An Evaluation of the Cost Effectiveness of HOV Lanes

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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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TECHNICAL REPORT

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 average 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.

Development Opportunities

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.

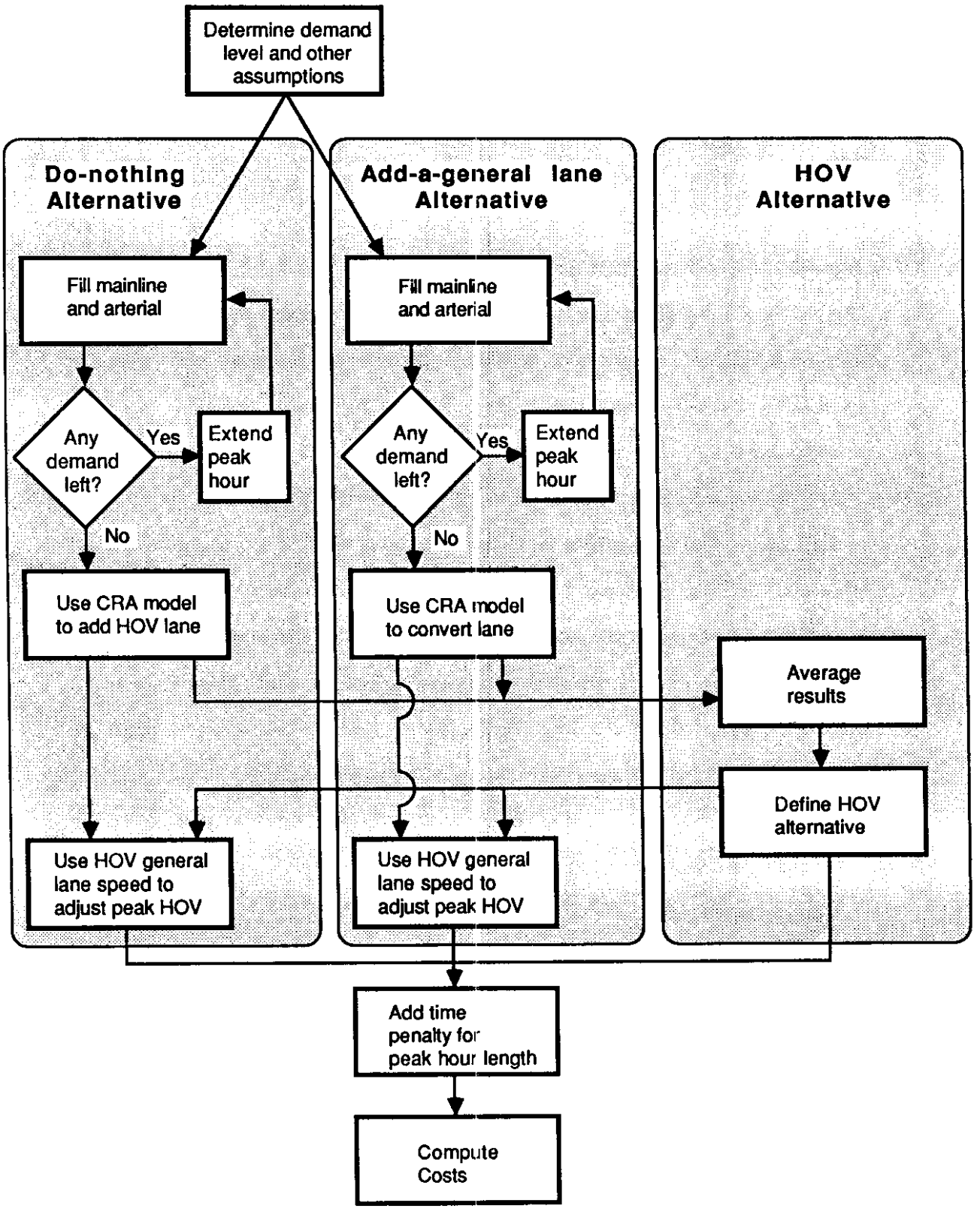

Figure 1. Forecast Method.

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.

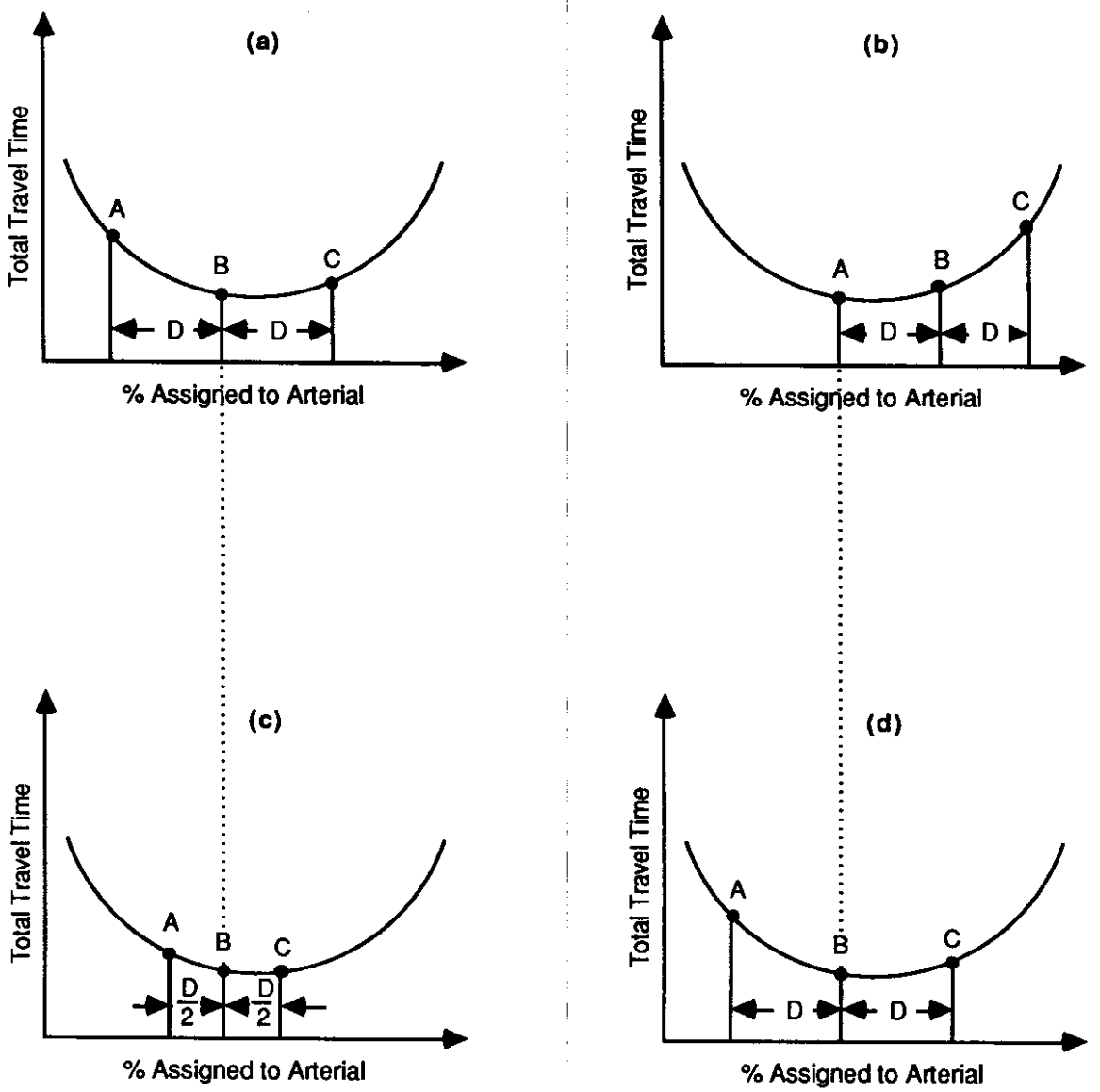

Figure 2. Optimization of Route Distribution.

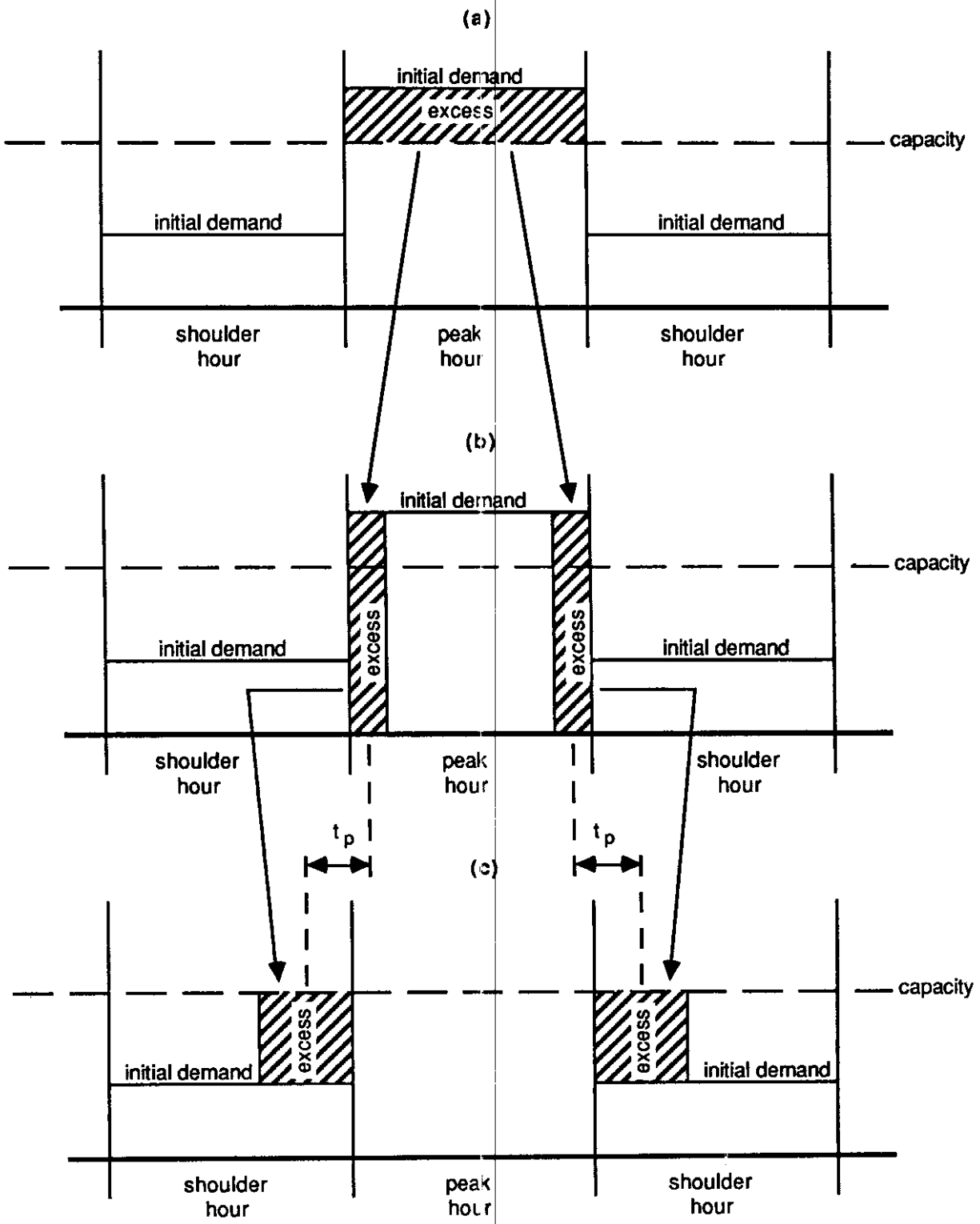

Figure 3. Computation of Time Penalty (t_p) for Vehicles Displaced Outside Peak Hour.

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,

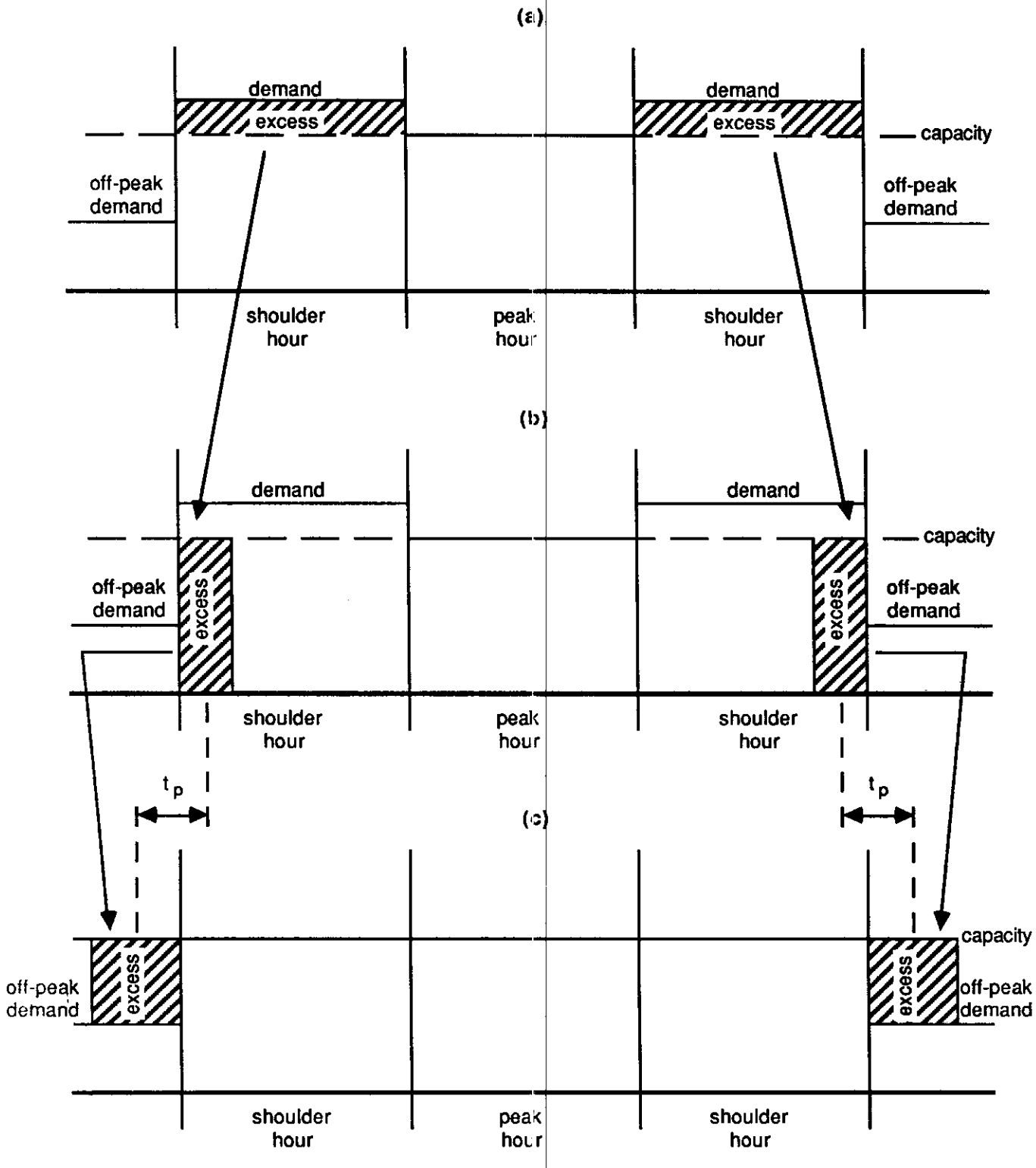

Figure 4. Computation of Time Penalty (t_p) for Vehicles Displaced Outside Peak Period.

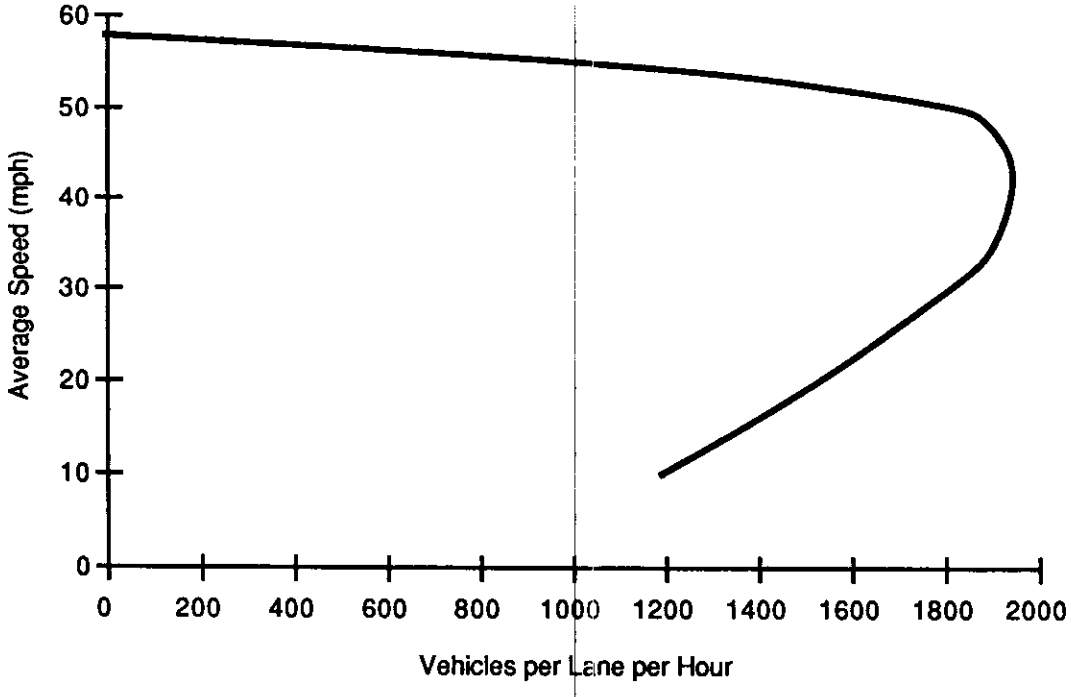

Figure 5. Speed-Flow Curve for I-5 North.

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

for lane volumes > q_1 and < q_2,

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

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

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

where:

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

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

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:

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

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		Add Mixed Lane		Add HOV Lane	
		1985	2000	1985	2000	1985	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		Add Mixed Lane		Add HOV Lane	
	1985	2000	1985	2000	1985	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)		Annual costs ($1,000's)		Miscellaneous	
SOV	3.71	Maint. cost	48	Value of time ($)	7.00
carpool	3.00	Extra HOV maint.	10	Discount rate (%)	4.0
vanpool	.00	Enforcement	105	Lane construction	9202
Operating costs				Extra HOV cost	920
car ($/mi.)	.23			Oper. cost elas.	.50
van ($/mi.)	.42			Bus fare	.80
bus ($/mi.)	1.31			Peak Factor	2.00
bus ($/hr.)	24.83				
bus ($/trip)	82.17				

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		Add Mixed Lane		Add HOV Lane	
		1985	2000	1985	2000	1985	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.)
March 26, 1987 2:03 PM

I-405 south of I-90

	Do Nothing		Add Mixed Lane		Add HOV Lane	
	1985	2000	1985	2000	1985	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 ($'s/day)	
SOV	3.71
carpool	3.00
vanpool	.00
Operating costs	
car ($/mi.)	.23
van ($/mi.)	.42
bus ($/mi.)	1.31
bus ($/hr.)	24.83
bus ($/trip)	82.17

Annual costs ($1,000's)	
Maint. cost	45
Extra HOV maint.	10
Enforcement	115

Miscellaneous	
Value of time ($)	7.00
Discount rate (%)	4.0
Lane construction	10067
Extra HOV cost	1007
Oper. cost elas.	.50
Bus fare	.80
Peak Factor	3.50

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
March 26, 1987 2:04 PM

SR520 east of Evergreen Point Bridge

		Do Nothing		Add Mixed Lane		Add HOV Lane	
		1985	2000	1985	2000	1985	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.)
March 26, 1987 2:04 PM

SR520 east of Evergreen Point Bridge

	Do Nothing		Add Mixed Lane		Add HOV Lane	
	1985	2000	1985	2000	1985	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	Model case	Net pres. value	Benefit cost rat.	Diff.
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

sbgp - (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/0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
     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,
     22,2,2,2,2,2,2,2,2,2,3,3,3,3,3/
      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),
```

```
36:       3len(6),ngpl(6),nhov(6),access(6),tpool(6),tvan(6),tbus(6),
37:       4strip(6),ctrip(6),vtrip(6),btrip(6),strips(6),ctrips(6),vtrip
    s(6),btrips(6),
38:       4stript(6),ctript(6),vtript(6),btript(6),narts(6),cpdefn(6),sp
    minf(6),spmina(6),prefpk(6),
39:       5v(6),vh(6),dispg(6),dispa(6),dispgs(6),dispas(6),ttime(3),
40:       6pcap(6),tbar(6),tlave(6),tlsov(6),tlpl2(6),tlpl3(6),tlvan(6),
41:       7tlbus(6),tmcar(6),tmvan(6),tmbus(6),tcost(6),
42:       8avspg(6),avsph(6),avspa(6),timcst(6),percst(6),agycst(6)
43:        equivalence (x(1,1),ptrips(1)),(x(1,2),sov(1)),(x(1,3),pool2(
    1)),
44:       1(x(1,4),pool3(1)),(x(1,5),poolv(1)),(x(1,6),bus(1)),(x(1,7),c
    pdefn(1)),(x(1,8),prefpk(1)),
45:       2(x(1,9),capg(1)),(x(1,10),caph(1)),(x(1,11),capa(1)),
46:       3(x(1,12),vgp(1)),(x(1,13),vhp(1)),(x(1,14),vap(1)),
47:       4(x(1,15),vgs(1)),(x(1,16),vhs(1)),(x(1,17),vas(1)),
48:       5(x(1,18),pspg(1)),(x(1,19),psph(1)),(x(1,20),pspa(1)),
49:       6(x(1,21),sspg(1)),(x(1,22),ssph(1)),(x(1,23),sspa(1)),
50:       7(x(1,24),len(1)),(x(1,25),ngpl(1)),(x(1,26),nhov(1)),(x(1,27)
    ,narts(1)),
51:       8(x(1,28),access(1)),(x(1,29),tpool(1)),(x(1,30),tvan(1)),
52:       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)),
53:       9(x(1,36),vtrip(1)),(x(1,37),btrip(1)),(x(1,38),strips(1)),
54:       9(x(1,39),ctrips(1)),(x(1,40),vtrips(1)),(x(1,41),btrips(1)),
55:       9(x(1,42),stript(1)),(x(1,43),ctript(1)),(x(1,44),vtript(1)),
56:       9(x(1,45),btript(1)),(x(1,46),dispg(1)),(x(1,47),dispa(1)),
57:       9(x(1,48),dispgs(1)),(x(1,49),dispas(1)),(x(1,50),pcap(1)),
58:       9(x(1,51),tbar(1)),(x(1,52),tlave(1)),(x(1,53),tlsov(1)),
59:       9(x(1,54),tlpl2(1)),(x(1,55),tlpl3(1)),(x(1,56),tlvan(1)),
60:       9(x(1,57),tlbus(1)),(x(1,58),tmcar(1)),(x(1,59),tmvan(1)),
61:       9(x(1,60),tmbus(1)),
62:       9(x(1,65),tcost(1))
63:        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,
64:       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/
65:        data npar/65/
66:        real y(18),maint,xs(6)
67:        common/delay/delg,delgs,dela,delas
68:        common/result/tc1,tc2,bc1,bc2
69:        common/cursor/ion1,ion2,ioff1,ioff2
70:        equivalence (y(1),pcsov),(y(2),pcpol),(y(3),pcvan),
71:       1(y(4),occar),(y(5),ocvan),
72:       2(y(9),maint),(y(10),hovmnt),(y(11),enf),
73:       3(y(12),tval),(y(13),disc),(y(14),constg),(y(15),consth),
74:       4(y(16),elas)
75:  c
76:  c       read in data
77:  c
78:        ion1=7
```

```
 79:         ion2=6
 80:         ioff1=0
 81:         ioff2=8
 82:         if (ioread(5,2,0,"crsdef")) go to 20
 83:         read (5,10) ion1,ion2,ioff1,ioff2
 84:      10 format (2i2)
 85:         if (ioclos(5)) stop
 86:      20 call crs(ioff1,ioff2)
 87:         call chfile(file,fcont)
 88:         if (file.eq."") go to 1100
 89:         if (ioread(5,2,0,file)) stop
 90:         read (5,100) ((x(i,j),i=1,6),j=1,npar)
 91:     100 format (6e13.6)
 92:         read (5,110) tval,pcsov,pcpol,pcvan,occar,ocvan,y(6),y(7),y(8
    ),disc,
 93:        1constg,consth,maint,hovmnt,enf,elas,bfare,pkfact
 94:     110 format (e13.6)
 95:         y(17)=bfare
 96:         y(18)=pkfact
 97:         read (5,100)(timcst(i),i=1,6),(percst(i),i=1,6),(agycst(i),i=
    1,6),
 98:        1(avspg(i),i=1,6),(avsph(i),i=1,6),(avspa(i),i=1,6)
 99:         if (ioclos(5)) stop
100:  c
101:  c       set up screens
102:  c
103:         do 200 ip=3,0,-1
104:         call chpage(ip)
105:     200 call vclear
106:         do 210 ip=0,3
107:         call printp("1985",24,1,12,ip)
108:         call printp("1985",44,1,12,ip)
109:         call printp("1985",64,1,12,ip)
110:         call printp("2000",31,1,12,ip)
111:         call printp("2000",51,1,12,ip)
112:         call printp("2000",71,1,12,ip)
113:         call printp("Do Nothing",24,0,13,ip)
114:         call printp("Add Mixed Lane",42,0,13,ip)
115:     210 call printp("Add HOV Lane",63,0,13,ip)
116:         call printp("Travel time (minutes)",0,12,11,1)
117:         call printp("Peak",3,13,11,1)
118:         call printp("Shoulder",3,17,11,1)
119:         call printp("Average",3,21,11,1)
120:         call printp("Displacements",0,2,11,2)
121:         call printp("Summary Statistics",0,7,11,2)
122:         call printp("Total Vehicle Miles (1000's)",0,17,11,2)
123:         call printp("Total Trip Length",0,10,11,2)
124:         call printp("Maximum Speeds",0,2,11,3)
125:         do 220 i=1,npar
126:         call printp(label(i),21-klen(label(i)),locy(i),14,locp(i))
127:         do 220 j=1,6
```

```
128:    220 call printp(snart(x(j,i),6,dec(i)),locx(j),locy(i),fmt(type(i
    )+1),locp(i))
129:        call chattp(0,8,21,12,3)
130:        call cstset(0,y,0)
131:        ip=-1
132:        call cstcal(ip,tcost,disc,constg,consth,maint,hovmnt,enf,
133:       1timcst,percst,agycst,tc1,tc2,bc1,bc2,pkfact,ichela)
134:        ip=0
135:  c
136:  c       print cursor and get instruction
137:  c
138:        ix=1
139:        iy=1
140:        move=3
141:    300 if (type(iy).eq.0.and.move.eq.3) go to 740
142:        if (type(iy).eq.0.and.move.eq.5) go to 740
143:        if (type(iy).eq.0.and.move.eq.0) go to 740
144:        if (type(iy).eq.0.and.move.eq.1) go to 720
145:        if (type(iy).eq.0.and.move.eq.6) go to 720
146:        ip=locp(iy)
147:        call chpage(ip)
148:        call chattp(locx(ix),locy(iy),6,138,locp(iy))
149:        call curm(locx(ix),locy(iy),locp(iy))
150:        call getam(a,move,nfunc)
151:        call chattp(locx(ix),locy(iy),6,fmt(type(iy)+1),locp(iy))
152:  c
153:  c       set CALC and select page
154:  c
155:        if (nfunc.gt.6) go to 470
156:        go to (700,400,440,450,450,450,450),nfunc+1
157:    400 if (icalc.eq.1) go to 420
158:        icalc=1
159:        do 410 ipt=0,3
160:    410 call printp("CALC",76,0,48,ipt)
161:        go to 300
162:    420 icalc=0
163:        do 430 ipt=0,3
164:    430 call printp("    ",76,0,7,ipt)
165:        go to 300
166:    440 if(icalc.eq.0) go to 300
167:        go to 600
168:    450 ip=nfunc-3
169:        call chpage(ip)
170:        if (ip.eq.3) go to 1000
171:    460 if (locp(iy).eq.ip) go to 300
172:        ix=1
173:        if (ip.eq.0) iy=1
174:        if (ip.eq.1) iy=24
175:        if (ip.eq.2) iy=46
176:        go to 300
177:    470 if (nfunc.eq.8) go to 510
```

```
178:         if (nfunc.lt.9) go to 300
179:         if (nfunc.eq.9) go to 480
180:         call pout(fcont)
181:         go to 300
182:     480 do 490 i=5,6
183:         call hovcom(len(i),pspg(i-4),ctrip(i-4),btrip(i-4),cpdefn(i),
184:        1pool2(i-4),pool3(i-4),poolv(i-4),bus(i-4),pool2(i),pool3(i),
185:        2poolv(i),bus(i))
186:         do 490 j=3,6
187:     490 call printp(snart(x(i,j),6,dec(j)),locx(i),locy(j),
188:        1fmt(type(j)+1),locp(j))
189:         if (icalc.eq.1) go to 300
190:         do 500 i=1,4
191:     500 ichng(i)=0
192:         ichng(5)=1
193:         ichng(6)=1
194:         go to 600
195:   c
196:   c       calculate elasticities
197:   c
198:     510 if (icalc.eq.1) go to 300
199:         ichela=1
200:         tc1s=tc1
201:         tc2s=tc2
202:         bc1s=bc1
203:         bc2s=bc2
204:         do 520 i=1,6
205:     520 xs(i)=x(i,iy)
206:         go to 810
207:     530 call printp(snart((tc1/tc1s-1.)/.1,10,3),26,23,12,3)
208:         call printp(snart((tc2/tc2s-1.)/.1,10,3),26,24,12,3)
209:         call printp(snart((bc1/bc1s-1.)/.1,10,3),66,23,12,3)
210:         call printp(snart((bc2/bc2s-1.)/.1,10,3),66,24,12,3)
211:         call printp(" -------------Elasticities-------------ã",33,20
     ,12,3)
212:         call wscp(33,21,3,25,12)
213:         call wscp(73,21,3,25,12)
214:         call chpage(3)
215:         call get(i1,i2)
216:         call printp("                                        ",33,20
     ,12,3)
217:         call printp("                                        ",33,21
     ,12,3)
218:         call chpage(ip)
219:         do 560 i=1,6
220:     560 x(i,iy)=xs(i)
221:         tc1=tc1s
222:         tc2=tc2s
223:         bc1=bc1s
224:         bc2=bc2s
225:         ichela=0
```

```
226:  c
227:  c     calculate results
228:  c
229:    600 do 680 i=1,6
230:        if (icalc.eq.1) go to 610
231:        if (ichng(i).eq.0) go to 680
232:    610 call sovcal(sov(i),ptrips(i),pool2(i),pool3(i),poolv(i),bus(i
    ))
233:        pcapt=narts(i)*capa(i)/(ngpl(i)*capg(i)+nhov(i)*caph(i)+narts
    (i)*capa(i))
234:        pinc=pcapt
235:        if (pinc.gt..5) pinc=1.-pinc
236:        lim=3
237:        if (pcapt.eq.0..or.pcapt.eq.1.) lim=1
238:    620 do 640 j=1,lim
239:        if (j.eq.1) pcap(i)=pcapt+pinc
240:        if (j.eq.2) pcap(i)=pcapt-pinc
241:        if (j.eq.3.or.lim.eq.1) pcap(i)=pcapt
242:    630 call lanes(sov(i),pool2(i),pool3(i),poolv(i),bus(i),
243:       1ngpl(i),nhov(i),narts(i),cpdefn(i),prefpk(i),spminf(i),spmina
    (i),
244:       2capg(i),caph(i),capa(i),pcap(i),
245:       3v(i),vh(i),vgp(i),vhp(i),vap(i),vgs(i),vhs(i),vas(i),
246:       4dispg(i),dispa(i),dispgs(i),dispas(i),x(i,61),x(i,62),x(i,63)
    )
247:        call speeds(pspg(i),sspg(i),psph(i),ssph(i),pspa(i),sspa(i),
248:       1capg(i),caph(i),capa(i),
249:       2vgp(i),vhp(i),vap(i),vgs(i),vhs(i),vas(i),
250:       3ngpl(i),nhov(i),narts(i),
251:       4spminf(i),spmina(i),
252:       5dispg(i),dispa(i),dispgs(i),dispas(i),
253:       6avspg(i),avsph(i),avspa(i),x(i,61),x(i,62),x(i,63),x(i,64))
254:        call times(nhov(i),narts(i),sov(i),pool2(i),cpdefn(i),
255:       1laccess(i),len(i),tpool(i),tvan(i),tbus(i),
256:       2pspg(i),sspg(i),psph(i),ssph(i),pspa(i),sspa(i),
257:       3v(i),vh(i),vgp(i),vhp(i),vap(i),vgs(i),vhs(i),vas(i),
258:       4strip(i),strips(i),stript(i),ctrip(i),ctrips(i),ctript(i),
259:       5vtrip(i),vtrips(i),vtript(i),btrip(i),btrips(i),btript(i))
260:        ttime(j)=sov(i)*stript(i)+2.*pool2(i)*ctript(i)+
261:       13.3*pool3(i)*ctript(i)+10.*poolv(i)*vtript(i)+45.*bus(i)*btri
    pt(i)+
262:       2dispg(i)*delg+dispgs(i)*delgs+dispa(i)*dela+dispas(i)*delas
263:    640 ttime(j)=ttime(j)/ptrips(i)
264:        if (pcapt.eq.0..or.pcapt.eq.1.) go to 660
265:        if (pcapt+pinc.gt.1.) go to 650
266:        if (pcapt-pinc.lt.0.) go to 650
267:        if ((ttime(1)-ttime(3))*(ttime(3)-ttime(2)).le.0.) go to 650
268:        if (ttime(1)-ttime(3).lt.0.) pcapt=pcapt+pinc
269:        if (ttime(1)-ttime(3).ge.0.) pcapt=pcapt-pinc
270:        go to 620
271:    650 if (pinc.lt..001) go to 660
```

```
272:          pinc=pinc/2.
273:          go to 620
274:      660 tbar(i)=ttime(lim)
275:          call length(sov(i),pool2(i),pool3(i),poolv(i),bus(i),tmcar(i)
     ,
276:         1tmvan(i),tmbus(i),tlave(i),tlsov(i),tlpl2(i),tlpl3(i),tlvan(i
     ),
277:         2tlbus(i))
278:          call cost(tcost(i),timcst(i),percst(i),agycst(i),tval,pcsov,
279:         1pcpol,pcvan,occar,ocvan,y(6),y(7),y(8),avspg(i),avsph(i),avsp
     a(i),elas,
280:         2sov(i),pool2(i),pool3(i),poolv(i),bus(i),len(i),pcap(i),
281:         3tmcar(i),tmvan(i),tmbus(i),tbar(i),ptrips(i),bfare,btript(i),
282:         4x(i,61),x(i,62),x(i,63))
283:          if (ichela.eq.1) go to 680
284:          do 670 j=1,npar
285:     670 if (type(j).eq.0) call printp(snart(x(i,j),6,dec(j)),locx(i),
     locy(j),7,locp(j))
286:     680 continue
287:          call cstcal(ip,tcost,disc,constg,consth,maint,hovmnt,enf,
288:         1timcst,percst,agycst,tc1,tc2,bc1,bc2,pkfact,ichela)
289:          if (ichela.eq.1) go to 530
290:          go to 300
291:   c
292:   c       move cursor
293:   c
294:     700 if (a.ne."") go to 800
295:     710 go to (300,720,730,740,750,760,770,1100),move+1
296:     720 iy=mod(iy+npar-2,npar)+1
297:          go to 300
298:     730 ix=mod(ix,6)+1
299:          go to 300
300:     740 if (iy.eq.npar) go to 1000
301:          iy=mod(iy,npar)+1
302:          go to 300
303:     750 ix=mod(ix+4,6)+1
304:          go to 300
305:     760 ix=1
306:          iy=1
307:          go to 300
308:     770 ix=6
309:          iy=npar
310:          go to 300
311:   c
312:   c       change data
313:   c
314:     800 if (clean(a,6)) go to 810
315:          call printp(a,locx(ix),locy(iy),140,locp(iy))
316:          call take(3.)
317:          call printp(snart(x(ix,iy),6,dec(iy)),locx(ix),locy(iy),fmt(t
     ype(iy)+1),locp(iy))
```

```
318:         go to 300
319:     810 do 820 i=1,6
320:     820 ichng(i)=0
321:         go to (830,840,860,880),type(iy)
322:     830 if (ichela.eq.0) x(ix,iy)=tran(a)
323:         if (ichela.eq.1) x(ix,iy)=x(ix,iy)*1.1
324:         ichng(ix)=1
325:         if (ichela.eq.1) go tc 900
326:         call printp(snart(x(ix,iy),6,dec(iy)),locx(ix),locy(iy),fmt(t
     ype(iy)+1),locp(iy))
327:         go to 900
328:     840 ist=2-mod(ix,2)
329:         do 850 ixx=ist,6,2
330:         ichng(ixx)=1
331:         if (ichela.eq.0) x(ixx,iy)=tran(a)
332:         if (ichela.eq.1) x(ixx,iy)=x(ixx,iy)*1.1
333:         if (ichela.eq.1) go tc 850
334:         call printp(snart(x(ixx,iy),6,dec(iy)),locx(ixx),locy(iy),fmt
     (type(iy)+1),locp(iy))
335:     850 continue
336:         go to 900
337:     860 ist=ix-1+mod(ix,2)
338:         do 870 ixx=ist,ist+1
339:         ichng(ixx)=1
340:         if (ichela.eq.0) x(ixx,iy)=tran(a)
341:         if (ichela.eq.1) x(ixx,iy)=x(ixx,iy)*1.1
342:         if (ichela.eq.1) go tc 870
343:         call printp(snart(x(ixx,iy),6,dec(iy)),locx(ixx),locy(iy),fmt
     (type(iy)+1),locp(iy))
344:     870 continue
345:         go to 900
346:     880 do 890 ixx=1,6
347:         ichng(ixx)=1
348:         if (ichela.eq.0) x(ixx,iy)=tran(a)
349:         if (ichela.eq.1) x(ixx,iy)=x(ixx,iy)*1.1
350:         if (ichela.eq.1) go tc 890
351:         call printp(snart(x(ixx,iy),6,dec(iy)),locx(ixx),locy(iy),fmt
     (type(iy)+1),locp(iy))
352:     890 continue
353:     900 if (icalc.eq.0) go to 600
354:         go to 710
355:  c
356:  c       set cost parameters
357:  c
358:    1000 call cstset(ip,y,icalc)
359:         iy=npar-1
360:         bfare=y(17)
361:         pkfact=y(18)
362:         if (ip.lt.4) go to 460
363:         if (ip.gt.13) go to 1100
364:         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
```

btrip 37 53 183 259
btrips 37 54 259
btript 38 56 259 261 281 368
bus 33 44 184 185 232 242 261 275 280 367
capa 35 45 233 244 248
capg 35 45 233 244 248
caph 35 45 233 244 248
cpdefn 38 44 183 243 254
ctrip 37 52 183 258
ctrips 37 54 258
ctript 38 55 258 260 261
dispa 39 56 246 252 262
dispas 39 57 246 252 262
dispg 39 56 246 252 262
dispgs 39 57 246 252 262
len 36 50 183 255 280 367
narts 38 50 233 243 250 254
ngpl 36 50 233 243 250
nhov 36 50 233 243 250 254
pcap 40 57 239 240 241 244 280 367
percst 42 97 133 278 288 365 372 389
poolv 33 44 184 185 232 242 261 275 280 367
pool2 33 43 184 232 242 254 260 275 280 367
pool3 33 44 184 232 242 261 275 280 367
prefpk 38 44 243
pspa 35 48 247 256
pspg 34 48 183 247 256
psph 34 48 247 256
ptrips 33 43 232 263 281 368
sov 33 43 232 242 254 260 275 280 367
spmina 38 52 243 251
spminf 38 52 243 251
sspa 35 49 247 256
sspg 35 49 247 256
ssph 35 49 247 256
strip 37 52 258
strips 37 53 258
stript 38 55 258 260
tbar 40 58 274 281 368
tbus 36 52 255
tcost 41 62 132 278 287 365 371
timcst 42 97 133 278 288 365 372 389
tlave 40 58 276
tlbus 41 60 277
tlpl2 40 59 276
tlpl3 40 59 276
tlsov 40 58 276
tlvan 40 59 276
tmbus 41 61 276 281 368
tmcar 41 60 275 281 368
tmvan 41 60 276 281 368

```
      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
```

```
 1:          Subroutine chfile(file,fcont)
 2:          character*10 a
 3:          character*40 filn(20),fcont
 4:          integer filnum(20)
 5:          character*8 file
 6:          character*4 nart
 7:          common/cursor/ion1,ion2,ioff1,ioff2
 8:          file=""
 9:          call chpage(0)
10:          call vclear
11:          call printp("Pick a case for analysis",0,0,14,0)
12:          if (ioread(5,2,0,"files")) go to 40
13:          read (5,10) nfil
14:       10 format (i0)
15:          read (5,20,errexit=40) (filnum(i),filn(i),i=1,nfil)
16:       20 format (i4,a0)
17:          if (ioclos(5)) stop
18:          do 30 i=1,nfil
19:       30 call printp(filn(i),0,i+1,7,0)
20:       40 call printp("""D"" - delete     ""A"" - add    ""C"" - choose
    ",0,24,7,0)
21:          ia=1
22:       50 call chattp(0,ia+1,40,138,0)
23:          call getd(a,im,if)
24:          call chattp(0,ia+1,40,7,0)
25:          if (im.eq.7) go to 145
26:          if (a.eq."D".or.a.eq."d") go to 100
27:          if (a.eq."A".or.a.eq."a") go to 130
28:          if (a.eq."C".or.a.eq."c") go to 140
29:          go to (50,60,70,70,60,80,90),im+1
30:       60 ia=mod(ia+nfil-2,nfil)+1
31:          go to 50
32:       70 ia=mod(ia,nfil)+1
33:          go to 50
34:       80 ia=1
35:          go to 50
36:       90 ia=nfil
37:          go to 50
38:      100 nfil=nfil-1
39:      110 call blnk(0,ia+1,39,ia+1)
40:          if (ia.le.nfil) go to 120
41:          ia=1
42:          go to 50
43:      120 filn(ia)=filn(ia+1)
44:          filnum(ia)=filnum(ia+1)
45:          call printp(filn(ia),0,ia+1,7,0)
46:          ia=ia+1
47:          go to 110
48:      130 nfil=nfil+1
49:          call vcurxy(0,nfil+1)
50:          call crs(ion1,ion2)
```

```
51:          call geta(filn(nfil),if,im)
52:          call crs(ioff1,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										
ioff1	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,avsp
    h,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),
     lctim(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)+
     lann/ds(j)
   30 tc(i)=tc(i)+pkfact*250.*(tcost(2*i-1)+float(j)*cinc)/ds(j)+an
     n/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	30	37	40	43	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 ($/trip)","Maint. cost","Ext
ra HOV maint.","Enforcement",
     2"Value of time ($)","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)
```

```
48:         if (nfunc.gt.0) go to 300
49:         if (a.ne."") go to 260
50:     205 go to (200,210,220,220,210,230,240,250),move+1
51:     210 if (ia.eq.1) return
52:         ia=mod(ia+16,18)+1
53:         go to 200
54:     220 ia=mod(ia,18)+1
55:         go to 200
56:     230 ia=1
57:         go to 200
58:     240 ia=18
59:         go to 200
60:     250 ip=99
61:         return
62:     260 if (clean(a,8)) go to 270
63:         call printp(a,locx(ia),locy(ia),14,3)
64:         call take(3.)
65:         call printp(snart(x(ia),6,dec(ia)),locx(ia),locy(ia),15,3)
66:         go to 200
67:     270 x(ia)=tran(a)
68:         call printp(snart(x(ia),6,dec(ia)),locx(ia),locy(ia),15,3)
69:         if (icalc.eq.1) go to 205
70:     280 ip=ip+10
71:         return
72:   c
73:   c       set up to change page
74:   c
75:     300 if (nfunc.eq.1) go to 400
76:         if (nfunc.eq.2.and.icalc.eq.1) go to 280
77:         if (nfunc.eq.8) go to 310
78:         if (nfunc.gt.5.or.nfunc.lt.3) go to 200
79:         ip=nfunc-3
80:         call chpage(ip)
81:         return
82:   c
83:   c       calculate elasticities
84:   c
85:     310 if (icalc.eq.1) go to 200
86:         ichela=1
87:         tc1s=tc1
88:         tc2s=tc2
89:         bc1s=bc1
90:         bc2s=bc2
91:         xs=x(ia)
92:         x(ia)=x(ia)*1.1
93:         go to 280
94:     320 call printp(snart((tc1/tc1s-1.)/.1,10,3),26,23,12,3)
95:         call printp(snart((tc2/tc2s-1.)/.1,10,3),26,24,12,3)
96:         call printp(snart((bc1/bc1s-1.)/.1,10,3),66,23,12,3)
97:         call printp(snart((bc2/bc2s-1.)/.1,10,3),66,24,12,3)
98:         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
```

```
 1:         Subroutine getam(a,im,if)
 2:         character*80 a
 3:         character*1 b
 4:         equivalence (icc,b)
 5:         data b/" "/
 6:         a=""
 7:         im=0
 8:         if=0
 9:      10 call get(ic,is)
10:         icc=ic
11:         if (is.eq.72) im=1
12:         if (is.eq.77) im=2
13:         if (is.eq.80) im=3
14:         if (is.eq.75) im=4
15:         if (is.eq.71) im=5
16:         if (is.eq.79) im=6
17:         if (ic.eq.27) im=7
18:         if (is.ge.59.and.is.le.68) if=is-58
19:         if (is.ge.84.and.is.le.113) if=is-73
20:         if (im+if.ne.0) return
21:         if (ic.eq.0) go to 10
22:         if (ic.eq.9.and.is.eq.15) go to 10
23:         if (ic.eq.8.and.is.eq.14) go to 10
24:         if (ic.eq.13.and.is.eq.28) return
25:         call curp(ix1,iy)
26:         ix=ix1
27:         a=b
28:      20 call wsc(ix,iy,ic,7)
29:      30 ix=ix+1
30:      40 call curm(ix,iy)
31:         if (ix.eq.ix1) go to 10
32:      50 call get(ic,is)
33:         icc=ic
34:         if (ic.eq.8.and.is.eq.14) go to 60
35:         if (ic.eq.13.and.is.eq.28) return
36:         if (is.eq.72) im=1
37:         if (is.eq.77) im=2
38:         if (is.eq.80) im=3
39:         if (is.eq.75) im=4
40:         if (is.eq.71) im=5
41:         if (is.eq.79) im=6
42:         if (ic.eq.27) im=7
43:         if (im.gt.0) return
44:         call addstg(a,b)
45:         go to 20
46:      60 ix=ix-1
47:         call blnk(ix,iy,ix,iy)
48:         call setlen(a,klen(a)-1)
49:         go to 40
50:         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(hov1,s0gp,t0pa,t0b,cpdefn,pool2,pool3,
 2:         1van0,b0peb,tpool2,tpool3,van1,b1hov)
 3:          time=hov1*60./s0gp
 4:          toffpa=t0pa-time
 5:          toffb=t0b-time
 6:          t1b=toffb+hov1*60./58.
 7:          t1pa=toffpa+hov1*60./58.
 8:          if (cpdefn.eq.2.) coeff=6.7
 9:          if (cpdefn.eq.3.) coeff=7.7
10:          delpa=-.203-coeff*(t1pa/t0pa-1.)+4.8*(t1b/t0b-1.)
11:          tpool2=pool2
12:          if (cpdefn.eq.2.) tpool2=pool2*(1.+delpa)
13:          tpool3=pool3*(1.+delpa)
14:          van1=van0*(1.+delpa)
15:          if (cpdefn.eq.2.) coeff=1.71
16:          if (cpdefn.eq.3.) coeff=.435
17:          delb=.227+coeff*(t1pa/t0pa-1.)
18:          if (delb.lt.0.) delb=0.
19:          b1hov=b0peb*(1.+delb)
20:          return
21:          end
```

real variables

b0peb	19					
b1hov	19					
coeff	8	9	10	15	16	17
cpdefn	8	9	12	15	16	
delb	17	18	19			
delpa	10	12	13	14		
hov1	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			
t1b	6	10				
t1pa	7	10	17			
van0	14					
van1	14					

```
 1:         Subroutine lanes(sov,pool2,pool3,poolv,bus,
 2:        1ngpl,nhov,narts,cpdefn,prefpk,spminf,spmina,
 3:        2capg,caph,capa,pcap,
 4:        3v,vh,vgp,vhp,vap,vgs,vhs,vas,
 5:        4dispg,dispa,dispgs,dispas,vmaxg,vmaxh,vmaxa)
 6:         real ngpl,nhov,narts
 7:         common/delay/delg,delgs,dela,delas
 8:         v=sov+pool2+pool3+poolv+bus
 9:         vg=v
10:         vh=0.
11:         vgp=0.
12:         vhp=0.
13:         vap=0.
14:         vgs=0.
15:         vhs=0.
16:         vas=0.
17:         delg=0.
18:         dela=0.
19:         delgs=0.
20:         delas=0.
21:         if (nhov.eq.0.) go to 200
22:   c
23:   c       assign HOV vehicles
24:   c
25:         go to (200,100,110),int(cpdefn)
26:     100 vh=v-sov
27:         vg=sov
28:         go to 120
29:     110 vh=v-sov-pool2
30:         vg=sov+pool2
31:     120 vhp=prefpk*vh
32:         vhs=vh-vhp
33:         if (vhp.le.caph*nhov) go to 200
34:         vhp=caph*nhov
35:         vhs=vh-vhp
36:   c
37:   c       assign other vehicles
38:   c
39:   c       split freeway and arterial traffic
40:   c
41:     200 va=pcap*vg
42:         if (va.lt.0.) va=0.
43:         vg=vg-va
44:   c
45:   c       split into peak/off-peak
46:   c
47:         vgp=prefpk*vg
48:         vap=prefpk*va
49:         vgs=vg-vgp
50:         vas=va-vap
51:   c
```

```
  52:  c       check peak capacities and compute displaced vehicles
  53:  c
  54:        dispg=0.
  55:        dispa=0.
  56:        dispgs=0.
  57:        dispas=0.
  58:        if (vgp.le.capg*ngpl) go to 300
  59:        vc=vgp/(capg*ngpl)
  60:        tcapg=ngpl*vol(spminf,capg,vmaxg)
  61:        rcapg=capg*ngpl-(vc-1.)*(capg*ngpl-tcapg)/.5
  62:        if (rcapg.lt.tcapg) rcapg=tcapg
  63:        dispg=vgp-rcapg
  64:        delg=15.*dispg/vgp+30.*dispg/(capg*ngpl-vgs/2.)
  65:        if (delg.gt.45..or.vgs/2..gt.capg*ngpl) delg=45.
  66:        vgp=vgp-dispg
  67:        vgs=vgs+dispg
  68:    300 if (va.eq.0.) go to 400
  69:        if (vap.le.capa*narts) go to 400
  70:        vc=vap/(capa*narts)
  71:        tcapa=narts*vol(spmina,capa,vmaxa)
  72:        rcapa=capa*narts-(vc-1.)*(capa*narts-tcapa)/.5
  73:        if (rcapa.lt.tcapa) rcapa=tcapa
  74:        dispa=vap-rcapa
  75:        dela=15.*dispa/vap+30.*dispa/(capa*narts-vas/2.)
  76:        if (dela.gt.45..or.vas/2..gt.capa*narts) dela=45.
  77:        vap=vap-dispa
  78:        vas=vas+dispa
  79:  c
  80:  c       check shoulder capacities and compute displaced vehicles
  81:  c
  82:    400 if (vgs.le.2.*capg*ngpl) go to 410
  83:        vc=vgs/(capg*ngpl)/2.
  84:        tcapg=2.*ngpl*vol(spminf,capg,vmaxg)
  85:        rcapg=2.*capg*ngpl-(vc-1.)*(2.*capg*ngpl-tcapg)/.5
  86:        if (rcapg.lt.tcapg) rcapg=tcapg
  87:        dispgs=vgs-rcapg
  88:        delgs=60.*dispgs/vgs+40.*dispgs/(capg*ngpl)
  89:        vgs=vgs-dispgs
  90:    410 if (va.eq.0.) go to 420
  91:        if (vas.le.2.*capa*narts) go to 420
  92:        vc=vas/(capa*narts)/2.
  93:        tcapa=2.*narts*vol(spmina,capa,vmaxa)
  94:        rcapa=2.*capa*narts-(vc-1.)*(2.*capa*narts-tcapa)/.5
  95:        if (rcapa.lt.tcapa) rcapa=tcapa
  96:        dispas=vas-rcapa
  97:        delas=60.*dispas/vas+40.*dispas/(capa*narts)
  98:        vas=vas-dispas
  99:    420 return
 100:        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
```

```
1:          Subroutine sovcal(sov,ptrips,pool2,pool3,poolv,bus)
2:          sov=ptrips-2.*pool2-3.3*pool3-10.*poolv-45.*bus
3:          return
4:          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,
     laccess,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,b
    trip,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								

```
    1:          Function vol(speed,cap,vmax)
    2:          rat=speed/vmax
    3:          vol=cap*(.3570128+1.8614055*rat-1.347161*rat**2)
    4:          return
    5:          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

```
 1:         character*10 a
 2:         real l0b,l0gp,l0hov,l1gp,l1hov
 3:         common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa
    ,
 4:        1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
 5:         common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
 6:        1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hov1
 7:         character*40 filn(20)
 8:         integer filnum(20)
 9:         character*8 fil1,fil2,fil3
10:         character*4 nart
11:       8 call crsoff
12:         call vclear
13:         call print("Pick case for analysis",0,0,14)
14:         if (ioread(5,2,0,"filelist")) stop
15:         read (5,2) nfil
16:       2 format (i0)
17:         read (5,3) (filnum(i),filn(i),i=1,nfil)
18:       3 format (i4,a0)
19:         if (ioclos(5)) stop
20:         do 4 i=1,nfil
21:       4 call print(filn(i),0,i+1,7)
22:         call print ("F1 - delete     F2 - add    F3 - choose    Esc -
     exit",0,24,7)
23:         ia=1
24:       5 call chatt(0,ia+1,40,15)
25:         call getd(a,im,if)
26:         call chatt(0,ia+1,40,7)
27:         if (im.eq.7) go to 80
28:         if (if.eq.1) go to 110
29:         if (if.eq.2) go to 120
30:         if (if.eq.3) go to 130
31:         go to (5,11,12,12,11,15,16),im+1
32:      11 ia=mod(ia+nfil-2,nfil)+1
33:         go to 5
34:      12 ia=mod(ia,nfil)+1
35:         go to 5
36:      15 ia=1
37:         go to 5
38:      16 ia=nfil
39:         go to 5
40:     110 nfil=nfil-1
41:     112 call blnk(0,ia+1,39,ia+1)
42:         if (ia.le.nfil) go to 111
43:         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

```
 1:         Subroutine wks1(next,fill)
 2:         real l0b,l0gp,l0hov,l1gp,l1hov
 3:         common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa
    ,
 4:        1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
 5:         common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
 6:        1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hov1
 7:         real inp(18)
 8:         integer locy(18),form(18)
 9:         data locy/2,3,4,5,6,7,9,11,12,13,14,16,17,18,20,21,22,23/
10:         data form/-1,-1,-1,-1,-1,-1,-1,1,1,1,1,1,1,1,-1,-1,-1,-1/
11:         logical clean
12:         character*8 fill
13:         character*10 snart,a
14:         next=2
15:         if (ioread(5,2,0,fill)) go to 1
16:         read (5,2) (inp(i),i=1,18)
17:       2 format (f0.0)
18:         if (ioclos(5)) stop
19:       1 v0npa=inp(1)
20:         v0pa=inp(2)
21:         v0hov=inp(3)
22:         b0peb=inp(4)
23:         b0hov=inp(5)
24:         v0b=inp(6)
25:         v0t=inp(7)
26:         t0npa=inp(8)
27:         t0pa=inp(9)
28:         t0hov=inp(10)
29:         t0b=inp(11)
30:         s0gp=inp(12)
31:         s0c=inp(13)
32:         s0b=inp(14)
33:         l0gp=inp(15)
34:         l0hov=inp(16)
35:         c0gp=inp(17)
36:         c0hov=inp(18)
37:         if (im.eq.7) go to 100
38:         call vclear
39:         call print("Worksheet 1: Baseline Data",0,0,14)
40:         call print("Volumes(peak-hour)",0,1,7)
41:         call print(". Automobiles, nonpriority",5,2,7)
42:         call print(". Automobiles, priority-eligible",5,3,7)
43:         call print(". Carpools on HOV lanes",5,4,7)
44:         call print(". Buses, priority eligible",5,5,7)
45:         call print(". Buses on HOV lane(s)",5,6,7)
46:         call print(". Bus passengers (HOV or priority eligible)",5,7,
    7)
47:         call print(". Bus load factor",5,8,7)
48:         call print(". Trucks",5,9,7)
49:         call print("Total Travel Time(peak-hour)",0,10,7)
```

```
 50:         call print(". Automobiles, nonpriority",5,11,7)
 51:         call print(". Automobiles, priority eligible",5,12,7)
 52:         call print(". Carpools on HOV lane(s)",5,13,7)
 53:         call print(". Buses (HOV or priority eligible)",5,14,7)
 54:         call print("Speed (average per hour)",0,15,7)
 55:         call print(". General purpose lane(s)",5,16,7)
 56:         call print(". HOV lane(s) - Carpools",5,17,7)
 57:         call print(". HOV lane(s) - Buses",5,18,7)
 58:         call print("Existing Supply/Capacity",0,19,7)
 59:         call print(". No. of general purpose lanes",5,20,7)
 60:         call print(". No. of HOV lanes",5,21,7)
 61:         call print(". Capacity, general purpose lanes",5,22,7)
 62:         call print(". Capacity, HOV lanes",5,23,7)
 63:         do 10 i=1,18
 64:      10 call print(snart(inp(i),10,form(i)),50,locy(i),7)
 65:         10b=0.
 66:         buses=b0peb
 67:         if (buses.eq.0.) buses=b0hov
 68:         if (buses.ne.0.) 10b=v0b/buses
 69:         call print(snart(10b,10,1),50,8,13)
 70:         ia=1
 71:      20 call chatt(5,locy(ia),60,15)
 72:         call vcurxy(50,locy(ia))
 73:         call geta(a,im,if)
 74:         call chatt(5,locy(ia),60,7)
 75:         if (if.ge.21.and.if.le.22) go to 99
 76:         if (if.gt.0) go to 20
 77:         go to (30,31,33,33,31,35,36,1),im+1
 78:      30 if (a.eq."") go to 33
 79:         if (.not.clean(a,nd)) go to 20
 80:         inp(ia)=tran(a)
 81:         call print(snart(inp(ia),10,form(ia)),50,locy(ia),7)
 82:         10b=0.
 83:         v0b=inp(6)
 84:         b0hov=inp(5)
 85:         b0peb=inp(4)
 86:         buses=b0peb
 87:         if (buses.eq.0.) buses=b0hov
 88:         if (buses.ne.0.) 10b=v0b/buses
 89:         call print(snart(10b,10,1),50,8,13)
 90:         go to 33
 91:      31 ia=mod(ia+16,18)+1
 92:         go to 20
 93:      33 ia=mod(ia,18)+1
 94:         go to 20
 95:      35 ia=1
 96:         go to 20
 97:      36 ia=18
 98:         go to 20
 99:      99 next=if-20
100:     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
```

```
 1:         Subroutine wks2(next,fil2)
 2:         real l0b,l0gp,l0hov,l1gp,l1hov
 3:         common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa
    ,
 4:        lt0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
 5:         common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
 6:        lt1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hov1
 7:         common/c4/pooldf
 8:         common/c6/hovalt
 9:         real inp(6)
10:         integer locy(6),form(6)
11:         data locy/4,8,9,10,11,12/
12:         data form/1,-1,-1,-1,-1,-1/
13:         integer hovalt,pooldf
14:         data hovalt,pooldf/1,0/
15:         logical clean
16:         character*8 fil2
17:         character*10 snart,a,nart
18:         iasave=0
19:         if (ioread(5,2,0,fil2)) go to 2
20:         read (5,3) (inp(i),i=1,6)
21:       3 format (f0.0)
22:         read (5,4) hovalt,pooldf
23:       4 format (2i1)
24:         if (ioclos(5)) stop
25:       2 ia=1
26:         call vclear
27:         call print("Worksheet 2: HOV policy and initial calculations"
    ,0,0,14)
28:         call print("HOV alternative:",0,2,7)
29:         call print("  (change w/F1)",0,3,7)
30:         call print("Bus only",21,2,15-4*hovalt)
31:         call print("Bus and Carpool (Carpool size:  +)",21,3,3+4*hova
    lt)
32:         call print("X",18,1+hovalt,11)
33:         call print("HOV length:",0,4,7)
34:         call print("Proposed supply/capacity",0,6,7)
35:         call print(". No. of general purpose lanes",5,8,7)
36:         call print(". No. of HOV lanes",5,9,7)
37:         call print(". Capacity, general purpose lanes",5,10,7)
38:         call print(". Capacity, HOV lanes",5,11,7)
39:         call print(". Buses per hour (exogenous)",5,12,7)
40:         call print("Existing travel times (over highway bounded by HO
    V lanes)",0,14,7)
41:         call print(". Automobiles, nonpriority",5,16,7)
42:         call print(". Automobiles, priority eligible",5,17,7)
43:         call print(". Buses (HOV or priority eligible)",5,18,7)
44:         call print("Existing travel times (off highway bounded by HOV
     lanes)",0,20,7)
45:         call print(". Automobiles, nonpriority",5,22,7)
46:         call print(". Automobiles, priority eligible",5,23,7)
```

```
47:         call print(". Buses (HOV or priority eligible)",5,24,7)
48:         if (pooldf.gt.0) call print(nart(pooldf+1),52,3,11)
49:       1 hov1=inp(1)
50:         l1gp=inp(2)
51:         l1hov=inp(3)
52:         c1gp=inp(4)
53:         c1hov=inp(5)
54:         b1hov=inp(6)
55:         do 10 i=1,6
56:      10 call print(snart(inp(i),10,form(i)),50,locy(i),7)
57:         t1=0.
58:         t2=0.
59:         t3=0.
60:         if (s0gp.eq.0.) go to 20
61:         t1=hov1*60./s0gp
62:         t2=t1
63:         t3=t1
64:         if (s0b.ne.0.) t3=hov1*60./s0b
65:         toffnp=t0npa-t1
66:         toffpa=t0pa-t2
67:         toffb=t0b-t3
68:      20 call print(snart(t1,10,1),50,16,13)
69:         call print(snart(t2,10,1),50,17,13)
70:         call print(snart(t3,10,1),50,18,13)
71:         call print(snart(toffnp,10,1),50,22,13)
72:         call print(snart(toffpa,10,1),50,23,13)
73:         call print(snart(toffb,10,1),50,24,13)
74:         next=3
75:      30 if (iasave.gt.0) ia=iasave
76:         iasave=0
77:         call chatt(0,locy(ia),60,15)
78:         call vcurxy(50,locy(ia))
79:         call geta(a,im,if)
80:         call chatt(0,locy(ia),60,7)
81:         go to (31,35,33,33,35,36,37,38),im+1
82:      31 if (a.ne."") go to 32
83:         if (a.eq.""".and.if.eq.0) go to 33
84:         if (if.eq.1) go to 130
85:         if (if.lt.21.or.if.gt.23) go to 30
86:         next=if-20
87:         go to 38
88:     130 go to (131,131,132,133,134),hovalt+pooldf
89:     131 hovalt=2
90:         pooldf=1
91:         call chatt(21,2,15,7)
92:         call chatt(21,3,50,11)
93:         call blnk(18,2,18,2)
94:         call print("X",18,3,11)
95:         go to 135
96:     132 pooldf=2
97:         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:         hov1=inp(1)
128:         l1gp=inp(2)
129:         l1hov=inp(3)
130:         c1gp=inp(4)
131:         c1hov=inp(5)
132:         b1hov=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
```

```
 1:         Subroutine wks3(next,fil3)
 2:         real l0b,l0gp,l0hov,l1gp,l1hov
 3:         common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa
    ,
 4:        lt0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
 5:         common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
 6:        lt1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hov1
 7:         common/c3/genlan
 8:         common/c5/s1hov
 9:         integer buson,autoon,genlan
10:         data buson,autoon,genlan/1,1,1/
11:         character*10 a,snart
12:         character*8 fil3
13:         if (ioread(5,2,0,fil3)) go to 3
14:         read(5,2) buson,autoon,genlan
15:       2 format (3i1)
16:         if (ioclos(5)) stop
17:       3 next=4
18:         call vclear
19:         call print("Worksheet 3: Estimate travel times - forecast per
    iod",0,0,14)
20:         call print("Buses on or eligible to use HOV lanes (F1 to chan
    ge)",0,2,7)
21:         call print("Buses already on HOV",11,4,15-4*buson)
22:         call print("Buses will be eligible to use HOV",11,5,3+4*buson
    )
23:         call print("HOV bus travel time =",5,7,7)
24:         call print("Autos on or eligible to use HOV lanes (F2 to chan
    ge)",0,9,7)
25:         call print("Autos already on HOV",11,11,15-4*autoon)
26:         call print("Autos will be eligible to use HOV",11,12,3+4*auto
    on)
27:         call print("HOV auto travel time =",5,14,7)
28:         call print("Autos on general purpose lanes (F3 to change)",0,
    16,7)
29:         call print("Capacity reduction or bus only lane",11,18,15-4*g
    enlan)
30:         call print("Capacity same and carpools granted priority",11,1
    9,3+4*genlan)
31:         call print("general lane travel speed =",5,21,7)
32:         call print("general lane travel time =",5,22,7)
33:         call print("eligibility factor =",5,24,7)
34:       1 call blnk(5,4,5,5)
35:         call blnk(5,11,5,12)
36:         call blnk(5,18,5,19)
37:         call chatt(11,6-buson,45,7)
38:         call chatt(11,13-autoon,45,7)
39:         call chatt(11,20-genlan,45,7)
40:         call print("X",5,3+buson,11)
41:         call print("X",5,10+autoon,11)
42:         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 (s1hov.lt.0.) go to 7
 47:          if (s0b.gt.0.) s1hov=s0b
 48:          if (s0b.eq.0.) s1hov=55.
 49:        7 if (s1hov.lt.0.) s1hov=-s1hov
 50:          t1b=t0b
 51:          if (buson.eq.2) t1b=toffb+hov1*60./s1hov
 52:          t1pa=t0hov
 53:          if (autoon.eq.2) t1pa=toffpa+hov1*60./s1hov
 54:          t1npa=t0npa
 55:          if (s1gp.lt.0.) go to 4
 56:          s1gp=s0gp
 57:          if (genlan.eq.1) go to 5
 58:          s1gp=60./(1.+((v0npa+v0pa)/c1gp)**15)
 59:          speed=s0c
 60:          if (s0c.eq.0) speed=s0b
 61:          if (s1gp.gt.speed.and.speed.ne.0.) s1gp=speed
 62:        4 if (s1gp.lt.0.) s1gp=-s1gp
 63:          t1npa=toffnp+hov1*60./s1gp
 64:        5 efctr=11gp*(v0npa+v0pa+2.*b0peb)/10gp/v0npa
 65:          call print(snart(t1b,10,1),26,7,13)
 66:          call print(snart(t1pa,10,1),27,14,13)
 67:          call print(snart(s1gp,10,1),33,21,13)
 68:          call print(snart(t1npa,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
      clgp     58
      efctr    64   69
      hov1     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
```

```
 1:         Subroutine wks4(next)
 2:         real l0b,l0gp,l0hov,l1gp,l1hov
 3:         common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa
    ,
 4:        1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
 5:         common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
 6:        1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hov1
 7:         common/c3/genlan
 8:         common/c4/pooldf
 9:         character*10 snart,a
10:         integer genlan,pooldf
11:         next=5
12:         call vclear
13:         call print ("Worksheet 4: Forecast nonpriority auto volume",0
    ,0,14)
14:         call print ("new volume =",5,2,7)
15:         call print ("new v/c ratio =",5,4,7)
16:      10 coeff=1.19
17:         if (pooldf.ge.2) coeff=.122
18:         delta=-.916-1.053*(t1npa/t0npa-1.)+coeff*(t1pa/t0pa-1.)+.278*
    (t1b/t0b-1.)+.949*efctr
19:         v1npa=(1.+delta)*v0npa
20:         call print (snart(v1npa,10,-1),17,2,13)
21:         if (genlan.ne.1) go to 20
22:      14 call print("force flow conditions,",5,6,10)
23:         call print("go to worksheet 5",5,7,10)
24:         call blnk(5,4,50,4)
25:      15 call getd(a,im,if)
26:         if (im.eq.7) return
27:         if (if.ge.21.and.if.le.25) go to 50
28:         go to 15
29:      20 vc=v1npa/c1gp
30:         call print(snart(vc,10,2),20,4,13)
31:         if (vc.ge.1.) go to 30
32:         s1new=60./(1.+vc**15)
33:         if (abs(s1new/s1gp-1.).lt..1) go to 25
34:         call print("has not reached equilibrium,",5,6,12)
35:         call print("repeat worksheet 3",5,7,12)
36:         next=3
37:         s1gp=-s1new
38:      22 call getd(a,im,if)
39:         if (im.eq.7) return
40:         if (if.ge.21.and.if.le.25) go to 50
41:         go to 22
42:      25 call print("equilibrium achieved,",5,6,10)
43:         call print("go to worksheet 5",5,7,10)
44:      26 call getd(a,im,if)
45:         if (im.eq.7) return
46:         if (if.ge.21.and.if.le.25) go to 50
47:         go to 26
48:      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
```

```
 1:         Subroutine wks5(next)
 2:         real l0b,l0gp,l0hov,l1gp,l1hov
 3:         common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa
    ,
 4:        1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
 5:         common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
 6:        1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hov1
 7:         common/c4/pooldf
 8:         common/c5/s1hov
 9:         character*10 snart,a
10:         integer pooldf
11:         next=6
12:         call vclear
13:         call print("Worksheet 5: Forecast priority auto volume",0,0,1
    4)
14:         call print("priority auto volume =",5,2,7)
15:         call print("total carpools on HOV lane =",5,4,7)
16:         if (pooldf.eq.1) go to 10
17:         delpa=-.203-7.7*(t1pa/t0pa-1.)+4.8*(t1b/t0b-1.)
18:         v1pa=v0pa*(1.+delpa)
19:         v1hov=v1pa
20:         go to 20
21:      10 if (t0hov.eq.0.) go to 15
22:         delhov=-.203-7.7*(t1pa/t0hov-1.)+4.8*(t1b/t0b-1.)
23:         delpa=-.203-6.7*(t1pa/t0pa-1.)+4.8*(t1b/t0b-1.)
24:         v1pa=v0pa*(1.+delpa)
25:         v1hov=v1pa+v0hov*(1.+delhov)
26:         go to 20
27:      15 delpa=-.203-6.7*(t1pa/t0pa-1.)+4.8*(t1b/t0b-1.)
28:         v1pa=v0pa*(1.+delpa)
29:         v1hov=v1pa
30:      20 call print(snart(v1pa,10,-1),28,2,13)
31:         call print(snart(v1hov,10,-1),34,4,13)
32:         buses=b0hov
33:         if (buses.eq.0.) buses=b0peb
34:         vc=(v1hov+buses)/c1hov
35:         call print ("v/c ratio =",5,6,7)
36:         call print(snart(vc,10,2),17,6,13)
37:         if (vc.gt..8) go to 30
38:         call print ("level of service on HOV lanes OK",5,8,10)
39:         call print ("go to worksheet 6",5,9,10)
40:         go to 40
41:      30 call print ("level of service on HOV lanes insufficient",5,8,
    12)
42:         call print ("repeat worksheet 3 using revised speed",5,9,12)
43:         s1hov=60./(1+vc**15)
44:         if (s1hov.lt.s1gp) s1hov=s1gp
45:         s1hov=-s1hov
46:         next=3
47:      40 call getd (a,im,if)
48:         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
```

```
 1:         Subroutine wks6(next)
 2:         real l0b,l0gp,l0hov,l1gp,l1hov
 3:         common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa
    ,
 4:        1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
 5:         common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
 6:        1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hov1
 7:         common/c4/pooldf
 8:         common/c6/hovalt
 9:         integer pooldf,hovalt,busopt
10:         character*10 a,snart
11:         if (hovalt.eq.1.and.b1hov.eq.0.) busopt=1
12:         if (hovalt.eq.1.and.b1hov.ne.0.) busopt=2
13:         if (hovalt.eq.2.and.pooldf.eq.1) busopt=4
14:         if (hovalt.eq.2.and.pooldf.gt.1) busopt=3
15:         next=7
16:         call vclear
17:         call print("Worksheet 6: Forecast priority bus volume",0,0,14
    )
18:         call print("Bus options",0,2,7)
19:         call print("     Bus only on HOV lane (bus supply determined
    endogenously)",5,4,7)
20:         call print("     Bus only on HOV lane (bus supply determined
    exogenously)",5,5,7)
21:         call print("     Buses and 3+ or 4+ person carpools on HOV la
    ne",5,6,7)
22:         call print("     Buses and 2+ person carpools on HOV lane",5,
    7,7)
23:         call print("Priority bus passenger volume =",5,9,7)
24:         call print("Priority bus volume =",5,11,7)
25:       1 call blnk(5,4,5,7)
26:         call print("X",5,3+busopt,11)
27:         call chatt(10,3+busopt,60,11)
28:         go to (10,20,30,40),busopt
29:      10 delb=-1.404*(t1b/t0b-1.)
30:         go to 50
31:      20 delb=0.
32:         if (b0peb.ne.0.) delb=-.308*(t1b/t0b-1.)+.422*(b1hov/b0peb-1.
    )
33:         go to 50
34:      30 delb=.227+.435*(t1pa/t0pa-1.)
35:         go to 50
36:      40 delb=.227+1.71*(t1pa/t0pa-1.)
37:      50 v1b=v0b*(1.+delb)
38:         if (busopt.eq.2) go to 55
39:         if (b1hov.eq.0.) b1hov=v1b/l0b
40:      55 call print(snart(v1b,10,-1),37,9,13)
41:         call print(snart(b1hov,10,-1),27,11,13)
42:      60 call print("go to worksheet 7",5,13,10)
43:      61 call getd(a,im,if)
44:         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
```

```
 1:         Subroutine wks7(next)
 2:         real l0b,l0gp,l0hov,l1gp,l1hov
 3:         common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,l0b,v0t,t0npa,t0pa
    ,
 4:        1t0hov,t0b,s0gp,s0c,s0b,l0gp,l0hov,c0gp,c0hov,l1gp,l1hov,c1gp
 5:         common/c2/c1hov,b1hov,toffnp,toffpa,toffb,t1b,t1pa,
 6:        1t1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,v1b,hov1
 7:         character*10 a,snart
 8:         character*16 type
 9:         character*1 nart
10:         common/c4/pooldf
11:         integer pooldf
12:         common/c5/s1hov
13:         type="("
14:         call addstg(type,nart(pooldf+1),"+ occupants)")
15:         next=8
16:         call vclear
17:         call print("Worksheet 7: Summary results",0,0,14)
18:         call print("Volumes (peak-hour)",0,2,7)
19:         call print(". Automobiles, nonpriority",5,4,7)
20:         call print(". Carpools",5,5,7)
21:         call print(type,16,5,7)
22:         call print(". Buses",5,6,7)
23:         call print(". Bus passengers",5,7,7)
24:         call print("Total travel time (peak-hour)",0,9,7)
25:         call print(". Automobiles, nonpriority",5,11,7)
26:         call print(". Carpools",5,12,7)
27:         call print(type,16,12,7)
28:         call print(". Buses",5,13,7)
29:         call print("Speeds (average peak hour)",0,15,7)
30:         call print(". General purpose lane(s)",5,17,7)
31:         call print(". HOV lane(s)",5,18,7)
32:         call print("Person-trips (peak hour)",0,20,7)
33:         call print("    Before",40,1,7)
34:         call print("     After",50,1,7)
35:         call print("  % change",60,1,7)
36:         call print(snart(v1npa,10,-1),50,4,13)
37:         call print(snart(v1hov,10,-1),50,5,13)
38:         call print(snart(b1hov,10,-1),50,6,13)
39:         call print(snart(v1b,10,-1),50,7,13)
40:         call print(snart(t1npa,10,1),50,11,13)
41:         call print(snart(t1pa,10,1),50,12,13)
42:         call print(snart(t1b,10,1),50,13,13)
43:         call print(snart(s1gp,10,1),50,17,13)
44:         call print(snart(s1hov,10,1),50,18,13)
45:         call print(snart(v0npa,10,-1),40,4,13)
46:         call print(snart(v0hov+v0pa,10,-1),40,5,13)
47:         call print(snart(b0hov+b0peb,10,-1),40,6,13)
48:         call print(snart(v0b,10,-1),40,7,13)
49:         call print(snart(t0npa,10,1),40,11,13)
50:         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
```