AN EVALUATION OF THE
COST EFFECTIVENESS OF HOV LANES

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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.
DISCLAIMER

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Transportation Commission, Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.
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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 HOVs, 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 Charniak (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 Holm 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)

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

Massachusetts - (Hatzı, 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; Heaery and Jacobs, 1984; and Washington State Department of Transportation, 1985)


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 (Bailley, 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 Vion, 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.

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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 Cos. 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. Time 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 (Winrey 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 essence 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 \( \leq 1500 \) vehicles per hour (vph),

\[
s = 58 - .002q
\]

for lane volumes \( > 1500 \) and \( < 1800 \) vph

\[
s = 79.876 - .0166q
\]

for lane volumes \( \geq 1800 \) and \( \leq 1873 \) 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 \( \leq q_1 \),
Figure 4. Computation of Time Penalty ($t_p$) for Vehicles Displaced Outside Peak Period.
Figure 5. Speed-Flow Curve for I-5 North.
\[ s = q_{\text{max}} \left( 1 - 0.06462 r_{\text{vol}} \right) \]
for lane volumes \( > q_1 \) and \( < q_2 \),
\[ s = q_{\text{max}} \left( 1.3793 - 0.5385 r_{\text{vol}} \right) \]
for lane volumes \( \geq q_2 \) and \( \leq q_{\text{max}} \).
\[ s = q_{\text{max}} \left( 0.69086 + 0.86157 \left( 1 - r_{\text{vol}} \right)^{1/2} \right) \]

where:
\[ q_1 = \text{first flow cutoff} \left( 0.8004 q_{\text{max}} \right) \]
\[ q_2 = \text{second flow cutoff} \left( 0.905 q_{\text{max}} \right) \]
\[ q_{\text{max}} = \text{maximum flow possible} \]
\[ r_{\text{vol}} = \text{demand to capacity ratio} \]

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:
\[ q_{\text{min}} = q_{\text{max}} \left( 0.357 + 1.8614 \text{speed} - 1.3472 \text{speed}^2 \right) \]

where:
\[ q_{\text{min}} = \text{the flow possible at the minimum speed} \]
\[ r_{\text{speed}} = \text{ratio of the minimum speed to maximum speed} \]

It was assumed that \( q_{\text{min}} \) 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 \( q_{\text{min}} \) and \( q_{\text{max}} \) based on demand to capacity ratio \( r_{\text{vol}} \). The actual flow used is constrained to be between \( q_{\text{min}} \) and \( q_{\text{max}} \). After these steps, the speed is computed using the equation:
\[ s = q_{\text{max}} \left( 0.69086 - 0.86157 \left( 1 - r_{\text{vol}} \right)^{1/2} \right) \]

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:

\[ d_{pa} = -.203 - 7.7(r_{time} - 1) + 4.8(r_{time} - 1) \]

where:

- \( r_{time} \) = 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:

\[ d_{pa} = -.203 - 6.7(r_{time} - 1) + 4.8(r_{time} - 1) \]

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

\[ d_{b} = .227 + .435(r_{time} - 1) \]

where:

- \( d_{b} \) = the proportional shift for buses

For buses and two person carpools, the equation is:

\[ d_{b} = .227 + 1.71(r_{time} - 1) \]

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 HOVs that the other alternatives did, nor did the HOVs 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 SOVs 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
I-5 north of Northgate

<table>
<thead>
<tr>
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<th>Do Nothing</th>
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<th>Add HOV Lane</th>
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<td>45100 54800</td>
<td>45100 54800</td>
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<td>4713 5727</td>
<td>4713 5727</td>
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<td>317 385</td>
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<td>.45 .45</td>
<td>.45 .45</td>
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<td>268 345</td>
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<td>17 17</td>
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<td>11.5 11.5</td>
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<td>.7 .7</td>
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<td>25 25</td>
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<tr>
<td>min. arterial speed</td>
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<td>Travel time (minutes)</td>
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<td></td>
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<td>vanpool</td>
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<td>22.05 21.96</td>
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<td>27.11 26.90</td>
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Table 1

Cost Model Outcomes for I-5 Alternative
### I-5 north of Northgate

#### Displacements

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<tr>
<th></th>
<th>Do Nothing 1985</th>
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#### Summary Statistics

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<tr>
<td>% on arterials</td>
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<td>.518</td>
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#### Total Trip Length

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<td>10.0</td>
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<td>vanpools</td>
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<td>20.0</td>
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<tr>
<td>buses</td>
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#### Total Vehicle Miles (1000's)

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#### Maximum Speeds

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#### TOTAL COSTS

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<tr>
<td></td>
<td>341.47</td>
<td>460.57</td>
<td>327.65</td>
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#### COST PARAMETERS

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<th>Cost Parameter</th>
<th>Value</th>
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<tr>
<td>Parking costs ($/s/day)</td>
<td>SOV 3.71</td>
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<tr>
<td>Annual costs ($1,000's)</td>
<td>Maint. cost 48</td>
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<tr>
<td>Miscellaneous</td>
<td>Value of time ($) 7.00</td>
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<td>Operating costs</td>
<td>Extra HOV maint. 10</td>
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<tr>
<td>car ($/mi.)</td>
<td>Discount rate (%) 4.0</td>
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<td>van ($/mi.)</td>
<td>Lane construction 9202</td>
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<td>Extra HOV cost 920</td>
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<td>bus ($/mi.)</td>
<td>Oper. cost elas. .50</td>
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<td>bus ($/trip)</td>
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#### Net Savings ($1,000,000's)

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Table 1 (continued)

Cost Model Outcomes for I-5 Alternative
### I-405 south of I-90

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### 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

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**COST PARAMETERS**

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Table 2 (continued)

Cost Model Outcomes for I-405 Alternative
## HOV Cost Model
March 26, 1987   21:04 PM

### SR520 east of Evergreen Point Bridge

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Table 3

Cost Model Outcomes for SR520 Alternative
SR520 east of Evergreen Point Bridge

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Summary Statistics

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Total Trip Length

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Total Vehicle Miles (1000's)

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Maximum Speeds

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TOTAL COSTS 117.47 190.58 115.47 172.97 111.76 163.26

COST PARAMETERS

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Operating costs

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<td>van ($/mi.)</td>
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<td>bus ($/mi.)</td>
<td>1.31</td>
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<tr>
<td>bus ($/hr.)</td>
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<td>bus ($/trip)</td>
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Net Savings ($1,000,000's)

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<th>agency</th>
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<td>24.7</td>
<td>-4.5</td>
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Table 3 (continued)

Cost Model Outcomes for SR520 Alternative

50
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 conducted by adding one extreme value 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.
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<td>bus access time</td>
<td>15% more</td>
<td>142.8</td>
<td>8.78</td>
<td>4.0</td>
</tr>
<tr>
<td>HOV lane enforcement</td>
<td>0.75</td>
<td>142.4</td>
<td>8.88</td>
<td>3.4</td>
</tr>
<tr>
<td>2000 buses</td>
<td>10% less</td>
<td>146.1</td>
<td>8.93</td>
<td>1.7</td>
</tr>
<tr>
<td>bus fare</td>
<td>10% less</td>
<td>144.6</td>
<td>9.00</td>
<td>1.4</td>
</tr>
<tr>
<td>auto operating cost</td>
<td>10% less</td>
<td>144.6</td>
<td>9.01</td>
<td>1.3</td>
</tr>
<tr>
<td>2000 2 pers. carpools</td>
<td>40% less growth</td>
<td>144.6</td>
<td>9.01</td>
<td>1.3</td>
</tr>
<tr>
<td>1985 3+ carpools</td>
<td>15% fewer</td>
<td>144.8</td>
<td>9.01</td>
<td>1.2</td>
</tr>
<tr>
<td>growth in vanpools</td>
<td>50% less</td>
<td>145.2</td>
<td>9.03</td>
<td>0.8</td>
</tr>
<tr>
<td>bus mileage cost</td>
<td>10% more</td>
<td>145.9</td>
<td>9.01</td>
<td>0.8</td>
</tr>
<tr>
<td>bus trip length</td>
<td>10% more</td>
<td>146.0</td>
<td>9.01</td>
<td>0.8</td>
</tr>
<tr>
<td>HOV parking cost</td>
<td>20% more</td>
<td>145.3</td>
<td>9.04</td>
<td>0.7</td>
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<tr>
<td>1985 2 pers. carpools</td>
<td>15% fewer</td>
<td>145.2</td>
<td>9.06</td>
<td>0.7</td>
</tr>
<tr>
<td>growth in buses</td>
<td>50% less</td>
<td>145.6</td>
<td>9.03</td>
<td>0.6</td>
</tr>
<tr>
<td>2000 vanpools</td>
<td>40% less growth</td>
<td>145.6</td>
<td>9.06</td>
<td>0.4</td>
</tr>
<tr>
<td>1985 vanpools</td>
<td>15% fewer</td>
<td>145.7</td>
<td>9.06</td>
<td>0.4</td>
</tr>
<tr>
<td>extra HOV lane maint.</td>
<td>50% more</td>
<td>146.0</td>
<td>9.05</td>
<td>0.3</td>
</tr>
<tr>
<td>vanpool formation time</td>
<td>3 min. more</td>
<td>145.7</td>
<td>9.07</td>
<td>0.3</td>
</tr>
<tr>
<td>van operating cost</td>
<td>10% more</td>
<td>146.0</td>
<td>9.06</td>
<td>0.2</td>
</tr>
<tr>
<td>vanpool trip length</td>
<td>10% more</td>
<td>146.0</td>
<td>9.08</td>
<td>0.1</td>
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<tr>
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<td>10% less</td>
<td>146.0</td>
<td>9.08</td>
<td>0.1</td>
</tr>
<tr>
<td>2 p. pool trip length</td>
<td>10% more</td>
<td>146.1</td>
<td>9.08</td>
<td>0.0</td>
</tr>
<tr>
<td>3+ carpool trip length</td>
<td>10% more</td>
<td>146.1</td>
<td>9.08</td>
<td>0.0</td>
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</table>
Table 6
Consecutive Addition of Extreme Assumptions in Comparison with "Add a General Lane" Alternative

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Worst case</th>
<th>Net pres. value</th>
<th>Benefit cost rat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>freeways capacity</td>
<td>10% more</td>
<td>40.1</td>
<td>5.07</td>
</tr>
<tr>
<td>discount rate</td>
<td>10% per year</td>
<td>23.9</td>
<td>4.62</td>
</tr>
<tr>
<td>min. arterial speed</td>
<td>3 mph less</td>
<td>20.9</td>
<td>4.16</td>
</tr>
<tr>
<td>min. freeway speed</td>
<td>5 mph more</td>
<td>23.9</td>
<td>4.81</td>
</tr>
<tr>
<td>carpool formation time</td>
<td>3 min. more</td>
<td>19.5</td>
<td>4.02</td>
</tr>
<tr>
<td>1985 person-trips</td>
<td>10% fewer</td>
<td>13.9</td>
<td>2.98</td>
</tr>
<tr>
<td>growth in 3+ carpools</td>
<td>50% less</td>
<td>16.2</td>
<td>3.30</td>
</tr>
<tr>
<td>arterial capacity</td>
<td>15% more</td>
<td>27.6</td>
<td>4.92</td>
</tr>
<tr>
<td>% preferring peak</td>
<td>0.38</td>
<td>21.2</td>
<td>3.95</td>
</tr>
<tr>
<td>freeways max. speed</td>
<td>5 mph more</td>
<td>17.3</td>
<td>3.39</td>
</tr>
<tr>
<td>SOV parking cost</td>
<td>20% less</td>
<td>13.9</td>
<td>2.92</td>
</tr>
<tr>
<td>arterial max. speed</td>
<td>3 mph more</td>
<td>13.1</td>
<td>2.80</td>
</tr>
<tr>
<td>value of time</td>
<td>$3 per hour</td>
<td>13.4</td>
<td>2.83</td>
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<td>HOV lane max. speed</td>
<td>5 mph less</td>
<td>11.5</td>
<td>2.55</td>
</tr>
<tr>
<td>length</td>
<td>10% less</td>
<td>11.5</td>
<td>2.55</td>
</tr>
<tr>
<td>peak factor</td>
<td>10% less</td>
<td>10.2</td>
<td>2.48</td>
</tr>
<tr>
<td>extra HOV construction</td>
<td>20% of lane cost</td>
<td>9.2</td>
<td>2.19</td>
</tr>
<tr>
<td>2000 person-trips</td>
<td>25% less growth</td>
<td>8.9</td>
<td>2.14</td>
</tr>
<tr>
<td>overall access time</td>
<td>15% more</td>
<td>8.8</td>
<td>2.13</td>
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<td>bus trip cost</td>
<td>10% more</td>
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<td>1.98</td>
</tr>
<tr>
<td>auto operating cost</td>
<td>10% less</td>
<td>7.3</td>
<td>1.86</td>
</tr>
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<td>2000 3+ carpools</td>
<td>40% less growth</td>
<td>6.1</td>
<td>1.73</td>
</tr>
<tr>
<td>bus access time</td>
<td>3 min. more</td>
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<td>1.70</td>
</tr>
<tr>
<td>HOV differential speed</td>
<td>5 mph less</td>
<td>5.9</td>
<td>1.68</td>
</tr>
<tr>
<td>average trip length</td>
<td>10% less</td>
<td>5.1</td>
<td>1.58</td>
</tr>
<tr>
<td>oper. cost elasticity</td>
<td>0.25</td>
<td>5.2</td>
<td>1.60</td>
</tr>
<tr>
<td>HOV lane enforcement</td>
<td>25% more</td>
<td>5.0</td>
<td>1.56</td>
</tr>
<tr>
<td>bus fare</td>
<td>10% less</td>
<td>5.0</td>
<td>1.55</td>
</tr>
<tr>
<td>2000 buses</td>
<td>10% fewer</td>
<td>4.8</td>
<td>1.53</td>
</tr>
<tr>
<td>1985 3+ carpools</td>
<td>15% fewer</td>
<td>4.7</td>
<td>1.52</td>
</tr>
<tr>
<td>2000 2 pers. carpools</td>
<td>40% less growth</td>
<td>3.6</td>
<td>1.40</td>
</tr>
<tr>
<td>growth in vanpools</td>
<td>50% less</td>
<td>3.0</td>
<td>1.33</td>
</tr>
<tr>
<td>HOV parking cost</td>
<td>20% more</td>
<td>2.9</td>
<td>1.32</td>
</tr>
<tr>
<td>bus mileage cost</td>
<td>10% more</td>
<td>2.8</td>
<td>1.30</td>
</tr>
<tr>
<td>bus trip length</td>
<td>10% more</td>
<td>2.6</td>
<td>1.28</td>
</tr>
<tr>
<td>1985 2 pers. carpools</td>
<td>15% fewer</td>
<td>2.6</td>
<td>1.28</td>
</tr>
<tr>
<td>2000 vanpools</td>
<td>40% less growth</td>
<td>2.6</td>
<td>1.28</td>
</tr>
<tr>
<td>growth in buses</td>
<td>50% less</td>
<td>-0.6</td>
<td>0.90</td>
</tr>
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</table>
### Table 7
Consecutive Addition of Extreme Assumptions in Comparison with "Do Nothing" Alternative

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

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

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 'HOCVCOST.' 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
btripr - (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
cine - (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

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

dispfs - (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

cnf - (var) HOV lane enforcement cost

facd - (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

fecont - (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 - (inc) 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

hvcom - (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

ioclas - (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)
loep - (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
pesov - (var) SOV parking cost
pcvan - (var) van parking cost
percost - (arr) total personal cost (auto operating, parking, etc.)
pinj - (var) increment used for proportion of traffic assigned to arterial lanes in the optimization of assignment
pinj - (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
ptrip - (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
reapg - (var) general traffic lane capacity taking excess demand into account

sgsp - (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

soveal - (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

sqr - (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

timest - (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

tsov - (arr) average SOV trip length

tvan - (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
tvam - (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

vcursy - (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
vtrip - (arr) total average van trip time

wcsp - (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

BIBLIOGRAPHY
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

1:     logical clean
2:     character*10 a, snart
3:     character*21 label(65)
4:     character*8 file
5:     character*40 fcontent
6:     data label//"Person-trips", "SOV’s", "2-pers. carpools", "3-pers. carpools", "Vanpools",
7:       \"Buses", \"Carpool definition\", \"% preferring peak\",\n8:       \"capacity - gen\", \"HOV\", \"art\", \"\# peak veh. - gen\", \"HOV\", \"art\",
9:       \"\# shoulder veh. - gen\", \"HOV\", \"art\", \"\# shoulder speeds - gen\", \"HOV"
10:      \"art\", \"\# length - gen\", \"HOV lanes\", \"\# arterial lanes\", \"access time\",
11:     \"\# carpool formation\", \"vanpool formation\", \"bus access\",
12:     \"min. freeway speed\", \"min. arterial speed\",
13:     \"SOV\", \"carpool\", \"vanpool\",
14:     \"bus\", \"SOV\", \"carpool\",
15:     \"vanpool\", \"bus\", \"SOV\", \"carpool\", \"vanpool\", \"bus\",
16:     \"peak freeway\", \"peak arterial\", \"shoulder freeway\",
17:     \"\# shoulder arterial\", \"% on arterials\", \"average trip time\",
18:     \"\# average\", \"SOV\", \"2-pers. carpool\", \"3-pers. carpool\",
19:     \"vanpools\", \"buses\", \"cars\", \"vanpools\", \"buses\", \"freeway\",
20:     \"HOV\", \"arterial\", \"HOV differential\", \"TOTAL COSTS\",
21:     integer locx(6), locy(65), locp(65), dec(65), type(65), fmt(5), ich
22:     data fmt/7, 15, 15, 15, 15/
23:     data type/1, 0, 1, 1, 1, 1, 3, 2, 3, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4, 3, 2
24:      14, 2, 2, 2, 2, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 2, 2, 2, 2
25:      20, 0, 0, 4, 3, 4, 3, 0/
26:     data locx/22, 29, 42, 49, 62, 69/
27:     data locy/2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,
28:     120, 21, 22, 23, 24, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18,
29:      219, 20, 21, 22, 23, 24, 3, 4, 5, 6, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 3, 4,
30:      5, 6, 8/
31:     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, 0, 0,
32:      11, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2
33:     real x(6, 65), ptrips(6), sov(6), pool2(6), pool3(6), poolv(6), bus(6),
34:      lvgp(6), vhp(6), vap(6), vgs(6), vhs(6), vas(6), pspg(6), pspw(6),
35:      2pspa(6), ssdp(6), ssph(6), sspl(6), capg(6), caph(6), capa(6), tpvg(6),
36:      tpvh(6), tpva(6),
36: 3len(6), ngpl(6), nhov(6), access(6), tpool(6), tvan(6), tbus(6),
37: strlp(6), ctrip(6), vtrip(6), btrip(6), strips(6), ctrip(6), vtrip
38: s(6), btrips(6),
39: strlp(6), ctrip(6), vtrip(6), btrip(6), narts(6), cpdefn(6), sp
40: minf(6), spmina(6), prefk(6),
41: 5v(6), vh(6), disp(6), dispaw(6), dispag(6), ttime(3),
42: 6pcap(6), tbar(6), tla(6), tlsow(6), tlp1(6), tlp3(6), tvan(6),
43: 7tbus(6), tmcar(6), tmvan(6), tmbus(6), tcost(6),
44: 8avspg(6), avsh(6), avspa(6), tincst(6), percst(6), agyast(6)
45: equivalence (x(1,1), ptrip(1), (x(1,2), sov(1)), (x(1,3), pool(1)),
46: 1(x(1,4), pool(1), (x(1,5), poolv(1)), (x(1,6), bus(1)), (x(1,7), c
47: pdefn(1)), (x(1,8), prefk(1)),
48: 2(x(1,9), capg(1), (x(1,10), caph(1), (x(1,11), capa(1)),
49: 3(x(1,12), vgp(1), (x(1,13), vhp(1)), (x(1,14), vap(1)),
50: 4(x(1,15), vgs(1), (x(1,16), vhs(1)), (x(1,17), vas(1)),
51: 5(x(1,18), pspg(1), (x(1,19), psh(1)), (x(1,20), psa(1)),
52: 6(x(1,21), sspg(1), (x(1,22), spsh(1)), (x(1,23), spsa(1)),
53: 7(x(1,24), lengl(1), (x(1,25), ngpl(1)), (x(1,26), nhov(1)), (x(1,27)
54: , narts(1)),
55: 8(x(1,28), access(1), (x(1,29), tpool(1)), (x(1,30), tvan(1)),
56: 9(x(1,31), tbos(1)), (x(1,32), spminf(1)), (x(1,33), spmina(1)), (x(1,34)
57: , strip(1)), (x(1,35), ctrip(1)),
58: 9(x(1,36), vtrip(1), (x(1,37), btrip(1)), (x(1,38), strips(1)),
59: 9(x(1,39), ctrip(1), (x(1,40), vtrip(1)), (x(1,41), btrip(1)),
60: 9(x(1,42), strip(1), (x(1,43), strip(1)), (x(1,44), vtrip(1)),
61: 9(x(1,45), btrip(1), (x(1,46), disp(1)), (x(1,47), disp(1)),
62: 9(x(1,48), disp(1), (x(1,49), disp(1)), (x(1,50), pcap(1)),
63: 9(x(1,51), tbar(1), (x(1,52), tla(1)), (x(1,53), tlsow(1)),
64: 9(x(1,54), tlp1(1), (x(1,55), tlp3(1)), (x(1,56), tvan(1)),
65: 9(x(1,57), tbus(1), (x(1,58), tmcar(1)), (x(1,59), tmvan(1)),
66: 9(x(1,60), tmbus(1)),
67: 9(x(1,61), tcost(1))
68: data dec/1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,
69: 1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1
70: ,1,1,2/
71: data npar/65/
72: real y(18), maint, xs(6)
73: common/delay/delg, delgs, dela, delas
74: common/result/tcl, tc2, bcl, bc2
75: common/cursor/ion1, ion2, ioff1, ioff2
76: equivalence (y(1), pscov), (y(2), pcpol), (y(3), pcvan),
77: 1(y(4), occar), (y(5), ocvan),
78: 2(y(9), maint), (y(10), hovent), (y(11), enf),
79: 3(y(12), tval), (y(13), disc), (y(14), constg), (y(15), consth),
80: 4(y(16), elas)
81: c
82: c
83: ion=7
84: c
85: read in data
86: c
87: ionl=7
ion2=6
ioff1=0
ioff2=8
if (ioread(5,2,0,"crsdef")) go to 20
read (5,10) ion1,ion2,ioff1,ioff2
10 format (2i2)
if (iocread(5)) stop
20 call crs(ioff1,ioff2)
call chfile(file,fcont)
if (file.eq."") go to 1100
if (iogread(5,2,0,file)) stop
read (5,100) ((x(i,j),i=1,5),j=1,npar)
100 format (5e13.6)
read (5,110) tval,pcsov,pcpol,pcvan,occar,ocvan,y(6),y(7),y(8)
,iconstg,consht,mainthovmmt,enf,elas,bfare,pkfact
110 format (e13.6)
y(17)=bfare
y(18)=pkfact
read (5,100) (timcst(i),i=1,6),(percst(i),i=1,6),(agcst(i),i=
1,6),
1(avspg(i),i=1,6),(avspgh(i),i=1,6),(avspa(i),i=1,6)
if (iocclos(5)) stop

; set up screens

do 200 ip=3,0,-1
call chpage(ip)
200 call vclear
do 210 ip=0,3
 call printf("1985",24,1,12,ip)
call printf("1985",44,1,12,ip)
call printf("1985",64,1,12,ip)
call printf("2000",31,1,12,ip)
call printf("2000",51,1,12,ip)
call printf("2000",71,1,12,ip)
call printf("Do Nothing",24,0,13,ip)
call printf("Add Mixed Lane",42,0,13,ip)
call printf("Add HOV Lane",63,0,13,ip)
call printf("Travel time (minutes)",0,12,11,1)
call printf("Peak",3,13,11,1)
call printf("Shoulder",3,17,11,1)
call printf("Average",3,21,11,1)
call printf("Displacements",0,2,11,2)
call printf("Summary Statistics",0,7,11,2)
call printf("Total Vehicle Miles (1000's)",0,17,11,2)
call printf("Total Trip Length",0,10,11,2)
call printf("Maximum Speeds",0,2,11,3)
do 220 i=1,npar
call printf(label(i),21-klen(label(i)),locy(i),14,locp(i))
do 220 j=1,6
220 call printp( snart(x(j,i),6,dec(i)), locx(j), locy(i), fmt(type(i) +1), locp(i) )
229      call chttpp(0,8,21,12,3)
230      call cstmt(0,y,0)
231      ip=-1
232      call cstmtl(ip,tcost,disc,constg,consth,maint,hovmnt,enf,
233                     ltimost,percst,agycst,tc1,tc2,bc1,bc2, pkfact, ichela)
234      ip=0
235      c
236      c      print cursor and get instruction
237      ix=1
238      iy=1
239      move=3
240      if (type(iy).eq.0.and.move.eq.3) go to 740
241      if (type(iy).eq.0.and.move.eq.5) go to 740
243      if (type(iy).eq.0.and.move.eq.0) go to 740
244      if (type(iy).eq.0.and.move.eq.1) go to 720
245      if (type(iy).eq.0.and.move.eq.6) go to 720
246      ip=locp(ip)
247      call chpage(ip)
248      call chttpp(locx(ix),locy(iy),6,138,locp(ip))
249      call curm(locx(ix),locy(iy),locp(ip))
250      call getam(a,move,nfunc)
251      call chttpp(locx(ix),locy(iy),6,fmt(type(iy)+1),locp(ip))
252      c
253      c      set CALC and select page
254      if (nfunc.gt.6) go to 470
255      go to (700,400,440,450,450,450,450), nfunc+1
256      400 if (icalc.eq.1) go to 420
257      icalc=1
258      do 410 ipt=0,3
259      410 call printp( "CALC",76,0,48,ipt)
260      go to 300
261      420 icalc=0
262      do 430 ipt=0,3
263      430 call printp( "

",76,0,7,ipt)
264      go to 300
265      440 if(icalc.eq.0) go to 300
266      go to 600
267      450 ip=nfunc-3
268      call chpage(ip)
269      if (ip.eq.3) go to 1000
270      460 if (locp(ip).eq.ip) go to 300
271      ix=1
272      if (ip.eq.0) iy=1
273      if (ip.eq.1) iy=24
274      if (ip.eq.2) iy=46
275      go to 300
276      470 if (nfunc.eq.4) go to 510

B4
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:  
183: do 490 i=5,6  
184: call hovcom(len(i), pspg(i-4), ctrip(i-4), btrip(i-4), cpdefn(i),  
185: pool2(i-4), pool3(i-4), poolv(i-4), bus(i-4), pool2(i), pool3(i),  
186: poolv(i), bus(i))  
187:  
188: call printp(smart(x(i,j), 6, dec(j)), locx(i), locy(j),  
189: fmt(type(j)+1), locp(j))  
190: if (icalc.eq.1) go to 300  
191: do 500 i=1,4  
192: ichng(i)=0  
193: ichng(5)=1  
194: ichng(6)=1  
195: go to 600  
196: c  
197: c calculate elasticities  
198: c  
199: if (icalc.eq.1) go to 300  
200: ichela=1  
201: tc1s=tc1  
202: tc2s=tc2  
203: bc1s=bc1  
204: bc2s=bc2  
205: do 520 i=1,6  
206: xs(i)=x(i,iy)  
207: go to 810  
208: call printp(smart((tc1/tc1s-1.)/.1,10,3),26,23,12,3)  
209: call printp(smart((tc2/tc2s-1.)/.1,10,3),26,24,12,3)  
210: call printp(smart((bc1/bc1s-1.)/.1,10,3),66,23,12,3)  
211: call printp(" -------------------Elasticities-------------------")  
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("  
217: call printp("  
218: call chpage(ip)  
219: do 560 i=1,6  
220: x(i,iy)=xs(i)  
221: tcl=tclts  
222: tc2=tc2s  
223: bc1=bc1s  
224: bc2=bc2s  
225: ichela=0

B-5
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),pstrips(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 (.eq.1) pcap(i)=pCapt+pinc
240:  if (.eq.2) pcap(i)=pCapt-pinc
241:  if (.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),pPrefk(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: 4disp(i),dispa(i),dispg(i),x(i,61),x(i,62),x(i,63)
247:  call speeds(pspg(i),sspg(i),psh(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: 5disp(i),dispa(i),dispg(i),disp(i),
253: 6avspg(i),av sph(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: 1acces(i),len(i),tPOOL(i),tvan(i),tbus(i),
256: 2pspg(i),sspg(i),psh(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),cstrip(i),cstrips(i),
259: 5vstrip(i),vstrips(i),vstrip(i),btrip(i),bstrip(i),bstrips(i)
260:  ttime(j)=sov(i)*stript(i)+2.*pool2(i)*cstrips(i)+
261: 13.3*pool3(i)*cstrips(i)-10.*poolv(i)*vstrip(i)+45.*bus(i)*btrip(i)+
262: 2disp(i)*delg+disp(i)*delg+disp(i)*delg+disp(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: 660 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: \[\text{pinc} = \frac{\text{pinc}}{2}.\]
273: \text{go to 620}
274: 
275: \text{660 tbar(i)=ttimelim}
276: \text{call length(mov(i), pool2(i), pool3(i), poolv(i), bus(i), tmcari),}
277: \text{ltmvani(t), tmbusi(t), tlav(i), tlvovi(t), tlpl2(i), tlpl3(i), tlvani(t),}
278: \text{2tlbus(i))}
279: \text{call cost(tcost(i), timcst(i), percest(i), agycst(i), tval, pcsov,}
280: \text{lpcpol, pcvan, ocvar, ocvan, y(6), y(7), y(8), avspgi, avspgh, avsp}
281: \text{a(i), elas,}
282: \text{2sov(i), pool2(i), pool3(i), poolv(i), bus(i), len(i), pcap(i),}
283: \text{3tmcar(t), tmvani(t), tmbusi(t), tbar(i), ptrips(i), bfare, btript(i),}
284: \text{4x(i,61), x(i,62), x(i,63))}
285: \text{if (ichela.eq.1) go to 680}
286: \text{do 670 j=1,npar}
287: \text{680 if (type(j).eq.0) call printp(smart(x(i,j),6,dec(j)), locx(i),}
288: \text{loccy(j), 7, loccp(j))}
289: \text{continue}
290: \text{call cstatcal(ip, tcost, disc, constq, consth,maint, hovmnb, enf,}
291: \text{ltimcst, percest, agycst, tcl, tc2, bcl, bc2, pkfact, ichela)}
292: \text{if (ichela.eq.1) go to 530}
293: \text{go to 300}
294: \text{c}
295: \text{move cursor}
296: \text{c}
297: \text{700 if (a.ne."" ) go to 800}
298: \text{710 go to (300,720,730,740,750,760,770,1100), move+1}
299: \text{720 iy=mod(iy+npar-2, npar)+1}
300: \text{go to 300}
301: \text{730 ix=mod(ix,6)+1}
302: \text{go to 300}
303: \text{740 if (iy.eq.npar) go to 1000}
304: \text{750 ix=mod(ix+4,6)+1}
305: \text{go to 300}
306: \text{760 ix=1}
307: \text{iy=1}
308: \text{go to 300}
309: \text{770 ix=6}
310: \text{iy=npar}
311: \text{go to 300}
312: \text{c}
313: \text{change data}
314: \text{c}
315: \text{800 if (clean(a,6)) go to 810}
316: \text{call printp(a, locx(ix), locy(iy), 140, locp(iy))}
317: \text{call take(3.)}
318: \text{call printp(smart(x(ix,iy),6,dec(iy)), locx(ix), locy(iy), fmt(t}
319: \text{ype(iy)+1), locp(iy))}
go to 300
810 do 820 i=1,6
820 ichng(i)=0
830 go to (830,840,860,880),type(iy)
832 if (ichela.eq.0) x(ix,iy)=tran(a)
833 if (ichela.eq.1) x(ix,iy)=x(ix,iy)*1.1
834 ichng(ix)=1
835 if (ichela.eq.1) go to 900
836 call printp(snot(x(ix,iy),6,dec(iy)),locx(ix),locy(iy),fmt(type(iy)+1),locp(iy))
837 go to 900
840 ist=2-mod(ix,2)
841 do 850 ix=ist,ist+6,2
842 ichng(ixx)=1
843 if (ichela.eq.0) x(ixx,iy)=tran(a)
844 if (ichela.eq.1) x(ixx,iy)=x(ixx,iy)*1.1
845 if (ichela.eq.1) go to 850
846 call printp(snot(x(ixx,iy),6,dec(iy)),locx(ixx),locy(iy),fmt(type(iy)+1),locp(iy))
847 go to 900
850 continue
860 ist=ix-1+mod(ix,2)
861 do 870 ix=ist,ist+1
862 ichng(ixx)=1
863 if (ichela.eq.0) x(ixx,iy)=tran(a)
864 if (ichela.eq.1) x(ixx,iy)=x(ixx,iy)*1.1
865 if (ichela.eq.1) go to 870
866 call printp(snot(x(ixx,iy),6,dec(iy)),locx(ixx),locy(iy),fmt(type(iy)+1),locp(iy))
867 go to 900
870 continue
880 do 890 ix=1,6
882 ichng(ixx)=1
883 if (ichela.eq.0) x(ixx,iy)=tran(a)
884 if (ichela.eq.1) x(ixx,iy)=x(ixx,iy)*1.1
885 if (ichela.eq.1) go to 890
886 call printp(snot(x(ixx,iy),6,dec(iy)),locx(ixx),locy(iy),fmt(type(iy)+1),locp(iy))
887 go to 900
890 continue
900 if (icalc.eq.0) go to 600
904 go to 710
945 c set cost parameters
946 c
950 call cstset(ip,y,icalc)
951 iy=npar-1
952 bfare=y(17)
953 pkfact=y(18)
954 if (ip.lt.4) go to 460
955 if (ip.gt.13) go to 1100
956 do 1010 i=1,6

B-8
call cost(tc1st(i),timcst(i),percst(i),agycst(i),tval,pcsov,
1pcpol,pcvan,occar,ocvan,y(6),y(7),y(8),avsph(i),avsp
a(i),elas,
2sov(i),pool2(i),pool3(i),poolv(i),bus(i),len(i),pcap(i),
3tmcar(i),tmvan(i),tmbus(i),tbar(i),ptrips(i),bfare,btripf(i),
4x(i,61),x(i,62),x(i,63)
1010 call printp(smart(x(i,npar),6,dec(npar)),locx(i),locy(npar),7
,locp(npar))
call cscval(ip,tcost,disc,constg,consth,maint,hoymnt,enf,
1timcst,percst,agycst,tc1,tc2,bcl,bc2,pkfact,ichela)
ip=ip-10
go to 1000
c
exit
Subroutines
chapp 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
cget 215
cgetam 150
chovcom 183
lanes 242
length 275
pout 180
printp 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121
integer variables

i 90 97 98 125 126 128 160 164 187 207 208 209 210 211 216 217
   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
ischela 133 199 225 283 288 289 322 323 325 331 333 340 341 342
       348 349 350 372
ioffl  80  83  86
ioff2  81  83  86
ionl  78  83  380
ion2  79  83  380
ip  103 104 106 107 108 109 110 111 112 113 114 115 131 132 134
    146 147 158 169 170 171 173 174 175 218 287 358 362 363 371
    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
iyy  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
il  215
it  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
nfnc  150 155 156 168 177 178 179
npar  90 125 284 296 300 301 309 359 370 384
real variables

bcl  133 202 209 223 288 372
bcls  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
tcl     133  200  207  221  288  372
tcls    200  207  221
tc2     133  201  208  222  288  372
tc2s    201  208  222
tval    73  92  278  365  386

calendar 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
avspsh    42  98 253  279  366  390

B-11
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
dispq  39  56  246  252  262
dispqs  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
percet  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
pshp  34  48  247  256
pxpg  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
spmin  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
stripes  37  53  258
strippt  38  55  258  260
tbar  40  58  274  281  368
tbus  36  52  255
tcost  41  62  132  278  287  365  371
timcost  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
tmcars  41  60  275  281  368
tmvan  41  60  276  281  368

B-12
tpool  36  51  255
tpva  35
tpvvg 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

candidate 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

candidate functions

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

B-13
Subroutine chfile(file,fcont)  
character*10 a  
character*40 filn(20),fcont  
integer filnum(20)  
character*8 file  
character*4 work  
common/cursor/ion1,ion2,ioff1,ioff2  
file=""  
call chpage(0)  
call vclear  
call printp("Pick a case for analysis",0,0,14,0)  
if (ioread(5,2,0,"files")) go to 40  
read (5,10) nfil  
10 format (i0)  
read (5,20,errexit=40) (filnum(i),filn(i),i=1,nfil)  
20 format (i4,a0)  
if (loclos(5)) stop  
do 30 i=1,nfil  
30 call printp(filn(i),0,i+1,7,0)  
40 call printp("","D"," - delete","A"," - add","C"," - choose ",0,24,7,0)  
ia=1  
50 call chtp(0,ia+1,40,138,0)  
call getd(a,im,if)  
call chtp(0,ia+1,40,7,0)  
if (im.eq.7) go to 145  
if (a.eq."D" .or.a.eq."d") go to 100  
if (a.eq."A" .or.a.eq."a") go to 130  
if (a.eq."C" .or.a.eq."c") go to 140  
go to (50,60,70,70,60,80,90),im+1  
60 ia=mod(ia+nfil-2,nfil)+1  
go to 50  
70 ia=mod(ia,nfil)+1  
go to 50  
80 ia=1  
go to 50  
90 ia=nfil  
go to 50  
100 nfil=nfil-1  
110 call blnk(0,ia+1,39,ia+1)  
if (ia.le.nfil) go to 120  
ia=1  
go to 50  
120 filn(ia)=filn(ia+1)  
filnum(ia)=filnum(ia+1)  
call printp(filn(ia),0,ia+1,7,0)  
a=ia+1  
go to 110  
130 nfil=nfil+1  
call vcurxy(0,nfil+1)  
call crs(ion1,ion2)
call geta(filn(nfil), if, im;
call crs(ioff1, ioff2)
filnum(nfil) = filnum(nfil-1) + 1
ia = nfil
go to 50
140 if (nfil.eq.0) go to 200
57: file = "hovin"
call addstg(file, nart(filnum(ia)))
59: if (iowrit(5, 2, 0, "files")) stop
60: write (5, 150) nfil
61: write (5, 160) (filnum(i), filn(i), i = 1, nfil)
63: if (iocos(5)) stop
65: if (im.eq.7) return
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: write (5, 180)
71: format(' ')
72: if (iocos(5)) stop
73: return
74: call printp("You must assign a file name", 20, 7, 12, 0)
call printp("before starting computation", 20, 8, 12, 0)
call printp("Re-enter program with ""HOGCOST"", 20, 9, 12, 0)
call take(5.)
77: return
78: end

subroutines

addstg  58
blink  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
Subroutine cost(tcost, timcst, percst, agycst, tval,
lpscov, pcpol, pcvanc, occar, ocvan, ocbsum, ocbusg, ocbusl, avspg, avspa,
h, avsps, elas,
2sov, pool2, pool3, poolv, bus, len, pcap,
3tmcar, tmvanc, tbus, tbar, ptrips, bfare, btript, vmaxg, vmaxh, vmaax)
real len
"timcst=tval*ptrips*tbar/60.
percst=pcsov*(sov+pool2)+pcpol*pool3+pcvanc*poolv+
11000.*(occar*tmcar+ocvanc*tmvanc)
fasc=elas*(1.-vmaxg/avspg)
fach=elas*(1.-vmaxh/avsp)
fac=elas*(1.-vmaxa/avspa)
percst=percst+occar*len*fasc*(1.-pcap)*sov
percst=percst+occar*len*fach*(pool2+pool3)
percst=percst+ocvanc*len*fach*poolv
percst=percst+occar*len*faca*pcap*sov
percst=percst+bfare*bus**45.
agycst=ocbusg*tbus*1000.+ocbusl*btript*bus/60.+ocbusl*bus
agycst=agycst-bfare*bus**45.
timcst=timcst/1000.
percst=percst/1000.
agycst=agycst/1000.
tcost=timcst+percst+agycst
return
end

real variables

agycst 17 18 21 22
avspa 11
avspg 9
avsp 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
ocbusg 17
ocbusl 17
ocbusl 17
occar 8 12 13 15
ocvanc 8 14
pcap 12 15
pcpol 7
pcsov 7
pcvanc 7
percst 7 12 13 14 15 16 20 22
poolv 7 14
<table>
<thead>
<tr>
<th>Variable</th>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
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<tr>
<td>pool2</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>pool3</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>ptrips</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>sov</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>tbar</td>
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<tr>
<td>tmcost</td>
<td>6</td>
<td>19</td>
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<tr>
<td>tmbus</td>
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<tr>
<td>tmcar</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>tmvan</td>
<td>8</td>
<td></td>
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<tr>
<td>tval</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>vmaxa</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>vmaxg</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>vmaxh</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
Subroutine cstcalc(ip,tcost,dis,dist,const,constr,maint,hovmnt,
lenf, timcst, percst, agycst, tcl, tc2, bcl, 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)=const

tc(3)=const+const

do 20 i=1,3
20 ctim(i)=0.

ptim(i)=0.

20 atim(i)=tc(i)

do 40 i=1,3
40 cinct=(tcost(2*i)-tcost(2*i-1))/15.
tinct=(timcst(2*i)-timcst(2*i-1))/15.
pinct=(percst(2*i)-percst(2*i-1))/15.
ainct=(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
30 ctim(i)=ctim(i)+pkfact*250.*(timcst(2*i-1)+float(j)*tinct)/ds(j)

ptim(i)=ptim(i)+pkfact*250.*(percst(2*i-1)+float(j)*pinct)/ds(j)

atim(i)=atim(i)+pkfact*250.*(agycst(2*i-1)+float(j)*ainct)/ds(j)

lan/ds(j)

30 tc(i)=tc(i)+pkfact*250.*(tcost(2*i-1)+float(j)*cinct)/ds(j)+an

n/ds(j)

30 ctim(i)=ctim(i)/1000.

ptim(i)=ptim(i)/1000.

atim(i)=atim(i)/1000.

40 tc(i)=tc(i)/1000.

tcl=tc(1)-tc(3).
tc2=tc(2)-tc(3).

call printp(snart(tcl,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(ptim(2)-ptim(3),10,1),46,24,15,3)
call printp(snart(atim(2)-atim(3),10,1),56,24,15,3)

bcl=0.
bcl=0.

if (atim(1)-atim(3).ne.0.)bcl=-(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))
3)/(atim(2)-atim(3))
47: call printp(smart(bcl,10,2),66,23,15,3)
48: call printp(smart(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
bcl  43 45 47
bc2  44 46 48
cinc  16 28
constg 9 10
consth 10
disc  7
enf  22
hovmmt 22
maint 3 21 22
pinc  18 25
pkfact 24 25 26 28
tcl  33 35
tc2  34 36
tinc 17 24

real arrays
agycst 3 19 26
atim  4 14 26 31 39 42 45 46
..1m  4 12 24 29 17 40 47 46
ds  4 7 24 25 26 27 28

B-20
percest  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

coracter functions

  snart  5  35  36  37  38  39  40  41  42  47  48
Subroutine cstset(ip,x,iCalc)
logic clean
character*10 snart,a
character*18 label(18)
data label/"SOV","carpool","vanpool","car ($/mi.)","van ($/mi .)","bus ($/mi.)","bus ($/hr.)","bus ($/trip)","Maint. cost","Extra HOV maint.","Enforcement",
"Value of time ($)","Discount rate (%)","Lane construction","Extra HOV cost","Oper. cost elas.",
"Bus fare","Peak Factor"/
common/result/tcl,tc2,bcl,bc2
real x(18),maint
integer locx(18),locy(18),dec(18)
data locx/18,18,18,18,18,18,18,18,18,18,18,18,18,18,18,18,18,72/18

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,-1,-1,-1,2,1,-1,-1,2,2,2/
if (ichela.eq.1) go to 320
if (ip.ne.0) go to 200
set up screen
ia=1
do 100 i=1,18
call printp(label(i),locx(i)-klen(label(i))-2,locy(i),14,3)
do 100 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
change cost parameters
200 call chattp(locx(ia),locy(ia),6,138,3)
call curm(locx(ia),locy(ia),3)
call getam(a,move,func)
call chattp(locx(ia),locy(ia),6,15,3)
if (nfunc.gt.0) go to 300
if (a.ne."\n") go to 260
205 go to (200,210,220,220,210,230,240,250),move+1
210 if (ia.eq.1) return
   ia=mod(ia+16,18)+1
   go to 200
220 ia=mod(ia,18)+1
   go to 200
230 ia=1
   go to 200
240 ia=18
   go to 200
250 ip=99
   return
260 if (clean(a,8)) go to 270
   call printp(a,locx(ia),locy(ia),14,3)
   call take(3.)
   call printp(smart(x(ia),6,dec(ia)),locx(ia),locy(ia),15,3)
   go to 200
270 x(ia)=tran(a)
   call printp(smart(x(ia),6,dec(ia)),locx(ia),locy(ia),15,3)
   if (icalc.eq.1) go to 205
   ip=ip+10
280 return

set up to change page
300 if (nfunc.eq.1) go to 400
   if (nfunc.eq.2.and.icalc.eq.1) go to 280
   if (nfunc.eq.8) go to 310
   if (nfunc.gt.5.or.nfunc.lt.3) go to 200
   ip=nfunc-3
   call chpage(ip)
310 return
calculate elasticities
320 if (icalc.eq.1) go to 200
   iche1a=1
tc1s=tcl
tc2s=tc2
bc1s=bc1
bc2s=bc2
xs=x(ia)
x(ia)=x(ia)*1.1
go to 280
320 call printp(smart((tc1/tc1s-1.)/.1,10,3),26,23,12,3)
call printp(smart((tc2/tc2s-1.)/.1,10,3),26,24,12,3)
call printp(smart((bc1/bc1s-1.)/.1,10,3),66,23,12,3)
call printp(smart((bc2/bc2s-1.)/.1,10,3),66,24,12,3)
call printp(" -----------Elasticities----------\n",33,20
99: call wscp(33,21,3,25,12)
100: call wscp(73,21,3,25,12)
101: call get(i1,i2)
102: call printp("12,3)
103: call printp("12,3)
104: x(ia)=xs
105: tcl=tcls
106: tc2=tc2s
107: bcl=bcls
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
ll 101

B-24
i2  101
move  46  50
nfunc  46  48  75  76  77  78  79

real variables

bcl  89  96  107
bcls  89  96  107
bc2  90  97  108
bc2s  90  97  108
maint  11
tcl  87  94  105
tcls  87  94  105
tc2  88  95  106
tc2s  88  95  106
xs  91  104

character variables

a  3  46  49  62  63  67

integer arrays

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

real arrays

x  11  24  65  67  68  91  92  104

character arrays

label  4  23

integer functions

klen  23
mod  52  54

real functions

tran  67

logical functions

clean  2  62

character functions

snart  3  24  65  68  94  95  96  97
Subroutine getam(a,im,if)
character*80 a
character*1 b
equivalence (icc,b)
data b/** /
a=""
im=0
if=0
10 call get(ic,is)
icc=ic
11: if (ic.eq.72) im=1
12: if (ic.eq.77) im=2
13: if (ic.eq.80) im=3
14: if (ic.eq.75) im=4
15: if (ic.eq.71) im=5
16: if (ic.eq.79) im=6
17: if (ic.eq.27) im=7
18: if (ic.ge.59.and.is.le.68) if=is-58
19: if (ic.eq.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(ixl,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 (ic.eq.72) im=1
37: if (ic.eq.77) im=2
38: if (ic.eq.80) im=3
39: if (ic.eq.75) im=4
40: if (ic.eq.71) im=5
41: if (ic.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
iccc   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
Subroutine hovcom(hovl,s0gp,t0pa,t0b,cpdefn,pool2,pool3,
ivan0,bopeb,tpool2,tpool3,vanl,bhov)
time=hovl*60./s0gp
toffpa=t0pa-time
toffb=t0b-time
tlb=toffb+hovl*60./58.
tlap=toffpa+hovl*60./58.
if (cpdefn.eq.2.) coeff=6.7
if (cpdefn.eq.3.) coeff=7.7
delvp=-.203-coeff*(tlpa/t0pa-1.)+4.8*(tlb/t0b-1.)
tpool2=pool2
if (cpdefn.eq.2.) tpool2=pool2*(1.+delvp)
tpool3=pool3*(1.+delvp)
vnl=van0*(1.+delvp)
if (cpdefn.eq.2.) coeff=1.71
if (cpdefn.eq.3.) coeff=.435
delb=.227+coeff*(tlpa/t0pa-1.)
if (delb.lt.0.) delb=0.
bhov=bopeb*(1.+delb)
return
end

real variables

bopeb 19
bhov 19
coeff 8 9 10 15 16 17
cpdefn 8 9 12 15 16
delb 17 18 19
delvp 10 12 13 14
hovl 3 6 7
pool2 11 12
pool3 13
s0gp 3
time 3 4 5
toffb 5 6
toffpa 4 7
tpool2 11 12
tpool3 13
t0b 5 10
t0pa 4 10 17
tlb 6 10
tlpa 7 10 17
vanl 14
vanl 14
Subroutine lanes(sov,pool2,pool3,poolv,bus,
lngpl,nhov,narts,cpdefn,prefpk,spminf,spmina,
capg,caph,capa,pcap,
vh,vp,vhp,vap,vgs,vhs,vas,
dispv,dispa,dispgs,dispas,vmaxg,vmaxh,vmaxa)
real ngpl,nhov,narts
common/delay/delg,delgs,dela,delas
v=sov+pool2+pool3+poolv+bus
vg=v
vh=0.
vhp=0.
vap=0.
vgs=0.
vhs=0.
vas=0.
delg=0.
dela=0.
delgs=0.
delas=0.
if (nhov.eq.0.) go to 200

assign HOV vehicles

go to (200,100,110),int(cpdefn)
100 vh=sv-sov
101 vg=sov
102 go to 120
110 vh=v-sov-pool2
111 vg=sov+pool2
120 vhp=prefpk*vh
121 vhs=vhp-vhp
122 if (vhp.le.caph*nrov) go to 200
123 vhp=caph*nrov
124 vhs=vhp
125 assign other vehicles
126 split freeway and arterial traffic
200 va=pcap*vg
201 if (va.lt.0.) va=0.
202 vg=vg-va
220 split into peak/off-peak
203 vgp=prefpk*vg
204 vap=prefpk*va
205 vgs=vg-vgp
206 vas=va-vap
207 c
check peak capacities and compute displaced vehicles

```c
52: c
53: c
54: disp=0.
55: dispa=0.
56: dispas=0.
57: dispas=0.
58: if (vgp.le.capg*ngpl) go to 300
59: vc=vgp/(capg*ngpl)
60: tcapg=ngpl*vol(spmirf, capg, vmaxg)
61: rcapg=capg*ngpl-(vc-1.)*(capg*ngpl-tcapg)/.5
62: if (rcapg.lt.tcapg) rcapg=tcapg
63: disp=gvp-rcapg
64: delg=15.*disp/gvp+30.*disp/(capg*ngpl-vgs/2.)
65: if (delg.gt.45..or.vgs/2..gt.capg*ngpl) delg=45.
66: vgp=gvp-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(spmi, capa, vmaxa)
72: rcap=capa*narts-(vc-1.)*(capa*narts-tcapa)/.5
73: if (rcapg.lt.tcapa) rcap=tcapa
74: disp=vap-rcapa
75: del=15.*disp/vap+30.*disp/(capa*narts-vas/2.)
76: if (del.gt.45..or.vas/2..gt.capa*narts) del=45.
77: vap=vap-dispa
78: vgs=vgs-dispa
79: c
80: c
81: check shoulder capacities and compute displaced vehicles
82: c
83: 400 if (vgs.le.2.*capg*ngpl) go to 410
84: vc=vgs/(capg*ngpl/2.
85: tcapg=2.*ngpl*vol(spmirf, capg, vmaxg)
86: rcapg=2.*capg*ngpl-(vc-1.)*(2.*capg*ngpl-tcapg)/.5
87: if (rcapg.lt.tcapg) rcapg=tcapg
88: disp=gvp-rcapg
89: delgs=60.*disp/gsvgs+40.*disp/(capg*ngpl)
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(spmia, capa, vmaxa)
94: rcap=2.*capa*narts-(vc-1.)*(2.*capa*narts-tcapa)/.5
95: if (rcapg.lt.tcapa) rcapa=tcapa
96: disvas=vas-rcapa
97: delas=60.*dispvas+40.*disp/(capa*narts)
98: vas=vas-dispas
99: 420 return
100: end
```

real variables
<table>
<thead>
<tr>
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<tr>
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<td>58 59 60 61 64 65 82 83 84 85 88</td>
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<tr>
<td>vmaxg</td>
<td>60 84</td>
</tr>
</tbody>
</table>

**integer functions**

| int | 25 |

**real functions**

| vol | 60 71 84 93 |
1:     subroutine length Sov, pool2, pool3, poolv, bus, tmcar, tmvan, tmbus 
      , tlave, 
2:     tltsov, tlpl2, tlpl3, tltvan, tltbus 
3:     tltsov=(tlave*(sov+pool2+pool3+poolv+bus)-pool2*tlpl2-pool3*tlpl3-
pl3-poolv*tlplv-bus*tltbus)/sov 
4:     tmcar=(sov*tltsov+pool2*tlpl2+pool3*tlpl3)/1000. 
5:     tmvan=poolv*tltvan/1000. 
6:     tmbus=bus*tltbus/1000. 
7:     return 
8:     end 

real variables

<p>| | |</p>
<table>
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<tbody>
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<td>poolv</td>
<td>3 5</td>
</tr>
<tr>
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<td>3 4</td>
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<tr>
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<td>4</td>
</tr>
<tr>
<td>tmvan</td>
<td>5</td>
</tr>
</tbody>
</table>
character*80 Function plin(il,ip)
integer*1 ich1
lim=79
if (il.eq.0) lim=75
do 10 i=0,lim
   call rscp(i,il,ip,ich,natt)
   ich1=ich
10 call putchr(plin,i+1,ich1)
return
end

subroutines
putchr  8
rscp   6

integer variables
i     5  6  8
ich  6  7
ich1  2  7  8
lim   3  4  5
natt  6

character variables
il    1  4  6
ip    1  6

character arrays
plin  1  8

B.33
Subroutine pout(fcont)
character*80 plin
data lenp/66/
character*40 fcont
character*50 line
character*9 time,mon(12),nart
data mon/"January"","February","March","April","May","June",
"July","August","September","October","November","December"/
if (ioread(5,2,0,"plines")) go to 2
read (5,1) lenp
1 format (i10)
if (iocios(5)) stop
2 call gttime(ih,im,is,ic)
call gdate(month,iday,iy)
line=mon(month)
call addstg(line," ",nart(iday)," ","
line=nart(line,nart(iy))
time=" AM"
if (ih.gt.11) time=" PM"
if (ih.gt.12) ih=ih-12
if (ih.eq.0) ih=12
call addstg(line," ",nart(ih),":")
call addstg(line,"0","
if (im.lt.10) call addstg(line,"0")
call addstg(line,nart(im),time)
write (4,3) line,fcont
3 format (33x,"HOV Cost Model"/28x,a0//1x,a0/
do 10 i=0,24
10 write (4,20) plin(i,0)
do 100 i=1,24
20 format (1x,a0)
do 30 i=2,24
30 write (4,20) plin(i,1)
do 40 i=1,lenp-53
40 write (4,50)
do 50 format ('')
write (4,55) line,fcont
45 format (29x,"HOV Cost Model (cont.)"/28x,a0//1x,a0/
do 60 i=0,20
60 write (4,20) plin(i,2)
do 70 i=2,8
70 write (4,20) plin(i,3)
do 80 i=10,24
write (4,50)
do 90 i=1,lenp-49
90 write (4,50)
return
end

subroutines
addstg 16 17 22 23 24

B-34
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
Function speed(vol, cap, disp, vmax)
  speed=0.
  if (cap.eq.0.) return
  if (vol.le..8004269*cap) speed=vmax-.06462069*vol*vmax/cap
  if (vol.gt..8004269*cap.and.vol.lt..96051227*cap) speed=
    11.37931*vmax-.53850575*vol*vmax/cap
  if (vol.ge..96051227*cap) speed=
    1.6908621*vmax+.86156925*vmax*sqrt(1.-vol/cap)
  if (disp.ne.0.) speed=
    1.6908621*vmax-.86156925*vmax*sqrt(1.-vol/cap)
  return
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
Subroutine speeds(pspg,sspg,psph,ssph,pspa,sspa,
1capg,caph,capa,
2vgp,vhp,vap,vgs,vhs,vas,
3ngpl,nhov,narts,
4spminf,spmina,
5dispg,dispa,dispgs,dispas,
6avspg,avsph,avspa,vmaxg,vmaxh,vmaxa,spdiff)
real ngpl,nhov,narts
c
compute speeds
c
100 psph=0.
130 ssph=0.
140 pspa=0.
150 sspa=0.
160 pspg=speed(vgp/ngpl,capg,dispg,vmaxg)
170 if (pspg.lt.spminf) pspg=spminf
180 ssph=speed(vgs/ngpl/2.,capg,dispgs,vmaxg)
190 if (ssph.lt.spminf) ssph=spminf
200 if (nhov.eq.0.) go to 110
210 psph=speed(vhp/nhov,caph,0.,vmaxh)
220 if (psph-pspg.gt.spdiff) psph=psph+spdiff
230 ssph=speed(vhs/nhov/2.,caph,0.,vmaxh)
240 if (ssph-sspg.gt.spdiff) ssph=ssph+spdiff
250 110 if (narts.eq.0.) go to 120
260 pspa=speed(vap/narts,capa,dispa,vmaxa)
270 if (pspa.lt.spmina) pspa=spmina
280 sspa=speed(vas/narts/2.,capa,dispas,vmaxa)
290 if (sspa.lt.spmina) sspa=spmina
300 120 avspg=vmaxg
310 if (vgp+vgs.ne.0.) avspg=(vgp*pspg+vgs*sspg)/(vgp+vgs)
320 avsph=vmaxh
330 if (vhp+vhs.ne.0.) avsph=(vhp*psph+vhs*ssph)/(vhp+vhs)
340 avspa=vmaxa
350 if (vap+vas.ne.0.) avspa=(vap*pspa+vas*sspa)/(vap+vas)
360 return
370 end

real variables

avspa  34  35
avspg  30  31
avspdh 32  33
capa  26  28
capg  16  18
caph  21  23
dispa  26
dispas  28
disp  16
dispgs  18
narts  8  25  26  28
|      |   8  |   16 |   18 |
|      |      |      |      |
| ngpl | 8    | 16   | 18   |
| nhov | 8    | 20   | 21   | 23   |
| pspa | 14   | 26   | 27   | 35   |
| pspg | 16   | 17   | 22   | 31   |
| psh  | 12   | 21   | 22   | 33   |
| spdiff| 22   | 24   |
| spminf| 27   | 29   |
| sspa | 17   | 19   |
| sspg | 15   | 28   | 29   | 35   |
| ssph | 18   | 19   | 24   | 31   |
| vap  | 13   | 23   | 24   | 33   |
| vas  | 26   | 35   |
| vgp  | 28   | 35   |
| vgs  | 18   | 31   |
| vhp  | 16   | 31   |
| vhs  | 21   | 33   |
| vmaxa| 23   | 33   |
| vmaxg| 26   | 28   | 34   |
| vmaxh| 16   | 18   | 30   |

**real functions**

|      |   16 |   18 |   21 |   23 |   26 |   28 |
|      |      |      |      |      |      |      |
| speed|      |      |      |      |      |      |
Subroutine times(nhov,narts,sov,POOL2,cpdefn,
laaccess,LEN,TPool,TVAN,THUS,
2pspg,spg,psph,SSPH,spsa,SSPA,
4strip,strip,strip,CTrip,CTrips,CTRIP,VTRIP,VTrips,VTRip,B
strip,BTrips,btript)

real nhov,narts,LEN

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

strip=(bGP*vGP+bAP*vAP)/(vGP+vAP)
strips=(bGS*vGS+bAS*vAS)/(vGS+vAS)
div=SOV

if (cpdefn.eq.3.) div=SOV+POOL2

strip=(strip*(vGP+vAP)+strips*(vGS+vAS))/div

CTrip=bHP+TPool
CTrips=bHS+TPool

CTrip=(CTRIP*vH+CTRips*vHs)/(vH+vHs)

VTRip=bHP+TVAN

VTrips=bHS+TVAN

VTRip=(VTRip*vH+VTrips*vHs)/(vH+vHs)

btrip=bHP+bTUs
btrips=bHS+bTUs

btrip=(btrip*vH+btrips*vHs)/(vH+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 strip=(bGP*vGP+bAP*vAP)/(vGP+vAP)
strips=(bGS*vGS+bAS*vAS)/(vGS+vAS)

strip=(strip*(vGP+vAP)+strips*(vGS+vAS))/(vGP+vAP+vGS+vAS)

CTrip=strip+tPool
CTrips=strips+tPool

VTRip=strip+TVAN

VTrips=strips+TVAN

VTRip=strip+TVAN

VTRip=strip+TVAN
51: \ btrip=strip+tbus  
52: \ btrips=strips+tbus  
53: \ btrip=tstript+tbus  
54: \ 130 \ return  
55: \ end  

real variables

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Function vol(speed, cap, vmax)
rat = speed / vmax
vol = cap * (0.3570128 + 1.8614055 * rat - 1.347161 * rat ** 2)
return
end

real variables

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

real functions

vol 1 3

B-42
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 10b,10gp,10hov,11gp,11hov
3: common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,10b,v0t,t0npa,t0pa
4: ltohv,olb,so0p,s0c,s0b,10gp,10hov,c0gp,c0hov,11gp,11hov,c1gp
5: common/c2/clhov,blhov,toffnp,toffpa,toffb,t1b,t1pa,
6: l1npa,slgp,efctr,vlnpa,v1pa,v1hov,vchov,v1b,hovl
7: character*40 filln(20)
8: integer filnum(20)
9: character*8 fill,fil2,fil3
10: character*4 nat
11: 8 call crsdf
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 -
23:  exit",0,24,7)
24:  ia=1
25: 5 call chatt(0,ia+1,40,15)
26:  call getd(a,im,if)
27:  call chatt(0,ia+1,40,7)
28:  if (im.eq.7) go to 80
29:  if (if.eq.1) go to 110
30:  if (if.eq.2) go to 120
31:  if (if.eq.3) go to 130
32:  go to (5,11,12,12,11,15,16),im+1
33: 11 ia=mod(ia+nfil-2,nfil)+1
34:  go to 5
35: 12 ia=mod(ia,nfil)+1
36:  go to 5
37: 15 ia=1
38:  go to 5
39: 16 ia=nfil
40:  go to 5
41: 110 nfil=nfil-1
42: 112 call blnk(0,ia+1,39,ia+1)
43:  if (ia.le.nfil) go to 111
44:  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 vcursy(0,nfil+1)
52:  call crosn
53:  call geta(filn(nfil),f,fill)
54:  call crosff
55:  filnum(nfil)=filnum(nfil-1)+1
56:  go to 5
57: 130 fill="dat1"
58:  call addstg(fill,nart(filnum(ia)))
59:  fill2="dat2"
60:  call addstg(fill,nart(filnum(ia)))
61:  fill3="dat3"
62:  call addstg(fill,3,nart(filnum(ia)))
63:  if (iowrit(5,2,0,"filelist")) stop
64:  write (5,131) nfil
65: 131 format (lx,l2)
66:  write (5,132) (filnum(i),filn(i),i=1,nfil)
67: 132 format (lx,l4,a0)
68:  if (ioclas(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,fill)
72:  go to 1
73: 20 call wks2(next,fill2)
74:  go to 1
75: 30 call wks3(next,fill3)
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 crosn
86:  call vclear
87:  stop
88:  end

subroutines

addstg 58 60 62
blink 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

  10b     2
  10gp    2
  10hov   2
  llgp    2
  llhov   2

character variables

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

integer arrays

filnum    8  17  46  55  58  60  62  66

character arrays

filn     7  17  21  45  47  53  66

integer functions

mod      32  34
logical functions

ioclos  19  68
ioread  14
iowrit  63

character functions

nart     10  58  60  62
Subroutine wks1(next, fill)
real lo0b, 10gp, 10hov, llgp, llhov
common/cl/v0npa, v0pa, v0hov, b0p0b, b0hov, v0b, 10b, v0t, t0npa, t0pa

lt0hov, t0b, s0gp, s0c, s0b, 10gp, 10hov, c0gp, c0hov, llgp, llhov, clgp
common/c2/clhov, blhov, toffnp, toffpa, toffb, tlb, tlpa,
ltlnpa, slgp, efctr, vlnpa, v1pa, v1hov, vchov, vlb, hovl
real inp(18)
integer locy(18), form(18)
data locy/2, 3, 4, 5, 6, 7, 9, 11, 12, 13, 14, 16, 17, 18, 20, 21, 22, 23/
data form/-1, -1, -1, -1, -1, -1, 1, 1, 1, 1, 1, 1, 1, 1, -1, -1, -1/
logical clean
character*8 fill
character*10 snart, a
next=2
if (loread(5, 2, 0, fill)) go to 1
read (5, 2) (inp(i), i=1, 18)
2 format (f0.0)
if (loclos(5)) stop
v0npa=inp(1)
v0pa=inp(2)
v0hov=inp(3)
b0p0b=inp(4)
b0hov=inp(5)
v0b=inp(6)
v0t=inp(7)
t0npa=inp(8)
t0pa=inp(9)
t0hov=inp(10)
t0b=inp(11)
s0gp=inp(12)
s0c=inp(13)
s0b=inp(14)
10gp=inp(15)
10hov=inp(16)
c0gp=inp(17)
c0hov=inp(18)
if (im.eq.7) go to 100
call vclear
call print("Worksheet 1: Baseline Data", 0, 0, 14)
call print("Volumes(peak-hour)", 0, 1, 7)
call print("Automobiles, nonpriority", 5, 2, 7)
call print("Automobiles, priority-eligible", 5, 3, 7)
call print("Carpools on HOV lanes", 5, 4, 7)
call print("Buses, priority eligible", 5, 5, 7)
call print("Buses on HOV lane(s)", 5, 6, 7)
call print("Bus passengers (HOV or priority eligible)", 5, 7,
7)
call print("Bus load factor", 5, 8, 7)
call print("Trucks", 5, 9, 7)
call print("Total Travel Time(peak-hour)", 0, 10, 7)
call print("Automobiles, nonpriority",5,11,7)
call print("Automobiles, priority eligible",5,12,7)
call print("Carpools on HOV lane(s)",5,13,7)
call print("Buses (HOV or priority eligible)",5,14,7)
call print("Speed (average per hour)",0,15,7)
call print("General purpose lane(s)",5,16,7)
call print("HOV lane(s) - Carpools",5,17,7)
call print("HOV lane(s) - Buses",5,18,7)
call print("Existing Supply/Capacity",0,19,7)
call print("No. of general purpose lanes",5,20,7)
call print("No. of HOV lanes",5,21,7)
call print("Capacity, general purpose lanes",5,22,7)
call print("Capacity, HOV lanes",5,23,7)
do 10 i=1,18
  10 call print(snart(inp(i),10,form(i)),50,locy(i),7)
  1b=0.
buses=b0peb
  if (buses.eq.0.) buses=b0hov
  if (buses.ne.0.) 1b=v0b/buses
  call print(snart(10b,10,1),50,8,13)
i=1
  20 call chatt(5,locy(ia),50,15)
call vcurxy(50,locy(ia))
call gta(a,im,if)
call chatt(5,locy(ia),50,7)
  if (if.ge.21.and.if.le.22) go to 99
  if (if.gt.0) go to 20
  go to (30,31,33,33,31,35,36,1),im+1
  30 if (a.eq."""') go to 33
  if (.not.clean(a,nd)) go to 20
  inp(ia)=tran(a)
call print(snart(inp(ia),10,form(ia)),50,locy(ia),7)
  1b=0.
v0b=inp(6)
b0hov=inp(5)
b0peb=inp(4)
buses=b0peb
  if (buses.eq.0.) buses=b0hov
  if (buses.ne.0.) 10b=v0b/buses
  call print(snart(10b,10,1),50,8,13)
  go to 33
  31 ia=mod(ia+16,18)+1
  go to 20
  33 ia=mod(ia,18)+1
go to 20
  35 ia=1
  go to 20
  36 ia=18
go to 20
  99 next=if-20
100 if (iowrit(5,2,0,fill)) stop
101:    write (5,110) (inp(i),i=1,:8)
102:    110 format (f10.1)
103:    if (ilocos(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
10b     2    65    68    69    82    88    89
10gp    2    33
10hov   2    34
11gp    2
11hov   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  
locoy   8  64  71  72  74  81

real arrays

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

integer functions

mod     91  93

real functions

tran    80

logical functions

clean   11  79  
ioclos  18  103  
ioread  15  
iowrit  100

character functions

snart   13  64  69  81  89
Subroutine wks2(next,fil2)
real 10b,10gp,10hov,11gp,11hov
common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,10b,v0t,t0npa,t0pa

lt0hov,t0b,s0gp,s0c,s0b,10gp,10hov,c0gp,c0hov,11gp,11hov,clgp
common/c2/clhov,bhov,toffnp,toffpa,toffb,tlb,tlpa,
ltnpa,slgp,efctr,vlnpa,v1pa,v1hov,vchov,vib,ho1
common/c4/pooldf
common/c6/hovalt
real inp(6)
integer locy(6),form(6)
data locy/4,8,9,10,11,12/
data form/1,-1,-1,-1,-1,-1/
integer hovalt,pooldf
data hovalt,pooldf/1,0/
logical clean
character*8 fil2
character*10 snart,a,nart
iasave=0
if (ioread(5,2,0,fil2)) go to 2
read (5,3) (inp(i),i=1,6)
format (f0.0)
read (5,4) hovalt,pooldf
format (21l)
if (ioclos(5)) stop
ia=1
call vclear
call print("Worksheet 2: HOV policy and initial calculations"
,0,0,14)
call print("HOV alternative:",0,2,7)
call print("(change w/F1)",0,3,7)
call print("Bus only",21,2,15-4*hovalt)
call print("Bus and Carpool (Carpool size: +)",21,3,3+4*hovalt)
call print("X",18,1+hovalt,11)
call print("HOV length:",0,4,7)
call print("Proposed supply/capacity",0,6,7)
call print(". No. of general purpose lanes",5,8,7)
call print(". No. of HOV lanes",5,9,7)
call print(". Capacity, general purpose lanes",5,10,7)
call print(". Capacity, HOV lanes",5,11,7)
call print(". Buses per hour (exogenous)",5,12,7)
call print("Existing travel times (over highway bounded by HO
V lanes)"),0,14,7)
call print(". Automobiles, nonpriority",5,16,7)
call print(". Automobiles, priority eligible",5,17,7)
call print(". Buses (HOV or priority eligible)",5,18,7)
call print("Existing travel times (off highway bounded by HO
lanes)",0,20,7)
call print(". Automobiles, nonpriority",5,22,7)
call print(". Automobiles, priority eligible",5,23,7)
call print(". Buses (HGV or priority eligible)",5,24,7)
if (pooldf.gt.0) call print(nart(pooldf+1),52,3,11)
1 hovl=inp(1)
llgp=inp(2)
lhov=inp(3)
clgp=inp(4)
clhov=inp(5)
bhov=inp(6)
do 10 i=1,6
10 call print(snart(inp(i),10,form(i)),50,locy(i),7)
t1=0.
t2=0.
t3=0.
if (s0gp.eq.0.) go to 20
  t1=hovl*60./s0gp
t2=t1
t3=t1
  if (s0b.ne.0.) t3=hovl*60./s0b
toffnp=t0npa-t1
toffpa=t0pa-t2
toffb=t0b-t3
20 call print(snart(t1,10,1),50,16,13)
call print(snart(t2,10,1),50,17,13)
call print(snart(t3,10,1),50,18,13)
call print(snart(toffnp,10,1),50,22,13)
call print(snart(toffpa,10,1),50,23,13)
call print(snart(toffb,10,1),50,24,13)
next=3
30 if (iasave.gt.0) ia=iasave
  iasave=0
call chatt(0,locy(ia),60,15)
call vcurxy(50,locy(ia))
call geta(a,im,if)
call chatt(0,locy(ia),60,7)
go to (31,35,33,33,35,36,37,38),im+1
31 if (a.ne."") go to 32
  if (a.eq."".and.if.eq.0) go to 33
  if (if.eq.1) go to 130
  if (if.1t.21.or.if.gt.23) go to 30
next=if-20
78: go to 38
130 go to (131,131,132,133,134),hovalt+pooldf
131 hovalt=2
pooldf=1
call chatt(21,2,15,7)
call chatt(21,3,50,11)
call blnk(18,2,18,2)
call print("X",18,3,11)
go to 135
132 pooldf=2
go to 135
98:  133  pooldf=3
99:  135  call print (nart(pooldf+1),52,3,11)
100:  go to 30
101:  134  call blnk(52,3,52,3)
102:  call chatt(21,3,40,7)
103:  call blnk(18,3,18,3)
104:  call print("X",18,2,11)
105:  pooldf=0
106:  hovalt=1
107:  call chatt(21,2,15,11)
108:  go to 30
109:  32  if (.not.clean(a,nd)) go to 30
110:  inp(ia)=tran(a)
111:  call print(snart(inp(ia),10,form(ia)),50,locy(ia),7)
112:  if (ia.eq.1) iasave=2
113:  if (ia.eq.1) go to 1
114:  33  ia=mod(ia,6)+1
115:  go to 30
116:  35  ia=mod(ia+4,6)+1
117:  go to 30
118:  36  ia=1
119:  go to 30
120:  37  ia=6
121:  go to 30
122:  38  if (iowrit(5,2,0,fil2)) stop
123:  write (5,100) (inp(i),i=1,6)
124:  100  format (f10.1)
125:  write (5,101) hovalt,pooldf
126:  101  format (1x,2i1)
127:    hoval=inp(1)
128:    llgp=inp(2)
129:    llhov=inp(3)
130:    clgp=inp(4)
131:    clhov=inp(5)
132:    blhov=inp(6)
133:  if (ioclos(5)) stop
134:  return
135:  end

subroutines

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

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

real variables

blhov  54  132
c1gp   52  130
c1hov  53  131
hoval 49  61  64  127
l0b    2
l0gp   2
l0hov  2
l1gp   2  50  128
l1hov  2  51  129
s0b    64
s0gp   60  61
t0ffb  67  73
t0ffnp 65  71
t0ffpa 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
  icclos  24  133
  ioread  19
  iowrit  122

character functions

  nart  17  48  99
  snart  17  56  68  69  70  71  72  73  111
Subroutine wks3(next,fil3)
real 10b,10gp,10hov,11gp,11hov
common/c1/v0npa,v0pa,v0hov,b0p0eb,b0hov,v0b,10b,v0t,t0npa,t0pa
lt0hov,t0b,s0gp,s0c,s0b,10gp,10hov,c0gp,c0hov,11gp,11hov,c1gp
common/c2/chi0v,bi0hov,t0ffnp,t0ffpa,t0ffb,tlb,tlpa,
l1npa,s1gp,efctr,v1npa,v1pa,v1hov,vchov,vlb,hov1
common/c3/genlan
common/c5/s1hov
integer buson,autoon,genlan
data buson,autoon,genlan/1,1,1/
character*10 a,snart
character*8 fil3
if (ioread(5,2,0,fil3)) go to 3
read(5,2) buson,autoon,genlan
2 format (3i1)
if (ioclos(5)) stop
next=4
call vclear
call print("Worksheet 3: Estimate travel times - forecast per
iod",0,0,14)
call print("Buses on or eligible to use HOV lanes (F1 to chan
ge)",0,2,7)
call print("Buses already on HOV",11,4,15-4*buson)
call print("Buses will be eligible to use HOV",11,5,3+4*buson

HOV bus travel time =",5,7,7)
call print("Autos on or eligible to use HOV lanes (F2 to chan
ges"),0,9,7)
call print("Autos already on HOV",11,11,15-4*autoon)
call print("Autos will be eligible to use HOV",11,12,3+4*auto
on)
call print("HOV auto travel time =",5,14,7)
call print("General purpose lanes (F3 to change)",0,
16,7)
call print("Capacity reduction or bus only lane",11,18,15-4*gen
lan)
call print("Capacity same and carpools granted priority",11,1
9,3+4*genlan)
call print("general lane travel speed =",5,21,7)
call print("general lane travel time =",5,22,7)
call print("eligibility factor =",5,24,7)
call blank(5,4,5,5)
call blank(5,11,5,12)
call blank(5,18,5,19)
call chatt(11,6-buson,45,7)
call chatt(11,13-autoon,45,7)
call chatt(11,20-genlan,45,7)
call print("X",5,3+buson,11)
call print("X",5,10+autoon,11)
call print("X",5,17+genlan,11)
call chatt(11,3+buson,45,11)
call chatt(11,10+autoon,45,11)
call chatt(11,17+genlan,45,11)
if (slhov.lt.0.) go to 7
if (s0b.gt.0.) slhov=s0b
if (s0b.eq.0.) slhov=55.
7 if (slhov.lt.0.) slhov=-slhov
tlb=t0b
   if (buson.eq.2) tlb=toffb+hovl*60./slhov
tlpa=t0hov
   if (autoon.eq.2) tlpa=toffpa+hovl*60./slhov
tlnpa=t0npa
   if (slgp.lt.0.) go to 4
   slgp=s0gp
   if (genlan.eq.1) go to 5
   slgp=60./(1.+((v0npa+v0pa)/clgp)**15)
speed=s0c
   if (s0c.eq.0) speed=s0b
   if (slgp.gt.speed.and.speed.ne.0.) slgp=speed
4 if (slgp.lt.0.) slgp=-slgp
tlnpa=toffnp+hovl*60./slgp
5 efctr=llgp*(v0npa+v0pa+2.*b0peb)/10gp/v0npa
call print(snart(tlb,10,1),26,7,13)
call print(snart(tlpa,10,1),27,14,13)
call print(snart(slgp,10,1),33,21,13)
call print(snart(tlnpa,10,1),32,22,13)
call print(snart(efctr,10,3),26,24,13)
10 call getd(a,im,if)
   if (im.eq.7) go to 20
   if (im.eq.0) go to 10
   if (if.eq.1) buson=3-buson
   if (if.eq.2) autoon=3-autoon
   if (if.eq.3) genlan=3-genlan
   if (lt.eq.4) go to 1
   if (if.lt.21.or.if.gt.24) go to 10
next=if-20
20 if (iowrit(5,2,0,fil3)) stop
write (5,30) buson,autoon,genlan
30 format (1x,3i1)
if (ioclos(5)) stop
return
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
  hovl  51 53 63
  10b      2
  10gp     2 64
  10hov    2
  11gp     2 64
  11hov    2
  speed   59 60 61
  s0b   47 48 60
  s0c     59 60
  s0gp    56
  slgp   55 56 58 61 62 63 67
  slhov  46 47 48 49 51 53
  toffb   51
  toffnp  63
  toffpa  53
  t0b     50
  t0hov   52
  t0npa   54
  tlb     50 51 65
  tlnpa  54 63 68
  t1pa    52 53 66
  v0nna    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
Subroutine wks4(next)
real 10b,10gp,10hov,11gp,11hov
common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,10b,v0t,t0npa,t0pa
10h0v,t0b,s0gp,s0c,s0b,10gp,10h0v,c0gp,c0h0v,11gp,11h0v,c1gp
common/c2/clhov,blhov,toffnp,toffpa,toffb,t1b,t1pa,
l1npa,s1gp,e1c1r,vlnpa,v1lpa,v1h0v,vchov,v1b,h0v1
common/c3/genlan
common/c4/pooldf
character*10 snart,a
integer genlan,pooldf
next=5
call vclear
call print ("Worksheet 4: Forecast nonpriority auto volume",0
,0,14)
call print ("new volume =",5,2,7)
call print ("new v/c ratio =",5,4,7)
10 coeff=1.19
if (pooldf.ge.2) coeff=.122
daleta=-.916-1.053*(tlnpa/t0npa-1.)+coeff*(t1pa/t0pa-1.)+.278*
(t1b/t0b-1.)+.949*efctr
vlnpa=(1.+-delta)*v0npa
call print (snart(vlnpa,10,-1),17,2,13)
if (genlan.ne.1) go to 20
14 call print("force flow conditions","5,6,10)
call print("go to worksheet 5",5,7,10)
call blnk(5,4,50,4)
15 call getd(a,im,if)
if (im.eq.7) return
if (if.ge.21.and.if.1e.25) go to 50
go to 15
20 vc=vlnpa/clgp
call print(snart(vc,10,2),20,4,13)
if (vc.ge.1.) go to 30
slnew=60./(1.+vc**15)
if (abs(slnew/s1gp-1.).lt..1) go to 25
call print("has not reached equilibrium","5,6,12)
call print("repeat worksheet 3",5,7,12)
nex=3
s1gp=-slnew
22 call getd(a,im,if)
if (im.eq.7) return
if (if.ge.21.and.if.1e.25) go to 50
go to 22
25 call print("equilibrium achieved","5,6,10)
call print("go to worksheet 5",5,7,10)
26 call getd(a,im,if)
if (im.eq.7) return
if (if.ge.21.and.if.1e.25) go to 50
go to 26
30 call print("v/c > 1, use force flow conditions","5,6,12)
49:    call print("repeat worksheet 4 (hit any key),",5,7,12)
50:    32 call get(il,i2)
51:    call blnk(5,6,60,7)
52:    35 tnnpa=t0npa
53:    slgp=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
    il   50
    i2   50
    next  11  36  56
    pooldf 10  17

real variables

    coeff  16  17  18
    clgp  29
    delta 18  19
    efctr 18
    l0b   2
    l0gp  2
    l0hov 2
    l1gp  2
    l1hov 2
    s0gp  53
    slgp  33  37  53
    slnew 32  33  37
    t0b  18
    t0npa 18  52
    t0pa  18
    t1b  18
    tinpa 18  52
    tipa  18
    vc  29  30  31  32
    v0npa 19
    vinpa 19  20  29
character variables
   a  9 25 38 44

real functions
   abs  33

character functions
   snart  9 20 30
Subroutine wks5(next)
real 10b,10gp,10hov,11gp,11hov
common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,10b,v0t,t0npa,t0pa
,lt0hov,t0b,s0gp,s0c,s0b,10gp,10hov,c0gp,c0hov,11gp,11hov,clgp
common/c2/clhov,blhov,tt0n,tt0fpa,ttffpa,ttfb,tlb,tlpa,
common/c4/pooldf
common/c5/slhov
character*10 snart,a
integer pooldf
next=6

call vclear

call print("Worksheet 5: Forecast priority auto volume",0,0,1

  4)
call print("priority auto volume =",5,2,7)
call print("total carpools on HOV lane =",5,4,7)
if (pooldf.eq.1) go to 10
delpa=-.203-7.7*(tlpa/t0pa-1.)+4.8*(tlb/t0b-1.)
vlpav0pa*(1.+.delpa)
vhov=vlp

go to 20

  10 if (t0hov.eq.0.) go to 15
delhov=-.203-7.7*(tlpa/t0hov-1.)+4.8*(tlb/t0b-1.)
delpa=-.203-6.7*(tlpa/t0pa-1.)+4.8*(tlb/t0b-1.)
vlpav0pa*(1.+.delpa)
vhov=vlpav0hov*(1.+.delhov)
go to 20

  15 delpa=-.203-6.7*(tlpa/t0pa-1.)+4.8*(tlb/t0b-1.)

  28: vlpav0pa*(1.+.delpa)

  29: vhov=vlp

  30 call print(snart(vlpav0pa,10,-1),28,2,13)
call print(snart(vhov,10,-1),34,4,13)
buses=b0hov

  33: if (buses.eq.0.) buses=b0peb
c
  34: v0=(vhov+buses)/clhov
call print("v/c ratio =",5,6,7)
call print(snart(vc,10,2),17,6,13)
if (vc.gt..8.) go to 30
call print("level of service on HOV lanes OK",5,8,10)
call print("go to worksheet 6",5,9,10)
go to 40

  30 call print("level of service on HOV lanes insufficient",5,8,12)
call print("repeat worksheet 3 using revised speed",5,9,12)
slhov=60./(1+vc**15)
if (slhov.lt.s1gp) slhov=s1gp
slhov=-slhov
next=3

  47: call getd (a,im,if)
if (im.eq.7) return

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

subroutines

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

integer variables

im 47 48
next 11 46 50
pooldf 10 16

real variables

buses 32 33 34
b0hov 32
b0peb 33
clhov 34
delhov 22 25
delpa 17 18 23 24 27 26
10b 2
10gp 2
10hov 2
11gp 2
11hov 2
slgp 44
slhov 43 44 45
t0b 17 22 23 27
t0hov 21 22
t0pa 17 23 27
tlb 17 22 23 27
tlpa 17 22 23 27
vc 34 36 37 43
v0hov 25
v0pa 18 24 28
vlhov 19 25 29 31 34
vlpa 18 19 24 25 28 29 30

character variables

  a 9 47

canacter functions

  snart 9 30 31 36
Subroutine wks6(next)
real 10b,10gp,10hov,11gp,11hov
common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,10b,v0t,t0npa,t0pa

lt0hov,t0b,s0gp,s0c,s0b,10gp,10hov,c0gp,c0hov,11gp,11hov,clgp
common/c2/clhov,bhov,toffnp,toffpa,toffb,t1b,t1pa,
lt1npa,slgp,eftcr,vlnpa,vipa,vihov,vchov,vib,hovl
common/c4/pooldf
common/c6/hovalt
integer pooldf,hovalt,busopt
character*10 a,snart
if (hovalt.eq.1.and.blhov.eq.0.) busopt=1
if (hovalt.eq.1.and.blhov.ne.0.) busopt=2
if (hovalt.eq.2.and.pooldf.eq.1) busopt=4
if (hovalt.eq.2.and.pooldf.gt.1) busopt=3
next=7
call vclear
call print("Worksheet 6: Forecast priority bus volume",0,0,14)

call print("Bus options",0,2,7)
call print(" Endogenously",5,4,7)
call print(" Exogenously",5,5,7)
call print(" Buses and 3+ or 4+ person carpools on HOV lane",5,6,7)
call print(" Buses and 2+ person carpools on HOV lane",5,7,7)
call print("Priority bus passenger volume =",5,9,7)
call print("Priority bus volume =",5,11,7)
call blnk(5,4,5,7)
call print("X",5,3+busopt,11)
call chatt(10,3+busopt,60,11)
go to (10,20,30,40),busopt
delb=-1.404*(t1b/t0b-1.)
go to 50
delb=0.
if (b0peb.ne.0.) delb=-.303*(t1b/t0b-1.)+.422*(blhov/b0peb-1.)
go to 50
delb=.227+.435*(t1pa/t0pa-1.)
go to 50
delb=.227+1.711*(t1pa/t0pa-1.)
vlb=v0b*(1.+delb)
if (busopt.eq.2) go to 55
if (blhov.eq.0.) blhov=vlb/10b
55 call print(snart(vlb,10,-1),37,9,13)
call print(snart(b1hov,10,-1),27,11,13)
call print("go to worksheet 7",5,13,10)
call getda(a,im,if)
if (if.ge.21.and.if.1e.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
blhov 11 12 32 39 41
delb 29 31 32 34 36 37
10b 2 39
10gp 2
l0hov 2
11gp 2
l1hov 2
t0b 29 32
t0pa 34 36
tlb 29 32
tlpa 34 36
v0b 37
v1b 37 39 40

character variables

a 10 43

character functions

snart 10 40 41
Subroutine wks7(next)
real 10b,10gp,10hov,11gp,11hov
common/c1/v0npa,v0pa,v0hov,b0peb,b0hov,v0b,10b,v0t,t0npa,t0pa

1t0hov,t0b,s0gp,s0c,s0b,10gp,10hov,c0gp,c0hov,11gp,11hov,clgp
common/c2/clhov,blhov,toffn,offpa,offb,tlb,tlpa,
1tlnpa,slgp,efctr,vinpa,v1pa,vihov,vchov,vlb,hovl
character*10 a,snart
character*16 type
character*1 nart
common/c4/pooldf
integer pooldf
common/c5/s1hov
type=""

call addstg(type,nart(pooldf+1),"+ occupants")
next=8

call vclear
call print("Worksheet 7: Summary results",0,0,14)
call print("Volumes (peak-hour)",0,2,7)
call print("Automobiles, nonpriority",5,4,7)
call print("Carpools",5,5,7)
call print(type,16,5,7)
call print("Buses",5,6,7)
call print("Bus passengers",5,7,7)
call print("Total travel time (peak-hour)",0,9,7)
call print("Automobiles, nonpriority",5,11,7)
call print("Carpools",5,12,7)
call print(type,16,12,7)
call print("Buses",5,13,7)
call print("Speeds (average peak hour)",0,15,7)
call print("General purpose lane(s)",5,17,7)
call print("HOV lane(s)",5,18,7)
call print("Person-trips (peak hour)",0,20,7)
call print("Before",40,1,7)
call print("After",50,1,7)
call print("% change",60,1,7)
call print(snart(vlnpa,10,-1),50,4,13)
call print(snart(vihov,10,-1),50,5,13)
call print(snart(bihov,10,-1),50,6,13)
call print(snart(vlb,10,-1),50,7,13)
call print(snart(tlnpa,10,1),50,11,13)
call print(snart(tlpa,10,1),50,12,13)
call print(snart(tlb,10,1),50,13,13)
call print(snart(slgp,10,1),50,17,13)
call print(snart(s1hov,10,1),50,18,13)
call print(snart(v0npa,10,-1),40,4,13)
call print(snart(v0hov+v0pa,10,-1),40,5,13)
call print(snart(b0hov+b0peb,10,-1),40,6,13)
call print(snart(v0b,10,-1),40,7,13)
call print(snart(t0npa,10,1),40,11,13)
call print(snart(t0pa,10,1),40,12,13)
call print(snart(t0b, 10, 1), 40, 13, 13)
call print(snart(s0gp, 10, 1), 40, 17, 13)
call print(snart(s0hov, 10, 1), 40, 18, 13)
if (pooldf.eq.1) facnfa = 1.1
if (pooldf.eq.2) facnfa = 1.1
if (pooldf.eq.3) facnfa = 1.3
if (pooldf.eq.1) facapa = 2.3
if (pooldf.eq.2) facapa = 3.8
if (pooldf.eq.3) facapa = 5.0
perbef = v0nfa * facnfa + (v0hov * v0pa) * facpa + v0b + v0t
perafit = v1nfa * facnfa + v1hov * facpa + v1b + v0t
call print(snart(perbef, 10, -1), 40, 20, 13)
call print(snart(perafit, 10, -1), 50, 20, 13)
call perprn(v1nfa, v0nfa, 4)
call perprn(v1hov, v0hcv + v0pa, 5)
call perprn(b1hov, b0hcv + b0peb, 6)
call perprn(v1b, v0b, 7)
call perprn(t1nfa, t0nfa, 11)
call perprn(t1pa, t0pa, 12)
call perprn(t1b, t0b, 13)
call perprn(s1gp, s0gp, 17)
call perprn(s1hov, s0hcv, 18)
call perprn(perafit, perbef, 20)
call getd(a, im, if)
if (im.eq.7) return
if (if.1t.21.or.if.gt.28) go to 10
next = if - 20
return
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

C-26
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**character variables**

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**character functions**

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