9.01	0.8
bus trip length	10% more	146.0	9.01	0.8
HOV parking cost	20% more	145.3	9.04	0.7
1985 2 pers. carpools	15% fewer	145.2	9.06	0.7
growth in buses	50% less	145.6	9.03	0.6
2000 vanpools	40% less growth	145.6	9.06	0.4
1985 vanpools	15% fewer	145.7	9.06	0.4
extra HOV lane maint.	50% more	146.0	9.05	0.3
vanpool formation time	3 min. more	145.7	9.07	0.3
bus hourly cost	10% more	146.0	9.06	0.2
van operating cost	10% more	146.0	9.08	0.1
vanpool trip length	10% more	146.0	9.08	0.1
HOV lane capacity	10% less	146.0	9.08	0.1
2 p. pool trip length	10% more	146.1	9.08	0.0
3+ carpool trip length	10% more	146.1	9.08	0.0

Table 6
Consecutive Addition of Extreme Assumptions in Comparison with "Add a General Lane" Alternative

Assumption	Worst case	Net pres. value	Benefit cost rat.
freeway capacity	10% more	40.1	5.07
discount rate	10% per year	23.9	4.62
min. arterial speed	3 mph less	20.9	4.16
min. freeway speed	5 mph more	23.9	4.81
carpool formation time	3 min. more	19.5	4.02
1985 person-trips	10% fewer	13.9	2.98
growth in 3+ carpools	50% less	16.2	3.30
arterial capacity	15% more	27.6	4.92
% preferring peak	0.38	21.2	3.95
freeway max. speed	5 mph more	17.3	3.39
SOV parking cost	20% less	13.9	2.92
arterial max. speed	3 mph more	13.1	2.80
value of time	$3 per hour	13.4	2.83
HOV lane max. speed	5 mph less	11.5	2.55
length	10% less	11.5	2.55
peak factor	10% less	10.2	2.48
extra HOV construction	20% of lane cost	9.2	2.19
2000 person-trips	25% less growth	8.9	2.14
overall access time	15% more	8.8	2.13
bus trip cost	10% more	8.3	1.98
auto operating cost	10% less	7.3	1.86
2000 3+ carpools	40% less growth	6.1	1.73
bus access time	3 min. more	6.0	1.70
HOV differential speed	5 mph less	5.9	1.68
average trip length	10% less	5.1	1.58
oper. cost elasticity	0.25	5.2	1.60
HOV lane enforcement	25% more	5.0	1.56
bus fare	10% less	5.0	1.55
2000 buses	10% fewer	4.8	1.53
1985 3+ carpools	15% fewer	4.7	1.52
2000 2 pers. carpools	40% less growth	3.6	1.40
growth in vanpools	50% less	3.0	1.33
HOV parking cost	20% more	2.9	1.32
bus mileage cost	10% more	2.8	1.30
bus trip length	10% more	2.6	1.28
1985 2 pers. carpools	15% fewer	2.6	1.28
2000 vanpools	40% less growth	2.6	1.28
growth in buses	50% less	-0.6	0.90

Table 7
Consecutive Addition of Extreme Assumptions in
Comparison with "Do Nothing" Alternative

Assumption	Worst case	Net pres. value	Benefit cost rat.
value of time	$3 per hour	76.5	5.23
discount rate	10% per year	40.3	3.66
% preferring peak	0.38	24.8	2.53
arterial capacity	15% more	19.0	2.12
freeway capacity	10% more	17.4	2.03
2000 person-trips	25% less growth	16.5	1.96
min. freeway speed	5 mph more	16.5	1.96
1985 person-trips	10% fewer	15.5	1.90
peak factor	10% less	12.8	1.77
carpool formation time	3 min. more	11.7	1.70
length	10% less	10.5	1.62
growth in 3+ carpools	50% less	10.3	1.62
arterial max. speed	3 mph more	8.5	1.50
min. arterial speed	3 mph more	8.5	1.50
SOV parking cost	20% less	6.1	1.36
freeway max. speed	5 mph more	5.3	1.31
HOV lane max. speed	5 mph less	3.7	1.22
lane maintenance cost	2.5 times nominal	3.1	1.18
extra HOV construction	20% of lane cost	2.2	1.12
lane construction cost	10% more	1.3	1.07
bus trip cost	10% less	0.6	1.03
overall access time	15% more	0.6	1.03
oper. cost elasticity	0.75	0.5	1.03
2000 3+ carpools	40% less growth	0.6	1.03
HOV differential speed	5 mph less	0.6	1.03
average trip length	10% less	-0.3	0.99

SECTION 5

DOCUMENTATION OF THE COMPUTER PROGRAMS

Two computer programs were developed for this project. One is simply representing the worksheets from the Parody model in an easy-to-use software package and the other is the cost model itself. The FORTRAN code and a map of the variables and functions employed in them may be found in the appendix.

PARODY MODEL

The Parody model is described in detail in the FHWA document listed in the bibliography (Parody, 1982). That description will not be repeated here. The computer program simply mimics the seven worksheets in the model. Since it is automated, the advantage in using the computer program is that the importance of various factors going into the sketch planning process can easily be tested in a sensitivity analysis.

The use of the program is mostly self-explanatory. It will run on virtually any microcomputer compatible with the IBM PC. A color graphics card is required. Basic instructions to use the program are as follows:

1) Upon entering the program using the command "PARODY," a screen describing optional data sets will appear. Choose the data set you wish to work on or modify the list using the instructions at the bottom of the screen.

2) Change the input data on the first two worksheets by moving the cursor with the arrow keys and typing in the appropriate values followed by <return>. New input data will automatically be stored in the data set.

3) The second and third worksheets contain some choices that can be made using the indicated function keys.

4) Move to the next appropriate worksheet by using the <esc> key.

5) You may move to a previous worksheet (but not a later one) by pressing the <ctrl> key and the function key corresponding to the worksheet you want.

6) After viewing the final worksheet containing the outcomes, pressing the <exc> will bring you back to the screen to select a data set.

7) Leave the program by pressing <esc> when the data set selection screen is showing.

COST ANALYSIS MODEL

A computer program was prepared to conveniently do all of the computations in the cost model and to allow for easily changing the parameters in the model. It will run on any microcomputer compatible with the IBM PC with a color graphics card. It was designed to allow the user to easily perform a sensitivity analysis on parameters assumed for the cost model and to compute the cost effectiveness indicators for any set of parameters.

Instructions for use of the model

1) Start the program by entering "HOVCOST." The first step is to choose a case for analysis. If there is none, you must define at least one.

2) There are four pages of information, some supplied by the user and some computed by the program. You can look at each of the four pages by pressing the function keys F3, F4, F5 and F6 for pages one through four, respectively.

3) The first three pages and part of the fourth contain data concerning the years 1985 and 2000 for each of the three alternatives. The fourth page contains cost parameters applying to all alternatives and the outcome measures of the relative benefits of HOV lanes compared with the other two alternatives.

4) On all pages, the bright numbers are supplied by the user. The flashing green indicates the current data point. It can be changed by typing in a new value and hitting the return key. For some data points, if you change the data, more than one data point will change at a time. For instance, if you change the number of arterial lanes, all the

numbers will change for the two years and three alternatives. If you change the number of person trips for the year 1985 in the "do nothing" alternative, it will change for the year 1985 for all three alternatives.

5) The program operates in two modes, one where values are automatically recalculated and a data entry mode in which no calculation takes place. Change the mode by pressing F1. If "CALC" appears in the upper right hand corner, you are in the data entry mode. However, even in this mode, you can recalculate everything by hitting F2. If the program is in the automatic recalculation mode, all necessary recalculations will be performed each time you change a value. At the end of recalculation in any mode, the fourth screen (containing the outcomes) will appear for about five seconds.

6) The program will automatically calculate HOV volumes using the method developed by Charles Rivers Associates if you press F9. You can also try different HOV volumes by changing them directly.

7) The program will also automatically calculate elasticities for the assumptions currently indicated by the cursor by pressing F8. The elasticities indicate the percentage change that will occur in four outcome measures when the currently indicated assumption changes by one percent. After the program computes the elasticities, the fourth page will appear with the elasticities in the appropriate place. Hit any key to leave the display. At the end of the display of elasticities, the screens will show the original values.

8) You can get a printout of the contents of the screens by pressing F10. The program will assume a page length of 66 lines unless there is a file called "PLINES" on the current directory containing the number of printer lines in the first line.

9) If the program does not turn the cursor off properly or does not leave you with the right cursor when you leave the program, you can change cursor definitions by using a program called "CURSOR."

10) You can leave the program anytime by pressing the escape key.

11) Summary of the function keys -

F1 --- Changes the calculation mode

F2 --- Recalculates when in the data entry mode

F3 --- Page 1 - Person trips, total vehicle numbers, carpool definition, capacities, vehicle distributions, speeds

F4 --- Page 2 - Length, number of lanes, off-facility access times, minimum speeds, travel times

F5 --- Page 3 - Displacements, percentage on arterials, average trip time, total trip lengths, total vehicle miles

F6 --- Page 4 - Maximum speeds, total costs, parking costs, vehicle operating costs, annual costs, miscellaneous cost parameters, outcomes

F7 --- Not used

F8 --- Automatic elasticity calculation

F9 --- Automatic calculation of HOV volumes

F10 -- Print out screens

Glossary of terms

The listing of the FORTRAN codes for the computer program may be found in the appendix. The following glossary of terms (var = variable, arr = variable array, sub = subroutine and fnc = function) used in the program will help to understand the code:

a - (var) temporary character variable read in from keyboard

access - (arr) total average access time

addstg - (sub) adds character variables together

agycst - (arr) total agency costs

ainc - (var) yearly incremental change in agency costs used in computing life cycle costs

ann - (var) total annual costs

atim - (arr) total life cycle agency costs

avspa - (arr) average speeds on arterials

avspg - (arr) average speeds on general traffic lanes

avsph - (arr) average speeds on HOV lanes

b0peb - (var) initial number of priority eligible buses in the peak hour

b1hov - (var) buses in the HOV lanes during the peak hour

bap - (var) total travel time for each vehicle on arterials during the peak hour

bas - (var) total travel time for each vehicle on arterials during the shoulder hours

bc1 - (var) marginal benefit cost ratio between HOV lane and do nothing alternatives

bc1s - (var) temporarily saving bc1 for computation of elasticity

bc2 - (var) marginal benefit cost ratio between HOV lane and general lane alternatives

bc2s - (var) temporarily saving bc2 for computation of elasticity

bfare - (var) average bus fare

bgp - (var) total travel time for each vehicle on general traffic lanes during the peak hour

bgs - (var) total travel time for each vehicle on general traffic lanes during the shoulder hours

bhp - (var) total travel time for each vehicle on HOV lanes during the peak hour

bhs - (var) total travel time for each vehicle on HOV lanes during the shoulder hours

blnk - (sub) blanks out a portion of the screen

btrip - (arr) bus trip time during the peak

btrips - (arr) bus trip time on shoulders of the peak

btript - (arr) total average bus trip time

bus - (arr) number of buses during the peak period

cap - (var) lane capacity

capa - (arr) arterial lane capacity

capg - (arr) general traffic lane capacity

caph - (arr) HOV lane capacity

chattp - (sub) changes the attribute of characters on the screen

chfile - (sub) chooses the data file

chpage - (sub) changes the page appearing on the screen

cinc - (var) yearly incremental change in total costs used in computing life cycle costs

clean - (fnc) tests a character variable to determine if it can be converted to a legal real variable

coeff - (var) regression coefficient used to forecast HOV volumes from Parody model

constg - (var) cost of constructing an extra lane

consth - (var) extra cost to construct an HOV lane

cost - (sub) computes the costs for one peak hour

cpdefn - (arr) carpool definition (1 = no HOV lanes, 2 = 2+ carpools are eligible, 3 = 3+ carpools are eligible)

crs - (sub) changes the value of the cursor

cstcal - (sub) calculates the life time costs and the outcome measures

cstset - (sub) sets the cost parameters

ctim - (arr) total life cycle costs

ctrip - (arr) carpool trip time during the peak

ctrips - (arr) carpool trip time during the shoulders of the peak

ctript - (arr) total average carpool trip time

curm - (sub) moves the cursor

dec - (arr) number of digits after the decimal point to display (-1 indicates no decimal point)

dela - (var) amount of delay caused by displacement from peak on arterial lanes

delas - (var) amount of delay caused by displacement from shoulder on arterial lanes

delb - (var) change in the number of buses when an HOV lane is introduced

delg - (var) amount of delay caused by displacement from peak on freeway lanes

delgs - (var) amount of delay caused by displacement from shoulder on freeway lanes

delpa - (var) change in the number of carpools and vanpools when an HOV lane is introduced disc - (var) discount rate

disp - (var) number of displaced vehicles

dispa - (arr) number of vehicles displaced from arterials during the peak hours

dispas - (arr) number of vehicles displaced from arterials during the shoulder hours

dispg - (arr) number of vehicles displaced from the freeway during the peak hours

dispgs - (arr) number of vehicles displaced from the freeway during the shoulder hours

div - (var) divisor which varies according to carpool definition

ds - (arr) discount factor computed for each year

elas - (var) operating cost elasticity

enf - (var) HOV lane enforcement cost

faca - (var) - factor for adjusting vehicle operating costs on arterials computed from operating cost elasticity

facg - (var) - factor for adjusting vehicle operating costs on general traffic lanes computed from operating cost elasticity

fach - (var) - factor for adjusting vehicle operating costs on HOV lanes computed from operating cost elasticity

fcont - (var) title of current scenario

file - (var) file name for current scenario

filn - (arr) data file titles

filnum - (arr) code numbers added to "HOVIN" to define the name of data files

float - (fnc) - changes an integer variable to a floating point variable

fmt - (arr) character format for display each of the five types (see "type") of data

gdate - (sub) returns the current date

get - (sub) receives a keystroke

geta - (sub) gets a character string, cursor movement information or a function key from the keyboard

getam - (sub) reads a string, a movement or a function getd - (sub) gets a character, cursor movement information or a function key from the keyboard

gtime - (sub) returns the current time

hovcom - (sub) computes HOV volumes with implementation of HOV lanes

hovl - (var) length of HOV lanes

hovmnt - (var) extra cost to maintain HOV lanes

i - (var) subscript with a variety of uses

i1 - (var) temporary key indicator

i2 - (var) temporary key indicator

ia - (var) index used to point to cost parameter variables

icalc - (var) switch to determine data entry mode, 0 = automatic calculation, 1 = data entry mode

ichela - (var) switch to indicate whether or not elasticities are being calculated, 0 = not calculating elasticities, 1 = calculating elasticities

ichng - (arr) indicator showing which scenarios must be recomputed because some data has been altered

im - (var) movement information from the keyboard, same as "move"

int - (fnc) returns the integer part of a real variable

ioclos - (fnc) closes a file

ioff1 - (var) first parameter to define cursor as "off"

ioff2 - (var) second parameter to define cursor as "off"

ion1 - (var) first parameter to define cursor as "on"

ion2 - (var) second parameter to define cursor as "on"

ioread - (fnc) opens a file for reading

iowrit - (fnc) opens a file for writing

ip - (var) indicates current page on the screen(0 to 3)

ipt - (var) index used to indicate page on the screen

ist - (var) beginning scenario when cycling through a list of scenarios ix - (var) indicates scenario (1 to 6)

iy - (var) indicates the variable number (1 to 65)

j - (var) subscript with a variety of uses

klen - (fnc) returns the length of a character variable

label - (arr) labels for variables other than cost parameters

lanes - (sub) assigns traffic to appropriate lanes

len - (arr) length of the study section

length - (sub) computes the trip lengths

lim - (var) number of options for which to compute total time in the optimization of assignment to freeway and arterials (1 or 3)

locp - (arr) page location for each variable

locx - (arr) column location for each scenario

locy - (arr) row location for each variable

maint - (var) maintenance cost for extra lane

mod - (fnc) performs modulus arithmetic

move - (var) indicates which type of movement instruction has been keyed (1 to 4 indicates arrows, 5 = home, 6 = end, and 7 = esc)

nart - (fnc) converts an integer to a character variable

narts - (arr) number of arterial lanes

nfil - (var) number of data files

nfunc - (var) indicates which function key has been pressed (1 to 10 = F1 to F10, 11 to 20 = alt-F1 to alt-F10 and 21 to 30 = ctrl-F1 to ctrl-F10)

ngpl - (arr) number of general traffic lanes on freeway

nhov - (arr) number of HOV lanes on the freeway

npar - (var) number of variables exclusive of cost parameter variables

ocbush - (var) hourly factor for bus operating costs

ocbusm - (var) mileage factor for bus operating costs ocbust - (var) trip factor for bus operating costs

occar - (var) auto operating cost per mile

ocvan - (var) van operating cost per mile

pcap - (arr) proportion of traffic traveling on the arterials

pcapt - (var) initial proportion of traffic assigned to arterial lanes

pcpol - (var) carpool parking cost

pcsov - (var) SOV parking cost

pcvan - (var) van parking cost

percst - (arr) total personal cost (auto operating, parking, etc.)

pinc - (var) increment used for proportion of traffic assigned to arterial lanes in the optimization of assignment

pinc - (var) yearly incremental change in personal costs used in computing life cycle costs

pkfact - (var) peak weighting factor used to indicate the equivalent number of peak hours and directions to weight the results for one peak hour in one direction

pool2 - (arr) number of two person carpools during the peak period

pool3 - (arr) number of three person and higher carpools during the peak period

poolv - (arr) number of vanpools in the peak period

pout - (sub) prints out the content of the screens

prefpk - (arr) proportion preferring to travel in the peak period

printp - (sub) prints a string on the screen

pspa - (arr) peak speeds on arterials

pspg - (arr) peak speeds on general traffic lanes

psph - (arr) peak speeds on HOV lanes

ptim - (arr) total life cycle personal costs

ptrips - (arr) total person trips during the peak period

rat - (var) ratio of speed to maximum speed definition

rcapa - (var) arterial lane capacity taking excess demand into account rcapg - (var) general traffic lane capacity taking excess demand into account

s0gp - (var) average speed in the general traffic lane in the "do nothing" alternative

snart - (fnc) converts a real variable to a character variable

sov - (arr) number of SOV's during the peak period

sovcal - (sub) calculates the number of SOV's

spdiff - (var) maximum speed difference between HOV lane and adjacent general traffic lane

speed - (fnc) computes speed using volume, capacity and maximum speed information

speeds - (sub) computes speeds

spmina - (arr) minimum speed on arterials

spminf - (arr) minimum speed on the freeway

sqrt - (fnc) square root

sspa - (arr) shoulder speeds on arterials

sspg - (arr) shoulder speeds on general traffic lanes

ssph - (arr) shoulder speeds on HOV lanes

strip - (arr) SOV trip time during the peak

strips - (arr) SOV trip time on shoulders of the peak

stript - (arr) total average SOV trip time

t0b - (var) travel time for buses in the "do nothing" alternative

t0pa - (var) travel time for carpools in the "do nothing" alternative

t1b - (var) travel time for buses after the introduction of HOV lanes

t1pa - (var) travel time for carpools after the introduction of HOV lanes

take - (sub) causes a delay in processing

tbar - (arr) total average trip time for all person trips

tbus - (arr) bus access time

tc1 - (var) net savings for HOV lane alternative over do nothing alternative

tc1s - (var) temporarily saving tc1 for computation of elasticity tc2 - (var) net savings for HOV lane alternative over add a general lane alternative

tc2s - (var) temporarily saving tc2 for computation of elasticity

tcapa - (var) arterial lane capacity at minimum arterial speed allowed

tcapg - (var) general traffic lane capacity at minimum freeway speed allowed

tcost - (arr) total cost for one peak hour

timcst - (arr) total cost for travel time

time - (var) travel time on the freeway in the "do nothing" alternative

times - (sub) computes travel times

tinc - (var) yearly incremental change in time costs used in computing life cycle costs

tlave - (arr) average trip length

tlbus - (arr) average bus trip length

tlpl2 - (arr) average 2 person carpool trip length

tlpl3 - (arr) average 3+ person carpool trip length

tlsov - (arr) average SOV trip length

tlvan - (arr) average vanpool trip length

tmbus - (arr) total vehicle miles for buses

tmcar - (arr) total vehicle miles for autos

tmvan - (arr) total vehicle miles for vans

toffb - (var) travel time for buses off the HOV lanes

toffpa - (var) travel time for carpools off the HOV lanes

tpool - (arr) carpool formation and access time

tpool2 - (var) number of two person carpools after the introduction of HOV lanes

tpool3 - (var) number of three or more person carpools after the introduction of HOV lanes

tran - (fnc) converts a character variable into a real variable

ttime - (arr) total travel time, including penalty for displacements

tval - (var) value of time

tvan - (arr) total vehicle miles for vans

type - (arr) indicates type of variable or which other scenarios should be changed at the same time (0 = computed variable, 1 = nothing else should change, 2 = change all data for the same year, 3 = change data for both years in the same alternative, 4 = change all scenarios at once)

v - (arr) total number of vehicles

va - (var) total number of vehicles on arterials

van0 - (var) number of vans for the "do nothing alternative"

van1 - (var) number of vans after the introduction of HOv lanes

vap - (arr) total number of vehicles on arterials during the peak hour

vas - (arr) total number of vehicles on arterials during the shoulder hours

vc - (var) volume capacity ratio

vclear - (sub) clears screen

vcurxy - (sub) moves the cursor on the screen

vg - (var) total number of vehicles on general traffic lanes

vgp - (arr) total number of vehicles on general traffic lanes during the peak hour

vgs - (arr) total number of vehicles on general traffic lanes during the shoulder hours

vh - (arr) total number of vehicles on HOV lanes

vhp - (arr) total number of vehicles on HOV lanes during the peak hour

vhs - (arr) total number of vehicles on HOv lanes during the shoulder hours

vmax - (var) maximum speed definition

vmaxa - (var) maximum speed on arterial lanes

vmaxg - (var) maximum speed on general traffic lanes

vol - (fnc) computes traffic volumes from speed and capacity information

vol - (var) number of vehicles

vtrip - (arr) van trip time during the peak

vtrips - (arr) van trip time on shoulders of the peak vtript - (arr) total average van trip time

wscp - (sub) puts one character on the screen

x - (arr) variable used in equivalence statement to represent all variables other than cost parameters

xs - (arr) used to store "x" temporarily during elasticity computation

y - (arr) variable used in equivalence statement to represent cost parameter variables

APPENDIX A

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APPENDIX A - BIBLIOGRAPHY

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APPENDIX B

LISTING OF FORTRAN PROGRAMS FOR THE COST MODEL

APPENDIX B - LISTING OF FORTRAN PROGRAMS FOR THE COST MODEL

Main program

```
      logical clean
      character*10 a,snart
      character*21 label(65)
      character*8 file
      character*40 fcont
      data label/"Person-trips","SOV's","2-pers. carpools","3-pers.
carpools","Vanpools",
     1"Buses","Carpool definition","% preferring peak",
     1"capacity - gen","HOV","art","# peak veh. - gen","HOV","art",
"# shoulder veh. - gen","HOV","art",
     2"peak speeds - gen","HOV","art","shoulder speeds - gen","HOV"
,"art",
     3"length","# gen.purp.lanes","# HOV lanes","# arterial lanes",
"access time",
     4"carpool formation","vanpool formation","bus access",
     4"min. freeway speed","min. arterial speed",
     5"SOV","carpool","vanpool",
     6"bus","SOV","carpool",
     7"vanpool","bus","SOV","carpool","vanpool","bus",
     8"peak freeway","peak arterial","shoulder freeway",
     9"shoulder arterial","% on arterials","average trip time",
     9"average","SOV","2-pers. carpool","3-pers. carpool",
     9"vanpools","buses","cars","vanpools","buses","freeway",
     9"HOV","arterial","HOV differential","TOTAL COSTS"/
      integer locx(6),locy(65),locp(65),dec(65),type(65),fmt(5),ich
ng(6)
      data fmt/7,15,15,15,15/
      data type/1,0,1,1,1,1,3,2,3,3,4,0,0,0,0,0,0,0,0,0,0,0,0,4,3,2
,
     14,2,2,2,2,2,2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,2,0,2,2,2,2
,
     20,0,0,4,3,4,3,0/
      data locx/22,29,42,49,62,69/
      data locy/2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,
     120,21,22,23,24,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,
     219,20,21,22,23,24,3,4,5,6,8,9,11,12,13,14,15,16,18,19,20,3,4,
5,6,8/
      data locp/0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
     11,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,2,2,2,2,2,2,
     22,2,2,2,2,2,2,2,2,3,3,3,3,3/
      real x(6,65),ptrips(6),sov(6),pool2(6),pool3(6),poolv(6),bus(
6),
     1vgp(6),vhp(6),vap(6),vgs(6),vhs(6),vas(6),pspg(6),psph(6),
     2pspa(6),sspg(6),ssph(6),sspa(6),capg(6),caph(6),capa(6),tpvg(
6),tpvh(6),tpva(6),
```

```
     3len(6),ngpl(6),nhov(6),access(6),tpool(6),tvan(6),tbus(6),
     4strip(6),ctrip(6),vtrip(6),btrip(6),strips(6),ctrips(6),vtrips(6),btrips(6),
     4stript(6),ctript(6),vtript(6),btript(6),narts(6),cpdefn(6),spminf(6),spmina(6),prefpk(6),
     5v(6),vh(6),dispg(6),dispa(6),dispgs(6),dispas(6),ttime(3),
     6pcap(6),tbar(6),tlave(6),tlsov(6),tlpl2(6),tlpl3(6),tlvan(6),
     7tlbus(6),tmcar(6),tmvan(6),tmbus(6),tcost(6),
     8avspg(6),avsph(6),avspa(6),timcst(6),percst(6),agycst(6)
      equivalence (x(1,1),ptrips(1)),(x(1,2),sov(1)),(x(1,3),pool2(1)),
     1(x(1,4),pool3(1)),(x(1,5),poolv(1)),(x(1,6),bus(1)),(x(1,7),cpdefn(1)),(x(1,8),prefpk(1)),
     2(x(1,9),capg(1)),(x(1,10),caph(1)),(x(1,11),capa(1)),
     3(x(1,12),vgp(1)),(x(1,13),vhp(1)),(x(1,14),vap(1)),
     4(x(1,15),vgs(1)),(x(1,16),vhs(1)),(x(1,17),vas(1)),
     5(x(1,18),pspg(1)),(x(1,19),psph(1)),(x(1,20),pspa(1)),
     6(x(1,21),sspg(1)),(x(1,22),ssph(1)),(x(1,23),sspa(1)),
     7(x(1,24),len(1)),(x(1,25),ngpl(1)),(x(1,26),nhov(1)),(x(1,27),narts(1)),
     8(x(1,28),access(1)),(x(1,29),tpool(1)),(x(1,30),tvan(1)),
     9(x(1,31),tbus(1)),(x(1,32),spminf(1)),(x(1,33),spmina(1)),(x(1,34),strip(1)),(x(1,35),ctrip(1)),
     9(x(1,36),vtrip(1)),(x(1,37),btrip(1)),(x(1,38),strips(1)),
     9(x(1,39),ctrips(1)),(x(1,40),vtrips(1)),(x(1,41),btrips(1)),
     9(x(1,42),stript(1)),(x(1,43),ctript(1)),(x(1,44),vtript(1)),
     9(x(1,45),btript(1)),(x(1,46),dispg(1)),(x(1,47),dispa(1)),
     9(x(1,48),dispgs(1)),(x(1,49),dispas(1)),(x(1,50),pcap(1)),
     9(x(1,51),tbar(1)),(x(1,52),tlave(1)),(x(1,53),tlsov(1)),
     9(x(1,54),tlpl2(1)),(x(1,55),tlpl3(1)),(x(1,56),tlvan(1)),
     9(x(1,57),tlbus(1)),(x(1,58),tmcar(1)),(x(1,59),tmvan(1)),
     9(x(1,60),tmbus(1)),
     9(x(1,65),tcost(1))
      data dec/-1,-1,-1,-1,-1,-1,-1,2,-1,-1,-1,-1,-1,-1,-1,-1,-1,1,1,1,1,1,1,1,1,1,-1,-1,1,1,1,1,1,-1,-1,
     12,2,2,2,2,2,2,2,2,2,2,2,-1,-1,-1,-1,3,2,1,1,1,1,1,1,2,2,2,1,1,1,1,2/
      data npar/65/
      real y(18),maint,xs(6)
      common/delay/delg,delgs,dela,delas
      common/result/tc1,tc2,bc1,bc2
      common/cursor/ion1,ion2,ioff1,ioff2
      equivalence (y(1),pcsov),(y(2),pcpol),(y(3),pcvan),
     1(y(4),occar),(y(5),ocvan),
     2(y(9),maint),(y(10),hovmnt),(y(11),enf),
     3(y(12),tval),(y(13),disc),(y(14),constg),(y(15),consth),
     4(y(16),elas)
c
c        read in data
c
      ion1=7
```

```
      ion2=6
      ioff1=0
      ioff2=8
      if (ioread(5,2,0,"crsdef")) go to 20
      read (5,10) ion1,ion2,ioff1,ioff2
   10 format (2i2)
      if (ioclos(5)) stop
   20 call crs(ioff1,ioff2)
      call chfile(file,fcont)
      if (file.eq."") go to 1100
      if (ioread(5,2,0,file)) stop
      read (5,100) ((x(i,j),i=1,6),j=1,npar)
  100 format (6e13.6)
      read (5,110) tval,pcsov,pcpol,pcvan,occar,ocvan,y(6),y(7),y(8
),disc,
     1constg,consth,maint,hovmnt,enf,elas,bfare,pkfact
  110 format (e13.6)
      y(17)=bfare
      y(18)=pkfact
      read (5,100)(timcst(i),i=1,6),(percst(i),i=1,6),(agycst(i),i=
1,6),
     1(avspg(i),i=1,6),(avsph(i),i=1,6),(avspa(i),i=1,6)
      if (ioclos(5)) stop
c
c       set up screens
c
      do 200 ip=3,0,-1
      call chpage(ip)
  200 call vclear
      do 210 ip=0,3
      call printp("1985",24,1,12,ip)
      call printp("1985",44,1,12,ip)
      call printp("1985",64,1,12,ip)
      call printp("2000",31,1,12,ip)
      call printp("2000",51,1,12,ip)
      call printp("2000",71,1,12,ip)
      call printp("Do Nothing",24,0,13,ip)
      call printp("Add Mixed Lane",42,0,13,ip)
  210 call printp("Add HOV Lane",63,0,13,ip)
      call printp("Travel time (minutes)",0,12,11,1)
      call printp("Peak",3,13,11,1)
      call printp("Shoulder",3,17,11,1)
      call printp("Average",3,21,11,1)
      call printp("Displacements",0,2,11,2)
      call printp("Summary Statistics",0,7,11,2)
      call printp("Total Vehicle Miles (1000's)",0,17,11,2)
      call printp("Total Trip Length",0,10,11,2)
      call printp("Maximum Speeds",0,2,11,3)
      do 220 i=1,npar
      call printp(label(i),21-klen(label(i)),locy(i),14,locp(i))
      do 220 j=1,6
```

```
  220 call printp(snart(x(j,i),6,dec(i)),locx(j),locy(i),fmt(type(i
 )+1),locp(i))
      call chattp(0,8,21,12,3)
      call cstset(0,y,0)
      ip=-1
      call cstcal(ip,tcost,disc,constg,consth,maint,hovmnt,enf,
     1timcst,percst,agycst,tc1,tc2,bc1,bc2,pkfact,ichela)
      ip=0
c
c        print cursor and get instruction
c
      ix=1
      iy=1
      move=3
  300 if (type(iy).eq.0.and.move.eq.3) go to 740
      if (type(iy).eq.0.and.move.eq.5) go to 740
      if (type(iy).eq.0.and.move.eq.0) go to 740
      if (type(iy).eq.0.and.move.eq.1) go to 720
      if (type(iy).eq.0.and.move.eq.6) go to 720
      ip=locp(iy)
      call chpage(ip)
      call chattp(locx(ix),locy(iy),6,138,locp(iy))
      call curm(locx(ix),locy(iy),locp(iy))
      call getam(a,move,nfunc)
      call chattp(locx(ix),locy(iy),6,fmt(type(iy)+1),locp(iy))
c
c        set CALC and select page
c
      if (nfunc.gt.6) go to 470
      go to (700,400,440,450,450,450,450),nfunc+1
  400 if (icalc.eq.1) go to 420
      icalc=1
      do 410 ipt=0,3
  410 call printp("CALC",76,0,48,ipt)
      go to 300
  420 icalc=0
      do 430 ipt=0,3
  430 call printp("    ",76,0,7,ipt)
      go to 300
  440 if(icalc.eq.0) go to 300
      go to 600
  450 ip=nfunc-3
      call chpage(ip)
      if (ip.eq.3) go to 1000
  460 if (locp(iy).eq.ip) go to 300
      ix=1
      if (ip.eq.0) iy=1
      if (ip.eq.1) iy=24
      if (ip.eq.2) iy=46
      go to 300
  470 if (nfunc.eq.8) go to 510
```

```
      if (nfunc.lt.9) go to 300
      if (nfunc.eq.9) go to 480
      call pout(fcont)
      go to 300
  480 do 490 i=5,6
      call hovcom(len(i),pspg(i-4),ctrip(i-4),btrip(i-4),cpdefn(i),
     1pool2(i-4),pool3(i-4),poolv(i-4),bus(i-4),pool2(i),pool3(i),
     2poolv(i),bus(i))
      do 490 j=3,6
  490 call printp(snart(x(i,j),6,dec(j)),locx(i),locy(j),
     1fmt(type(j)+1),locp(j))
      if (icalc.eq.1) go to 300
      do 500 i=1,4
  500 ichng(i)=0
      ichng(5)=1
      ichng(6)=1
      go to 600
c
c       calculate elasticities
c
  510 if (icalc.eq.1) go to 300
      ichela=1
      tc1s=tc1
      tc2s=tc2
      bc1s=bc1
      bc2s=bc2
      do 520 i=1,6
  520 xs(i)=x(i,iy)
      go to 810
  530 call printp(snart((tc1/tc1s-1.)/.1,10,3),26,23,12,3)
      call printp(snart((tc2/tc2s-1.)/.1,10,3),26,24,12,3)
      call printp(snart((bc1/bc1s-1.)/.1,10,3),66,23,12,3)
      call printp(snart((bc2/bc2s-1.)/.1,10,3),66,24,12,3)
      call printp(" -------------Elasticities-------------ã",33,20
,12,3)
      call wscp(33,21,3,25,12)
      call wscp(73,21,3,25,12)
      call chpage(3)
      call get(i1,i2)
      call printp("                                          ",33,20
,12,3)
      call printp("                                          ",33,21
,12,3)
      call chpage(ip)
      do 560 i=1,6
  560 x(i,iy)=xs(i)
      tc1=tc1s
      tc2=tc2s
      bc1=bc1s
      bc2=bc2s
      ichela=0
```

```
c
c     calculate results
c
  600 do 680 i=1,6
      if (icalc.eq.1) go to 610
      if (ichng(i).eq.0) go to 680
  610 call sovcal(sov(i),ptrips(i),pool2(i),pool3(i),poolv(i),bus(i
))
      pcapt=narts(i)*capa(i)/(ngpl(i)*capg(i)+nhov(i)*caph(i)+narts
(i)*capa(i))
      pinc=pcapt
      if (pinc.gt..5) pinc=1.-pinc
      lim=3
      if (pcapt.eq.0..or.pcapt.eq.1.) lim=1
  620 do 640 j=1,lim
      if (j.eq.1) pcap(i)=pcapt+pinc
      if (j.eq.2) pcap(i)=pcapt-pinc
      if (j.eq.3.or.lim.eq.1) pcap(i)=pcapt
  630 call lanes(sov(i),pool2(i),pool3(i),poolv(i),bus(i),
     1ngpl(i),nhov(i),narts(i),cpdefn(i),prefpk(i),spminf(i),spmina
(i),
     2capg(i),caph(i),capa(i),pcap(i),
     3v(i),vh(i),vgp(i),vhp(i),vap(i),vgs(i),vhs(i),vas(i),
     4dispg(i),dispa(i),dispgs(i),dispas(i),x(i,61),x(i,62),x(i,63)
)
      call speeds(pspg(i),sspg(i),psph(i),ssph(i),pspa(i),sspa(i),
     1capg(i),caph(i),capa(i),
     2vgp(i),vhp(i),vap(i),vgs(i),vhs(i),vas(i),
     3ngpl(i),nhov(i),narts(i),
     4spminf(i),spmina(i),
     5dispg(i),dispa(i),dispgs(i),dispas(i),
     6avspg(i),avsph(i),avspa(i),x(i,61),x(i,62),x(i,63),x(i,64))
      call times(nhov(i),narts(i),sov(i),pool2(i),cpdefn(i),
     1access(i),len(i),tpool(i),tvan(i),tbus(i),
     2pspg(i),sspg(i),psph(i),ssph(i),pspa(i),sspa(i),
     3v(i),vh(i),vgp(i),vhp(i),vap(i),vgs(i),vhs(i),vas(i),
     4strip(i),strips(i),stript(i),ctrip(i),ctrips(i),ctript(i),
     5vtrip(i),vtrips(i),vtript(i),btrip(i),btrips(i),btript(i))
      ttime(j)=sov(i)*stript(i)+2.*pool2(i)*ctript(i)+
     13.3*pool3(i)*ctript(i)+10.*poolv(i)*vtript(i)+45.*bus(i)*btri
pt(i)+
     2dispg(i)*delg+dispgs(i)*delgs+dispa(i)*dela+dispas(i)*delas
  640 ttime(j)=ttime(j)/ptrips(i)
      if (pcapt.eq.0..or.pcapt.eq.1.) go to 660
      if (pcapt+pinc.gt.1.) go to 650
      if (pcapt-pinc.lt.0.) go to 650
      if ((ttime(1)-ttime(3))*(ttime(3)-ttime(2)).le.0.) go to 650
      if (ttime(1)-ttime(3).lt.0.) pcapt=pcapt+pinc
      if (ttime(1)-ttime(3).ge.0.) pcapt=pcapt-pinc
      go to 620
  650 if (pinc.lt..001) go to 660
```

```
         pinc=pinc/2.
         go to 620
     660 tbar(i)=ttime(lim)
         call length(sov(i),pool2(i),pool3(i),poolv(i),bus(i),tmcar(i)
,
        1tmvan(i),tmbus(i),tlave(i),tlsov(i),tlpl2(i),tlpl3(i),tlvan(i
),
        2tlbus(i))
         call cost(tcost(i),timcst(i),percst(i),agycst(i),tval,pcsov,
        1pcpol,pcvan,occar,ocvan,y(6),y(7),y(8),avspg(i),avsph(i),avsp
a(i),elas,
        2sov(i),pool2(i),pool3(i),poolv(i),bus(i),len(i),pcap(i),
        3tmcar(i),tmvan(i),tmbus(i),tbar(i),ptrips(i),bfare,btript(i),
        4x(i,61),x(i,62),x(i,63))
         if (ichela.eq.1) go to 680
         do 670 j=1,npar
     670 if (type(j).eq.0) call printp(snart(x(i,j),6,dec(j)),locx(i),
locy(j),7,locp(j))
     680 continue
         call cstcal(ip,tcost,disc,constg,consth,maint,hovmnt,enf,
        1timcst,percst,agycst,tc1,tc2,bc1,bc2,pkfact,ichela)
         if (ichela.eq.1) go to 530
         go to 300
c
c          move cursor
c
     700 if (a.ne."") go to 800
     710 go to (300,720,730,740,750,760,770,1100),move+1
     720 iy=mod(iy+npar-2,npar)+1
         go to 300
     730 ix=mod(ix,6)+1
         go to 300
     740 if (iy.eq.npar) go to 1000
         iy=mod(iy,npar)+1
         go to 300
     750 ix=mod(ix+4,6)+1
         go to 300
     760 ix=1
         iy=1
         go to 300
     770 ix=6
         iy=npar
         go to 300
c
c          change data
c
     800 if (clean(a,6)) go to 810
         call printp(a,locx(ix),locy(iy),140,locp(iy))
         call take(3.)
         call printp(snart(x(ix,iy),6,dec(iy)),locx(ix),locy(iy),fmt(t
ype(iy)+1),locp(iy))
```

```
      go to 300
  810 do 820 i=1,6
  820 ichng(i)=0
      go to (830,840,860,880),type(iy)
  830 if (ichela.eq.0) x(ix,iy)=tran(a)
      if (ichela.eq.1) x(ix,iy)=x(ix,iy)*1.1
      ichng(ix)=1
      if (ichela.eq.1) go tc 900
      call printp(snart(x(ix,iy),6,dec(iy)),locx(ix),locy(iy),fmt(t
ype(iy)+1),locp(iy))
      go to 900
  840 ist=2-mod(ix,2)
      do 850 ixx=ist,6,2
      ichng(ixx)=1
      if (ichela.eq.0) x(ixx,iy)=tran(a)
      if (ichela.eq.1) x(ixx,iy)=x(ixx,iy)*1.1
      if (ichela.eq.1) go tc 850
      call printp(snart(x(ixx,iy),6,dec(iy)),locx(ixx),locy(iy),fmt
(type(iy)+1),locp(iy))
  850 continue
      go to 900
  860 ist=ix-1+mod(ix,2)
      do 870 ixx=ist,ist+1
      ichng(ixx)=1
      if (ichela.eq.0) x(ixx,iy)=tran(a)
      if (ichela.eq.1) x(ixx,iy)=x(ixx,iy)*1.1
      if (ichela.eq.1) go tc 870
      call printp(snart(x(ixx,iy),6,dec(iy)),locx(ixx),locy(iy),fmt
(type(iy)+1),locp(iy))
  870 continue
      go to 900
  880 do 890 ixx=1,6
      ichng(ixx)=1
      if (ichela.eq.0) x(ixx,iy)=tran(a)
      if (ichela.eq.1) x(ixx,iy)=x(ixx,iy)*1.1
      if (ichela.eq.1) go tc 890
      call printp(snart(x(ixx,iy),6,dec(iy)),locx(ixx),locy(iy),fmt
(type(iy)+1),locp(iy))
  890 continue
  900 if (icalc.eq.0) go to 600
      go to 710
c
c       set cost parameters
c
 1000 call cstset(ip,y,icalc)
      iy=npar-1
      bfare=y(17)
      pkfact=y(18)
      if (ip.lt.4) go to 460
      if (ip.gt.13) go to 1100
      do 1010 i=1,6
```

```
365:        call cost(tcost(i),timcst(i),percst(i),agycst(i),tval,pcsov,
366:       1pcpol,pcvan,occar,ocvan,y(6),y(7),y(8),avspg(i),avsph(i),avsp
     a(i),elas,
367:       2sov(i),pool2(i),pool3(i),poolv(i),bus(i),len(i),pcap(i),
368:       3tmcar(i),tmvan(i),tmbus(i),tbar(i),ptrips(i),bfare,btript(i),
369:       4x(i,61),x(i,62),x(i,63))
370:  1010 call printp(snart(x(i,npar),6,dec(npar)),locx(i),locy(npar),7
     ,locp(npar))
371:        call cstcal(ip,tcost,disc,constg,consth,maint,hovmnt,enf,
372:       1timcst,percst,agycst,tc1,tc2,bc1,bc2,pkfact,ichela)
373:        ip=ip-10
374:        go to 1000
375: c
376: c       exit
377: c
378:  1100 call chpage(0)
379:        call vclear
380:        call crs(ion1,ion2)
381:        call curm(0,0,0)
382:        if (file.eq."") stop
383:        if (iowrit(6,2,0,file)) stop
384:        write (6,1110) ((x(i,j),i=1,6),j=1,npar)
385:  1110 format (1x,6e13.6)
386:        write (6,1120) tval,pcsov,pcpol,pcvan,occar,ocvan,y(6),y(7),y
     (8),disc,
387:       1constg,consth,maint,hovmnt,enf,elas,bfare,pkfact
388:  1120 format (1x,e13.6)
389:        write (6,1110) (timcst(i),i=1,6),(percst(i),i=1,6),(agycst(i)
     ,i=1,6),
390:       1(avspg(i),i=1,6),(avsph(i),i=1,6),(avspa(i),i=1,6)
391:        if (ioclos(6)) stop
392:        stop
393:        end
```

subroutines

```
chattp 129 148 151
chfile  87
chpage 104 147 169 214 218 378
cost   278 365
crs     86 380
cstcal 132 287 371
cstset 130 358
curm   149 381
get    215
getam  150
hovcom 183
lanes  242
length 275
pout   180
printp 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121
```

```
           122 123 124 126 128 160 164 187 207 208 209 210 211 216 217
           285 315 317 326 334 343 351 370
   sovcal  232
   speeds  247
   take    316
   times   254
   vclear  105 379
   wscp    212 213
```

integer variables

```
   i         90  97  98 125 126 128 182 183 184 185 187 190 191 204 205
           219 220 229 231 232 233 239 240 241 242 243 244 245 246 247
           248 249 250 251 252 253 254 255 256 257 258 259 260 261 262
           263 274 275 276 277 278 279 280 281 282 285 319 320 364 365
           366 367 368 369 370 384 389 390
   icalc   157 158 162 166 189 198 230 353 358
   ichela  133 199 225 283 288 289 322 323 325 331 332 333 340 341 342
           348 349 350 372
   ioff1    80  83  86
   ioff2    81  83  86
   ion1     78  83 380
   ion2     79  83 380
   ip      103 104 106 107 108 109 110 111 112 113 114 115 131 132 134
           146 147 168 169 170 171 173 174 175 218 287 358 362 363 371
           373
   ipt     159 160 163 164
   ist     328 329 337 338
   ix      138 148 149 151 172 298 303 305 308 315 317 322 323 324 326
           328 337
   ixx     329 330 331 332 334 338 339 340 341 343 346 347 348 349 351

   iy      139 141 142 143 144 145 146 148 149 151 171 173 174 175 205
           220 296 300 301 306 309 315 317 321 322 323 326 331 332 334
           340 341 343 348 349 351 359
   i1      215
   i2      215
   j        90 127 128 186 187 188 238 239 240 241 260 263 284 285 384

   lim     236 237 238 241 274
   move    140 141 142 143 144 145 150 295
   nfunc   150 155 156 168 177 178 179
   npar     90 125 284 296 300 301 309 359 370 384
```

real variables

```
   bc1     133 202 209 223 288 372
   bc1s    202 209 223
   bc2     133 203 210 224 288 372
   bc2s    203 210 224
   bfare    93  95 281 360 368 387
```

```
constg   73  93 132 287 371 387
consth   73  93 132 287 371 387
dela    262
delas   262
delg    262
delgs   262
disc     73  92 132 287 371 386
elas     74  93 279 366 387
enf      72  93 132 287 371 387
hovmnt   72  93 132 287 371 387
maint    66  72  93 132 287 371 387
occar    71  92 279 366 386
ocvan    71  92 279 366 386
pcapt   233 234 237 239 240 241 264 265 266 268 269
pcpol    70  92 279 366 386
pcsov    70  92 278 365 386
pcvan    70  92 279 366 386
pinc    234 235 239 240 265 266 268 269 271 272
pkfact   93  96 133 288 361 372 387
tc1     133 200 207 221 288 372
tc1s    200 207 221
tc2     133 201 208 222 288 372
tc2s    201 208 222
tval     73  92 278 365 386
```

character variables

```
a          2 150 294 314 315 322 331 340 348
fcont      5  87 180
file       4  87  88  89 382 383
```

integer arrays

```
dec       21 128 187 285 317 326 334 343 351 370
fmt       21 128 151 188 317 326 334 343 351
ichng     21 191 192 193 231 320 324 330 339 347
locp      21 126 128 146 148 149 151 171 188 285 315 317 326 334 343
         351 370
locx      21 128 148 149 151 187 285 315 317 326 334 343 351 370
locy      21 126 128 148 149 151 187 285 315 317 326 334 343 351 370

type      21 128 141 142 143 144 145 151 188 285 317 321 326 334 343
         351
```

real arrays

```
access    36  51 255
agycst    42  97 133 278 288 365 372 389
avspa     42  98 253 279 366 390
avspg     42  98 253 279 366 390
avsph     42  98 253 279 366 390
```

```
     tpool    36  51 255
     tpva     35
     tpvg     35
     tpvh     35
     ttime    39 260 263 267 268 269 274
     tvan     36  51 255
     v        39 245 257
     vap      34  46 245 249 257
     vas      34  47 245 249 257
     vgp      34  46 245 249 257
     vgs      34  47 245 249 257
     vh       39 245 257
     vhp      34  46 245 249 257
     vhs      34  47 245 249 257
     vtrip    37  53 259
     vtrips   37  54 259
     vtript   38  55 259 261
     x        33  43  44  45  46  47  48  49  50  51  52  53  54  55  56
              57  58  59  60  61  62  90 128 187 205 220 246 253 282 285
             317 322 323 326 331 332 334 340 341 343 348 349 351 369 370
             384
     xs       66 205 220
     y        66  70  71  72  73  74  92  95  96 130 279 358 360 361 366
             386

character arrays

     label     3 126

integer functions

     klen    126
     mod     296 298 301 303 328 337

real functions

     tran    322 331 340 348

logical functions

     clean     1 314
     ioclos  85  99 391
     ioread  82  89
     iowrit 383

character functions

     snart     2 128 187 207 208 209 210 285 317 326 334 343 351 370
```

```
      Subroutine chfile(file,fcont)
      character*10 a
      character*40 filn(20),fcont
      integer filnum(20)
      character*8 file
      character*4 nart
      common/cursor/ion1,ion2,ioff1,ioff2
      file=""
      call chpage(0)
      call vclear
      call printp("Pick a case for analysis",0,0,14,0)
      if (ioread(5,2,0,"files")) go to 40
      read (5,10) nfil
   10 format (i0)
      read (5,20,errexit=40) (filnum(i),filn(i),i=1,nfil)
   20 format (i4,a0)
      if (ioclos(5)) stop
      do 30 i=1,nfil
   30 call printp(filn(i),0,i+1,7,0)
   40 call printp("""D"" - delete      ""A"" - add      ""C"" - choose
",0,24,7,0)
      ia=1
   50 call chattp(0,ia+1,40,138,0)
      call getd(a,im,if)
      call chattp(0,ia+1,40,7,0)
      if (im.eq.7) go to 145
      if (a.eq."D".or.a.eq."d") go to 100
      if (a.eq."A".or.a.eq."a") go to 130
      if (a.eq."C".or.a.eq."c") go to 140
      go to (50,60,70,70,60,80,90),im+1
   60 ia=mod(ia+nfil-2,nfil)+1
      go to 50
   70 ia=mod(ia,nfil)+1
      go to 50
   80 ia=1
      go to 50
   90 ia=nfil
      go to 50
  100 nfil=nfil-1
  110 call blnk(0,ia+1,39,ia+1)
      if (ia.le.nfil) go to 120
      ia=1
      go to 50
  120 filn(ia)=filn(ia+1)
      filnum(ia)=filnum(ia+1)
      call printp(filn(ia),0,ia+1,7,0)
      ia=ia+1
      go to 110
  130 nfil=nfil+1
      call vcurxy(0,nfil+1)
      call crs(ion1,ion2)
```

```
51:          call geta(filn(nfil),if,im)
52:          call crs(ioffl,ioff2)
53:          filnum(nfil)=filnum(nfil-1)+1
54:          ia=nfil
55:          go to 50
56:      140 if (nfil.eq.0) go to 200
57:          file="hovin"
58:          call addstg(file,nart(filnum(ia)))
59:      145 if (iowrit(5,2,0,"files")) stop
60:          write (5,150) nfil
61:      150 format (1x,i2)
62:          write (5,160) (filnum(i),filn(i),i=1,nfil)
63:      160 format (1x,i4,a0)
64:          if (ioclos(5)) stop
65:          if (im.eq.7) return
66:          fcont=filn(ia)
67:          if (.not.ioread(5,2,0,file)) go to 190
68:          if (iowrit(5,2,0,file)) stop
69:          do 170 i=1,89
70:      170 write (5,180)
71:      180 format('  ')
72:      190 if (ioclos(5)) stop
73:          return
74:      200 call printp("You must assign a file name",20,7,12,0)
75:          call printp("before starting computation",20,8,12,0)
76:          call printp("Re-enter program with ""HOVCOST""",20,9,12,0)
77:          call take(5.)
78:          return
79:          end
```

subroutines

```
addstg  58
blnk    39
chattp  22  24
chpage   9
crs     50  52
geta    51
getd    23
printp  11  19  20  45  74  75  76
take    77
vclear  10
vcurxy  49
```

integer variables

```
i       15  18  19  62  69
ia      21  22  24  30  32  34  36  39  40  41  43  44  45  46  54
        58  66
im      23  25  29  51  65
ioffl   52
```

ioff2	52														
ion1	50														
ion2	50														
nfil	13	15	18	30	32	36	38	40	48	49	51	53	54	56	60
	62														

real variables

add	20
choose	20
delete	20

character variables

a	2	23	26	27	28
fcont	3	66			
file	5	8	57	58	67	68

integer arrays

filnum	4	15	44	53	58	62

character arrays

filn	3	15	19	43	45	51	62	66

integer functions

mod	30	32

logical functions

ioclos	17	64	72
ioread	12	67	
iowrit	59	68	

character functions

nart	6	58

```
 1:        Subroutine cost(tcost,timcst,percst,agycst,tval,
 2:       1pcsov,pcpol,pcvan,occar,ocvan,ocbusm,ocbush,ocbust,avspg,avsph,avspa,elas,
 3:       2sov,pool2,pool3,poolv,bus,len,pcap,
 4:       3tmcar,tmvan,tmbus,tbar,ptrips,bfare,btript,vmaxg,vmaxh,vmaxa)
 5:        real len
 6:        timcst=tval*ptrips*tbar/60.
 7:        percst=pcsov*(sov+pool2)+pcpol*pool3+pcvan*poolv+
 8:       11000.*(occar*tmcar+ocvan*tmvan)
 9:        facg=elas*(1.-vmaxg/avspg)
10:        fach=elas*(1.-vmaxh/avsph)
11:        faca=elas*(1.-vmaxa/avspa)
12:        percst=percst+occar*len*facg*(1.-pcap)*sov
13:        percst=percst+occar*len*fach*(pool2+pool3)
14:        percst=percst+ocvan*len*fach*poolv
15:        percst=percst+occar*len*faca*pcap*sov
16:        percst=percst+bfare*bus*45.
17:        agycst=ocbusm*tmbus*1000.+ocbush*btript*bus/60.+ocbust*bus
18:        agycst=agycst-bfare*bus*45.
19:        timcst=timcst/1000.
20:        percst=percst/1000.
21:        agycst=agycst/1000.
22:        tcost=timcst+percst+agycst
23:        return
24:        end
```

real variables

agycst	17	18	21	22				
avspa	11							
avspg	9							
avsph	10							
bfare	16	18						
btript	17							
bus	16	17	18					
elas	9	10	11					
faca	11	15						
facg	9	12						
fach	10	13	14					
len	5	12	13	14	15			
ocbush	17							
ocbusm	17							
ocbust	17							
occar	8	12	13	15				
ocvan	8	14						
pcap	12	15						
pcpol	7							
pcsov	7							
pcvan	7							
percst	7	12	13	14	15	16	20	22
poolv	7	14						

pool2	7	13	
pool3	7	13	
ptrips	6		
sov	7	12	15
tbar	6		
tcost	22		
timcst	6	19	22
tmbus	17		
tmcar	8		
tmvan	8		
tval	6		
vmaxa	11		
vmaxg	9		
vmaxh	10		

```
      Subroutine cstcal(ip,tcost,disc,constg,consth,maint,hovmnt,
     lenf,timcst,percst,agycst,tc1,tc2,bc1,bc2,pkfact,ichela)
      real tcost(6),tc(3),maint,timcst(6),percst(6),agycst(6),
     1ctim(3),ptim(3),atim(3),ds(20)
      character*10 snart
      do 10 i=1,20
   10 ds(i)=(1.+disc/100.)**i
      tc(1)=0.
      tc(2)=constg
      tc(3)=constg+consth
      do 20 i=1,3
      ctim(i)=0.
      ptim(i)=0.
   20 atim(i)=tc(i)
      do 40 i=1,3
      cinc=(tcost(2*i)-tcost(2*i-1))/15.
      tinc=(timcst(2*i)-timcst(2*i-1))/15.
      pinc=(percst(2*i)-percst(2*i-1))/15.
      ainc=(agycst(2*i)-agycst(2*i-1))/15.
      ann=0.
      if (i.eq.2) ann=maint
      if (i.eq.3) ann=maint+hovmnt+enf
      do 30 j=1,20
      ctim(i)=ctim(i)+pkfact*250.*(timcst(2*i-1)+float(j)*tinc)/ds(j)
      ptim(i)=ptim(i)+pkfact*250.*(percst(2*i-1)+float(j)*pinc)/ds(j)
      atim(i)=atim(i)+pkfact*250.*(agycst(2*i-1)+float(j)*ainc)/ds(j)+
     1ann/ds(j)
   30 tc(i)=tc(i)+pkfact*250.*(tcost(2*i-1)+float(j)*cinc)/ds(j)+ann/ds(j)
      ctim(i)=ctim(i)/1000.
      ptim(i)=ptim(i)/1000.
      atim(i)=atim(i)/1000.
   40 tc(i)=tc(i)/1000.
      tc1=tc(1)-tc(3)
      tc2=tc(2)-tc(3)
      call printp(snart(tc1,10,1),26,23,15,3)
      call printp(snart(tc2,10,1),26,24,15,3)
      call printp(snart(ctim(1)-ctim(3),10,1),36,23,15,3)
      call printp(snart(ptim(1)-ptim(3),10,1),46,23,15,3)
      call printp(snart(atim(1)-atim(3),10,1),56,23,15,3)
      call printp(snart(ctim(2)-ctim(3),10,1),36,24,15,3)
      call printp(snart(ptim(2)-ptim(3),10,1),46,24,15,3)
      call printp(snart(atim(2)-atim(3),10,1),56,24,15,3)
      bc1=0.
      bc2=0.
      if (atim(1)-atim(3).ne.0.)bc1=-(ctim(1)-ctim(3)+ptim(1)-ptim(3))/(atim(1)-atim(3))
      if (atim(2)-atim(3).ne.0.)bc2=-(ctim(2)-ctim(3)+ptim(2)-ptim(
```

```
   3))/(atim(2)-atim(3))
47:        call printp(snart(bc1,10,2),66,23,15,3)
48:        call printp(snart(bc2,10,2),66,24,15,3)
49:        if (ip.gt.3) return
50:        if (ip.lt.0) return
51:        if (ichela.eq.1) return
52:        call chpage(3)
53:        call take(5.)
54:        call chpage(ip)
55:        return
56:        end
```

```
subroutines

   chpage   52  54
   printp   35  36  37  38  39  40  41  42  47  48
   take     53

integer variables

   i         6   7  11  12  13  14  15  16  17  18  19  21  22  24  25
            26  28  29  30  31  32
   ichela   51
   ip       49  50  54
   j        23  24  25  26  27  28

real variables

   ainc     19  26
   ann      20  21  22  27  28
   bc1      43  45  47
   bc2      44  46  48
   cinc     16  28
   constg    9  10
   consth   10
   disc      7
   enf      22
   hovmnt   22
   maint     3  21  22
   pinc     18  25
   pkfact   24  25  26  28
   tc1      33  35
   tc2      34  36
   tinc     17  24

real arrays

   agycst    3  19  26
   atim      4  14  26  31  39  42  45  46
   ctim      4  13  24  29  37  40  45  46
   ds        4   7  24  25  26  27  28
```

percst	3	18	25							
ptim	4	13	25	30	38	41	45	46		
tc	3	8	9	10	14	28	32	33	34	
tcost	3	16	28							
timcst	3	17	24							

real functions

float	24	25	26	28

character functions

snart	5	35	36	37	38	39	40	41	42	47	48

```
      Subroutine cstset(ip,x,icalc)
      logical clean
      character*10 snart,a
      character*18 label(18)
      data label/"SOV","carpool","vanpool","car ($/mi.)","van ($/mi.)",
     1"bus ($/mi.)","bus ($/hr.)","bus ($/trip)","Maint. cost","Extra HOV maint.","Enforcement",
     2"Value of time ($)","Discount rate (%)",
     3"Lane construction","Extra HOV cost","Oper. cost elas.",
     4"Bus fare","Peak Factor"/
      common/result/tc1,tc2,bc1,bc2
      real x(18),maint
      integer locx(18),locy(18),dec(18)
      data locx/18,18,18,18,18,18,18,18,45,45,45,72,72,72,72,72,72,72/
      data locy/12,13,14,16,17,18,19,20,12,13,14,12,13,14,15,16,17,18/
      data dec/2,2,2,2,2,2,2,2,-1,-1,-1,2,1,-1,-1,2,2,2/
      if (ichela.eq.1) go to 320
      if (ip.ne.0) go to 200
c
c       set up screen
c
      ia=1
      do 100 i=1,18
      call printp(label(i),locx(i)-klen(label(i))-2,locy(i),14,3)
  100 call printp(snart(x(i),6,dec(i)),locx(i),locy(i),15,3)
      do 110 i=0,79
  110 call printp("-",i,9,13,3)
      call printp("COST PARAMETERS",0,10,13,3)
      call printp("Parking costs ($'s/day)",0,11,11,3)
      call printp("Operating costs",0,15,11,3)
      call printp("Annual costs ($1,000's)",27,11,11,3)
      call printp("Miscellaneous",53,11,11,3)
      call printp("Net Savings ($1,000,000's)",0,22,13,3)
      call printp("total",31,22,11,3)
      call printp("time",42,22,11,3)
      call printp("personal",48,22,11,3)
      call printp("agency",60,22,11,3)
      call printp("marg b/c",68,22,11,3)
      call printp("HOV - Do Nothing",3,23,15,3)
      call printp("HOV - Add Gen'l Lane",3,24,15,3)
      return
c
c       change cost parameters
c
  200 call chattp(locx(ia),locy(ia),6,138,3)
      call curm(locx(ia),locy(ia),3)
      call getam(a,move,nfunc)
      call chattp(locx(ia),locy(ia),6,15,3)
```

```
      if (nfunc.gt.0) go to 300
      if (a.ne."") go to 260
  205 go to (200,210,220,220,210,230,240,250),move+1
  210 if (ia.eq.1) return
      ia=mod(ia+16,18)+1
      go to 200
  220 ia=mod(ia,18)+1
      go to 200
  230 ia=1
      go to 200
  240 ia=18
      go to 200
  250 ip=99
      return
  260 if (clean(a,8)) go to 270
      call printp(a,locx(ia),locy(ia),14,3)
      call take(3.)
      call printp(snart(x(ia),6,dec(ia)),locx(ia),locy(ia),15,3)
      go to 200
  270 x(ia)=tran(a)
      call printp(snart(x(ia),6,dec(ia)),locx(ia),locy(ia),15,3)
      if (icalc.eq.1) go to 205
  280 ip=ip+10
      return
c
c        set up to change page
c
  300 if (nfunc.eq.1) go to 400
      if (nfunc.eq.2.and.icalc.eq.1) go to 280
      if (nfunc.eq.8) go to 310
      if (nfunc.gt.5.or.nfunc.lt.3) go to 200
      ip=nfunc-3
      call chpage(ip)
      return
c
c        calculate elasticities
c
  310 if (icalc.eq.1) go to 200
      ichela=1
      tc1s=tc1
      tc2s=tc2
      bc1s=bc1
      bc2s=bc2
      xs=x(ia)
      x(ia)=x(ia)*1.1
      go to 280
  320 call printp(snart((tc1/tc1s-1.)/.1,10,3),26,23,12,3)
      call printp(snart((tc2/tc2s-1.)/.1,10,3),26,24,12,3)
      call printp(snart((bc1/bc1s-1.)/.1,10,3),66,23,12,3)
      call printp(snart((bc2/bc2s-1.)/.1,10,3),66,24,12,3)
      call printp(" -------------Elasticities-------------ã",33,20
```

```
     ,12,3)
 99:          call wscp(33,21,3,25,12)
100:          call wscp(73,21,3,25,12)
101:          call get(i1,i2)
102:          call printp("                                                          ",33,20
     ,12,3)
103:          call printp("                                                          ",33,21
     ,12,3)
104:          x(ia)=xs
105:          tc1=tc1s
106:          tc2=tc2s
107:          bc1=bc1s
108:          bc2=bc2s
109:          ichela=0
110:          go to 280
111:  c
112:  c         set CALC
113:  c
114:     400 if (icalc.eq.1) go to 420
115:          icalc=1
116:          do 410 ipt=0,3
117:     410 call printp("CALC",76,0,48,ipt)
118:          go to 200
119:     420 icalc=0
120:          do 430 ipt=0,3
121:     430 call printp("    ",76,0,7,ipt)
122:          go to 200
123:          end
```

subroutines

```
      chattp  44  47
      chpage  80
      curm    45
      get    101
      getam   46
      printp  23  24  26  27  28  29  30  31  32  33  34  35  36  37  38
              39  63  65  68  94  95  96  97  98 102 103 117 121
      take    64
      wscp    99 100
```

integer variables

```
      i       22  23  24  25  26
      ia      21  44  45  47  51  52  54  56  58  63  65  67  68  91  92
             104
      icalc   69  76  85 114 115 119
      ichela  16  86 109
      ip      17  60  70  79  80
      ipt    116 117 120 121
      i1     101
```

```
      i2      101
      move     46   50
      nfunc    46   48   75   76   77   78   79

real variables

      bc1      89   96  107
      bc1s     89   96  107
      bc2      90   97  108
      bc2s     90   97  108
      maint    11
      tc1      87   94  105
      tc1s     87   94  105
      tc2      88   95  106
      tc2s     88   95  106
      xs       91  104

character variables

      a         3   46   49   62   63   67

integer arrays

      dec      12   24   65   68
      locx     12   23   24   44   45   47   63   65   68
      locy     12   23   24   44   45   47   63   65   68

real arrays

      x        11   24   65   67   68   91   92  104

character arrays

      label     4   23

integer functions

      klen     23
      mod      52   54

real functions

      tran     67

logical functions

      clean     2   62

character functions

      snart     3   24   65   68   94   95   96   97
```

```
      Subroutine getam(a,im,if)
      character*80 a
      character*1 b
      equivalence (icc,b)
      data b/" "/
      a=""
      im=0
      if=0
   10 call get(ic,is)
      icc=ic
      if (is.eq.72) im=1
      if (is.eq.77) im=2
      if (is.eq.80) im=3
      if (is.eq.75) im=4
      if (is.eq.71) im=5
      if (is.eq.79) im=6
      if (ic.eq.27) im=7
      if (is.ge.59.and.is.le.68) if=is-58
      if (is.ge.84.and.is.le.113) if=is-73
      if (im+if.ne.0) return
      if (ic.eq.0) go to 10
      if (ic.eq.9.and.is.eq.15) go to 10
      if (ic.eq.8.and.is.eq.14) go to 10
      if (ic.eq.13.and.is.eq.28) return
      call curp(ix1,iy)
      ix=ix1
      a=b
   20 call wsc(ix,iy,ic,7)
   30 ix=ix+1
   40 call curm(ix,iy)
      if (ix.eq.ix1) go to 10
   50 call get(ic,is)
      icc=ic
      if (ic.eq.8.and.is.eq.14) go to 60
      if (ic.eq.13.and.is.eq.28) return
      if (is.eq.72) im=1
      if (is.eq.77) im=2
      if (is.eq.80) im=3
      if (is.eq.75) im=4
      if (is.eq.71) im=5
      if (is.eq.79) im=6
      if (ic.eq.27) im=7
      if (im.gt.0) return
      call addstg(a,b)
      go to 20
   60 ix=ix-1
      call blnk(ix,iy,ix,iy)
      call setlen(a,klen(a)-1)
      go to 40
      end
```

```
subroutines

      addstg  44
      blnk    47
      curm    30
      curp    25
      get      9  32
      setlen  48
      wsc     28

integer variables

      ic       9  10  17  21  22  23  24  28  32  33  34  35  42
      icc      4  10  33
      im       7  11  12  13  14  15  16  17  20  36  37  38  39  40  41
              42  43
      is       9  11  12  13  14  15  16  18  19  22  23  24  32  34  35
              36  37  38  39  40  41
      ix      26  28  29  30  31  46  47
      ixl     25  26  31
      iy      25  28  30  47

character variables

      a        2   6  27  44  48
      b        3   4  27  44

integer functions

      klen    48
```

```
 1:        Subroutine hovcom(hovl,s0gp,t0pa,t0b,cpdefn,pool2,pool3,
 2:       1van0,b0peb,tpool2,tpool3,vanl,blhov)
 3:        time=hovl*60./s0gp
 4:        toffpa=t0pa-time
 5:        toffb=t0b-time
 6:        tlb=toffb+hovl*60./58.
 7:        tlpa=toffpa+hovl*60./58.
 8:        if (cpdefn.eq.2.) coeff=6.7
 9:        if (cpdefn.eq.3.) coeff=7.7
10:        delpa=-.203-coeff*(tlpa/t0pa-1.)+4.8*(tlb/t0b-1.)
11:        tpool2=pool2
12:        if (cpdefn.eq.2.) tpool2=pool2*(1.+delpa)
13:        tpool3=pool3*(1.+delpa)
14:        vanl=van0*(1.+delpa)
15:        if (cpdefn.eq.2.) coeff=1.71
16:        if (cpdefn.eq.3.) coeff=.435
17:        delb=.227+coeff*(tlpa/t0pa-1.)
18:        if (delb.lt.0.) delb=0.
19:        blhov=b0peb*(1.+delb)
20:        return
21:        end
```

real variables

b0peb	19					
blhov	19					
coeff	8	9	10	15	16	17
cpdefn	8	9	12	15	16	
delb	17	18	19			
delpa	10	12	13	14		
hovl	3	6	7			
pool2	11	12				
pool3	13					
s0gp	3					
time	3	4	5			
toffb	5	6				
toffpa	4	7				
tpool2	11	12				
tpool3	13					
t0b	5	10				
t0pa	4	10	17			
tlb	6	10				
tlpa	7	10	17			
van0	14					
vanl	14					

```
      Subroutine lanes(sov,pool2,pool3,poolv,bus,
     1ngpl,nhov,narts,cpdefn,prefpk,spminf,spmina,
     2capg,caph,capa,pcap,
     3v,vh,vgp,vhp,vap,vgs,vhs,vas,
     4dispg,dispa,dispgs,dispas,vmaxg,vmaxh,vmaxa)
      real ngpl,nhov,narts
      common/delay/delg,delgs,dela,delas
      v=sov+pool2+pool3+poolv+bus
      vg=v
      vh=0.
      vgp=0.
      vhp=0.
      vap=0.
      vgs=0.
      vhs=0.
      vas=0.
      delg=0.
      dela=0.
      delgs=0.
      delas=0.
      if (nhov.eq.0.) go to 200
c
c       assign HOV vehicles
c
      go to (200,100,110),int(cpdefn)
  100 vh=v-sov
      vg=sov
      go to 120
  110 vh=v-sov-pool2
      vg=sov+pool2
  120 vhp=prefpk*vh
      vhs=vh-vhp
      if (vhp.le.caph*nhov) go to 200
      vhp=caph*nhov
      vhs=vh-vhp
c
c       assign other vehicles
c
c       split freeway and arterial traffic
c
  200 va=pcap*vg
      if (va.lt.0.) va=0.
      vg=vg-va
c
c       split into peak/off-peak
c
      vgp=prefpk*vg
      vap=prefpk*va
      vgs=vg-vgp
      vas=va-vap
c
```

```
c          check peak capacities and compute displaced vehicles
c
           dispg=0.
           dispa=0.
           dispgs=0.
           dispas=0.
           if (vgp.le.capg*ngpl) go to 300
           vc=vgp/(capg*ngpl)
           tcapg=ngpl*vol(spminf,capg,vmaxg)
           rcapg=capg*ngpl-(vc-1.)*(capg*ngpl-tcapg)/.5
           if (rcapg.lt.tcapg) rcapg=tcapg
           dispg=vgp-rcapg
           delg=15.*dispg/vgp+30.*dispg/(capg*ngpl-vgs/2.)
           if (delg.gt.45..or.vgs/2..gt.capg*ngpl) delg=45.
           vgp=vgp-dispg
           vgs=vgs+dispg
       300 if (va.eq.0.) go to 400
           if (vap.le.capa*narts) go to 400
           vc=vap/(capa*narts)
           tcapa=narts*vol(spmina,capa,vmaxa)
           rcapa=capa*narts-(vc-1.)*(capa*narts-tcapa)/.5
           if (rcapa.lt.tcapa) rcapa=tcapa
           dispa=vap-rcapa
           dela=15.*dispa/vap+30.*dispa/(capa*narts-vas/2.)
           if (dela.gt.45..or.vas/2..gt.capa*narts) dela=45.
           vap=vap-dispa
           vas=vas+dispa
c
c          check shoulder capacities and compute displaced vehicles
c
       400 if (vgs.le.2.*capg*ngpl) go to 410
           vc=vgs/(capg*ngpl)/2.
           tcapg=2.*ngpl*vol(spminf,capg,vmaxg)
           rcapg=2.*capg*ngpl-(vc-1.)*(2.*capg*ngpl-tcapg)/.5
           if (rcapg.lt.tcapg) rcapg=tcapg
           dispgs=vgs-rcapg
           delgs=60.*dispgs/vgs+40.*dispgs/(capg*ngpl)
           vgs=vgs-dispgs
       410 if (va.eq.0.) go to 420
           if (vas.le.2.*capa*narts) go to 420
           vc=vas/(capa*narts)/2.
           tcapa=2.*narts*vol(spmina,capa,vmaxa)
           rcapa=2.*capa*narts-(vc-1.)*(2.*capa*narts-tcapa)/.5
           if (rcapa.lt.tcapa) rcapa=tcapa
           dispas=vas-rcapa
           delas=60.*dispas/vas+40.*dispas/(capa*narts)
           vas=vas-dispas
       420 return
           end
```

real variables

```
      bus       8
      capa     69   70   71   72   75   76   91   92   93   94   97
      capg     58   59   60   61   64   65   82   83   84   85   88
      caph     33   34
      cpdefn   25
      dela     18   75   76
      delas    20   97
      delg     17   64   65
      delgs    19   88
      dispa    55   74   75   77   78
      dispas   57   96   97   98
      dispg    54   63   64   66   67
      dispgs   56   87   88   89
      narts     6   69   70   71   72   75   76   91   92   93   94   97
      ngpl      6   58   59   60   61   64   65   82   83   84   85   88
      nhov      6   21   33   34
      pcap     41
      poolv     8
      pool2     8   29   30
      pool3     8
      prefpk   31   47   48
      rcapa    72   73   74   94   95   96
      rcapg    61   62   63   85   86   87
      sov       8   26   27   29   30
      spmina   71   93
      spminf   60   84
      tcapa    71   72   73   93   94   95
      tcapg    60   61   62   84   85   86
      v         8    9   26   29
      va       41   42   43   48   50   68   90
      vap      13   48   50   69   70   74   75   77
      vas      16   50   75   76   78   91   92   96   97   98
      vc       59   61   70   72   83   85   92   94
      vg        9   27   30   41   43   47   49
      vgp      11   47   49   58   59   63   64   66
      vgs      14   49   64   65   67   82   83   87   88   89
      vh       10   26   29   31   32   35
      vhp      12   31   32   33   34   35
      vhs      15   32   35
      vmaxa    71   93
      vmaxg    60   84

integer functions

      int      25

real functions

      vol      60   71   84   93
```

```
1:          Subroutine length(sov,pool2,pool3,poolv,bus,tmcar,tmvan,tmbus
   ,tlave,
2:         1tlsov,tlpl2,tlpl3,tlvan,tlbus)
3:          tlsov=(tlave*(sov+pool2+pool3+poolv+bus)-pool2*tlpl2-pool3*tl
   pl3-poolv*tlplv-bus*tlbus)/sov
4:          tmcar=(sov*tlsov+pool2*tlpl2+pool3*tlpl3)/1000.
5:          tmvan=poolv*tlvan/1000.
6:          tmbus=bus*tlbus/1000.
7:          return
8:          end
```

real variables

```
      bus       3   6
      poolv     3   5
      pool2     3   4
      pool3     3   4
      sov       3   4
      tlave     3
      tlbus     3   6
      tlplv     3
      tlpl2     3   4
      tlpl3     3   4
      tlsov     3   4
      tlvan     5
      tmbus     6
      tmcar     4
      tmvan     5
```

```
 1:        character*80 Function plin(il,ip)
 2:        integer*1 ichl
 3:        lim=79
 4:        if (il.eq.0) lim=75
 5:        do 10 i=0,lim
 6:        call rscp(i,il,ip,ich,natt)
 7:        ichl=ich
 8:     10 call putchr(plin,i+1,ichl)
 9:        return
10:        end
```

subroutines

```
putchr   8
rscp     6
```

integer variables

```
i        5   6   8
ich      6   7
ichl     2   7   8
lim      3   4   5
natt     6
```

character variables

```
il       1   4   6
ip       1   6
```

character arrays

```
plin     1   8
```

```
 1:          Subroutine pout(fcont)
 2:          character*80 plin
 3:          data lenp/66/
 4:          character*40 fcont
 5:          character*50 line
 6:          character*9 time,mon(12),nart
 7:          data mon/"January","February","March","April","May","June",
 8:         1"July","August","September","October","November","December"/
 9:          if (ioread(5,2,0,"plines")) go to 2
10:          read (5,1) lenp
11:        1 format (i0)
12:          if (ioclos(5)) stop
13:        2 call gtime(ih,im,is,ic)
14:          call gdate(month,iday,iy)
15:          line=mon(month)
16:          call addstg(line," ",nart(iday),", ")
17:          call addstg(line,nart(iy))
18:          time=" AM"
19:          if (ih.gt.11) time=" PM"
20:          if (ih.gt.12) ih=ih-12
21:          if (ih.eq.0) ih=12
22:          call addstg(line,"   ",nart(ih),":")
23:          if (im.lt.10) call addstg(line,"0")
24:          call addstg(line,nart(im),time)
25:          write (4,3) line,fcont
26:        3 format (33x,"HOV Cost Model"/28x,a0//1x,a0/)
27:          do 10 i=0,24
28:       10 write (4,20) plin(i,0)
29:       20 format (1x,a0)
30:          do 30 i=2,24
31:       30 write (4,20) plin(i,1)
32:          do 40 i=1,lenp-53
33:       40 write (4,50)
34:       50 format ('  ')
35:          write (4,55) line,fcont
36:       55 format (29x,"HOV Cost Model (cont.)"/28x,a0//1x,a0/)
37:          do 60 i=0,20
38:       60 write (4,20) plin(i,2)
39:          do 70 i=2,8
40:       70 write (4,20) plin(i,3)
41:          write (4,50)
42:          do 80 i=10,24
43:       80 write (4,20) plin(i,3)
44:          do 90 i=1,lenp-49
45:       90 write (4,50)
46:          return
47:          end
```

subroutines

addstg 16 17 22 23 24

```
      gdate    14
      gtime    13

integer variables

      i        27   28   30   31   32   37   38   39   40   42   43   44
      ic       13
      iday     14   16
      ih       13   19   20   21   22
      im       13   23   24
      is       13
      iy       14   17
      lenp     10   32   44
      month    14   15

character variables

      fcont     4   25   35
      line      5   15   16   17   22   23   24   25   35
      time      6   18   19   24

character arrays

      mon       6   15

logical functions

      ioclos   12
      ioread    9

character functions

      nart      6   16   17   22   24
      plin      2   28   31   38   40   43
```

```
      Subroutine sovcal(sov,ptrips,pool2,pool3,poolv,bus)
      sov=ptrips-2.*pool2-3.3*pool3-10.*poolv-45.*bus
      return
      end
```

```
real variables

     bus      2
     poolv    2
     pool2    2
     pool3    2
     ptrips   2
     sov      2
```

```
 1:        Function speed(vol,cap,disp,vmax)
 2:        speed=0.
 3:        if (cap.eq.0.) return
 4:        if (vol.le..8004269*cap) speed=vmax-.06462069*vol*vmax/cap
 5:        if (vol.gt..8004269*cap.and.vol.lt..96051227*cap) speed=
 6:       11.37931*vmax-.53850575*vol*vmax/cap
 7:        if (vol.ge..96051227*cap) speed=
 8:       1.6908621*vmax+.86156925*vmax*sqrt(1.-vol/cap)
 9:        if (disp.ne.0.) speed=
10:       1.6908621*vmax-.86156925*vmax*sqrt(1.-vol/cap)
11:        return
12:        end
```

real variables

cap	1	3	4	5	6	7	8	10
disp	1	9						
vmax	1	4	6	8	10			
vol	1	4	5	6	7	8	10	

real functions

speed	1	2	4	5	7	9
sqrt	8	10				

```
 1:         Subroutine speeds(pspg,sspg,psph,ssph,pspa,sspa,
 2:        1capg,caph,capa,
 3:        2vgp,vhp,vap,vgs,vhs,vas,
 4:        3ngpl,nhov,narts,
 5:        4spminf,spmina,
 6:        5dispg,dispa,dispgs,dispas,
 7:        6avspg,avsph,avspa,vmaxg,vmaxh,vmaxa,spdiff)
 8:         real ngpl,nhov,narts
 9:   c
10:   c        compute speeds
11:   c
12:     100 psph=0.
13:         ssph=0.
14:         pspa=0.
15:         sspa=0.
16:         pspg=speed(vgp/ngpl,capg,dispg,vmaxg)
17:         if (pspg.lt.spminf) pspg=spminf
18:         sspg=speed(vgs/ngpl/2.,capg,dispgs,vmaxg)
19:         if (sspg.lt.spminf) sspg=spminf
20:         if (nhov.eq.0.) go to 110
21:         psph=speed(vhp/nhov,caph,0.,vmaxh)
22:         if (psph-pspg.gt.spdiff) psph=pspg+spdiff
23:         ssph=speed(vhs/nhov/2.,caph,0.,vmaxh)
24:         if (ssph-sspg.gt.spdiff) ssph=sspg+spdiff
25:     110 if (narts.eq.0.) go to 120
26:         pspa=speed(vap/narts,capa,dispa,vmaxa)
27:         if (pspa.lt.spmina) pspa=spmina
28:         sspa=speed(vas/narts/2.,capa,dispas,vmaxa)
29:         if (sspa.lt.spmina) sspa=spmina
30:     120 avspg=vmaxg
31:         if (vgp+vgs.ne.0.) avspg=(vgp*pspg+vgs*sspg)/(vgp+vgs)
32:         avsph=vmaxh
33:         if (vhp+vhs.ne.0.) avsph=(vhp*psph+vhs*ssph)/(vhp+vhs)
34:         avspa=vmaxa
35:         if (vap+vas.ne.0.) avspa=(vap*pspa+vas*sspa)/(vap+vas)
36:         return
37:         end
```

real variables

avspa	34	35		
avspg	30	31		
avsph	32	33		
capa	26	28		
capg	16	18		
caph	21	23		
dispa	26			
dispas	28			
dispg	16			
dispgs	18			
narts	8	25	26	28

ngpl	8	16	18	
nhov	8	20	21	23
pspa	14	26	27	35
pspg	16	17	22	31
psph	12	21	22	33
spdiff	22	24		
spmina	27	29		
spminf	17	19		
sspa	15	28	29	35
sspg	18	19	24	31
ssph	13	23	24	33
vap	26	35		
vas	28	35		
vgp	16	31		
vgs	18	31		
vhp	21	33		
vhs	23	33		
vmaxa	26	28	34	
vmaxg	16	18	30	
vmaxh	21	23	32	

real functions

speed	16	18	21	23	26	28

```
      Subroutine times(nhov,narts,sov,pool2,cpdefn,
     1access,len,tpool,tvan,tbus,
     2pspg,sspg,psph,ssph,pspa,sspa,
     3v,vh,vgp,vhp,vap,vgs,vhs,vas,
     4strip,strips,stript,ctrip,ctrips,ctript,vtrip,vtrips,vtript,btrip,btrips,btript)
      real nhov,narts,len
c
c       compute times
c
      if (nhov.eq.0.) go to 110
      bgp=access+60.*len/pspg
      bgs=access+60.*len/sspg
      bhp=access+60.*len/psph
      bhs=access+60.*len/ssph
      bap=0.
      bas=0.
      if (narts.eq.0.) go to 100
      bap=access+60.*len/pspa
      bas=access+60.*len/sspa
  100 strip=(bgp*vgp+bap*vap)/(vgp+vap)
      strips=(bgs*vgs+bas*vas)/(vgs+vas)
      div=sov
      if (cpdefn.eq.3.) div=sov+pool2
      stript=(strip*(vgp+vap)+strips*(vgs+vas))/div
      ctrip=bhp+tpool
      ctrips=bhs+tpool
      ctript=(ctrip*vhp+ctrips*vhs)/(vhp+vhs)
      vtrip=bhp+tvan
      vtrips=bhs+tvan
      vtript=(vtrip*vhp+vtrips*vhs)/(vhp+vhs)
      btrip=bhp+tbus
      btrips=bhs+tbus
      btript=(btrip*vhp+btrips*vhs)/(vhp+vhs)
      go to 130
  110 bgp=access+60.*len/pspg
      bgs=access+60.*len/sspg
      bap=0.
      bas=0.
      if (narts.eq.0.) go to 120
      bap=access+60.*len/pspa
      bas=access+60.*len/sspa
  120 st=(bgp*vgp+bap*vap)/(vgp+vap)
      strips=(bgs*vgs+bas*vas)/(vgs+vas)
      stript=(strip*(vgp+vap)+strips*(vgs+vas))/(vgp+vap+vgs+vas)
      ctrip=strip+tpool
      ctrips=strips+tpool
      ctript=stript+tpool
      vtrip=strip+tvan
      vtrips=strips+tvan
      vtript=stript+tvan
```

```
51:         btrip=strip+tbus
52:         btrips=strips+tbus
53:         btript=stript+tbus
54:     130 return
55:         end
```

real variables

```
      access  11  12  13  14  18  19  35  36  40  41
      bap     15  18  20  37  40  42
      bas     16  19  21  38  41  43
      bgp     11  20  35  42
      bgs     12  21  36  43
      bhp     13  25  28  31
      bhs     14  26  29  32
      btrip   31  33  51
      btrips  32  33  52
      btript  33  53
      cpdefn  23
      ctrip   25  27  45
      ctrips  26  27  46
      ctript  27  47
      div     22  23  24
      len      6  11  12  13  14  18  19  35  36  40  41
      narts    6  17  39
      nhov     6  10
      pool2   23
      pspa    18  40
      pspg    11  35
      psph    13
      sov     22  23
      sspa    19  41
      sspg    12  36
      ssph    14
      st      42
      strip   20  24  44  45  48  51
      strips  21  24  43  44  46  49  52
      stript  24  44  47  50  53
      tbus    31  32  51  52  53
      tpool   25  26  45  46  47
      tvan    28  29  48  49  50
      vap     20  24  42  44
      vas     21  24  43  44
      vgp     20  24  42  44
      vgs     21  24  43  44
      vhp     27  30  33
      vhs     27  30  33
      vtrip   28  30  48
      vtrips  29  30  49
      vtript  30  50
```

```
Function vol(speed,cap,vmax)
rat=speed/vmax
vol=cap*(.3570128+1.8614055*rat-1.347161*rat**2)
return
end
```

real variables

cap	1	3
rat	2	3
speed	1	2
vmax	1	2

real functions

vol	1	3

APPENDIX C

LISTING OF FORTRAN PROGRAMS FOR THE PARODY MODEL

APPENDIX C - LISTING OF FORTRAN PROGRAMS FOR THE PARODY MODEL

Main program

```
      character*10 a
      real l0b,l0gp,l0hov,l1gp,l1hov
      common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa
     1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
      common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
     1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hovl
      character*40 filn(20)
      integer filnum(20)
      character*8 fil1,fil2,fil3
      character*4 nart
    8 call crsoff
      call vclear
      call print("Pick case for analysis",0,0,14)
      if (ioread(5,2,0,"filelist")) stop
      read (5,2) nfil
    2 format (i0)
      read (5,3) (filnum(i),filn(i),i=1,nfil)
    3 format (i4,a0)
      if (ioclos(5)) stop
      do 4 i=1,nfil
    4 call print(filn(i),0,i+1,7)
      call print ("F1 - delete     F2 - add     F3 - choose     Esc -
exit",0,24,7)
      ia=1
    5 call chatt(0,ia+1,40,15)
      call getd(a,im,if)
      call chatt(0,ia+1,40,7)
      if (im.eq.7) go to 80
      if (if.eq.1) go to 110
      if (if.eq.2) go to 120
      if (if.eq.3) go to 130
      go to (5,11,12,12,11,15,16),im+1
   11 ia=mod(ia+nfil-2,nfil)+1
      go to 5
   12 ia=mod(ia,nfil)+1
      go to 5
   15 ia=1
      go to 5
   16 ia=nfil
      go to 5
  110 nfil=nfil-1
  112 call blnk(0,ia+1,39,ia+1)
      if (ia.le.nfil) go to 111
      ia=nfil
```

```
44:        go to 5
45:    111 filn(ia)=filn(ia+1)
46:        filnum(ia)=filnum(ia+1)
47:        call print(filn(ia),0,ia+1,7)
48:        ia=ia+1
49:        go to 112
50:    120 nfil=nfil+1
51:        call vcurxy(0,nfil+1)
52:        call crson
53:        call geta(filn(nfil),if,im)
54:        call crsoff
55:        filnum(nfil)=filnum(nfil-1)+1
56:        go to 5
57:    130 fil1="dat1"
58:        call addstg(fil1,nart(filnum(ia)))
59:        fil2="dat2"
60:        call addstg(fil2,nart(filnum(ia)))
61:        fil3="dat3"
62:        call addstg(fil3,nart(filnum(ia)))
63:        if (iowrit(5,2,0,"filelist")) stop
64:        write (5,131) nfil
65:    131 format (1x,i2)
66:        write (5,132) (filnum(i),filn(i),i=1,nfil)
67:    132 format (1x,i4,a0)
68:        if (ioclos(5)) stop
69:        next=1
70:      1 go to (1,10,20,30,40,50,60,70,8),next+1
71:     10 call wks1(next,fil1)
72:        go to 1
73:     20 call wks2(next,fil2)
74:        go to 1
75:     30 call wks3(next,fil3)
76:        go to 1
77:     40 call wks4(next)
78:        go to 1
79:     50 call wks5(next)
80:        go to 1
81:     60 call wks6(next)
82:        go to 1
83:     70 call wks7(next)
84:        go to 1
85:     80 call crson
86:        call vclear
87:        stop
88:        end
```

subroutines

addstg	58	60	62
blnk	41		
chatt	24	26	

```
       crsoff  11  54
       crson   52  85
       geta    53
       getd    25
       print   13  21  22  47
       vclear  12  86
       vcurxy  51
       wks1    71
       wks2    73
       wks3    75
       wks4    77
       wks5    79
       wks6    81
       wks7    83

integer variables

       i       17  20  21  66
       ia      23  24  26  32  34  36  38  41  42  43  45  46  47  48  58
               60  62
       im      25  27  31  53
       next    69  70  71  73  75  77  79  81  83
       nfil    15  17  20  32  34  38  40  42  43  50  51  53  55  64  66

real variables

       l0b      2
       l0gp     2
       l0hov    2
       l1gp     2
       l1hov    2

character variables

       a        1  25
       fil1     9  57  58  71
       fil2     9  59  60  73
       fil3     9  61  62  75

integer arrays

       filnum   8  17  46  55  58  60  62  66

character arrays

       filn     7  17  21  45  47  53  66

integer functions

       mod     32  34
```

logical functions

```
ioclos  19  68
ioread  14
iowrit  63
```

character functions

```
nart    10  58  60  62
```

```
      Subroutine wks1(next,fill)
      real l0b,l0gp,l0hov,l1gp,l1hov
      common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa,
     1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
      common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
     1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hovl
      real inp(18)
      integer locy(18),form(18)
      data locy/2,3,4,5,6,7,9,11,12,13,14,16,17,18,20,21,22,23/
      data form/-1,-1,-1,-1,-1,-1,-1,1,1,1,1,1,1,1,-1,-1,-1,-1/
      logical clean
      character*8 fill
      character*10 snart,a
      next=2
      if (ioread(5,2,0,fill)) go to 1
      read (5,2) (inp(i),i=1,18)
    2 format (f0.0)
      if (ioclos(5)) stop
    1 v0npa=inp(1)
      v0pa=inp(2)
      v0hov=inp(3)
      b0peb=inp(4)
      b0hov=inp(5)
      v0b=inp(6)
      v0t=inp(7)
      t0npa=inp(8)
      t0pa=inp(9)
      t0hov=inp(10)
      t0b=inp(11)
      s0gp=inp(12)
      s0c=inp(13)
      s0b=inp(14)
      l0gp=inp(15)
      l0hov=inp(16)
      c0gp=inp(17)
      c0hov=inp(18)
      if (im.eq.7) go to 100
      call vclear
      call print("Worksheet 1: Baseline Data",0,0,14)
      call print("Volumes(peak-hour)",0,1,7)
      call print(". Automobiles, nonpriority",5,2,7)
      call print(". Automobiles, priority-eligible",5,3,7)
      call print(". Carpools on HOV lanes",5,4,7)
      call print(". Buses, priority eligible",5,5,7)
      call print(". Buses on HOV lane(s)",5,6,7)
      call print(". Bus passengers (HOV or priority eligible)",5,7,7)
      call print(". Bus load factor",5,8,7)
      call print(". Trucks",5,9,7)
      call print("Total Travel Time(peak-hour)",0,10,7)
```

```
      call print(". Automobiles, nonpriority",5,11,7)
      call print(". Automobiles, priority eligible",5,12,7)
      call print(". Carpools on HOV lane(s)",5,13,7)
      call print(". Buses (HOV or priority eligible)",5,14,7)
      call print("Speed (average per hour)",0,15,7)
      call print(". General purpose lane(s)",5,16,7)
      call print(". HOV lane(s) - Carpools",5,17,7)
      call print(". HOV lane(s) - Buses",5,18,7)
      call print("Existing Supply/Capacity",0,19,7)
      call print(". No. of general purpose lanes",5,20,7)
      call print(". No. of HOV lanes",5,21,7)
      call print(". Capacity, general purpose lanes",5,22,7)
      call print(". Capacity, HOV lanes",5,23,7)
      do 10 i=1,18
   10 call print(snart(inp(i),10,form(i)),50,locy(i),7)
      l0b=0.
      buses=b0peb
      if (buses.eq.0.) buses=b0hov
      if (buses.ne.0.) l0b=v0b/buses
      call print(snart(l0b,10,1),50,8,13)
      ia=1
   20 call chatt(5,locy(ia),60,15)
      call vcurxy(50,locy(ia))
      call geta(a,im,if)
      call chatt(5,locy(ia),60,7)
      if (if.ge.21.and.if.le.22) go to 99
      if (if.gt.0) go to 20
      go to (30,31,33,33,31,35,36,1),im+1
   30 if (a.eq."") go to 33
      if (.not.clean(a,nd)) go to 20
      inp(ia)=tran(a)
      call print(snart(inp(ia),10,form(ia)),50,locy(ia),7)
      l0b=0.
      v0b=inp(6)
      b0hov=inp(5)
      b0peb=inp(4)
      buses=b0peb
      if (buses.eq.0.) buses=b0hov
      if (buses.ne.0.) l0b=v0b/buses
      call print(snart(l0b,10,1),50,8,13)
      go to 33
   31 ia=mod(ia+16,18)+1
      go to 20
   33 ia=mod(ia,18)+1
      go to 20
   35 ia=1
      go to 20
   36 ia=18
      go to 20
   99 next=if-20
  100 if (iowrit(5,2,0,fill)) stop
```

```
101:          write (5,110) (inp(i),i=1,18)
102:      110 format (f10.1)
103:          if (ioclos(5)) stop
104:          im=0
105:          return
106:          end
```

subroutines

```
      chatt   71  74
      geta    73
      print   39  40  41  42  43  44  45  46  47  48  49  50  51  52  53
              54  55  56  57  58  59  60  61  62  64  69  81  89
      vclear  38
      vcurxy  72
```

integer variables

```
      i       16  63  64 101
      ia      70  71  72  74  80  81  91  93  95  97
      im      37  73  77 104
      nd      79
      next    14  99
```

real variables

```
      buses   66  67  68  86  87  88
      b0hov   23  67  84  87
      b0peb   22  66  85  86
      c0gp    35
      c0hov   36
      l0b      2  65  68  69  82  88  89
      l0gp     2  33
      l0hov    2  34
      l1gp     2
      l1hov    2
      s0b     32
      s0c     31
      s0gp    30
      t0b     29
      t0hov   28
      t0npa   26
      t0pa    27
      v0b     24  68  83  88
      v0hov   21
      v0npa   19
      v0pa    20
      v0t     25
```

character variables

```
      a        13   73   78   79   80
      fill     12   15  100

integer arrays

      form      8   64   81
      locy      8   64   71   72   74   81

real arrays

      inp       7   16   19   20   21   22   23   24   25   26   27   28   29   30   31
               32   33   34   35   36   64   80   81   83   84   85  101

integer functions

      mod      91   93

real functions

      tran     80

logical functions

      clean    11   79
      ioclos   18  103
      ioread   15
      iowrit  100

character functions

      snart    13   64   69   81   89
```

```
      Subroutine wks2(next,fil2)
      real l0b,l0gp,l0hov,l1gp,l1hov
      common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa,
     1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
      common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
     1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hovl
      common/c4/pooldf
      common/c6/hovalt
      real inp(6)
      integer locy(6),form(6)
      data locy/4,8,9,10,11,12/
      data form/1,-1,-1,-1,-1,-1/
      integer hovalt,pooldf
      data hovalt,pooldf/1,0/
      logical clean
      character*8 fil2
      character*10 snart,a,nart
      iasave=0
      if (ioread(5,2,0,fil2)) go to 2
      read (5,3) (inp(i),i=1,6)
    3 format (f0.0)
      read (5,4) hovalt,pooldf
    4 format (2i1)
      if (ioclos(5)) stop
    2 ia=1
      call vclear
      call print("Worksheet 2: HOV policy and initial calculations",0,0,14)
      call print("HOV alternative:",0,2,7)
      call print("  (change w/F1)",0,3,7)
      call print("Bus only",21,2,15-4*hovalt)
      call print("Bus and Carpool (Carpool size:  +)",21,3,3+4*hovalt)
      call print("X",18,1+hovalt,11)
      call print("HOV length:",0,4,7)
      call print("Proposed supply/capacity",0,6,7)
      call print(". No. of general purpose lanes",5,8,7)
      call print(". No. of HOV lanes",5,9,7)
      call print(". Capacity, general purpose lanes",5,10,7)
      call print(". Capacity, HOV lanes",5,11,7)
      call print(". Buses per hour (exogenous)",5,12,7)
      call print("Existing travel times (over highway bounded by HOV lanes)",0,14,7)
      call print(". Automobiles, nonpriority",5,16,7)
      call print(". Automobiles, priority eligible",5,17,7)
      call print(". Buses (HOV or priority eligible)",5,18,7)
      call print("Existing travel times (off highway bounded by HOV lanes)",0,20,7)
      call print(". Automobiles, nonpriority",5,22,7)
      call print(". Automobiles, priority eligible",5,23,7)
```

```
      call print(". Buses (HOV or priority eligible)",5,24,7)
      if (pooldf.gt.0) call print(nart(pooldf+1),52,3,11)
    1 hovl=inp(1)
      llgp=inp(2)
      llhov=inp(3)
      clgp=inp(4)
      clhov=inp(5)
      blhov=inp(6)
      do 10 i=1,6
   10 call print(snart(inp(i),10,form(i)),50,locy(i),7)
      t1=0.
      t2=0.
      t3=0.
      if (s0gp.eq.0.) go to 20
      t1=hovl*60./s0gp
      t2=t1
      t3=t1
      if (s0b.ne.0.) t3=hovl*60./s0b
      toffnp=t0npa-t1
      toffpa=t0pa-t2
      toffb=t0b-t3
   20 call print(snart(t1,10,1),50,16,13)
      call print(snart(t2,10,1),50,17,13)
      call print(snart(t3,10,1),50,18,13)
      call print(snart(toffnp,10,1),50,22,13)
      call print(snart(toffpa,10,1),50,23,13)
      call print(snart(toffb,10,1),50,24,13)
      next=3
   30 if (iasave.gt.0) ia=iasave
      iasave=0
      call chatt(0,locy(ia),60,15)
      call vcurxy(50,locy(ia))
      call geta(a,im,if)
      call chatt(0,locy(ia),60,7)
      go to (31,35,33,33,35,36,37,38),im+1
   31 if (a.ne."") go to 32
      if (a.eq."".and.if.eq.0) go to 33
      if (if.eq.1) go to 130
      if (if.lt.21.or.if.gt.23) go to 30
      next=if-20
      go to 38
  130 go to (131,131,132,133,134),hovalt+pooldf
  131 hovalt=2
      pooldf=1
      call chatt(21,2,15,7)
      call chatt(21,3,50,11)
      call blnk(18,2,18,2)
      call print("X",18,3,11)
      go to 135
  132 pooldf=2
      go to 135
```

```
 98:     133 pooldf=3
 99:     135 call print (nart(pooldf+1),52,3,11)
100:         go to 30
101:     134 call blnk(52,3,52,3)
102:         call chatt(21,3,40,7)
103:         call blnk(18,3,18,3)
104:         call print("X",18,2,11)
105:         pooldf=0
106:         hovalt=1
107:         call chatt(21,2,15,11)
108:         go to 30
109:      32 if (.not.clean(a,nd)) go to 30
110:         inp(ia)=tran(a)
111:         call print(snart(inp(ia),10,form(ia)),50,locy(ia),7)
112:         if (ia.eq.1) iasave=2
113:         if (ia.eq.1) go to 1
114:      33 ia=mod(ia,6)+1
115:         go to 30
116:      35 ia=mod(ia+4,6)+1
117:         go to 30
118:      36 ia=1
119:         go to 30
120:      37 ia=6
121:         go to 30
122:      38 if (iowrit(5,2,0,fil2)) stop
123:         write (5,100) (inp(i),i=1,6)
124:     100 format (f10.1)
125:         write (5,101) hovalt,pooldf
126:     101 format (1x,2i1)
127:         hovl=inp(1)
128:         llgp=inp(2)
129:         llhov=inp(3)
130:         clgp=inp(4)
131:         clhov=inp(5)
132:         blhov=inp(6)
133:         if (ioclos(5)) stop
134:         return
135:         end
```

subroutines

```
     blnk    93 101 103
     chatt   77  80  91  92 102 107
     geta    79
     print   27  28  29  30  31  32  33  34  35  36  37  38  39  40  41
             42  43  44  45  46  47  48  56  68  69  70  71  72  73  94
             99 104 111
     vclear  26
     vcurxy  78
```

integer variables

```
      hovalt  13  22  30  31  32  88  89 106 125
      i       20  55  56 123
      ia      25  75  77  78  80 110 111 112 113 114 116 118 120
      iasave  18  75  76 112
      im      79  81
      nd     109
      next    74  86
      pooldf  13  22  48  88  90  96  98  99 105 125

real variables

      blhov   54 132
      clgp    52 130
      clhov   53 131
      hovl    49  61  64 127
      l0b      2
      l0gp     2
      l0hov    2
      l1gp     2  50 128
      l1hov    2  51 129
      s0b     64
      s0gp    60  61
      toffb   67  73
      toffnp  65  71
      toffpa  66  72
      t0b     67
      t0npa   65
      t0pa    66
      t1      57  61  62  63  65  68
      t2      58  62  66  69
      t3      59  63  64  67  70

character variables

      a       17  79  82  83 109 110
      fil2    16  19 122

integer arrays

      form    10  56 111
      locy    10  56  77  78  80 111

real arrays

      inp      9  20  49  50  51  52  53  54  56 110 111 123 127 128 129
             130 131 132

integer functions

      mod    114 116
```

```
real functions

      tran   110

logical functions

      clean   15 109
      ioclos  24 133
      ioread  19
      iowrit 122

character functions

      nart    17  48  99
      snart   17  56  68  69  70  71  72  73 111
```

```
      Subroutine wks3(next,fil3)
      real l0b,l0gp,l0hov,l1gp,l1hov
      common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa,
     1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
      common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
     1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hov1
      common/c3/genlan
      common/c5/s1hov
      integer buson,autoon,genlan
      data buson,autoon,genlan/1,1,1/
      character*10 a,snart
      character*8 fil3
      if (ioread(5,2,0,fil3)) go to 3
      read(5,2) buson,autoon,genlan
    2 format (3i1)
      if (ioclos(5)) stop
    3 next=4
      call vclear
      call print("Worksheet 3: Estimate travel times - forecast period",0,0,14)
      call print("Buses on or eligible to use HOV lanes (F1 to change)",0,2,7)
      call print("Buses already on HOV",11,4,15-4*buson)
      call print("Buses will be eligible to use HOV",11,5,3+4*buson)
      call print("HOV bus travel time =",5,7,7)
      call print("Autos on or eligible to use HOV lanes (F2 to change)",0,9,7)
      call print("Autos already on HOV",11,11,15-4*autoon)
      call print("Autos will be eligible to use HOV",11,12,3+4*autoon)
      call print("HOV auto travel time =",5,14,7)
      call print("Autos on general purpose lanes (F3 to change)",0,16,7)
      call print("Capacity reduction or bus only lane",11,18,15-4*genlan)
      call print("Capacity same and carpools granted priority",11,19,3+4*genlan)
      call print("general lane travel speed =",5,21,7)
      call print("general lane travel time =",5,22,7)
      call print("eligibility factor =",5,24,7)
    1 call blnk(5,4,5,5)
      call blnk(5,11,5,12)
      call blnk(5,18,5,19)
      call chatt(11,6-buson,45,7)
      call chatt(11,13-autoon,45,7)
      call chatt(11,20-genlan,45,7)
      call print("X",5,3+buson,11)
      call print("X",5,10+autoon,11)
      call print("X",5,17+genlan,11)
```

```
43:          call chatt(11,3+buson,45,11)
44:          call chatt(11,10+autoon,45,11)
45:          call chatt(11,17+genlan,45,11)
46:          if (slhov.lt.0.) go to 7
47:          if (s0b.gt.0.) slhov=s0b
48:          if (s0b.eq.0.) slhov=55.
49:        7 if (slhov.lt.0.) slhov=-slhov
50:          tlb=t0b
51:          if (buson.eq.2) tlb=toffb+hovl*60./slhov
52:          tlpa=t0hov
53:          if (autoon.eq.2) tlpa=toffpa+hovl*60./slhov
54:          tlnpa=t0npa
55:          if (slgp.lt.0.) go to 4
56:          slgp=s0gp
57:          if (genlan.eq.1) go to 5
58:          slgp=60./(1.+((v0npa+v0pa)/clgp)**15)
59:          speed=s0c
60:          if (s0c.eq.0) speed=s0b
61:          if (slgp.gt.speed.and.speed.ne.0.) slgp=speed
62:        4 if (slgp.lt.0.) slgp=-slgp
63:          tlnpa=toffnp+hovl*60./slgp
64:        5 efctr=llgp*(v0npa+v0pa+2.*b0peb)/l0gp/v0npa
65:          call print(snart(tlb,10,1),26,7,13)
66:          call print(snart(tlpa,10,1),27,14,13)
67:          call print(snart(slgp,10,1),33,21,13)
68:          call print(snart(tlnpa,10,1),32,22,13)
69:          call print(snart(efctr,10,3),26,24,13)
70:       10 call getd(a,im,if)
71:          if (im.eq.7) go to 20
72:          if (if.eq.0) go to 10
73:          if (if.eq.1) buson=3-buson
74:          if (if.eq.2) autoon=3-autoon
75:          if (if.eq.3) genlan=3-genlan
76:          if (if.lt.4) go to 1
77:          if (if.lt.21.or.if.gt.24) go to 10
78:          next=if-20
79:       20 if (iowrit(5,2,0,fil3)) stop
80:          write (5,30) buson,autoon,genlan
81:       30 format (1x,3i1)
82:          if (ioclos(5)) stop
83:          return
84:          end
```

subroutines

blnk	34	35	36												
chatt	37	38	39	43	44	45									
getd	70														
print	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	40	41	42	65	66	67	68	69							
vclear	18														

integer variables

autoon	9	14	25	26	38	41	44	53	74	80
buson	9	14	21	22	37	40	43	51	73	80
genlan	9	14	29	30	39	42	45	57	75	80
im	70	71								
next	17	78								

real variables

b0peb	64						
c1gp	58						
efctr	64	69					
hovl	51	53	63				
l0b	2						
l0gp	2	64					
l0hov	2						
l1gp	2	64					
l1hov	2						
speed	59	60	61				
s0b	47	48	60				
s0c	59	60					
s0gp	56						
s1gp	55	56	58	61	62	63	67
s1hov	46	47	48	49	51	53	
toffb	51						
toffnp	63						
toffpa	53						
t0b	50						
t0hov	52						
t0npa	54						
t1b	50	51	65				
t1npa	54	63	68				
t1pa	52	53	66				
v0npa	58	64					
v0pa	58	64					

character variables

a	11	70	
fil3	12	13	79

logical functions

ioclos	16	82
ioread	13	
iowrit	79	

character functions

snart 11 65 66 67 68 69

```
      Subroutine wks4(next)
      real l0b,l0gp,l0hov,l1gp,l1hov
      common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa,
     1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
      common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
     1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hovl
      common/c3/genlan
      common/c4/pooldf
      character*10 snart,a
      integer genlan,pooldf
      next=5
      call vclear
      call print ("Worksheet 4: Forecast nonpriority auto volume",0,0,14)
      call print ("new volume =",5,2,7)
      call print ("new v/c ratio =",5,4,7)
   10 coeff=1.19
      if (pooldf.ge.2) coeff=.122
      delta=-.916-1.053*(t1npa/t0npa-1.)+coeff*(t1pa/t0pa-1.)+.278*(t1b/t0b-1.)+.949*efctr
      v1npa=(1.+delta)*v0npa
      call print (snart(v1npa,10,-1),17,2,13)
      if (genlan.ne.1) go to 20
   14 call print("force flow conditions,",5,6,10)
      call print("go to worksheet 5",5,7,10)
      call blnk(5,4,50,4)
   15 call getd(a,im,if)
      if (im.eq.7) return
      if (if.ge.21.and.if.le.25) go to 50
      go to 15
   20 vc=v1npa/c1gp
      call print(snart(vc,10,2),20,4,13)
      if (vc.ge.1.) go to 30
      s1new=60./(1.+vc**15)
      if (abs(s1new/s1gp-1.).lt..1) go to 25
      call print("has not reached equilibrium,",5,6,12)
      call print("repeat worksheet 3",5,7,12)
      next=3
      s1gp=-s1new
   22 call getd(a,im,if)
      if (im.eq.7) return
      if (if.ge.21.and.if.le.25) go to 50
      go to 22
   25 call print("equilibrium achieved,",5,6,10)
      call print("go to worksheet 5",5,7,10)
   26 call getd(a,im,if)
      if (im.eq.7) return
      if (if.ge.21.and.if.le.25) go to 50
      go to 26
   30 call print("v/c > 1, use force flow conditions,",5,6,12)
```

```
49:          call print("repeat worksheet 4 (hit any key),",5,7,12)
50:       32 call get(i1,i2)
51:          call blnk(5,6,60,7)
52:       35 t1npa=t0npa
53:          s1gp=s0gp
54:          genlan=1
55:          go to 10
56:       50 next=if-20
57:          return
58:          end
```

subroutines

blnk	24	51											
get	50												
getd	25	38	44										
print	13	14	15	20	22	23	30	34	35	42	43	48	49
vclear	12												

integer variables

genlan	10	21	54			
im	25	26	38	39	44	45
i1	50					
i2	50					
next	11	36	56			
pooldf	10	17				

real variables

coeff	16	17	18	
c1gp	29			
delta	18	19		
efctr	18			
l0b	2			
l0gp	2			
l0hov	2			
l1gp	2			
l1hov	2			
s0gp	53			
s1gp	33	37	53	
s1new	32	33	37	
t0b	18			
t0npa	18	52		
t0pa	18			
t1b	18			
t1npa	18	52		
t1pa	18			
vc	29	30	31	32
v0npa	19			
v1npa	19	20	29	

```
character variables

      a         9   25   38   44

real functions

      abs      33

character functions

      snart     9   20   30
```

```
      Subroutine wks5(next)
      real l0b,l0gp,l0hov,l1gp,l1hov
      common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa,
     1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
      common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
     1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hovl
      common/c4/pooldf
      common/c5/s1hov
      character*10 snart,a
      integer pooldf
      next=6
      call vclear
      call print("Worksheet 5: Forecast priority auto volume",0,0,14)
      call print("priority auto volume =",5,2,7)
      call print("total carpools on HOV lane =",5,4,7)
      if (pooldf.eq.1) go to 10
      delpa=-.203-7.7*(t1pa/t0pa-1.)+4.8*(t1b/t0b-1.)
      v1pa=v0pa*(1.+delpa)
      v1hov=v1pa
      go to 20
   10 if (t0hov.eq.0.) go to 15
      delhov=-.203-7.7*(t1pa/t0hov-1.)+4.8*(t1b/t0b-1.)
      delpa=-.203-6.7*(t1pa/t0pa-1.)+4.8*(t1b/t0b-1.)
      v1pa=v0pa*(1.+delpa)
      v1hov=v1pa+v0hov*(1.+delhov)
      go to 20
   15 delpa=-.203-6.7*(t1pa/t0pa-1.)+4.8*(t1b/t0b-1.)
      v1pa=v0pa*(1.+delpa)
      v1hov=v1pa
   20 call print(snart(v1pa,10,-1),28,2,13)
      call print(snart(v1hov,10,-1),34,4,13)
      buses=b0hov
      if (buses.eq.0.) buses=b0peb
      vc=(v1hov+buses)/c1hov
      call print ("v/c ratio =",5,6,7)
      call print(snart(vc,10,2),17,6,13)
      if (vc.gt..8) go to 30
      call print ("level of service on HOV lanes OK",5,8,10)
      call print ("go to worksheet 6",5,9,10)
      go to 40
   30 call print ("level of service on HOV lanes insufficient",5,8,12)
      call print ("repeat worksheet 3 using revised speed",5,9,12)
      s1hov=60./(1+vc**15)
      if (s1hov.lt.s1gp) s1hov=s1gp
      s1hov=-s1hov
      next=3
   40 call getd (a,im,if)
      if (im.eq.7) return
```

```
49:         if (if.lt.21.or.if.gt.26) go to 40
50:         next=if-20
51:         return
52:         end
```

subroutines

getd	47										
print	13	14	15	30	31	35	36	38	39	41	42
vclear	12										

integer variables

im	47	48	
next	11	46	50
pooldf	10	16	

real variables

buses	32	33	34				
b0hov	32						
b0peb	33						
c1hov	34						
delhov	22	25					
delpa	17	18	23	24	27	28	
l0b	2						
l0gp	2						
l0hov	2						
l1gp	2						
l1hov	2						
s1gp	44						
s1hov	43	44	45				
t0b	17	22	23	27			
t0hov	21	22					
t0pa	17	23	27				
t1b	17	22	23	27			
t1pa	17	22	23	27			
vc	34	36	37	43			
v0hov	25						
v0pa	18	24	28				
v1hov	19	25	29	31	34		
v1pa	18	19	24	25	28	29	30

character variables

a	9	47

character functions

snart	9	30	31	36

```
      Subroutine wks6(next)
      real l0b,l0gp,l0hov,l1gp,l1hov
      common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa,
     1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
      common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
     1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hovl
      common/c4/pooldf
      common/c6/hovalt
      integer pooldf,hovalt,busopt
      character*10 a,snart
      if (hovalt.eq.1.and.b1hov.eq.0.) busopt=1
      if (hovalt.eq.1.and.b1hov.ne.0.) busopt=2
      if (hovalt.eq.2.and.pooldf.eq.1) busopt=4
      if (hovalt.eq.2.and.pooldf.gt.1) busopt=3
      next=7
      call vclear
      call print("Worksheet 6: Forecast priority bus volume",0,0,14)
      call print("Bus options",0,2,7)
      call print("     Bus only on HOV lane (bus supply determined endogenously)",5,4,7)
      call print("     Bus only on HOV lane (bus supply determined exogenously)",5,5,7)
      call print("     Buses and 3+ or 4+ person carpools on HOV lane",5,6,7)
      call print("     Buses and 2+ person carpools on HOV lane",5,7,7)
      call print("Priority bus passenger volume =",5,9,7)
      call print("Priority bus volume =",5,11,7)
    1 call blnk(5,4,5,7)
      call print("X",5,3+busopt,11)
      call chatt(10,3+busopt,60,11)
      go to (10,20,30,40),busopt
   10 delb=-1.404*(t1b/t0b-1.)
      go to 50
   20 delb=0.
      if (b0peb.ne.0.) delb=-.308*(t1b/t0b-1.)+.422*(b1hov/b0peb-1.)
      go to 50
   30 delb=.227+.435*(t1pa/t0pa-1.)
      go to 50
   40 delb=.227+1.71*(t1pa/t0pa-1.)
   50 v1b=v0b*(1.+delb)
      if (busopt.eq.2) go to 55
      if (b1hov.eq.0.) b1hov=v1b/l0b
   55 call print(snart(v1b,10,-1),37,9,13)
      call print(snart(b1hov,10,-1),27,11,13)
   60 call print("go to worksheet 7",5,13,10)
   61 call getd(a,im,if)
      if (if.ge.21.and.if.le.27) go to 70
```

```
45:           if (im.eq.7) return
46:           go to 61
47:        70 next=if-20
48:           return
49:           end
```

```
subroutines

      blnk    25
      chatt   27
      getd    43
      print   17  18  19  20  21  22  23  24  26  40  41  42
      vclear  16

integer variables

      busopt   9  11  12  13  14  26  27  28  38
      hovalt   9  11  12  13  14
      im      43  45
      next    15  47
      pooldf   9  13  14

real variables

      b0peb   32
      b1hov   11  12  32  39  41
      delb    29  31  32  34  36  37
      l0b      2  39
      l0gp     2
      l0hov    2
      l1gp     2
      l1hov    2
      t0b     29  32
      t0pa    34  36
      t1b     29  32
      t1pa    34  36
      v0b     37
      v1b     37  39  40

character variables

      a       10  43

character functions

      snart   10  40  41
```

```
      Subroutine wks7(next)
      real l0b,l0gp,l0hov,l1gp,l1hov
      common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa
,
     1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
      common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
     1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hovl
      character*10 a,snart
      character*16 type
      character*1 nart
      common/c4/pooldf
      integer pooldf
      common/c5/s1hov
      type="("
      call addstg(type,nart(pooldf+1),"+ occupants)")
      next=8
      call vclear
      call print("Worksheet 7: Summary results",0,0,14)
      call print("Volumes (peak-hour)",0,2,7)
      call print(". Automobiles, nonpriority",5,4,7)
      call print(". Carpools",5,5,7)
      call print(type,16,5,7)
      call print(". Buses",5,6,7)
      call print(". Bus passengers",5,7,7)
      call print("Total travel time (peak-hour)",0,9,7)
      call print(". Automobiles, nonpriority",5,11,7)
      call print(". Carpools",5,12,7)
      call print(type,16,12,7)
      call print(". Buses",5,13,7)
      call print("Speeds (average peak hour)",0,15,7)
      call print(". General purpose lane(s)",5,17,7)
      call print(". HOV lane(s)",5,18,7)
      call print("Person-trips (peak hour)",0,20,7)
      call print("    Before",40,1,7)
      call print("     After",50,1,7)
      call print("  % change",60,1,7)
      call print(snart(v1npa,10,-1),50,4,13)
      call print(snart(v1hov,10,-1),50,5,13)
      call print(snart(b1hov,10,-1),50,6,13)
      call print(snart(v1b,10,-1),50,7,13)
      call print(snart(t1npa,10,1),50,11,13)
      call print(snart(t1pa,10,1),50,12,13)
      call print(snart(t1b,10,1),50,13,13)
      call print(snart(s1gp,10,1),50,17,13)
      call print(snart(s1hov,10,1),50,18,13)
      call print(snart(v0npa,10,-1),40,4,13)
      call print(snart(v0hov+v0pa,10,-1),40,5,13)
      call print(snart(b0hov+b0peb,10,-1),40,6,13)
      call print(snart(v0b,10,-1),40,7,13)
      call print(snart(t0npa,10,1),40,11,13)
      call print(snart(t0pa,10,1),40,12,13)
```

```
51:          call print(snart(t0b,10,1),40,13,13)
52:          call print(snart(s0gp,10,1),40,17,13)
53:          call print(snart(s0hov,10,1),40,18,13)
54:          if (pooldf.eq.1) facnpa=1.
55:          if (pooldf.eq.2) facnpa=1.1
56:          if (pooldf.eq.3) facnpa=1.3
57:          if (pooldf.eq.1) facpa=2.3
58:          if (pooldf.eq.2) facpa=3.8
59:          if (pooldf.eq.3) facpa=5.0
60:          perbef=v0npa*facnpa+(v0hov+v0pa)*facpa+v0b+v0t
61:          peraft=v1npa*facnpa+v1hov*facpa+v1b+v0t
62:          call print(snart(perbef,10,-1),40,20,13)
63:          call print(snart(peraft,10,-1),50,20,13)
64:          call perprn(v1npa,v0npa,4)
65:          call perprn(v1hov,v0hov+v0pa,5)
66:          call perprn(b1hov,b0hov+b0peb,6)
67:          call perprn(v1b,v0b,7)
68:          call perprn(t1npa,t0npa,11)
69:          call perprn(t1pa,t0pa,12)
70:          call perprn(t1b,t0b,13)
71:          call perprn(s1gp,s0gp,17)
72:          call perprn(s1hov,s0hov,18)
73:          call perprn(peraft,perbef,20)
74:       10 call getd(a,im,if)
75:          if (im.eq.7) return
76:          if (if.lt.21.or.if.gt.28) go to 10
77:          next=if-20
78:          return
79:          end
```

subroutines

addstg	14														
getd	74														
perprn	64	65	66	67	68	69	70	71	72	73					
print	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
	47	48	49	50	51	52	53	62	63						
vclear	16														

integer variables

im	74	75						
next	15	77						
pooldf	11	14	54	55	56	57	58	59

real variables

b0hov	47	66
b0peb	47	66
b1hov	38	66

facnpa	54	55	56	60	61
facpa	57	58	59	60	61
l0b	2				
l0gp	2				
l0hov	2				
l1gp	2				
l1hov	2				
peraft	61	63	73		
perbef	60	62	73		
s0gp	52	71			
s0hov	53	72			
s1gp	43	71			
s1hov	44	72			
t0b	51	70			
t0npa	49	68			
t0pa	50	69			
t1b	42	70			
t1npa	40	68			
t1pa	41	69			
v0b	48	60	67		
v0hov	46	60	65		
v0npa	45	60	64		
v0pa	46	60	65		
v0t	60	61			
v1b	39	61	67		
v1hov	37	61	65		
v1npa	36	61	64		

character variables

a	7	74			
type	8	13	14	21	27

character functions

nart	9	14												
snart	7	36	37	38	39	40	41	42	43	44	45	46	47	48	49
	50	51	52	53	62	63								