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VEHICLE OCCUPANCY DETERMINATORS

Final Report

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16. ABSTRACT

By using extensive and detailed counts and surveys of vehicle occupancy, conducted in Phoenix, this research project was intended to determine which factors have the greatest influence on vehicle occupancy and which conclusions about vehicle occupancy could be transferred from one metropolitan area to another. Trip purpose was determined to be the most significant factor affecting vehicle occupancy. With the exception of having a private vehicle available for making the trip in question, all other factors, including household income and trip distance were deemed to be far less important determinators of vehicle occupancy.

As the percentages of trips by purpose vary greatly by time of day, vehicle occupancy rates were also shown to vary greatly by time of day. The lowest vehicle occupancy rates were associated with home-work-based trips. Given that home-work-based trips represent a larger proportion of trips during AM and PM peak hours, vehicle occupancies for those hours are lower than during off peak hours. (Extensive data about vehicle occupancy rates are provided in this report.)

The 1988 daily regional vehicle occupancy rate of 1.33 derived for the Phoenix metropolitan area is very similar to the rates counted in Phoenix in previous years and to rates derived in other metropolitan areas. The conclusions about vehicle occupancy and the vehicle occupancy rates derived from this research are judged applicable in other metropolitan areas having Phoenix's development patterns, auto ownership rates and demographic characteristics.

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1. INTRODUCTION

This report presents the results of a study of vehicle occupancy conducted in Phoenix, Arizona to determine what factors have the greatest influence on having persons travel together to make trips in private vehicles. In this report, the words vehicle occupancy will be the ones used to describe how many persons are being transported by the private vehicles counted or surveyed as traveling in different geographic areas, on different types of roadways, for different trip purposes or at different times of the day.

The Maricopa Association of Governments, Transportation and Planning Office (MAGTPO) is responsible for developing and applying the travel demand forecasting models for the Phoenix metropolitan area. MAGTPO's forecasting models are used in a variety of ways by agencies engaged in transportation planning and project development activities. One of the primary uses of the models is to create forecasts of trips made in private vehicles or on transit during an average weekday or during the peak hour of travel.

MAGTPO's travel forecasting models, like those used by other transportation planning agencies, are continuously undergoing refinements to incorporate the availability of additional data or to improve specific predictive capabilities. In previous work efforts, the MAGTPO models have been modified to reflect the results of a transit on-board survey and to account for external travel occurring in the Phoenix metropolitan area. [1]

Increasing attention is being given in the Phoenix metropolitan area to the concept that carpooling is a mode of travel that should be considered as a way to address future transportation supply deficiencies.[2] An existing section of I-10 in Phoenix contains lanes reserved for high-occupancy vehicles, and those lanes are planned to be extended in conjunction with the construction of new freeways in the Phoenix metropolitan area.[3]

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[1]External trips are classified as those with one trip end outside the region being modeled. On that basis, trips either beginning or ending outside the Phoenix metropolitan area would be classified as external trips.

[2]The term carpooling, as used in this report, is defined as having persons travel together in the same vehicle to complete a journey. Carpooling is often called ridesharing in a broader context, to account for all of the different kinds of private vehicles that persons could be traveling in.

[3]High-occupancy vehicles, called HOV's by transportation planners, include carpools, vanpools, buspools and regularly scheduled buses. The numbers of persons that must be traveling together in a private vehicle for that vehicle to be classified as an HOV is set by policy and can vary by facility or location. In some places an HOV may carry just 2 persons to be qualified to use lanes designated for use by HOV's, while in other places an HOV must carry three or more persons.

The mode choice model used by MAGTPO creates forecasts of trips made by persons driving together and by persons riding transit.[4] Characteristics of the households where trips originate, of the zones where trips are destined, and relative travel time and cost differences between modes are used to create the forecasts of persons traveling on each mode assumed to be available.[5]

The equations that comprise the shared-ride mode choice model have been set up to incorporate variables related to characteristics of the origin zone, of the destination zone, and of the relative travel times and costs between origins and destinations. Although some data were available from vehicle occupancy counts and a household survey done in Phoenix, the coefficients incorporated into the MAGTPO mode choice equations were based on carpooling data from other metropolitan areas.[6]

In summary, the current MAGTPO mode choice model has been calibrated to create regional forecasts of travel by persons driving alone and by persons sharing rides. With planning underway for additional HOV lanes, MAGTPO made the decision to review its mode choice model for ridesharing and incorporate into the modeling process local data about the characteristics of travelers or zones in the Phoenix metropolitan area that would reflect the propensity of persons to travel together.

A. Purpose of Study

The research described in this report was performed to develop information about which factors exert influence on or help determine the propensity of persons to travel together in private vehicles. Although the data were collected in the Phoenix metropolitan area for the purpose of refining the MAGTPO mode split model for vehicle trips, the conclusions reached in this study of vehicle occupancy are also intended to be checked against data from other metropolitan areas. (Vehicle occupancy is the term used throughout this report to encompass all discussions of persons traveling together in a private vehicle, and not just the calculation of persons traveling together per vehicle trip.)

This study of factors at the origin and destination ends of trips that affect vehicle occupancy rates in the Phoenix metropolitan area was conducted to accomplish

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[4]The mode choice model creates forecasts of travel made during the average weekday or during a peak hour on each of the modes available in the region.

[5]The regional forecasts of trips by mode are based on summing the mode split model's forecasts of trips made on each mode available between distinct origin and destination pairs of travel analysis zones.

[6]Barton-Aschman Associates, Inc. Development and Calibration of Travel Demand Models for the Phoenix Area. June 1984. Pp.78-86.

three major research and application objectives. The objectives of this study, which affected the design of the data collection efforts described in the next chapter, were as follows:

1. The primary objective of the study was to collect the data necessary to calibrate the shared-ride component of the mode choice model now used by the Maricopa Association of Governments, Transportation and Planning Office (MAGTPO), so as to have the model reflect carpooling characteristics occurring in the Phoenix metropolitan area.

2. Affiliated with the primary objective were the following technical objectives:

   – The research had to distinguish between vehicle occupancy determinators that can be directly affected by public policy and those that cannot.[7] (Vehicle occupancy determinators could be characteristics of the traveler, of the destination, or of the trip purpose that would determine if persons would travel together in a private vehicle.)

   – The research had to provide information for a stratified sample of trip types in order to collect reliable statistics about vehicle occupancy rates and determinators for home-based-work, home-based other, and non-home-based trips.[8]

   – The survey techniques had to be capable of being updated in an economical and consistent manner, such as in conjunction with the results of the next Census of Population.

3. The research was intended to describe the conclusions that can be transferred to other metropolitan areas, and the relations between the conclusions reached in this study and the findings reached about vehicle occupancy determinators in other metropolitan areas.

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[7]The term determinator, as used for this study, has the following meaning:High-occupancy vehicles, called HOV's by transportation planners, include carpools, vanpools, buspools and regularly scheduled buses. The numbers of persons that must be traveling together in a private vehicle for that vehicle to be classified as an HOV is set by policy and can vary that which determines or decides (what will happen).

[8]Home-based-work trips are categorized as those made from the traveler's home directly to work and from their place of work directly back to home. Home-based-other trips are those trips made from the traveler's home to any destination other than work and from that destination back to home. Non-home-based trips are defined as those that neither end or begin at the traveler's home. The mode split model would be applied to create separate forecasts of persons driving alone or traveling together in private vehicles. Different vehicle occupancy rates are used to convert vehicle-person trips into vehicle trips by trip purpose.

B. Problem Statement

Phoenix and other rapidly growing metropolitan areas are looking to a wide mix of transportation modes to provide additional capacity to serve travelers in the future. Some of the facilities planned for the Phoenix metropolitan area would provide travel time advantages to persons traveling in carpools of two or more in an attempt to transport more persons in fewer vehicles (i.e., increase vehicle occupancy rates).

Transportation planners know that vehicle occupancy rates vary greatly by trip purpose, as does the propensity of persons from different households to travel together. The costs of the possible investments in busways and high-occupancy-vehicle (HOV) lanes being considered in Phoenix require that local statistics be available to understand existing conditions and create more realistic simulations of future travel before additional decisions are made to determine which other policy actions could be implemented to increase vehicle occupancy rates.

In order to satisfy the objectives described above, the following issues were addressed in accomplishing the work described in this report:

1. An accurate base of knowledge that could be used to describe and understand the existing characteristics of persons, particularly from different households, who travel together for different purposes in Phoenix did not exist.

2. The lack of information describing aspects of travel behavior affecting vehicle occupancy rates did not allow for a high level of confidence to be associated with directly comparing vehicle occupancy data for Phoenix and other metropolitan areas. Knowledge about existing vehicle occupancy characteristics was needed so that information could be used to establish possible changes in vehicle occupancy rates based on future investment and policy options.

3. Since a network of carpool lanes or other regional policy actions designed to increase vehicle occupancy rates do not exist in the Phoenix metropolitan area, surveys had to be designed to properly identify the determinators of vehicle occupancy required to create an accurate predictive model.

4. Although asking detailed survey questions about travelers' attitudes and motivations may be of interest to some analysts, concentrating on the compilation of statistics about characteristics of the production end of trips (persons or households) and the attraction end of trips (land uses by geographic and other categories) has proved to be a more reliable and cost-effective means of collecting the information required to create an accurate predictive model of vehicle occupancy rates.

5. Persons who travel in carpools, especially carpools involving members of more than one household, comprise a very small proportion of all travelers. For example, based on the results from surveys in various metropolitan areas, less than 20 percent of persons traveling to work will be sharing rides on any day, and less than 10 percent of all vehicles transporting persons to work will be a carpool or vanpool. Thus, the survey of Phoenix area residents had to be designed to generate sufficient valid responses from persons who are carpooling now.[9]

C. Organization of this Report

This report contains five chapters that have been used to describe the major milestones that occurred during the chronological course of this research into vehicle occupancy. Each chapter has the following purpose and contains the following subjects:

I. Introduction. This chapter describes the reasons for undertaking the research.

II. Study Design. The assessment of data collection techniques was used to recommend the ways in which counts and surveys would be used to collect vehicle occupancy data in Phoenix. This chapter also describes the procedures that were used to count vehicles by occupancy rate and to conduct surveys of vehicle occupancy characteristics.

III. Analysis of Data. The information collected from the counts and surveys is presented in this chapter, together with a comparison of the data collected in Phoenix with vehicle occupancy data collected previously in Phoenix and in other areas.

IV. Evaluation of Existing Vehicle Occupancy Models for Phoenix. The methodology used to evaluate the simulations of vehicle occupancy produced by the existing MAGTPO travel demand models is discussed in this chapter, as are the refinements recommended to enhance the model's capability to reflect changes in vehicle occupancy by time of day.

V. Conclusions. The results of the data collection and analysis tasks are presented in this final chapter, as well as recommendations for further research into vehicle occupancy determinators.

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[9]Federal Highway Administration. Journey-to-Work Trends, (Based on 1960, 1979 and 1980 Decennial Censuses). July 1986, pp 6-18.

2. STUDY DESIGN AND DATA COLLECTION PROCEDURES

This chapter describes how the data collection procedures were defined and what data collection procedures were used to accomplish the objectives of this study. Ideas and suggestions about defining the procedures that should be used to collect vehicle occupancy data came from primarily two sources. First, a literature search was conducted to provide suggestions about optional ways of collecting data about vehicle occupancy. Second, discussions were held between the consultant and staff from MAGTPO, the Arizona Department of Transportation (ADOT) and the City of Phoenix to review the results of the literature search and to select the data collection procedures to be used in this study.

Before the data collection tasks could begin, it was necessary to specify the types of data that would be required to refine the MAGTPO mode choice model for vehicle occupancy and to more directly relate the effects of certain variables on vehicle occupancy rates. The review of reference materials was used to ascertain what had been determined from research into vehicle occupancy done in other metropolitan areas, as well as to describe the different types of procedures that could be used to collect data about vehicle occupancy. One clear objective of the literature search was to develop a list of variables about which information would need to be gathered, so as to identify those variables that were likely to have the greatest influence on vehicle occupancy rates in Phoenix. Those variables would be called vehicle occupancy determinators, because the research would indicate that very strong correlations exist between those variables and a propensity to share rides.

The following activities, which occurred during the design phase of the study, are discussed in this chapter:

- defining the data items to be collected,
- identifying possible ways of collecting those data items,
- recommending the specific data collection procedures to be used in this study,
- designing the survey and count procedures to be used,
- pre-testing the survey,
- designing the final data collection procedures, and
- implementing the data collection procedures.

While the literature search can be viewed as an activity separate from the rest of the design phase, what was learned from the review of other reports was used to reach

conclusions about most of the activities described above. Due to the importance that the literature search had on establishing the direction for this study, the results of that effort will be discussed first.

A. Literature Search

Even though the search for relevant reference materials was concentrated on finding technical reports describing how to conduct counts or surveys of vehicle occupancy, the literature search was not limited to those topics. Due to the many descriptive words that can be associated with the study of vehicle occupancy, the search for useful reference materials also produced a listing of references containing information about vehicle occupancy data, historical trends in vehicle occupancy rates, and descriptions of factors influencing vehicle occupancy.

The subject of vehicle occupancy can be described using a wide variety of words including the following descriptors: vehicle occupancy, vehicle occupancy surveys, auto occupancy, carpooling and ridesharing. An initial review of the descriptors used by the Transportation Research Information Service (TRIS), was used to determine which descriptors should be mentioned in the search for relevant reference materials.[10] The results of that initial review were used to select those descriptors that should be used in the final, focused literature search, based on two objectives. The first objective was that the reference materials provide relevant assessments about how to collect data describing vehicle occupancy. The second objective was that the reference materials present information about other metropolitan areas that could be used to corroborate the conclusions reached by this research into vehicle occupancy in Phoenix. Based on those two objectives, the literature search was conducted by using the following descriptors to identify the reports most relevant to this research: vehicle occupancy and travel forecasting, and vehicle occupancy and transportation planning.

The literature search revealed that while there have been numerous reports written to describe the results of counts or surveys of vehicle occupancy, very few reports have been written to describe the procedures that should be used to collect information about vehicle occupancy. Fewer than ten books or articles were found to provide guidance or insights about the issues that should be considered when designing data collection programs about vehicle occupancy. Since those reference materials were used to design the data collection procedures for this research, abstracts and syntheses of their most important subject matter are presented on the following pages. Other reference materials identified through the literature search -

[10]TRIS was used because this database was developed by the Transportation Research Board to be the central source of transportation reference materials. Listings of reports and abstracts included in the TRIS database are provided by government agencies, universities and various planning and engineering journals.

those describing characteristics or data about vehicle occupancy - are presented and discussed in subsequent chapters of this report.

The abstracts presented in Table 1 summarize those books and articles that were used to design the data collection procedures in this study.[11] The abstracts presented in Table 2 describe those reference materials used to confirm that the recommended data collection procedures would work correctly, i.e., that the desired information would be collected.

B. Possible Data to be Collected

Recommendations or conclusions presented in the reference sources listed in Tables 1 and 2 were used to assess the possible ways of collecting the data that could be used to prove linkages between certain factors and vehicle occupancy. Those possible data collection approaches are described on the next page, following the presentation of data variables that were nominated for consideration in this research.

The review of the literature revealed that, while there is no unanimity about the variables that determine vehicle occupancy, there is wide agreement on the most likely factors. One reason why most analysts agree on the factors that are most important is that most analysts have searched for the same categories of factors. That is, the typical categories defined to analyze travel are arranged in the same manner as are the elements of a journey and describe the same kinds of characteristics represented by the typical mode choice model, as follows:

1. Characteristics of the trip origin, such as household size, household income, auto availability, and trip purpose at the origin of the trip.

2. Characteristics of the trip destination, such as parking cost and trip purpose at the destination of the trip; and

3. Comparison of travel modes, including comparisons of total travel time and costs required to accomplish the trip.

Since the factors that may influence vehicle occupancy describe 1) conditions that exist where trips begin and end, 2) characteristics of the travelers and of the households where they live, and 3) the journeys that are made for different purposes at different times of day, data about vehicle occupancy could be collected a number of different ways. The benefits and costs of different data collection strategies are presented in the following pages to present the context for the data collection decisions made in this research project.

[11] Abstracts for reference materials describing the results of studies analyzing data about vehicle occupancy are presented in Appendix A. Those reference materials were not used directly in this study, but are listed in Appendix A as a supplement to Tables 1 and 2.

TABLE 1
ABSTRACTS OF REFERENCE DOCUMENTS DISCUSSING VEHICLE OCCUPANCY DATA COLLECTION

GUIDE FOR ESTIMATING URBAN VEHICLE CLASSIFICATION AND OCCUPANCY
Ferlis, RA
Peat, Marwick, Mitchell and Company, 1990 K Street, N.W., Washington, DC 20006;
Federal Highway Administration Office of Highway Planning, 4700 7th Street,
SW Washington, DC 20590.
March 1981, Final Report 60 p.
REPORT NO: HS-032 518
CONTRACT NO: DOT-FH-11-9249
SUBFILE: HRIS; HSL
AVAILABLE FROM: National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161

This manual provides sampling and data collection procedures for field surveys that estimate vehicle classification and occupancy and (when combined with estimates of vehicle-miles of travel derived from parallel mechanical traffic counting programs) that estimate travel by vehicle type and person travel. Because sound statistical sampling techniques are used, these surveys can provide valid estimates at predetermined levels of precision and at the lowest possible cost.

APPLICATIONS AND USE OF TRANSPORTATION DATA
McLau, Mary, ed.
Transportation Res. Board, 2101 Constitution Ave., N. W. Washington, DC 20418
1979, 440.
REPORT NO: TRR-701; HS-027 080, includes HS-027 081--HS-027 087
SUBFILE: HSL
AVAILABLE FROM : TRB

Seven papers are compiled which individually cover the following aspects of transportation data collection and use: field data collection and sampling procedures for measuring regional vehicle classification and occupancy; research in the Seattle area on techniques for monitoring automobile occupancy; Georgia's evaluation of Federal Highway Administration procedures for estimating urban vehicle miles of travel; U.S. Census travel data for transportation planning; workplace interviews as an efficient source of travel survey data; design of small-sample home-interview travel surveys; and use of travel diaries in collecting travel data on elderly and handicapped persons.

TABLE 1 (Continued)
ABSTRACTS OF REFERENCE DOCUMENTS DISCUSSING VEHICLE OCCUPANCY DATA COLLECTION

GUIDE TO URBAN TRAFFIC VOLUME COUNTING
Office of the Secretary of Transportation, 400 7th Street SW Washington, DC 20590
September 1981, 52 p.
SUBFILE: HRIS; UMTRIS
AVAILABLE FROM: Federal Highway Administration Office of Urban Planning, 400 7th Street, SW Washington, DC 20590.

This report presents methods by which urbanized areas can develop and implement integrated traffic data counting programs to serve the volume data needs of all their agencies. The procedures presented complement the techniques for measuring vehicle type and occupancy presented in the Guide for Estimating Urban Vehicle Classification and Occupancy. Methods for estimating volume at a single location, volume across a particular cordonline, cutline, vehicle-miles traveled within a corridor, and regional vehicle-miles traveled are presented. Of particular value to transportation analysts in urban areas, these techniques permit collection of volume data at pre-determined levels of precision, and in a cost-effective manner.

TRANSIT AND TRAFFIC ANALYSIS
Carter, MM
Transportation Research Board
Transportation Research Board Special Report, No. 206, 1985 pp. 152-157.
REPORT NO: Part V
SUBFILE: HRIS
AVAILABLE FROM: Transportation Research Board Publications Office,
2101 Constitution Avenue, NW Washington, DC 20418

Proceedings on the National Conference on Decennial Census Data for Transportation Planning, Orlando, Florida, December 9-12, 1984. Workshop Report. This workshop focused on those planning areas that are more near-term in nature, including short-range planning, operations impacts, and alternatives analyses. The workshop reviewed its findings for the 1980 UTPP (Urban Transportation Planning Package) and compared it with its expectations in the major areas of transportation planning. This paper presents a summary of the discussions in each of the following areas: updating urban and transportation planning data sets; model development, updating, and validation; rideshare data sets; special generator information; obtaining the work-trip file; transit market analysis; mode-of-access information; vehicle occupancy; residential and industrial development planning; and general observations. Detailed recommendations are presented on questionnaire content, procedures and sample size, geographic coding, data products and comparability.

TABLE 2
ABSTRACTS OF REFERENCE DOCUMENTS REVIEWING VEHICLE OCCUPANCY DATA COLLECTION TECHNIQUES

ATLANTA VEHICLE OCCUPANCY MONITORING
Fisher, RF; Williams, GJ; Boyd, JP (Georgia Department of Transportation; Atlanta Regional Commission)
Transportation Research Board
Transportation Research Record No. 779, 1980, pp 27-32.
SUBFILE: HRIS
AVAILABLE FROM: Transportation Research Board Publications Office, 2101 Constitution Avenue, NW Washington, DC 20418

This report describes the implementation of a statistically defined survey technique for collecting vehicle classification and occupancy data in the Atlanta region. The paper describes the results of a stratified, areawide survey for collecting passenger occupancy rates. The potential movement of people provided by the capacity of the roadway system is virtually an untapped resource, according to the data collected for this study. Sponsored by the U.S. Department of Transportation, efforts are being made to improve the usefulness of passenger vehicles through current programs that include vanpooling, ride-sharing programs, and park-and-ride lots. The success of these ventures, which are likely to become more significant in the future, can be measured by a dependable vehicle-occupancy monitoring program. This research has proved that the Guide for Estimating Urban Vehicle Classification and Occupancy provides a statistically acceptable method to measure vehicle occupancy rates. The minimum sample requirement for determining occupancy rates by area and facility type is desirable for an annual program of this nature.

AUTO OCCUPANCY, VEHICLE TRIPS, AND TRIP PURPOSE; SOME FORECASTING PROBLEMS
Ohstrom, EG; Stopher, PR (Humana Incorporated; Schimpeler-Corradino, Associates)
Transportation Research Board
Transportation Research Record No. 987, 1984, pp 8-13
REPORT NO: HS-038 816
AVAILABLE FROM: Transportation Research Board, Publications Office, 2101 Constitution Avenue, NW Washington, DC 20418

The problems with estimating automobile occupancy by trip purpose for use in travel forecasting and in the policy decisions that frequently follow from forecasts are described. Investigations of data and development of logit models of mode choice reveal that the occupants of multi-occupant automobiles frequently have disparate trip purposes, even within the restricted trip-purpose definitions usually encountered in practical transportation planning. These disparate purposes mean that, although occupants can be classified by trip purpose, the automobile vehicle cannot be defined as being used for a single trip purpose, as it is necessary to compute accurately the automobile occupancy for a purpose and to convert automobile-person trips by purpose to automobile-vehicle trips for assignment of automobile vehicles to the highway network. This has serious repercussions on a variety of contemporary policy decisions. The problems are discussed, and some alternative procedures that can be used as a compromise computation of vehicle occupancy by purpose are given. The problems and solutions are demonstrated in the context of a case study.

C. Possible Survey Approaches

Travel forecasting models typically compare the travel costs and times for three different trip purposes, and based on certain characteristics of the origin and destination of the simulated trips, create estimates of travel by mode. The model developed for and used by MAGTPO is of this type. Forecasts of trips generated by mode are created for home-based work (hbw), home-based-other (hbo), and non-home- based (nhb) trip purposes. Those forecasts are based on the simulated comparisons of in-vehicle and out-of-vehicle travel times and costs. Characteristics of the production ends of the travelers making the trips (household income stratifications and terminal times to reach the highway or transit network), and of the attraction ends of trips (terminal times and costs and general activity type stratifications) are also used. Finally, the travel time and cost characteristics of each network are used to forecast usage levels for persons driving their automobile without sharing that ride (drive alone), persons who are transporting passengers (shared-ride), and persons riding regularly scheduled transportation (transit).[12]

Different data sources are required to calibrate travel models, because to have the various dependent components of the models replicate available information about existing conditions means that accurate and reliable information must be available. The decennial Census of Population through the Urban Transportation Planning Package (UTPP) provides a special tabulation of data derived from a subset of Census responses. UTPP reports can be used to describe the following types of information about travelers to places (zones) of employment or from places (zones) of residence: individual income, industry of employment, occupation, commuting mode, and travel time by commuting mode. Origin-destination matrices can be derived describing where groups of persons live and work, their commuting modes, and travel times by mode. Since those data are available down to the block-group level, there are typically sufficient data records to use in developing and calibrating work-travel models that may be reasonably accurate down to the level of transportation analysis zones.

While good data are available on a recurring (five-or ten-year) basis for home-to-work trips, similar data are not typically available for other trip purposes. Data describing home-base-other trips (trips that are usually related to work travel but that do not have home as a trip end) are most often derived from surveys of households. Those surveys, where persons from the selected sample of households are asked to describe their trips during a certain period of time (to create a travel diary), are very expensive to administer. Due to the high costs of household surveys (because of the need to gain the cooperation of a stratified sample of households), those surveys are done infrequently and typically include only sufficient households to derive trip-generation rates and origin-destination matrices for aggregations of transportation analysis zones.

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[12]Barton-Aschman Associates, Inc. Mode Choice Model Update for the Phoenix Region. March 1988. Pp 22-27.

This research was initiated to determine if and how the MAGTPO travel model would need to be refined and calibrated to create more realistic forecasts of shared-ride trips, i.e., to recommend if and how the coefficients of the model would be modified to create simulations of shared-ride travel that are sensitive to characteristics of households, destinations and transportation networks in the Phoenix metropolitan area. To decide what changes might need to be made, data would have to be collected describing the existing characteristics of persons, locations and trip purposes that could affect vehicle occupancy rates. The ways available to collect information about auto occupancy are described in the following paragraphs.

Direct Observation. In this approach, vehicles in the traffic stream are observed and the frequencies of vehicle occupancies are recorded by time period. An unbiased estimate of the mean auto occupancy and the standard deviation of the mean can be obtained from a random sample of locations from which auto occupancies are recorded.

This method can provide frequency distributions of car occupancy by time of day. However, these counts of private vehicles carrying different numbers of persons do not provide car occupancy rates by purpose of trip, length of trip, income of travelers, or parking costs of the trip. Those data would be needed to verify why vehicle occupancy rates change by time of day and by other characteristics of journeys and travelers making each journey.

Interview Travelers at Their Residence — Home Interview. This is a standard data collection procedure that has been used for decades in transportation planning. Individual travelers are contacted at their place of residence via an interview to obtain travel data for a typical day. Statistically reliable data on vehicle occupancy can be obtained for relatively small sample surveys, such as 1,000 households. Moreover, those data can be stratified by trip purpose, cars owned, trip length, income and other characteristics. However, most origin-destination (O-D) surveys have not reliably collected data on persons traveling in the same vehicle, but who are from different households.

The utility of the home interview survey as a basis for vehicle occupancy data is further limited by the fact that multi-passenger auto trips are relatively infrequent when compared to drive-alone auto travel. For home-based work trips, interviews would have to occur with over 90 auto drivers making a work trip before finding one drive in a vehicle with two or more passengers. To find that at least one of the travelers in a vehicle with two or more passengers was from a different household than the driver would require over 95 interviews.

Survey of Travelers at Place of Destination. Yet another survey approach would be to interview travelers at the destination (attraction) end of their trip. One could survey establishments--shopping centers, office buildings, manufacturing plants,

etc. As travelers approach or enter an establishment or site, they could be interviewed and given a self-enumeration questionnaire. The approach would yield data that could be weighted by establishment type and employment size, i.e., an unbiased estimate of car occupancy could be made from the data collected in such a survey. The liabilities of this approach are much the same as those of the home interview—that travelers from different households are not linked. In addition, the frequency of multi-passenger vehicles is usually so low that a very large number of questionnaires would need to be distributed to obtain a statistically significant sample of multi-passenger vehicles. Since the vehicle would not be observed in this approach, one could not vary the sample rate according to the number of passengers in the vehicle.

After considering possible ways of collecting the information required to refine the MAGTPO travel model, the following conclusions were reached:

1. Surveys of households would not be cost-effective, because of the high costs involved to generate a statistically valid sample, and the difficulty in getting reliable information for a wide variety of trips.

2. Roadside surveys would not be cost-effective, because as shared-ride trips make up only a small proportion of all vehicle trips, a large number of drivers would have to be inconvenienced in order to find persons sharing rides. In addition, the roadway is not a rational unit to be used for factoring, nor would roadside surveys be statistically valid at the destination end.

D. Data Collection Procedures Initially Recommended

After considering the possible data collection options, the decision was made to undertake a sample survey of vehicles arriving at a sample of destinations and to take sample counts to determine vehicle occupancy rates by trip purpose and provide data required for validation of the refined MAGTPO carpool mode-split model. Vehicle occupancy rates by trip purpose were to be derived from a sample survey of vehicles arriving at a sample of parking lots and garages. Data on vehicle occupancy by time of day by geographic area and highway facility type were to be collected from counts of vehicles stratified by occupancy taken at a sample of locations. The two procedures are described below.

1. <u>Direct Observation of Vehicle Occupancy Rates</u>

The first type of data collection would require direct observation (counts) of levels of car occupancy at a sample of locations in the Phoenix metropolitan area. Those observations would be stratified by geographic area and highway facility type. In this type of count, the frequencies of private vehicles transporting one, two, three, four, five and six or more persons were to be recorded at each of the sample locations. (Private vehicles would include automobiles, vans, and trucks.)

The initial definition of procedures was that the surveyor(s) would begin work at each location at 7:00 AM and count vehicles until 11:00 AM. After going to lunch, the surveyor(s) would resume counting vehicles at 12:30 PM and continue until 2:30 PM. After taking another break, the surveyor(s) would resume counting vehicles at 3:30 PM and continue counting until 5:30 PM. The total of eight hours of observation would have provided vehicle-occupancy data for a two-hour AM peak period (7:00 - 9:00 AM), a four-hour midday period (9:00 AM - 11:00 AM and 12:30 - 2:30 PM), and a two-hour PM peak period (3:30 - 5:30 PM).[13]

A systematic "short-count" procedure, in which observations are made for a fixed interval in each hour of the day, was to be used to enhance the potential for producing relatively accurate daily estimates, while conserving manpower resources. The following three basic types of short-count procedures were considered:[14]

1. Using one or more surveyors to count all vehicles that pass by during a fixed interval within each hour (e.g., count for 45 minutes and rest for 15 minutes, thus representing a 75 percent systematic sample).

2. Using one surveyor to count vehicles that pass by on each lane during a fixed interval within each hour (e.g., count each of three lanes during successive 15-minute periods and rest for 15 minutes within each hour, thus representing a 25 percent systematic sample).

3. Using one or more surveyors to systematically observe two or more locations concurrently by counting all vehicles passing a particular location during the same time interval within each hour (e.g., count vehicles at one location from 7:00 to 7:45, etc., thus representing a 25 percent systematic sample).

Sampling Approach. The sampling approach was designed on the basis of the "link-day" as the sampling unit.[15] A link-day represents the combination of a particular roadway segment and the number of hours of surveying that would occur in a day. To accomplish an areawide survey, such as this one, would involve the random selection of links in the regional highway network and the selection of data that would be collected on the selected links.

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[13]The final procedures adopted for the counts are different than those described here, and are presented on page 34.

[14]Ferris, RA., Office of Highway Planning, Federal Highway Administration, Guide for estimating Urban Vehicle Classification and Occupancy, March 1981, pp. 7-8.

[15]Op. cit., p 7

Sample Size. The sample size of link-days needed to estimate average vehicle occupancy was computed as follows:[16]

$$N = \frac{Z^2 \times SO^2}{DOCC^2}$$

Where:

DOCC = Desired tolerance, or the acceptable difference between the estimated average occupancy and the true value.

SO = Composite standard deviation of average occupancy.

Z = Normal variant for the specific level of confidence, two-tailed test (i.e,. as represented in standard tables)

N = Number of link-days of data collection required.

In turn, the composite standard deviation was based on the following formula:

$$SO = (SOL^2+SOS^2+SOW^2)1/2$$

where:

SOL = Standard deviation of average occupancy across link-days within a season.

SOS = Standard deviation of average occupancy across seasons.

SOW = Standard deviation of average occupancy across time periods during a day resulting from use of short-counts.

Using recommended values for SOL, SOS, and SOW of .063, .015, and .017[17], yielded SO = .067.[17] Therefore, the following sample sizes would be required, depending on the desired confidence level and tolerance:

Tolerance	Confidence Level	Sample Size	Confidence Level	Samples Size
±.02	95%	43	90%	30
±.03	95%	19	90%	13
±.04	95%	11	90%	8
±.05	95%	7	90%	5

[16]Op. cit., p 12
[17]Ibid.

The observations of vehicle occupancy would be stratified geographically and by highway facility type. The classification of geographic areas would be CBD and fringe, urban, and suburban and rural. On the basis of definitions established by MAGTPO for modeling purposes, the geographic stratifications would include the following area types: CBD and fringe — Area Types 1 and 2, Urban — Area Type 3, and Suburban and rural — area types 4 and 5.[18] Figure 1 shows the Area Types defined for travel forecasting (modeling) purposes in the Phoenix metropolitan area. Within each geographic area, the observations would be stratified into the following two facility types: freeways and expressways, and arterials (primary and secondary) and collectors.

On the basis of the variability estimates cited in the Guide for Estimating Urban Vehicle Classification and Occupancy, a very small sample would provide an overall estimate of car occupancy with a very small sampling error at the 90 percent confidence level. Assuming a standard deviation of .067 and a mean vehicle occupancy of 1.3 for the Phoenix metropolitan area, the sampling error for alternative samples was calculated. Since a stratification by three area types and two facility types was desired, the sample sizes would be 12, 18, 24, 30....N (at least 2 samples per cell are required to estimate variance). The standard error for sample sizes ranging between 12 and 36 samples was calculated and was found to be very small because the estimated standard deviation of .067 is only 5.1 percent of mean of 1.3.[19]

After discussions were held between the consultant and staff from the Arizona Department of Transportation, the decision was made to accept the recommendation that 30 count locations be selected in addition to the six count locations in the Phoenix metropolitan area where counts of car occupancy were taken in the last five years. The sample of 36 count locations would yield a calculation of actual overall vehicle occupancy rates in Phoenix with a very small estimate of sampling error, while including the six previous count locations would provide for continuity in analyzing those vehicle occupancy counts. (The new count locations were to be selected randomly using the MAGTPO highway network in which links are stratified by area type and facility type. How that was done is explained on page 26.

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[18]Barton-Aschman Associates, Inc., for Maricopa Association of Governments Transportation and Planning Office, Development and Calculation of Travel Models for the Phoenix Area, June 1984, Appendix B, pp. 3-5.

[19]The formula presented on page 16,

$$N = \frac{Z^2 * SOCC^2}{DOCC^2}$$

was used to calculate that the standard error would be ±0.15 with a sample size of 12 locations and ±0.085 with a sample size of 36 locations, with Z = 2 (at the 95 percent confidence level).

2. Sample Survey of Arriving Vehicles

The second survey required for this study of vehicle occupancy determinators in Phoenix was the intercept survey of arriving vehicles. This survey type was selected in order to be able to find high-occupancy vehicles in quantities sufficient for purposes of statistical accuracy, without having to interview an enormous number of persons driving alone. (Another major factor favoring the intercept type of interview is the fact that it provides access to ride-sharing passengers from households other than the household of the driver. Assembling those ridesharing households in a telephone interview survey would be an almost impossible task.)

Each of the occupants of the vehicle included in the intercept sample would receive a self-enumeration questionnaire to fill out and mail back or return directly to the surveyor at the sample site. (For some garages or lots, it was thought possible that the surveyors would be able to accept the completed questionnaire when the driver and passengers would be returning to their cars to proceed to their next destination. Some occupants of sampled vehicles were also expected to complete their questionnaires immediately and turn the completed questionnaires directly back to the surveyor).

Distribution of surveys would not need to occur throughout the day in order to compile the required sample at each type of parking space. Analysis of parking accumulation data indicated that 100 percent of the vehicles arriving to park at a garage or lot associated with a particular land use arrive by the following times: at offices — by 10:00 AM, and at retail centers — by 1:00 PM on weekdays and by 3:00 PM on Saturdays.[20] (Those times are not presented to indicate that there will be no parking turnover, but that a survey of office-related parking can be concentrated in the morning hours and of retail-related parking in the mid-day hours.)

Conducting the intercept surveys of vehicles arriving at parking lots or garages could have taken place at a variety of different types of sites. Before deciding where to conduct the surveys, the data collection needs of this research were compared against the likely attributes of different types of destinations to identify those attributes that could most directly affect vehicle occupancy.

One piece of information that proved very useful was an array of destination types against trip purposes likely to occur there. As shown in Table 3, that array showed that while there are many different types of destination areas that would attract persons traveling for work-related and non-work trips, parking costs would only be likely to occur at a much smaller number of destinations. As this variable was considered to be one of the most important ones affecting vehicle occupancy, the list of destination types to be possibly surveyed was greatly reduced.

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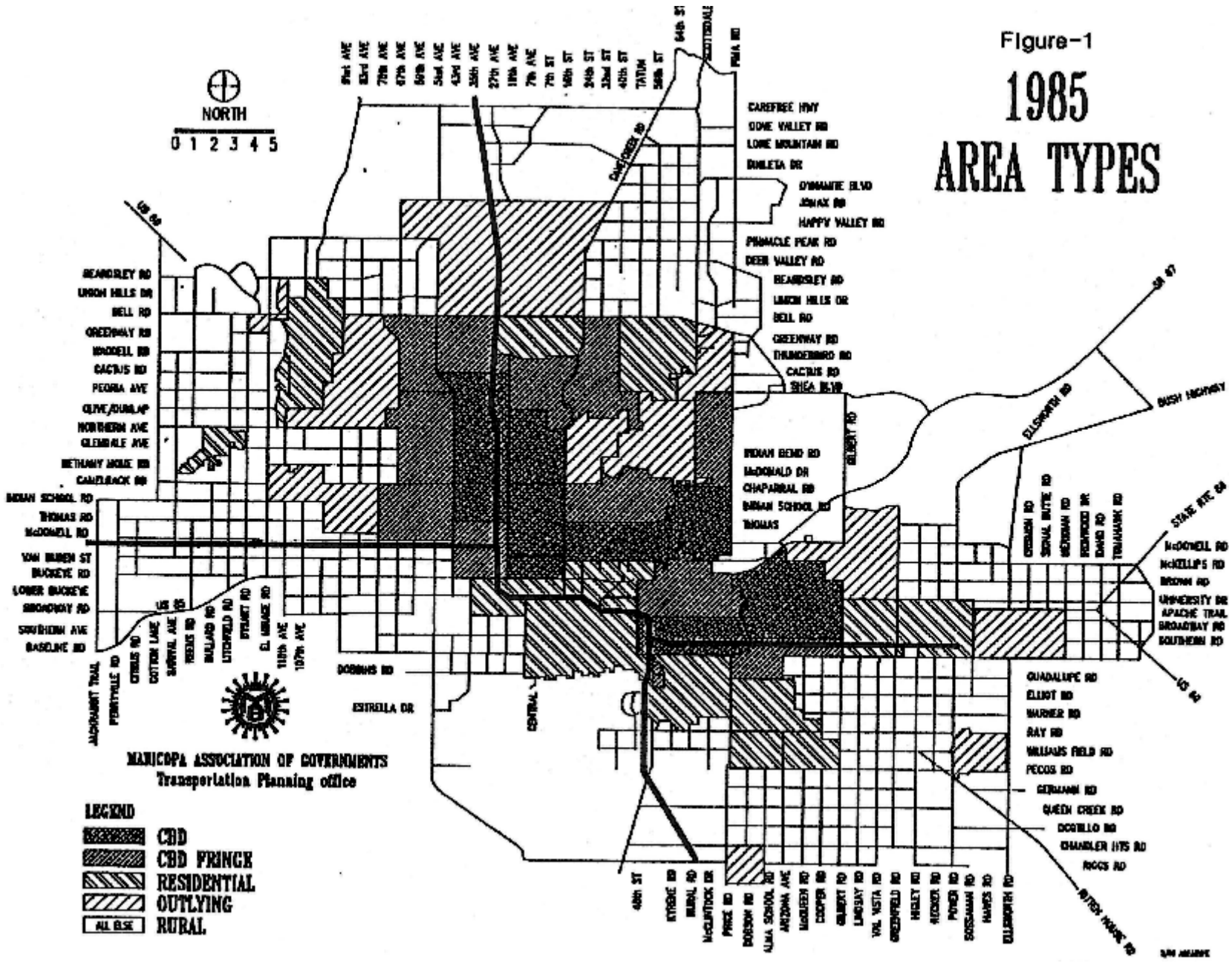
[20]Barton-Aschman Associates, Inc., for Urban Land Institute, Shared Parking Study, June 1983, pages 19 and 21.

Figure-1

1985 AREA TYPES



After the determination was made to concentrate the intercept surveys at those locations where parking fees would be charged, at least for some vehicles, the destinations remaining to be considered were in or near downtown Phoenix, at Arizona State University, or at hospitals. Parking charges do occur at other destination areas, but MAGTPO staff concluded that those areas contained far fewer parking spaces than the locations mentioned above and that it would not be cost-effective to conduct surveys there. After further consideration, Arizona State University was eliminated as a location for the intercept surveys because that destination attracts primarily education-related travel, and that unique trip purpose was deemed to require its own survey. Travel by staff, patients and visitors to hospitals was also judged to be so special that this type of destination was also determined to be one that should not be included in this research.

The prime reasons for finally selecting the downtown core of Phoenix, the State Capitol Complex and the Central Avenue corridor as the locations of the intercept surveys were as follows:

1. These areas contain the preponderant majority of the paid parking spaces available in the Phoenix metropolitan area, and parking cost was deemed to be a factor that could significantly affect vehicle occupancy rates.

2. The emphasis of this research was to refine MAGTPO's vehicle occupancy modeling capabilities in order to produce better estimates of policy effects on peak-period vehicle occupancies. With high-occupancy vehicle (HOV) lanes being considered for Phoenix primarily to provide additional person-carrying capacity during peak hours of congestion, the areas selected for the surveys were thought to present the greatest propensities for higher vehicle occupancy rates. (Parking fees, active ridesharing programs, and large employers are the characteristics of the sample locations that would most directly generate higher vehicle occupancy rates for work trips.)

3. Data already exist from other studies to describe vehicle occupancy rates at other work destinations in the Phoenix metropolitan area.

4. The surveys needed to focus on work trips because those trips are the primary ones made during hours of congestion and vehicle occupancy rates for other trip purposes are not as susceptible to public policy initiatives such as HOV lanes or parking supply and cost guidelines.[21]

After the decision was made on the geographic areas where the intercept surveys would occur, the next decision was to select the sample of vehicle whose passengers were to be surveyed.

[21]The discussion to concentrate the sample intercept surveys in the central area of Phoenix was reached in a meeting of staff from MAGTPO and ADOT and the consultant on November 5, 1987

TABLE 3
DESTINATION AREA TRIPS BY TRIP PURPOSE ATTRACTED AND PARKING CHARGE

TRIP TYPES ATTRACTED				
Destination Area Type	Home-Based Work	Home-Based Other	Non-Home-Based	Parking Fees Charged
Downtown[a]	X	X	X	[d]
State Capitol Complex[b]	X	X	X	[d]
Arizona State University	X	X	X	yes
Central Avenue Corridor[c]	X	X	X	yes[d]
Offices in other parts of the region	X		X	no
Industrial land uses	X		X	no
Regional shopping centers	X	X	X	no
Neighborhood shopping centers or commercial areas	X	X	X	no
Downtowns in other cities	X	X	X	yes

[a]Defined as the area bounded by 7th Street, Moreland Street (I-10), 7th Avenue and Southern Pacific Railroad.

[b]Defined as the area bounded by 19th Avenue, Van Buren Street, 12th Avenue, 15th Avenue and the Southern Pacific Railroad tracks.

[c]Defined as the area bounded by one block on either side of Central Avenue between Moreland Street and Camelback Road.

[d]Both on-street and off-street parking fees are charged here.

Source: Barton-Aschman Associates, Inc.

The number of sites selected for the surveys would need to be large enough to provide a representative sample of different types of parking facilities, as well as of different geographic locations. In addition to being representative, the number of sample responses would have to be adequate to permit a sound statistical interpretation of the results. That is, the sampling error must not be so great as to obscure or cloud the conclusions about vehicle occupancy determinators.

The level of precision associated with a survey's results is basically a function of sample size. Table 4 presents the size of the sample required under different accuracy requirements and different confidence levels. Sample accuracy is an inverse function of the square root of the size of the sample. Note that if twice the precision of a 10 percent error is desired (that is ± 5 percent rather ± 10 percent), the required sample size is four times as large instead of twice as large.

TABLE 4
SAMPLES REQUIRED FOR DIFFERING LEVELS OF PRECISION AND CONFIDENCE

	Level of Confidence		
Relative Error	68% (σ)	90% (σ)	95% (σ)
± 10%	100	269	384
± 5%	400	1,076	1,537
± 2%	2,500	6,724	9,604
± 1%	10,000	26,896	38,416

Source: Barton-Aschman Associates, Inc.

Obtaining extreme precision can be not only a costly but even an unnecessary endeavor. For example, obtaining a relative accuracy of ± 1 percent at the 95 percent confidence level would require over 38,000 samples (ignoring finite universe size adjustment). As the decision was made to include three separate geographic areas in the intercept survey, a sample of about 270 responses was recommended as the target for each area, for an overall sample size of about 810 percent confidence level, or ± 6.9 percent relative accuracy at the 95 percent confidence level. For each of the geographic areas, the relative accuracy would be ± 10 percent at the 90 percent confidence level.

The number of questionnaires that would have to be distributed is a function of the response rate obtained. While a more exact estimate of probable response rate would be obtained from the pre-test of the survey, experience in other mail-back surveys suggested a response rate of between .20 and .25. Those responses rates would result in a factor of 4 or 5 for the number of questionnaires distributed and

each completed questionnaire returned. On this basis for determining the questionnaires to be handed out, between 3,240 and 4,050 questionnaire sets were estimated to be needed. (A set of questionnaires is the number of questionnaires required to be distributed to each occupant of a vehicle arriving at the survey site.)

Samples were proposed to be allocated on the basis of parking spaces in a garage or lot. With the sample requirement specified by geography and parking facility type, the actual parking facilities were then to be selected. Within each cell of facility and geography, sites were to be selected until the sums of the parking places at the selected sites equaled (approximately) the number of questionnaires to be distributed within that cell. The proposed samples of vehicles to which questionnaires were to be distributed by geographic area are presented in Table 5.

Vehicles parking at a sampled parking facility were to be classified according to their number of occupants and time of arrival by 15 minute intervals. Each vehicle that arrived carrying two or more occupants would be noted, and questionnaires equal in number to the number of occupants would be handed to the driver and passengers. The surveyor would record the serial range of the distributed questionnaires on a log of arriving vehicles. If necessary, the surveyor would record the license plate number of the sampled vehicle. For vehicles with only a driver, the surveyor would distribute a questionnaire to every tenth such vehicle. (See Table 5.) The surveyor would record the serial number of the questionnaire distributed on the vehicle arrival log, and would note that vehicle was a driver-only vehicle. (That redundancy is a precaution to ensure that driver-only arrivals are separable from shared-ride arrivals.) The details of the intercept survey procedures are described in Appendix B.

After the decision was made on how the intercept surveys would be done, a first draft of the questionnaire was prepared. The contents of the questionnaire were established after defining the information that would need to be collected about all of the variables that would be used to refine the MAGTPO vehicle-occupancy mode split model. A copy of the initial questionnaire, showing the changes that were made to create the questionnaire used for the pre-test is shown in Appendix C.

The questionnaire developed for the intercept surveys was based on the following concepts:

1. That trip purpose is a very difficult variable for lay people to define, so that definition of trip purpose is best left to technical staff. For this survey, the combination of answers to two questions was intended to provide an unambiguous description of trip purpose.

2. Redundancy, especially when trying to determine how many persons were traveling together in the vehicle as it arrived or before it arrived at the location of the survey, was viewed as a virtue.

TABLE 5
PROPOSED SAMPLE OF INTERCEPT SURVEY QUESTIONNAIRES

Location and Vehicle Occupancy	Vehicles Arriving[a]	Site Sampling Rate[b]	Parking Spaces at Sampled Sites[c]	Vehicle Sampling Rate at Sampled Sites[d]	Sample Interval at Sites	Questionnaire Sets Distributed	Questionnaires to be Returned[f]
CBD							
One Person	22,860	21.3%	4,869	11.1%	9.0	540	135
Two Plus Person	2,540	21.3%	540	100.0%	1.0	540	135
Total Vehicles	25,400	21.3%	5,409	20.0%	5.0	1,080	270
Government Center							
One Person	7,200	67.5%	4,860	11.1%	9.0	540	135
Two Plus Persons	800	67.5%	540	100.0%	1.0	540	135
Total Vehicles	8,000	67.5%	5,400	20.0%	5.0	1,080	270
Central Ave							
One Person	4,000	54.0%	2,160	25.0%	4.0	540	135
Two Plus Persons	1,000	54.0%	540	100.0%	1.0	540	135
Total Vehicles	5,000	54.0%	2,700	40.0%	2.5	1,080	270
Total							
One Person	34,060	34.9%	11,889	25%	7.3	1,620	405
Two Plus Persons	4,340	37.3%	1,620	100%	1.0	1,620	405
Total Vehicles	38,400	35.2%	13,509	24.0%	4.2	3,240	810

[a]Estimate, based on number of spaces counted by others and full utilization of each space throughout the day.

[b]Derived percentage, based on generating the number of desired responses from each area.

[c]Based on the previous column, represents the number of vehicles arriving to be parked that would need to be available.

[d]Based on generating the desired members of responses from occupants of driver-only, and 2 or more-person vehicle trips.

[e]A questionnaire set consists of the number of questionnaires to be distributed to each adult occupant of a vehicle arriving at the survey site.

[f]The questionnaires that would be needed from each occupant representing either drivers or passengers.

3. Understanding who paid for parking, when parking fees were charged, was deemed as important as estimating how many travelers had to pay for parking.

4. Questions about the driver's and passengers' estimates of travel times and of travel time differences between driving alone and sharing rides were asked, even though the characteristics of the MAGTPO highway network were to be used to calculate total travel times and costs.

On February 11, 1988, a pre-test of the intercept of survey procedures was conducted at a parking lot in the State Office Complex. Of the approximately 200 vehicles that entered the lot, approximately 20 questionnaires were distributed and 10 were returned completed. The pre-test was used to:

1. Explain the field procedures to the survey takers.

2. Provide the survey takers with the opportunity to experience the requirements of the intercept survey.

3. Evaluate the performance of the survey takers.

4. Clarify certain instructions that were found confusing by the survey takers, and

5. Analyze the responses to identify revisions to the questionnaire.

As a result of the pre-test, one question (Number 4) was changed to eliminate possible confusion by the respondent about the information requested on distance between the parking place and the traveler's actual destination. The evolution of the questions presented in the questionnaire can be seen by reviewing the copies of the initial, pre-test and final versions of the intercept questionnaire presented in Appendix C.

E. Data Collection and Data Processing Procedures Selected

This section contains descriptions of the locations that were selected for the vehicle occupancy counts and intercept surveys, of the forms used to record the data to be collected, and of the coding procedures that were used. While there were changes made between the initial recommendations and final decisions as to where the counts and surveys were to occur, the basic descriptions of the recommended procedures are the same as described in previous pages. Minor changes also were made to the duration (the number of hours) when the counts and surveys were to take place.

1. Vehicle Occupancy Counts

Direct observation and counting of vehicles by vehicle occupancy were to occur at thirty-six (36) locations, of which six were to be the same locations at which vehicle counts had been taken in previous years. Therefore, 30 new count locations had to be selected. That selection process involved the following steps:

a. The MAGTPO 1985 highway network was used as the source for the sample of roadway links.[22]

b. The sample selected was to be a systematic sample of links stratified by area type and facility type, with a random start in each stratum.[23]

c. The list of links selected for the sample was reviewed by the consultant and MAGTPO staff.

d. Changes were made to the original sample of links to select locations that would provide more separation between sample locations and higher-volume intersections, or to avoid locations where it would be physically impossible.

A map and list of 36 locations selected for the vehicle occupancy counts, descriptions of the types of roadways represented in the sample counts and all data derived from the counts are included in a data binder submitted separately to MAGTPO.[24]

The hours of the counts were expanded from those described in the initial version of the procedures (see page 16). In expanding the number of hours of counts at each location from eight to ten, however, the decision was made to not count during the midday in order to count during longer peak commute periods. The duration of the counts in this research was nevertheless much longer than the four hours of counts conducted previously in Phoenix.[25]

2. Intercept Surveys

Surveys of travelers arriving in vehicles occurred at thirty-three parking lots and garages. That number of locations was not selected in advance, but turned out to

[22]A link is a representation of a roadway between two freeway interchanges or two intersections.

[23]A stratum is each of the sets considered as an integrated whole that make up an ordered group of sets. In this case, each stratum of links would be comprised of links having the same area type and facility type.

[24]That data binder is called Counts of Vehicle Occupancy.

[25]For this research, counts were taken between 7:00 AM and 12:00 PM and between 2:00 PM and 7:00 PM. Vehicle occupancy surveys had been conducted in the Phoenix metropolitan area at six different locations since 1974. In previous years (before this research), counts were taken between 7:00-8:00 AM, 9:00-10:00 AM, 2:00-3:00 PM and 4:30-5:30 PM.

be the number of parking lots and garages where surveys needed to be distributed in order to receive about 270 surveys back from each area. (See page 30 for a discussion of the sampling requirements for the intercept surveys.) The parking garages and lots where the surveys occurred are listed in the Intercept Surveys Data Binder, while the procedures and control forms used to carry out the intercept surveys are described in Appendix B. Information about the numbers of questionnaires distributed and summaries of the responses received are also presented in the Intercept Surveys Data Binder submitted separately to MAGTPO.

The intercept surveys were accomplished during March and April 1988 in order to avoid the months when the greatest number of visitors would be staying in the Phoenix metropolitan area.[26] As the surveys occurred in places not frequented by visitors, receiving responses from visitors to the region was not deemed a significant issue affecting the use of this survey data for regional transportation planning purposes.

[26]The months between November and April are the months with the greatest numbers of visitors to Phoenix, with the peak number of visitors occurring before the baseball spring training season ends in late March.

3. ANALYSIS OF DATA COLLECTED

Analysis requirements dictated what types of data needed to be collected. The following two types of data were collected as part of this research: counts of vehicle occupancy by time of day, and responses to questionnaires distributed to samples of vehicles arriving at selected parking sites. Counts of vehicle occupancy were needed for validation and calibration of the MAGTPO travel model (including checking the reasonableness of travel simulations). Intercept surveys were needed to confirm or identify which characteristics of the travelers, of the journey, or of the destination have the greatest influence on vehicle occupancy rates. The procedures that were used to implement the counts and surveys were described in previous chapters. The data that were collected and the results of the analysis of that data are described in this chapter.

A. Vehicle Occupancy Counts

Counts of vehicles by vehicle occupancy were taken at 36 locations scattered throughout the Phoenix metropolitan area. Those locations were selected to provide a proper sample of facility classes and area types.

Although detailed data are available to describe vehicle occupancy by time of day for each of the 36 locations where sample counts took place, the analysis of data presented in this report is based on aggregating the data collected to provide summaries of vehicle occupancy by facility type and area type. This step was followed so as to discuss in this report vehicle occupancy data that would be statistically significant at the regional level, or by facility type or by area type. As discussed further later in this chapter, the standard error of the estimates associated with data for individual count locations or for facility types within area types would be too large to use those detailed data for analysis.[27] Therefore, the analysis of vehicle occupancy that follows is based on summaries of vehicle occupancy counts for three facility classes (freeways, arterials and collectors, and all facilities), and three area types (the downtown area of Phoenix and the higher density areas surrounding the regional core; other portions of Phoenix, Scottsdale, Tempe and Mesa; and the lower-density suburban areas of the region.[28]

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[27]The sample counts taken at each location (of each lane every 15 minutes) and the summaries of the counts for each location where the counts occurred are presented in the Vehicle Occupancy Counts Data Binder submitted to MAGTPO.

[28]On the basis of the geographic areas defined by MAGTPO, the regional core includes Area Types 1 and 2, the higher-density area includes Area Type 3, and the suburban area includes Area Types 4 and 5. MAGTPO's Area Types are shown in Figure 1.

1. Vehicle Occupancies in 1988

For the ten hours (between 7:00 AM and 7:00 PM) when counts were actually taken, the vehicle occupancy rate for the Phoenix metropolitan area was calculated to be 1.315, which was rounded off to 1.32. Based on analyzing the sample counts of vehicle occupancy, the average daily vehicle occupancy rate occurring in the Phoenix metropolitan area in 1988 was calculated to be 1.33. That rate is derived from a comparison of the hourly rates calculated directly from the counts and adjustment factors found to account for variations in vehicle occupancy by time of day.[29]

Vehicle occupancy rates vary by time of day, facility type and area type. The following conclusions are based on reviewing the vehicle occupancy data summarized in Table 6 and depicted in Figures 2 through 6:

1. The lowest vehicle occupancy rates occur during the AM peak period, while the highest vehicle occupancy rates occur during the midday or early evening hours. The regional vehicle occupancy rate for the AM peak period (1.20) is 14 percent lower than the regional rate (1.39) recorded for the early evening hours. (See Table 6 and Figures 2 through 6.)

2. The lowest vehicle occupancy rates occur in the core area of the region (surrounding downtown Phoenix) and the highest in the outlying suburban areas. The vehicle occupancy rates recorded in the core area are about 4 to 7 percent lower than the rates recorded in the suburban areas, depending on the time of day. (See Table 6 and Figure 4.)

3. Vehicles traveling on freeways were counted as having lower occupancy rates than vehicles traveling on arterials and collectors. Vehicle occupancy rates for freeways in the Phoenix metropolitan area are about 2 to 12 percent lower than for arterials and collectors with the greatest differences recorded during the early morning and PM peak hours and the smallest differences during the AM peak and midday hours. (See Table 6 and Figure 3.) These same differences between freeways and arterials and collectors are presented on an hourly basis in Table 7.

Although causes for the relationships just described cannot be directly ascertained from the counts of vehicle occupancy, it is possible to surmise as to what are the most likely reasons for those relationships. The following reasons are not based solely on evaluating the characteristics of the Phoenix metropolitan area, but are also the result of considering the similarities in travel patterns that exist across metropolitan areas:[30]

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[29]Table 13 in Quick - Response Urban Travel Estimation Techniques and Transferable Parameters (National Cooperative Highway Research Program Report 187, 1978) presents adjustment factors to convert hourly vehicle occupancy rates to a 24-hour average rate.

[30]Additional justifications for these interpretations can be found starting on page 47, where the responses to the vehicle intercept surveys are discussed.

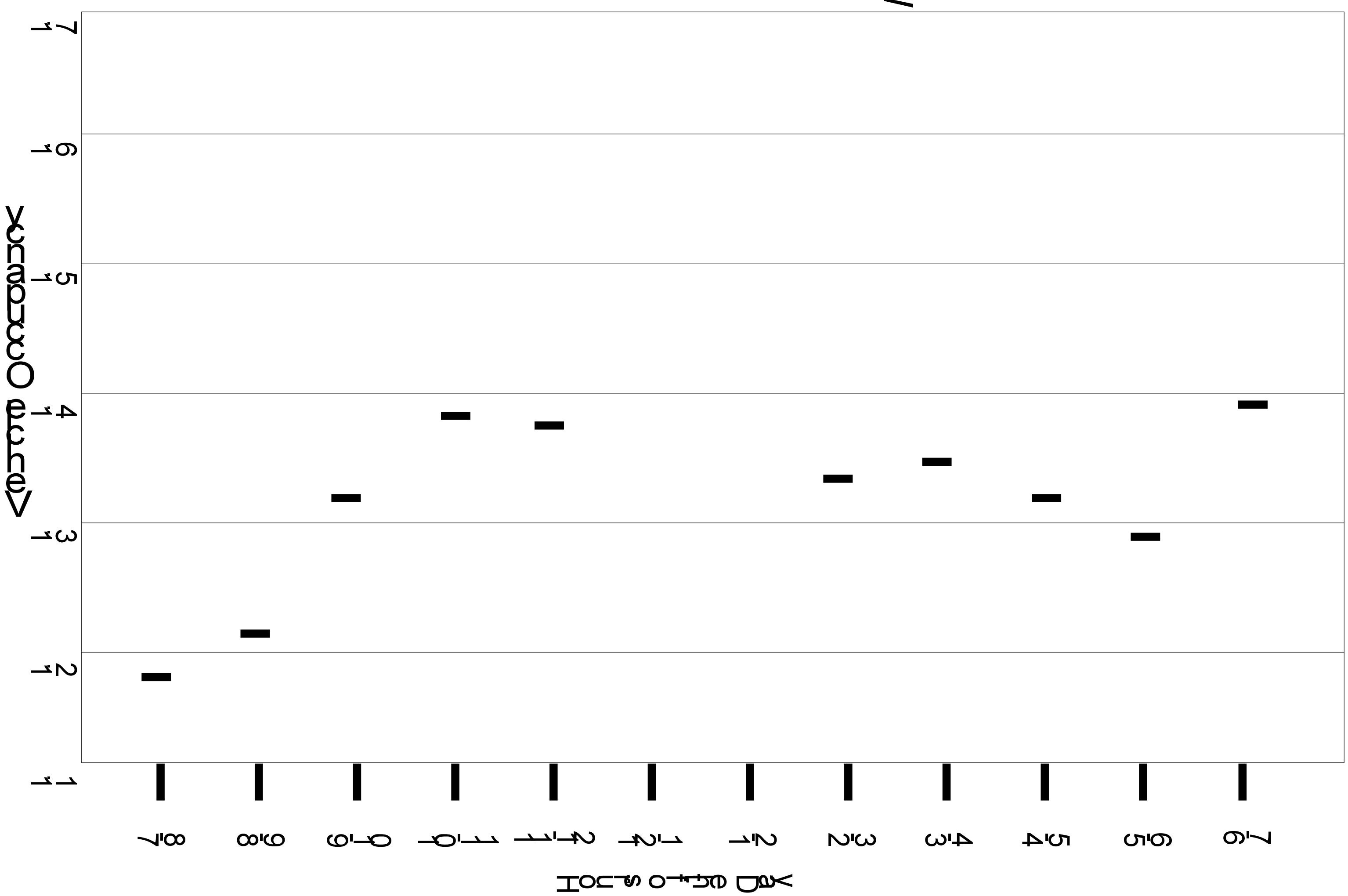
TABLE 6
VEHICLE OCCUPANCY RATES BY TIME OF DAY, FACILITY TYPE AND GEOGRAPHIC AREA

	Time of Day				
Location	AM[a]	MD[b]	PM[c]	EVE[d]	TOTAL[e]
All Facilities in Region	1.20	1.35	1.31	1.39	1.32
All Freeways in Region	1.19	1.34	1.25	1.31	1.29
All Arterials + Collectors in Region	1.21	1.36	1.38	1.49	1.35
All Facilities in core Area[f]	1.18	1.32	1.26	1.36	1.28
Freeways in Core Area	1.18	1.32	1.20	1.26	1.26
Arterials + Collectors in Core Area	1.18	1.32	1.32	1.45	1.30
All Facilities in HD Urban Area[g]	1.20	1.35	1.32	1.39	1.32
Freeways in HD Urban Area	1.17	1.31	1.27	1.38	1.27
Arterials + Collectors in HD Urban Area	1.38	1.49	1.41	1.40	1.44
All Facilities in Suburban Area[h]	1.23	1.41	1.38	1.45	1.37
Freeways in Suburban Area	1.21	1.39	1.30	1.35	1.33
Arterials + Collectors in Suburban Area	1.26	1.43	1.53	1.62	1.44

[a]From 7:00 - 9:00 AM
[b]From 9:00 AM - 12:00 PM and 2:00 - 4:00 PM
[c]From 4:00 - 6:00 PM
[d]From 6:00 - 7:00 PM
[e]For all hours on which occupancy counts occurred
[f]The core area consists of Area Types 1 and 2 (See Figure 1.)
[g]The higher-density part of the urban area consists of Area Type 3
[h]The suburban area consists of Area Types 4 and 5.
Source: Vehicle occupancy counts taken by Barton-Aschman Associates, Inc. during February and March 1988.

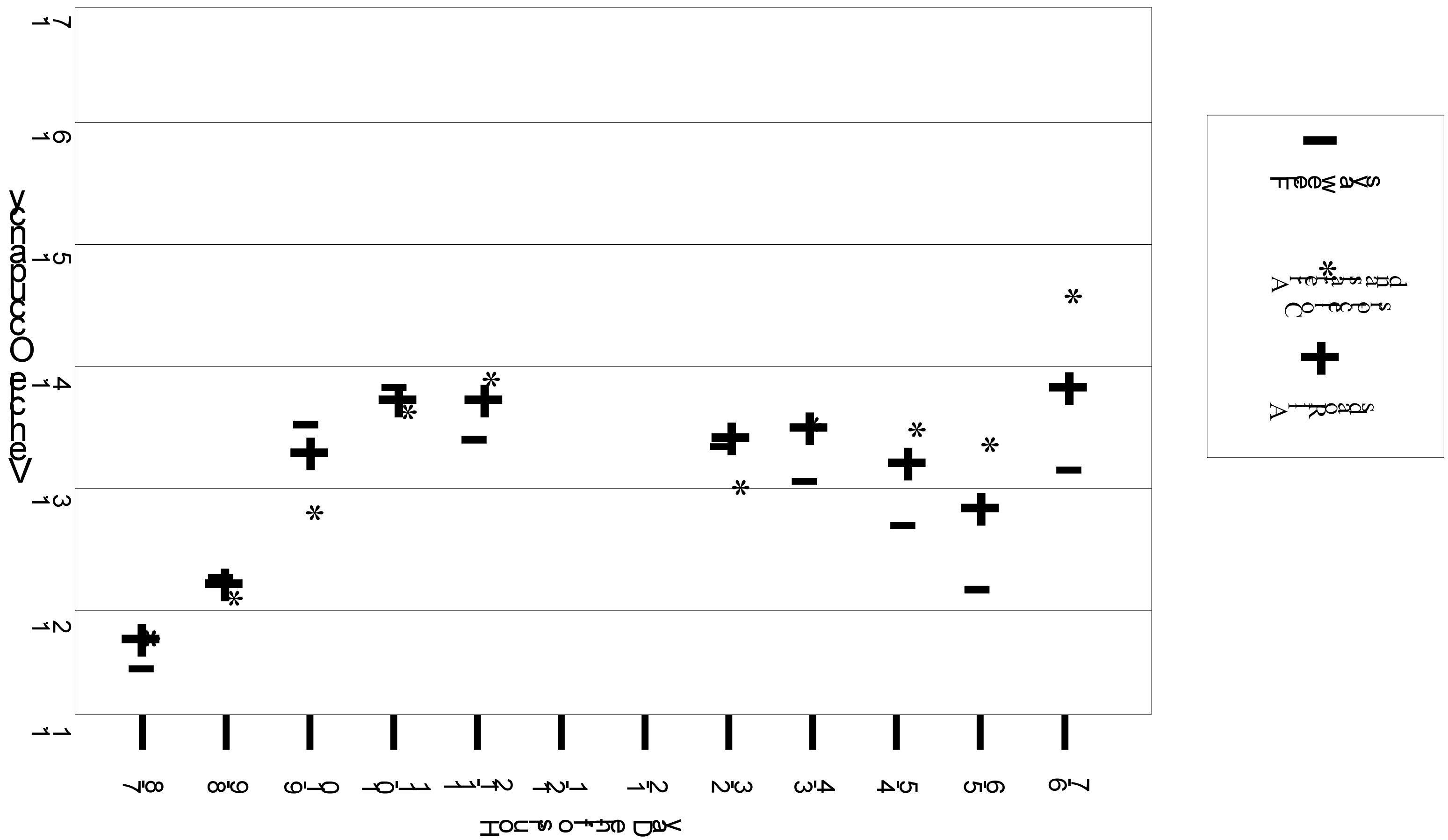
Table 2

VEHICLE OCCUPANCY FOR ALL ROADWAYS IN REGION



Source: Counts done by Barton-Aschman Associates, Inc. during February and March 1988

Figure 3



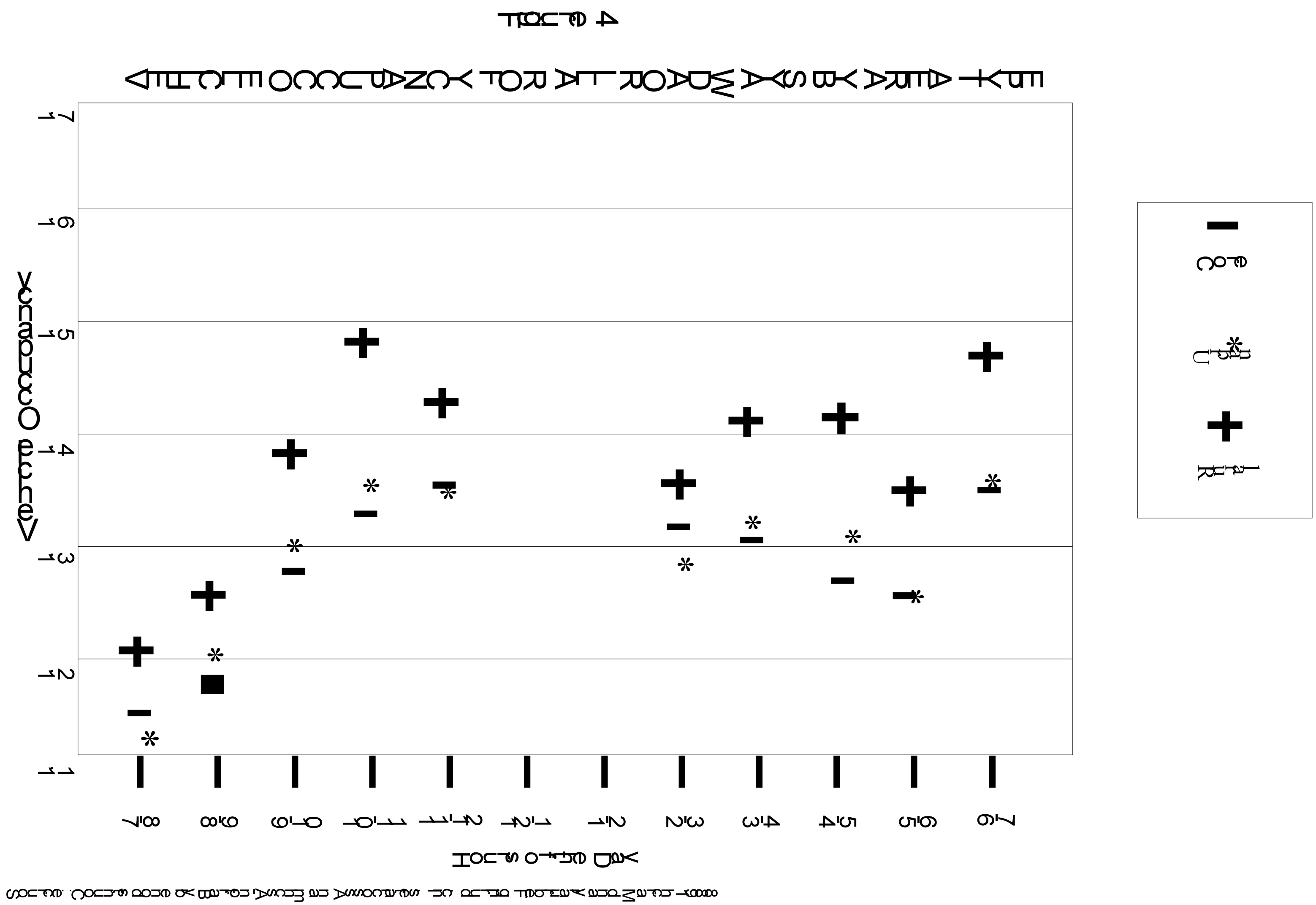
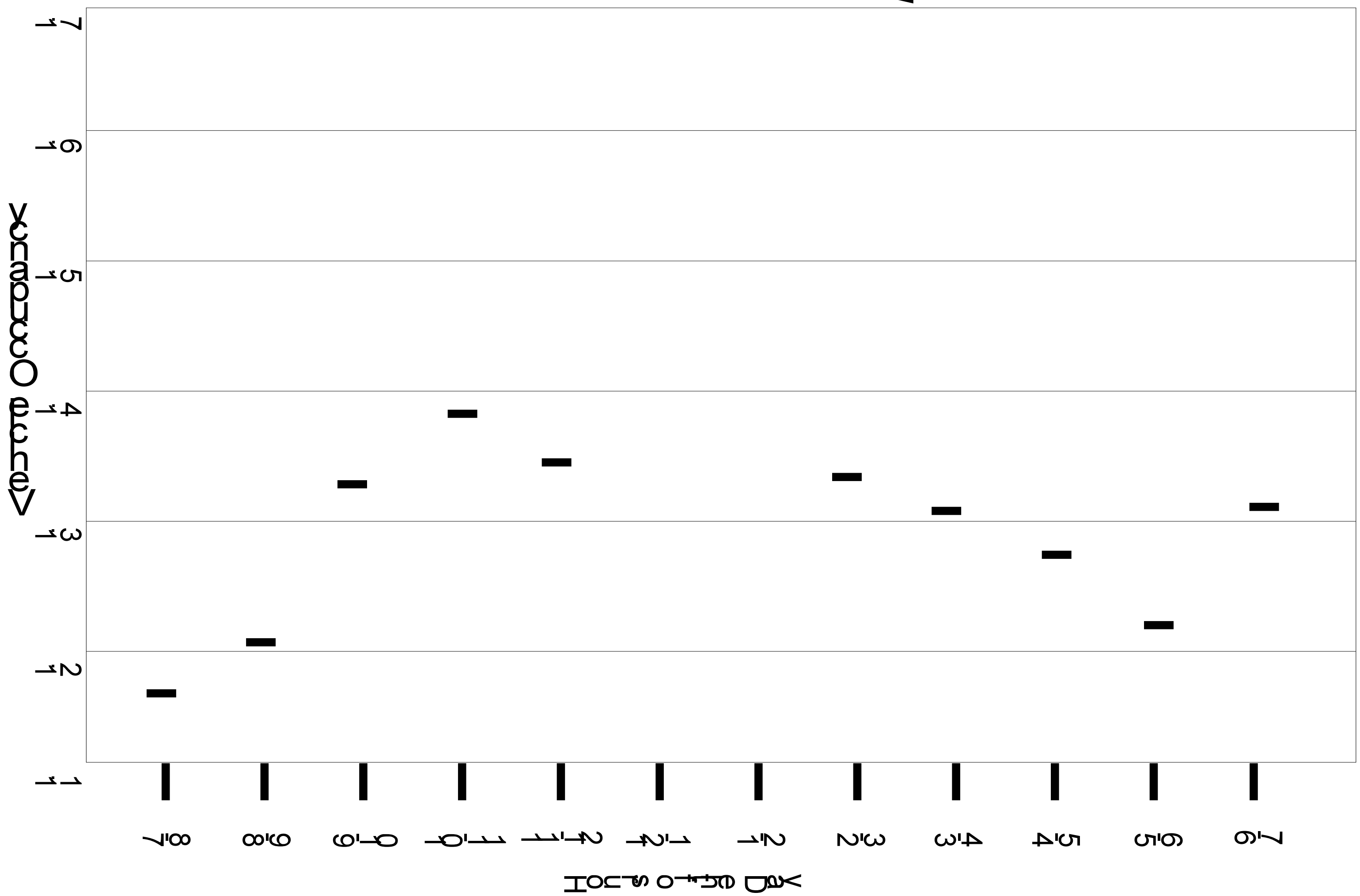


Figure 5

AVERAGE OCCUPANCY FOR ALL FREEWAYS IN REGION



Source: Counts done by Barton-Aschman Associates, Inc. during February and March 1988

Figure 6

Histogram of Log Base 2 Geometric Mean of Sample Size

TABLE 7
REGIONAL VEHICLE OCCUPANCY RATES BY TIME OF DAY AND FACILITY TYPE[a]

Time[b]	Freeways	Arterials and Collectors	All Facilities
7:00 AM	1.16	1.20	1.18
8:00 AM	1.21	1.22	1.22
9:00 AM	1.34	1.30	1.32
10:00 AM	1.38	1.39	1.39
11:00 AM	1.35	1.41	1.38
2:00 PM	1.34	1.33	1.33
3:00 PM	1.30	1.38	1.34
4:00 PM	1.27	1.38	1.32
5:00 PM	1.23	1.37	1.29
6:00 PM	1.31	1.49	1.39

[a]The time-of-day occupancy rates presented in Table 6 should be used with a greater degree of confidence than the hourly rates presented here, because of the differences in the numbers of vehicle trips counted to calculate the two types of occupancy rates.

[b]For the hour beginning at:

Source: Vehicle occupancy counts taken by Barton-Aschman Associates, Inc. during February and March 1988.

1. The lowest number of persons traveling together occur when commuting to work is the predominant trip purpose, for home-based-work trips exhibit the lowest vehicle occupancy rates of any trip purpose. Home-based-work trips represent the greatest proportion of all trip purposes made during the AM peak hour of travel than they do of trips made during any other periods of the day. (During the PM peak period of travel, trip purposes other than traveling to or from work represent a larger percentage of all trip purposes than during the AM peak period.)[31]

2. The highest numbers of persons traveling together occur when persons are traveling for purposes where they need or want to travel together. Going shopping or to different forms of entertainment are the most likely trip purposes that are accomplished by groups of persons who want to be together when they get to their common destination. These non-work related trips represent the greatest proportion of all trip purposes made during the off-peak hours of the day. (Obviously, these are also the times when the proportions of home-to-work or work-to-home trips are lowest.) For these reasons, vehicle occupancies were recorded as always being higher during off-peak hours, regardless of facility type or geographic area.

3. Vehicles traveling in the core area of Phoenix were recorded as having lower occupancy rates than vehicles in other areas primarily because this area of the region contains far fewer land uses that would attract non-work trips. Conversely, this area of the region attracts more work-related and (probably) personal business travel than other areas of the region. (As discussed earlier, vehicle occupancies for personal business trips, such as traveling to an appointment with a doctor or an attorney, are typically the second lowest vehicle occupancies by trip purpose, after vehicle occupancies for work trips.)[32]

4. Vehicles traveling in the outlying urbanized areas and the non-urbanized areas of the region were recorded as having the highest occupancy rates, regardless of time of day or facility class. A number of reasons, some complementing each other, would appear to offer the most likely explanations. First, there are more self-contained retirement communities located in outlying areas of the Phoenix region than in the interior of the urbanized area. Persons living in those developments would be making very few, if any work-related trips (which are the trips recorded as having the lowest vehicle occupancies). While older persons would be living in households with fewer persons per household than younger persons, especially older persons living in retirement communities, the social-recreational purpose of their trips and their less-than-universal capability to drive is likely to result in higher vehicle occupancies per daily trip than for

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[31] Quick - Response Urban Travel Estimation Techniques and Transferable Parameters (User's Guide). Pp 90 and 101-110.

[32] Ibid. P. 90.

younger residents of the region. Second, there are probably more elementary and high schools per square mile in those outlying residential areas than in other parts of the region. Home-based-non-work trips, which exhibit high occupancy rates, are probably occurring at a higher proportion of all trip purposes occurring in those residential areas. The trip purposes in this category would be made by parents driving their children to school (in the case of elementary and junior high school students) or students traveling together (in the case of senior high school students).

5. Vehicles traveling on freeways have lower occupancy rates than vehicles traveling on arterials and collectors because of differences in the trip purposes served by the two categories of highways. As home-based-work trips are generally the longest-distance trips made, those trips represent a higher proportion of all trips made on freeways, particularly during peak commute hours. During the AM commute hours, however, when home-based work trips represent a greater proportion of all trips purposes than they do during PM commute hours, the differences in vehicle occupancy rates at the regional level and in the core area are not statistically significant. In the other areas of the region, the vehicle occupancy rates recorded are lower on freeways than on arterials and collectors at all times of the day because in those areas there is a big difference in the purpose of the trips occurring on each category of highway. While in the core area, persons may be traveling on either freeways or arterials to get to work or to State or municipal government offices, in other areas of the region, persons who are traveling for purposes that would exhibit higher vehicle occupancies (such as neighborhood-oriented travel) are more likely to be using arterials than freeways.

Due to the large numbers of vehicles that were counted at the regional level, the standard errors for the regional estimates of daily vehicle occupancy rates derived from the counts are very small. The following standard errors were calculated to estimates of daily vehicle occupancy rates in the Phoenix metropolitan area: for all roadways -0.002, for freeways -0.002, and for arterials and collectors -0.003. Very small standard errors were also calculated for the overall regional vehicle occupancy rates for different times of the day, as follows: 0.003 for 7:00 to 9:00 AM, 9:00 AM to 3:00 PM, and 4:00 to 6:00 PM; and 0.006 for the single hour starting at 6:00 PM.

The standard errors of the vehicle occupancy rates estimated for each of the three area types or for the two roadway types are all smaller than 0.015, even when estimating vehicle occupancies by time of day. This finding would apply to vehicle occupancies such as for all roadways within an area type by all time periods except 6:00 PM, or for roadways within a facility type and area type for the entire day. (The complete sets of standard deviations and standard errors calculated for the estimates of vehicle occupancy discussed in this report are presented in Appendix F).

Given that the standard errors for the vehicle occupancy rates calculated for the entire region by area type, or by facility type are all smaller than 0.015 for all times of day, any differences between vehicle occupancy rates greater than 0.015 (and in many cases, less) are statistically significant. Comparisons of vehicle occupancy rates by area type and facility type for almost all times of day that show a difference greater than 0.015 are also statistically significant. The standard error of the counts was calculated to be more than 0.015, also statistically significant. The standard error of the counts was calculated to be more then 0.015 for the single hour starting at 6:00 PM (when the standard error ranges between 0.010 to 0.029), for arterials and collectors in Area Type 3 between 7:00 to 9:00 AM (0.03) and between 4:00 to 6:00 PM (0.029), and for arterials and collectors in Area Types 4 and 5 after 6:00 PM (0.022).

The counts of vehicle occupancy were also used to calculate occupancy rates for vehicles classified as carpools, with carpools defined to be vehicles transporting two or more persons. For the ten hours (between 7:00 AM and 7:00 PM) when counts were actually taken, carpools in the Phoenix metropolitan area were counted as having an average occupancy rate of 2.24 persons per (carpool) vehicle (trip). Based on the relationship derived between vehicle occupancy for the ten hours when counts occurred and daily vehicle occupancy, the average daily occupancy rate for carpools in the Phoenix metropolitan area is estimated to be 2.27 persons (carpool) vehicle (trip).

Occupancy rates for carpools (vehicles transporting 2 or more persons) vary by time of day, facility type and area type, much as do overall vehicle occupancy rates. As indicated by the data summarized in Table 8, carpool vehicle occupancy rates in the Phoenix metropolitan area vary as follows:

1. The lowest carpool occupancy rates occur during the AM peak period, while the highest rates occur during the PM peak period and early evening hours. The preponderance of work trips as a proportion of all trips made during the AM peak period, and the low carpooling rates associated with work trips are half of the reasons for this finding. Conversely, the other half of the answer is that trips other than work make up a larger percentage of all trips made at the other times of the day.

2. The lowest carpool occupancy rates for all times of day were counted for vehicles traveling on freeways in the higher density areas of the region surrounding the core, while vehicles traveling on arterials and collectors in this same part of the region were counted as having the highest carpool vehicle occupancy rates during the AM and midday hours. Carpool vehicles traveling on arterials and collectors in outlying suburban areas were counted as having the highest carpool vehicle occupancy rates during PM and early evening hours.

The explanations presented on pages 36 and 37 for overall vehicle occupancy rates would also help explain these findings about carpool vehicle occupancy rates. Carpool vehicle occupancy rates would be highest at times and locations where persons would be traveling for almost any purpose but work or personal business. Persons traveling for those two trip purposes would be traveling together at far lower rates than would persons traveling to go shopping, eat a meal, or out for entertainment or recreation. (See also page 53 for a discussion of the responses from the vehicle intercept surveys.)

The vehicle occupancy counts also provide information showing: 1) how the percentages of persons traveling in vehicles carrying one or two or three or more persons vary by time of day, and 2) the relationships between the percentages of all vehicles by vehicle occupancy and the percentages of all persons traveling categorized by vehicle occupancy. The regional summaries of vehicle occupancy counts have been used to calculate the percentages of vehicles and travelers presented in Tables 9, 10, and 11. Analysis of the data in those supplements the findings described earlier about changes in vehicle occupancy, as follows:

1. The largest percentages of trips in vehicles transporting only the driver occur during the AM peak period, while the lowest percentages occur during off-peak hours. About 82 percent of all vehicles traveling in the AM peak hours are transporting only the driver, compared to about 70-75 percent of all vehicles on freeways and all roadways, and about 65-75 percent of all vehicles on arterials and collectors at other hours of the day.

2. Conversely, the largest percentages of trips in vehicles transporting two or more persons occur during off-peak hours, while the lowest percentages occur during the AM peak period. During off-peak hours, when home-based-work trips comprise the smallest percentage of all trip purposes, about 27-31 percent of all vehicles are transporting two or more persons. During the AM peak period, about 15-18 percent of all vehicles are transporting two or more persons.

3. Similarly, the largest percentages of persons traveling in vehicles transporting two or more persons occur during off-peak hours and the smallest percentages during the AM peak period. During off-peak hours, about 45-50 percent of all persons traveling in vehicles are traveling in vehicles transporting two or more persons, but that percentage drops to about 30 percent during the AM peak period.

4. Freeways serve lower percentages of vehicles transporting two or more persons than do arterials and collectors. While differences between the two facility types exist for all hours of the day, the greatest differences occur during the PM peak period when about 20 percent of all vehicles on freeways

are transporting two or more persons, compared to about 29 percent of all vehicles on arterials and collectors. During the AM peak period, the difference is only between about 15 percent of all vehicles on freeways and about 16 percent of all vehicles on arterials and collectors.

5. The differences in carpool vehicles served by freeways and by arterials and collectors are caused primarily by the percentages of vehicles transporting three or more persons. During the AM peak hours, while about 3 percent of all vehicles on arterials and collectors are transporting three or more persons, only about 2 percent of all vehicles on freeways are doing the same. That gap widens during off-peak hours when about 3.5 - 4.5 percent of all vehicles on freeways are transporting three or more persons, compared to about 5 to 6 percent of all vehicles on arterials and collectors.

TABLE 8
OCCUPANCY RATES FOR CARPOOLS BY TIME OF DAY, FACILITY TYPES AND GEOGRAPHIC AREA[a]

	Time of Day				
Location	AM[b]	MD[c]	PM[d]	EVE[e]	TOTAL[f]
All Facilities in Region	2.21	2.23	2.26	2.26	2.24
All Freeways in Region	2.15	2.19	2.20	2.19	2.19
All Arterials + Collectors in Region	2.26	2.28	2.32	2.33	2.29
All Facilities in core Area	2.21	2.26	2.27	2.27	2.26
Freeways in Core Area	2.20	2.26	2.26	2.27	2.26
Arterials + Collectors in Core Area	2.22	2.26	2.28	2.27	2.26
All Facilities in HD Urban Area	2.16	2.16	2.17	2.15	2.16
Freeways in HD Urban Area	2.05	2.08	2.08	2.08	2.07
Arterials + Collectors in HD Urban Area	2.51	2.35	2.31	2.31	2.35
All Facilities in Suburban Area	2.22	2.23	2.29	2.31	2.26
Freeways in Suburban Area	2.19	2.19	2.20	2.18	2.19
Arterials + Collectors in Suburban Area	2.27	2.29	2.41	2.41	2.33

[a]Carpools are defined as vehicles transporting 2 or more persons.
[b]From 7:00 - 9:00 AM.
[c]From 9:00 AM - 12:00 PM and 2:00 - 4:00 PM.
[d]From 4:00 - 6:00 PM.
[e]From 6:00 - 7:00 PM
[f]For all hours on which occupancy counts occurred.
Source: Vehicle occupancy counts taken by Barton-Aschman Associates, Inc. during February and March 1988.

TABLE 9
PERCENTAGES OF VEHICLES AND TRAVELERS BY VEHICLE OCCUPANCY BY TIME OF DAY - ALL FACILITIES IN REGION

Time[a]	Vehicles and Travelers By Persons per Vehicle (Percent)[b]					
	One		Two		Three or More	
	% of Vehicles	% of Travelers	% of Vehicles	% of Travelers	% of Vehicles	% of Travelers
7:00 AM	84.7	71.4	13.1	22.1	2.2	6.5
8:00 AM	82.3	67.7	15.1	24.9	2.6	7.4
9:00 AM	73.4	55.6	22.8	34.6	3.8	9.8
10:00 AM	68.7	49.5	26.2	37.9	5.1	12.6
11:00 AM	68.6	49.6	26.4	38.1	5.0	12.3
2:00 PM	73.2	55.0	22.3	33.5	4.5	11.5
3:00 PM	72.7	54.1	22.6	33.7	4.7	12.2
4:00 PM	74.6	56.4	20.7	31.3	4.7	12.3
5:00 PM	76.8	59.5	19.1	29.6	4.1	11.9
6:00 PM	69.1	49.7	25.3	36.4	5.6	13.9

[a]For the hour beginning at:
[b]Percentages of vehicles or travelers by persons per vehicle.
Source: Counts taken by Barton-Aschman Associates, Inc. during March and April 1988.

TABLE 10
PERCENTAGES OF VEHICLES AND TRAVELERS BY VEHICLE OCCUPANCY BY TIME OF DAY - FREEWAYS IN REGION

Time[a]	Vehicles and Travelers By Persons per Vehicle (Percent)[b]					
	One		Two		Three or More	
	% of Vehicles	% of Travelers	% of Vehicles	% of Travelers	% of Vehicles	% of Travelers
7:00 AM	85.6	73.6	12.8	22.1	1.6	4.3
8:00 AM	81.8	67.5	16.1	26.5	2.1	6.0
9:00 AM	71.4	53.5	25.3	37.8	3.3	8.7
10:00 AM	68.1	49.2	27.2	39.3	4.7	11.5
11:00 AM	69.7	51.5	26.6	39.3	3.7	9.2
2:00 PM	71.8	53.7	24.4	36.5	3.8	9.8
3:00 PM	74.5	57.0	21.7	33.2	3.8	9.8
4:00 PM	77.6	60.9	18.8	29.5	3.6	9.6
5:00 PM	80.7	65.9	16.9	27.7	2.4	6.4
6:00 PM	73.7	56.1	22.7	34.5	3.6	9.4

[a]For the hour beginning at:
[b]Percentages of vehicles or travelers by persons per vehicle.
Source: Counts taken by Barton-Aschman Associates, Inc. during March and April 1988.

TABLE 11
PERCENTAGES OF VEHICLES AND TRAVELERS BY VEHICLE OCCUPANCY BY TIME OF DAY - ARTERIALS AND COLLECTORS

Time[a]	Vehicles and Travelers By Persons per Vehicle (Percent)[b]					
	One		Two		Three or More	
	% of Vehicles	% of Travelers	% of Vehicles	% of Travelers	% of Vehicles	% of Travelers
7:00 AM	83.7	69.6	13.4	22.3	2.9	8.1
8:00 AM	82.8	68.0	14.1	23.2	3.1	8.8
9:00 AM	75.7	58.2	20.0	30.8	4.3	11.0
10:00 AM	69.2	49.9	25.2	36.3	5.6	13.8
11:00 AM	67.6	47.9	26.2	37.1	6.2	15.0
2:00 PM	74.6	56.2	20.4	30.8	5.0	13.0
3:00 PM	70.6	51.1	23.7	34.3	5.7	14.6
4:00 PM	71.0	51.4	23.0	33.3	6.0	15.3
5:00 PM	72.0	52.5	21.8	31.7	6.2	15.8
6:00 PM	63.0	42.2	28.8	38.6	8.2	19.2

[a]For the hour beginning at:
[b]Percentages of vehicles or travelers by persons per vehicle.
Source: Counts taken by Barton-Aschman Associates, Inc. during March and April 1988.

6. While at least 70 percent of all vehicles are usually transporting only the driver, thus making carpools a minority of vehicles on the road, carpool travelers comprise much greater shares of all persons traveling in vehicles. This distinction between vehicles and travelers is vital when describing market shares. For example, during AM peak hours about 30 percent of all persons traveling in vehicles are traveling in carpools of two or more persons, but only about 15 percent of all vehicles are in this category of occupancy. During off-peak hours, about 45-50 percent of all persons traveling in vehicles are traveling in carpools of two or more persons, but only about 23-31 percent of all vehicles are in this category of occupancy.

7. The percentages of all vehicles transporting three or more persons are much smaller than the percentages of all vehicles transporting two persons. During the AM peak hours, about 6 times as many vehicles are transporting two persons as are transporting three or more persons. During other hours, that ratio between carpools with two persons and carpools with three or more persons drops to about 4 of 5 to 1.

In summary, the analysis of vehicle occupancy counts for the Phoenix metropolitan area indicates that the highest vehicle occupancies on weekdays occur on lower-volume roadways, and during off-peak hours. The lowest weekday vehicle occupancies occur on higher-volume roadways (particularly freeways) and during peak hours of travel (particularly during the AM peak when work trips predominate). Vehicles transporting only the driver represent the majority of all vehicles at almost all hours of the day, but persons traveling in carpools (of two or more persons) represent about half of all persons traveling in vehicles during off-peak hours. Finally, and maybe most importantly, what is said about vehicle occupancy has to be precise enough to account for the variations identified among times of day, facility types and geographic areas.

2. Comparisons with Other years and Other Urban Areas

Comparisons between the vehicle occupancies derived from the counts taken in Phoenix in previous years or for other metropolitan areas have two major purposes. First, the comparisons can reveal what historical changes have taken place in vehicle occupancy rates in the Phoenix metropolitan area. Second, the comparisons of Phoenix's vehicle occupancy rates with those of other metropolitan areas can indicate how valid it would be to transfer the data collected here to applications in other urban areas, and also how valid it would be to transfer vehicle occupancy data from other metropolitan areas to complement the use of this data for creating projections of vehicle occupancies in the Phoenix metropolitan area.

Vehicle occupancies were counted in Phoenix between 1977 and 1982 at six locations as compared to the 36 locations where vehicle occupancies were counted in 1988 for this research. Six of the 36 locations are the same ones where counts

were taken in previous years. While vehicle occupancies at each of those six locations could be compared directly, only the composite vehicle occupancies calculated from the counts in previous years will be compared to the regional vehicle occupancies calculated for 1988. The reason for this decision is to focus the composite vehicle occupancies calculated for 1988. The reason for this decision is also to focus the comparison on changes in vehicle occupancy that would be due to changes in travel behavior and not on changes in vehicle occupancy that would really be due to variability in the rates derived for each location. Some of the differences in the vehicle occupancy rates calculated for the same locations would be due to the shorter or different time periods used to count vehicles between 1977 and 1982. (See pages 25 and 26 for an explanation of those differences.)

Notwithstanding the methodological and mathematical constraints alluded to above, the comparison of regional vehicle occupancy rates indicates that the rates for the Phoenix Metropolitan Area have been very stable through the years. The following conclusions about historical trends in regional vehicle occupancies are based on reviewing the data presented in Table 12.

1. For the twelve hours between about 7:00 AM and 7:00 PM, the 1988 vehicle occupancy rate of 1.32 is as high as the rate counted in 1979 (during the time of fuel shortages and high fuel prices). At the same time, the 1988 rate is only 3 percent higher than the lowest rate counted between 1977 and 1982, and only 1.5 percent higher than the average of the rates counted in those previous six years. Even though the standard error associated with the regional vehicle occupancy rate calculated for 1988 is 0.002 and 0.005 for the rates calculated between 1977 and 1982, there is no statistically valid change in travel behavior that can be identified from this comparison.

2. No statistically valid changes in vehicle occupancy rates were found to have occurred during any of the times of day when counts were taken.

3. The percentages of vehicles by vehicle occupancy are also statistically similar for all times of day.

The daily regional vehicle occupancy rate of 1.33 derived from the 1988 counts is identical to the rate derived from the 1981 (sample) household survey conducted by MAGTPO. The daily average occupancy for carpool vehicles (those transporting two or more persons) was estimated to be 2.27 in 1988, while 2.32 was the value derived from the responses to the 1981 household survey. Vehicle occupancy counts in previous years yielded a carpool occupancy rate of about 2.28, indicating that the responses to the 1981 household survey may over-represent the numbers of persons who are actually traveling together in carpools.

TABLE 12
COMPARISON OF VEHICLE OCCUPANCY CLASSIFICATIONS AND OCCUPANCY RATES FOR PHOENIX

		Vehicles by Persons Per Vehicle				
Time of Day	Year	1	2	3	4+	Occupancy Rate
		Percent				
Morning Peak[a]	1988	84%	13%	2%	1%	1.20
	1982	84	13	2	1	1.20
	1981	84	13	2	1	1.20
	1980	82	15	2	1	1.22
	1979	83	14	2	1	1.21
	1978	[f]	f	f	f	1.21
	1977	83	15	2	1	1.21
Morning Off-Peak[b]	1988	74	22	3	1	1.31
	1982	77	19	3	1	1.29
	1981	78	19	2	1	1.27
	1980	77	19	3	1	1.26
	1979	74	21	3	2	1.31
	1978	f	f	f	f	1.29
	1977	82	14	2	1	1.24
Afternoon Off-Peak[c]	1988	74	22	3	1	1.33
	1981	76	20	3	1	1.32
	1980	75	21	3	1	1.32
	1979	74	20	4	2	1.34
	1978	f	f	f	f	1.33
	1977	75	20	4	1	1.33
Afternoon Peak[d]	1988	76	20	3	1	1.31
	1982	76	18	4	2	1.32
	1981	76	19	3	2	1.30
	1980	77	19	3	1	1.30
	1979	71	24	3	2	1.35
	1978	f	f	f	f	1.32
	1977	77	18	4	1	1.32
12-Hour Average[e]	1988	74	21	3	2	1.32
	1982	77	19	3	1	1.30
	1981	78	18	3	1	1.28
	1980	77	19	3	1	1.29
	1979	74	21	3	2	1.32
	1978	f	f	f	f	1.30
	1977	78	18	3	1	1.29

[a]Defined as 6:30 to 8:00 AM for 1977-1982, and 7:00 to 9:00 AM for 1988.

[b]Defined as 8:00 AM to 12:00 PM for 1977-1982, and 9:00 AM to 12:00 PM for 1988.

[c]Defined as 12:00 to 4:30 PM for 1977-1982, and 2:00 to 4:00 PM for 1988.

[d]Defined as 4:30 to 6:30 PM for 1977-1982, and 4:00 to 6:00 PM for 1988.

[e]Defined as between 6:30 AM and 6:30 PM for 1977-1982, and 7:00 AM and 7:00 PM for 1988.

[f] Information not available in format needed for table.

Sources: For 1977 to 1982 data — Maricopa Association of Governments Transportation and Planning Office, Phoenix Urban Area Vehicle Occupancy Study, June 1982, P. 5. For 1988 data — vehicle occupancy counts taken by Barton-Aschman Associates, Inc. during March and April 1988.

Daily vehicle occupancy rates are very similar for different metropolitan areas, typically ranging between 1.30 and 1.45 during the 1980's. Regional vehicle occupancy rates have been dropping steadily in the last ten to twenty years due to three major reasons. First, decreases in the number of persons per household mean that there are fewer persons in each household that could be traveling together for any home-based trip purpose. Second, increases in the numbers of persons employed per household mean that persons are making fewer home-based trips and are chaining together more trip purposes into work-related trips. Third, the scatterization of work places and the needs of many workers to accomplish different purposes on their way to or from work have made it much more difficult for carpools to form for work-related trips. In the San Francisco Bay Region, for example, the weekday vehicle occupancy rate decreased from 1.44 in 1965 to 1.30 in 1980.[33] This decrease of about 10 percent in weekday vehicle occupancy rates has also occurred in other metropolitan areas, because the changes in demographic characteristics and travel patterns described above have reduced the opportunities for people to travel together, either from their homes or from other places. For those reasons, the daily occupancy rates of about 1.50 that were common during the 1970's are now typically down to about 1.35 because occupancy rates have declined for all trip purposes.[34]

The 1988 vehicle occupancy rates estimated for the Phoenix metropolitan area are in line with recent estimates for similar urban areas. While Phoenix's vehicle occupancy rates have remained stable, and have not declined as have vehicle occupancy rates in other areas, perhaps the main reason for this stability is that Phoenix's development patterns and demographic changes over the last ten years have been consistent with those of other high-growth cities in Sunbelt States.

B. Vehicle Intercept Surveys

To collect information that could be used to compare the characteristics of persons who are driving alone against the characteristics of persons who are sharing rides, vehicle intercept surveys were conducted at a sample of parking sites in the Phoenix metropolitan area.[35] The samples of vehicles arriving at the parking sites selected for the surveys were determined to generate as many responses as possible from occupants of vehicles transporting two or more persons. (The sample design was based on the knowledge that vehicles containing two or more persons

[33]Kollo, Hanna P. and Charles L. Purvis, "Changes in Regional Travel Characteristics in the San Francisco Bay Area: 1960-1981, "Transportation Research Record 987, pp. 64-65.

[34]Quick Response Urban Travel Estimation Techniques, Op. cit., P. 90.

[35]The decisions made to select the parking sites for the vehicle intercept surveys are described on pages 18 through 20. The list of parking sites selected, the summaries of vehicle counts and questionnaires distributed at each site, and all detailed data produced by the vehicle intercept surveys are presented in the separate Intercept Surveys Data binder submitted to MAGTPO.

typically comprise a minority of all vehicles in the traffic stream, as shown by the data collected in Phoenix presented in Table 9.)

In order to directly compare the responses from different types of travelers, the following vehicle occupancy classification scheme was defined for this analysis:

1. Driver traveling alone;
2. Driver of a vehicle with two or more occupants, all from the same household;
3. Driver of a vehicle with two or more occupants from different households;
4. Passenger of a vehicle with two or more occupants, all from the same household; and
5. Passenger of a vehicle with two or more occupants from different households.[36]

The responses received were summarized by these five categories when it was necessary to evaluate if a specific characteristic of each type of traveler would help explain differences among factors influencing people to drive alone or share rides. Sometimes it was necessary to assign only one value of a variable to the different types of vehicle occupancies and not to compare the responses of drivers and passengers of carpools (vehicles transporting two or more occupants.[2] At those times, only the drivers' responses were used to create data files which were analyzed to identify differences among persons driving alone, carpools with all occupants from the same household or carpools with occupants from different households.

A total of 969 intercept survey questionnaires were returned, with 469 coming from drivers traveling alone and 500 from drivers or passengers from vehicles with two or more occupants.[37] As shown in Table 13, those questionnaires represented about 32.8 percent of all questionnaires distributed, 41.1 percent of all questionnaires distributed to drivers traveling alone and 27.6 percent of all questionnaires distributed to occupants of carpools. Almost all of the questionnaires that were returned contained responses to all of the questions, with response rates to individual questions ranging from 99 percent for almost all questions to 95 percent for the question about household income.[38]

The responses that were returned were also categorized using the responses to questions about trip purpose so that the level of confidence associated with utilizing summaries of responses classified by trip purpose could be determined. Sufficient

[36]The ways in which the responses to the questionnaire were used to classify occupants of the vehicles intercepted for the vehicle occupancy survey are explained in Appendix D.

[37]Nine-hundred seventy one questionnaires were actually returned, but two of those were excluded from the analysis files because their serial numbers were outside the range of serial numbers distributed, as reported in the Vehicle Occupancy Survey Logs.

[38]The response rates to individual questions are presented in the Intercept Surveys Data Binder submitted to MAGTPO.

responses were received from persons making home-based-work trips to be able to conclude that 95 percent of the time (i.e., at the 95 percent confidence level) that those responses would have a relative error of less than 6 percent, or that 90 percent of the time those responses would have a relative error of less than 6 percent. Sufficient responses were also received from persons making non-home-based trips to conclude that about 80 percent of the time the relative error of those responses would be 10 percent. However, the number of responses received from persons making non-home-based trips is so small that only about 68 percent of the time would it be possible to conclude that the relative error associated with those responses would be 10 percent. As shown in Table 14, 724 responses were received from persons making home-based-work trips, 65 from persons making home-based-other trips, and 167 from persons making non-home-based trips.

TABLE 13

SUMMARY OF INTERCEPT SURVEY QUESTIONNAIRES DISTRIBUTED AND RETURNED

Geographic Area	Questionnaires Distributed			Questionnaires Returned			Percent Questionnaires Returned		
	Drive Alone	Carpool	Total	Drive Alone	Carpool	Total	Drive Alone	Carpool	Total
State Office Complex	337	597	934	144	182	326	42.7%	30.5%	34.9%
Downtown Phoenix	462	630	1,092	137	168	305	29.7%	26.7%	27.9%
Central Avenue Corridor	342	583	925	188	150	338	55.0%	25.7%	36.5%
Total	1,141	1,811	2,951	469	500	969	41.1%	27.6%	32.8%

Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc., during March and April, 1988.

It is the responses received, classified by trip purpose, that actually establish the level of confidence associated with the analysis results presented in the following pages, for the characteristics of the travelers and the factors affecting vehicle occupancy vary greatly by trip purpose. While the levels of precision associated with survey responses for home-based-other and non-home-based trips are far lower than those associated with home-based-work trips, the numbers of responses received by trip purpose are in conformance with the objectives of the intercept survey. As discussed on page 20, the intercept surveys were intended to focus on collecting information about home-based-work trips. That objective was met by having the number of responses received from persons making home-based-work trips be sufficiently large to provide a small relative error at a high level of confidence.

TABLE 14
NUMBER OF INTERCEPT SURVEY RESPONSES BY CATEGORY OF VEHICLE OCCUPANT AND TRIP PURPOSE

	Trip Purpose			
Category of Vehicle Occupant	Home-Based Work	Home-Based Other	Non-Home Based	All
Driver traveling alone (Drive Alone)	392	16	55	463
Driver of a carpool with all occupants from same household (Driver, Different Households)	56	14	6	76
Driver of a carpool with occupants different households (Driver, Different Households)	129	11	52	192
Subtotal, Drivers with Household Status	577	41	113	731
Passenger of a carpool with all occupants from same household (Passenger, Same Household)	28	9	4	41
Passenger of a carpool with occupants from different households (Passenger, Different Households)	113	15	50	178
Subtotal, Passengers with Household Status	141	24	54	219
Subtotal, Passengers or Drivers with Household Status	718	65	167	950
Driver of a carpool with no response identifying household status	4	0	0	4
Passenger of a carpool with no response identifying household status	2	0	0	2
Subtotal, Passengers or Drivers with Trip Purpose Known	724	65	167	956
Unknown Trips Purpose				
Driver traveling alone				6
Driver of a carpool with all occupants from the same household				1
Driver of a carpool with occupants from different households				2
Passenger of a carpool with all occupants from the same household				2
Passenger of a carpool with occupants from different households				2
Subtotal, Drivers or passengers with Unknown Trip Purpose				13
Grand Total, Drivers and Passengers	724	65	167	969

Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988.

The following paragraphs present the results of analyzing the responses received to the intercept surveys. To make the information presented as relevant as possible to the main question to be answered by this research, the summaries of survey responses are organized by trip purpose and vehicle occupancy so that differences

among variables can be more easily explained. As will be noted repeatedly, the responses reflect characteristics of travel made to downtown Phoenix, the State Capitol (office) complex and the Central Avenue Corridor and cannot be used to extrapolate conclusions about other parts of the region with different development patterns.[39]

Vehicle Occupancy. Taking into account the responses that indicated that some persons had been dropped off before the sample vehicle was intercepted at the parking site, resulted in the calculation of the following mean values for vehicle occupancies for travel to the central area of the Phoenix region: 1.16 home-based-work trips, 1.38 for home-based-other trips, and 1.32 for non-home-based trips. (The relative errors associated with the responses received for each trip purpose category were discussed on page 50.) The vehicle occupancies for vehicles transporting two or more persons to the central area of the Phoenix region were estimated to be as follows: 2.26 for home-based-work trips, 2.49 for home-based-other trips and 2.65 for non-home-based trips.

While exactly comparable data were not collected from the vehicle intercept surveys and the vehicle occupancy counts, it is possible to validly compare some of the rates derived from both sources of information. The vehicle occupancy calculated for the aggregation of all purposes of trips made to the central area of the region is 1.19, while the vehicle occupancy derived from the counts of vehicles traveling in the larger area of the region represented by Area Types 1 and 2 is 1.26.[40] There is no statistically valid reason that should be inferred as to why vehicle occupancies for carpools might be 5 percent higher for carpools traveling to the very core of the region than throughout the larger area encompassed by Area Types 1 and 2.

The responses to the vehicle intercept surveys were also used to calculate the percentages of vehicles by trip purpose and vehicle occupancy and corroborate the changes in vehicle occupancy by time of day noted from the counts of vehicle occupancy. As shown in Table 15, the largest percentages of vehicles with only the driver occur when persons are making home-based-work trips. (About 87.2 percent of all vehicles whose occupants responded that they were traveling for this trip purpose are transporting only the driver.)

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[39]See pages 19 and 20 for the descriptions of the boundaries of these areas and the reasons why the intercept surveys occurred there. While this report discusses the results of surveys for the combination of these geographic areas, the Intercept Surveys Data Binder submitted to MAGTPO contains tabulations of separate responses from each geographic area for parking cost and walking distance of the travelers' destinations.

[40]This vehicle occupancy was calculated by summing the numbers of vehicles counted by occupancy category in the area represented by Area Types 1 and 2 between 7:00 and 11:00 AM, the hours when most of the intercept surveys were accomplished. See page 17 and 19 to compare the boundaries of the two different areas. The vehicle intercept surveys were conducted at parking lots, garages and on-street segments located in or next to the most intensively developed blocks in Central Phoenix, while Area Types 1 and 2 include a much larger geographic area of the City of Phoenix.

Conversely, the smallest percentages of vehicles transporting only the driver are associated with home-based-other and non-home-based trip purposes. The differences in the percentages of drive alone and carpool trips made for those two trip purposes apply only to the area where the intercept surveys occurred. For example, a smaller percentage of home-based-other trips than on non-home based trips may be made in carpools because there are very few land uses in downtown Phoenix that would attract members of the same household for shopping or entertainment purposes during daytime hours, while there are businesses, public facilities and restaurants that would attract persons traveling together from their workplace or other non-home locations.

Numbers of Households in Carpool Trips. The data presented in Table 15, which are based on responses by drivers, also reveal that about 46 percent of all carpools whose occupants are traveling from home to work are transporting persons from the same household. In other words, according to the drivers' responses, only about 54 percent of all carpool trips made from home to work in the central area of Phoenix are being made by persons from different households.

Persons making trips from home to any location but work are far more likely to travel together with persons from their own household, as supported by the survey responses from drivers indicating that about 65 percent of the carpools whose occupants are making home-based-other trips are from the same household. On the other hand, persons making non-home-based trips are much more likely to travel together with persons from other households, because they are working or studying with many more persons from other households than from their own households. Only about 21 percent of all carpools whose drivers responded that they were traveling to accomplish non-home-based trips reported that they were transporting persons from the same household.

The passengers' responses to the question about the number of households from which the persons traveling in the (carpool) vehicle came from varied considerably from the drivers' responses, although the responses may represent a response bias. For example, as indicated by the data presented in Table 16, approximately 46 percent of all carpools formed for home-based-work trips carried persons from the same household according to the drivers' responses, but only about 18 percent did so according to the passengers' responses.

While there may be a response bias that resulted in receiving more responses from drivers of carpools comprised of persons from the same household than of drivers of carpools comprised of persons from different households, there is no doubt that the survey methodology generates two type of biases in responses from passengers. The first bias results from distributing the questionnaires when vehicles were intercepted arriving at a parking site. As will be discussed further in the next section, large percentages of persons traveling in carpools from the same household were dropped off somewhere before the vehicle they were riding in arrived at the parking site. Obviously those passengers did not even receive questionnaires to fill out. The second type of bias results from designing the survey to have occupants of the vehicle answer the questionnaire and not having all occupants of the vehicle be interviewed by the survey takers. Lower response rates from passengers who came from the same household as the driver, caused by these persons not being interested in filling out the same questionnaire as the driver, could be under-representing the existence of these passengers.

TABLE 15
PERCENTAGES OF TRIPS BY TRIP PURPOSE AND VEHICLE OCCUPANCY BY NUMBER OF SEPARATE HOUSEHOLDS IN VEHICLE[a]

Category of Occupancy[b]	Households in Vehicle					Total of Occupancy Category
	One	Two	Three	Four	Five+	
	(percent of all trips with same purpose)					
	Home-Based-Work Trips					
Drive Alone	87.1					87.1
Carpool, Same Household	5.8					5.8
Carpool, Different Household		5.9	1.0	0[c]		6.9
Unknown						.2
If Unknown Responses are Removed						
Drive Alone	87.2					87.2
Carpool, Same Household	5.8					5.8
Carpool, Different Household		5.9	1.0	.1		7.0
	Home-Based-Other Trips					
Drive Alone	74.6					74.6
Carpool, Same Household	16.4					16.4
Carpool, Different Household		8.1	.9			9.0
	Non-Home-Based Trips					
Drive Alone	80.6					80.6
Carpool, Same Household	4.0					4.0
Carpool, Different Household		9.1	3.2	2.6	.5	15.4

[a]Based on drivers' responses, with percentages calculated for each trip purpose.

[b]The categories of occupancy are defined by the responses provided to selected questions of the intercept survey questionnaire. See Appendix D for the classifications of vehicle occupancy used for this analysis.

[c]Rounded off from .04.

Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988.

TABLE 16
PERCENTAGES OF SEPARATE HOUSEHOLDS IN CARPOOL VEHICLES BY TRIP PURPOSE — COMPARISON OF DRIVERS' AND PASSENGERS' RESPONSES[a]

Responses From[b]	Households				
	Home-Based-Work Trips				
	Same	Two	Three	Four	Five or more
	(percent)				
Drivers					
Actual Distribution	45.9	46.1	7.6	0.3	0
Cumulative Distribution	45.9	92.0	99.6	100	
Passengers					
Actual Distribution	17.7	63.1	13.6	5.6	0
Cumulative Distribution	17.7	80.8	94.4	100	
	Home-Based-Other Trips				
Drivers					
Actual Distribution	64.8	31.7.	3.5	0	0
Cumulative Distribution	64.8	96.5	100		
Passengers					
Actual Distribution	25.0	51.4	11.2	3.0	9.5
Cumulative Distribution	25.0	76.4	87.6	90.6	100
	Non-Home-Based Trips				
Drivers					
Actual Distribution	20.6	47.0	16.4	13.3	2.7
Cumulative Distribution	20.6	67.6	84.0	97.3	100
Passengers					
Actual Distribution	7.6	66.6	14.4	9.2	2.3
Cumulative Distribution	7.6	74.2	88.6	97.8	100

[a]Carpool vehicles are those vehicles transporting two or more persons to accomplish a trip together.

[b]Percentages are calculated for each category of responses.

Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988.

The differences in driver's and passengers' responses are not statistically significant for the other two trip purposes. Only 49 responses were received from persons making home-based-other trips in carpools, with 23 of these from occupants of carpools from the same household and 26 from occupants of carpools from different households. These numbers of responses are too small to use to derive statistically valid conclusions. Finally, the responses received from persons making non-home-based trips may not only reflect the same biases as those described above for non-home-based-work trips, but the differences in responses from drivers and passengers making non-home-based trips are smaller than the relative error associated with the summaries of responses for that trip purpose.

Persons Dropped Off At Different Sites. Not all persons traveling together in carpools (or vanpools) travel together all the way from the same origin to the same destination. The responses to the intercept surveys indicate that whether or not persons are dropped off earlier is highly dependent on trip purpose and numbers of households represented in each carpool. As shown by the responses summarized in Table 17, only about 15 percent of the carpools comprised of persons from the same household making home-based-work trips have all occupants travel together all the way to the site where the vehicle is parked, and only about 57 percent of the carpools comprised of persons from different households have all occupants travel together to the parking site.

While persons may travel together in carpools to get to work in order to save money or because they have no other form of transportation available, persons will usually travel together for other trip purposes because they want to be together when they get to their common destination. That is why far greater percentages of carpools whose occupants are traveling together for home-based-other trips (about 81 percent) or non-home-based trips (also about 81 percent) have all occupants travel together to the vehicle's parking site, (as compared to carpools whose occupants are traveling together for home-to-work trips).

Household Income. The occupancy varied by trip purpose and whether or not persons traveling together came from the same household. As shown by the data summarized in Table 18, persons driving alone on home-based-work trips reported lower household incomes than persons carpooling together from the same household. In turn, persons carpooling together from the same household on home-based-work trips reported substantially higher incomes than persons traveling together from different households. The following average household incomes were reported for the combination of all trip purposes: persons driving alone--$42,000 drivers of carpools from the same household--$44,500 drivers of carpools from different households--$38,000 passengers of carpools from the same household--$39,000, and passengers of carpools from different households--$35,000.

The intercept questionnaire was not designed to provide direct explanations of the different distributions of household income by vehicle occupancy and number of households represented by persons traveling together. Nevertheless, the following factors may explain the differences noted:

TABLE 17
PERCENTAGES OF NUMBERS OF PERSONS DROPPED OFF BEFORE VEHICLE ARRIVED AT SURVEY LOCATION BY TRIP PURPOSE[a]

	Persons Dropped Off			
Category of Carpool	0	1	2	3
	(Percent)[b]			
	Home-Based-Work Trips			
Carpool, Same Household[c]	15.1	68.1	13.0	3.9
Carpool, Different Households[d]	57.1	28.0	9.9	5.0
All Carpools	37.8	46.3	11.3	4.5
	Home-Based-Other Trips			
Carpool, Same Household[c]	71.1	3.5	25.4	0
Carpool, Different Households[d]	100	0	0	0
All Carpools	81.3	2.3	16.4	0
	Non-Home-Based Trips			
Carpool, Same Household[c]	100	0	0	0
Carpool, Different Households[d]	76.0	15.0	0	9.0
All Carpools	80.9	12.0	0	7.2

[a]Based on responses provided by drivers.
[b]Percentages are calculated for each category of carpool.
[c]All occupants traveling together in those vehicles came from the same household.
[d]The occupants traveling together in those vehicles came from different households.
Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988.

TABLE 18
DISTRIBUTIONS OF VEHICLE OCCUPANCY BY HOUSEHOLD INCOME AND TRIP PURPOSE[a]

	Household Income					
Category of Occupancy[b]	Under $10,000	$10,000-$20,000	$20,000-$30,000	$30,000-$40,000	$40000-$50,000	$50,000 and over
	(percent)[c]					
	Home-Based-Work Trips					
	Actual Distribution					
Drive Alone	1.4	11.5	16.9	17.6	14.8	37.8
Carpool, Same Household	0	4.4	4.9	13.6	39.8	37.3
Carpool, Different Households	.7	32.0	11.6	10.0	29.1	16.7
	Cumulative Distribution					
Drive Alone	1.4	12.9	29.8	47.4	62.2	100
Carpool, Same Household	0	4.4	9.3	22.9	62.7	100
Carpool, Different Households	.7	32.7	44.3	54.3	83.4	100
	Home-Based-Other Trips					
	Actual Distribution					
Drive Alone	0	7.7	21.3	29.8	6.8	34.5
Carpool, Same Household	8.3	8.5	18.4	28.8	4.9	31.1
Carpool, Different Households	0	18.7	7.0	31.6	16.1	26.6
	Cumulative Distribution					
Drive Alone	0	7.7	29.0	58.8	65.6	100
Carpool, Same Household	8.3	16.8	35.2	64.0	68.9	100
Carpool, Different Households	0	18.7	25.7	57.3	73.4	100
	Non-Home-Based Trips					
	Actual Distribution					
Drive Alone	1.7	10.1	13.4	14.8	12.5	47.6
Carpool, Same Household	0	0	3.8	85.3	6.2	4.7
Carpool, Different Households	1.5	2.1	5.9	24.5	12.0	54.1
	Cumulative Distribution					
Drive Alone	1.7	11.8	25.2	40.0	52.5	100
Carpool, Same Household	0	0	3.8	89.1	95.3	100
Carpool, Different Households	1.5	3.6	9.5	34.0	46.0	100

[a]Based on responses provided by drivers.

[b]The categories of occupancy are defined by the responses provided to selected questions of the intercept survey questionnaire. See Appendix D for the classifications of vehicle occupancy used for this analysis.

[c]Percentages are calculated for each category of occupancy.

Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988.

1. Persons driving alone on home-based-work trips have household incomes that are high enough for them to not need or want to have to travel together to share travel-related costs. For example, whereas only 62.7 percent of persons driving alone reported household incomes of up to $50,000, 83.4 percent of the persons traveling together from different households reported that their household incomes were this high or lower.

2. At the same time, a greater percentage of persons driving alone may be living alone and not generating the same levels of household income as households with two or more persons in the labor force. For example, a greater percentage of persons driving alone reported household incomes of up to $40,000 (47.4 percent) than did persons traveling together from the same household (22.9 percent).

3. Greater percentages of persons from different households may be traveling together to accomplish their home-based-work trips because they need or want to reduce their travel-related expenses, because their household incomes are lower than those of other travelers. About 32.7 percent of the persons traveling together who came from different households reported household incomes of up to $20,000. However, only about 12.9 percent of persons driving alone and 4.9 percent of persons from the same household traveling together reported that they had the same household incomes.

Vehicle occupancies for home-based-other trips made to downtown Phoenix appear to be much less affected by household income characteristics than vehicle occupancies for home-based-work trips. The data presented in Table 18 indicate no statistically significant variation in household income by vehicle occupancy for this trip purpose. Persons appear to be traveling together to non-work locations in downtown Phoenix not because they need to save money, but because they want to travel together.

The relatively small number of responses makes it very difficult to determine if vehicle occupancies for non-home-based trips may be affected by household income characteristics. While about 89.1 percent of the occupants of carpools formed by members of the same household reported household incomes of up to $40,000, only 40 percent of persons driving alone and 34 percent of occupants of carpools coming from different households reported these same household income levels. Possible reasons for what may be statistically invalid distributions of household incomes can only be surmised and not derived from the intercept surveys.

Frequency of Making Trips. The number of times that the trips described in the intercept surveys are actually made vary greatly by trip purpose, with no discernible pattern associated with vehicle occupancy. As shown in Table 19, home-base-work

trips are made on a regular basis, with about 90 percent of all respondents declaring that they make that type of trip 5 days per week.

Persons making home-based-other trips reported that they make those trips on a much more infrequent basis, with some significant differences noted between responses from persons driving alone or traveling in carpools. Only about 25 percent of the persons who drive alone to make home-based-other trips indicated that they made the same trip 5 days per week. Most of the persons traveling in carpools also responded that they make the same trips from home to shopping, personal business, social recreation, or other non-work places fewer than 1 day per week.

The non-home-based trips made by persons intercepted for the surveys are also made very infrequently, although not as infrequently as home-based-other trips. At least half of all persons making trips from places other than home to other activities in downtown Phoenix reported that they make the same trip 4 or fewer days per week. While the numbers of responses received may be too small to identify differences where none may be statistically significant, the responses by persons from the same household traveling together indicate that the passengers make the carpool trip very infrequently. Those responses make it easier to accept the relatively high shares of non-home-based carpool trips estimated to be made by members of the same household. (The 20.6 percent of all carpool drivers who, as shown in Table 16, indicated that all occupants of the carpool traveling for a non-home-based work trip were from the same household are reporting trips that are made fewer than 2 days per week.)

Distance From Parking Site To Destination. The overwhelming majority of all respondents (at least 80 percent of all drivers and passengers who returned questionnaires) indicated that their destination was no more than one block away from their parking site. The average walking distances for all trip purposes were reported to be as follows: for persons driving alone — 0.7 blocks, for drivers of carpools from the same household — 0.5 blocks, for drivers of carpools from different households — 1.2 blocks, for passengers of carpools from the same household — 0.6 blocks, and for passengers of carpools from different households — 0.9 blocks. Indeed, as shown in Table 20, even approximately 90 percent of the persons traveling to work responded that they walk one block or less from their parking site to get to the place where they work.

With the exception of drivers of carpools whose occupants came from different households, approximately 90 percent of the persons traveling on non-home-based trips responded that they would be walking one block or less from their parking site to their actual destination. About 30 percent of the drivers of carpools whose occupants came from different households responded that they parked their vehicles six or more blocks away from their actual destination. This seems to be a surprisingly long distance for these persons to traverse, but it could be due to the very small number of respondents in the category (16) who wanted to reduce their parking costs by not parking at a fee garage or lot closer to their actual destination.

TABLE 19
FREQUENCY OF MAKING THIS TRIP[a]

	Number of Days Per Week or Month							
	1-3	1 per	2 per	3 per	4 per	5 per	6 per	7 per
Category of Vehicle Occupant[b]	Times per month	Week	Week	Week	Week	Week	Week	Week
	(Percent)							
	Home-Based-Work Trips							
Drive Alone	1.8	0.7	1.2	2.6	2.3	86.6	4.3	0.5
Driver, Same Household	0	4.0	0	0	0.3	91.3	0	4.5
Passenger, Same Household	0	0	0	3.2	2.5	91.3	3.0	0
Driver, Different Households	0.3	0	0.7	0.4	1.5	90.2	6.5	0.5
Passenger, Different Households	0	3.7	2.9	1.3	1.2	88.4	2.5	0
	Home-Based-Other Trips							
Drive Alone	54.0	0	9.4	11.4	0	25.3	0	0
Driver, Same Household	84.0	15.6	0	0	0	0	0	0
Passenger, Same Household	35.8	16.5	33.5	0	0	14.2	0	0
Driver, Different Households	87.1	12.9	0	0	0	0	0	0
Passenger, Different Households	66.3	19.6	8.5	5.7	0	0	0	0
	Non-Home-Based Trips							
Drive Alone	12.5	21.5	9.6	9.5	7.4	34.7	4.9	0
Driver, Same Household	0	19.0	0	0	0	81.0	0	0
Passenger, Same Household	71.5	0	28.5	0	0	0	0	0
Driver, Different Households	18.8	16.8	5.9	17.6	1.7	27.2	0	12.0
Passenger, Different Households	44.6	32.1	5.4	0	2.4	12.6	3.1	0

[a]This is the trip on which the respondents were traveling when their vehicle was intercepted and selected for the survey.

[b]The categories of occupancy are defined by the responses provided to selected questions of the intercept survey questionnaire. See Appendix D for the classifications of vehicle occupancy used for this analysis.

Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988.

TABLE 20
DISTANCE WALKED FROM PARKING SITE TO DESTINATION

	Place to Where Traveler is Distanced Away From Parking Site							
	Same Building	Same Block	1 Block	2 Blocks	3 Blocks	4 Blocks	5 Blocks	6 or More Blocks
Category of Vehicle	(Percent)							
Drive Alone	51.2	28.6	11.6	3.6	1.6	1.0	0.4	2.0
Driver, Same Household	62.9	23.1	9.5	3.2	0	0.9	0	0.3
Passenger, Same Household	55.5	31.0	8.0	0	2.8	2.7	0	0
Driver, Different Households	39.7	35.9	15.7	2.3	4.2	0.4	0.4	1.3
Passenger, Different Households	44.0	26.5	13.0	11.0	1.6	1.0	2.3	0.6
	Home-Based-Other Trips							
Drive Alone	10.9	40.8	13.6	20.8	0	0	0	13.9
Driver, Same Household	13.9	32.4	47.4	6.3	0	0	0	0
Passenger, Same Household	41.1	12.4	24.9	9.2	0	0	0	12.4
Driver, Different Households	10.0	43.0	25.7	14.8	0	0	0	6.5
Passenger, Different Households	15.2	18.0	33.4	5.4	22.8	0	0	5.2
	Non-Home-Based Trips							
Drive Alone	38.3	26.1	23.1	6.5	4.1	0	0	1.9
Driver, Same Household	44.8	0	48.3	6.8	0	0	0	0
Passenger, Same Household	75.3	0	24.8	0	0	0	0	0
Driver, Different Households	9.2	36.7	12.6	7.0	0	2.9	1.8	29.9
Passenger, Different Households	33.9	33.8	21.2	7.5	1.8	0	0	1.9

Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988.

About 13 percent of drivers traveling alone and passengers of carpools from the same household reported that they would walk six or more blocks to get to their non-work destination (when they were traveling from home). This also seems to be a surprisingly long walking distance for persons making home-based-other trips to traverse, but it could be due to the small numbers respondents in these categories (2 drivers and 1 passenger) who wanted to reduce their parking costs. (The incidences of parking fees paid by persons traveling for different trip purposes are presented in Table 24.)

Travel Distances and Times. The following two sources of information were used to calculate the distances and times for the trips made by persons responding to the intercept surveys:

1. The locations of the places described as being the origins of the trips were geographically coded so that a data file could be created assigning zone numbers from MAGTPO's traffic analysis zone system to each origin response.

2. Each of the parking garages selected for the surveys was defined to represent the destination zone of the travelers who parked at each garage because the responses that about 90 percent of all drivers and passengers walked fewer than 2 blocks away from their parking site to their actual destination. (A traffic analysis zone number from MAGTPO's zone system was then assigned to each parking garage.)

MAGTPO's AM peak highway network was used to calculate the travel distances and times between each trip's origin zone and destination zone. The reports of travel distances were then classified by the categories of vehicle occupancy and by the 5-mile increments shown in Table 21.

The average distance traveled by all respondents (for all trip purposes) was calculated to be about 10.6 miles, with the following average distances calculated by category of traveler: persons driving alone— 10 miles, drivers of carpools from the same household — 11 miles, drivers of carpool from different households — 9 miles, passengers of carpools from the same household — 11 miles, and passengers of carpools from different households — 8 miles. While it is not surprising to see that persons in carpools from the same household are traveling longer distances than persons driving alone (11 miles vs 10 miles), the expectation that persons who carpool travel longer distances seems to be contradicted by the survey responses which show that persons in carpools from different households are actually traveling the shortest distances. However, given that this study's intercept surveys took place in central Phoenix and given that lower income households in Phoenix (the ones that the survey responses show share rides among households at higher rate) are located primarily near central Phoenix, this survey's conclusions may not be applicable in other parts of Phoenix or other metropolitan areas.

No major differences in the distances traveled by persons driving alone or in carpools to get from home to work are exhibited by the data summarized in Table 21. The median distance traveled by persons making home-based-work trips to

downtown Phoenix was between 10 and 15 miles, except that passengers from different households reported a median distance between 5 and 10 miles. Persons in carpools from the same household were estimated to be making slightly longer trips than persons driving alone or carpools formed by members of different households.

Differences in distances traveled by persons making home-based-other trips are not significant among vehicle occupancy categories. Too few responses were received to ascertain if the differences reported between persons in carpools whose occupants come from different households and other persons making home-based-other trips are statistically viable.

Non-home-based trips were reported to be much shorter than trips made for other purposes. Those responses coincide with the expectation that the majority of non-home-based trips are made to a place near the traveler's place of work. Persons driving alone reported slightly longer distances to accomplish their non-home-based trips than persons in carpools, perhaps reflecting the capability of a person traveling alone to travel further by not losing travel time to pick up or drop off passengers.

The responses validate the contention that carpools comprised of persons from different households getting together for home-based trips are usually made up by drivers who travel from origins further out than their passengers. Both the responses by drivers and passengers from different households making home-based-work and home-based-other trips indicate that the passengers are traveling shorter distances (anywhere from 0 to 5 miles shorter) than the drivers, even for carpool trips shorter than 20 miles.

Persons traveling in carpools to make non-home-based trips, unlike persons traveling in carpool to make non-home-based trips, reported that they traveled the same distances, even when the occupants of the carpools came from different households. Persons who get together to form carpools for non-home-based trips, unlike persons who get together to form carpools for home-based trips, want or need to travel together from the same origin to the same destination.

The data presented in Tables 17 and 21 clarify the point that carpool journeys, especially for home-based trips, do not have the same origin and the same destination. Large percentages of carpools transporting persons from the same household do not transport all the persons to the same destinations. Smaller, but still noteworthy, percentages of carpools making home-based trips from different households do not transport all the persons to the same destinations. Carpools have the same origins and destinations for all their occupants only when people are traveling together to make non-home-based trips.

TABLE 21
CUMULATIVE TRAVEL DISTANCES BY TRIP PURPOSE AND CATEGORY OF VEHICLE OCCUPANCY

	Miles[b]							
Category of Vehicle Occupant[a]	5	10	15	20	25	30	35	40
	Percent[c]							
	Home-Based Work Trips							
Drive Alone	19.4	49.2	80.1	94.4	98.7	99.5	99.5	100
Driver, Same Household	8.9	38.6	67.0	95.4	100			
Passenger, Same Household	7.5	32.7	73.9	100				
Driver, Different Household	8.0	42.3	80.0	96.7	98.8	99.4	99.7	100
Passenger, Different Households	22.3	53.4	85.1	95.6	98.3	98.3	99.4	100
	Home-Based-Other Trips							
Drive Alone	13.0	38.3	76.8	93.2	93.2	93.2	100	
Driver, Same Household	34.7	47.2	90.5	94.4	94.4	94.4	100	
Passenger, Same Household	0	41.1	70.6	84.1	100			
Driver, Different Household	0	28.8	58.5	64.6	100			
Passenger, Different Households	22.9	67.3	72.1	84.6	84.6	96.3	100	
	Non-Home-Based Trips							
Drive Alone	54.1	70.2	87.1	98.3	98.3	100		
Driver, Same Household	95.9	100						
Passenger, Same Household	100							
Driver, Different Household	86.7	95.4	98.9	98.9	98.9	100		
Passenger, Different Households	75.6	92.9	97.7	100				

[a] The categories of occupancy are defined by the responses provided to selected questions of the intercept survey questionnaire. See Appendix D for the classifications of vehicle occupancy used for this analysis.

[b] The data presented in this table are based on using the responses to calculate inter-zonal distances derived from the MAGTPO modeling zone system. (The responses were used to create geographic data files for trip origins and destinations that were coded to represent MAGTPO zones).

[c] Percentages are calculated for each category of vehicle occupant.

Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988.

Average travel times derived from survey responses (but calculated using MAGTPO's AM highway network times between zones) exhibit the same pattern for the vehicle occupant categories as the average travel distances discussed above. The average travel times for all trip purposes for persons driving alone (21 minutes) are slightly shorter than for occupants of carpools from the same households (19 minutes) and passengers of carpools from different households (18 minutes).

The travel times presented in Table 22 reflect the conclusions described above for the travel distances associated with different trip purposes and occupancy categories. The mean travel times for trips to the central area of Phoenix were estimated to be 20-25 minutes for home-based-work trips, but 25-30 minutes for home-based-work trips by carpools from the same household; 20-25 minutes for home-based-other trips (with too few responses to explain the statistical validity of the differences presented in Table 22); and 5-10 minutes for non-home-based trips.

Possible Time Savings If Not Carpooling. Drivers and passengers of carpools were asked if they would save time and how much time they would save if they were to make the same trip by driving alone. Only the responses that came from drivers were analyzed, however, because drivers and passengers of carpool from the same household would be (almost always) covering the same distance and as indicated in Table 21, drivers responded that they traveled further than passengers to form carpools from different households. Passengers of carpools from different households would only be able to reduce their travel times if they had a vehicle available that they could use to drive alone.

The responses summarized in Table 23 indicate that the vast majority of drivers of carpools traveling to downtown Phoenix believe that they would save only 5 or fewer minutes if they were not in a carpool. Almost all (100 percent) of the drivers of carpools making home-based-other trips or non-home-based trips said that they would save 5 or fewer minutes if they were to drive by themselves to accomplish the same trips. There are two probable reasons for these responses. First non-home-based trips are too short (see Table 22) for trips in carpools to take noticeably more time than driving alone. Second, for both home-based-other and non-home-based trips, the drivers may be responding that they do not anticipate making the same trips if they were not traveling together with other persons.

The largest potential savings in travel times were reported by drivers of carpools making home-based-work trips. These responses are in keeping with the longer distances traveled by drivers of these carpools (than by drivers of other carpools) to complete their own home-to-work journey and pick up their passengers.

Parking Costs. About 70 percent of all persons who responded to the surveys said that they did not have to pay to park their vehicle in the central area of Phoenix.[41]

[41]This percentage is reported in the printout of parking cost responses included in the Intercept Surveys Data Binder.

TABLE 22
CUMULATIVE TRAVEL TIMES BY TRIP PURPOSE AND CATEGORY OF VEHICLE OCCUPANT

Category of Vehicle Occupant	Minutes[a] 5	10	15	20	25	30	35	40	45	50	55	60
	(Percent of vehicle occupant category)											
Drive Alone	4.6	12.5	23.7	42.9	59.4	77.6	91.1	96.8	98.2	99.5	100	
Driver, Same Household	.5	.9	18.4	36.7	47.1	66.3	90.2	95.4	95.8	100		
Passenger, Same Household	0	3.4	19.0	28.5	41.3	73.6	84.0	93.3	100			
Driver, Different Household	0	1.0	9.0	37.8	57.5	72.5	91.7	97.6	98.9	99.4	100	
Passenger, Different Households	2.8	11.5	30.0	45.1	63.4	85.8	92.3	95.9	97.0	98.1	98.7	100
						Home-Based-Other Trips						
Drive Alone	0	13.0	18.2	31.8	49.2	76.5	93.2	93.2	93.2	93.2	93.2	100
Driver, Same Household	0	0	34.7	43.3	81.2	90.5	94.5	94.5	100			
Passenger, Same Household	0	0	27.5	27.5	57.0	84.1	84.1	84.1	84.1	100		
Driver, Different Household	0	0	10.0	17.8	27.7	64.6	64.6	100				
Passenger, Different Households	17.1	22.9	22.9	41.7	67.3	77.1	77.1	88.8	96.4	96.4	100	
						Non-Home-Based Trips						
Drive Alone	35.3	47.3	60.1	64.3	72.4	88.8	96.6	100				
Driver, Same Household	5.1	57.0	100									
Passenger, Same Household	67.6	100										
Driver, Different Household	60.1	84.7	87.8	94.9	97.2	98.9	98.9	100				
Passenger, Different Households	26.8	71.1	80.2	95.1	95.1	97.7	97.7	97.7	97.7	100		

[a] Based on coding the responses received and deriving the travel times between traffic analysis zones from MAGTPO's AM peak highway network.
Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988.

TABLE 23
POSSIBLE TIME SAVINGS IF CARPOOLERS HAD BEEN TRAVELING ALONE, BY TRIP PURPOSE[a]

	Minutes						
Type of Driver	0	5	10	15	20	25	30
	(Percent)[b]						
Driver, Same Household							
Actual Distribution	61.4	3.3	16.8	18.6	0	0	0
Cumulative Distribution	61.4	64.7	81.5	100			
Driver, Different Household							
Actual Distribution	48.2	16.2	14.6	5.2	12.3	0	3.5
Cumulative Distribution	48.2	64.4	79.0	84.2	96.5	96.5	100
	Home-Based-Other Trips						
Driver, Same Household							
Actual Distribution	96.5	3.5	0	0	0	0	0
Cumulative Distribution	96.5	100					
Driver, Different Household							
Actual Distribution	81.7	0	0	10.0	0	8.3	0
Cumulative Distribution	81.7	81.7	81.7	91.7	91.7	100	
	Non-Home-Based Trips						
Driver, Same Household							
Actual Distribution	100	0	0	0	0	0	0
Cumulative Distribution	100						
Driver, Different Household							
Actual Distribution	98.9	1.1	0	0	0	0	0
Cumulative Distribution	98.9	100					

[a]Carpoolers are persons traveling together to accomplish a trip. Responses used in this table were provided by drivers.

[b]Percentages are calculated for each type of driver.

Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. March and April 1988.

About 70 percent of the persons making home-to-work trips reported that free parking was provided to them, while only about 54 percent of all persons making home-base-other trips reported that they found free parking. About 75 percent of the persons making non-home-based trips stated that they did not pay for parking, but the significance of that statistic is clouded by the fact that about half of the responses received from persons making home-based-work trips came from persons who stated that they were destined back to work.[42]

The detailed distributions of responses to the question about parking costs shown in Table 24 identify very few statistically valid differences between the costs of parking paid by persons driving alone or carpooling. One difference is that about 84 percent of the persons in carpools reported that they parked for free, compared to about 68 percent of the persons who drove alone. As employers are not providing free parking to carpool vehicles, the most likely explanation of this difference is that persons who travel in carpools want to save money and are parking in nearby free lots or on-street spaces. The number of responses received from persons making home-based-other trips is too small to identify statistically valid differences for those trips. While about 75 percent of all persons making non-home-based trips reported that they parked for free, only about 18 percent of the persons who traveled in carpools from the same household reported that they parked for free. As differences in parking costs should only be attributed to differences in parking costs associated with different types of land uses at the destination ends of non-home-based trips, and as there were too few responses received from persons in this category to compare their origin and destination trip ends to those reported by other persons making non-home-based trips, no statistically valid differences among parking costs should be inferred for non-home-based trips and different vehicle occupancies.

Other Data Collected. Not all of the information that can be derived from the responses to the intercept survey questionnaires have been presented and discussed in this report. Data files have been created for the following types of responses, but are not discussed here for the following reasons:

1. Trip purpose at the origin of the trip and at the destination of the trip. The MAGTPO travel demand model structure uses three trip purposes — home-based-work, home-based-other and non-home-based — for trip generation and mode split. Those three trip purposes have been used to classify the responses received.

2. Relationship to the driver. First, the responses from passengers of carpools provide information that duplicates the information used to categorize occupants of carpools into coming from the same or different households. Second, these responses provide only additional details about the familial relationships among carpool occupants.

[42]This percentage is reported in the printout of responses to the question about trip purposes at the destination included in the Intercept Surveys Data Binder.

TABLE 24
DAILY PARKING COSTS BY VEHICLE OCCUPANCY AND TRIP PURPOSE[a]

	Daily Parking Costs[b]																		
Category of Vehicle	Free	$0.25	$0.50	$0.75	$1.00	$1.25	$1.50	$1.75	$2.00	$2.25	$2.50	$2.75	$3.00	$3.25	$3.50	$4.00	$4.50	$6.00	$8.00
	(Percent)																		
	Home-Based=Work Trips																		
Drive Alone	67.9	.1	6.4	3.1	1.6	2.7	6.0	2.0	4.7	.6	2.7	.9	.3	.5	.4	0	0	0	0
Carpool, Same Households	83.3	.5	.6	4.9	0	.5	5.0	5.4	0	0	0	0	0	0	0	0	0	0	0
Carpool, Different Household	84.4	0	1.4	7.0	.3	5.3	.5	0	1.1	0	0	0	0	0	0	0	0	0	0
	Home-Based-Other Trips																		
Drive Alone	50.9	6.5	6.2	0	6.5	0	13.3	5.2	5.0	0	0	0	0	0	0	6.2	0	0	0
Carpool, Same Households	71.4	0	0	28.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpool, Different Household	45.5	0	0	10.0	0	0	24.9	6.5	0	0	0	0	0	0	6.5	0	0	6.5	0
	Non-Home-Based Trips																		
Drive Alone	77.0	1.7	2.0	2.2	6.1	2.6	3.9	0	0	0	3.0	1.7	0	0	0	0	0	0	0
Carpool, Same Households	17.8	0	3.8	0	0	36.3	0	0	0	0	42.2	0	0	0	0	0	0	0	0
Carpool, Different Household	83.2	0	0	1.4	2.1	3.6	1.1	0	0	3.2	0	0	0	0	1.9	0	1.9	0	1.7

[a]Based on responses provided by drivers. Weekly costs were converted to daily costs by dividing by 5 and monthly costs were converted to daily costs by dividing by 22.

[b]Percentages are calculated by category of vehicle. If cost values are not shown, then no responses were submitted for those parking costs.

Source: Vehicle intercept surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988.

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3. Arrangements for paying for parking by carpool occupants. As the large majorities of persons sharing rides stated that they did not pay for parking, very small numbers of respondents would be represented in this data summary. In addition, this information would not explain differences among vehicle occupancy categories.

4. Driver's license. The questionnaires were only distributed to adults. As all drivers are expected to have a valid driver's license, summarizing those responses would not have provided information relevant to this research. Almost 95 percent of all passengers indicated that they did have a driver's license and were able to drive.[43] This is not a surprising statistic, because children did not receive questionnaires and very few adults do not have a driver's license. (Note: The questionnaire did not include a question about having a vehicle available to make the same trip by driving alone.)

[43]This percentage is reported in a printout included in the Intercept Surveys Data Binder.

4. EVALUATION OF EXISTING VEHICLE OCCUPANCY MODELS FOR THE PHOENIX AREA

This research project was intended to achieve two related and sequential purposes. First, detailed information was to be generated about which characteristics of travelers or their travel could be identified as determinators of vehicle occupancy. Second, possible changes in the modeling process used by MAGTPO would be recommended so as to reflect the conclusions reached about vehicle occupancy determinators.[44]

The different types of information collected from the vehicle occupancy counts and the vehicle intercept surveys were presented and analyzed in the previous chapter. The ways in which specific types of information were used to arrive at recommendations for changing MAGTPO's modeling procedures to better reflect the conclusions drawn about vehicle occupancy determinators are discussed in this chapter.

The approach followed in this task was to compare the inputs (variables) needed and outputs (forecasts) created by the existing travel demand models against the vehicle occupancy counts and intercept responses discussed in the previous chapter. To clarify how the conclusions reached in this analysis helped define changes, and in some cases the lack of changes, to the existing travel demand models, this chapter is organized as follows:

1. The next section — Existing Regional Travel Demand Models — explains the structure, content and development of the models affecting simulations of vehicle occupancy in the Phoenix metropolitan area.[45]

2. The section after that one — Comparisons of Existing Model Forecasts and New Data — presents differences of similarities in vehicle occupancy between a simulation of existing travel and vehicle occupancy data extracted from the counts and intercept surveys. The significance of the differences noted is explained in that section using both statistical parameters and travel demand theory.

3. The last section — Recommended Modeling Changes — discusses which of the components of the travel demand models used in Phoenix could be refined using the information collected during this research.

A. Existing Regional Travel Demand Models

Not all of the components of the existing modeling process used in the Phoenix region would be affected by the conclusions reached in this research about vehicle occupancy determinators. The following paragraphs describe the types of models that comprise the set of travel demand models run by MAGTPO and explain why only some of the models would directly affect simulations of vehicle occupancy.

[44]A completed description of the purposes of this research is presented on page 2.

[45]The work simulations as used here refer to using travel demand models to create estimates of current or past travel forecasts of future travel.

The four major models that comprise the set of travel demand models used by MAGTPO fall into the following traditional and basic categories: trip generation, trip distribution, mode choice and assignment.[46] Of these modeling categories, only that of mode choice would be affected by this research. The trip generation models are not related to vehicle occupancy because these models produce forecasts of trips made by persons from individual analysis zones or to individual analyses zones, and not trips made by persons in vehicles. The trip distribution models would also not affect simulations of vehicle occupancy because these models take the outputs of the trip generation models and create simulations of trips made by persons traveling between each pair of analysis zones in the region. The trip distribution models produce simulations of trips by persons traveling between each pair of analysis zones, not simulations of trips by persons traveling in vehicles or other modes of travel.

The mode split models, the ones that split the simulations of trips by persons traveling between a pair of analysis zones in the region into trips in vehicles or transit, comprise the first category of models that would affect simulations of vehicle occupancy. Typically, mode choice models split person trips into trips made by persons driving alone, persons driving or riding in private vehicles transporting two or more persons and persons riding transit. For some metropolitan areas, mode split models have been formulated to separate person trips even further, into those made by persons in carpools of two persons and those made in carpools of three or more occupants.

The following modes are recognized by the Phoenix mode choice models: one — private vehicle trips made by the driver traveling alone; group — private vehicle trips made by two or more persons traveling together; and transit — trips made by persons using bus routes or rail lines.[47]

The Phoenix mode choice models are based on a logit formulation which relates the probability of choosing a specific node by using the following equations:

$$P_i = \frac{Ui}{U_k}$$

Where:

P_i is the probability of choosing mode i,

u_i is a linear function of the descriptors of modal alternative i, and

e^{uk} are linear functions of the descriptors of all the modal alternatives for which a choice is feasible.

[46]Separate models were actually developed and are applied to create separate simulations of trips generated, trips distributed and trips split by mode for the three following trip purposes: home-based-work, home-based-other, and non-home-based. The assignment model uses the sums of all trips distributed between zone pairs by mode to simulate numbers of vehicle trips on roadway segments and numbers of person trips on transit route segments.

[47]Barton-Aschman Associates, Inc., Development and Calibration of Travel Demand Models for the Phoenix Area. For Maricopa Association of Governments Transportation and Planning Office. June 1984, p. 79.

The normal convention for logit models is to have the linear functions (the U's) specified as a linear equation and the U's the negative value of the linear equation, as in the following examples: Mode A = 0.01*Mode A Time + 0.02*Mode A cost + Mode A constant; and U_A = Mode A. This convention is followed by the Phoenix mode choice models, as shown by the mode split equations for each trip purpose listed in Table 25.

The mode choice model equations presented in Table 25 were formulated to create a complete set of travel demand models for MAGTPO to use. The models were calibrated using data from a home interview survey conducted in 1981, travel speed surveys, an on-board transit rider survey conducted in 1981, and numerous highway vehicle counts.[48] The responses from the 1981 home interview survey were used as the basis for vehicle occupancy parameters included in the mode choice models. Specifically, the group mode occupancy values by trip purpose listed in Table 25 were used to calculate the numbers of vehicles transporting two or more persons. (When estimates of group mode vehicle trips are added to the estimates of vehicles carrying only the driver, the Phoenix mode choice models produce the overall vehicle occupancies presented in Table 26.)

To complete the process of developing the travel demand models for the Phoenix metropolitan area, the ability of the entire model set to produce acceptable simulations of travel was evaluated. That is, statistical comparisons were made of the simulated assignments of vehicle volumes and transit person trips against counts of vehicle volumes and transit person trips. Estimates of vehicle miles of travel by area type and facility type and vehicle volumes assigned at selected roadways produced by the models' assignment process were compared against estimates of vehicle miles travel demand from responses to the home interview survey and counts of vehicle volumes, respectively.

B. Comparison of Existing Model Forecasts and New Data

In the original model validation process, vehicle occupancy outputs were directly compared against actual data only at the regional level for home-based-work trips. As the responses received from the home interview survey were used to establish the vehicle occupancies to be used in modeling each of the three trip purposes, separate data that could be used for comparison purposes existed only for work-related trips. For those trips, the Bureau of the Census reported that both in 1970 and 1980, the daily vehicle occupancy in the Phoenix region had been 1.13.[49] By comparison, the mode split equations applied to simulations of home-based-work trips produce a vehicle occupancy of 1.10 for the Phoenix region.[50] (The approximately 3 percent difference between those two occupancy rates may be due to differences between the 1980 Journey-to-Work Census and the 1981 Household Survey in sample sizes and specific definitions of responses.)

[48]The transit mode choice models were refined in 1988 using data from an on-board transit rider survey conducted in 1986.

[49]Federal Highway Administration, Journey-to-Work Trends. Based on 1960, 1970, and 1980 Census, July 1986.

[50]This number is derived from comparing the simulations of person trips and vehicle trips by trip purpose.

TABLE 25

MODE SPLIT EQUATIONS FOR PHOENIX MODE CHOICE MODELS

HOME-BASED-WORK MODE CHOICE MODEL

Transit = 0.0332*WALK + 0.0319 WAIT TWO + 0.0769* WAIT ONE + 0.0078* FARE + 0.0145* TRN RUN + 0.1005 * AUTO RUN + 0.0588 * TXFERS + AUTO PENALTY (I) * AUTO CONN[a] [b]

One = 0.0693 * HWY EXC + 0.145 * HWY RUN1 + 0.0078 HWY COST1 + Income Coefficient (1, 1) * INCOME[a] [b]

Group = 0.0174 * HWY EXC + 0.0145 * HWY RUN2 + 0.0078 HWY COST2+ Income Coefficient (2, 1) * INCOME[a] [b]

The group mode vehicle occupancy value is 2.18 for all income groups[c]

Coefficients by Highway Mode Income Group are as follows:

Income Group	Coefficient for Highway Mode: One	Group
1	-1.3617	1.1058
2	-1.7807	0.5199
3	-2.3857	-0.1508

Auto penalty coefficients by income group are as follows:

Income Group	Auto Penalty (I)
1	1.0607
2	0.8251
3	0.2301

HOME-BASED-OTHER MODE CHOICE MODEL

Transit = 0.0165 * WALK + 0.0198 * WAIT ONE + 0.0231 * WAIT TWO + 0.0116 * FARE + 0.0066 * TRN RUN + 0.0066 * AUTO ACC + 1.7826 (I) * AUTO CONN + INCOME COEFFICIENT (I) * INCOME [a] [b]

One = 0.0403 * HWY EXC + 0.0066 * HWY RUN1 + 0.0116 * HWY COST1 + 0319* HWY PRKCST1[a] [b]

TABLE 25 (Continued)

MODE SPLIT EQUATIONS FOR PHOENIX MODE CHOICE MODELS

HOME-BASED-OTHER MODE CHOICE MODEL

Two = 0.2828 * HWY EXC + 0.0066 * HWY RUN2 + 0.116 * HWY COST2 + 0.0316 * HWY PRKCST2[a] [b]

Income coefficients by mode are as follows:

Income Group[c]	Transit Coefficient	One Coefficient
1	1.8576	1.2113
2	2.0694	-0.4297
3	2.5754	-0.6707

The group mode vehicle occupancy value is 2.35 for all income groups.

[a] All times are specified in minutes and all costs are specified in cents.

[b] The independent variables used in the Mode Choice Models are:

Transit Variables

- WALK ○ Walk time to and from the transit system
- WAIT ONE ○ The waiting time to board the first transit vehicle
- WAIT TWO ○ The waiting time to board the second and subsequent transit vehicle
- TRN RUN ○ The time spent riding in a transit vehicle
- AUTO ACC ○ The time spent riding in an automobile to access the transit system.
- FARE ○ The cost of using transit (i.e., the fare)
- TXERS ○ The number of transfers required
- AUTO CONN ○ A dummy variable signifying if an automobile was required to access the transit system (0 is no, 1 is yes)

Highway Variables

- HWY RUN (X) ○ The time spent riding in the automobile, by highway mode X.
- HWY COST (X) ○ The out-of-pocket cost of the automobile, including a cost per mile. Total highway cost is divided by the occupants of the vehicle to obtain the cost for highway mode X.
- HWY EXC ○ The time spent parking and unparking the vehicle
- HWY PRKCST ○ One-half of the parking cost which is also divided by the occupants of the vehicle

Socioeconomic Variables

- INCOME ○ The three income groups consist of low, medium and high income tertiles. The income tertiles have the following income ranges:

Income Tertile	Range ($,1980)
1	0-$14,735
2	$14,736-$26,605
3	$26,606+

Source: Barton-Aschman Associates, Inc., Mode Choice Model Update for the Phoenix Region. Regional Public Transit Authority. March 1988, pp. 23, 25, 27.

TABLE 25 (Continued)

MODE SPLIT EQUATIONS FOR PHOENIX MODE CHOICE MODELS

The group mode vehicle occupancy value is 2.35 for all income groups.

NON-HOME-BASED MODE CHOICE MODEL

Transit = 0.038 * (WALK) + 0.0393 * (WAIT ONE + WAIT TWO) + 0.0047 * FARE + 0.0131 * TRN RUN + 0.0131 * AUTO ACC + 1.5469 * AUTO CONN + 4.6187

One = 0.2423 * HWY EXC + 0.0131 * HWY RUN1 + 0.0047 * HWY COST1 + 0.0291 * HWY PRKCST1 - 0.5915

Two = 0.3048 * HWY EXC + 0.0131 */ HWY RUN2 + 0.0047 * HWY COST2 + 0.0291 * HWY PRKCST2

The group mode vehicle occupancy value is 2.31 for all income groups.

Vehicle occupancy values derived from applying the existing travel modes were compared against both the summaries of responses from the intercept surveys and the vehicle occupancy counts. Two types of comparisons were required because the intercept survey responses provide vehicle occupancy data about travel to downtown Phoenix by trip purpose, while the vehicle occupancy counts provide vehicle occupancy data by area types and facility types but not by trip purpose. Furthermore, the vehicle intercept survey responses provide statistically significant data primarily for home-based-work trips and the vehicle occupancy counts cannot be stratified both by area type and facility type without greatly increasing the relative errors of those estimates. Nevertheless, the comparisons described below provide valid indications of the sensitivity of the existing mode split models to factors affecting vehicle occupancy.

To determine how the existing mode split models respond to inputs describing parking costs at the destination ends of trips, the responses to the vehicle intercept surveys were compared against vehicle occupancy values derived from the models for a simulation of travel to zones in downtown Phoenix. The occupancy rates presented in Table 26 were compiled from the vehicle intercept survey responses and from the mode split model's simulation of 1985 trips attracted to the aggregation of analysis zones where the intercept surveys occurred.

The existing mode split models produce a higher vehicle occupancy rate for simulations of home-based-work trips attracted to downtown Phoenix (1.13) than throughout the region (1.11). That 2 percent difference is caused solely by the differences in parking costs described to all-day parking available in downtown Phoenix and the almost universally free parking available throughout the rest of the region. (Downtown Phoenix contains the vast majority of sites where travelers have to pay for parking.)

TABLE 26
COMPARISON OF VEHICLE OCCUPANCIES FOR DOWNTOWN PHOENIX[a]

Trip Purpose	Vehicle Intercept Surveys[b]	Model Outputs[c]
	All Vehicles	
Home-Based-Work	1.16	1.13
Home-Based-Other	1.38	1.70
Non-Home-Based	1.32	1.43
	Vehicles With Two or More Occupants	
Home-Based-Work	2.26	2.18[d]
Home-Based-Other	2.49	2.35
Non-Home-Based	2.65	2.31

[a]The vehicle intercept surveys occurred in the downtown core of Phoenix, the State Capitol (office) Complex, and the Central Avenue Corridor. The boundaries of these areas are defined on page 20.

[b]These are summaries of responses received to surveys conducted by Barton-Aschman Associates, Inc. during March and April 1988. Vehicles arriving at a sample of parking sites were intercepted between about 7:00 A.M. and 2:00 P.M.

[c]These are the numbers of persons per vehicle derived from the mode choice models'. Simulations of daily trips attracted in 1985 to the traffic analysis zones where the intercept surveys occurred.

[d]These are regional values used as inputs, no area specific values are used.

The existing model simulation of vehicle occupancy for home-based-work trips attracted to downtown Phoenix is lower than the value derived from the vehicle occupancy surveys (1.13 vs 1.16). That 2.5 percent difference can be explained from two different perspectives. Using one perspective, that difference can be explained as not being statistically significant, given the standard error associated with the survey responses received. Applying another perspective, the survey responses may reflect the existence of higher parking costs not reflected in the inputs used to produce the simulation of existing travel and also increases in vehicle occupancy caused by rideshare promotion programs.

The existing mode split models produce higher vehicle occupancy rates for simulations of home-based-other trips attracted to downtown Phoenix (1.70) than throughout the region (1.51). That 12.5 percent difference is caused, like the difference in vehicle occupancy rates for home-based-work trips, by the fact that parking costs are charged for parking associated with non-work land uses in downtown Phoenix but not in almost all other locations in the region.

The existing models' simulation of vehicle occupancy for home-based-other trips attracted to downtown Phoenix (1.70) cannot be directly compared to the responses received from the intercept surveys (1.38). Not only were too few responses received to the intercept surveys from persons making home-based-work trips, but the intercept surveys were not conducted during evening hours or near locations where greater numbers of persons making home-based-other trips would have been traveling in carpools.

As with the other two trips purposes, the existing mode split models produce a higher vehicle occupancy rate for non-home-based trips to downtown Phoenix (1.43) than throughout the region (1.29). That 11 percent difference is also due to the higher parking costs occurring in downtown Phoenix.

The existing models' simulation of vehicle occupancy for non-home-based trips attracted to downtown Phoenix (1.43) is higher than the vehicle occupancy rate derived from the intercept surveys (1.32). That 8 percent difference may not be statistically significant given the relative error associated with the number of survey responses received, as well as the travel models' simulation for a particular area of the region.

In the second type of comparison, the vehicle occupancies derived from a simulated assignment of vehicle trips were compared to the vehicle occupancy counts by area type and facility type. Table 27 shows the vehicle occupancy rates calculated directly from the counts collected during ten hours at a sample of locations throughout the region, the 24-hour occupancy rates derived from those rates, and the occupancy rates associated with a mile-weighted assignment of vehicle trips and vehicle person trips. Finally, that table also presents the regional vehicle occupancy rate that is produced by the mode split models. That vehicle occupancy rate is weighted by person trips, unlike the other ones shown under Model Assignment which are weighted by mileage of the roadway segments in each facility type and geographic area.

The vehicle occupancies listed in Table 27 cannot be directly compared to each other because those listed under assignment model reflect the bias resulting from weighting trips by the distance of the roadway segments over which the trips were assigned. The mileage-induced bias is why the regional vehicle occupancy rate produced by the mode split models (1.31) is significantly lower than the one produced by the mile-weighted average of rates from all geographic areas in the region (1.36). Nevertheless, the mode split models do seem to logically produce trip tables that reflect slightly higher vehicle occupancy rates for longer distance trips. For that reason, the model's occupancy rates are nearly identical to the counts for the central parts of the region, but begin to diverge at the outer and rural areas with longer distances between roadways and longer trips.

B. Recommended Modeling Changes

The comparisons between model outputs and data collected by this research discussed in the previous pages have shown the following about the travel models used by MAGTPO, as far as simulations of vehicle occupancy are concerned:

1. The regional overall daily vehicle occupancy rate produced by the models (1.31) is nearly identical to the rate derived from the counts (1.33).

2. The mode split model for home-based-work produces a simulated vehicle occupancy rate (1.13) which is only 2.5 percent lower than that derived from the intercept surveys conducted in downtown Phoenix.

3. There were not enough responses received from the intercept surveys to determine if vehicle occupancies for the other two types of trips are properly simulated.

4. The regional overall daily occupancy rate for carpools of two or more occupants produced by the models (2.32) is only 2 percent higher than value derived from the counts.

5. The mode split models are producing slightly higher vehicle occupancies for longer-distance trips, reflecting the conclusions of the intercept surveys and the counts.

Given all of these findings, only two changes are recommended to MAGTPO's models at this time. One would be to utilize the responses to the 1988 home interview survey to validate the vehicle occupancy values for home-based-other and non-home-based trips. The other change would be to produce peak-hour assignments of vehicle trips that are based on differentiating the diurnal distributions of trips by purposes. That recommendation is discussed further below.

TABLE 27

COMPARISON OF VEHICLE OCCUPANCIES BY AREA TYPE AND FACILITY TYPE

	Vehicle	Occupancy	Counts
	10-Hours[a]	24-Hours[b]	Assignment Model[c]
Area Types 1 and 2	1.28	1.30	1.32
Area Type 3	1.32	1.33	1.36
Area Type 4 and 5	1.37	1.39	1.37-1.45
Freeways	1.29	1.30	1.41
Expressways			1.48
Minor Arterials			1.36
"Slow Speed" Arterials			1.33
Major Arterials	1.35	1.36	1.38
All Facilities in Region	1.32	1.33	1.36
Mode Split Models[d]			1.31

[a]The vehicle occupancy counts occurred between the hours of 7:00 AM to 12:00 PM and 2:00 PM to 7:00 PM.

[b]These vehicle occupancy rates are derived from the vehicle occupancy counts by applying factors to represent the relationships between typical vehicle occupancy rates in other hours to the vehicle occupancy rates for the hours when the counts occurred. See page 27 for further details.

[c]The values shown are based on mile-weighted assignments of vehicles and persons in vehicles.

[d]This is the value derived for the mode split models' outputs.

As demonstrated by this research, vehicle occupancy rates vary greatly by trip purpose. Because different trip purposes represent different proportions of all trips made at different times of the day, vehicle occupancies vary greatly by time of day.

The assignment model used by MAGTPO produces a peak-hour assignment of trips that reflects the daily distribution of trip purposes. This occurs because the MAGTPO assignment model produces a 24-hour capacity-restrained assignment for which a roadway link's 24-hour capacity is calculated by dividing the hourly capacity by 0.1. The simulated vehicle occupancy derived from the peak-hour assignment is too high compared to actual values for both the AM and PM peak hours because home-based-work trips (which have the lowest vehicle occupancies) comprise a greater proportion of peak-hour trips than of daily trips. This bias could be overcome by producing peak-hour vehicle assignments that are based on the percentages of peak-hour trips represented by each trip purpose.

5. CONCLUSIONS

This research produced extensive information about vehicle occupancies in the Phoenix region that shows how vehicle occupancies change by time of day and locations. Responses to vehicle intercept surveys were used in combination with vehicle occupancy counts to try to define determinators of vehicle occupancy and explain their significance.

The information and conclusions derived from the analysis of data collected for this research are described in detail in the three previous chapters. This chapter presents a summary of the key conclusions developed from analyzing the data collected in the Phoenix metropolitan area and recommendations on how to interpret that data both for applications in the Phoenix metropolitan area and in other cities.

Transportation planners and others who have conducted research into what factors affect the decisions made by persons to travel together in private vehicles have reached general agreement on what the most important factors are. Although research has been done by different agencies and at different levels of sophistication to try to understand why persons travel together in private vehicles to make work trips, very little research has been done to identify why people travel together to make non-work trips. As a result, the long list of factors presented in Table 27 represents the results of research primarily into work travel behavior. While some of the factors listed in Table 28 do affect what vehicle occupancies turn out to be for non-work travel, the relative importance of these or other factors is not as well understood (as it is for work travel).

The analysis of vehicle occupancy data collected from this research shows that vehicle occupancy rates vary by time of day, roadway facility type and geographic area. The following conclusions are based on reviewing the vehicle occupancy data summarized in Table 6 and depicted in Figures 2 through 6:

1. The lowest vehicle occupancy rates occur during the AM peak period, while the highest vehicle occupancy rates occur during the midday or early evening hours.

2. The lowest vehicle occupancy rates occur in the core area of the region (surrounding downtown Phoenix) and the highest in the outlying suburban areas.

3. Vehicles traveling on freeways were counted as having lower occupancy rates than vehicles traveling on arterials and collectors.

Causes for those relationships cannot be directly ascertained from just counts of vehicle occupancy, likely reasons for those relationships are provided by the responses to the vehicle intercept surveys. The following explanations are not based solely on evaluating the characteristics of the Phoenix metropolitan area, but are also the result of considering the similarities in travel patterns that exist across metropolitan areas:

TABLE 28

CHARACTERISTICS TYPICALLY USED TO EXPLAIN VEHICLE OCCUPANCY

Characteristics of the Travelers	Age Income Auto Availability Workers per Household Martial Status Occupation Household Size Licensed Drivers per Household Salary Level
Characteristics of Travel	Trip Purpose Trip Distance Frequency of Making the Trip Length of Residence at Same Address Length of Employment at Same Location Work Hours (Schedule, Flexibility) Parking Cost (and Availability) at work place
Attitudinal Perceptions	Convenience Reliability Comfort Potential for Time Savings Potential for Cost Savings Waiting for Others Traveling with Others Reducing Driving Stress

Source: Kostynivk, Ledia P. State-of-the-Art Review of Demand Analysis for Ridesharing. U.S.D.O.T. Transportation Systems Center, July 1980. Pp. 21-38.

1. The lowest numbers of persons traveling together occur when commuting to work is the predominant trip purpose, for home-based-work trips exhibit the lowest vehicle occupancy rates of any trip purpose. Home-based-work trips represent the greatest proportion of all trips purposes made during the AM peak hour of travel than they do of all trips made during any other periods of the day. (During the PM peak period of travel, trip purposes other than traveling to or from work represent a larger percentage of all trip purposes than they do during the AM peak period.)[51]

2. The highest numbers of persons traveling together occur when persons are traveling for purposes where they need or want to travel together. Going shopping or to different forms of entertainment are the most likely trip purposes that are accomplished by groups of persons who want to be together when they get to their common destination. These non-work related trips represent the greatest proportion of all trip purposes made during the off-peak hours of the day. (Obviously, these are also the times when the proportions of home-to-work or work-to-home trips are the lowest). For these reasons, vehicle occupancies were recorded as always being higher during off-peak hours, regardless of roadway facility class or geographic area.

3. Vehicles traveling in the core area of Phoenix were recorded as having lower occupancy rates than vehicles in other areas primarily because this area of the region contains far fewer land uses that would attract non-work trips. Conversely, this area of the region attracts more work-related and (probably) personal business travel than other areas of the region.

4. Vehicles traveling in the outlying urbanized areas and the non-urbanized areas of the Phoenix region were recorded as having the highest occupancy rates, regardless of time of day or facility class. Simply reversing the descriptions of the characteristics of the core and outer areas of Phoenix presented in point three (above) provides the most direct explanation of this finding. For instance, there are more self-contained retirement communities located in outlying areas of the Phoenix region than in the interior of the urbanized area. The social-recreational purpose of the majority of the trips made by the persons living in the retirement communities and those persons' less-than-universal capability to drive is likely to result in higher vehicle occupancies per daily trip than for younger residents of the region. In addition, there are probably more elementary and high schools per

[51] In a separate study of vehicle occupancy at places of work throughout the Phoenix region conducted in 1986, the regional vehicle occupancy rate for work-related travel was estimated to be 1.12. Vehicle occupancy by area type ranged from 1.10 for Area Type 2 and 3, to 1.12 for Area Types 1 and 4, and 1.19 for Area Type 5 (which included one manufacturing firm reported to have a large proportion of low income workers.) These vehicle occupancy rates, which show generally very little difference among area types, are similar to the rates for work-related travel identified in this research.

square mile in those outlying residential areas than in other parts of the region. As a result, home-based-non-work trips, which exhibit high occupancy rates, are probably occurring at a higher proportion of all trip purposes occurring in those residential areas.

5. Vehicles traveling on freeways have lower occupancy rates than vehicles traveling on arterials and collectors because of differences in the trip purposes served by the two categories of highways. As home-based-work trips are generally the longest-distance trips made, those trips represent a higher proportion of all trips made on freeways, particularly during peak commute hours.

Occupancy rates for carpools (vehicles transporting 2 or more persons) vary by time of day, facility class and area type, much as do overall vehicle occupancy rates. As indicated by the data summarized in Table 7, carpool vehicle occupancy rates in the Phoenix metropolitan area vary as follows:

1. The lowest occupancy rates for carpools occur during the AM peak period, while the highest rates occur during the PM peak period and early evening hours. The preponderance of work trips as a proportion of all trips made during the AM peak period, and the low carpooling rates associated with work trips are the primary reasons for this finding.

2. At all time of day, the lowest occupancy rates for carpools were counted for carpool vehicles traveling on freeways in the higher density areas of the region surrounding downtown Phoenix. Carpool vehicles traveling on arterials and collectors in this same part of the region were counted as having the highest carpool vehicle occupancy rates during the AM and midday hours. Carpool vehicles traveling on arterials and collectors in outlying suburban areas were counted as having the highest carpool vehicle occupancy rates during PM and early evening hours.[52]

The vehicle occupancy counts also provide information showing: 1) how the percentages of the persons traveling in vehicles carrying one or two or three or more persons vary by time of day, and 2) the relationships between the percentages of all vehicles by vehicle occupancy and the percentages of all persons traveling categorized by vehicle occupancy. The regional summaries of vehicle occupancy counts have been used to calculate the percentages of vehicles and travelers presented in Tables 9, 10 and 11. Analysis of the data in those tables supplements the findings described earlier about changes in vehicle occupancy, as follows:

[52]The dispersal of land uses such as schools, shopping centers, restaurants, and parks throughout all areas of Phoenix means that residents of the region do not have to travel far to reach these kinds of uses that attract a higher rate of vehicles transporting two or more persons. For that reason, it is not surprising that vehicle occupancy rates on arterials and collectors were counted as being higher than on freeways. This may be viewed as an explanation that applies in many metropolitan areas in the United States. However, it is also possible that Phoenix's low ratio of freeway miles per capita causes fewer trips (or portions of trips) to the types of neighborhood or sub-regionally oriented land uses that attract a higher rate of carpool vehicles to occur on Phoenix's freeways.

1. The largest percentages of trips in vehicles transporting only the driver occur during the AM peak period, while the lowest percentages occur during off-peak hours of the day.

2. Conversely, the largest percentages of trips in vehicles transporting two or more persons occur during off-peak hours, while the lowest percentages occur during the AM peak period.

3. Similarly, the largest percentages of persons traveling in vehicles transporting two or more persons occur during off-peak hours and the smallest percentages during the AM peak period.

4. Freeways serve lower percentages of vehicles transporting two or more persons than do arterials and collectors. While differences between the two facility classes exist for all hours of the day, the greatest differences occur during the PM peak period.

5. The differences in the percentages of vehicles transporting two or more persons served by freeways and by arterials and collectors are caused primarily by the percentages of vehicles transporting three or more persons.

6. While at least 70 percent of all vehicles are usually transporting only the driver, thus making carpools a minority of vehicles on the road, carpool travelers comprise much greater shares of all persons traveling in vehicles. This distinction between vehicles and travelers is vital when describing market shares of travelers by time of day.

7. The percentages of vehicles transporting three or more persons are much smaller than the percentages of vehicles transporting two persons.

In summary, the analysis of vehicle occupancy counts of the Phoenix metropolitan area indicates that the highest vehicle occupancies on weekdays occur on lower-volume roadways, and during off-peak hours. The lowest weekday vehicle occupancies occur on higher-volume roadways (particularly freeways) and during peak hours of travel (particularly during the AM peak when work trips predominate). Vehicles transporting only the driver represent the majority of all vehicles at almost all hours of the day, but persons traveling in carpools (of two or more persons) represent about half of all persons traveling in vehicles during off-peak hours. Finally, and maybe most importantly, what is said about vehicle occupancy has to be precise enough to account for the variations identified among times of day, facility classes and geographic areas.

The 1988 vehicle occupancy rate of 1.33 for all trips throughout the day estimated for the Phoenix metropolitan area is in line with recent estimates for similar urban areas.[53] Nationwide research and local travel surveys have concluded that daily

[53]As the vehicle intercept surveys were conducted only in downtown Phoenix, vehicle occupancy rates by trip purpose derived from this study are valid only for downtown Phoenix and not for the entire region.

vehicle occupancy rates are very similar for different metropolitan areas, typically ranging between 1.30 and 1.45 during the 1980's.

While vehicle occupancy rates have tended to decline in other metropolitan areas, Phoenix's vehicle occupancy rates have remained stable during the 1970's and 1980's. Perhaps the main reason for this stability is that Phoenix's development patterns and demographic changes over (at least) the last twenty years have been consistent with those of other high-growth cities in Sunbelt States. In other words, metropolitan areas are becoming more like Phoenix has been throughout the last forty years, with low density dispersed development making it very difficult for people to share rides. For that reason, all of the information collected in this research about vehicle occupancy determinators should be transferable to other metropolitan areas with the same demographic characteristics and development patterns as Phoenix.

APPENDIX A

ABSTRACTS OF SELECTED REFERENCE MATERIALS

DISCUSSING VEHICLE OCCUPANCY[1]

[1]Other reference materials, actually directly used to define the survey procedures used in this research, are presented in Section A. — Literature Search of Chapter 2. — Study Design and Data Collection Procedures.

A STUDY OF TRAVEL BEHAVIOR FOR RETIREMENT COMMUNITIES. VOLUME I: FINAL REPORT

Shapiro, P.
Comsis Corporation, 11501 Georgia Avenue, Suite 312 Wheaton, Maryland 20902; Arizona Department of Transportation, 205 South 17th Avenue, Phoenix Arizona 85007.
July 1986, 70 p.
REPORT NO: FHWA/AZ-86-224-I
SUBFILE: HRIS
AVAILABLE FROM: National Technical Information Service 5285 Port Royal Road, Springfield, Virginia 22161

The purpose of this survey, conducted for the Arizona Department of Transportation, was to identify how travel characteristics of the residents of a retirement community, particularly Green Valley, Arizona, are different from those of the surrounding metropolitan area. Of particular interest was how trip generation, trip distribution, and vehicle occupancy might be different from those currently assumed in the regional modeling process. This Technical Report summarizes the results of the Green Valley Travel Survey and also described how the PAGTPD travel models were modified to reflect the travel behavior of this self-contained retirement community. The Green Valley travel diary survey was completed by 668 households between March 6 and March 21, 1985. The survey data indicate that: 1) the average Green Valley household made 7.7 vehicle person trips as compared to 7.48 trips generated by the regional model for the average medium income household; 2) the average vehicle occupancy is 1.38 persons/vehicle as compared to 1.51 persons/vehicle that would be predicted by the regional model; 3) a smaller percentage of trips by Green valley residents are home-based-work trips than would be predicted by the regional model; 4) the average length of trips made by Green Valley residents is considerably shorter than would be predicted by the regional model; and 5) less than 6 percent of Green Valley residents are under 60 years of age. The implications of the survey findings on the regional travel demand forecasting process are to take the following actions: 1) treat Green Valley zones as a special generator through the application of unique household size and household trip rates; 2) apply vehicle occupancy rates unique to trips originating in the retirement community; and 3) reclassify employment in the retirement community to community shopping center rather than other non-retail. Volume I — Final Report, Volume II — Appendices.

SPECIAL-PURPOSE TRAVEL SURVEYS

Norris, BB; Shunk, GA
Transportation Research Board
Transportation Research Record No. 1097, 1986, pp. 20-22
SUBFILE: HRIS; UMTRIS
AVAILABLE FROM: Transportation Research Board Publications Office 2101 Constitution Avenue, NW Washington D.C. 20418

Regional travel forecasting models often assume that trip generation rates are stable over time. Though the validity of this assumption is confirmed with regard to overall trip rates per household, the assumption is less applicable to disaggregated trips. It is the contention of this paper that because of the demographic and labor-force transformations of the 1970s and 1980s, the composition of person trips has changed through a relative decline in the share of home-based/non-work trips, as well as through an absolute drop in the average number of these trips per household. Paralleling this decline has been a rise in the shares and numbers of home-based-work and non-home-based trips. A comparison of the results with other metropolitan areas suggests that, in general, rates for special-purpose trips are more likely to be stable cross-sectionally than inter-temporarily. According to the 1984 Dallas-Fort Worth travel survey, an average household made 8.68 trips per day, a rate that has remained fairly stable since 1964. Person trips per person and vehicle trips per person, however, have had a pronounced increase since 1964 reflecting the smaller household size and lower automobile occupancy rates of the recent decade. The results of the 1984 travel survey also indicate that (a) the average trip length in the metropolitan area is about 7 miles, (b) the average trip duration is 17 to 19 min., (c) the automobile occupancy rate is 1.13 for work trips and 1.5 for non-work trips, (d) the transit mode share is 1.7 percent, and (e) the peak-hours of travel are between 7-8 AM and 5-6 PM.

PASSENGER CAR COMFORT AND TRAVEL DECISIONS

Neumann, ES; Romansky, ML; Plummer, RW (West Virginia University)
London School of Economic and Political Science.
Journal of Transport Economics and Policy, Vol. 12 No. 3, Sept. 1978, pp 231-243.

Despite attempts to introduce smaller cars in the United States, Americans still preferred larger cars. Passenger cars produced since 1956 show large changes in characteristics affecting the comfort of occupants. Measures of physiological stress and subjective discomfort were taken in a laboratory environment representing the extremes in comfort represented by current car designs. Twenty-five male subjects between the ages of 18 and 39 were used. Noise and temperature were the main variables examined. Significantly different physiological consequences were discovered, as were noticeable differences in the subjective acceptability of the environments. Evidence was found to suggest that if cars became less comfortable (for example, if energy constraints necessitated the design of less comfortable cars) drivers might prefer to decrease the duration of trips. This effect might be the most noticeable for vacation trips and the least likely for work trips. It was concluded that the concept of stress could not easily be incorporated into travel forecasting models and that reactions to laboratory tests may well be different from those experienced under actual driving conditions.

TRANSPORT EFFICIENCIES AND VEHICLE OCCUPANCY RATES

Bers, Eric L.
Interstate Commerce Commission, Washington, D.C.
HS-027 011, “Transportation and Energy,” New York, 1978 Monograph 1978, p. 358-69.

Intercity and intracity travel modes in the U.S. were investigated in terms of existing energy consumption (Btu/passenger-mile), with focus on passenger loadings per vehicle for each type of modal service. The study was designed to identify methods for increasing vehicle occupancies and to determine their resulting effect on transportation efficiency. Current transportation consumption patterns are documented followed by a series of policy choices for achieving higher vehicle loadings. The brokerage approach to higher occupancy levels of paratransit is explained, as well as for private automobile and conventional transit. The primary duty of the agent (broker) is to market programs selected by the respective jurisdictions; the programs are merged into a single implementation package, developed according to the site-specific conditions of the area. A strong marketing effort is required to raise vehicle occupancy rates. Advantages of the program are that new technology is not required and that travel preferences are unaffected. Presented at Urban Transportation Div., American Society of Civil Engineers, Specialty Conference, Washington, D.C., 22-24 May 1978.

TRAVEL ANALYSIS AND IMPLICATIONS FOR THE FUTURE
Sweet, CE, Jr.; Tidwell, E (Sweet (CE) and Associates)
Institute of Transportation Engineers, 1997, pp. 497-503.
SUBFILE: EIT; HRIS; UMTRIS
AVAILABLE FROM: Engineering Societies Library, 345 East 47th Street, New York, New York 10017.

The paper reports on a study to evaluate results from various policy scenarios tested in the SANBAG Mode Choice Model used for travel forecasting. An attempt was made to predict transit ridership if one or a combination of several changes occur in the factors affecting travel characteristics in the San Bernardino Valley Metropolitan area. All tests were made using variations of two basic transportation systems — a historical base of 1970 highway and transit networks and future year systems networks. The policy variables tested were auto operating costs, auto parking costs (in major commercial areas), transit running speed, transit fares, and auto occupancy. The scenarios tested were identified as Base, Moderate, and Extreme. Compendium of Technical Papers of the 47th Annual Meeting of the Institute of the Transportation Engineers at the Fourth World Transportation Engineers Conference, Mexico City, October 2-6, 1977.

CHARACTERISTICS OF TRAVEL IN THE BALTIMORE REGION

Goodman, CR; Rosapep, T.
Regional Planning Council, 701 Saint Paul Street, Baltimore, Maryland 21202.
December 1976, Spec Report 41 p.
REPORT NO: BLT/RPC-79/002
AVAILABLE FROM: National Technical Information Service 5285 Port Royal road Springfield Virginia 22161.

A concerted effort is being made in the Baltimore region to deal with travel and its implications on personal mobility, traffic congestion, job accessibility, economic development, parking shortages, air quality and energy consumption. To assist this effort, information has been collected on the characteristics of the region's travel. In summary, travel in the region is currently: peaked (60 percent of commuter work trips are made during short rush hours); auto dependent (88 percent of peak trips

are in automobiles); work trip dominated; dominated by long trips (80 percent of commuter traffic on trips longer than 10 miles one way); made in low occupancy vehicles; and diffused.

SHORT-TERM IMPLICATIONS OF SELECTED TRANSPORTATION POLICY ALTERNATIVES

Goodman, CR; Rosapep, TJ; Bent, MD; Mordecai, JM.
Regional Planning Council, 701 Saint Paul Street Baltimore, Maryland 21202.
May 1977, Spec Rpt 63 p.
REPORT NO. BLT/RPC-77/002
SUBFILE: NTIS; HRIS; UMTRIS
AVAILABLE FROM: National Technical Information Service 5285 Port Royal Road Springfield Virginia 22161.

The Continuing, Comprehensive, and Cooperative (3-C) Transportation Planning Process recently completed an analysis of travel demand likely by the year 1985. The primary conclusion of the analysis is that peak traffic is likely to continue increasing. In may locations, traffic conditions will significantly deteriorate unless actions are taken to reduce the growth in peak vehicular traffic or to construct and improve highways. Several alternatives could reduce the projected increase in vehicular traffic volumes. The purpose of this report is to determine how effective each alternative would be in reducing traffic demand, fuel consumption and auto emissions. Each alternative was explored independently to provide a thorough understanding of the potential ramifications. The implications of seven alternatives are estimated for the year 1985.

CARPOOL INFORMATION PROJECT: INNOVATIVE APPROACHES IMPROVE RESULTS

Scheiner, JI; Keiper, SA (Booz-Allen and Hamilton, Incorporated; Luzerne County, Pennsylvania
Transportation Research Record No. 619, pp 16-18.
SUBFILE: HRIS
AVAILABLE FROM: Transportation Research Board Publications Office 2101 Constitution Avenue, NW Washington D.C. 20418

The purpose of this paper is to describe and evaluate the Wilkes-Barre carpool information system. The carpool information project was one of three elements that comprised the Transportation Action Plan for Energy Conservation in Wyoming Valley. Three approaches were used to compile the data base from which carpool lists could be formulated. Each approach was aimed at a different target population, and their results were markedly different. The area wide approach included radio, television, and newspaper marketing effort to provide public information on the use and value of carpooling. The major employers program included the use of a grid map, posting announcements, and distribution forms. The third alternative, labor union participation, provided names and other necessary information on their members. The evaluation process was directed at measuring the incremental impact of the program to create more use of carpooling, beyond that which was already being practiced. The relatively low level of new carpool information in the study area in 1974 was attributed to the following factors: there

were no incentives to car poolers, or disincentives for single-occupant cars — for the duration of the carpool information system, gasoline was plentiful in the area, at the beginning of the project, the area already had a high level of car pooling and transit use, and during the project, the unemployment rate in the area hindered new carpool formation.

MANUAL TECHNIQUES AND TRANSFERABLE PARAMETERS FOR URBAN TRANSPORTATION PLANNING
Sosslau, AB; Carter, MM; Hassam, AB (Comsis Corporation; Peat, Marwick, Mitchell and Company)
Transportation Research Board
Transportation Research Record No. 673, 1978, pp. 32-40.
SUBFILE: HRIS; UMTRIS
AVAILABLE FROM: Transportation Research Board Publications Office 2101 Constitution Avenue, NW Washington, D.C. 20418

This paper summarizes research conducted under the National Cooperative Highway Research Program to identify contemporary transportation policy issues and to evaluate current travel estimation models and procedures in terms of their abilities to respond to such issues. A set of manual techniques and transferable parameters corresponding to the commonly used four-step transportation planning process is described. Brief descriptions are provided for trip generation, trip distribution, mode choice, traffic assignment, time-of-day characteristics, car occupancy factors, capacity analysis, and land development and highway spacing relationships. The travel estimation material developed has been organized in the form of a user's guide, which also include applications to three scenarios of realistic situations. The manual methods are more advantageous than the computer methods in that transferable parameters allow for quick response in terms of the time required to collect and process local information.

QUICK-RESPONSE URBAN TRAVEL ESTIMATION TECHNIQUES AND TRANSFERABLE PARAMETERS. USERS'S GUIDE
Sosslau, AB; Hassam, AB; Carter, MM; Wickstrom, GV (Comsis Corporation)
Transportation Research Board
NCHRP Report No. 187, 1978, 229 p.
SUBFILE: HRIS; UMTRIS
AVAILABLE FROM: Transportation Research Board Publications Office 2101 Constitution Avenue, NW Washington D.C. 20418

This report provides detailed descriptions of manual techniques for use in each aspect of travel demand estimation, i.e., trip generation, trip distribution, modal choice, auto occupancy, time-of-day distribution, traffic assignment, capacity analysis, and development density versus highway spacing relationships. Numerous charts, tables, and nomographs are included to simplify each analysis step. Data requirements are also reduced by making maximum use of transferable parameters developed from other studies and urban areas. Three scenario applications of the manual techniques are included to illustrate the potential usefulness of the various analysis techniques. Much of the information contained in the report is also applicable to computer analysis. The presentation of the procedures is structured to allow their utilization by transportation planners with

various levels of experience. A companion document, NCHRP Report 186, described and evaluates other manual and computer methodologies that are available.

TRAVEL ESTIMATION PROCEDURES FOR QUICK RESPONSE TO URBAN POLICY ISSUES
Sosslau, AB; Hassam, AB; Carter, MM; Wickstrrom, GV (Comsis Corporation)
Transportation Research Board
NCHRP Report No. 186, 1978, 70 p.
SUBFILE: HRIS; UMTRIS; NTIS
AVAILABLE FROM: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22561

The results of a 2-phase effort are presented here. In Phase I, policy issues facing transportation planning agencies were identified by on-site visits to agencies at the state, regional and county levels. Questionnaire responses from urban areas, planning documents and literature were reviewed. Policy issues were compiled and classified and the demands placed on travel estimating procedures were determined. Available estimation procedures were compiled, cataloged, described and evaluated. Phase I recommended that a set of capabilities be developed that include: simplified computerized methods for the 4-step (trip generation, distribution, mode split and traffic assignment) procedure that is efficient and will provide quick response at the regional and subarea level; an efficient, policy-sensitive procedure that would evaluate transportation service and cost changes in terms of economics and social and environmental impacts on a macro basis, manual methods useful for short-range application at the corridor and project level. A Users Guide was developed in Phase II to describe transferable parameters, factors, manual techniques, and the like to enable the user to carry out a simplified analysis without the need for reference to other sources. The Guide covers the following planning elements: transportation planning; trip generation; trip distribution; mode choice; auto occupancy; time-of-day distribution; traffic assignment; capacity analysis; and development density; highway spacing relationships. The Guide also illustrate how models may be changed or modified and applied to provide a quicker and less expensive planning tool.

ENERGY SAVINGS FOR WORK TRIPS: ANALYSIS OF ALTERNATIVE COMMUTING PATTERS FOR NEW JERSEY
Lutin, JN (Princeton University)
Transportation Research Board
Transportation Research Record No. 561, 1976, pp. 23-36.
SUBFILE: HRIS; UMTRIS
AVAILABLE FROM: Transportation Research Board Publications Office 2101 Constitution Avenue, NW Washington D.C. 20418

This paper analyzes energy consumption for work trips in New Jersey. Prepared as an aid to the New Jersey Task Force of Energy, it develops a methodology to quantitatively compare alternative transportation policies intended to reduce energy consumption. Data were obtained on work trip distribution, transit patronage, and modal split for each of the 21 counties in New Jersey for 1970. From these data, work trip lengths and automobile and transit occupancy rates were calculated.

Based on these as inputs to a model that predicted total work trip energy by utilization, the total daily energy consumption was computed for work trips of New Jersey residents. Modal split, energy per vehicle mile (kilometer), and vehicle occupancy rates were then varied to test alternative strategies for reducing energy consumption. In general, the results of this analysis showed that, given current work trip patterns, greater savings in energy could be achieved by using automobiles than by increasing public transit patronage. Specific policy recommendations were then outlined for automobile and public transit planning.

SPECIAL STUDY — ST. LOUIS CENTRAL BUSINESS DISTRICT
Sheehan, EM; Hubbard, JR
East-West Gateway Coordinating Council, 112 North Fourth Street, Suite 1200, St. Louis Missouri 63102
June 1978, Final Rpt. 62 p.
REPORT NO: EWG-ES-0364-10-2
SUBFILE: HRIS; UMTRIS
AVAILABLE FROM: East-West Gateway Coordinating Council 112 North 4th Street, St. Louis Missouri 63102

This study documents the results of efforts to develop current socioeconomic and transportation data on a detailed level needed for major transportation planning efforts to be undertaken in the near future. The data developed includes pedestrian counts, peak-hour cordon line traffic counts, employment estimates and auto occupancy counts.

PHOENIX METROPOLITAN AREA EXTERNAL TRIP STUDY. VOLUME I: FINAL REPORT
Barton-Aschman Associates, Incorporated 180 South Lake Avenue, Suite 510 Pasadena California 91101; Arizona Department of Transportation 206 South 17th Avenue Phoenix, Arizona 85007.
December 1986, 24 p.
REPORT NO.: FHWA/AZ 86/226-1
SUBFILE: HRIS; UMTRIS
AVAILABLE FROM: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

The Maricopa Association of Governments Transportation Planning Office is updating the computer models used to prepare forecasts of traffic volume in the Phoenix area. One element of the modeling effort involves external travel or trips having both origin and destination outside the area but passing through the area. Roadside interviews were conducted to gather data on such trips to aid in model calibration. Specifically, data was gathered on the following items: trip origin, trip destination, trip purpose, vehicle garaging location, vehicle occupancy, vehicle classification, and vehicle registration. The document describes the procedures utilized in the gathering of the described data.

PHOENIX METROPOLITAN AREA EXTERNAL TRIP STUDY. VOLUME II: SURVEY PROCEDURES MANUAL
Barton-Aschman Associates, Incorporated 180 South Lake Avenue, Suite 510 Pasadena California 91101; Arizona Department of Transportation 206 South 17th Avenue Phoenix Arizona 85007
December 1986, 33 p.
REPORT NO: FHWA/AZ 86/226-11
SUBFILE: HRIS; UMTRIS
AVAILABLE FROM: National Technical Information Service 5285 Port Royal road Springfield Virginia 22161

The Maricopa Association of Governments Transportation Planning Office is currently involved in a major effort to update all aspects of the transportation model for the Phoenix Metropolitan Area. One component of the model estimates external travel and the purpose of this study is to update the external trips portion of the model to reflect current conditions and state of the art advancements. In performing this task an extensive literature search was conducted and new methodologies examined. Sampling procedures were developed and coding and factoring of sample results was accomplished and documented. Based on the sample results, an external trip model was developed and the transferability of that model to other areas was described.

DEMOGRAPHIC CHANGE AND RECENT WORK TRIP TRAVEL TRENDS, VOLUMES I AND II. FINAL REPORT
O'Hare, W; Morris, M
Joint Center for Political Studies 1301 Pennsylvania Avenue, NW, Suite 400 Washington D.C. 20004.
February 1985, 320 p.
REPORT NO: UMTA-DC-09-7009-85
SUBFILE: UMTRIS
AVAILABLE FROM: National Technical Information Service 5285 Port Royal Road Springfield Virginia 22161

Release of the 1980 Census information on the journey to work provides an opportunity to study recent changes in work-trip patterns in more detail than was previously possible. In this 2 volume report, data from the 1970 and 1980 Public Use Microdata Samples of the Census Bureau are used to examine changes in the use of public transportation during the journey to work by various demographic subgroups living in urbanized areas. Volume I contains the analysis of the trends, and volume II contains the statistical tables which support the narrative in Volume I. Volume I is organized around 8 chapters. Chapter 1 introduces the topic, data sources and limitations of the study. Chapter 2 provides an overview of changes in the use of public transportation. Chapter 3 considers changes in the choice of public transportation modes. Chapter 4 provides information on the use of public transportation for the transportation disadvantaged. Chapters 5 and 6 assesses the changes in work place location. Chapter 7 assess the influence of changes in

household characteristics. Chapter 8 completes the report with a discussion of future implications.

SUMMARY OF TRAVEL TRENDS. 1983-84 NATIONWIDE PERSONAL TRANSPORTATION STUDY
Comsis Corporation 11501 George Avenue, Suite 312 Wheaton Maryland 20902; Office of the Secretary of Transportation 400 7th Street, SW Washington D.C. 20590; Federal Highway Administration Office of Highway Information Management, 400 7th Street, SW Washington D.C. 20590; National Highway Traffic Safety Administration 400 7th Street, SW Washington D.C. 20590
November 1985, 21 p.
REPORT NO: DOT-P36-85-2
SUBFILE: UMTRIS
AVAILABLE FROM: Federal Highway Administration Office of Highway Information Management, 400 7th Street, SW Washington, D.C. 20590

The Nationwide Personal Transportation Study (NPTS) contains national data on the nature and characteristics of travel. It addresses a broad range of travel in the United States, providing data on household trips and travel for all purposes and modes of transportation. Only household trips and travel for all purposes and modes of transportation. Only household travel characteristics are depicted by the NPTS; data on freight movement is not collected. This volume of the 1983/84 NPTS, Summary of NPTS Trends, presents trends which can be traced through the 1969, 1977 and 1983/84 series of the NPTS. Included is information on national demographics, household composition, vehicle ownership, household travel, journey to work, vehicle utilization, auto occupancy, mode split, and drivers. Please note that there are different time spans between the 1969, 1977 and 1983/84 surveys (eight and six years respectively). This report does not attempt to depict these differences in its graphic presentations. In addition, to this document, a full report on the 1983/84 NPTS will be published which will provide more detail on transportation trends over time. In the full report special emphasis will be placed on the 1983 data, since it has not previously been published. The survey provides the information necessary to assist transportation planners and others who need comprehensive data on travel and transportation patterns in the United States. The 1983/84 NPTS is sponsored by several agencies of the U.S. Department of Transportation (DOT). These include the Federal Highway Administration, the Office of the Secretary, the National Highway Traffic Safety Administration and the Urban Mass Transportation Administration. The survey was conducted by the Bureau of Census.

TRANSPORTATION POOLING
Voorhees (Alan M) and Associates, Incorporated Westgate Research Park McLean Virginia 22101 IT-06-0092
January 1974, 283 pp.
REPORT NO: UMTA-IT-06-0092-74-1
SUBFILE: HRIS; UMTRIS
AVAILABLE FROM: National Technical Information Service 5285 Port Royal Road Springfield Virginia 22151

With the advent of impending energy shortages in the winter of 1973-74, the U.S. Department of Transportation embarked on an accelerated program to promote increased use of high-occupancy vehicles — transit and carpools. As part of this program a series of report was prepared that summarized in the major aspects of carpool programs designed to assist local areas in initiating successful pooling action programs. This report is a collection of the ten individual reports. The goal of the Carpool/Buspool Program is to satisfy travel requirements more efficiently by increasing passenger occupancy in autos and buses, thereby reducing the number of vehicles using the streets and highway. Achievement of that goal calls for coordination among many institutions within a metropolitan region. The information and techniques presented in this report should be considered as a guide to the development of a sound program in a metropolitan area. The individual reports contained in this volume are: Review of Carpool Activities, Organization for Carpooling, Approaches to Matching, Legal and Institutional Issues, Incentives to Carpooling, Transit/Taxi coordination, Vanpools, Buspools, Pooling for the Disadvantaged, and Carpool Backup Systems.

EQUILIBRIUM MODEL FOR CARPOOLS ON AN URBAN NETWORK
Daganzo, CF (California University, Berkeley)
Transportation Research Board
Transportation Research Board No. 835, 1981, pp. 74-79.
SUBFILE: HRIS; UMTRIS
AVAILABLE FROM: Transportation Research Board Publications Office 2101 Constitution Avenue, NW Washington D.C. 20418.

Traffic equilibrium methods are presented in which the population of motorists consists of individuals who are minimizers of a linear combination of cost and travel time. The relative importance of travel time versus cost varies across the population, but fairly mild conditions for the existence and uniqueness of the equilibrium can nevertheless be identified. The paradigm is a particular interest for carpooling studies because the occupants of carpools can divide the cost amount themselves, but they cannot do the same with the travel time. Thus, vehicles that have different occupancies compete for segments of the roads that are crowded or have tolls. It is therefore, very useful to predict the impacts of special carpooling lanes, lower tolls for high-occupancy vehicles, and other transportation-system-management strategies on the distribution of traffic over an urban network.

1983 NATIONWIDE PERSONAL TRANSPORTATION STUDY (NPTS)
SPONSORING ORG: Federal Highway Administration
PERFORMING ORG: Department of Commerce 14th Between E Street and Constitution Avenue, NW Washington D.C. 20230
CONTRACT NO: 81-Y-30042; Contract
PROJECT START DATE: ND
PROJECT TERMINATION DATE; ND
SUBFILE: HRIS

This study supports an ongoing nationwide survey of personal travel patterns which serves as a pertinent source of safety exposure data. Survey findings provide data on average annual miles traveled by various driver characteristics (e.g., age, sex, household income) and vehicle characteristics (e.g., vehicle type, size). Data is also provided on the amount of travel by time of day, day of week, purpose of trip, trip length and vehicle occupancy. The survey is conducted by the Bureau of Census under an interagency agreement with DOT.
DESCRIPTORS: DRIVER CHARACTERISTICS; PERSONAL TRANSPORTATION SYSTEMS; RESEARCH PROJECT; SURVEYS/DATA COLLECTION; TRAVEL PATTERNS; TRIP LENGTH; TRIP PURPOSE; VEHICLE CHARACTERISTICS; VEHICLE OCCUPANCY

NATIONWIDE PERSONAL TRANSPORTATION STUDY, 1969-1970
Federal Highway Administration 400 7th Street, SW Washington D.C. 20590
One-Time n.p.
SUBFILE: HRIS; TSRF; TSC
AVAILABLE FROM: Federal Highway Administration 400 7th Street, SW Washington D.C. 50590

APPENDIX B

INTERCEPT SURVEY PROCEDURES AND SURVEY LOG

INSTRUCTIONS FOR COUNTING VEHICLES AND DISTRIBUTION OCCUPANCY QUESTIONNAIRES

The objectives of this survey are:

1. To count and classify arriving vehicles into two categories - vehicles with just a driver and vehicles with two or more persons (counting the driver),

2. To distribute survey questionnaires to the driver of a sample of vehicles with just a driver and to all occupants of all vehicles containing two or more people.

The following section presents the specific tasks that you must complete for each parking facility to which you are assigned.

WORK RULES

To do your work properly and to be paid, you should do the following:

1. Report to Work at the Sampled Parking Facility

   Report to work at the parking lot or garage described on the Vehicle Occupancy Survey Log to set up for work. Report to work 15-30 minutes before counting is to begin. Wear your Survey Taker badge and carry your official Survey Taker letter.

2. Determine Whether or Not There Is An Attendant

   If there is an attendant on duty, introduce yourself, present your letter of introduction, and briefly describe what you will be doing. The parking facility will have been contacted in advance, so the attendant(s) should be expecting you.

   If the attendant has any questions, refer him (her) to the contact person.

   It is very important that you get on good terms with the parking attendant because he (she) can help you in your survey tasks.

   If there is no attendant on duty when you begin work, proceed with the following steps. If the attendant shows up later, accomplish your introduction while continuing the survey.

3. Check Your Vehicle Occupancy Survey Log

   Figures 1A and 1B present the Vehicle Occupancy Survey Log. The basic difference between Figure 1A and Figure 1B is the descriptive

information on Figure 1A concerning the parking facility. Typically, both pages 1 and 2 of the Survey Log will be filled out. Sometimes, three or more pages might be needed for a particular lot.

- Assignment # should be filled in.

  A work assignment will be prepared for each sampled parking facility. Assignments will be given a unique assignment number starting at 001 and continuing sequentially for all parking lots and garages selected for the survey. A unique assignment number will be entered on the Vehicle Occupancy Survey Log on page 1 and page 2. The entry on page 2 is critical since this is the only way to relate survey counts at the parking garage to the name of the facility. Always check the assignment number on page 2 with the assignment number shown on page 1.

  If no assignment number is given on page 1 of the log, contact your supervisor when you have completed the assignment. Until you receive an assignment number, enter the street address and parking facility street name on all pages of the log.

- Name of Facility should be filled in.

- Location of Facility should be filled in.

- The "begin" serial number for Deck 1 should be filled in. If you will need to use additional decks, enter "end" number of Deck 1 and "begin" number of Deck 2 when questionnaires from Deck 2 are required. The same steps should be repeated for Deck 3, if needed.

- Date should be filled in.

- Type of Parking should be identified and Free/Paid should be checked.

- Draw a sketch of the parking facility in the space provided, if that sketch has not been drawn on the log.

Assignment Number: ☐☐☐

Figure 1A

VEHICLE OCCUPNACY SURVEY LOG

1. _____
Name of Parking Lot or Parking Garage

2. _____
Location

3. Serial:

	Deck 1	Deck 2	Deck 3
Begin			
End			

Sketch: E=Entrance X=Exit

4. Date: _____

5. Type: ☐ Building ☐ Lot ☐ Free ☐ Paid

6. Number of Spaces: _____

7. Number Parked: _____ Begin ☐☐☐☐ AM PM Time _____ End ☐☐☐☐ AM PM Time

8. Name of Contact Person: _____ Tel. No. _____

Drive Alone Vehicles

Sample 1: _____

Vehicle Count

Serial Number of Questionnaires

Vehicles with 2 or More Occupnats

Time: 7 AM - 8 AM

Serial and Number in Car

Time: 8 AM - 9 AM

Vehicle Count

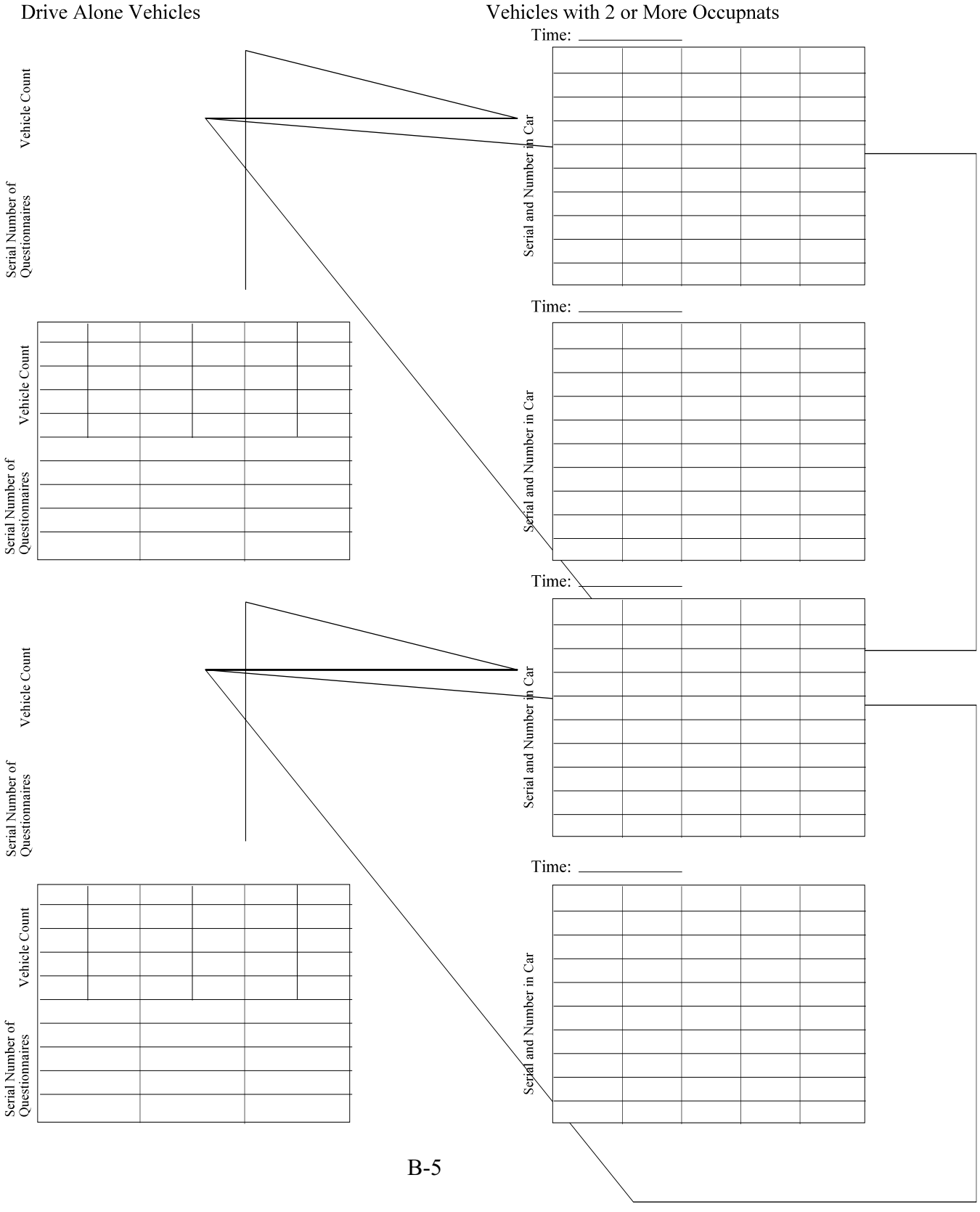
Serial Number of Questionnaires

Serial and Number in Car

Assignment Number: ☐☐☐

FIGURE 1B

VEHICLE OCCUPANCY SURVEY LOG



- The total number of parking spaces should be filled in. If not, determine the total number of parking spaces at the garage or lot by counting them. If you need to, count the number of parking spaces after your survey assignment has ended and you are also counting the number of vehicles parked at the "end" time of your assignment.

- Count the parked vehicles at the time you arrive at the site.

- Count arriving vehicles and distribute questionnaires.

- Count the number of parked vehicles at the time you leave the site. Accomplish this count after the "end" time of your work assignment.

Distribution of Questionnaires at Facilities Where the Vehicle Must Stop

At facilities where the vehicle must stop before proceeding to a parking space, the distribution procedures are fairly simple. Those procedures would apply both to lots and to buildings with attendants or automatic ticket dispensers. The different locations from which to disperse questionnaires will vary according to the parking facility design and will be discussed later.

- Time Period — Notice on the Vehicle Occupancy Survey Log that there are two time-period spaces on page 1 and four on page 2. Enter the time period for the blocks on page 2, if they have not already been entered. (The beginning and end time periods should be filled in for your assignment on line 7 — "number parked").

  Figure 2 shows a hypothetical form with the first time period (7 AM - 8 AM) filled in. The second time period will usually be 8 AM to 9 AM, and the third time period might be 9 AM - 10 AM. That information should be shown on the log for the assignment. If there is not enough room in the block to complete the count of vehicles, use an extra block (and page) and enter the assignment number and the time period with the word "continued" — e.g., 7 AM - 8 AM (continued).

  It is possible that at some parking lots or garages, the survey will not begin at 7 AM. In those cases, different hours will be written on page 1 of the Vehicle Occupancy Survey Log.

- Count the Arriving Vehicles — There will be two types of arriving vehicles:

  (1) Vehicles with only the driver, and (2) vehicles containing a driver and one or more passengers. For each vehicle with only a driver, enter a hash mark(/) in the uppermost and leftmost box under "drive alone" that has less than five (/////) hash marks. Each time a box reaches /////, start a new box, moving from left to right and down.

Assignment Number: ☐☐☐

Figure 2

VEHICLE OCCUPANCY SURVEY LOG

1. Acme Garage
   Name of Parking Lot or Parking Garage

2. 5 th & Maine
   Location

3. Serial:

	Deck 1	Deck 2	Deck 3
Begin	0001		
End			

Sketch: E=Entrance X=Exit

3 Stories Automatic... Ticket dispenser

4. Date: 2/3/88

5. Type: [X] Building [ ] Lot [ ] Free [X] Paid

6. Number of Spaces: 180

7. Number Parked: 10 (Begin) 0700 AM PM (Time) 169 (End) 1130 AM PM (Time)

8. Name of Contact Person: J. Smith Tel. No. 372-1647

Drive Alone Vehicles

Sample 1: _____

Vehicle Count: 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 /

Serial Number of Questionnaires: 0001 0007 0010

Vehicles with 2 or More Occupnats

Time: 7 AM - 8 AM

Serial and Number in Car: 0002-3 0005-2 0008-2

Time: 8 AM - 9 AM

Vehicle Count

Serial Number of Questionnaires

Serial and Number in Car

For arriving vehicles with two or more occupants, enter the serial number of the next questionnaire in your dispenser in the leftmost, uppermost box under "Vehicles with two or more occupants".

Note: There is a basic difference in recording the count of vehicles with only a driver and of vehicles with two or more occupants. Driver-only vehicles are recorded with a single hash mark (/). The total for a time period is the sum of these hash marks (E.g., /////, ///// /// equals 13.) Vehicles with two or more occupants are recorded by writing in a box (on the Log) the serial number of the first questionnaire given to the occupants. The total for such vehicles is obtained by counting the number of serial-number entries for any given time period. The count for people in driver-only vehicles is, of course, identical with the vehicle count. The count of people in vehicles with two or more occupants is obtained by counting the serial-number suffixes as described below.

- Handing Out Questionnaires

  Handing out questionnaires requires that the questionnaire(s) be handed to the driver in the vehicle. Instructions and information about the survey are printed on the questionnaire. Refer any questions, such as, "Hey, what's this all about?," to the questionnaire by saying, "The purpose of the survey is explained on the questionnaire." If the person persists, say that the survey is being done in the interests of improving transportation in the Greater Phoenix area.

  For drive-alone vehicles, a sample of vehicles will be taken. The sample interval will be specified on the log. If the sample is one vehicle in 10, then a questionnaire should be given to every tenth driver-only vehicle arriving at the garage. If the sample is some other interval, it can be determined by dividing the arrival count by the interval; e.g., if the interval is six, then the 6^{th}, 12^{th}, 18^{th}, 24^{th}, etc., vehicle will receive a questionnaire. Record the serial number of each questionnaire distributed to driver-only vehicles in the larger box below the hash mark boxes under "drive-alone vehicles".

  Every vehicle with two or more occupants will be sampled. When a vehicle with two or more persons enters the parking facility, take out the next two questionnaires, write the serial number of the next questionnaire you are handing out, and write the number of persons in the vehicle in the next open box under "Vehicles with 2 or more occupants". Then hand the two questionnaires to the two occupants of the car. For example, suppose the next serial number is 0007. The entry would be:

  0007-3 for three occupants, or

  0007-2 for two occupants, or

  0007-4 for four occupants.

For these examples, hand out 3, 2, or 4 questionnaires, respectively, to the vehicle occupants.

(Figure 2 presents a sample log filled out for 31 driver-only vehicles, a sample rate of 10 percent, and three vehicles with two or more occupants, assuming the first serial number was 1.)

Distribution of Questionnaires at Facilities Where the Vehicle May Not Stop

At some lots, vehicles will not be stopped by a gate. You will be directed to count vehicles and distribute questionnaires based on the design of the lot. At small parking lots (lots that are not affiliated with shopping centers), you will follow the same procedures as if drivers were to stop at a gate. That is, you will intercept vehicles at the entrance to the lot and distribute the questionnaires to the occupants before people leave the cars they used to travel to the lot.

Make sure that you record the number of vehicles by their number of occupants, and that each occupant of a sampled vehicle receives a questionnaire.

QUESTIONNAIRE

QUESTIONNAIRE

QUESTIONNAIRE

Assignment Number: ☐☐☐

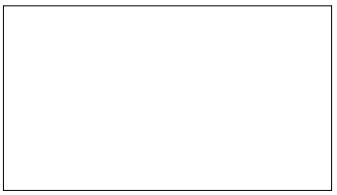
Figure 1A

VEHICLE OCCUPANCY SURVEY LOG

1. _____
Name of Parking Lot or Parking Garage

2. _____
Location

Sketch: E=Entrance X=Exit



3. Serial:

	Deck 1	Deck 2	Deck 3
Begin			
End			

4. Date: _____

5. Type: ☐ Building ☐ Lot ☐ Free ☐ Paid

6. Number of Spaces: 180

7. Number Parked: _____ Begin Time ☐☐☐☐ (AM) PM

_____ End Time ☐☐☐☐ (AM) PM

8. Name of Contact Person: J. Smith Tel. No. 372-1647

Drive Alone Vehicles

Sample 1: _____

Vehicle Count

Serial Number of Questionnaires

Vehicles with 2 or More Occupnats

Time: 7 AM - 8 AM

Serial and Number in Car

Time: 8 AM - 9 AM

Serial and Number in Car

Assignment Number: ☐☐☐

VEHICLE OCCUPANCY SURVEY LOG

Drive Alone Vehicles

Vehicle Count

Serial Number of Questionnaires

Vehicle Count

Serial Number of Questionnaires

Vehicle Count

Serial Number of Questionnaires

Vehicle Count

Serial Number of Questionnaires

Vehicles with 2 or More Occupnats

Time: _____

Serial and Number in Car

Time: _____

Serial and Number in Car

Time: _____

Serial and Number in Car

Time: _____

Serial and Number in Car

APPENDIX D

CLASSIFICATION OF RESPONSES TO INTERCEPT SURVEYS

The responses prepared by persons who received and returned the survey intercept questionnaire were used to classify occupants of sample vehicles.[1] This method was used, rather than observations by the survey takers, to take advantage of the detailed data that could be generated from the redundancies incorporated into the design of the questionnaire. The following five classifications of occupants were defined:

- driver traveling alone;
- driver of a vehicle with two or more occupants, all from the same household;
- driver of a vehicle with two or more occupants, from different households;
- passenger of a vehicle with two or more occupants, all from the same household; and
- passenger of a vehicle with two or more occupants from different households.

The responses to the questionnaire were used in the following ways to determine the classification of the occupants of the vehicles intercepted for the survey who responded with completed questionnaires:

1. Drive Alone — Those who responded that 1) they were the driver (to question 5), 2) there was only one person in the vehicle (response 1 to question 6), and 3) zero occupants were dropped off before the vehicle arrived at the parking site (response 1 to question 7);

2. Driver, Same Household — Those who responded that 1) they were the driver (to question 5), 2) there were 2 or more persons in the vehicle (responses 2 through 9 to question 6), and 3) there was one household represented in the vehicle (response 1 to question 10);

3. Driver, Different Households — Those who responded that 1) they were a passenger (to question 5), 2) there were 2 or more persons in the vehicle (responses 2 through 9 to question 6), and 3) they were a member of the driver's household (to question 8);

4. Passenger, Same Household — Those who responded that 1) they were a passenger (to question 5), 2) there were 2 or more persons in the vehicle (responses 2 through 9 to question 6), and 3) they were not a member of the driver's household (to question 8)

[1]The questionnaire distributed to occupants of vehicles intercepted for this vehicle occupancy survey is presented in Appendix C.

APPENDIX E

FACTORING THE INTERCEPT SURVEY RESPONSES

Derivation of Expansion Factors

The samples designed for vehicles arriving and parking at the samples of destination garages and lots were chosen to ensure collecting sufficient information about people traveling together. The fact that the persons conducting the surveys could observe how many people were in each vehicle arriving at the parking site permitted the concentration of multiple-passenger vehicles in the sample. Vehicles with only the driver were sampled at a rate of one in ten, while all vehicles containing two or more persons were selected to have their occupants receive questionnaires. Those sampling rates produced an overall sample of vehicles composed (nearly) equally of drive-alone vehicles and multi-passenger vehicles.

DEFINITION OF EXPANSION FACTORS

In order to properly represent the responses from occupants in the sample of vehicles at each parking location, expansion factors needed to be calculated. An expansion factor is defined as the factor that would produce the estimate driver and passenger attributes that would have been obtained from a 100 percent sample of arriving vehicles had all persons in the vehicles selected for the survey responded to the questionnaires they received. In other words, expansion factors would be the ratios of the number of person counted arriving at each parking site to the number of passengers who responded to the questionnaires.

$$f_{hj} = \frac{O_{hj}}{N_{hj}}$$

Where:

f_{hj} = expansion for stratum h and parking site j

O_{hj} = number of persons counted arriving, by car occupancy stratum h at parking site j

N_{hj} = number of persons responding to the questionnaire distributed, by car occupancy stratum h at parking site j

h = drive alone, carpool driver and carpool passenger strata

The numbers of persons in each vehicle occupancy strata were determined directly from the logs of counts compiled by the survey takers. The Vehicle Occupancy Survey Log prepared for each parking site presents the number of vehicles arriving by vehicle occupancy category and the number of survey forms distributed by vehicle occupancy category. That information made it possible to calculate an expansion factor for every completed survey form, as follows:

1. The counts of drive-alone vehicles arriving at each parking site were defined to equal the numbers of drive-alone persons arriving at each parking site.

2. The numbers of persons arriving in carpools were determined by the numbers of survey forms distributed to occupants of carpool vehicles. The numbers of drivers of carpools arriving were defined as equal to the numbers of arriving carpool vehicles, and the numbers of passengers were defined as equal to the numbers of survey forms

distributed to each carpool vehicle minus one (the survey form distributed to the driver).

While expansion factors were calculated separately for drivers of all drive-alone vehicles, for drivers of 2-person carpools and for passengers of 2-person carpools for each parking site, expansion factors for drivers and passengers of carpools with 3 or more occupants were calculated only for the aggregation of all parking sites. That decision was based on not counting sufficient carpools with 3 or more occupants arriving at many parking sites to be able to derive individual expansion factors for these vehicle occupancy categories.

The expansion factors were based on the survey takers' categorization of vehicle occupancy, even for those survey forms that were returned by drivers who indicated that they had dropped someone off before the vehicle arrived at the sample parking site. Those survey forms were expanded as if they belonged to the drive-alone category of vehicle occupancy to account for other, similar vehicles which were counted as (arriving as) drive-alone vehicles whose occupants were not given a survey form. (The expansion factors are presented in the table on page E-5.)

DETAILED PROCEDURES FOR FACTORING THE CAR OCCUPANCY RECORDS

The Vehicle Occupancy Survey Log was the basis for generating a file of records containing the following information:

- assignment number (parking site number),
- serial number of questionnaire,
- number of persons in vehicle (arriving at the parking site), and
- vehicle number.

(An example of a Vehicle Occupancy Survey Log used to organize this information is included at the end of this appendix.)

The data file created from the information described above was summarized by assignment (parking site) number. The numbers of vehicles arriving at each site were also summarized by drive-alone and multiple-person occupancy categories, and checked against the logs prepared by the survey takers for each site. Possible duplication in serial numbers of inaccurate numbers of persons per vehicle were checked and corrected.

The file created for each parking site was matched by serial number to the returned questionnaires, so that there would be no unmatched returned questionnaires. The numbers of persons in each vehicle and the assigned vehicle numbers were appended to the data file containing responses to the survey. The questionnaires were sorted by serial number within vehicle occupancy category within assignment number. Subtotals of drivers and passengers by car occupancy were calculated in the table presented on the next page. Counts of drivers, passengers and vehicles observed (counted) arriving by car occupancy were summarized using the Vehicle Occupancy Survey Logs.

The tabulations were reviewed to see if cells with no responses were present. Responses and counts were aggregated to avoid zeros, and then the factors were calculate. Finally, factors were established for each questionnaire returned, with different factors for responses from drivers and passengers, as shown in the following table.

TABLE USED TO CALCULATE EXPANSION FACTORS

	Counts of Arriving:		Questionnaires Distributed To:		Responses By:		Factors	
Occupancy Category	Drivers[a]	Passengers[b]	Drivers	Passengers	Drivers	Passengers	Drivers	Passengers
Drive Alone								
Two per Vehicle								
Three per Vehicle								
Four per Vehicle								
Five per Vehicle								
Six per Vehicle								
Seven per Vehicle								
Eight per Vehicle								
Nine or More per Vehicle								

[a]Equals the number of arriving vehicles.

[b]Equals the numbers of questionnaires distributed minus the number of drivers.

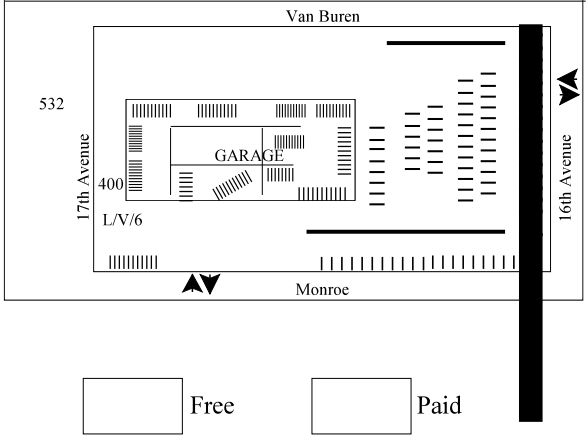
Assignment Number: 0 0 1

VEHICLE OCCUPNACY SURVEY LOG

1. Department of Revenue card opening gate only in garage
   Name of Parking Lot or Parking Garage

2. 17th Avenue & Van Buren (SE corner)
   Location

Sketch: E=Entrance X=Exit



3. Serial:

	Deck 1	Deck 2	Deck 3
Begin	0001	0051	0101
End	0050	0100	0104

4. Date: 3-14-88

5. Type: [X] Building [X] Lot [ ] Free [ ] Paid

6. Number of Spaces: 97 outside lot 520-garage

7. Number Parked: 18 outside lot / 13 garage — Begin — Time: 0630 AM

   95 outside / 380 garage — End — Time: 0900 PM

8. Name of Contact Person: Robert Pike Tel. No. 965-2404

Drive Alone Vehicles

Sample 1: 10

Vehicle Count: 25

Serial Number of Questionnaires:

001	0012	0026
004	0013	0029
007	0020	0034
008	0023	0035
0011	0024	

Time: 7:13 AM

Vehicle Count: 12

Serial Number of Questionnaires:

0036	0055	
0037R		
0042		
0047		
0054		

Vehicles with 2 or More Occupnats

6:30 AM -7:30 AM

Time: 7 AM - 8 AM

Serial and Number in Car:

1	002-2				
2	005-2				
3	009-2				
4	0014-2				
5	0016-2				
6	0018-2				
7	0021-2				
8	0027-2				
9	0030-2				
10	0032-2				

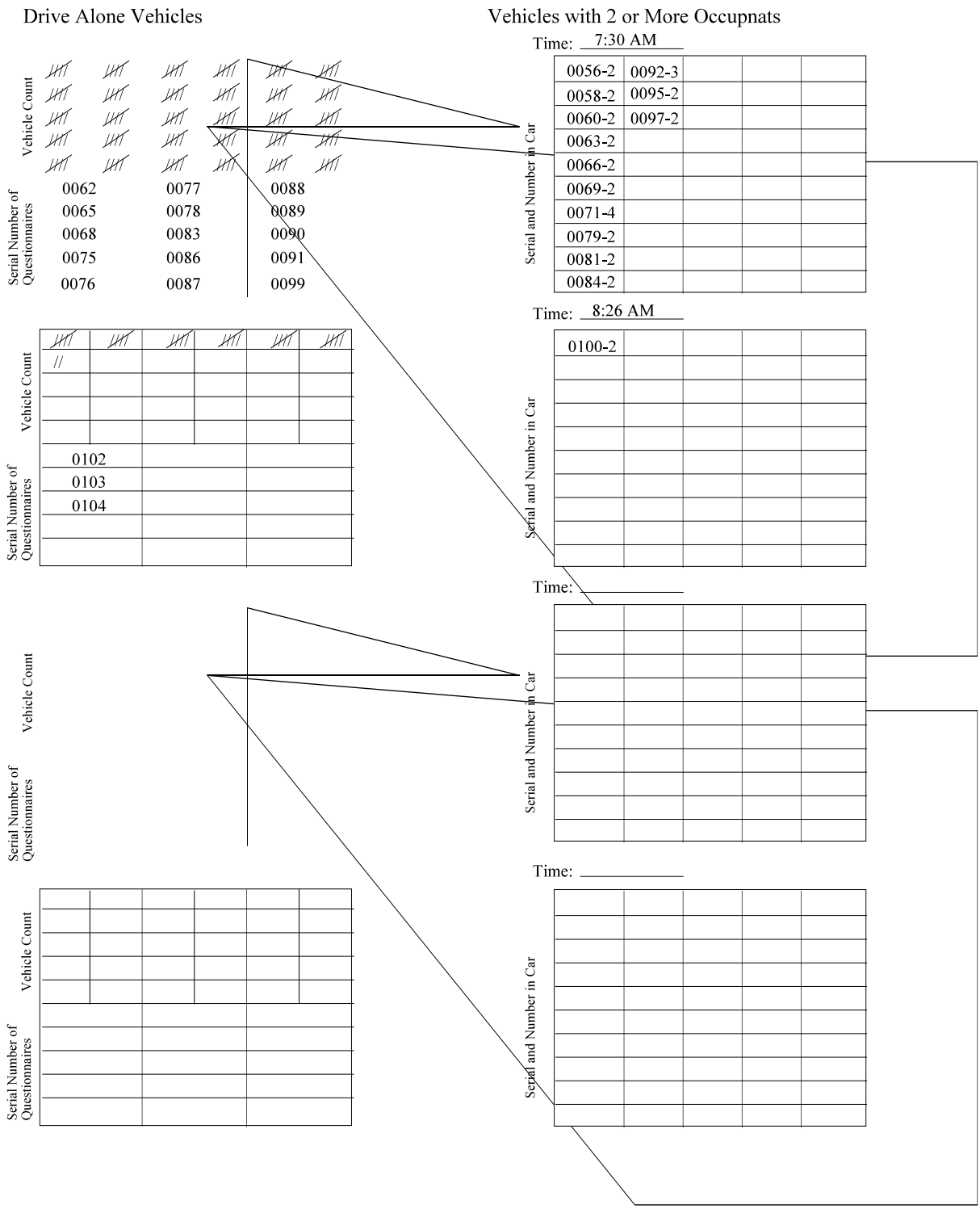
Time: 8 AM - 9 AM

Serial and Number in Car:

11	0038-2				
12	0040-2				
13	0043-2				
14	0045-2				
15	0048-2				
16	0050-2				
17	0052-2				

Assignment Number: 0 0 1

VEHICLE OCCUPANCY SURVEY LOG



APPENDIX F

STANDARD DEVIATIONS AND STANDARD ERRORS

FOR

ESTIMATES OF VEHICLE OCCUPANCY

Standard Deviation and Standard Errors

for

Estimates of Vehicle Occupancy Rates

		Facility Type					
Area Type	Time of Day	All Roadways		Freeways		Arterials and Collectors	
		σ[a]	$\sigma_{\bar{x}}$[b]	σ[a]	$\sigma_{\bar{x}}$[b]	σ[a]	$\sigma_{\bar{x}}$[b]
Region							
	7:00-9:00 AM	.501	.003	.462	.004	.538	.005
	9:00 AM - 3:00 PM	..641	.003	.608	.003	.673	.004
	4:00 - 6:00 PM	.629	.003	.550	.004	.707	.006
	6:00 - 7:00 PM	.682	.006	.593	.007	.774	.010
	All Day	.621	.002	.570	.002	.671	.003
Core Area (Area Types 1 and 2)							
	7:00-9:00 AM	.475	.004	.483	.008	.480	.005
	9:00 AM - 3:00 PM	.629	.004	.630	.006	.629	.005
	4:00 - 6:00 PM	.593	.004	.525	.005	.641	.006
	6:00 - 7:00 PM	.659	.008	.587	.010	.714	.012
	All Day	.600	.002	.764	.008	.617	.003
Higher Density Urban Area (Area Type 3)							
	7:00-9:00 AM	.503	.008	.393	.006	.826	.030
	9:00 AM - 3:00 PM	.601	.006	.511	.006	.775	.015
	4:00 - 6:00 PM	.583	.008	.498	.009	.712	.018
	6:00 - 7:00 PM	.599	.014	.543	.015	.704	.029
	All Day	.580	.004	.490	.004	.758	.010
Outer Areas (Area Types 4 and 5)							
	7:00-9:00 AM	.538	.006	.505	.007	.583	.010
	9:00 AM - 3:00 PM	.672	.006	.640	.006	.716	.008
	4:00 - 6:00 PM	.701	.006	.597	.007	.841	.014
	6:00 - 7:00 PM	.748	.012	.618	.012	.901	.022
	All Day	.669	.003	.606	.003	.748	.006

[a]Standard Deviation

[b]Standard Error