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16. Abstract

This report presents the results of an evaluation and adaptation of three existing high-occupancy vehicle (HOV) lane carpool demand estimation models for possible use in Houston and other large Texas cities. The models evaluated in this study were originally developed for the Washington, D.C. region. These models use trip tables, networks and zone structures that are consistent with the regional travel demand modeling process currently in use in Texas. By implementing the HOV carpool models in a structure that is consistent with the regional travel demand modeling process, it is possible to estimate the carpool demand for an HOV facility and to evaluate the effects of the following changes in HOV lane configuration and operating strategies: (1) Effects of additional and/or alternative access points; (2) Effects of extending and HOV lane; and (3) Effects of changing the definition of eligible HOV carpools. The models have produced promising results in test applications in Houston.

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IMPLEMENTATION OF A MEZZO-LEVEL HOV CARPOOL MODEL FOR TEXAS

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Research Report 1103-2F

Research Study No. 2-10-87-1103
Validation of the Shirley Highway HOV Lane
Demand Model in Texas

Sponsored by

Texas State Department of Highways and Public Transportation
in cooperation with the
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Federal Highway Administration

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College Station, Texas 77843-3135

November 1989

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

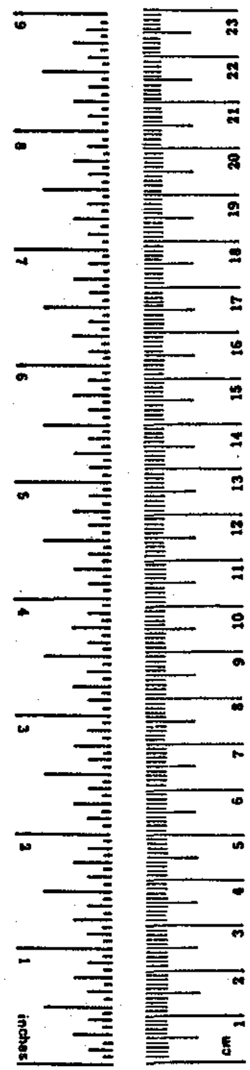
Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in²	square inches	645.2	millimetres squared	mm²
ft²	square feet	0.0929	metres squared	m²
yd²	square yards	0.836	metres squared	m²
mi²	square miles	2.59	kilometres squared	km²
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft³	cubic feet	0.0328	metres cubed	m³
yd³	cubic yards	0.0765	metres cubed	m³

NOTE: Volumes greater than 1000 L shall be shown in m³.

TEMPERATURE (exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* SI is the symbol for the International System of Measurements



APPROXIMATE CONVERSIONS TO SI UNITS

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m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
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m²	metres squared	10.764	square feet	ft²
km²	kilometres squared	0.39	square miles	mi²
ha	hectores (10 000 m²)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m³	metres cubed	35.315	cubic feet	ft³
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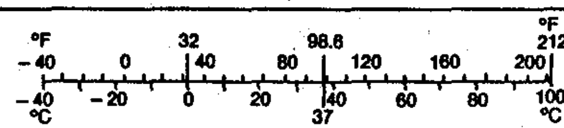

These factors conform to the requirement of FHWA Order 5190.1A.

ABSTRACT

This report presents the results of an evaluation and adaptation of three existing high-occupancy vehicle (HOV) lane carpool demand estimation models for possible use in Houston and other large Texas cities. The models evaluated in this study were originally developed for the Washington, D.C. region. These models use trip tables, networks and zone structures that are consistent with the regional travel demand modeling process currently in use in Texas. By implementing the HOV carpool models in a structure that is consistent with the regional travel demand modeling process, it is possible to estimate the carpool demand for an HOV facility and to evaluate the effects of the following changes in HOV lane configuration and operating strategies: (1) Effects of additional and/or alternative access points; (2) Effects of extending an HOV lane; and (3) Effects of changing the definition of eligible HOV carpools. The models have produced promising results in test applications in Houston.

Keywords: High-occupancy vehicle lanes, carpool demand models, travel demand modeling.

IMPLEMENTATION STATEMENT

The goal of this research study is to assist the Texas State Department of Highways and Public Transportation (SDHPT) in modeling the demand for carpools on high-occupancy vehicle (HOV) lanes in Texas. The results of this study will be useful to SDHPT and other transportation planners and policy analysts in planning, evaluating, designing and implementing HOV facilities in the major urban areas of Texas and other states.

DISCLAIMER

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I. INTRODUCTION

Historically, the emphasis of highway planning has been to assess the capability of a proposed system of highway improvements to serve the forecasted travel demands. Expansion of the freeway system is often necessary to serve the projected demand. However, the planned addition of more traffic lanes by itself is often not sufficient to provide the capacity needed to prevent severe peak period congestion and travel time delays.

In such situations, consideration is often given to providing special lanes designated for the exclusive use of high-occupancy vehicles (HOVs), such as buses and carpools. Experience has shown that these special lanes can be an effective means of moving large volumes of persons during highly congested peak periods. During the peak hour, it is estimated that HOV facilities can move the person trip equivalent of three normal traffic lanes. Obviously, the magnitude of the person movement capability of HOV lanes can significantly enhance the peak period person movement capability of a severely congested freeway corridor.

It is this demonstrated ability of HOV lanes (transitways) to move high volumes of peak period commuters in congested freeway corridors that has led to the large commitment to HOV lanes in Texas. Projections for some of the HOV lanes being developed in Texas anticipate service volumes of approximately 7,000 persons in the peak hour by 1995.

Since very few HOV lanes are currently in operation, no widely accepted procedures exist for analyzing the potential carpool demands for such facilities. The available "quick response" procedures may be adequate for sketch planning purposes but do not lend themselves to system-level analyses and are not particularly "policy-sensitive." For example, these models cannot address an issue such as: what would be the expected increase in carpools if additional access points were provided. Clearly, to address such issues, a more detailed network based modelling approach is needed.

When this study was initiated, a new Shirley Highway HOV Lane Demand Model was being developed by the COMSIS Corp. under contracts with the FHWA and UMTA. This model represented one of the more promising efforts in the area of HOV lane demand modeling. The new model is a network based model intended for applications at the zonal interchange level using the Urban Transportation Planning System (UTPS) software package. At the outset of this study, it was hoped that the Shirley Highway HOV Lane Demand Model could be adapted for general use in Texas cities.

The results of the first year of this study indicated that it was not feasible at that time to pursue the implementation of the new Shirley Model in Texas. This assessment was based on a review of a number of technical and policy-related issues, which are discussed in detail in Research Report 1103-1 (1). Based on the results of the first year study efforts, the following recommendations were made regarding the scope of the research under this study:

1. Efforts should be initiated to develop a somewhat less sophisticated HOV lane carpool demand estimation procedure(s) (i.e., a "mezzo-level" planning model) which would be better suited to meet the short-term planning needs in Texas. It was felt that a "mezzo-level" model could fill a void between the currently available sketch planning models and the very detailed models such as the Shirley Model.

2. Efforts to validate the new Shirley Model in Texas, or to develop more sophisticated regional HOV lane demand models comparable to the Shirley Model, should be undertaken as a part of a separate research project. Indeed, the Texas Transportation Institute (TTI), under an UMTA assistance grant (UMTA Study No. TX-06-0056), will be demonstrating the use of the new Shirley Highway data base and models to incorporate an HOV carpool demand modeling capability as a part of a regional mode choice model in Houston.

It should be emphasized that the HOV modeling work under the UMTA grant will demonstrate how the Shirley Model data base can be used to incorporate an HOV carpool element into a mode choice model for a given urban area but NOT to provide a specific model for application in other urban areas. In contrast, it is anticipated that the "mezzo-level" model developed under this study is essentially a "portable" modelling procedure (much like a trip distribution model) which can be used in other Texas cities.

II. MODEL SELECTION

From a travel demand modeling perspective, HOV carpool demand modeling is a relatively new and evolving area with rather limited experience to draw from. It is certainly reasonable to expect that as more of these facilities are implemented in cities across the country, the data base for the development of these models will grow and new models will evolve. Clearly, none of the models currently available can be considered the definitive HOV carpool demand model.

The initial task was to review the available HOV carpool demand models to identify a promising model for "mezzo-level" adaptation. The "mezzo-level" modeling procedure implemented under this study should be a procedure which can be incorporated into the travel demand modeling process for Texas cities.

Selection Criteria

Before discussing the model selected, it is worthwhile to briefly review some key criteria which were considered in the selection process. The first step was to identify the kinds of questions or issues which the model will likely be used to address. Perhaps the most basic question which all the HOV models should be capable of addressing is: What is the expected peak period carpool demand on an HOV facility? Because upwards of 90% of the peak period trips using HOV carpool facilities are likely to be work trips and because this model will be incorporated into the travel demand modeling process, it was felt that the more appropriate form for this basic question from a modelling perspective would be: What is the expected homebased-work carpool demand? While these questions are certainly not identical, they are in effect very similar. It was felt that a modeling procedure which could address the latter would be a very useful tool for planners. The following are other questions which the model selected should be capable of addressing:

- What is the anticipated impact on HOV carpool demand if the HOV carpool definition (i.e., the minimum number of persons per vehicle for HOV eligible carpools) is changed from 4 to 3 persons per vehicle or from 3 to 2 persons per vehicle?

- What is the anticipated impact on HOV carpool demand if the HOV facility is significantly extended?

- What is the anticipated impact on HOV carpool demand if additional access points to the facility are provided?

It was felt that these are representative of the kinds of questions which planners are being asked and that the model would be utilized in addressing.

It was clearly recognized from the outset that model applicability would likely be limited to major controlled access HOV facilities where significant peak period travel time savings could be realized by carpool users. This certainly seems to be the type of facility which would most likely be under consideration in our major urban areas in Texas and which the travel demand models would most likely be called on to consider.

It was also recognized from the outset that the model (as well as the "mezzo-level" adaptation of the model) is expected to require a homebased-work person trip table for the urban area. Additionally, the HOV model can be expected to require two peak period highway travel time data sets, one representing the expected zone-to-zone peak period travel times for normal highway trips and the other representing the expected travel times for HOV eligible HOV carpool trips. These were considered to be reasonable data requirements for the model.

From a "portability" perspective and a "mezzo-level" adaptation perspective, it was felt that models which are essentially post-mode-choice models would be preferable. The model should explicitly recognize that a portion of the HOV carpool person trips will be drawn from the transit ridership. It is important, therefore, that the model require and utilize information on expected transit patronage. In general, it was felt that it would be desirable for the "mezzo-level" model not to preempt the urban area's mode choice model and attempt to estimate transit patronage directly.

Generally, the urban area's mode choice models will not only estimate transit patronage, but will also estimate auto occupancy to convert the nontransit person trips to vehicle trips. Hence, it was felt that it would be reasonable for the HOV model to require the input of what the expected auto occupancies would be if carpools were not allowed to use the HOV facility. The HOV model would, however, be expected to estimate the change in auto occupancy which would be expected for allowing carpools to utilize the HOV facility.

Models Selected

Based on the review of the available HOV lane carpool demand models, the model developed by Barton-Aschman Associates, Inc. (BAA) for the Atlanta Regional Commission (commonly referred to as the "Atlanta HOV Model") was selected for "mezzo-level" adaptation (2). The Atlanta model satisfied all the selection criteria with only one exception. It was designed to handle only eligible carpool definitions of 3 or more persons per vehicle (i.e., 3+ person carpools) or 4 or more persons per vehicle (i.e., 4+ person carpools) but did not allow the consideration of 2+ person carpools. In carefully reviewing the model, it was clear that the methods used to differentiate between the 3+ and 4+ person carpool definitions could be logically and easily extended to accommodate a 2+ person carpool definition.

Three-Model Approach

One of the very salient features of the Atlanta Model is its use of three models. In developing the Atlanta Model, Barton-Aschman Associates, Inc. reviewed three existing HOV carpool estimation models for possible implementation for Atlanta. The three models, originally developed for use in the Washington, D.C. region, were: (1) the travel time ratio model developed by JHK & Associates for use in estimating carpools in the Shirley Highway and I-66 corridor, inside the Beltway; (2) the logit model developed by Barton-Aschman Associates (BAA) for use in estimating carpools in the Bolling/Anacostia Corridor; and (3) the time savings model developed by the Metropolitan Washington Council of Governments for estimating carpools for long range planning. These three models are described in Appendix A of this report.

In their review and analyses of the three models, BAA concluded that it was impossible to judge with any degree of assurance which of the three models is more accurate for all conditions and, indeed, for any specific condition. Based on their analyses, BAA recommended that the Atlanta model make use of all three models. The Atlanta Model , therefore, applies each of the three models to each zonal interchange to estimate the HOV carpools and computes a weighted average of these estimates for the final "best estimate." BAA recommended that all three models be given equal weights in computing the weighted average "best estimate" but provides the analyst the option of specifying different weights in their software implementation.

The Atlanta Model software not only produces summaries of the weighted average estimates but also summarizes the results from each of the three individual model applications. It was felt that this is a very desirable feature in that it should provide the analyst with an indication of the magnitude of the range of reasonable estimates. With this information available, the analyst may wish to report not only the "best estimate" of probable carpool utilization of a proposed HOV facility but a range of likely levels of carpool utilization.

Other Salient Features

All three models used information from the Shirley Highway HOV lanes in order to develop the parameters of the models, as well as information from other areas and mode choice models. BAA noted that none of the models has been calibrated in the formal sense (i.e., with a disaggregate data set and statistical calibration of the model's parameters). All three models have been accepted and used for planning HOV facilities in the Washington, D.C. region.

The three models do not require information on the characteristics of the trip maker, such as income of the trip maker or the automobiles available to the trip maker. This is certainly a salient feature both from a "mezzo-level" adaptation perspective and from a "portability" perspective.

In the Atlanta Model, the three models are used as "shift" models with the region's travel demand model data used as the basis for the shift. This methodology not only reduces the potential errors in the models but allows the HOV model's estimates to be compatible with other estimates and forecasts being made for the area without the use of carpool facilities; another very desirable feature from a "portability" perspective.

In the Atlanta Model, a set of average auto occupancy models (which will be referred to as the base auto occupancy models) are used as a bridge between the normal regional modeling effort and the HOV model. These average auto occupancy models are used to disaggregate the highway person trip estimates into the four integer auto occupancy groups (i.e., 1 person/vehicle, 2 persons/vehicle, 3 persons/vehicle and 4+ persons/vehicle) for use by the HOV models. The application of the models requires the average auto occupancy as input. As will be discussed later in this report, these base average auto occupancy models were replaced in the "mezzo-level" model with a new set developed using Texas data (see Appendix B).

The software implementing the models is coded in FORTRAN. The source code is not only very well structured but is well "commented" such that it can be easily read and followed. The model logic is also well documented in the BAA report (2). This certainly facilitated the conversion of the software to interface with the Texas software and the software changes needed for the "mezzo-level" adaptation.

III. INITIAL IMPLEMENTATION

The Atlanta Model software was developed to interface with the UTPS travel demand modeling package. The initial implementation of the Texas software therefore required both the changes needed for conversion to a "mezzo-level" model and the changes needed to incorporate the software into the Texas Travel Demand Package.

"Mezzo-Level" Adaptation

The first step in implementation was to identify the basic changes needed in the Atlanta Model for "mezzo-level" adaptation. Three key areas were identified: (1) the input of average auto occupancy estimates; (2) the input of mode split information; and (3) the residual rounding procedure. The following discusses the changes in each of the three areas and the flexibility provided in terms of the level of detail used.

Auto Occupancy Input

To use the Atlanta HOV Model, the normal regional model chain is applied through the mode choice step without HOV carpools (i.e., the Atlanta HOV model is a post-mode-choice model). The Atlanta HOV Model requires three trip tables from the regional models as input: (1) the homebased-work total person trip table for the region; (2) the homebased-work transit person trip table; and (3) the homebased-work vehicle trip table. To estimate the base average auto occupancy for a given zone pair (i.e., the average auto occupancy estimated by the regional models without HOV carpool facilities), the model first subtracts the transit person trips for the zone pair from the total person trips for the zone pair to obtain the number of highway person trips for the zone pair. Next, the model divides the highway person trips for the zone pair by the vehicle trips for the zone pair to compute the base average auto occupancy for the zone pair.

While the Atlanta Model approach to estimating the base average auto occupancies is a very logical approach, this approach would be a problem for some key Texas applications. Urban transportation studies in Texas have traditionally used much smaller zones (i.e., a much larger number of zones) in their regional travel models than is customary in other parts of the country. Perhaps the best example of this is the Houston-Galveston region. The new model chain currently being developed for the Houston-Galveston eight county region uses 2,598 internal zones for trip generation, trip distribution, and highway assignment. While the Houston regional models probably use more zones than any other study area in the nation, it is one of the leading areas in HOV lane implementation and is anticipated to be one of the key users of the "mezzo-level" model. The Houston zone structure provides a good base for illustrating the problem foreseen in the Atlanta Model approach for estimating the base average auto occupancies at the zone interchange level.

With 2,598 zones, there are 6.75 million possible zone pairs for the Houston-Galveston eight-county region. The 1985 homebased-work (HBW) person trips for the region is estimated at 2.15 million daily trips (i.e., less than one-third the number of possible zone pairs). In reviewing the HBW person trip table, it was noted that approximately 87% of the zone pairs had an interchange volume of zero and that approximately 9.5% of the possible zone pairs had an interchange volume of one or two person trips (which accounted for more than 35.7% of the total HBW person trips). From an HOV carpool modeling perspective, the very short HBW work trips are not likely to be candidates for HOV carpools. Looking at the HBW person trips of approximately 8 miles or longer, it was noted that nearly 70% of these trips are distributed between zone pairs with an interchange volume of one, two, three or four person trips. The average nonzero interchange volume for interchanges of 8 miles or longer is approximately 1.75 trips per interaction. Interestingly, if these zones were combined on say a 4-to-1 ratio (i.e., the number of zones were reduced to approximately 650 zones), the average nonzero interchange would likely increase by a factor of roughly 16 (i.e., increase from approximately 1.75 trip per interaction to approximately 38 trips per interaction). With a relatively small average volume per interaction, it was presumed that the approach used in the Atlanta Model would not consistently give a good estimate of the expected average auto occupancy. Had the average volume per interaction been in the vicinity of 30 to 40, the Atlanta methodology would not have been as significant a concern.

Still another problem which dictated a need for a different approach for estimating average auto occupancies at the zonal interchange level is that in some Texas cities, the mode choice modeling is performed at a different level of zonal detail than the highway modeling. For example, while the Houston region uses approximately 2600 zones for trip generation, trip distribution and highway assignment, the mode choice modeling is performed using approximately 800 zones (the highway zones are nested within the transit zones). Clearly, with these differing levels of zonal detail, the Atlanta approach would pose a problem.

To address these concerns, it was felt that the best approach would be to allow the average auto occupancy to be input by the model user at the sector interchange level. This approach actually provides a very useful "bridge" between two different levels of zonal detail. It was felt that this would be a more desirable approach both from a "mezzo-level" perspective and from a "portability" perspective.

Mode Choice Input

As previously noted, the transit person trip table is an input to the Atlanta model. As also noted in the previous section, in some Texas cities different zone structures are used for mode choice and highway modeling. It was decided that the best approach for the new "mezzo-level" model would be to allow the expected percent transit to be input at the sector interchange level. Again, for regions using different zone structures for transit and highway modeling, this provides a very useful and reasonably straightforward "bridge" between the two modeling efforts. By specifying the expected percent transit rather than the expected number of transit trips, it is likely that this data could often continue to be used when minor changes are made in the person trip table without rerunning the mode choice model. Hence, only one trip table (rather than three) will be required for applying the new "mezzo-level" version of the HOV carpool model.

By using a sector interchange level for the input of both the expected percent transit and the expected average auto occupancy, the sector structure should be fairly detailed. Most of the large urban areas already use relatively detailed sector structures for summarizing their trip distribution results. It is likely that these could also be used for the HOV model applications.

Variable Level of Detail

By allowing the base average auto occupancy and the base percent transit utilization to be input at the sector interchange level, the new model provides for a substantial range in terms of the level of detail and sophistication which may be used in the model applications. The level of detail employed in the sector structure is, of course, the key. For fairly quick response sketch planning applications, a fairly coarse sector structure might be employed to simplify and reduce the data input requirements. Applications for more detailed analyses will likely require a more detailed sector structure in order to reflect more detailed mode split and auto occupancy information.

New Residual Rounding

The large number of zones with relatively small interchange volumes not only was viewed as a problem for the average auto occupancy estimates but also for the traditional residual rounding procedure. As may be recalled from the Houston example, the average nonzero interchange volume (i.e., the average trips per interaction) for HBW person trips of 8 miles or longer is approximately 1.75. It is likely, therefore, that the average nonzero carpool volume will likely be less than 0.2 for 2 or more persons per auto and less than 0.1 for 3 or more persons per auto. It was feared that the traditional residual rounding for such small interchange volumes would severely mask the model results. This was also a concern when the new procedure for factoring trip tables to represent peak period trips was developed (3). A new residual rounding procedure was developed for use in peak period applications. Since the problem was even more severe for the carpool trip tables, this new procedure was also implemented in the new HOV model routines. As will be discussed in the next chapter, an enhanced and more computational efficient version of this new procedure was developed and implemented during the testing of the "mezzo-level" model.

Software Implementation

The new "mezzo-level" model software was developed for implementation as a new routine (i.e., the "HOVMODEL" routine) in the Texas Trip Distribution Package. The Atlanta model software was programmed in FORTRAN to interface with the UTPS software package. The new version of the software is also programmed in FORTRAN but is designed to interface with the Texas software packages (see Appendix C).

Data Set Formats

The Texas Travel Demand Package software and the UTPS Package each employ different formats for trip tables and for separation matrices (i.e., skim tree tables). The new "HOVMODEL" routine provides for the input of three key data sets created by the Texas Travel Demand Package. These input data sets are:

1. Person Trip Table Data Set: For HOV model applications, this data set will be the HBW person trip table for the study area. This trip table should be in the same format as those produced by the application of one of the Texas trip distribution models.

2. Peak Period Highway Separation Matrix Data Set: This data set provides the estimated zone-to-zone peak period travel times using the normal highway system (i.e., the expected vehicle travel times for trips which do not use the HOV facilities). The separation matrix data sets used by this routine are the "unedited" separation matrix data sets produced by the Texas Large Network Package. In these data sets, the zone-to-zone travel times are integer values representing the travel times in one-hundredth of a minute units (e.g., a zone-to-zone travel time of 37.46 minutes would be an integer value of 3746 in the separation matrix data set).

3. Peak Period HOV Separation Matrix Data Set: This data set provides the estimated zone-to-zone peak period travel times from the coded highway/HOV facility network. Like the normal highway separation matrix, this data set is the "unedited" separation matrix data set prepared by the Texas Large Network Package.

The HOV model routine outputs two trip table data sets in the Texas format. These output data sets are:

1. HOV Carpool Vehicle Trip Table: This data set will contain the estimated zone-to-zone carpool vehicle trips which would use the HOV facilities being studied. This data set will be in the same format as those produced by the Texas trip distribution model routines.

2. Normal Highway Vehicle Trip Table: This data set will contain the estimated zone-to-zone vehicle trips which would not be expected to use the HOV carpool facilities being studied. Again, this data set will be in the Texas trip distribution model format.

The Program Documentation Manual for the Texas Trip Distribution Models (4) provides detailed descriptions of these data set formats and the information provided in the header records of these data sets.

Changes for Auto Occupancy and Mode Input

The HOV model software had to be modified to accept, store and utilize the sector structure definition (i.e., the zones contained in each sector) as well as the base average auto occupancy and percent mode split information at the sector interchange level. From a software perspective, these changes represented a major programming effort to modify the Atlanta programs.

All user supplied data (other than the person trip table and the two separation matrices) are input in card image format (i.e., 80-column fixed blocked records). The sector structure definition is input to the model using "EQUALS" cards which are in the same format used by the Texas trip distribution models. New data card formats were defined for the input of model parameter data, base average auto occupancy estimates, and base mode split estimates. All the new input cards are fixed format cards. The format for each of these new data cards is described in detail in Appendix C.

New Tabular Summaries Added

The Atlanta model specifications provided for printing only two (one-page) reports summarizing the HOV carpool model results. In implementing the new Texas HOV model the printed output summaries were substantially expanded. The printed output from the Texas software includes:

- A printed summary of the sector structure definition (i.e., the zone to sector equivalencies) used in applying the HOV model;
- An echo of the data card input providing the user specified parameters, the user supplied base average auto occupancy information and the user supplied mode split information;
- A one-page regional travel summary; and,
- Seven reports (i.e., seven tables) summarizing the HOV carpool model results.

The printed output summarizing the model application results were limited to 80 columns so that the tables could be easily copied and used in reports.

Provision for Adding Models

As previously noted, HOV carpool modeling is a relatively new and evolving area in travel demand modeling. As new HOV facilities are implemented around the country and the data base for observed behavior relative to HOV carpools is expanded, it is expected that new or improved models will be developed. It is likely that some of the models will be adaptable to a "mezzo-level" environment and that it would be desirable to add these to the three models already implemented in the Texas model software. The software was, therefore, designed to add up to three additional models without requiring major software revisions. The structuring of the software to facilitate the addition of up to three additional carpool models was felt to be a salient feature of the new software.

Limits on the Number of Zones and Sectors

In the Texas Trip Distribution Package software, the space for major arrays dimensioned for the maximum number of zones and sectors are defined in the main program and shared by the various routines in the package. Hence, all routines in the package, including the new HOV carpool model routine, have the same limits in terms of the maximum number of zones and sectors. The SDHPT normally sets these limits at 3,200 centroids and 100 sectors. These limits can be easily expanded (assuming computer memory space is available). The procedures for changing these limits are provided in the Program Documentation Manual for the Texas Trip Distribution Package (4).

IV. MODEL REFINEMENTS AND ENHANCEMENTS

At various stages in the development of the HOV model, several refinements to the individual submodels were implemented. These refinements were made in an effort to adapt the models for application in Texas cities. The refinements which were developed included: (1) extension of the models to handle 2+ carpool estimates; (2) development of a new auto occupancy model; (3) revision of the eligibility (travel time savings) criteria; and (4) several miscellaneous revisions and enhancements. In certain instances, it was obvious from the beginning of the development process that a particular refinement was not only desirable but necessary. In other cases, a refinement was implemented as a result of test applications of the model. A more detailed review of the individual refinements is presented below.

Modifications For 2+ Carpools

Because three of the four HOV facilities in Houston are operating with a 2+ person occupancy requirement, it was recognized from the outset that the three submodels would have to be modified to be able to account for and estimate 2+ person carpools. All three submodels were originally developed to estimate 4+ person carpool demand. With their adaptation for use in Atlanta, the models were refined to estimate 3+ person carpools. In order to adapt the submodels for application in Texas, it was necessary to modify the models so that they had the ability to account for 2+ person carpools.

Initially, the modification of the Travel Time Ratio model to estimate 2+ person carpools was carried out in the same fashion as was used in Atlanta to refine the models to handle 3+ person carpools. This approach involved making provisions to apply shifts in carpool mode usage to the person trip total for the 2 person car mode as well as the 3 and 4 person car mode. Unfortunately, and as was noted in the report on the Atlanta HOV modeling effort (2), the documentation on the original JHK model does not explain how to use the model when the definition of a carpool is less than 4 persons per automobile. Although this appears not to have been a serious problem in Atlanta, where the minimum carpool definition was 3 person cars, it was an issue in the adaptation of the model for use in Texas. By applying the model in the same manner as in Atlanta, it appears that the model generously estimates 2+ person carpool probabilities. This resulted in further refinement of the travel time ratio model. More specifically, it included adjustments to the ratio of auto to carpool trips for different carpool definitions.

From a carpool demand estimation perspective, the key relationship of the Travel Time Ratio model is the ratio of the highway person trips to the carpool person trips, referred to as the R1 value, as related by the ratio of the travel times of the respective modes. As the models are applied as "shift" models, the R1 value for the expected travel time ratio is compared to the R1 value for a travel time ratio of 1 (i.e., no HOV facility, hence no travel time difference). The change in the R1 value is used to estimate the "shift" in carpools that would be expected from allowing the carpools to use the HOV facility.

The R1 function utilized in the JHK model was developed based on data from the Shirley Highway and I-66 in Washington, D.C., where the minimum carpool definition is 4+person vehicles. In Atlanta, where 3+ person vehicles are the minimum carpool definition, the same function was utilized. However, in Texas, where currently operating HOV facilities have a minimum carpool definition of 2+ person vehicles, it was thought that modifying the R1 function was necessary to account for the fact that 2 and 3 person vehicles are represented in the denominator of the ratio. Unfortunately, the documentation on the JHK model contains no guidelines as to how to account for this. Therefore, a somewhat conservative approach was taken.

A new set of R1 values for the 3+ carpool condition were developed by transferring the assumed portion of 3+ trips in the original ratios from the auto or numerator portion of the ratio to the carpool or denominator portion of the ratio. The assumption being that the portion of auto trips carried in 3 person cars is equal to the portion carried in 4+ person cars. A set of R1 values for the 2+ carpool condition were developed from the 3+ R1 values in a similar manner. Assuming that the portion carried in 2 person cars is equal to the portion carried in 3+ person cars, the 2 person car portion was transferred from the auto to the carpool portion of the ratio. Admittedly, the methodology utilized in developing separate R1 values for 2+ and 3+ carpool conditions may have some shortcomings. However, it was felt necessary to account for the difference in carpool characteristics (i.e. 4+ versus 2+) between Washington, D.C., where the original JHK model was developed, and urban areas in Texas, where the newly adapted model would be applied. In short, it seemed that it would be incorrect to simply assume there was no need for a modification of the R1 values. A more detailed description of the Travel Time Ratio model is presented in Appendix A.

The refinement of the Logit Model to handle 2+ person carpools was a fairly straightforward process. The process used to refine the model to estimate 2+ person carpools was similar to the approach employed in Atlanta, when the model was refined to estimate 3+ person carpools. In fact, because the model logic was already in place, this did not constitute any true extension of the model's capabilities.

In the adaptation of the Logit Model, the independent variable of the utile equations is the modal travel time savings. The models are first applied using the expected normal highway travel time for each integer occupancy group. Next, the models are applied substituting the HOV travel time for carpool eligible groups. The results for these two applications are used as the basis for estimating the expected "shift" in carpools. By simply allowing the travel time savings to influence the utile value of the 2 person car mode as well as the 3 and 4 person car mode, the model is able to estimate the shift to 2+ person carpools. The Logit Model is discussed in detail in Appendix A.

The Travel Time Savings model was originally developed for 4+ person carpools. The process used in Atlanta to extend the model for 3+ person carpools was simply carried one step further for the 2+ carpool definition. In applying the Travel Time Savings model, the HOV carpool travel time savings is used to estimate the change in average auto occupancy. This information is then applied to estimate the "shift" to carpools. A detailed review of the entire Travel Time Savings model is presented in Appendix A.

<u>Development of New Base Auto Occupancy Model</u>

The average auto occupancy models utilized in Atlanta are applied to estimate the percent of vehicles by integer occupancy groups (i.e., 1, 2, 3 and 4+ person autos) for a specified average auto occupancy group. The Atlanta version of the base auto occupancy models was developed using data from the Washington, D.C. area and only allows consideration of average auto occupancies as low as 1.15. This minimum limit of 1.15 for the specified average auto occupancy for HBW trips was found to be a serious constraint for Texas applications. While 1.15 may be considered as a relatively low average auto occupancy for HBW trips in the Washington, D.C. area, it is probably very close to the regional average for the HBW trips in the larger urban areas in Texas. Indeed, the recent travel survey for Houston (5) indicates a regional average auto occupancy of 1.13 for HBW trips. Since the regional average auto occupancy for HBW trips in larger urban areas in Texas is probably in the vicinity of 1.15, it is likely that a majority of average auto occupancy estimates at the sector interchange level will be below the 1.15 constraint in the Atlanta Model. In the Atlanta Model, base estimates of average auto occupancies below 1.15 are automatically changed to 1.15 before applying the "shift" models. With the low auto occupancies expected in Texas applications, it was felt that this approach would tend to overestimate potential carpool usage on HOV facilities in Texas.

Therefore, a new set of auto occupancy models was calibrated which are felt to be more representative of urban areas of Texas, such as Houston. The new models allow the estimation of integer car probabilities in cases where average auto occupancy is less than 1.15. The new Texas Base Auto Occupancy Model, like the Atlanta model, is a set of regression models. The new model was developed through the use of vehicle classification data from the Houston area. The new model allows for consideration of average auto occupancies as low as 1.06. Appendix B contains a detailed description of the new base auto occupancy model.

Revision of Eligibility Criteria

The trips which are input into the HOV models to estimate potential carpool users are referred to as carpool "eligible" trips. As applied in Washington, D.C., only those trips with travel time savings of 5 minutes or more were considered "eligible" HOV trips. This eligibility criteria was also used with the Atlanta adaptations of the HOV models.

As the minimum time savings is a key variable in the HOV models, it was thought that the user of the model should have some ability to control this input parameter. Therefore, in order to increase the flexibility of the model, the user is able to override the default minimum travel time savings of 5 minutes and specify a minimum travel time savings as low as 0.01 minutes. This enhancement to the model allows the analyst to utilize his knowledge of local conditions to determine the level of travel time savings necessary for trips to be considered carpool "eligible" trips.

Unfortunately, this proved to be an extremely sensitive parameter. However, with the second site application of the model to Phase I of the Gulf Freeway HOV Lane in Houston, it became apparent that simply allowing only those trips with travel time savings of 5 or more minutes would result in a large underestimation of potential carpool trips. In fact, because of the relatively short length of Phase I of the Gulf Freeway HOV Lane, the maximum travel time savings possible in the morning peak period on the network was less than 5 minutes. Clearly, the model needed to be modified to account for the users of a facility who experience "marginal" travel time savings, but without the high degree of sensitivity of the initially applied minimum travel time savings parameter.

Implementation of Candidate Approach

To reduce the sensitivity of the model to the minimum travel time savings parameter, and to provide reasonable estimates for applications such as Phase I of the Gulf Freeway HOV lane, a Candidate Person Trip Model was superimposed on the model structure. This option, which should be used with caution, allows the user to reduce the minimum travel time savings below 5 minutes.

As with the Atlanta model, all person trips with travel time savings of 5 minutes or more are considered candidate trips (or eligible trips) and input to the HOV models to estimate the potential carpool users. For travel time savings of less than 5 minutes, the candidate model is applied to estimate the portion of the possible person trips which are input to the HOV carpool models and the remainder are treated as noneligible person trips. The underlying assumption of this approach is that only a portion of the possible users would recognize potential travel time savings of less than 5 minutes and that few, if any, would bother to use the HOV lane for travel time savings of less than 1 minute.

Again, the model user should be cautioned to carefully review the results of any application of this model and to consider the carpool users with less than 5 minutes travel time savings as "marginal" users.

Other Revisions and Enhancements

During the development of the modeling approach, some enhancements were made to the model in addition to those outlined above. These included (1) improving the efficiency of the residual rounding technique; and (2) revision to allow the user to input auto occupancies by separation as well as by sector interchange.

In its original form, the residual rounding technique accounted for all fractional numbers of trips and included them in the final statistics. However, due to the nature of the operation of the technique, the rounding process was somewhat inefficient. As a result, a relatively large amount of calculation or CPU time was accumulated during the running of the model. This problem is a concern especially when dealing with a very detailed network and its accompanying large number of zones. The CPU time needed to run the model can become quite long. Therefore, an effort was made to modify the computer coding of the rounding technique such that the operation of the rounding process consumed less time.

As mentioned previously, estimates of auto occupancy are inputs to the mezzo-level model. Initially, the model allowed either an estimate of regional average auto occupancy, or, if desired, a sector to sector interchange specific auto occupancy. Following preliminary testing of the model in this form, it was felt that it would be desirable to have the ability to also specify an auto occupancy on a time-based separation basis. It was projected that by allowing the input of both sector specific and separation specific auto occupancy estimates, the flexibility of the model would be significantly enhanced. A description of the coding format for both the sector and separation specific auto occupancy estimates can be found in Appendix C.

V. MODEL TESTING AND EVALUATION

As a means of verifying that the various refinements to the HOV models and model structure were performing adequately, a series of model tests and evaluations was performed. The testing and evaluation effort focused on the ability of the model to reasonably replicate observed levels of carpool usage on the HOV facilities on which the model was applied. Obviously, the first task was to choose a facility (or facilities) in Texas which would adequately meet the requirements of the testing and evaluation process.

Site Selection

In order to apply and adequately evaluate the model, it was decided to select two operational HOV facilities where historical data regarding the operation and usage of the facilities was available. Two sites in Houston, the Katy Freeway (I-10W) Transitway and Phase I of the Gulf Freeway (I-45S) Transitway, emerged as the sites to be used in the testing and evaluation process.

The Katy Freeway Transitway, which began operation in 1984, is an 11.5-mile long limited access facility which exists in the median section of the Katy (I-10W) Freeway between SH 6 and the West Loop (I-610). Intermediate access points are provided from a park-and-ride lot at SH-6 and from the freeway median near Gessner Road. Extensive data exist regarding carpool operation on the Katy Transitway, as it is one of the most studied facilities of its kind in the country. The availability of this data made it the primary focus for the testing and evaluation of the models. The Phase I portion of the Gulf Freeway Transitway is a 5.9-mile long facility which operates in the median section of the Gulf (I-45S) Freeway and runs from just south of the South Loop (I-610) to Dowling street in downtown Houston, with intermediate access points located at the South Loop and a transit center. Although it was felt the Phase I portion of the Gulf Freeway Transitway was a marginal facility in terms of length of operation (relative to the Katy Transitway), the facility was chosen as the secondary site for model testing and evaluation.

The primary reason for choosing the Phase I Gulf Transitway as a test site was that it was the only other operating HOV facility in the state on which carpools were allowed and for which data existed. Although there are a number of other carpool facilities around the state, these are only in the planning stages, and hence, no data exists which could be used to properly evaluate the performance of the mezzo-level model.

Another factor which played a role in the selection process was the fact that the Houston regional travel demand models were in the process of being updated. As the base year for this model update was 1985, the testing and evaluation could be done with trip tables and networks that were reasonably close in time to the 1987 and 1988 observed data from the test sites. However, using 1985 data as input data to the HOV models would result in an estimation of carpool trips in 1985 and would essentially be a "backward estimation." However, any differences between carpool demand in 1985 and 1988 were assumed to be reasonably minimal. This assumption proved to be correct as the testing and evaluation of the HOV models produced reasonable planning level estimates of carpool demands.

Test Data Base

Another crucial task was the compilation of the data base to be used in the testing and evaluation of the HOV models. The network used for the HOV model testing and evaluation was a 1985 census tract level network which was developed in conjunction with the processing of a 1985 regional travel survey. This network consisted of approximately 700 zones and was coded with 24-hour speeds. This particular network was chosen over an available 2600 zone, 24-hour network for reasons of computation efficiency, recognizing that many iterations would be necessary during the testing and debugging of the HOV models.

Because the estimates of carpool demands produced by the HOV models would be in terms of the peak period, the 24-hour speeds on the network were converted to speeds representing peak period conditions. At that time, however, there existed no functional peak period model which could facilitate the conversion of a 24-hour network to a peak period network. Therefore, a somewhat simplistic approach of obtaining a peak-period network was taken. Extensive data regarding travel times was available from studies conducted in Houston by TTI in 1985 (5). Freeways in the network were coded in large segment groupings with the average of the a.m. and p.m. peak period speeds from the travel time study data. Peak period speed data for nonfreeway facilities was used in conjunction with the 24-hour speeds for the facilities to develop a simple regression equation which related a given 24-hour speed to a peak period speed. In this manner, each nonfreeway link in the network received a unique peak period speed based upon its coded 24-hour speed.

A second part of the data base compilation was the development of the HOV networks representing the two facilities to be tested. The HOV networks were developed by simply superimposing a link by link representation of the HOV network on the 1985 census tract level network. The HOV network was coded to reduce the possibility of "backtracking" of trips and the use of illogical paths to access the HOV facility. Because the HOV models estimate total regional HOV carpool trips, separate model "runs" would have to be made to produce estimates of carpool trips for the Katy and Phase I Gulf facilities. This also required the development of two HOV networks. One network contained a representation of the Katy HOV facility and a separate HOV network contained the Phase I Gulf Transitway.

The data base used in testing and evaluating the models included two different trip tables. During the initial testing process, a 1980 census journey-to-work trip table was utilized. This trip table was used as an interim trip table while a 1985 person trip table was being compiled. The second primary trip table used was a 2598 zone 1985 homebased-work (HBW) trip table borrowed from the Houston model update effort. Although the trip table represented only one trip purpose (HBW), it was felt that this trip table would perform well in the testing and evaluation process. In fact, studies have shown that on the order of 90% of peak period carpool trips on the transitways in Houston are work-related trips. In order for the trip table to be compatible with the census tract level network, it was collapsed to a 700 zone trip table.

Another aspect of the test data base was the development of three sets of skim trees from the three networks. Skim trees from each of the two peak-period HOV networks and the peak-period highway network were built in order to develop three separation matrices for use in the mezzo-level model.

Estimates of mode choice formed another component of the test data base. Unfortunately, at the time of this task there was no recently calibrated mode choice model available for the Houston region. In order to estimate transit mode choice, an expanded 1985 Houston transit origin-destination (O-D) survey was used. This expanded O-D survey allowed estimation of the sector (district) to sector (district) transit usage for the Houston region. However, the model does not require the user to have estimates of sector to sector transit mode share. The model will accept a single estimate of regional transit usage. For those urban areas in Texas which may not be able to readily estimate transit usage on a sector level, this characteristic of the model could prove helpful.

Test Results

The following summarizes the test and evaluation results for the two HOV carpool facilities.

Katy Freeway HOV Lane Application

The Katy Freeway (I-10W) HOV facility is an 11.5-mile long limited access transitway facility which begins just west of SH 6 and terminates just outside of the IH-610 loop. The HOV facility serves inbound trips during the morning hours of operation and outbound trips during the evening hours. The 1985 networks indicated a maximum potential peak period time savings of approximately 13.5 minutes. The September 1987 count data indicated that approximately 2,600 carpools (with 2 or more persons per carpool vehicle) were utilizing the facility during the morning operation of the facility or roughly 5,200 HBW carpools per day (6). Recalling that the model data base was for the spring of 1985 and recognizing that there had been some growth in traffic in the corridor during the 2½ year period from the spring of 1985 to the fall of 1987, it was estimated that the HOV facility would have carried approximately 4,800 HBW carpools with 2 or more persons if the facility had been operating in the spring of 1985 (i.e., approximately 7% to 8% fewer than was observed for September 1987).

At the outset, it was believed that it was important to establish the range of estimates that would be considered as "good" results and the range that would be considered as "acceptable" results from the HOV model. In validating regional travel demand models, a general rule-of-thumb often used in judging the base year model chain results for freeways is: assigned freeway volumes within 10% of the counted volume are generally considered as "good" results and that assigned freeway volumes within 15% (and occasionally 20%) of counted volumes are usually considered as "acceptable" results. Since the HOV model is applied to the regional model data as a "shift" model, it was felt that a slightly more relaxed version of the freeway volume "rule-of-thumb" criteria would be appropriate for judging the quality of the HOV model results. Since the regional models were producing "good" assigned 24-hour volumes on the Katy Freeway (i.e., assigned volumes generally within 10% of the counted volumes), it was felt that HOV model results within $\pm$12.5% of the estimated 1985 HBW carpools should be considered as "good" carpool estimates and results within $\pm$20% should probably be considered as "acceptable" carpool estimates.

The results of the new "mezzo-level" model indicated that between 4,273 and 5,432 HBW carpools per day would likely have used the Katy Freeway HOV in 1985 and that the "best estimate" (i.e., the average of the three individual submodels) would be 4,822 HBW carpools per day. Compared to the "backcasted" 1985 estimate (based on September 1987 counts) of 4,800 HBW carpools per day, it was felt the HOV model results were very "good" estimates. Indeed, not only was the average estimate almost perfect, the results from each of the three submodels were within the $\pm$12.5% criteria. These results should probably be considered as unusually good results and should not be misconstrued to imply that all applications will yield results with such an unusual level of precision.

The HOV carpool model results indicated that a significant number of new carpools would be formed to take advantage of the travel time savings offered by the HOV facility. The application of the base average auto occupancy model to the regional data indicated that within the group of candidate trips (i.e., the person trips which could save approximately 5 minutes or more using the HOV carpool facility) there would be approximately 3,426 vehicles carrying two or more persons (before any formation of new carpools). The application of the model indicated that the formation of new carpools would increase this number by approximately 41% (with the individual submodels indicating increases from 25% to 59%).

Gulf Freeway Phase I HOV Lane Application

The initial segment (i.e., the Phase I segment) of the Gulf Freeway (I-45S) HOV facility is an 5.9-mile long limited access transitway facility which begins just south of the IH-610 Loop and terminates just south of the Houston CBD. The HOV facility serves inbound trips during the morning hours of operation and outbound trips during the evening hours. The 1985 networks indicated a maximum potential peak period time savings of only approximately 4.5 minutes. From an HOV carpool modeling perspective, this is a very marginal application which required extension of the models to accommodate. Indeed the minimum travel time savings for candidate trips had to be lowered to 3 minutes for this application. The March 1989 count data indicated that only approximately 760 carpools (with 2 or more persons per carpool vehicle) were utilizing the facility during the morning operation of the facility, or roughly 1,560 HBW carpools per day (7). Recalling that the model data base was for the spring of 1985 and recognizing that there had been some growth in traffic in the corridor during the 4-year period from the spring of 1985 to the spring of 1989, it was estimated that the HOV facility would have carried approximately 1,450 HBW carpools with 2 or more persons if the facility had been operating in the spring of 1985.

Essentially the same criteria were used to judge this application as were used in the Katy Freeway HOV application. Since the regional models were producing "good" assigned 24-hour volumes on the Gulf Freeway (i.e., assigned volumes generally within 10% of the counted volumes), HOV model results within ±12.5% of the estimated 1985 HBW carpools should be considered as "good" carpool estimates, and HOV model results within ±20% should probably be considered as "acceptable" estimates. In other words, model results in the range of 1,160 to 1,740 HBW carpools per day would be considered as "acceptable" estimates and model results in the range of 1,268 to 1,631 HBW carpools per day would be considered as "good" estimates.

The results of the new "mezzo-level" model indicated that between 1,402 and 1,733 HBW carpools per day would likely have used the Phase I Gulf Freeway HOV in 1985 and that the "best estimate" (i.e., the average of the three individual submodels) would be 1,576 HBW carpools per day. Compared to the "backcasted" 1985 estimate (based on March 1989 counts) of 1,450 HBW carpools per day, it was felt the HOV model results were "good" estimates. Indeed, the average estimate was only 8.7% over the best estimate, based on observed counts. The results from each of the three submodels were all within the ±20% range for "acceptable", and two of the three were within the ±12.5% range for "good" results. Since this was considered a rather marginal application for the new HOV carpool model, the results were encouraging.

The HOV carpool model results indicated that some new carpools would be formed to take advantage of the marginal travel time savings offered by the HOV facility. The application of the base average auto occupancy model to the regional data indicated that within the group of candidate trips (i.e., HBW person trips with potential travel time savings of from approximately 3 to 4.5 minutes) there would be approximately 1,249 vehicles carrying two or more persons (before any formation of new carpools). The application of the model indicated that the formation of new carpools would increase this number by approximately 26% (with the individual sub-models indicating increases of 12%, 27% and 39%).

Conclusion and Recommendation

The test results from the two applications of the new "mezzo-level" HOV carpool model were judged to be "good" (i.e., within ±12.5% of observed volumes). Since the models are applied as "shift" models using the regional model results, it was felt that the model could be expected to generally produce reasonable carpool estimates which are consistent with the regional forecast. It is recommended, therefore, that the new "mezzo-level" model be included in the Texas Trip Distribution Package software for application in Texas cities.

VII. REFERENCES

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APPENDIX A

THE HOV CARPOOL SUB-MODELS

Travel Time Ratio Model

The Travel Time Ratio model is an adaptation of a model developed by JHK and Associates for use in Washington, D.C., and modified by Barton-Ashman and Associates for application in Atlanta. The JHK model utilizes peak period travel time ratios to estimate transit, auto and carpool modal probabilities and calculate the shift in carpool modal probabilities. This is done by estimating the carpool probabilities with and without HOV lanes and applying the change or "shift" in probabilities to a base amount of trips.

Two sets of cross-classification curves relate (1) the transit to highway (auto) travel time ratio to the ratio of transit person trips to highway person trips and (2) the auto to HOV (carpool) travel time ratio to the ratio of highway person trips to carpool person trips. By using the cross-classification curves and mathematical formulations the model can estimate the percent of transit, auto, and carpool modal probabilities.

The JHK model was developed using Shirley Highway data, where the minimum carpool definition is 4+ persons. To account for the fact that the model would be applied in Texas, where the minimum carpool definition is as low as 2+ and the proportion of auto trips would be different for different levels of carpooling, new values were developed for the 2+ and 3+ minimum carpool definition, respectively. Table A-1 shows the three sets of values for the various minimum carpool definitions (R1), as well as the values for the transit to auto trip ratios (R2) and the corresponding travel time ratio.

Based upon these functions, modal probabilities are initially estimated for the no HOV lane condition using the following mathematical definitions:

A = Percent Automobile Person Trips
C = Percent Carpool Person Trips
T = Percent Transit Person Trips

$$A + C + T = 100$$
$$R1 = A/C$$
$$R2 = T/A$$

Given these definitions, the following mathematical manipulations can be performed.

$$A = R1 * C$$
$$R2 = T/(R1 * C)$$
$$T = R1 * R2 * C$$
$$R1 * C + C + R1 * R2 * C = 100$$
$$C * (R1 + 1 + R1 * R2) = 100$$

With the following equations, the percent mode usage is estimated for the no HOV lane condition:

$$C = 100/(R1 + 1 + R1 * R2)$$
$$A = R1 * C$$
$$T = R2 * A$$

Table A-1. Ratios Used in Travel Time Ratio Model

Travel Time Ratio	R2 Transit/Auto Ratio	4+ R1 Auto/Carpool Ratio	3+ R1 Auto/Carpool Ratio	2+ R1 Auto/Carpool Ratio
0.55	3.450	8.00	3.50	1.25
0.60	2.250	8.00	3.50	1.25
0.70	1.250	8.00	3.50	1.25
0.80	0.800	8.00	3.50	1.25
0.90	0.550	8.00	3.50	1.25
1.00	0.450	8.00	3.50	1.25
1.10	0.380	5.40	2.36	0.84
1.20	0.320	4.20	1.84	0.66
1.30	0.270	3.40	1.49	0.53
1.40	0.230	2.70	1.18	0.42
1.50	0.200	2.30	1.01	0.36
1.60	0.180	1.85	0.81	0.29
1.70	0.170	1.50	0.66	0.23
1.80	0.165	1.20	0.53	0.19
1.90	0.165	0.90	0.39	0.14
2.00	0.165	0.65	0.28	0.10

The no HOV lane condition simply means that the R1 value used would correspond to an auto to carpool travel time ratio of 1.0 (i.e., no travel time savings) The R2 value is computed based upon the input person trip table and transit mode share. The transit person trip part of the ratio is estimated from the input percent transit. The auto portion of the ratio is calculated by subtracting the estimated transit person trips from the total person trips obtained from the input trip table.

Utilizing the same functions and equations, modal probabilities for transit, auto, and carpool are reestimated based upon a new R1 value. The new R1 value will correspond to the value of the travel time ratio which reflects the travel time savings the HOV lane offers.

The shift in carpool, highway and transit modal probabilities is then calculated by comparing the probabilities for the three modes with and without carpool lanes. These shifts are then applied to the total person trips for 1, 2, 3, and 4+ person cars as well as transit for the base condition to obtain the final person and vehicle trip probabilities for the integer car modes, as well as the person trip probability for the transit mode.

Logit Model

The Logit Based model is an adaptation of the Bolling-Anacostia model originally developed in Washington, D.C. by Barton-Aschman Associates (BAA) and modified for use in Atlanta by Barton-Aschman. As its name indicates, this model is a logit model which estimates the probability of each integer car mode. The model as applied in both Washington, D.C. and in Atlanta incorporated both a time and cost element into the logit equations for each of four modes (1, 2, 3 and 4+ person vehicle). The adaption of the BAA model for application in Texas has eliminated the use of the cost variable from the logit equations. The logit equations are as follows:

$$U(1\ person/car) = (-0.0388 * NHTT) - 1.65075$$
$$U(2\ person/car) = (-0.0388 * (NHTT + 1.1)) - 2.20850$$
$$U(3\ person/car) = (-0.0388 * (NHTT + 2.2)) - 3.47975$$
$$U(4\ person/car) = (-0.0388 * (NHTT + 3.2)) - 3.51075$$

where:

NHTT = peak period highway travel time

As the above formulas indicate, the logit equations are used to calculate utile values for each of the four modes. The probability of each mode is calculated by exponentiating and summing the values of the preceding equations and applying the values as follows:

$$\text{Probability of mode}(x) = \frac{EXP(U(x))}{\sum_{i=1}^{n} EXP(U(x))}$$

where:

n = number of modes

Because the model is not considered a true "calibrated" logit model, it is applied with a "shift" technique. Initially, the logit equations are applied to obtain estimates of the modal probabilities in the no HOV lane condition. It should be noted that the probabilities that are calculated are in the form of highway person trips and not total person trips. The transit person trips are dealt with in a separate calculation.

The model probabilities are reestimated using the same logit equations as were used to calculate the non HOV lane probabilities. However, the logit equations used to calculate the utile values for each mode contain a time variable which represents the HOV travel time (NHTT-time savings):

U(1 person/car) = (-0.0388 * (NHTT) - TMESV) - 1.65075
U(2 person/car) = (-0.0388 * (NHTT - TMESV) + 1.1)) - 2.20850
U(3 person/car) = (-0.0388 * (NHTT - TMESV) + 2.2)) - 3.47975
U(4 person/car) = (-0.0388 * (NHTT - TMESV) + 3.2)) - 1.65075

where:

TMESV = travel time savings of HOV lane

The utiles are exponentiated and summed, just as in the non-HOV lane condition to obtain estimates of modal probabilities. The shifts in the modal probabilities are computed by comparing the probabilities in the non-HOV lane condition with those in the HOV lane condition. These shifts are then applied to the highway person portion of the total person probabilities to obtain highway person probability in the HOV lane condition.

The computation of the shifts was performed while holding the transit probability constant. Obviously, there is some shift in the transit probability due to the implementation of an HOV lane. The Logit Based model assumes that the shift in transit is the same as the shift in the highway or noncarpool modes. This shift is applied to the transit person portion of the total person probability and allotted to the mode representing the minimum eligible carpool.

Once all shifts have been computed and applied to the appropriate mode, the person trips are calculated by multiplying the new modal probabilities by the base person trip total. From these person trip values, new vehicle trip totals are calculated.

Time Savings Model

The Time Savings model is an adaptation of the model developed in Washington, D.C. by the Metropolitan Washington Council of Governments (MWCOG) and adapted for use in Atlanta by Barton-Aschman Associates. The model is a regression model which uses travel time savings (normal highway travel time minus carpool travel time) as an independent variable and the change in average auto occupancy as the dependent variable. As with the other HOV models, the Time Savings model is applied with a "shift" technique.

The Time Savings model can estimate either percent or absolute change in average auto occupancy based upon travel time savings as shown below:

ABS. CAR OCC. CHG. = 0.05 + 0.006 * TIME SAVINGS

PCT. CAR OCC. CHG. = 3.80 + 0.450 * TIME SAVINGS

The change in auto occupancy based upon travel time savings offered by the HOV lane is added to the base average auto occupancy to obtain a new average auto occupancy. The integer car (1, 2, 3 and 4+) vehicle probabilities are then estimated from the new average auto occupancy estimate using a series of linear regressions which relate the average auto occupancy to the percent of trips in each integer auto occupancy group, otherwise referred to as an auto occupancy model.

The auto occupancy model used in the Texas version of the Time Savings Model is the New Texas Auto Occupancy Model. This model is adapted from the auto occupancy model used in the original MWCOG model. This newly adapted model, which is described in detail in Appendix B, appears to give much better results in cases where average auto occupancies are on the order of 1.15 or less.

The shift in both the carpool and normal highway vehicle probabilities is computed by comparing the vehicle probability estimates from the New Texas Auto Occupancy Model with the base vehicle probabilities. The shift in vehicle probabilities is then applied to the base vehicle car probabilities, with the shift in highway vehicle probability applied to the defined normal highway modes and the shift in carpool probability applied to the defined carpool modes. The results of this application are the new integer car vehicle probabilities.

The integer car vehicle probabilities are then converted to integer car highway person probabilities. In order to compute the total person probability, it is necessary to estimate the shift in transit person trip probability. The Time Savings model assumes that the shift in transit person trip probability is the same as the shift in noncarpool mode(s) vehicle trip probability. Once the transit shift has been calculated, the total integer car and transit person trip probabilities and person trips are computed. The total integer car person trip probabilities are converted to vehicle trip probabilities for inclusion into the final statistics.

APPENDIX B

NEW TEXAS AVERAGE AUTO OCCUPANCY MODELS

The average auto occupancy models provide a very important "bridge" between the regional model chain and the HOV carpool model. Given an expected average auto occupancy, the average auto occupancy models are applied to estimate the expected percentage distribution of vehicles by the four integer auto occupancy groups (i.e., 1 occupant vehicles, 2 occupant vehicles, 3 occupant vehicles and 4+ occupant vehicles). These results can then used to estimate the expected percentage distribution of highway person trips by the four integer occupancy groups. Given the estimated percent transit, the expected percentage distribution of total person trips by the five modal groups (i.e., transit, drive alone, 2 occupant vehicles, 3 occupant vehicles and 4+ occupant vehicles) can be easily computed. In the HOV model applications, the average auto occupancy and percent transit data would normally be obtained from the regional model chain results.

A new set of average auto occupancy models were developed for implementation in the new "mezzo-level" HOV carpool model for Texas. This was a very important step in adapting the Atlanta model for applications in Texas cities.

Data Base

The data base used in developing the new average auto occupancy model set consisted of 214 peak period vehicle classification counts (i.e., vehicle counts stratified by the four integer occupancy groups) collected at various locations on the Houston freeway system. Forty-four of the 214 counts were collected at locations where HOV carpool facilities were in operation and included the HOV carpools in the count data collected. The observed average auto occupancies for the 214 counts ranged from 1.035 to 1.334 persons per auto. The average auto occupancy for the 214 counts was 1.155 persons per vehicle and the median auto occupancy for the 214 observations was 1.145 persons per vehicle. It was felt that a new set of models developed using these data would better reflect travel behavior in Texas cities than models developed using vehicle classification counts from the Washington, D.C. area.

Model Development

The average auto occupancy model is a set of four simple linear regression models (i.e., a model for each of the four integer occupancy groups). For each model, the independent variable is the average auto occupancy, and the dependent variable is the expected percent vehicles for the integer occupancy group. The new models developed using the Texas data are:

$$P(1) = 1.79689686 - (0.80510746 * A)$$
$$P(2) = -0.64408871 + (0.65782773 * A)$$
$$P(3) = -0.10251317 + (0.09966693 * A)$$
$$P(4+) = -0.05029499 + (0.04761280 * A)$$

where:

$P(I)$ = the expected percent of vehicles in integer occupancy group I

A = the average auto occupancy

The R-square values for these four models were 0.985, 0.940, 0.782 and 0.589, respectively.

Figure B-1 displays the observed percentages of one occupant vehicles for the 214 vehicle classification counts used in the model development. The new Texas model for one occupant vehicles was applied for each of the 214 observations, and the model results are also displayed in Figure B-1. Figures B-2 to B-4 display the observed and modelled results for the two-occupant vehicles, the three-occupant vehicles, and the four-or-more occupant vehicles, respectively.

Comparison With Atlanta Models

The average auto occupancy models implemented in Atlanta were developed using vehicle classification count data from the Washington, D.C. area. Like the new Texas models, the Atlanta average auto occupancy models are a set of four linear models using the average auto occupancy as the independent variable. To provide a graphical comparison of the two model sets, the Atlanta models were applied to the 214 observations in the Texas data base. The Atlanta model results along with the Texas model results and the observed Texas data are displayed in Figures B-5 through B-8. In reviewing these figures, it should be recalled that in the Atlanta model, average auto occupancies below 1.15 are automatically reset to 1.15. From the graphical displays, it would appear that this constraint was needed to avoid the negative percentage estimates. Similarly, a constraint of 1.06 was imposed on the Texas models to avoid negative values. The Atlanta model constraint of 1.15 would have been applicable to more than half of the 214 observations in the Texas data base. In contrast, the Texas model constraint of 1.06 would only be applicable to three of the 214 observations. The ability of the new Texas models to handle average auto occupancies in the range of 1.06 to 1.15 was really a requirement for Texas applications. Also, the graphical comparisons presented in Figures B-5 through B-8 certainly suggest that the new models are much more reflective of the travel behavior in Texas.

FIGURE B-1

NEW MODEL FOR 1 PERSON CARS

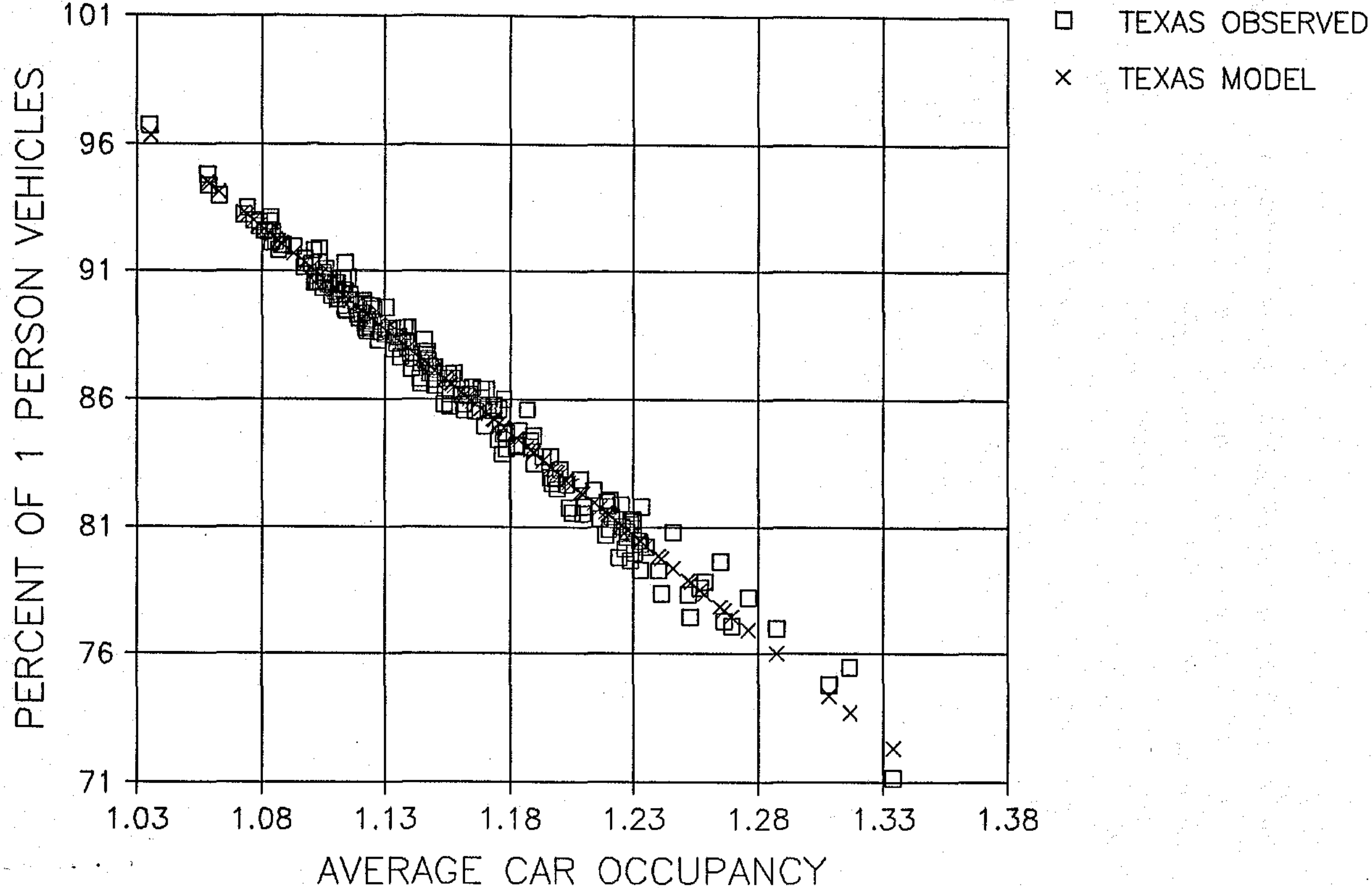


FIGURE B-2

NEW MODEL FOR 2 PERSON CARS

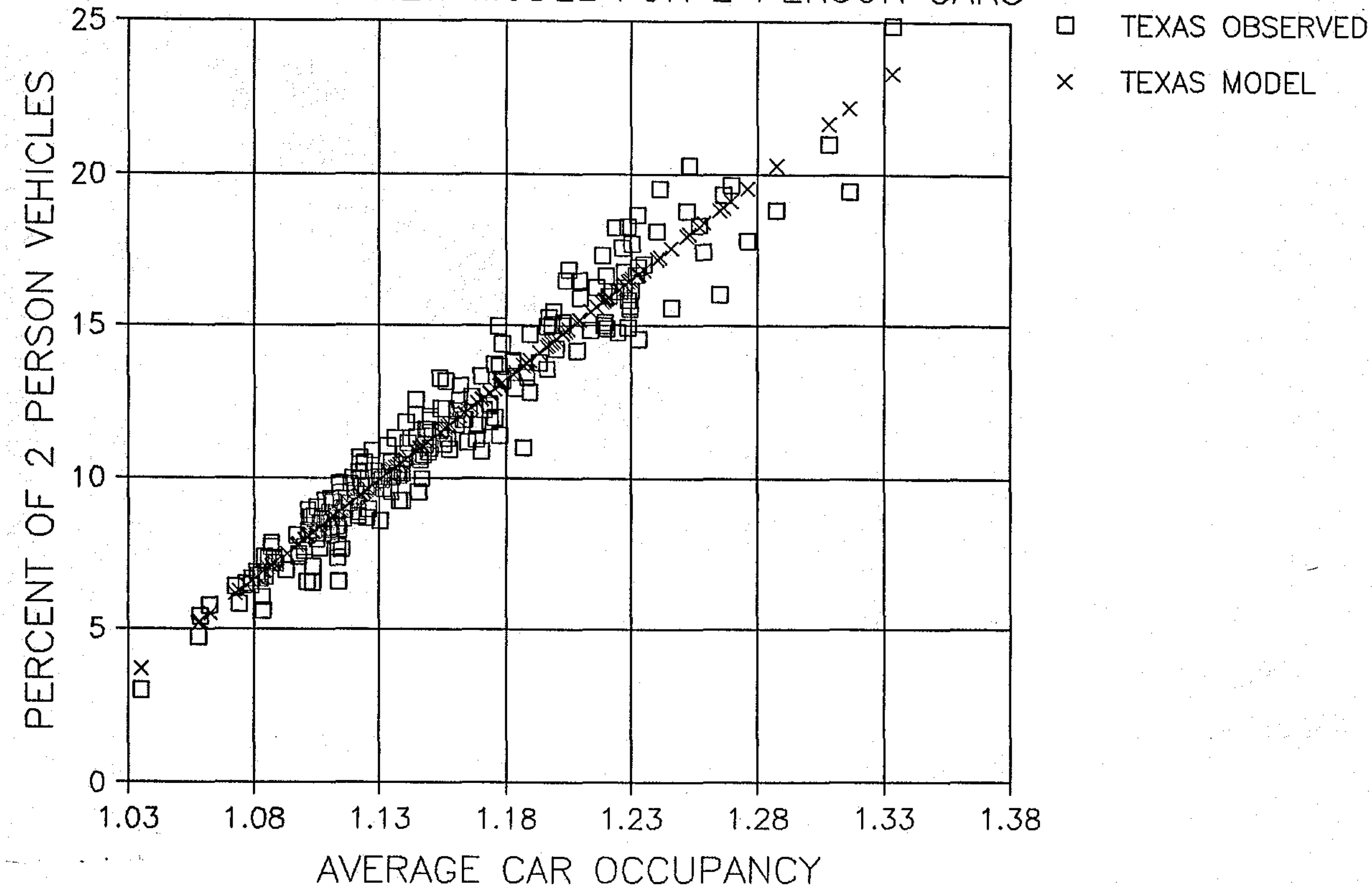


FIGURE B-3

NEW MODEL FOR 3 PERSON CARS

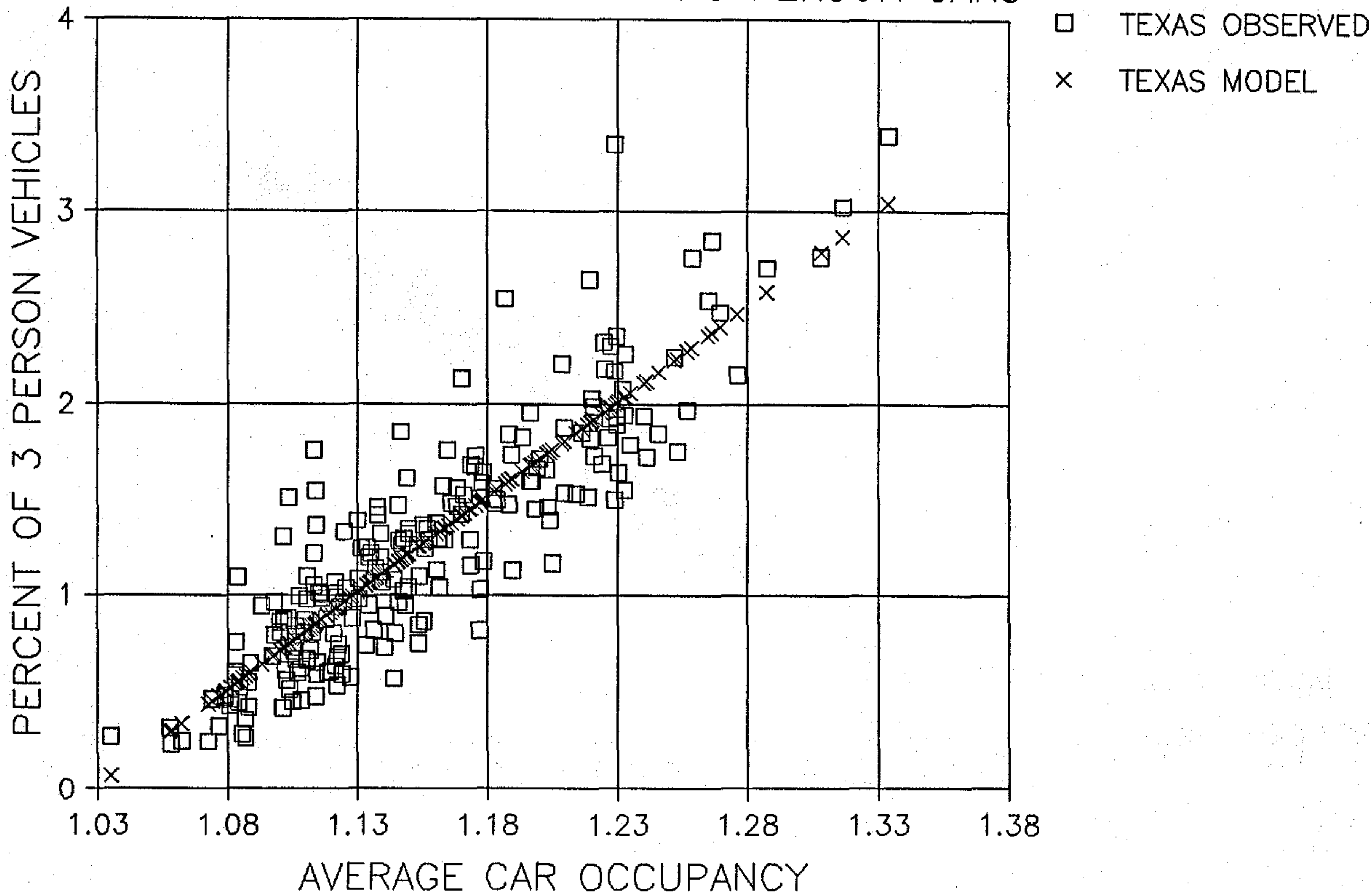


FIGURE B-4

NEW MODEL FOR 4+ PERSON CARS

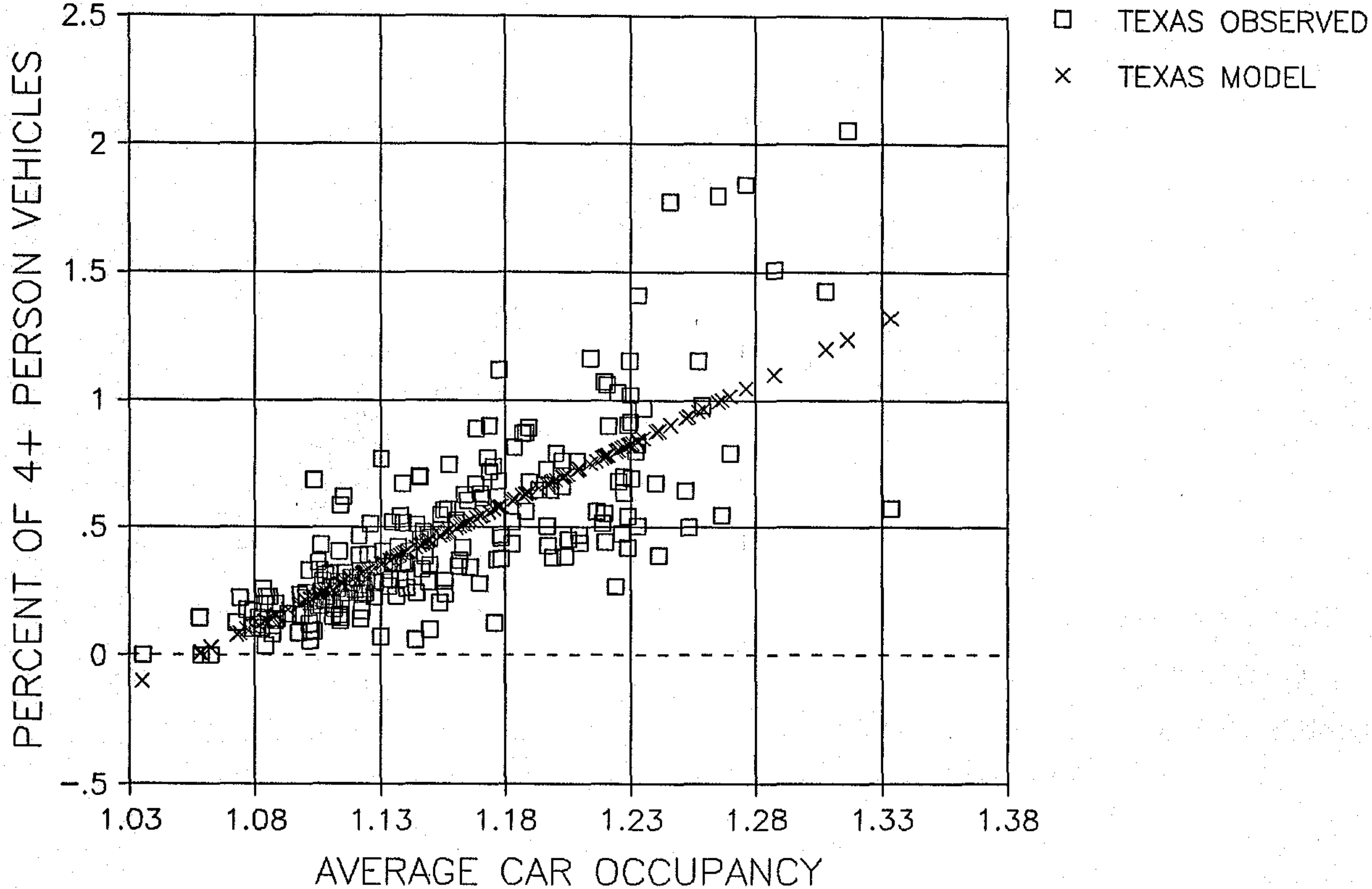


FIGURE B-5

COMPARISON OF 1 PERSON CAR MODELS

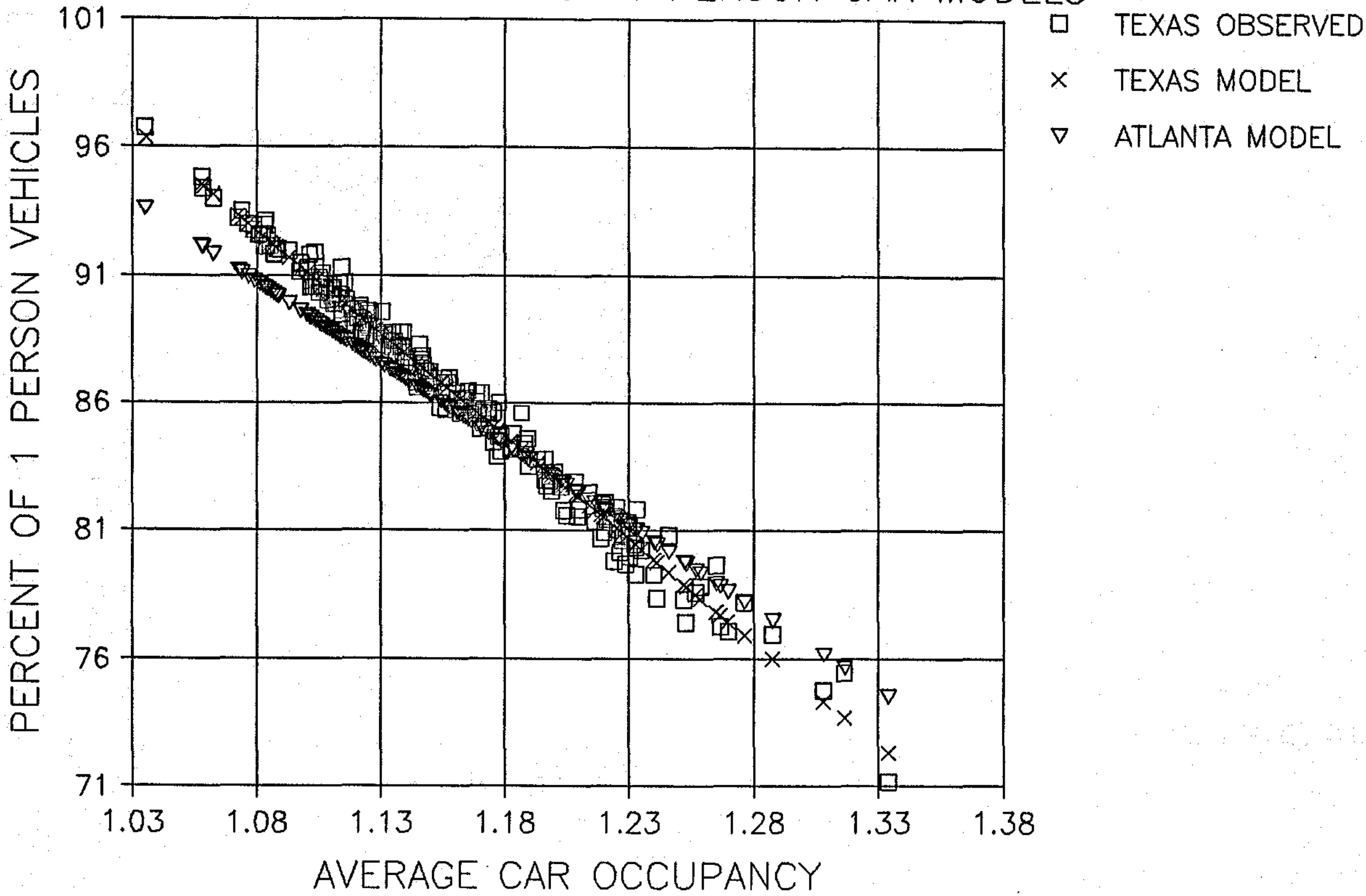


FIGURE B-6

COMPARISON OF 2 PERSON CAR MODELS

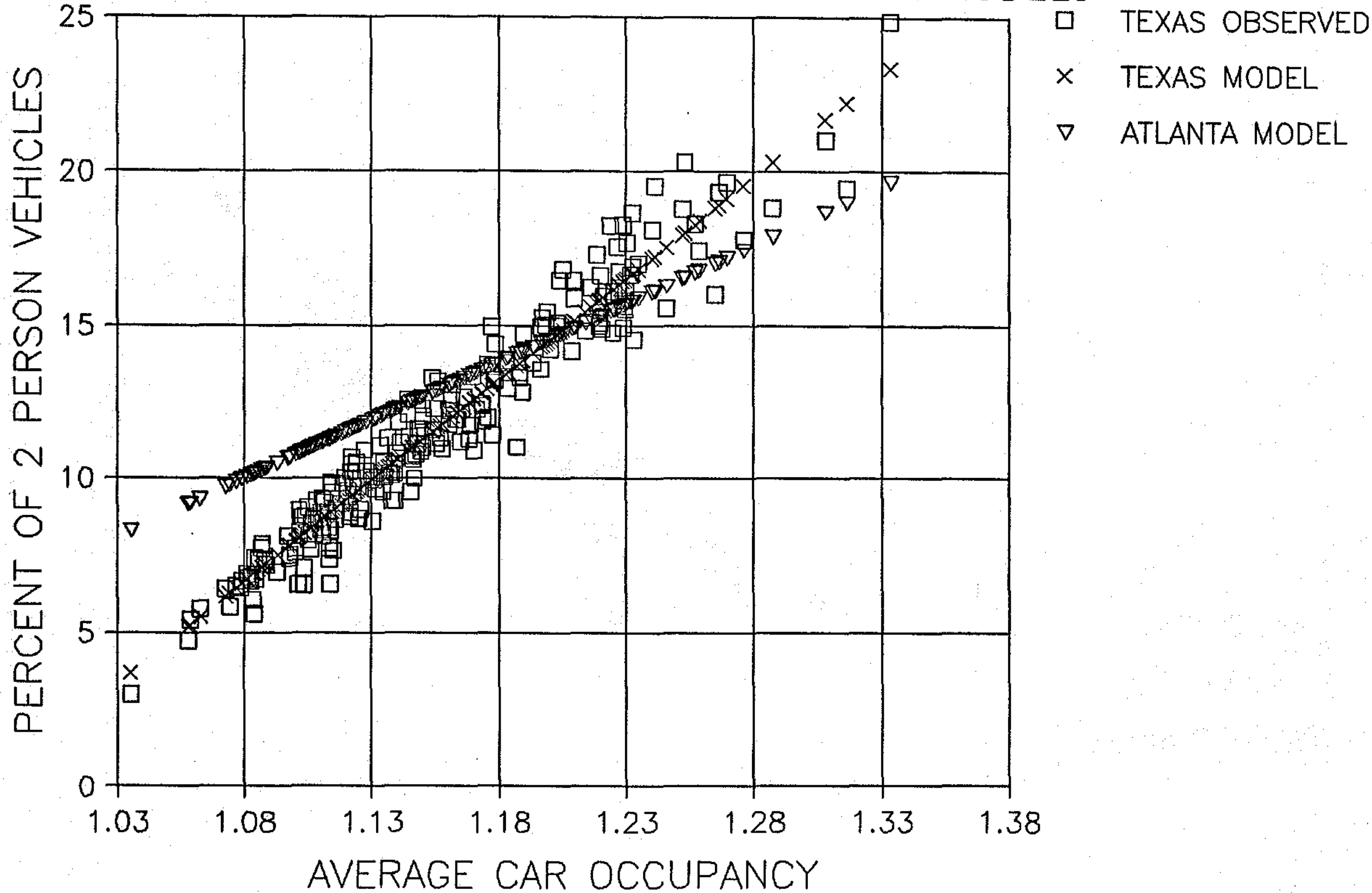


FIGURE B-7

COMPARISON OF 3 PERSON CAR MODELS

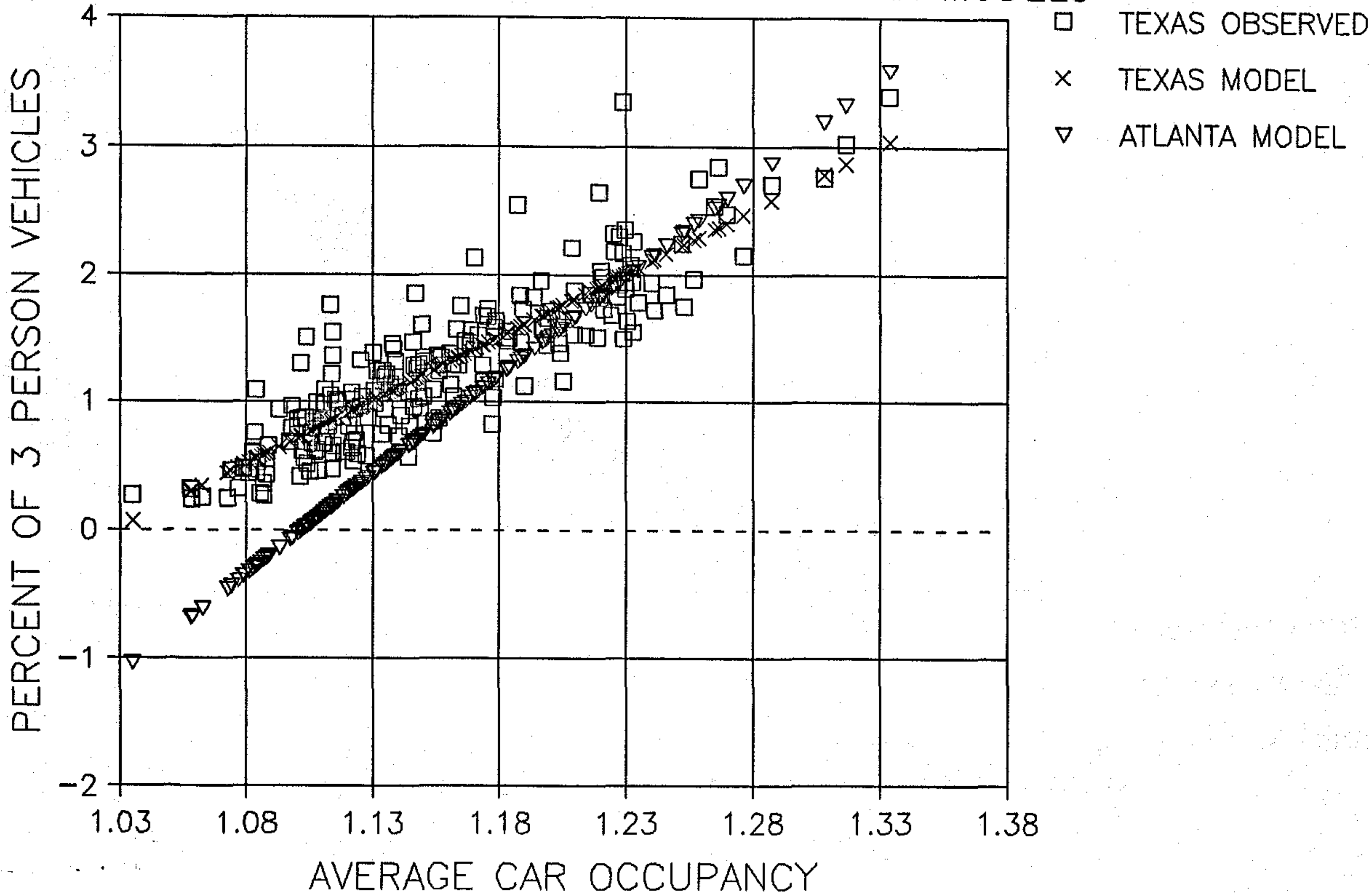
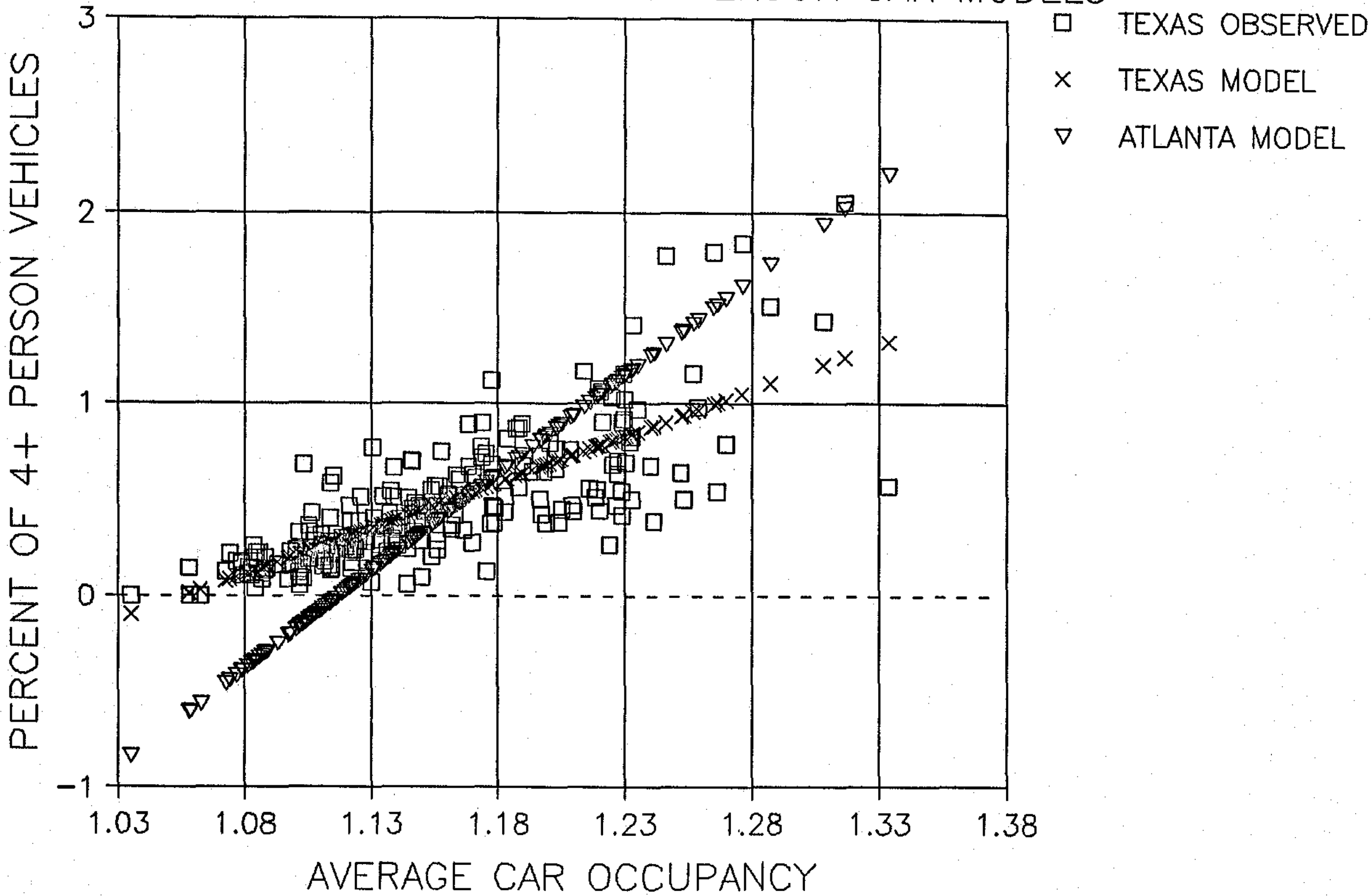


FIGURE B-8

COMPARISON OF 4+ PERSON CAR MODELS



APPENDIX C

STRUCTURE AND PROGRAM DOCUMENTATION FOR THE TEXAS MEZZO-LEVEL CARPOOL MODEL

Model Structure

This Appendix documents (1) the structure of the mezzo-level model, (2) the necessary inputs, and (3) the process by which the model feeds the three HOV submodels to produce estimates of carpool demand on a HOV facility. Details of the action of the three HOV models can be found in Appendix A.

Initialization Phase

Initially, the header records for the input trip table as well as the HOV and normal highway peak period separation matrices are read. Following this step, the processing of the input cards is performed. The first step in the modeling process is the input of the sector (district) structure through the EQUATE subroutine. Through this subroutine all centroids or zones are equated to a sector in the region based upon the sector table of equivalencies. The next step is the input of the various parameter cards.

The subroutine HSETUP is used to input HOVPARMS, SECTAO, SEPAO, and SECTMS cards. The HOVPARM card contains the default average auto occupancy, terminal times and minimum HOV carpool size. The HOVPARMS card also includes specifications as to the relative weightings of the individual estimates produced by the HOV models in the production of a final estimate of carpool demand. A second input parameter is the SECTAO card. This card, which is an optional input, contains information regarding the estimates of sector to sector auto occupancies the user desires to model with. If no SECTAO card is used, then the default average auto occupancy from the HPARM card will be used for each zonal interchange. The SEPAO card, also an optional input, contains the same information as the SECTAO card, average auto occupancy, but on a separation (in terms of time) basis rather than a sector basis.

A fourth optional input is contained in the SECTMS card. This card inputs the user's estimate of transit mode share on a sector to sector basis. If the SECTMS card is not utilized, the submodels use the default regional transit mode share as specified in the HOVPARM card and apply it on a zonal interchange basis.

As they are read, the sector interchange average auto occupancies and mode splits are saved into sector arrays to be used in the processing of zonal interchanges based upon the previously input sector structure.

Modeling Phase

The first step in the modeling phase is the reading of a row of the person trip table and a row of the HOV and normal highway separation matrices. Once these values have been read, the model then verifies that an interchange volume exists. If none is found, the processing of that row is finished and the model then performs residual rounding and outputs the row to the new trip tables.

When a zonal interchange volume is found, travel time savings for that zonal interchange due to the HOV facility is computed based upon the HOV and highway separation matrices. If the travel time savings is found to be less than the minimum input travel time savings as determined by the user or through the default value, the interchange is considered a non-HOV eligible interchange. At this point, the base auto occupancy model is used to calculate the number of highway vehicle trips. The data is then included into the summary data for the region, passed onto residual rounding and output into the new trip tables.

For those non-zero zonal interchanges which possess travel time savings due to the HOV facility of greater than the minimum travel time savings, the HOV submodels are applied. Once the submodels have been applied the results of all HOV models are averaged, based upon the weighting specified by the user, to produce a single estimate of HOV carpool trips. At this point, residual rounding is performed and the data is output to a row of each of the new trip tables.

This process is repeated for each row of the input person trip table until all zonal interchanges are processed.

HOVMODEL: Function

The HOVMODEL routine implements the new "mezzo-level" HOV carpool model developed for application in Texas cities. The model inputs the HBW person trip table for the region and two "unedited" separation matricies: (1) the peak period travel times by normal highway (from the peak period highway network) and (2) the peak period travel times for carpools using the HOV carpool facility (from the HOV network). The model outputs two HBW vehicle trip tables: (1) the carpool trips which are expected to use the HOV carpool facility and (2) the vehicle trips which are expected to use the normal highway facilities. Base mode choice and average auto occupancy information for the region are input via data cards for use in the modeling process.

The HOVMODEL routine also provides an option for simply applying the base mode choice and average auto occupancy information to simply "convert" a person trip table to a vehicle trip table. This is a particularily salient option for study areas where the mode choice and auto occupancy modeling is performed at a different level of zonal detail than the highway modeling.

Execution Requirements

HOVMODEL is an independent routine. The execution of the routine will likely destroy some of the key arrays used by other routines in the package.

Parameter References

Required	Defined
	N
	MT = HYWTRP

Data Set References

Input	Output
MT = [3]	HWYTRP = [33]
RAWPEK = [31]	HOVTRP = [34]
RAWHOV = [32]	

Data Card References

Input

EQUALS

HOVPARMS

SECTMS (optional)

SECTAO (optional)

SEPAO (optional)

SECTTT (optional)

Operation

The EQUALS cards must be the first data cards input to the HOVMODEL routine. The HPARMS card must be the first card following the EQUALS cards. The remaining card inputs can be in any order.

Printed Output

The printed output from the HOVMODEL routine includes:

- A printed summary of the sector structure definition (i.e., the zone to sector equivalencies).
- An "echo" of the data card input (other than the EQUALS cards). Any error messages related to a data card are printed immediately following the "echo" of the data card.
- A one-page regional travel summary.
- Seven HOV carpool reports (i.e., seven tables) summarizing the HOV model results. if the user elects the option of not applying the HOV carpool models, these seven tables will not be printed.

The printed output from the HOVMODEL routine are limited to 80 columns so that these tables can easily be copied and used in reports.

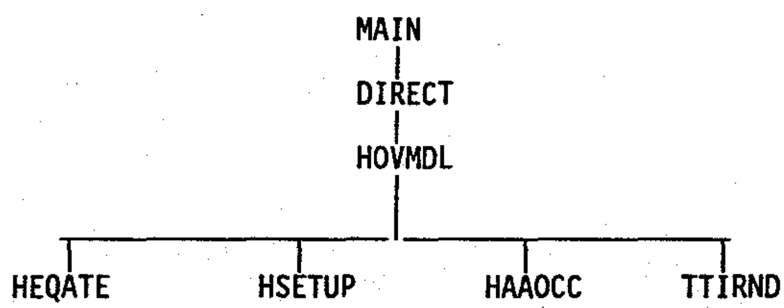
User Considerations

The HOVMODEL routine provides an option for simply applying the base mode choice and average auto occupancy information to simply "convert" a person trip table to a vehicle trip table. This is a particularily attractive option for study areas where the mode choice and auto occupancy models are applied at a different level of zonal detail than the highway modeling. The user can elect this option by simply specifying zero weights for the HOV carpool models in the HPARMS card. The zero weights serve as a signal to the software not to apply the HOV carpool models. Under this option, the HOV separation matrix will not be read and the HOV trip table will not be produced.

Another option available to the user is the specification of average auto occupancies by travel time (using the SEPAO cards) rather than by sector interchange (using the SECTAO cards). The user can actually elect to use a combination of the two options. For example, the user can specify the expected auto occupancies for short trips (e.g., trips of say 10 minutes or less) using the SEPAO card option and for trips greater than 10 minutes to allow the sector interchange estimate (from the SECTAO cards) to apply. This would be accomplished by inputing SEPAO cards only for the first 10 minutes and inputting the traditional SECTAO cards specifying th expected average auto occupancies for the longer trips (i.e., the trips over 10 minutes). In effect, the SEPAO estimates (when present) take priority over sector interchange estimates. It was felt that this combination of options provides the user with considerable flexibility for inputting average auto occupancies.

The HOVMODEL routine also provides the option of specifying terminal times by sectors using the SECTT cards. Since terminal times are normally used in mode choice modeling, it was felt that this would be a desirable option.

<u>Sequence of Subroutines Called</u>



HOVPARMS: Purpose

The HOVPARMS card input the parameters for the HOV Carpool Model.

Associated Routines

Input
HOVMODEL

Entry Sequence

This card must follow the set of EQUALS cards but precede the other data card inputs to the HOVMODEL routine.

Card Layout (fixed)

FORMAT(2A4,2X,F5.3,2X,I1,2X,5F5.0)

COLUMNS	TYPE	CONTENTS
1 - 8	Literal	'HOVPARMS'
9 - 10	--	Blank
11 - 15	Real	Default Average Auto Occupancy(DAAO) (1.0 <= DAAO <= 2.5)
16 - 17	--	Blank
18	Integer	Minimum HOV Carpool Size (MINHOV) (2 <= MINHOV <= 4)
19 - 20	--	Blank
21 - 25	Real	Minimum Time Savings for HOV lanes (in minutes--- 2.0 = 2 minutes)
26 - 30	Real	Optional Relative Weight for the Base Model Carpool Estimates (NORMALLY LEFT BLANK)
31 - 35	Real	Relative Weight for Traveltime Ratio Carpool Model Estimates
36 - 40	Real	Relative Weight for Logit Based Carpool Model Estimates
41 - 45	Real	Relative Weight for Traveltime Savings Carpool Model Estimates
46 - 60	--	Blank (Reserved for additional models which may be added later)

SECTAO: Purpose

The SECTAO card enter the sector interchange average auto occupancy data.

Associated Routines

Input
HOVMODEL

Entry Sequence

The SECTAO cards can be in any order.

Card Layout (fixed)

```
FORMAT(2A4,5X,I2,3X,I2,3X,I2,3X,I2,5X,F5.4)
```

COLUMNS	TYPE	CONTENTS
1 - 8	Literal	'SECTAO '
9 - 13	--	Blank
		PRODUCTION SECTOR (OR RANGE):
14 - 15	Integer	Production Sector Number
16 - 18	Literal	' - ' or blank (Optional for Range specification)
19 - 20	Integer	Production Sector Number (Optional for Range specification)
21 - 23	--	Blank
		ATTRACTION SECTOR (OR RANGE):
24 - 25	Integer	Attraction Sector Number
26 - 28	Literal	' - ' or blank (Optional for Range specification)
29 - 30	Integer	Attraction Sector Number (Optional for Range specification)
31 - 35	--	Blank

(card format continued on next page)

COLUMNS	TYPE	CONTENTS
		AUTO OCCUPANCY ESTIMATE:
36 - 40	Real	Estimated Auto Occupancy for the Specified Sector Pair(s) (a value of 1.15 implies that the average auto occupancy for trips from the production sector(s) to the attraction sector(s) is estimated to be 1.15 persons/vehicle)

SECTMS: Purpose

The SECTMS cards enter the sector interchange mode split information.

Associated Routines

Input
HOVMODEL

Entry Sequence

The SECTMS cards can be in any order.

Card Layout (fixed)

FORMAT(2A4,5X,I2,3X,I2,3X,I2,3X,I2,5X,F5.4)

COLUMNS	TYPE	CONTENTS
1 - 8	Literal	'SECTMS '
9 - 13	--	Blank
		PRODUCTION SECTOR (OR RANGE):
14 - 15	Integer	Production Sector Number
16 - 18	Literal	' - ' or blank (Optional for Range specification)
19 - 20	Integer	Production Sector Number (Optional for Range specification)
21 - 23	--	Blank
		ATTRACTION SECTOR (OR RANGE):
24 - 25	Integer	Attraction Sector Number
26 - 28	Literal	' - ' or blank (Optional for Range specification)
29 - 30	Integer	Production Sector Number (Optional for Range specification)
31 - 35	--	Blank

(Card format continued on next page)

COLUMNS	TYPE	CONTENTS
		MODE SPLIT ESTIMATE:
36 - 40	Real	Estimated Portion of Person Trips by Transit for the Specified Sector Pair(s) (a value of .03 implies that 3% of the person trips from the production sector(s) to the attraction sector(s) are expected to use transit)

SECTTT: Purpose

The SECTTT cards enter the production and attraction terminal times.

Associated Routines

Input
HOVMODEL

Entry Sequence

The SECTTT cards can be in any order.

Card Layout (fixed)

FORMAT(2A4,5X,I2,3X,I2,5X,2F5.3)

COLUMNS	TYPE	CONTENTS
1 - 8	Literal	'SECTTT '
9 - 13	--	Blank
		SECTOR (OR RANGE):
14 - 15	Integer	Sector Number
16 - 18	Literal	' - ' or blank (Optional for Range specification)
19 - 20	Integer	Sector Number (Optional for Range specification)
21 - 25	--	Blank
		TERMINAL TIME ESTIMATES:
26 - 30	Real	Estimated PRODUCTION Terminal Time in minutes for the specified sector(s) (a value of 1.15 implies an average production terminal time of 1.15 minutes)
31 - 35	Real	Estimated ATTRACTION Terminal Time in minutes for the specified sector(s) (a value of 2.50 implies an average attraction terminal time of 2.50 minutes)

SEPAO: Purpose

The SEPAO cards enter the average auto occupancies by separation.

Associated Routines

Input
HOVMODEL

Entry Sequence

The SEPAO cards can be in any order.

Card Layout (fixed)

FORMAT(2A4,4X,I3,3X,I3,4X,F5.4)

COLUMNS	TYPE	CONTENTS
1 - 8	Literal	'SEPAO '
9 - 12	--	Blank
		TIME IN MINUTES (OR RANGE);
13 - 15	Integer	Travel time in minutes
16 - 18	Literal	' - ' or blank (Optional for Range specification)
19 - 21	Integer	Travel time in minutes (Optional for Range specification)
22 - 25	--	Blank
		AUTO OCCUPANCY ESTIMATE:
26 - 30	Real	Estimated Auto Occupancy for the Specified Travel Time Range (a value of 1.15 implies that the average auto occupancy for trips in the specified travel time range is estimated to be 1.15 persons/vehicle)