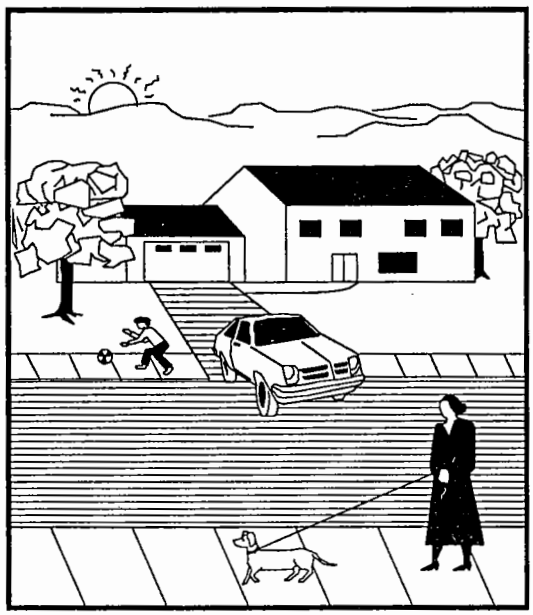


1988/1989

Household Travel Survey

Maricopa Association of Governments
Transportation Planning Office
1739 West Jackson Street, Room 108P
Phoenix, Arizona 85007

1988/1989 HOUSEHOLD TRAVEL STUDY

July 1989

prepared for

Maricopa Association of Governments
Transportation Planning Office
1739 West Jackson Street, Room 108P
Phoenix, Arizona 85007

prepared by

Behavior Research Center, Inc.
1117 North Third Street
Phoenix, Arizona
(602) 258-4554

TABLE OF CONTENTS

LISTING OF TABLES

LISTING OF TABLES

EXECUTIVE SUMMARY

This study was commissioned by the Maricopa Association of Governments Transportation and Planning Office (MAGTPO). The primary objectives of this study were: (1) to update the trip generation rates used in the MAG travel demand forecasting process, and; (2) to provide data to validate the MAG trip distribution model.

The information contained in this report is based on a statistically valid survey of 2,992 households residing within the MAG Urban Planning Area. The data collection procedure utilized on this project was a telephone-mail-telephone methodology.

o Trip Frequency

The average urban planning area household generates 8.38 person trips per day compared to 7.66 trips in 1981. Further, the average number of trips generated per houshold in 1989 increased over 1981 within each key socio-demographic subgroup except households with a head under 25 years of age, or between 35 and 44 years of age.

o Trip Purpose

A shift appears to have occurred between 1981 and 1989 in terms of trip purpose. Home-based non-work trips decreased 7.2 points as a proportion of all trips, while non-home-based trips increased by 4.9 points. Home-based work trips remained relatively unchanged since 1981, increasing from 20.5 percent of all trips in that year to 22.8 percent today. While it is apparent that a change has taken place in household travel patterns since 1981, some of the change may be due to the diary methodology utilized in the most recent study which seems to have improved the reporting of non-home-based trips.

o Trip Timing

As was the case in 1981, the 3:00 PM to 5:59 PM time period generates the highest traffic volume, with a reading of 23.8 percent. The majority of home-based work trips are concentrated in the customary early morning (6:00 AM to 9:00 AM) and late afternoon (3:00 PM to 6:00 PM) high peak periods while other home-based trips are distributed more evenly throughout the day. The majority of non-home-based trips (57.1%) occur between 9:00 AM and 3:00 PM.

o **Travel Mode**

Better than three out of every four person trips (75.7) in 1989 were made by auto-drivers while 18.9 percent were made by auto-passengers. These figures represent a 4.2 point increase in auto-driver trips in 1989 over 981 and a corresponding decrease in auto-passenger trips (5.7 points).

o **Vehicle Occupancy**

Since 1981 the average vehicle occupancy on auto-driver trips has declined from 1.43 persons per auto to 1.38. Overall, better than seven out of ten (73.9%) auto-driver trips are made with only one occupant, up from 69.8 percent in 1981. The decline recorded in vehicle occupancy is found among each of the three primary trip purpose types analyzed except home-based work trips which increased slightly.

o **Land Use At Trip Destination**

The most common land use at trip destination is residential (42.3%) followed by retail (15.6%) and commercial office (11.2%). As could be expected, major variations in land use at destination are recorded in terms of trip purpose.

o **Vehicle Ownership**

Ninety-six percent of metropolitan area households own a motor vehicle with the average household owning 1.91 vehicles. These figures are virtually unchanged since the 1981 study. However, the percentage of households owning a passenger car has declined by 11 points while the percentage owning trucks and vans has increased by nine points.

1.0 INTRODUCTION

This study was commissioned by the Maricopa Association of Governments Transportation and Planning Office (MAGTPO). The primary objectives of this study were to provide the data: (1) to update the trip generation rates used in the MAG travel demand forecasting process, and; (2) to validate the MAG trip distribution model.

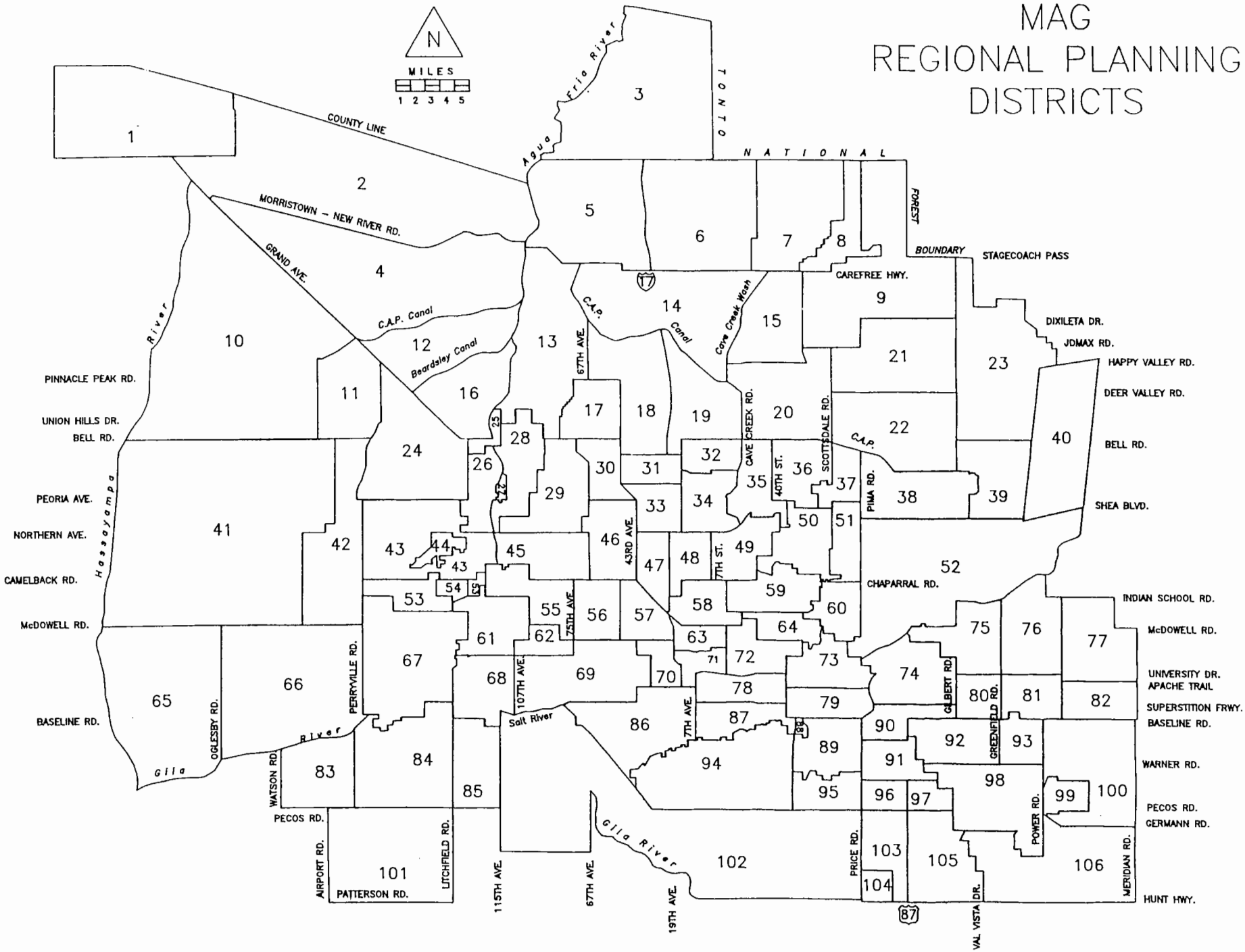
The basic intent of this summary report is to provide the reader with a description of the procedures followed during the undertaking of this study and a general overview of travel patterns within the Metropolitan Phoenix Area (see map on following page). Where appropriate, the data is compared to the results from the 1981 Household Travel Survey to examine changes in travel patterns.

This report does not attempt to validate or calibrate MAGTPO's forecasting models. This task is left to the agency, which in addition to this report, has been provided with a computer diskettes containing all of the survey results.

The Behavior Research Center (BRC) has presented all of the data it believes germane to the basic research objectives of this project. However, if additional data retrieval or analysis is required by MAGTPO, we stand ready to provide such input.

BEHAVIOR RESEARCH CENTER

MAG REGIONAL PLANNING DISTRICTS



2.0 METHODOLOGY

The information contained in this report is based on a statistically valid survey of 2,992 households residing within the MAG Urban Planning Area.

The data collection procedure utilized on this project was a telephone-mail-telephone methodology. This methodology was selected after an indepth review of procedures used to conduct travel surveys in other areas of the country. This review found that this type of survey had been successfully conducted in the twin cities area, Denver and Seattle during the past five years and generated highly reliable data in a very cost-effective manner.

A door-to-door, home-interview survey methodology was also studied, as it was believed to provide the most accurate information of any survey type, but it was rejected. This rejection was based on the recent experiences with a door-to-door survey in the Dallas-Forth Worth area. The principle problem encountered was the quality and turnover of the personnel conducting the interviews. In addition, this method is much more expensive than telephone interviews.

Using the telephone-mail-telephone methodology, the following general procedure was followed:

- First Contact (Telephone)
  Households were called and screened into the survey.

- Second Contact (Mail)
  Participating households were mailed a packet containing the necessary survey documents.

- Third Contact (Telephone)
  Participating households were called and their travel and household data was collected.

On the following pages is provided a detailed description of the procedures followed during the course of this project.

2.1 Data Collection Forms

The survey questionnaires, travel diaries, and all of the other forms utilized on this project were designed by BRC in consultation with MAGTPO. Examples of each of these forms are provided in Appendix 4.1 of this report.

This study was designed to collect the following data elements:

Data On Each Household

- Address of household
- Total number of people living in household
- Number of household members five years of age or older
- Number and type of motor vehicles in operating condition available to household
- Household income

Data On Each Person Age 5 or Over

- Head or relationship to head
- Age
- Sex
- Licensed to drive
- Employment status
- Parking fees paid if employed
- Traveled on assigned travel day

Data For Each Trip Made By Each Household Member Or Visitor Over 5 Years Of Age

- Person number
- Trip number
- Origin address
- Destination address
- Trip purpose
- Time of origination
- Time of arrival at destination
- Mode of travel
- Number of persons in vehicle
- Land use at destination

After each of the required study forms were designed and received preliminary MAGTPO approval, a pre-test was conducted with a randomly selected cross-section of 52 area households. The purpose of this effort was fourfold: (1) to test the clarity and design of the respondent forms (Instruction Form, Household Information Form, and Travel Diary Form); (2) to test the clarity and design of the internal forms (Screener/ Reminder Call Form, Base Interview Form, Instruction Forms, and Control Forms); (3) to determine probable study response rates; and (4) to monitor the overall design and flow of the study process. The pre-test revealed that with few exceptions, respondents found the study materials clear and easy to use.

2.2 Sample Design

A disproportionate stratified sample was utilized on this project. Using this procedure, the sample was stratified on the basis of household size and vehicle ownership and quotas were assigned to each strata. The base for the quota assignments was the trip making variability within each strata (see Appendix 4.2).

During the pre-test segment of this project it was determined that with repeated callbacks and travel day re-scheduling approximately 65 percent of those households which agreed to participate in this study would actually do so. With this in mind, screening quotas were assigned that took into account a non-participation rate. Presented on the following page are the initial screening and completed interview quotas.

Vehicles in HH/ Persons in HH	Initial Screening Quota	Initial Completed Interview Quota
0/1-5+	469	286
1/1	681	436
1/2	494	316
1/3	310	198
1/4-5+	AA	AA
2/1	AA	AA
2/2	306	196
2/3	242	155
2/4	243	155
2/5+	243	155
3+/1	AA	AA
3+/2	361	231
3+/3	210	134
3+/4	210	134
3+/5+	725	446
TOTAL	4494	2860

* AA = As Acquired.

Household selection on this project was accomplished via a computer-generated random digit dial telephone sample which selects households on the basis of telephone prefix. This method was used because it ensures a randomly selected sample of area households proportionately allocated throughout the sample uni-

verse. This method also insures that all unlisted and newly listed telephone households are included in the sample (approximately 30% to 35% in the metro Phoenix area).

The sample used on this project was obtained from Survey Sampling, Inc., the nation's foremost producer of high quality random digit dial samples. A description of the procedures used by Survey Sampling, Inc. is provided in Appendix 4.5.

During the screening segment of this study, only the male or female head of household was interviewed. This methodology was utilized because prior studies of this nature have shown that these are the individuals within each household who have the knowledge and background to respond to the topics under consideration.

2.3 Data Collection

All of the screening interviewing on this project was conducted at BRC's central location telephone facility in Phoenix and at Walker Research's central location telephone facility in Tempe. Each interviewer who worked on this project was under direct BRC supervision 100 percent of the time.

Once the field dates had been finalized on this project the field personnel were called in for an indepth briefing on the

particulars of this study. This briefing addressed the following issues:

- Description and purpose of survey.
- Survey organization.
- Preparations for the interview.
- Definitions.
- Specific interview instructions, including sample forms, conduct of the survey, interviewing suggestions, how to deal with refusals, and discussion of each data element to be obtained.
- Post-interview instructions.

Following the briefing, each interviewer completed a set of practice interviews under the observation of a supevisor to assure that all procedures were being fully followed.

The initial screening calls on this study were conducted during approximately equal cross-sections of day, evening and weekend hours. This procedure was followed to futher ensure that all households were equally represented, regardless of the work schedules of the household heads. Further, during the screening segment of this study, up to 12 separate attempts -- on different days and during different times of day -- were made to contact each selected household. Only after 12 unsuccessful attempts was a selected household substituted in the sample. Using this methodology, the full sample was completed, and partialy completed interviews were not accepted, nor were they counted toward fulfillment of the total sample quotas.

The screening calls on this study were very important in increasing study participation. The initial screening calls included a brief explanation of the purpose of the survey and captured the following data elements:

- Address of household
- Total number of people living in household
- Number of household members five years of age or older
- Number of motor vehicles in operating condition available to household

In addition to the above, travel dates were assigned (Monday through Friday) and respondents were alerted to the fact that their household would be receiving a travel packet with diaries and instructions several days before their travel day.

Travel survey packets were mailed to participating households so that they arrived several days before the assigned travel day. The packets included travel diaries, a form listing the household questions that would be asked, simple instructions, and a letter urging participation in the survey.

Travel diaries were sent to each participating household in an effort to ensure the full reporting of travel. The diaries were printed on card stock for durability and designed to fit easily into a coat, pocket, or purse.

Two days prior to each respondent's assigned travel day they were contacted by telephone to remind them of their travel day and to answer any questions they might have. It is felt that this step had an important impact on household participation.

Telephone collection of the survey data was conducted one or two days after each household's assigned travel day. Internal collection forms were identical to the household questionnaire and travel diaries mailed to participating households in order to minimize confusion in the collection process.

The screening and interviewing segment of the project was conducted between October 8 and December 15, 1988 (for travel days prior to November 22), and January 27 and February 20, 1989. It was the initial intent to have all of the data collection completed prior to the holiday season (Thanksgiving through New Year's). However, although a total of 2852 interviews were completed prior to the holiday season, the strict quota restrictions applied to the study necessitated some data collection in the post-holiday period. Thus, in order to complete the required sampling quotas, a second round of screening and interviewing was conducted in January and February 1989. The results of the screening and interviewing calls are presented on the following page.

SAMPLE DISPOSITION

	Number	Percent
Initial Screening Contacts	**15,866**	**100.0**
Unsuccessful Contact	**10,586**	**66.7**
Refused to participate	3,974	25.0
Disconnected numbers	1,876	11.8
Commercial numbers	971	6.1
Language barrier	62	.4
Busy or no answer[1]	823	5.2
Over quota[2]	2,880	18.2
Successful Contact (Agreed To Participate)	**5,280**	**33.3**
Refused to complete interview	2,014	12.7
Completed interviews - rejected	274	1.7
Income not determined	208	1.3
Outside planning area	12	.07
Incomplete data	54	.3
Completed interviews - usable	2,992	18.9

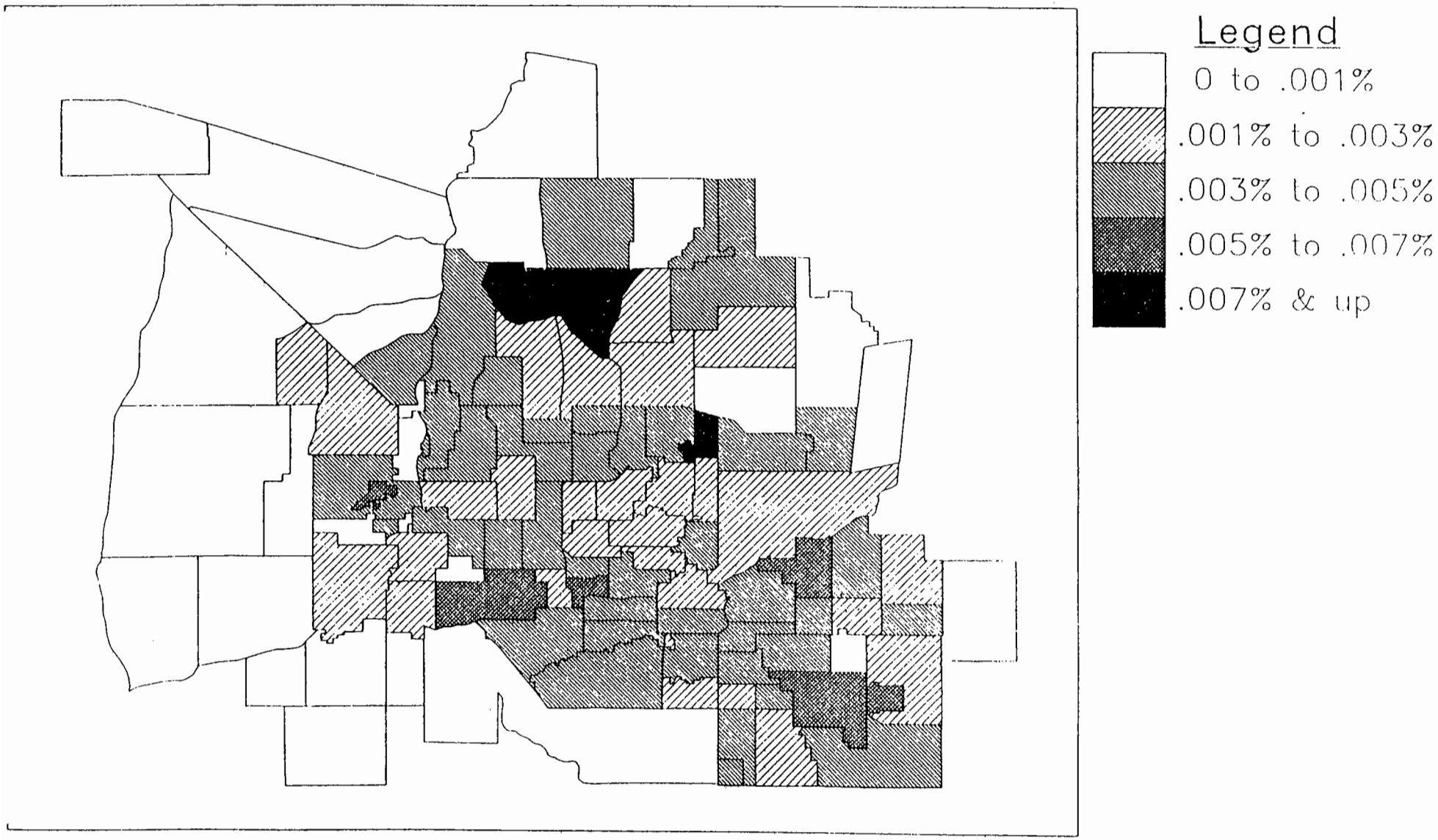
[1] After 12 attempts.

[2] High figure is a direct result of the necessity to greatly oversample households with no vehicles or with three or more vehicles.

The map on the following page reveals the percentage of households surveyed by MAG Regional Planning District.

PERCENT HOUSEHOLDS SURVEYED

BY DISTRICT



2.4 Data Coding and Sample Adjustment

As the interviewing segment of this project was being undertaken, completed interviews were turned over to the BRC coding department where they were edited and coded. Those interviews which were found to contain errors were pulled, the respondent recalled, and the error corrected. Following this process, the completed interviews were turned over to MAGTPO where they were geo-coded using the department's LandTrak computer program.

Following completion of the coding process it was necessary to "weight" the raw survey data to make it representative of the regional population base. This was necessary because the original sample design called for the significant oversampling of households with either no vehicles or three or more vehicles.

The survey data was weighted on the basis of two factors: (1) persons in household, and; (2) vehicles in household. The persons per household data was derived from the 1985 Census and the vehicles-per-household data was derived from the first 2,076 households screened into this survey. The vehicle-per-household figures derived from the first 2,076 screeners were used in the weighting process because they represented a random-sample reflection of the study universe. That is, it was at this number (2,076) that the first of the study's 20 vehicle quota categories was filled.

1985 Census

Persons in Household	Percent
1	23.07
2	36.80
3	16.33
4	13.95
5+	9.85
	100.00

1989 Household Travel Survey

Persons In HH	Vehicles In HH	Distribution-First 2,076 Screeners
1	0	10.5%
	1	75.2
	2	11.9
	3+	2.4
		100.0%
2	0	2.3%
	1	36.8
	2	41.8
	3+	19.1
		100.0%
3	0	1.7%
	1	22.1
	2	42.1
	3+	34.1
		100.0%
4	0	1.4%
	1	13.2
	2	46.0
	3+	39.4
		100.0%
5+	0	1.8%
	1	16.2
	2	39.6
	3+	42.4
		100.0%

Utilizing the above distributions, the following weights were developed.

Quota Number	Vehicles in HH/ Persons in HH	Completed Survey Distribution (N=2992 HHlds)	Weights
01	0/1	4.4%	2.42%
02	0/2	2.3	.85
03	0/3	.8	.28
04	0/4	.3	.20
05	0/5+	.6	.18
06	1/1	14.8	17.35
07	1/2	11.8	13.54
08	1/3	3.2	3.61
09	1/4	2.6	1.84
10	1/5+	1.5	1.60
11	2/1	2.1	2.75
12	2/2	6.7	15.38
13	2/3	5.6	6.87
14	2/4	6.3	6.42
15	2/5+	4.6	3.90
16	3+/1	.5	.55
17	3+/2	6.7	7.03
18	3+/3	5.5	5.57
19	3+/4	5.3	5.49
20	3+/5+	14.3	4.17
		99.9%	100.00%

Note: Total does not equal 100.0% due to rounding.

The impact of these weights on the survey data is as follows:

Vehicles in HH:	Unweighted	Weighted
0	8.4%	3.9%
1	33.9	37.9
2	25.3	35.1
3+	32.3	23.1
	99.9%	100.0%
Persons in HH:		
1	21.8%	23.3%
2	27.5	37.0
3	15.1	16.2
4	14.5	13.9
5+	21.0	9.6
	99.9%	100.0%

(cont.)

HH Income:	Unweighted	Weighted
Under $15K	19.4%	17.9%
$15K to $24.9K	20.9	22.1
$25K to $34.9K	20.8	22.7
$35K to $49.9K	18.4	18.7
$50K or over	20.5	18.5
	100.0%	99.9%
Age Head of HH:		
Under 25	5.5%	5.8%
25 to 34	23.0	23.0
35 to 44	25.0	22.3
45 to 54	16.2	15.3
55 to 64	11.5	12.6
65 or over	18.6	20.9
Not determined	.2	0
	100.0%	99.9%

Note: Totals may not equal 100% due to rounding.

2.5 Sample Accuracy

This survey, as in the case with all surveys, is subject to sampling error. Sampling error, stated simply, is the difference between the result obtained from a sample and those which would be obtained by surveying the entire population under consideration. The size of sampling error varies, to some extent, with the number of interviews completed and with the division of opinion on a particular question.

An estimate of the sampling error range for this study is provided in the following table. The sampling error presented in the table has been calculated at the confidence level most fre-

quently used by social scientists -- the 95 percent level. The sampling error figures shown in the table are average figures that represent the maximum error for the sample bases shown (i.e., for the survey findings where the division of opinion is approximately 50%/50%). Survey findings that show a more one-sided distribution of opinion, such as 70%/30% or 90%/10%, are usually subject to slightly lower sampling tolerances than those shown in the table.

As may be seen in the table, the overall sampling error for this study is approximately +/- 1.8 percent, when the sample is studied in total (i.e., all 2,992 cases). However, when sub-sets of the total sample are studied, the amount of sampling error increases based on the sample size within the sub-set.

Sample Size	Approximate Sampling Error at a 95% Confidence Level (Plus/Minus Percentage of Sampling Tolerance
3000	1.8%
2500	2.0
2000	2.2
1500	2.6
1000	3.2
800	3.5
600	4.1
400	5.0
300	5.8
200	7.1

3.0 SUMMARY OF THE FINDINGS

3.1 Trip Frequency

The average urban planning area household generates 8.38 person trips per day compared to 7.66 trips in 1981. Further, the average number of trips generated per household in 1989 increased over 1981 within each key socio-demographic subgroup except households with a head under 25 years of age, or between 35 and 44 years of age.

As might be expected, household trip generation increases in direct correlation to increases in the following socio-demographic areas: (1) number of persons in household; (2) number of vehicles in household; (3) number of employed persons in household; (4) number of licensed drivers in household; and (5) household income.

NOTE: All of data in this section has been weighted according to the procedure described in Section 2.4.

TRIPS PER HOUSEHOLD

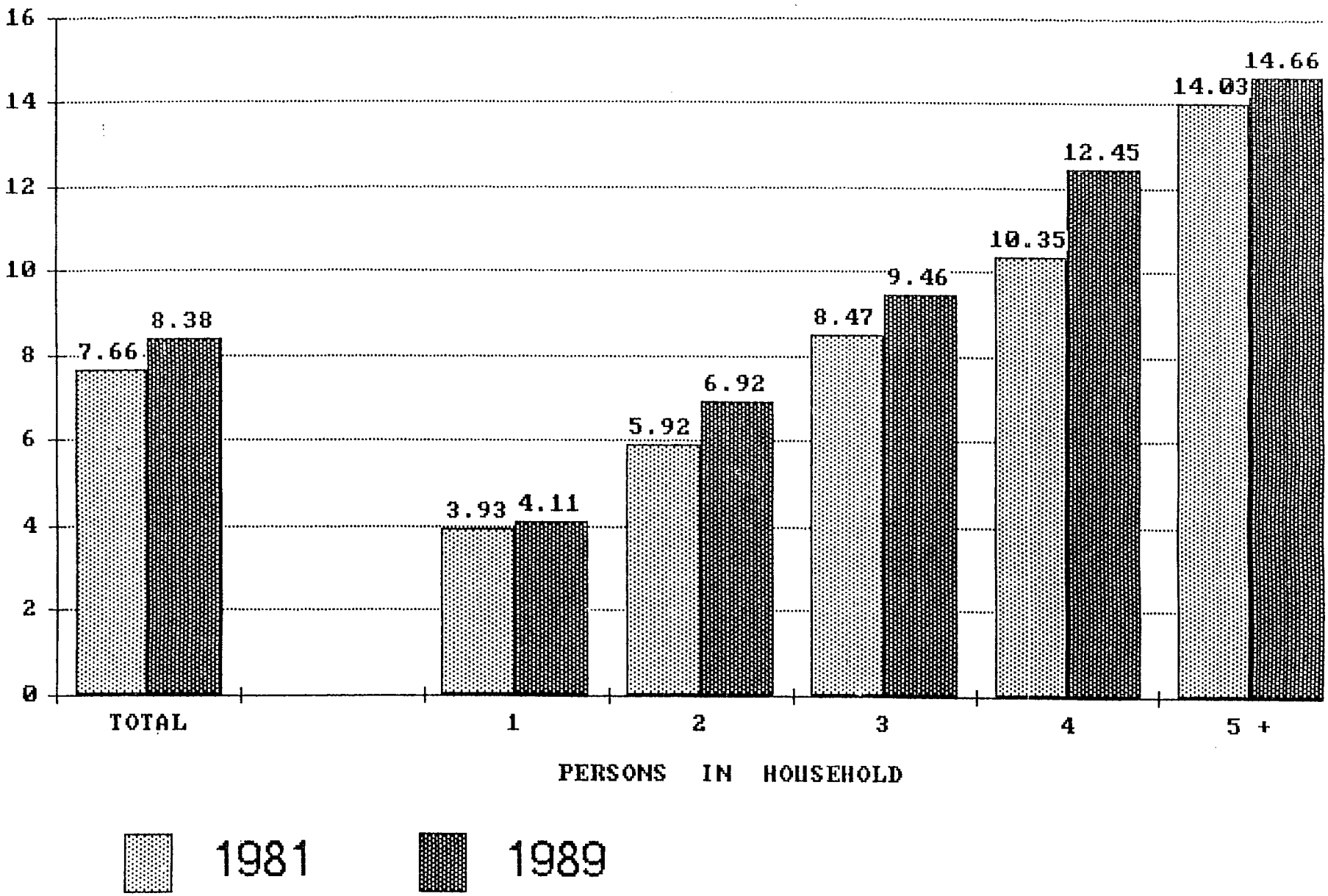


TABLE 1: MEAN DAILY PERSON TRIPS PER HOUSEHOLD

	Number of Trips	
	1989	1981
Total	8.38	7.66
Persons in Household		
One	4.11	3.93
Two	6.92	5.92
Three	9.46	8.47
Four	12.45	10.35
Five or more	14.66	14.03
Household Income		
Under $15,000	4.90	
$15,000 to $24,999	6.93	
$25,000 to $34,999	8.52	NC
$35,000 to $49,999	10.21	
$50,000 or over	11.53	
Vehicles in Household		
None	2.68	1.20
One	5.86	5.38
Two	9.42	8.25
Three or more	11.88	11.66
Total Employed in Household		
None	6.14	4.37
One	7.85	7.48
Two	10.17	9.12
Three or more	15.65	10.41
Licensed Drivers in Household		
None	4.54	1.08
One	5.45	4.57
Two	9.54	8.08
Three or more	14.95	12.37
Age: Head of Household		
Under 25	3.25	7.66
25 to 34	8.90	8.18
35 to 44	11.05	11.24
45 to 54	10.47	9.68
55 to 64	7.51	5.90
65 or over	6.23	3.38

(cont.)

(CONT.) TABLE 1: MEAN DAILY PERSON TRIPS PER HOUSEHOLD

	1989	1981
Trip Purpose		
Home-based work	1.86	
Home-based non-work	3.97	NA
Non-home-based	2.33	
MEAN NUMBER OF TRIPS PER PERSON	4.16	NA
NUMBER OF TRIPS PER PERSON		
Zero	.1%	
1	1.6	
2	32.8	
3	11.3	
4	20.4	
5	10.4	NA
6	8.9	
7	4.8	
8	3.7	
9	2.2	
10	1.4	
11 or more	1.5	

NC = Not Comparable.
NA = Not Available.

3.2 Trip Purpose

A shift appears to have occurred between 1981 and 1989 in terms of trip purpose. Home-based non-work trips decreased 7.2 points as a proportion of all trips, while non-home-based trips increased by 4.9 points. Home-based work trips remained relatively unchanged since 1981, increasing from 20.5 percent of all trips in that year to 22.8 percent today. While it is apparent that a change has taken place in household travel patterns since 1981, some of the change may be due to the diary methodology utilized in the most recent study which seems to have improved the reporting of non-home-based trips.

Within the home-based non-work trip category, shopping trips increased from 13.5 percent to 15.3 percent and school trips increased from 7.3 percent to 10.0 percent of all trips. Other types of home-based non-work trips decreased from 34.4 percent to 22.7 percent.

TRIP PURPOSE

(AS A % OF ALL TRIPS)

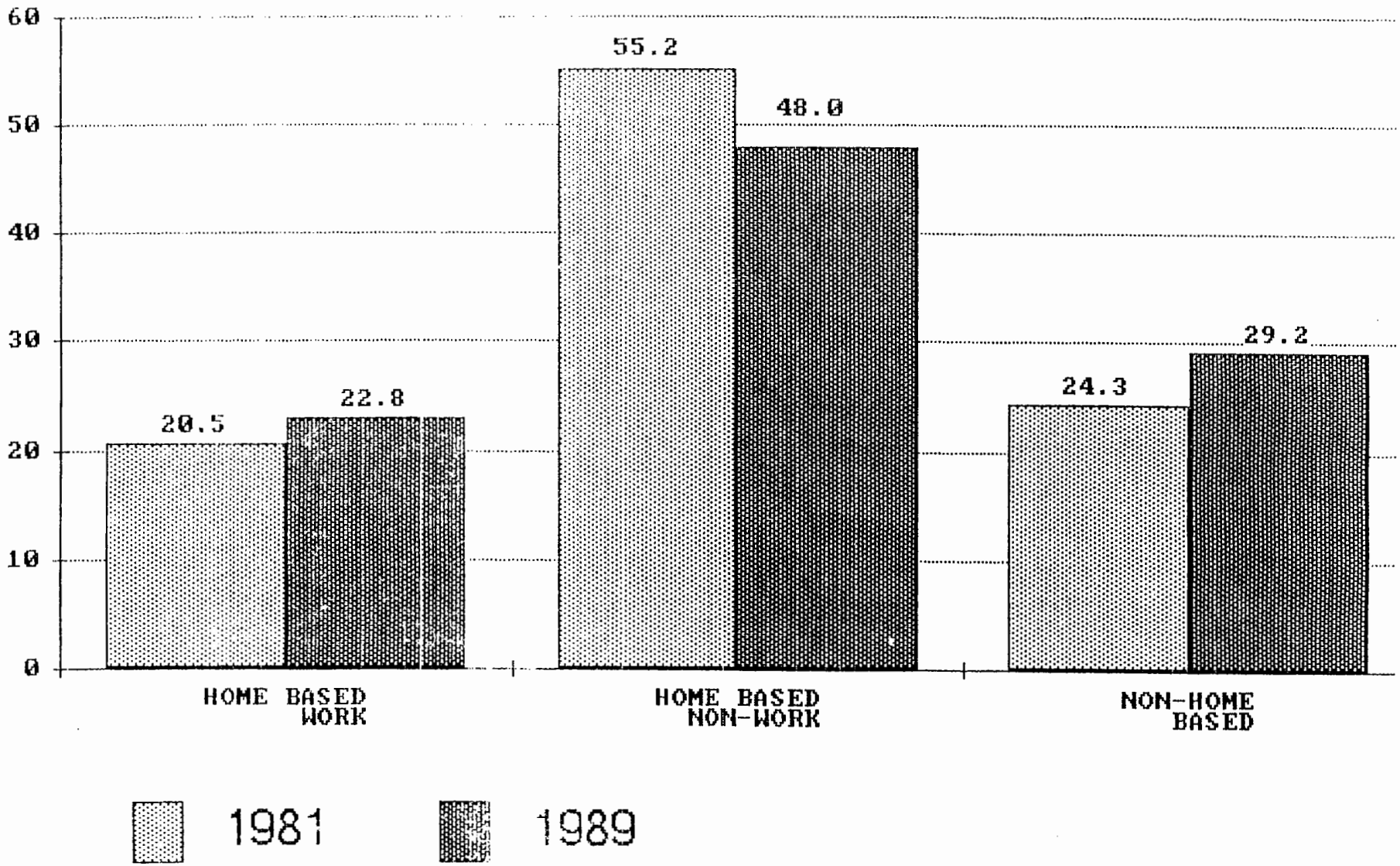


TABLE 2: TRIP PURPOSE - OVERALL

	1989	1981
Home-based: work	22.8	20.5
Home-based: shop	15.3	13.5
Home-based: school	10.0	7.3
Home-based: other	22.7	34.4
Non-home-based	29.2	24.3
	100.0%	100.0%

TABLE 3: TRIP PURPOSE BY MODE, OCCUPANCY AND TIMING

		Home-Based		
	Total	Work	Other	Non-Home-Based
Vehicle Mode				
Auto: driver	75.7	89.0%	64.8%	80.8%
Auto: passenger	18.9	5.8	26.8	16.4
School bus	3.1	.1	6.0	.8
City bus	1.0	1.6	1.1	.5
Motorcycle	.7	.9	.6	.8
Taxi	.1	.03	.1	.1
Walk to work	NA	1.0	NA	NA
Bicycle to work	NA	1.5	NA	NA
Other	.6	.2	.7	.7
	100.1%	100.1%	100.1%	100.1%
Vehicle Occupancy				
One	73.9%	91.8%	64.7%	72.9%
Two	18.4	6.1	24.3	20.2
Three	4.8	1.6	6.7	4.3
Four	1.8	.3	2.7	1.7
Five or more	1.1	.2	1.7	.9
	100.0%	100.0%	100.1%	100.0%
Trip Start Time				
6:00 AM to 6:59 AM	3.9%	12.3%	1.7%	1.1%
7:00 AM to 7:59 AM	7.9	15.2	7.7	2.5
8:00 AM to 8:59 AM	6.1	7.1	6.6	3.8
9:00 AM to 11:59 AM	16.8	7.7	15.5	27.1
NOON to 2:59 PM	19.2	10.9	17.3	30.0
3:00 PM to 3:59 PM	8.2	7.6	8.4	8.6
4:00 PM to 4:59 PM	7.6	10.7	6.5	7.7
5:00 PM to 5:59 PM	8.0	10.1	8.1	6.2
6:00 PM to 8:59 PM	14.1	7.7	20.1	9.6
9:00 PM to 11:59 PM	4.8	3.7	6.6	2.4
MIDNIGHT to 5:59 AM	3.4	7.1	1.5	1.1
	100.0%	100.1%	100.0%	100.1%

Totals may not equal 100% due to rounding.
NA = Not applicable, walk and bicycle trip counted on work trips only.

3.3 Trip Timing

As was the case in 1981, the 3:00 PM to 5:59 PM time period generates the highest traffic volume, with a reading of 23.8 percent. The majority of home-based work trips are concentrated in the customary early morning (6:00 AM to 9:00 AM) and late afternoon (3:00 PM to 6:00 PM) high peak periods while other home-based trips are distributed more evenly throughout the day. The majority of non-home-based trips (57.1%) occur between 9:00 AM and 3:00 PM.

TABLE 4: TRIPS BY TIME OF DAY

	1989		1981	
6:00 AM to 6:59 AM	3.9%		3.2%	
7:00 AM to 7:59 AM	7.9	† 17.9	6.4	† 16.1
8:00 AM to 8:59 AM	6.1		6.5	
9:00 AM to 9:59 AM	4.7		3.9	
10:00 AM to 10:59 AM	5.5	† 16.9	5.3	† 15.4
11:00 AM to 11:59 AM	6.7		6.2	
NOON to 12:59 PM	5.8		5.8	
1:00 PM to 1:59 PM	5.6	† 19.1	5.1	† 17.9
2:00 PM to 2:59 PM	7.7		7.0	
3:00 PM to 3:59 PM	8.2		8.9	
4:00 PM to 4:59 PM	7.6	† 23.8	8.2	† 25.7
5:00 PM to 5:59 PM	8.0		8.6	
6:00 PM to 6:59 PM	6.3		7.1	
7:00 PM to 7:59 PM	4.4	† 14.1	5.1	† 15.5
8:00 PM to 8:59 PM	3.4		3.3	
9:00 PM to 9:59 PM	2.6		3.1	
10:00 PM to 10:59 PM	1.5	† 4.8	2.3	† 6.6
11:00 PM to 11:59 PM	.7		1.2	
MIDNIGHT to 5:59 AM	3.4		2.3	
Not Determined	NA		.6	

Totals may not equal 100% due to rounding.

TRIPS BY TIME OF DAY

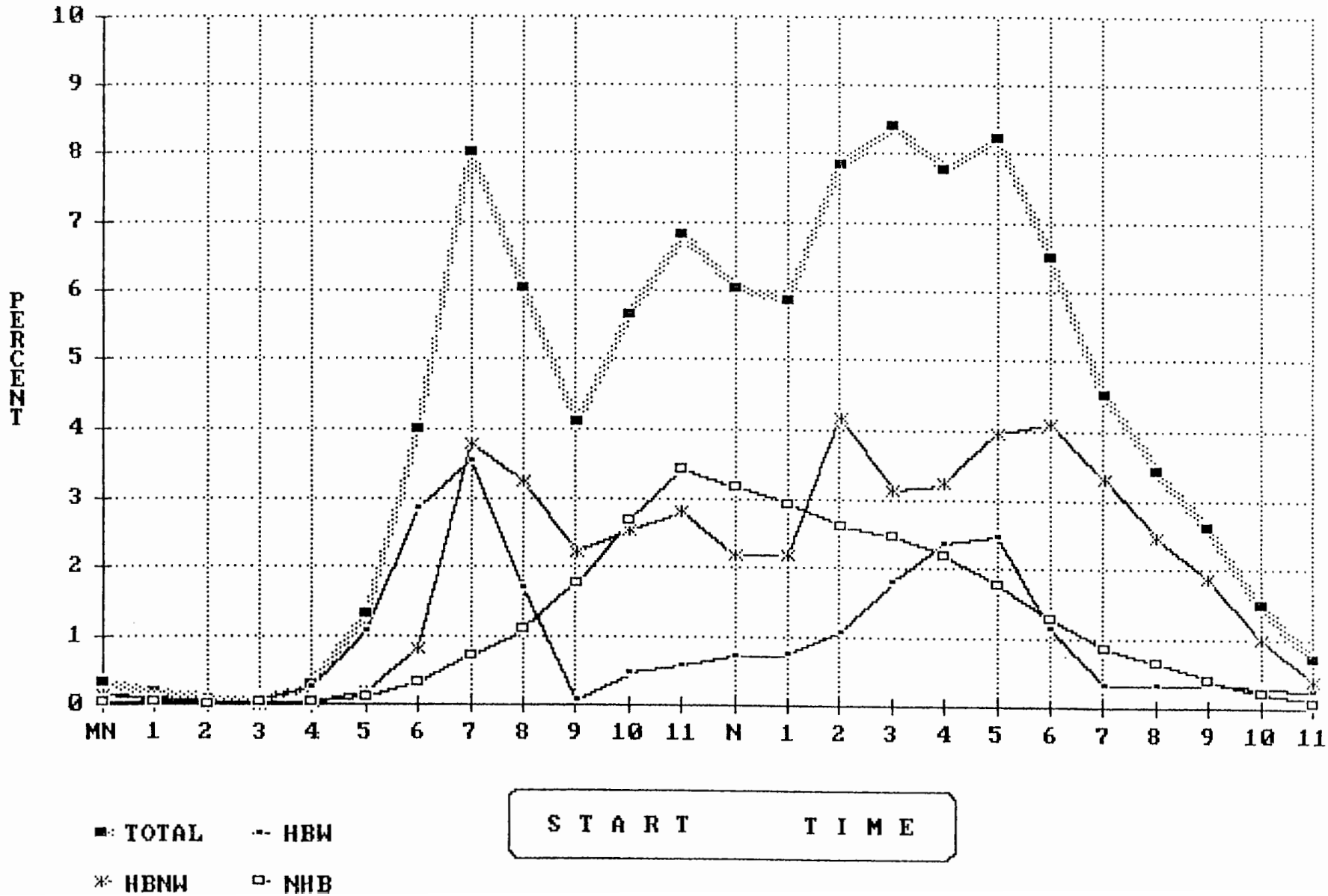


TABLE 5: TRIP PURPOSE BY TIME OF DAY (AS A PERCENT OF TRIP PURPOSE)

	Total	Home-Based Work	Home-Based Other	Non-Home-Based
6:00 AM to 8:59 AM	17.9%	34.7%	16.0%	7.4%
9:00 AM to 2:59 PM	36.0	18.6	32.6	57.1
3:00 PM to 5:59 PM	23.8	28.3	22.9	22.5
6:00 PM to 5:59 AM	22.3	18.4	28.5	13.0
	100.0%	100.0%	100.0%	100.0%

TABLE 6: TRIP PURPOSE BY TIME OF DAY (AS A PERCENT OF TIME OF DAY)

	Home-Based Work	Home-Based Other	Non-Home-Based	
6:00 AM to 6:59 AM	69.4%	19.9%	10.7%	(100%)
7:00 AM to 7:59 AM	42.3	45.1	12.6	(100%)
8:00 AM to 8:59 AM	25.7	48.3	26.0	(100%)
9:00 AM to 9:59 AM	15.6	44.9	39.5	(100%)
10:00 AM to 10:59 AM	7.6	44.0	48.4	(100%)
11:00 AM to 11:59 AM	8.1	40.3	51.6	(100%)
12:00 PM to 12:59 PM	11.6	35.2	53.2	(100%)
1:00 PM to 1:59 PM	12.5	36.6	50.9	(100%)
2:00 PM to 2:59 PM	13.2	51.2	35.6	(100%)
3:00 PM to 3:59 PM	20.4	47.8	31.8	(100%)
4:00 PM to 4:59 PM	29.3	40.2	30.5	(100%)
5:00 PM to 5:59 PM	29.2	46.4	24.4	(100%)
6:00 PM to 6:59 PM	16.9	60.6	22.5	(100%)
7:00 PM to 7:59 PM	7.3	71.9	20.8	(100%)
8:00 PM to 8:59 PM	9.2	69.8	21.0	(100%)
9:00 PM to 9:59 PM	12.8	67.5	19.7	(100%)
10:00 PM to 10:59 PM	17.7	63.6	18.7	(100%)
11:00 PM to 11:59 PM	30.0	50.0	20.0	(100%)
12:00 AM to 12:59 AM	44.1	42.6	13.3	(100%)
1:00 AM to 1:59 AM	30.2	50.1	19.7	(100%)
2:00 AM to 2:59 AM	50.6	28.7	20.7	(100%)
3:00 AM to 3:59 AM	67.6	6.3	26.1	(100%)
4:00 AM to 4:59 AM	81.2	7.9	10.9	(100%)
5:00 AM to 5:59 AM	77.3	12.9	9.8	(100%)

3.4 Travel Mode

Better than three out of every four person trips (75.7) in 1989 were made by auto-drivers while 18.9 percent were made by auto-passengers. These figures represent a 4.2 point increase in auto-driver trips in 1989 over 1981 and a corresponding decrease in auto-passenger trips (5.7 points).

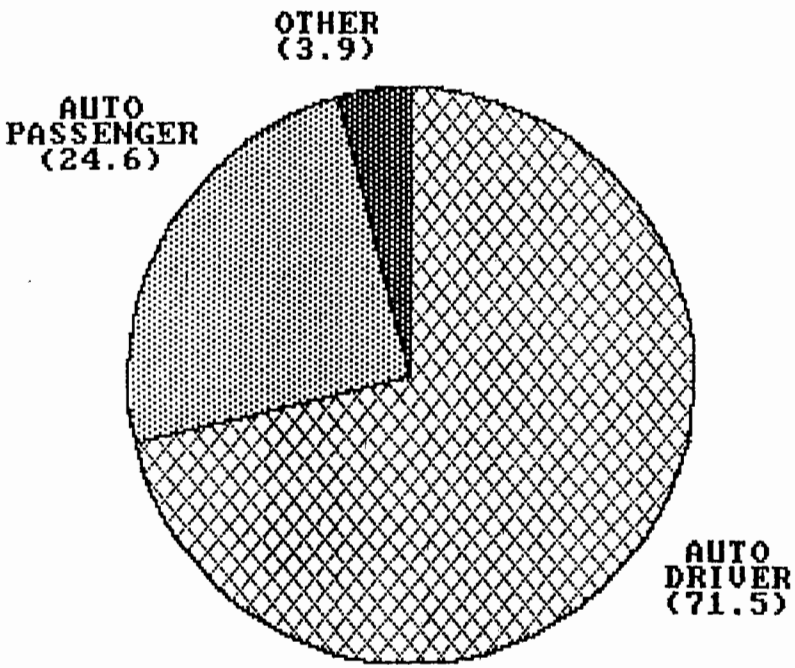
The data also reveals that school bus trips as a percentage of all person trips have increased since 1981 (2.1%, 1981; 3.1%, 1989) as have city bus trips (.7%, 1981; 1.0%; 1989).

TABLE 7: TRAVEL MODE

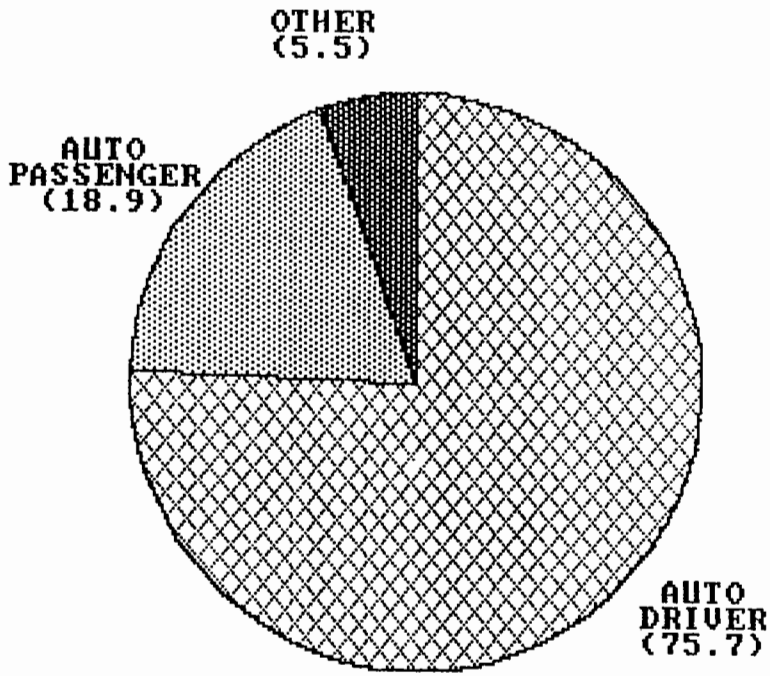
	1989	1981	Change
Auto: driver	75.7	71.5	+ 4.2
Auto: passenger	18.9	24.6	- 5.7
School bus	3.1	2.1	+ 1.0
City bus	1.0	.7	+ .3
Motorcycle	.7	1.0	- .3
Taxi	.1	.1	0
Other	.6	NA	NA

Excludes walk and bicycle trips to work.

TRAVEL MODE



1981



1989

3.5 Vehicle Occupancy

Since 1981, the average vehicle occupancy on auto-driver trips has declined from 1.43 persons per auto to 1.38. Overall, better than seven out of ten (73.9) auto-driver trips are made with only one occupant, up from 69.8 percent in 1981. The decline recorded in vehicle occupancy is found among each of the three primary trip purpose types analyzed except home-based work trips which increased slightly.

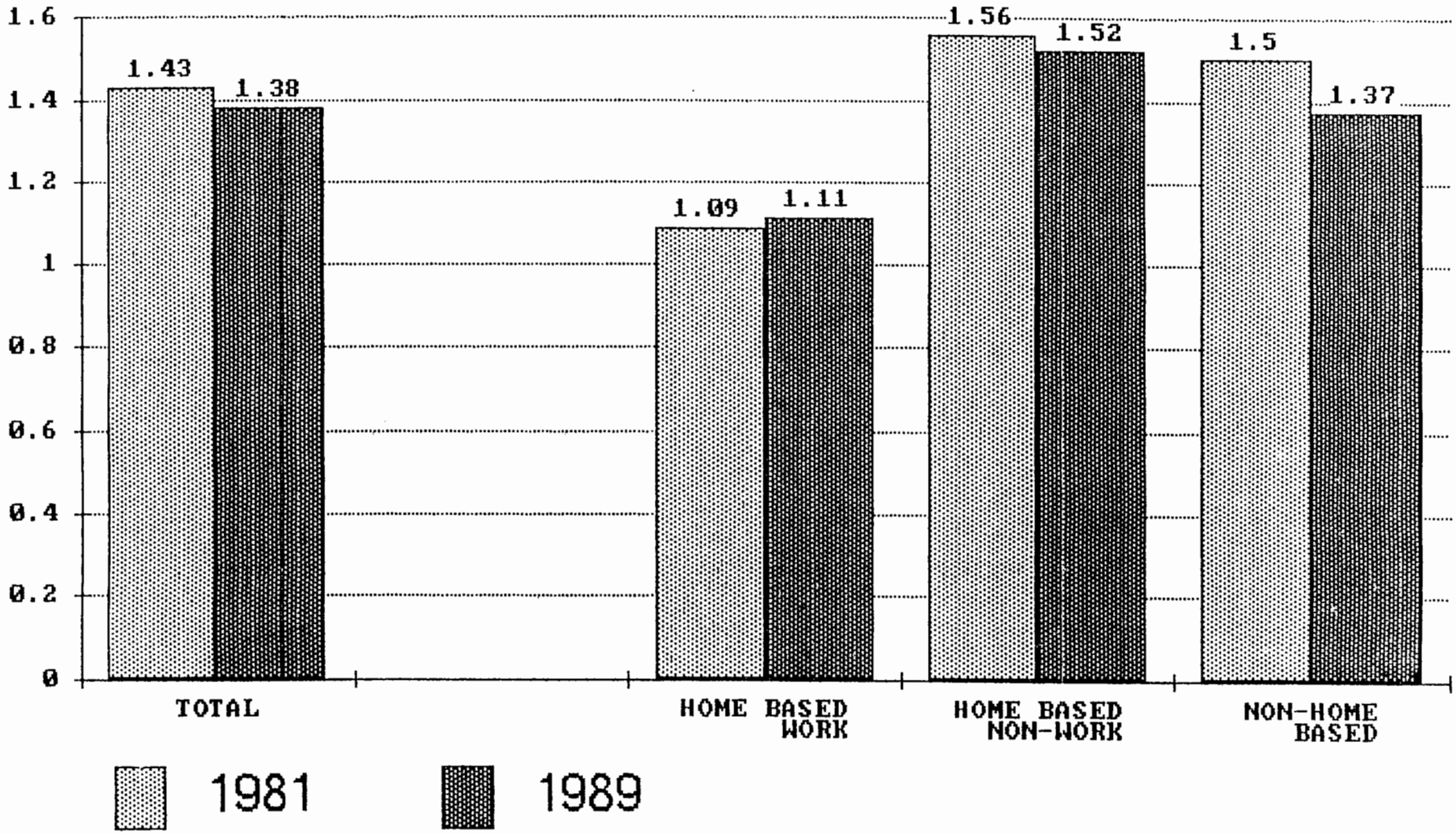
TABLE 8: VEHICLE OCCUPANCY*

	1989	1981
One	73.9%	69.8%
Two	18.4	22.1
Three	4.8	4.9
Four	1.8	2.2
Five or more	1.1	1.0
	100.0%	100.0%
Mean Occupancy		
Total Trips	1.38	1.43
Home-based: work	1.11	1.09
Home-based: other	1.52	1.56
Non-home-based	1.37	1.50

* Auto driver trips only.

VEHICLE OCCUPANCY

(VEHICLE DRIVER TRIPS ONLY)



3.6 Land Use At Trip Destination

The most common land use at trip destination is residential (42.3%) followed by retail (15.6%) and commercial office (11.2%). As Table 9 indicates, and as could be expected, major variations in land use at destination are recorded in terms of trip purpose.

TABLE 9: LAND USE AT TRIP DESTINATION

		Home-Based		
	Total	Work	Other	Non-Home-Based
Home	42.3%	47.3%	57.7%	17.1%
Shopping center/Retail store	15.6	6.8	12.1	26.2
Office building	11.2	24.3	1.6	16.8
School	7.2	4.3	9.5	5.8
Restaurant	4.9	1.2	3.5	9.2
Church/Social building	3.2	1.1	4.1	3.2
Medical office/Hospital	3.1	2.9	2.8	3.6
Bank	2.6	.8	2.2	4.4
Grocery store	2.5	.3	2.1	4.3
Manufacturing plant	1.4	4.1	.1	1.5
Outdoor recreation	1.2	.3	1.7	1.2
Construction site	.7	1.3	.1	1.2
Transit stop/Park & Ride lot	.6	.3	.3	1.1
Other	3.5	5.0	2.2	4.4
	100.0%	100.0%	100.0%	100.0%

3.7 Vehicle Ownership

Ninety-six percent of metropolitan area households own a motor vehicle with the average household owning 1.91 vehicles. These figures are virtually unchanged since the 1981 study.

A change has occured, however, in terms of the types of vehicles owned by households. Thus, as Table 10 reveals, the percentage of households owning a passenger car has declined by 11 points while the percentage owning trucks and vans has increased by nine points.

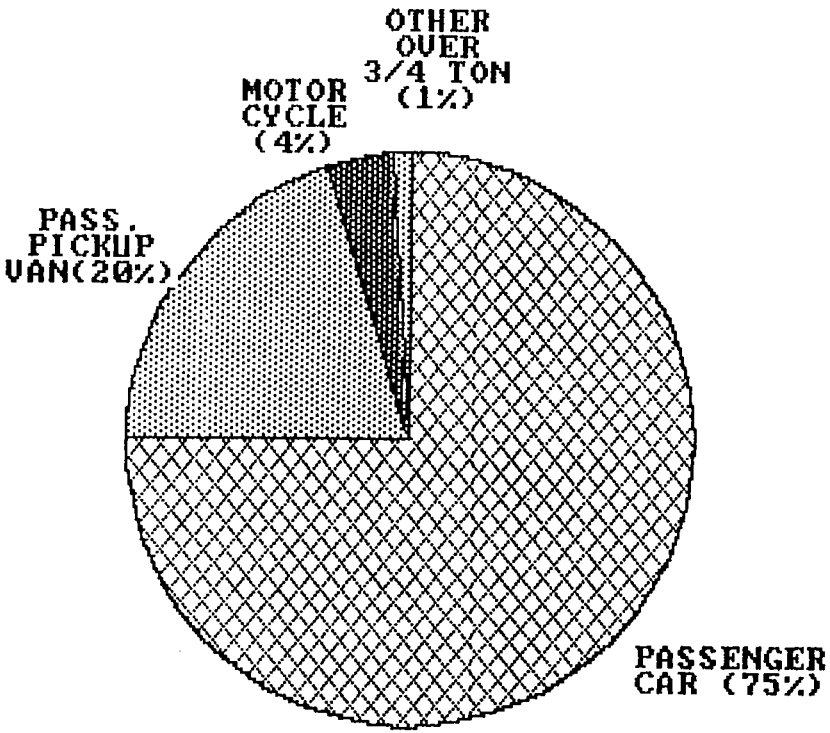
TABLE 10: VEHICLE OWNERSHIP

		Number of Vehicles Owned			
		0	1	2	3+
Passenger car	- 1989	10%	56%	26%	8%
	- 1981	9	53	30	8
Passenger pick-up trucks or vans	- 1989	59	33	6	2
	- 1981	68	28	4	*
Other vehicles over 3/4 tons	- 1989	96	4	*	*
	- 1981	98	2	*	0
Motorcycles	- 1989	94	5	1	*
	- 1981	93	6	1	*
Total Vehicles	- 1989	4	38	35	23
	- 1981	4	36	39	21

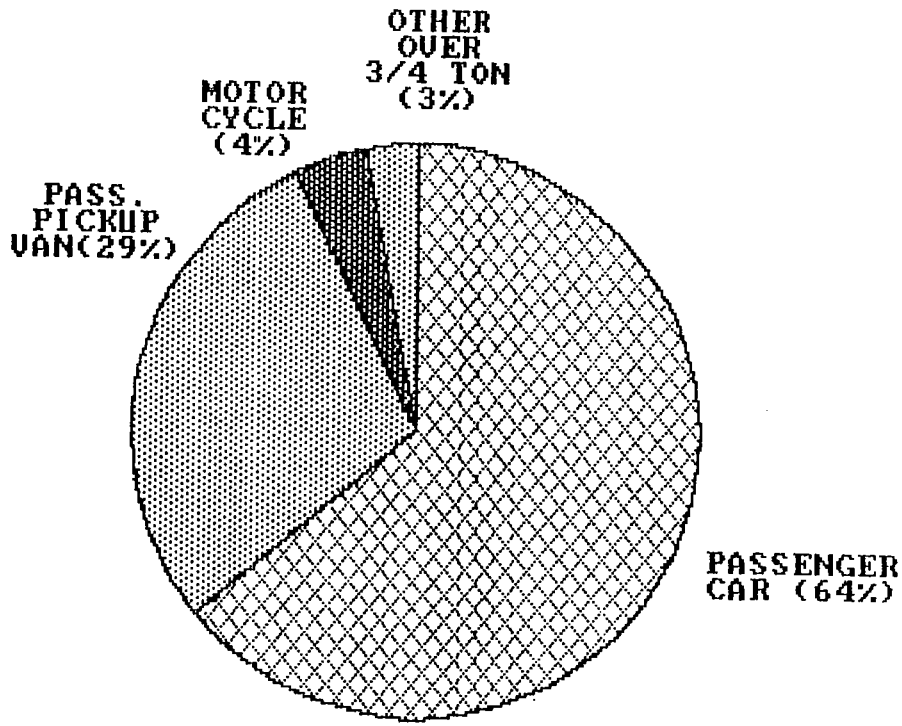
As % of All Vehicles	1989	1981	Change
Passenger car	64%	75%	- 11
Passenger pick-up trucks or vans	29	20	+ 9
Other vehicles over 3/4 tons	3	1	+ 2
Motorcycles	4	4	0
Average	1.91	1.87	+.04

* Vehicles owned, leased or regularly available to household.

VEHICLE OWNERSHIP



1981



1989

As one would expect, vehicle ownership increases in direct correlation to increases in household size, number of employed in household, number of licensed drivers in household and income.

TABLE 11: AVERAGE NUMBER OF VEHICLES

	1989	1981
Total	1.91	1.87
Persons in Household		
One	1.17	.96
Two	1.86	1.73
Three	2.09	2.12
Four	2.21	2.27
Five or more	2.84	2.59
Household Income		
Under $15,000	1.21	
$15,000 to $24,999	1.62	
$25,000 to $34,999	1.90	NC
$35,000 to $49,999	2.26	
$50,000 or over	2.60	
Total Employed in Household		
None	1.36	1.20
One	1.71	1.78
Two	2.25	2.16
Three or more	3.37	3.44
Licensed Drivers in Household		
None	.34	.06
One	1.25	1.14
Two	2.08	1.98
Three or more	3.31	3.01
Age: Head of Household		
Under 25	1.38	1.75
25 to 34	1.81	1.89
35 to 44	2.25	2.28
45 to 54	2.34	2.32
55 to 64	2.01	1.74
65 or over	1.48	1.29

NC = Not Comparable.

4.0 APPENDIX

4.1 Survey Forms

MARICOPA•ASSOCIATION•OF•GOVERNMENTS
Transportation & Planning Office (602) 254-3842

Dear Valley Resident:

Thank you for agreeing to participate in the Maricopa Association of Governments' Regional Travel Survey. This survey will play an important part in planning for transportation needs in the Valley. The purpose of this survey is to find out how often people travel, where they travel, and what kinds of transportation they use.

As stated in the telephone call you received from the survey team several days ago, your household was chosen at random. The information you provide will be strictly confidential and will be combined with responses from other residents to summarize regional travel characteristics. Instructions on how to fill out the needed information forms are provided on the following pages.

Your cooperation is very important in our effort to meet the transportation needs of residents in the cities, towns and unincorporated areas of Maricopa County. If you have any questions about the purpose of the survey or about how to fill out any of the forms, please call Mrs. Collier at the Travel Survey Office, 254-3842.

Sincerely,

Roger A. Herzog

Roger A. Herzog
Manager, Transportation
and Planning Office

REGIONAL TRAVEL SURVEY

INSTRUCTIONS

This survey has two parts.

"Part 1: Household Information" requests information about you and your household for statistical purposes. An example of a filled-out household information form is provided below.

PART 1: HOUSEHOLD INFORMATION

Mr. John Allen 0801
1501 N. Jones Street
Tempe, AZ 85282

(4)

Your Travel Day Is: THURSDAY, AUGUST 11

The label above includes some of the information you provided when our interviewer called. Included are your home address and the number of persons five years of age or older in your household. If any of these items are incorrect, please write the correct information directly on the label.

Please fill out the information below on your household.

1. **Starting with yourself as "person number 1,"** please assign a "person number" to each person residing in your household who is five years of age or older. Then fill in the boxes to the right for each person. Be sure that the person number on this form corresponds to the person number used on the Travel Diary.

Person Number	Age	Gender M/F	Relationship To Person Number 1 (Check One) Spouse	Child	Relative	Not Related	Does This Person Have A Valid Driver's License? Yes	No	Is This Person Employed Full-time, Part-time Or Not Employed Full Time	Part Time Only	Not Employed	If Employed: Amount This Person Pays For Parking At Work Each Month
1	46	M	Person Number 1				☒	☐	☒	☐	☐	$ 30.00 Per Mo.
2	41	F	☒	☐	☐	☐	☒	☐	☒	☐	☐	$ -0- Per Mo.
3	16	F	☐	☒	☐	☐	☒	☐	☐	☒	☐	$ -0- Per Mo.
4	5	M	☐	☒	☐	☐	☐	☒	☐	☐	☒	$ Per Mo.
5			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
6			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
7			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
8			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
9			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo
10			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.

2. What was your total family income for last year, before taxes, and including everyone in your household? (Check One)

A ☐ Under $15,000
B ☐ $15,000 - $24,999
C ☒ $25,000 - $34,999
D ☐ $35,000 - $49,999
E ☐ $50,000 or over

This completes Part 1. Next, on your assigned travel day, please fill out one of the enclosed Travel Diaries yourself and ask every household member over five years of age to do the same. Leave this form and the completed diaries in a convenient place at home so they will be available when the interviewer calls. If you have any questions, call Mrs. Collier at the Travel Survey Office at 254-3842.

"Part 2: Travel Diary" are diaries for each member in your household five years old or older to record the trips they take.

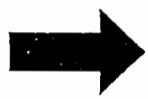
- Please have each member of your household five years of age or older fill out a separate Travel Diary on the assigned travel day. Feel free to help children fill out their Travel Diary.

- Be sure to have each household member include their assigned person number (see Part 1: Household Information) on their Travel Diary.

- Fill out one line on the Travel Diary for every place you go on the assigned travel day.

FOR EXAMPLE, LET'S SAY THE FOLLOWING TRIPS WERE MADE:

Trip Number	
(1)	YOU LEAVE HOME AND DRIVE TO A DAYCARE CENTER
(2)	THEN YOU DRIVE TO WORK
(3)	THEN YOU DRIVE TO LUNCH
(4)	THEN YOU DRIVE TO A STORE
(5)	THEN YOU DRIVE BACK TO WORK
(6)	THEN YOU DRIVE TO A DAYCARE CENTER
(7)	THEN YOU DRIVE HOME



IF YOU MADE NO ADDITIONAL TRIPS ON THE TRAVEL DAY YOU WOULD HAVE FILLED OUT SEVEN LINES AS INDICATED ON THE SAMPLE TRAVEL DIARY ON THE FOLLOWING PAGE.

PART 2: TRAVEL DIARY

TRAVEL DAY AND DATE: Thursday, August 11

FOR PERSON NUMBER 2 (Write in number from Household Information form)

On this day, did you travel away from your home? (Check One)

X YES - Continue below
_ NO - Return questionnaire

MY FIRST TRIP TODAY BEGAN AT

X Home _ Other Location (indicate address below)

Address or closest intersecting streets

City

INSTRUCTIONS:

Please carry this diary with you throughout the travel day shown above.

- *Record each trip you make in the order you make it*
- *Include the specific data requested for each trip*
- *Do not record walking or bicycle trips except to go to or from work*

	THIS LOCATION'S ADDRESS (Please indicate address if known. Otherwise, list two closest intersecting streets.)	TRIP TIME (Circle AM/PM) BEGIN	END	PURPOSE OF TRIP (Enter code no. from below in box at left)	KIND OF PLACE (Restaurant, Store, Bank, Office, House, etc.)	MODE OF TRAVEL (Enter code no. from below in box at left)	NUMBER OF PERSONS IN VEHICLE (Including Driver)
FIRST I WENT TO	1730 E. Baseline / Tempe	AM 7:30	AM 7:40	8	Day Care	1	2
THEN I WENT TO	701 W. Washington / Phoenix	AM 7:45	AM 8:10	1	Office	1	1
THEN I WENT TO	3rd Ave & Roosevelt / Phoenix	PM 12:05	PM 12:10	4	Restaurant	1	4
THEN I WENT TO	1st St & Fillmore / Phoenix	PM 1:00	PM 1:05	4	Conv. Store	1	4
THEN I WENT TO	701 W. Washington / Phoenix	PM 1:08	PM 1:12	1	Office	1	4

Purpose of trip codes:
1. To work
2. Work-related
3. School
4. Shopping or meal
5. Social or recreation
6. Personal business
7. Return home
8. Serve a passenger
9. Change mode (e.g. auto to bus)

Mode of travel codes:
1. **Driver** of Car, Van or Pick-up
2. **Passenger** in Car, Van or Pick-up
3. City Bus
4. School Bus
5. Taxi
6. Motorcycle
7. Walk to work
8. Bicycle to work
9. Other

For Further Information Call Mrs. Collier at the Travel Survey Office: 254-3842

	THIS LOCATION'S ADDRESS (Please indicate address if known. Otherwise, list two closest intersecting streets.)	TRIP TIME (Circle AM/PM) BEGIN	END	PURPOSE OF TRIP (Enter code no. from below in box at left)	KIND OF PLACE (Restaurant, Store, Bank, Office, House, etc.)	MODE OF TRAVEL (Enter code no. from below in box at left)	NUMBER OF PERSONS IN VEHICLE (Including Driver)
THEN I WENT TO	1730 E. Baseline / Tempe	PM 5:10	PM 5:35	8	Day Care	1	1
THEN I WENT TO	Home	PM 5:40	PM 5:50	7	Home	1	2
THEN I WENT TO		AM / PM	AM / PM				
THEN I WENT TO		AM / PM	AM / PM				
THEN I WENT TO		AM / PM	AM / PM				
THEN I WENT TO		AM / PM	AM / PM				
THEN I WENT TO		AM / PM	AM / PM				
THEN I WENT TO		AM / PM	AM / PM				
THEN I WENT TO		AM / PM	AM / PM				

Purpose of trip codes:
1. To work
2. Work-related
3. School
4. Shopping or meal
5. Social or recreation
6. Personal business
7. Return home
8. Serve a passenger
9. Change mode (e.g. auto to bus)

Mode of travel codes:
1. **Driver** of Car, Van or Pick-up
2. **Passenger** in Car, Van or Pick-up
3. City Bus
4. School Bus
5. Taxi
6. Motorcycle
7. Walk to work
8. Bicycle to work
9. Other

For Further Information Call Mrs. Collier at the Travel Survey Office: 254-3842

DEFINITION OF TERMS

Travel Day

The travel day is the 24-hour period starting at 4:00 a.m. of the travel day and ending at 4:00 a.m. of the following day.

A Trip

A trip is defined as travel from one point to another for a particular purpose. For example, if you drive to a store to shop and then drive home, you would record two trips; one for the trip to shopping and one for the trip back home. In addition, a continuous trip such as a pleasure drive from your home through a park and then back home, is also considered two trips; one for the most distant point reached during the drive and one for the trip back home.

Purpose of Trip

1 **To Work:** Trips to your place of employment, such as a factory, a shop, a store, an office, a construction site, etc.

2 **Work-related:** Trips to locations while performing a day's work. For example, a sales representative calling on a customer, a business person going to a meeting, or a delivery driver making daily rounds.

3 **School:** Trips made by students to school. Trips by teachers or school employees to school are "to work" trips. Trips by parents to drop off students at school should be reported as "serve a passenger" trips.

4 **Shopping or Meal:** Trips to shop where merchandise is sold or to eat a meal. Trips made to a store for the purpose of "just looking" are classified as "shopping" trips even if nothing is purchased. Trips made for repairs to autos, radios, or other items, as well as for cleaning or pressing clothes, etc., are also "shopping" trips. If you are employed and stop for items such as gas or cigarettes on your way to or from work, you should record each stop as a "shopping" trip.

5 **Social or Recreation:** Trips made for social or recreational purposes. This includes trips to social meetings, lectures, cultural events, visits to friends and church activities that are social in nature. It also includes trips for golfing, fishing, movies, bowling, athletic events, pleasure driving and other leisure time pursuits, whether indoors or outdoors.

6 **Personal Business:** Trips made to complete personal or household transactions unrelated to employment. This includes trips to a beauty parlor, a barber shop, a bank to transact personal business, a post office, an office to pay a bill, a lawyer to discuss personal matters, a doctor, or a dentist, etc.

7 **Return Home:** Trips to your place of residence.

8 **Serve A Passenger:** Trips made to pick up or drop off a passenger.

9 **Change Mode:** These are trips made to locations where a change in mode of transportation is made. For example, if a person going to work drives his auto from home to a Park and Ride bus stop and then rides the bus to work, two trips are recorded. The first trip is recorded as "change mode" as an auto driver, and the second trip is recorded as "to work" as a bus rider. Transfers from one bus route to another

(Continued on next page)

Kind of Place

"Kind of Place" refers to the type of facility at the end of a trip. Among the more common types of facilities are the following:

- Home (all types)
- Shopping center or retail store
- Restaurant
- Bar
- Nightclub
- Manufacturing plant
- Industrial park
- Office building
- Construction site
- Grocery store
- Medical office
- Bank
- School (please indicate whether elementary, high school, college or university)
- Transit stop/Park & Ride lot

Mode of Travel

The "Mode of Travel" is the means by which a person or group of persons make a trip. For the purpose of this Travel Survey, the following "Modes of Travel" are used:

1 **Driver** of car, van or pick-up

2 **Passenger** in car, van or pick-up

3 City bus

4 School bus

5 Taxi

6 Motorcycle

7 Walk (used **only** for a person's first trip to go to **work** or last trip from **work** to go home)

8 Bicycle (used **only** for a person's first trip to go to **work** or last trip from **work** to go home)

9 Other (train, airplane)

Please be sure to keep the Household Information form and all of the completed Travel Diaries in a convenient place at home so they will be available when we call. We will call you within three days of your travel day. After we have called, please return the completed Household Information form and the completed Travel Diaries in the postage-paid return envelope provided.

If you have any questions, call Mrs. Collier at the Travel Survey Office at 254-3842.

THANK YOU.

PART 1: HOUSEHOLD INFORMATION

Your Travel Day Is: _____

The label above includes some of the information you provided when our interviewer called. Included are your home address and the number of persons five years of age or older in your household. If any of these items are incorrect, please write the correct information directly on the label.

Please fill out the information below on your household.

1. **Starting with yourself as "person number 1,"** please assign a "person number" to each person residing in your household who is five years of age or older. Then fill in the boxes to the right for each person. Be sure that the person number on this form corresponds to the person number used on the Travel Diary.

Person Number	Age	Gender	Relationship To Person Number 1 (Check One)				Does This Person Have A Valid Driver's License?		Is This Person Employed Full-time, Part-time Or Not Employed			If Employed: Amount This Person Pays For Parking At Work Each Month
		M/F	Spouse	Child	Relative	Not Related	Yes	No	Full Time	Part Time Only	Not Employed	
1			Person Number 1				☐	☐	☐	☐	☐	$ Per Mo.
2			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
3			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
4			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
5			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
6			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
7			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
8			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
9			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.
10			☐	☐	☐	☐	☐	☐	☐	☐	☐	$ Per Mo.

2. What was your total family income for last year, before taxes, and including everyone in your household? (Check One)

A ☐ Under $15,000
B ☐ $15,000 - $24,999
C ☐ $25,000 - $34,999
D ☐ $35,000 - $49,999
E ☐ $50,000 or over

This completes Part 1. Next, on your assigned travel day, please fill out one of the enclosed Travel Diaries yourself and ask every household member over five years of age to do the same. Leave this form and the completed diaries in a convenient place at home so they will be available when the interviewer calls. If you have any questions, call Mrs. Collier at the Travel Survey Office at 254-3842.

MARICOPA•ASSOCIATION•OF•GOVERNMENTS
Transportation & Planning Office *

REMEMBER

YOUR TRAVEL DAY:

(4:00 AM to 4:00 AM)

REMEMBER:

- To give every household member a Travel Diary.
- To have every household member keep a record of his or her trips on the Travel Day.

For Further Information Call Mrs. Collier at the Travel Survey Office: 254-3842

MARICOPA•ASSOCIATION•OF•GOVERNMENTS
Transportation & Planning Office *

DESCRIPTION OF MAG FORECASTING MODELS

The following sections summarize the MAG model stream for forecasting urban activity and travel. The first section describes how MAG allocates regional total population and employment forecasts to small areas. This creates the socioeconomic description of the urban area which is used by the MAG travel demand model to generate travel estimates. The next section summarizes how the travel models use this data to produce estimates of motor vehicle traffic on the various streets and highways of the region.

These models have evolved over many years in response to increased understanding of urban travel behavior and collection of new data. It can be anticipated that they will continue to improve in response to requirements for new kinds of analysis, more sophisticated tools, and better understanding of complex urban systems.

These models produce the input databases for many of the procedures which estimate air pollution emissions. In particular, estimates of motor vehicle emissions are derived directly from them, including estimates of vehicular traffic at airports. Figure B-1 shows the location of the airports with respect to the MAG travel demand modeling domain. Estimates of aircraft activity at airports relates to employment at airports, but is projected independently of the MAG socioeconomic models.

MAG Socioeconomic Forecasting Models

MAG uses the Disaggregate Residential Allocation Model (DRAM) and the Employment Allocation Model (EMPAL) to distribute regional control totals of population and employment to 141 Regional Analysis Zones (RAZs). The forecasted RAZ employment and population distributions are disaggregated to 1272 Traffic Analysis Zones (TAZs). Socioeconomic data derived from these forecasts are used as input variables to the travel demand modeling process.

DRAM/EMPAL

DRAM is used for the spatial allocation of residents or population to zones in a metropolitan region and EMPAL is used for the spatial allocation of employment to zones. DRAM and EMPAL each requires two groups of input data in order to run. First, the models require a set of "card image" data containing the various model controls, previously estimated equation coefficients, and region wide population and employment forecasts. The second input needed by DRAM and EMPAL is a set of files, in binary format, that contain zonal data on base year employment, population, land use, and zone-to-zone travel times or costs.

DRAM and EMPAL allow four types of constraints to occur within the forecasting process.

Type I - an absolute constraint on the amount of employment or number of households of a specific type in a specific zone.

Type II - an absolute constraint on the total employment or number of households of all types in a specified zone.

Type III - a maximum value for a particular employment or household type in a specific zone. (Only operates when forecast exceeds the maximum.)

Figure B-1

Type IV - a minimum value for a particular employment or household type in a specific zone. (Only operates when forecast is less than the minimum.)

K-Factor Option

An optional, input data set of K-factors may be included as binary input. K-factors are prepared by the KFAC program and are used for verification runs and forecast runs.

For verification runs, the DRAM and EMPAL models should provide estimates of households and employment locations that equal (match) the observed, actual locations. K-factors can be used to produce an exact match by adjusting the estimates made by DRAM/EMPAL. The K-factors are derived through an iterative process. Once the K-factors are determined, runs can be verified by not attenuating the K-factors.

For forecast runs, considering that no changes occurred in zonal conditions from the base year, K-factors are not modified. K-factors are determined according to base year conditions, which will gradually lose influence in future conditions over time. To account for the diminishing effect of the base year conditions, the K-factors are attenuated for future year forecasts. Typically, for a five year forecast interval, K-factors are multiplied by 0.75 for the first forecast period, 0.5 for the second, and 0.25 for the third. K-factors are not recommended for use beyond 15 years, since it is assumed that the base year conditions will have no influence on zonal conditions 15 or more year into the future.

For forecast runs where the zonal conditions have changed from the base year conditions, the K-factor must be modified and attenuated. The program KFAC is used to adjust the K-factors and the attractiveness of zones, thus improving the accuracy of DRAM and EMPAL forecasts. However, caution must be taken when adjusting the K-factors to avoid a magnification of the factor throughout all the iterations.

MAG Application of DRAM/EMPAL

The initial run of DRAM/EMPAL uses actual observed data, acquired from census data on households and population. Employment data is obtained from an employment place of work survey/study. The exogenous variables used for forecasting employment include travel times, base employment distribution, total zonal acres, and lagged employment. The variables used to forecast household distributions are travel times, vacant acres, percent developed acres, residential acres and base household distribution.

Adjustments of the exogenous variable parameters is achieved through an iterative process of calibration on base year data. Once a "best fit" has been achieved, residual data is stored as K-factors. The K-factors are applied in a verification run as a final check to ensure that all parameters, switches and input ratios have been properly set.

Once the model is calibrated, forecasts are be built off of the original data set to estimate future employment and population. MAG has actual data available for 1985 and 1990 conditions. For verification of the model MAG used the 1990 data as the base year data set.

After a forecast run, the model provides estimates of employment and residents for each regional analysis zone (RAZ). Because the MAG travel demand model (TDM) requires input data by traffic analysis zones (TAZ), the output from DRAM/EMPAL must be converted from RAZs to TAZs. The data is broken down into TAZs using the Subregional Allocation Model (SAM). Population and

employment estimates by TAZ are input into the TAZ master file, which serves as input data for the TDM.

Description of standard data base

The standard data base, referred to as the TAZ master file, contains all the socioeconomic and land use conditions for each TAZ. The master file contains information concerning population, households, employment, household incomes, developable and undevelopable area, vehicles, school enrollment, retirement or non-retirement zone, terminal time, parking costs, and Sky Harbor enplanements. DRAM/EMPAL forecasted employment and population are input into the TAZ master file for the forecast year. Table B-1 presents the format for the TAZ master file.

Implications for air quality analysis at airports

It is possible that there is a logical connection between airport operations and airport landside trip generation. If there is such a connection, it may be reasonable to model general airports as special generators, as is the case with Sky Harbor International.

An examination of projected employment versus the number of aircraft operations projected from the RASP for 2015 revealed no correlation between aircraft operations and employment. This may be due to several factors. First, none of the employment categories (other, public, retail, office, or industrial) specifically addresses the employment associated with aviation activities. Second, many of the airports are located in TAZs which contain other employment sources, such as industrial activities or office/business centers not directly associated with the airport. Third, within Maricopa County there are a mix of private and public airports. Private and public airports operate differently and handle different types of aircraft operations. Therefore, these two types of airports might need to be analyzed separately to obtain statistically significant correlations with employment.

Table B-1: Format for TAZ master file

Variable Name
Year
TAZ (Traffic Analysis Zone) ID
District ID
Metropolitan Planning Area ID
Resident Population in Households
Resident Population in Group Quarters
Transient Population
Seasonal Population
Occupied Resident Households
Occupied Group Quarters Households
Occupied Transient Households
Occupied Seasonal Households
Other Employment
Public/Quasi-Public Employment
Retail Employment
Office Employment
Industrial Employment
Mean Household Income (in 1988 dollars)
Developed Residential Area (sq. mi. x 100)
Undeveloped Residential Area (sq. mi. x 100)
Developed Employment Area (sq. mi. x 100)
Undeveloped Employment Area (sq. mi. x 100)
Undevelopable Area (sq. mi. x 100)
Total Area (sq. mi. x 100)
Vehicles (owned and garaged)
Post High School Enrollment
Retirement Pointer (1 = Retirement Zone, 0 = otherwise)
Distance to ASU (miles x 10)
Daily Parking Costs (cents in 1988 dollars)
Hourly Parking Costs (cents in 1988 dollars)
Sky Harbor Enplanements (Sky Harbor only)
Terminal Time (minutes)

MAG Regional Travel Demand Models

The MAG regional travel demand model (TDM) process follows the traditional methodology for trip generation, trip distribution, modal choice, and traffic and transit assignment. The model has recently been converted from the Urban Transportation Planning System (UTPS) to EMME/2 programs.[1] Additional programs are included for the estimation of transit and highway resource requirements, and to provide system evaluation data. Submodels are available to estimate data such as households by income and size. Figure B-2 shows how the parts of the travel models relate to each other.

Ongoing model improvement efforts include amending the trip distribution and generation models to account for changing travel patterns by time of day, improved accuracy of model distances and speeds, and a more sophisticated modeling of the feedback between congested roadway speeds and travel decisions.

Trip Generation

The trip generation model relates person trip productions and attractions to land use and socio-economic characteristics of the region. Only travel internal to the MAG planning area is generated by this model. Trips with one or both ends outside the planning area and by commercial vehicles, such as trucks and taxis, are accounted for separately. Input files required by the trip generation model include the highway and transit networks and the TAZ master file. The trip generation process calculates trip productions and attractions, which serve as input to the trip distribution model. The trip generation model set includes submodels which estimate households by income quintile and average persons per household, a set of cross-classification trip rates to estimate trip productions, and a set of linear regression equations to estimate trip attractions.

The models were not changed in the conversion to EMME/2 programs. They are well documented.[2,3]

The household model estimates the number of households by income group and household size given total households, average income and average persons per household. This model was calibrated using the 1980 census data and is applied at the traffic analysis zone (TAZ) level.

Since the MAG trip generation models were developed and calibrated before DRAM and EMPAL, the interfaces between these models are still in a development stage. The DRAM model estimates the number of households by income quintile for regional analysis zones. This data is then transformed into an estimate of total households and average household income by traffic analysis zone in the Subregional Allocation Model (SAM). In the trip generation process, average household income is used to disaggregate households into number of households by income quintile.

There is a difference in assumptions between the DRAM model and the household income distribution submodel of trip generation. DRAM assumes that the percentage of households by income quintile changes over time with overall changes in real income levels. The trip generation submodel assumes that the percentage of households in each income group is constant over time. MAG is in the process of updating the trip generation relationships to improve operational efficiency and consistency with the DRAM model.

There are eight trip generation purposes: home-based work, home-based shopping, home-based secondary school, home-based ASU, home-based other university, home-based other, non-home-based work, and non-home-based other. The trip production models use income and household size as the primary independent variables. Five trip purposes (home-based work, home-based shopping, home-based other, home-based secondary school, and non-home-based) also consider if the household is in a retirement area or not and use the retirement pointer as an additional cross-classification variable. The models were calibrated using a cross-classification technique at the household level and are applied at the TAZ level. The ASU cross-classification model includes the airline distance as a third independent variable. The airline distance accounts for the fact that households closer to ASU will produce more trips than those further away.

The trip attraction model uses employments by type (retail, public, office, industrial, other), households, population, and university student enrollment as the primary independent variables. The model was calibrated by linear regression at the district level and is applied at the TAZ level.

In addition, two variables were developed to explain the effects of urban form. These are population and employment within one mile of a zone centroid.

Non-home-based trips are a function of attraction variables. For non-home-based work and non-home-based other trips, productions are set equal to attractions. However, total non-home-based trips are calculated on the production end by household and summed up to a regional total. Non-home-based work and other attractions and productions are factored to equal this total.

Home-based work, home-based ASU and home-based other university trip productions are normalized to regional total trip attractions. That is, they are factored so that total productions equal total attractions. For other purposes, trip attractions are normalized to regional production totals. Home-based work trip attractions are broken down by income quintile, as a function of area type (density).

Trip Distribution

The trip distribution model uses the gravity model formula to estimate the number of trips traveling from one zone to another for a specific purpose. The model is calibrated for seven basic trip purposes: home-based work, home-based shopping, home-base other, home-based school, home-based post high school, non-home-based work, and non-home-based other. For home-based work trips, separate tables are generated for each income class, using separate sets of friction-factors. The trip distribution model was revised during the conversion to EMME/2.[4]

The gravity model, as it applies to transportation planning, states that the number of trips between one traffic analysis zone and another is dependent on the relative attractiveness of the destination zone and the impedance between the origin and destination zone. "Attractiveness" of a zone is expressed in terms of trip ends or attractions and the impedance between zones is expressed in weighted units of travel time and cost. In general, the greater the travel time between two zones, the less the propensity to make a trip; and, the lower the attractiveness of the destination zone, the fewer the trips that will be sent to it. The gravity model formula is as follows:

$$T_{ij} = \frac{P_i \times A_j \times F_{ij}}{\Sigma (A_j \times F_{ij})}$$

where: T_{ij} = the number of trips from zone i to zone j.
P_i = the number of trips produced in zone i for a specific purpose.
A_j = the number of attractions in zone j for a specific purpose.
F_{ij} = an empirically derived friction factor which expresses the average area-wide effect of spatial separation on the trip interchanges between the two zones, i and j.

A travel time adjustment of 2 minutes is incorporated into the trip distribution model to represent the barrier effect of the Agua Fria and Salt Rivers.

Modal Choice

The MAG mode choice model is based on a New Orleans model, with appropriate adjustments made to the model bias coefficients to calibrate the model to Maricopa County conditions. The 1988 household travel survey and the 1991 on-board transit ridership survey provided information to analyze and revise the model coefficients to more accurately reflect Phoenix mode choice travel behavior. The mode choice model uses a logit formulation, which relates the probability of choosing a specific mode by using the following formula:

$$P_i = \frac{e^{Ui}}{\Sigma e^{Uk}}$$

where: P_i = the probability of choosing mode i
U_i = linear function of the descriptors of alternative i
U_k = linear functions of the descriptors of all the alternatives for which a choice is feasible.

Logit models can be used to estimate a change in mode choice if two items of information are known. These items are (1) the original or baseline percent choice, and (2) the absolute change in the "coefficient-variable" product.

There are mode choice models for three trip purposes: home-based work, home-based non-work, and non-home-based. Each model contains a set of three mode split equations; one for transit, one for single occupancy auto, and one for multi-occupancy (two or more) auto. Mode choice equations are presented in Tables 5-2, 5-3, and 5-4 of the Mode Choice chapter of the *Transportation Model Documentation*.[5]

The mode choice equation give significant advantage to drive-alone trips through the so-called "bias coefficients." These reflect the tendency of travelers to choose that mode if all other factors are equal. Bias coefficients are given for three income classes, with high income classes more likely to choose auto modes then low income classes.

Table B-2 summarizes the variables included in the MAG mode choice model. In-vehicle travel time, out-of-vehicle walk, wait and transfer time, and cost variables are included for all modes. Cost variables include transit fare, auto operating cost and parking costs. These coefficients have negative signs in all cases, meaning that increases in travel time or cost variables result in decreases in modal share. This is the expected result.

Table B-2: Summary of Variables in MAG Mode Choice Model

Purpose/Mode	In-Vehicle Time	Out-of-Vehicle Time	Cost	No. of Transfers	Auto Access Time	Bias Variables		
						Low Income	Middle Income	High Income
Home-Based Work								
Transit-Walk Access[1]	-	-	-	-				
Transit-Auto Access[1]	-	-	-	-	-	-	-	-
Drive-Alone Auto	-	-	-			+	+	+
Group Auto	-	-	-			-	-	(+,-)[2]
Home-Base Non-Work								
Transit-Walk Access[1]	-	-	-	-		-	-	-
Transit-Auto Access[1]	-	-	-	-	-	-	-	-
Drive-Alone Auto	-	-	-			+	+	+
Group Auto	-	-	-					
Non-Home-Based								
Transit-Walk Access[1]	-	-	-			-[3]		
Transit-Auto Access[1]	-	-	-		-	-[3]		
Drive-Alone	-	-	-			+[3]		
Group Auto	-	-	-					

Note: - means an increase in this variable reduces the probability of using this mode.

+ means this variable increases the probability of using this mode.

[1] Transit-walk and auto access (park and ride) are the same equation, but auto access mode includes additional variables.

[2] For Group Auto Home-based Work purpose, bias coefficient is positive for 2 person carpools and negative for 3 and 4 plus person carpools.

[3] For Non-Home-Based trips, bias coefficients are the same for all income classes.

Transit and Highway Assignment

Trip assignment is the final phase in the four-step travel demand modeling process. Both highway and transit assignments can be performed. The highway assignment process consists of assigning a total daily vehicle trip table in origin and destination format to the highway network utilizing a nine iteration capacity constrained assignment with equilibrium algorithm. The transit trip assignment component separately assigns work transit trips and non-work transit trips, which are further stratified by walk versus auto access, to the transit network.

Special Generator Models

Sky Harbor airport and the Tempe campus of Arizona State University (ASU) are special generators with special travel demand submodels. MAG is currently updating these models based on new travel behavior data collected during 1994. Data collection has been completed and model calibration will be forthcoming. The ASU model is integrated with the other person trip models. Home-to-ASU school trips are generated separately in the trip generation model and distributed separately in the trip distribution model. These were described above.

Vehicle trips to Sky Harbor Airport are generated by a separate submodel. The current model consists of a production equation for non-airport zones and an attraction trip rate for Sky Harbor. Since there is only one possible destination, no trip distribution is needed. Trip productions are a function of number of housing units, employment, and household income. Attractions are a function of passenger enplanements. These Sky Harbor trips are in addition to travel to the airport for other purposes, such as work trips, for which the airport is treated as any other zone.

The current update will attempt to address several issues: miscellaneous shuttle trips to rental cars, hotels and remote parking lots, traffic traveling through the airport without stopping, and the potential for reliever air carrier airport(s).[6,7]

Peak Period Model[8]

The peak period model used by MAG simulates the peak-spreading within the AM and PM peak periods as a facility becomes congested. The model was developed to represent the effect of peak-period congestion on the temporal distribution of demand during that period. The peak period model requires separate trip tables as input for each of three time periods: a three-hour A.M. peak, a three-hour P.M. peak, and an off-peak which includes all other times. MAG produces the trip tables using the matrix manipulation program UMATRIX.

The actual forecasting of peak-spreading occurs within UROAD. The development of new peak-spreading models and peak-hour volume-speed models required that the UROAD network equilibrium traffic assignment program be modified. In the revised program the new peak-spreading and volume-speed models are applied to each link each time link speed updating is required. The added steps are as follows:

1. Compute ratio of current assigned (three-hour) volume to three-hour link capacity.
2. Apply peak-spreading model to provide peaking factor: the ratio of one-hour volume to three-hour volume.

3. Determine peak-hour volume as the product of the peaking factor and the assigned three-hour volume.
4. Compute ratio of peak-hour volume to hourly link capacity.
5. Apply peak-hour speed model to estimate revised link speed.

This link updating process continues throughout the iterative equilibrium procedure.

When the network assignment is complete, link volumes represent peak-period (three-hour) flows, but link speeds correspond to peak-hour conditions. The UROAD modification provide the option of either using the peak spreading model to determine a final set of peak-hour volumes or to retain the peak period volumes.

This model may soon be replaced by changes in trip generation and distribution models to directly account for change in time of day.

External Trip Model

The external trip model accounts for trips entering, exiting, or traveling through the MAG modeling region. The model was developed based on results from an external trip survey conducted in 1986.[9]

External travel models are documented in Chapters 8 and 9 of *Transportation Model Documentation*.[10] External travel is measured at external stations, where roadways cross the edge of the transportation modeling region. For modeling purposes, trips can start or end at an external station.

There are two parts to external travel. The first is external-external travel, consisting of trips which pass through the transportation modeling region without stopping. External-external travel was determined using the 1986 survey data to create a base year trip table. One growth rate is used to estimate future external travel for all external stations. At the present time, the base year trip table is assumed to grow at the rate of growth of Arizona's population.

The second part of external travel is external-internal travel. Trips with one end outside the region and one end inside the transportation modeling region are referred to as external-internal trips. Productions are assumed to occur at external stations. Attractions are calculated by trip generation equations for internal zones.

Prior to conversion of the models to EMME/2, a direct estimation of travel from external zone to internal zone was made by an exponential equation. This proved unstable, so the model was reformatted for a gravity model distribution.

Productions at each external station were determined using the 1986 survey data. One growth rate is used to estimate future external productions at all external stations. Attractions are calculated separately for trips by 2-axle vehicles, 3-axle vehicles, and 4 or more axle vehicles. Trips are also calculated separately for external stations on freeways, other state highways, and local highways. This gives a total of 9 attraction equations, 9 sets of gravity model factors and 9 internal-external trip tables.

Commercial Vehicle Travel Model

The commercial vehicle travel model is used to estimate trips by commercial vehicles. The model follows the same process as that for the TDM and is calibrated using the results of the 1989 Commercial Vehicle Travel Survey.

Commercial vehicle trip generation is a land use-based rate model, which estimates trip productions and attractions based on land use and socioeconomic data for each zone. Land use-based models were developed for five commercial vehicle weight classes: 0-8,000 lbs, 8-28,000 lbs, 28-64,000 lbs, 64,000+ lbs, and 28,000+ lbs. The independent variables include households classifications, employment classifications, zonal area, and vehicles. The final trip generation model coefficients are presented in Table 4.5 of the *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area.*[11]

Commercial vehicle trip distribution follows the standard gravity-type model structure. Thus, trips for a particular weight category between production zone i and attraction zone j are directly proportional to the total number of trips productions in zone i, attractions in zone j, and an attractiveness factor based on impedance from i to j.

Prior to the assignment of the commercial vehicle trips, adjustments were made using an axles per vehicle trip factor and a combined registration and under-reporting factor. The axles per vehicle expansion factor means that the commercial vehicle trip table is in units of "passenger car equivalents" instead of vehicles. That is, a 3-axle truck is treated as 1.5 vehicles.

Changes with conversion to EMME/2

Many small changes were made to the travel demand model upon conversion to EMME/2.[12] First, the mode split model was recalibrated to include the 1991 On-Board Transit Survey. The significant variables found from the model calibration were parking cost and the bias coefficients. Further recalibration is planned. A second change was made to the speed/distance coefficient factor, which affects the travel times in the model. Since the model was overestimating the vehicle miles traveled (VMT), the expansion factor on non-home-based trips was removed in order to match ground counts. The trip distribution model was revalidated, the peak period factors were updated, the external-internal model was revised and the assignment process was validated.

Previous versions of the MAG model have also been documented.[13,14,15]

Implications for air quality analysis at airports

As trips to and from airports vary, so does the air quality at the airports. Therefore, it is important to understand the travel behavior around the airports within Maricopa County. Currently, the travel demand model accounts directly for production trips from and attraction trips to the Sky Harbor International Airport. Other airport sites may need to be explicitly included in the modeling process to correctly model aviation travel demand and to accurately estimate the air quality due to motor vehicle travel around airports.

It may be possible to adapt the Sky Harbor Special Generator model for use at Williams Gateway Airport (previously referred to as Williams Air Force Base), after it has been converted to a

commercial aviation airport. If so, the data requirements, as listed below for the Sky Harbor Special Generator, would need to be collected for Williams Gateway Airport.

To create the Sky Harbor Special Generator model, MAG conducted an extensive data collection effort. Information requested from Sky Harbor included:

1. Capacities of each parking structure/facility under Airport control including all public and employee lots.
2. Number of vehicles entering and exiting each public and employee parking structure/facility by hour.
3. Monthly activity reports for all months of 1993.
4. Daily passenger statistics including enplanements, deplanements, transfers, etc., by hour and day of week.
5. Daily passenger and employee forecasts to year 2020.
6. Number of employees classified by shift or time of day.
7. Schedules and occupancy data for shuttle buses serving Sky Harbor parking lots, off-site hotels and off-site parking lots.
8. Copies of any traffic studies (or traffic counts) at the Airport completed after Terminal 4 was completed.
9. Autocad files (on computer diskette) of the roadway network for purposes of identifying video camera locations.
10. Addresses (without names) or zip codes of employees' residences by job classification (i.e. pilot, baggage handler, airport security, etc).
11. Number of taxicabs by terminal, by hour and by day.
12. Number of rental cars by terminal, by hour and by day.
13. The names of companies operating off-airport parking lots and their locations.
14. Description of the approval process(es) necessary to: 1) conduct the video surveys, and 2) conduct interview surveys in either public terminal areas or in waiting areas.
15. Potential traffic (coning) schemes for redirecting traffic around the airport.

REFERENCES

1. Barton-Aschman Associates and Maricopa Association of Governments Transportation & Planning Office, November 1994. *Task 8 - Transportation Model Documentation*. Maricopa Association of Governments, Phoenix, AZ.

2. Barton-Aschman Associates and Maricopa Association of Governments Transportation & Planning Office, November 1994. *Task 8 - Transportation Model Documentation*, Chapter 2. Maricopa Association of Governments, Phoenix, AZ.

3. Barton-Aschman Associates and COMSIS Corporation, January 1990. *Phoenix Travel Demand Model Update Project*, Chapter 3. Maricopa Association of Governments, Phoenix, AZ.

4. Barton-Aschman Associates and COMSIS Corporation, January 1990. *Phoenix Travel Demand Model Update Project*, Chapter 4. Maricopa Association of Governments, Phoenix, AZ.

5. Barton-Aschman Associates and Maricopa Association of Governments Transportation & Planning Office, November 1994. *Task 8 - Transportation Model Documentation*, Chapter 5. Maricopa Association of Governments, Phoenix, AZ.

6. Behavior Research Center, Inc., November 1989. *Sky Harbor International Airport Visitor Study, Vol. I - Analysis*. Prepared for Phoenix Aviation Administration.

7. Barton-Aschman Associates, March 1995, Draft, Major Generator Study, *Sky Harbor International Airport and Arizona State University Interview Survey Results*, Maricopa Association of Governments, Phoenix, AZ.

8. Cambridge Systematics, Inc., 1988. *Analysis of Temporal Demand Shifts to Improve Highway Speed Modeling*. Arizona Department of Transportation, Phoenix, AZ.

9. Barton-Aschman Associates, Inc., 1986. *Phoenix Metropolitan Area External Trip Study*. Arizona Department of Transportation, Phoenix, AZ.

10. Barton-Aschman Associates and Maricopa Association of Governments Transportation & Planning Office, November 1994. *Task 8 - Transportation Model Documentation*, Chapters 8 and 9. Maricopa Association of Governments, Phoenix, AZ.

11. Cambridge Systematics, Inc., 1991. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*. Arizona Department of Transportation, Arizona Transportation Research Center, Phoenix, AZ.

12. Barton-Aschman Associates, Inc. and Maricopa Association of Governments Transportation and Planning Office, November 1994. *Task 8 - Transportation Model Documentation*. Maricopa Association of Governments, Phoenix, AZ.

13. Barton-Aschman Associates, Inc. and COMSIS Corporation, January 1990. *Phoenix Travel Demand Model Update Project*. Maricopa Association of Governments, Phoenix, AZ.

14. Barton-Aschman Associates, Inc., June 1984. *Travel Demand Model Users Guide.* Maricopa Association of Governments Transportation Planning Office, Phoenix, AZ.

15. Barton-Aschman Associates, June 1984. *Development and Calibration of Travel Demand Models for the Phoenix Area.* Maricopa Association of Governments Transportation and Planning Office, Phoenix, AZ.

PART 2: TRAVEL DIARY

TRAVEL DAY AND DATE: _____

FOR PERSON NUMBER _____ (Write in number from Household Information form)

On this day, did you travel away from your home? (Check One)

[ ] YES - Continue below

[ ] NO - Return questionnaire

INSTRUCTIONS:

Please carry this diary with you throughout the travel day shown above.

- *Record each trip you make in the order you make it*
- *Include the specific data requested for each trip*
- *Do not record walking or bicycle trips except to go to or from work*

MY FIRST TRIP TODAY BEGAN AT

[ ] Home [ ] Other Location (indicate address below)

Address or closest intersecting streets

City

	THIS LOCATION'S ADDRESS (Please indicate address if known. Otherwise, list two closest intersecting streets.)	TRIP TIME (Circle AM/PM) BEGIN	TRIP TIME (Circle AM/PM) END	PURPOSE OF TRIP (Enter code no. from below in box at left)	KIND OF PLACE (Restaurant, Store, Bank, Office, House, etc.)	MODE OF TRAVEL (Enter code no. from below in box at left)	NUMBER OF PERSONS IN VEHICLE (Including Driver)
FIRST I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME	1 To work 2 Work-related 3 School 4 Shopping or meal 5 Social or recreation 6 Personal business 7 Return home 8 Serve a passenger 9 Change mode (e.g. auto to bus)	Auto	1 Driver of Car, Van or Pick-up 2 Passenger in Car, Van or Pick-up 3 City Bus 4 School Bus 5 Taxi 6 Motorcycle 7 Walk to work 8 Bicycle to work 9 Other	A
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME				
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME				
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME				
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME				

For Further Information Call or Contact the Travel Survey Office 254-...

	THIS LOCATION'S ADDRESS (Please indicate address if known. Otherwise, list two closest intersecting streets)	TRIP TIME (Circle AM/PM) BEGIN	END		PURPOSE OF TRIP (Enter code no. from below in box at left)	KIND OF PLACE (Restaurant, Store, Bank, Office, House, etc.)		MODE OF TRAVEL (Enter code no. from below in box at left)	NUMBER OF PERSONS IN VEHICLE (Including Driver)
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME						
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME						
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME						
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME		1 To work 2 Work-related 3 School 4 Shopping or meal 5 Social or recreation 6 Personal business 7 Return home 8 Serve a passenger 9 Change mode (e.g. auto to bus)			1 **Driver** of Car, Van or Pick up 2 **Passenger** in Car, Van or Pick up 3 City Bus 4 School Bus 5 Taxi 6 Motorcycle 7 Walk to work 8 Bicycle to work 9 Other	
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME						
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME						
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME						
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME						
THEN I WENT TO	Address or closest intersecting streets City	AM / PM : TIME	AM / PM : TIME						

For Further Information Call Mrs. Collier at the Travel Survey Office: 254-3842

BEHAVIOR RESEARCH CENTER, INC.
1117 E. Third Street
Phoenix, AZ 85004
(602) 253-4551

(AFFIX LABEL HERE)

MAG-TPO METRO FIGURES
HOUSEHOLD TRAVEL SURVEY FORM #1

JOB ID# 98081 (1-5)

Status Code: ___ ___ ___ ___ ___

(1) RESP ID# (6-9)

SCREENING QUESTIONNAIRE

Hello, my name is _____ and I'm with the Behavior Research Center of Arizona. I'm calling on behalf of the Maricopa Association of Governments and I'd like to speak with the (male/female) head of your household. Are you the (male/female) head of your household?

IF YES - CONTINUE

IF NO - ASK TO SPEAK WITH (MALE/FEMALE) HEAD AND START AT BEGINNING. IF NOT AVAILABLE, INDICATE ON CALL RECORD BELOW AND DETERMINE CALLBACK TIME.

The purpose of this study is to determine where, when and how people travel throughout Maricopa County. This information is essential for the proper planning of transportation services in this area. Your household is one of only 2800 selected in Maricopa County to participate in this effort so your input is very important. All of your answers will be treated confidentially and used only in summarizing statistics.

SCREENING CALL/CALL RECORD FORM

			Dead		Alive					
Call Number	Date	Time	Discon-nected	Busi-ness	Term/ Refused	Language Barrier	RNA/ Busy	No Qual. Resp.	Call-back	Com-plete
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										

CB INFO

1. To begin, how many of each of the following types of motor vehicles are owned, leased, or regularly available to members of your household? Please only count vehicles that are currently in operating condition. (READ EACH)

   A. Passenger cars..... _____ (10)

   B. Passenger pick-up trucks or vans..... _____ (11)

   C. Other vehicles over three-quarter ton such as motorhomes..... _____ (12)

   D. Street-driven motorcycles..... _____ (13)

   SUM: TOTAL VEHICLES _____ (14-15)

2. Next, how many people currently live in your household? NUMBER: _____ (16-17)

3. And how many of these (NUMBER FROM Q2) people are five years of age or older? (2) NUMBER: _____ (18-19)

   (3) SUM: (QUOTA CATEGORY: _____ (20-21)

As I mentioned, the purpose of this study is to find out where, when and how people travel in Maricopa County. To determine this, we are asking you and each member of your household to record their travel patterns over a one-day period.

Your travel day will be (DAY AND DATE) and you will receive your travel packet several days prior to that day. Your travel day will be on a reminder card that you can post in a prominent place. It is very important that every household member keep a record of their travel for (DAY AND DATE). Travel diaries are enclosed in your packet for this purpose. We will be calling you a couple of days after your travel day to collect this information. What time of day would you prefer to have us call, in the morning, the afternoon, or the evening?

1 - Morning 2 - Afternoon 3 - Evening 4 - Weekend 5 - Any

In order to make sure your travel packet gets delivered correctly, I need your name, address and zip code. (VERIFY PHONE NUMBER. PRINT CLEARLY)

(4) NAME: Mr/Mrs/Ms _____ (6) PHONE: _____

(5) ADDRESS: _____ APT #: _____

CITY: _____ ZIP CODE: _____

SCREENER DATE: _____ NUMBER: _____

TRAVEL DAY/DATE: _____ (7) NUMBER: _____ (22-23)

REMINDER CALL DAY/DATE: _____ (8) NUMBER: _____

INTERVIEW DAY/DATE: _____ (9) NUMBER: _____

INTERVIEWER NAME: _____ NUMBER: _____

Thank you for your cooperation. If you should have any questions, you can call Mrs. Collier at the Travel Survey Office at 254-3042, 9 AM to 5 PM weekdays. We look forward to talking to you again.

REMINDER CALL QUESTIONNAIRE

Hello, may I speak to (LISTED PERSON) please?
(WHEN PROPER PERSON ON LINE, CONTINUE. IF NOT AVAILABLE, INDICATE ON CALL RECORD BELOW AND DETERMINE CALLBACK TIME.)

Hello, Mr/Mrs/Ms (LISTED PERSON), this is _____ from the Maricopa Association of Governments Travel Survey Office and I'm calling to see if you received the Travel Study materials we sent you.

4. Did you receive the materials we sent you? IF YES - GO TO Q5 IF NO - GO TO Q4a

4a. Apparently your packet was misplaced in the mail. Let me make sure we have your proper address (READ ADDRESS TO RESPONDENT AND MAKE ANY NECESSARY CHANGES). What we'd like to do is send you out a new packet of materials with a new assigned travel day.

Thank you for your cooperation. We'll be talking to you again in a week or so.

5. Did the packet we send you contain the following materials? (READ EACH)

		Yes	No
A.	An instruction booklet	1	2
B.	A household information form	1	2
C.	A travel Diary for each member of your household 5 years of age or older	1	[2] ↓
			7 Rec'd

(IF "NO" TO ANY OF ABOVE, INDICATE TO RESPONDENT THAT WE WILL FORWARD THEM THE NEEDED MATERIALS - ALERT SUPERVISOR)

6. Do you have any questions I could answer? (ANSWER ANY QUESTIONS). Thanks again for your cooperation; we look forward to talking to you again in a few days to collect your travel information. Remember your participation in this very important project is essential for the proper planning of transportation here in the Valley. Don't forget, your travel day is (DAY AND DATE).

REMINDER CALL/CALL RECORD FORM

CALL NUMBER	DATE	TIME	OUTCOME
1			
2			
3			
4			
5			
6			

INTERVIEW CALL INTRODUCTION QUESTIONNAIRE

Hello, may I speak to (LISTED NAME) please?
(WHEN PROPER PERSON ON LINE, CONTINUE. IF NOT AVAILABLE, INDICATE ON CALL RECORD BELOW AND DETERMINE CALLBACK TIME).

Hello, Mr/Mrs/Ms (LISTED NAME), this is _____ from the Maricopa Association of Governments Travel Survey Office. I'm calling to collect the information you recorded on your family's travel patterns. Could you please get the household information form and the travel diaries so that we can go over the information?

(WHEN RESPONDENT HAS FORMS HANDY, CONTINUE WITH BASE QUESTIONNAIRE. IF DATA WAS NOT COLLECTED ON ASSIGNED TRAVEL DAY, THANK RESPONDENT AND TERMINATE. RECORD OUTCOME ON CALLBACK FORM).

INTERVIEW CALL/CALL RECORD FORM

CALL NUMBER	DATE	TIME	OUTCOME
1			
2			
3			
4			
5			
6			

BEHAVIOR RESEARCH CENTER, INC.
1117 N. Third Street
Phoenix, AZ 85004
(602) 258-4554

MAG-TPO METRO PHOENIX
HOUSEHOLD TRAVEL SURVEY FORM #2

88081

BASE INTERVIEW

Let's begin with the **Household Information** form. According to the information you provided in our earlier call you have (NO. OF PEOPLE 5+ FROM SCREENER) person/people in your household 5 years of age or older. Is this correct?

YES - CONTINUE NO - (ASK:) What is the correct number? (Fill in below and continue)

CORRECT NUMBER:_____

1. Now I'd like to collect the data on the individual listed as person number (1, 2, 3, etc.) on the form.
   - B/C. What is this person's age and gender?
   - D. (IF OTHER THAN PERSON 1, ASK:) What is this person's relationship to person number 1?
   - E. Does this person have a valid drivers license?
   - F. Is this person employed full-time, part-time, or not employed?
   - G. (IF EMPLOYED, ASK:) How much, if anything, does this person pay for parking at work each month?
   - H. Did this person make any trips on the assigned travel day?

REPEAT PROCEDURE UNTIL DATA COLLECTED ON EACH PERSON IN HOUSEHOLD 5 OR OVER.

A	B	C	D						E	F		G	H	
			Relation To Person 1											
Person Number	Age (2 Digit)	Gender M F	Head	Spouse	Child	Relative	Not Related		License Y N	Employment Full	Part No	Parking Amount	Traveled Yes	No
01 (23)	(24-25)	1 2 (26)	1					(27)	1 2 (28)	1	2 3 (29)	. (30-34)	1	2 (35)
02 (36)	(37-38)	1 2 (39)		2	3	4	5 (40)		1 2 (41)	1	2 3 (42)	. (43-47)	1	2 (48)
03 (49)	(50-51)	1 2 (52)		2	3	4	5 (53)		1 2 (54)	1	2 3 (55)	. (56-60)	1	2 (61)
04 (62)	(63-64)	1 2 (65)		2	3	4	5 (66)		1 2 (67)	1	2 3 (68)	. (69-73)	1	2 (74)
05 (75)	(76-77)	1 2 (78)		2	3	4	5 (79)		1 2 (80)	1	2 3 (81)	. (82-86)	1	2 (87)
06 (88)	(89-90)	1 2 (91)		2	3	4	5 (92)		1 2 (93)	1	2 3 (94)	. (95-99)	1	2 (100)
07 (101)	(102-103)	1 2 (104)		2	3	4	5 (105)		1 2 (106)	1	2 3 (107)	. (108-112)	1	2 (113)
08 (114)	(115-116)	1 2 (117)		2	3	4	5 (118)		1 2 (119)	1	2 3 (120)	. (121-125)	1	2 (126)
09 (127)	(128-129)	1 2 (130)		2	3	4	5 (131)		1 2 (132)	1	2 3 (133)	. (134-138)	1	2 (139)
10 (140)	(141-142)	1 2 (143)		2	3	4	5 (144)		1 2 (145)	1	2 3 (146)	. (147-151)	1	2 (152)

2. Okay, the last piece of information I need from the **Household Information** form is your total household income for last year -- which one of the letters from A to E on the form best reflect it?

A - Under $15K...1
B - $15K to $24.9K...2
C - $25K to $34.9K...3
D - $35K to $49.9K...4
E - $50K or over...5
Refused...6

(153)

Now let's go to the Travel Diary for person number (FIRST PERSON MAKING TRIPS).

CLOSING STATEMENT

Thank you very much, that completes the interview. Since you've given me the required information, please do not mail back the **Household Information** form and **Travel Diaries** as instructed, simply discard them. Have a good (evening/afternoon).

INTERVIEWER NAME:_____ NUMBER:_____ _____ (451-453)

SUMMARY DATA - FOR INTERNAL USE ONLY

1. Age - head of household. . . . . _____ (454-455)
2. No. of driver's licenses in HH . . . . . _____ (456-457)
3. No. of employed persons in HH - Full . . . . . _____ (458-459)
   - Part . . . . _____ (460-461)
   - TOTAL. . . . _____ (462-463)
4. Total No. of trips reported by household . . . . . _____ (464-465)
5. No. of persons with unknown trips. . . . . _____ (466-467)

080881

MAG-TPO METRO PHOENIX
HOUSEHOLD TRAVEL SURVEY FORM #3

Person Number.: _____ (154-155)

Sheet _____ of _____

INTERNAL TRIP REPORT

A. How many total trips did this person make on the travel day? NUMBER: _____ (156-157)

B. Where did this person's first trip begin? In what city is that?

_____ City _____ (158-161)

Trip No.	What Is The Address Of The Location Where This Trip Ended? What Is The Address Of The Next Location This Person Traveled To? In What City Is That?	At What Time Did This Trip Begin And End?		What Was The Code Number For The Purpose Of This Trip?	At What Kind Of Place Did This Trip End?	What Was The Code For The Mode Of Travel On This Trip?	How Many People Were In The Vehicle?
01	_____ _____ City	Begin AM/PM _____	End AM/PM _____				
(162-163)	(164-167)	(168-169)	(170-171)	(172)	(173-174)	(175)	(176-177)
02	_____ _____ City	Begin AM/PM _____	End AM/PM _____				
(178-179)	(180-183)	(184-185)	(186-187)	(188)	(189-190)	(191)	(192-193)
03	_____ _____ City	Begin AM/PM _____	End AM/PM _____				
(194-195)	(196-199)	(200-201)	(202-203)	(204)	(205-206)	(207)	(208-209)
04	_____ _____ City	Begin AM/PM _____	End AM/PM _____				
(210-211)	(212-215)	(216-217)	(218-219)	(220)	(221-222)	(223)	(224-225)
05	_____ _____ City	Begin AM/PM _____	End AM/PM _____				
(226-227)	(228-231)	(232-233)	(234-235)	(236)	(237-238)	(239)	(240-241)
06	_____ _____ City	Begin AM/PM _____	End AM/PM _____				
(242-243)	(244-247)	(248-249)	(250-251)	(252)	(253-254)	(255)	(256-257)
07	_____ _____ City	Begin AM/PM _____	End AM/PM _____				
(258-259)	(260-263)	(264-265)	(266-267)	(268)	(269-270)	(271)	(272-273)

4.2 Sample Design

4.2.1 Introduction

After MAGTPO examined different approaches to designing the sampling strategy, a method outlined by John Hamburg of Barton-Aschman was chosen. The method was discussed in a Technical Memorandum prepared by Mr. Hamburg for the Dallas-Fort Worth Metropolitan Area Regional Travel Survey. The following document draws heavily from Mr. Hamburg's Technical Memorandum.

4.2.2. Home Interview Survey

The major objective of the home interview survey is to update the trip generation rates used in the travel demand forecasting process. The objective is not to collect the origin-destination linkages for the MAGTPO transportaion analysis zone system. Massive surveys, conducted in the '50s and '60s, were required to obtain this kind of geographic detail; sample rates ranged anywhere from one percent to ten percent. These large scale surveys were very expensive. Moreover, it appears that the use of a distribution model, in conjunction with trip productions and attractions, simulates ground count data as well as trip table data obtained in an origin-destination survey.

Basically, the home interview survey has evolved from a survey to obtain zone-to-zone person movements to a technique to obtain the data necessary to calibrate and validate two of the models used in travel demand: trip generation and trip distribution. Thus our consideration of sample size is based not on filling in a zone-to-zone travel matrix but on collecting travel data by household to be used in calibrating the travel demand models.

4.2.3. Quota Sample

Because our intent is to obtain travel data for trip generation and trip distribution, there is no need for a large scale systematic sample by geographic location. Instead, the issues are the data requirements of the models being used and the sample size needed. Many earlier sample designs were based on the use of a sample frame of households from which a systematic sample was selected. The distribution of households by car ownership, family size, income or other characteristics was left to chance since the sheer size of the sample ensured good coverage of most any variable one might wish to consider. Moreover, one often did not know exactly how trip generation would be done so it was critical to cover all bases. However, if we know, for example, that we want to estimate home-based work trips per household by household size and number of vehicles, we can design a sample that includes enough households in each category to yield a specified level of precision. To follow this approach requires (1)

a determination of the basic models to be calibrated with the data being collected and (2) a frame of secondary data, such as the MAG socioeconomic database, against which the rates developed in the survey can be applied. In other words, for each cell in the trip distribution model, one should make certain an adequate number of cases has been obtained in the sample to provide sufficient statistical reliability for that cell. The smaller the overall sample, the more critical it becomes to avoid having too many samples in one or more cells and not enough in other cells.

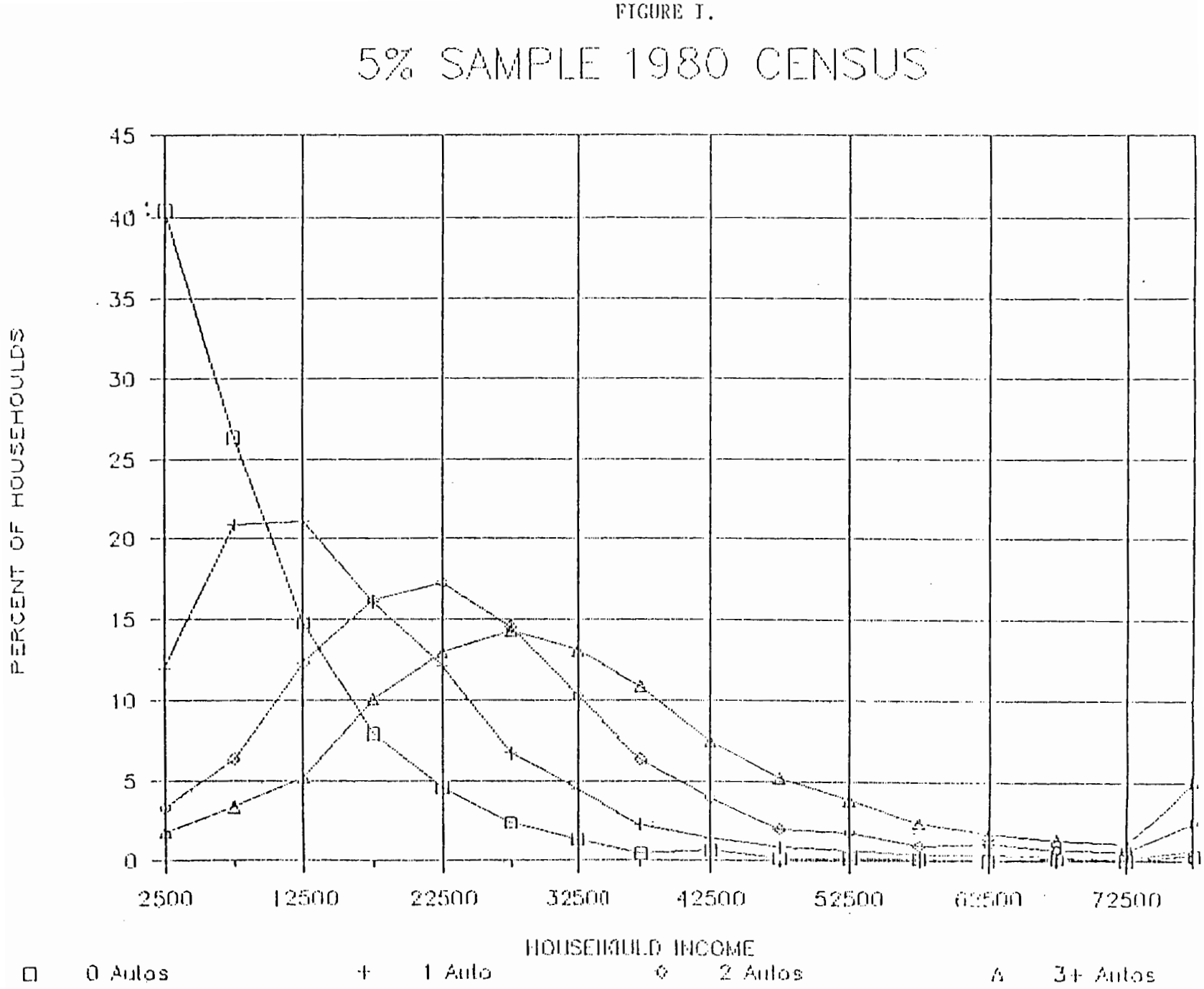
4.2.4. Variables

The establishment of a set of sample quotas depends upon the variables to be used in the trip generation models, the availability of the same data by transportation analysis zone and, finally, upon the anticipated willingness of the potential respondent to divulge that information to the interviewer. Based on the current trip generation models used by MAGTPO and upon recent research conducted by the MAGTPO staff, the two variables that would be used would be income per household and number of persons living in the household. The six classes of trip productions are home-based work trips, home-based shop trips, home-based secondary school trips, home-based post high school trips, home-based other trips, and non-home-based trips. The trip generation model uses cross classification rates based on household income and persons per household, and since this model structure seems satisfactory no change is planned for the model structure.

However, asking income is a sensitive question and it was decided not to ask for household income in the telephone pre-qualification stage of the survey. This decision was based on the concern that an income question over the telephone would result in a substantial increase in the number of households refusing to participate in the survey.

It is recommended that auto ownership be used as a proxy for income and quotas be established for the cells of the matrix formed by the four car ownership categories (zero cars, one car, two cars and three or more cars) and the six household size categories (one through six or more persons per household). While auto ownership will not give the exact income quotas one might prefer, auto ownership does give an indication of household income. (See Figure 1.)

FIGURE I.


5% SAMPLE 1980 CENSUS
PERCENT OF HOUSEHOULDS
45
40
35
30
25
20
15
10
5
0
2500
12500
22500
32500
42500
52500
62500
72500
HOUSEHOULD INCOME
0 Autos
1 Auto
2 Autos
3+ Autos

4.2.5. Establishing Quotas Per Stratum

The problem is to establish the number of households required for each stratum. Household size and car ownership were the two independent variables selected for use. The number of households in each stratum, for the region is presented in Table 12 and the percentages of households in each stratum are presented in Table 13. Notice that some stratum have very few households. It was decided that no sample quotas would be set for stratums with less than three percent of the households because precise data on these stratums will add very little to confidence in the models and would increase survey costs significantly.

TABLE 12: NUMBER OF VEHICLES PER HOUSEHOLD BY PERSONS PER HOUSEHOLD (1980 CENSUS - MARICOPA COUNTY)

Vehicle/ HHld:	Persons/Household					
	ALL	1	2	3	4	5+
0	32,478	21,369	6,155	2,073	1,244	1,637
1	206,700	77,710	77,098	22,838	15,650	13,404
2	186,887	11,508	81,914	34,836	33,146	25,483
3+	118,692	3,962	26,503	29,435	29,057	29,735
ALL	544,757	114,549	191,670	89,182	79,097	70,259

TABLE 13: PERCENT OF VEHICLES PER HOUSEHOLD BY PERSONS PER HOUSEHOLD (1980 CENSUS - MARICOPA COUNTY)

Vehicle/ HHld:	Persons/Household					
	ALL	1	2	3	4	5+
0	5.96	3.92	1.13	0.38	0.23	0.30
1	37.94	14.27	14.15	4.19	2.87	2.46
2	34.31	2.11	15.04	6.39	6.08	4.68
3+	21.79	0.73	4.87	5.40	5.33	5.46
ALL	100.00	21.03	35.18	16.37	14.52	12.90

TABLE 14: HOME-BASED WORK TRIP COEFFICIENTS OF VARIATION (1981 PHOENIX HOUSEHOLD SURVEY)

Income:	Persons/Household					
	1	2	3	4	5	6+
$0 to $7.5K	2.49	2.40	0.90	1.28	1.05	1.41
$7.5K to $15K	1.61	1.26	0.84	0.88	1.06	0.98
$15K to $22.5K	1.33	1.06	0.69	0.78	0.69	0.78
$22.5K to $30K	0.83	0.89	0.76	0.77	0.76	0.89
$30K and up	0.97	0.93	0.77	0.62	0.60	0.73

TABLE 15: HOME-BASED WORK TRIP COEFFICIENTS OF VARIATION (1964 DALLAS-FORT WORTH SURVEY)

Income Quartile:	Persons/Household					
	1	2	3	4	5	6+
1	1.38	1.08	1.01	1.04	1.02	1.15
2	1.23	.95	.87	.89	.84	.98
3	1.32	.88	.78	.76	.76	.87
4	1.31	.89	.74	.71	.67	.75

The coefficient of variations for home-based work trips and home-based non-work trips (see Tables 16 and 17) were examined by the stratum to be used for setting the survey quotas. The coefficient of variation that was the highest was then selected for determining the sample size in each stratum (see Table 18).

TABLE 16: HOME-BASED WORK TRIP COEFFICIENTS OF VARIATION (1964 DALLAS-FORT WORTH SURVEY)

Vehicle/ HHld:	Persons/Household					
	ALL	1	2	3	4	5+
0	1.56	2.05	1.43	1.13	1.13	1.19
1	0.99	1.27	1.08	0.86	0.86	0.97
2	0.74	1.23	0.77	0.71	0.71	0.76
3+	0.94	2.23	0.92	0.71	0.71	1.31
ALL	1	1.52	1.01	0.82	0.82	1.07

The sample size requirements for each stratum were calculated using the following statistic:

$$n = \frac{CV^2 Z^2}{e^2}$$

Where: n = sample size required
CV = coefficient of variation (standard deviation divided by the sample mean)
z = level of confidence
e = relative error

For example:

e = .10 (plus or minus ten percent)
CV = .95
Z = 1.645 for 90% confidence level

$$n = \frac{(1.645)^2 (.95)^2}{(.10)^2} = 244$$

The coefficient of variation was calculated for each stratum of home-based work trips used in the 1981 Phoenix Household Survey (see Table 14). It should be noted that the stratum used in the 1981 Phoenix Household Survey was income and household size (the coefficients of variation were not calculated for the proposed stratum of vehicles and household size because of the amount of work involved). Home-based work trips were selected because a study conducted in Dallas-Fort Worth found that in most stratum, work trips had a higher coefficient of variation than non-work trips, thus producing a more conservative sample size. The Dallas-Fort Worth coefficients of variation for each stratum

(see Table 15) were then compared with the Phoenix coefficients of variation and found to be similar. Since the Dallas-Forth Worth coefficients of variation were similar to the Phoenix survey for similar stratum, it was decided to use the Dallas-Fort Worth coefficients for the stratum defined by auto ownership and household size for determining the survey sample size (since they were not available from the 1981 Phoenix Household Survey).

TABLE 17: HOME-BASED NON-WORK TRIP COEFFICIENTS OF VARIATION (1964 DALLAS-FORT WORTH SURVEY)

Vehicle/ HHld:	Persons/Household					
	ALL	1	2	3	4	5+
0	1.69	1.77	1.65	1.29	1.29	1.34
1	1.01	1.07	0.89	0.85	0.85	0.85
2	0.85	0.91	0.85	0.76	0.76	0.73
3+	0.78	0.64	0.81	0.7	0.7	0.71
ALL	1.05	1.3	0.94	0.83	0.83	0.84

TABLE 18: COEFFICIENTS OF VARIATION USED TO DETERMINE SAMPLE QUOTAS

Vehicle/ HHld:	Persons/Household					
	ALL	1	2	3	4	5+
0	1.69					
1		1.27	1.08	0.86	0.00	0.00
2		0.85	0.76	0.76	0.76	
3+			0.92	0.71	0.71	1.31

Using the coefficients of variation in Table 18, sample quotas were calculated assuming a ten percent precision for all stratum, a 90 percent level of confidence for households with autos, and a 68 percent level of confidence for households without autos. The lower level of confidence was accepted for the households without autos because they represent a small portion (5.96%) of the population and a higher level of confidence would require 487 more interviews in that stratum, which would mean doubling the number of screening interviews and hence a significant cost. In addition, no household size quotas will be set for the households with no autos because of the anticipated difficulty in acquiring surveys.

4.3 Calculation of Expansion Factors

In order to calculate trip production and attraction rates and trip lengths, which are representative of total regional trip making, expansion factors were calculated to expand to the total universe of households and to account for any geographical bias. Expansion to the household universe was done by determining the number of households sampled versus the estimated number of households in 1988 by household size and vehicle availability, grouped into Quotas. Given the size of the regional zone system and the likely sparsity of trip movements within individual interchanges, the calculation of expansion factors to account for geographic bias was conducted at a Superdistrict level. Table 19 shows:

- The aggregation of geographic location into superdistricts employed for weighting the survey data.
- The total number of households from the MAG 1988 estimates.

Table 20 shows:

- The number of households that MAG estimated for 1988.
- The number of sampled households stratified by household size and auto availability as grouped into quotas for weighing purposes.

Table 21 shows the FRATAR matrix expansion method used to calculate expansion factors. The inputs for the FRATAR method are the survey data disaggregated by superdistrict and quota, plus aggregate 1988 MAG data for each superdistrict (see figure 2) and each quota. The resulting expansion factors are shown in Table 22.

FIGURE 2

SUPER DISTRICTS

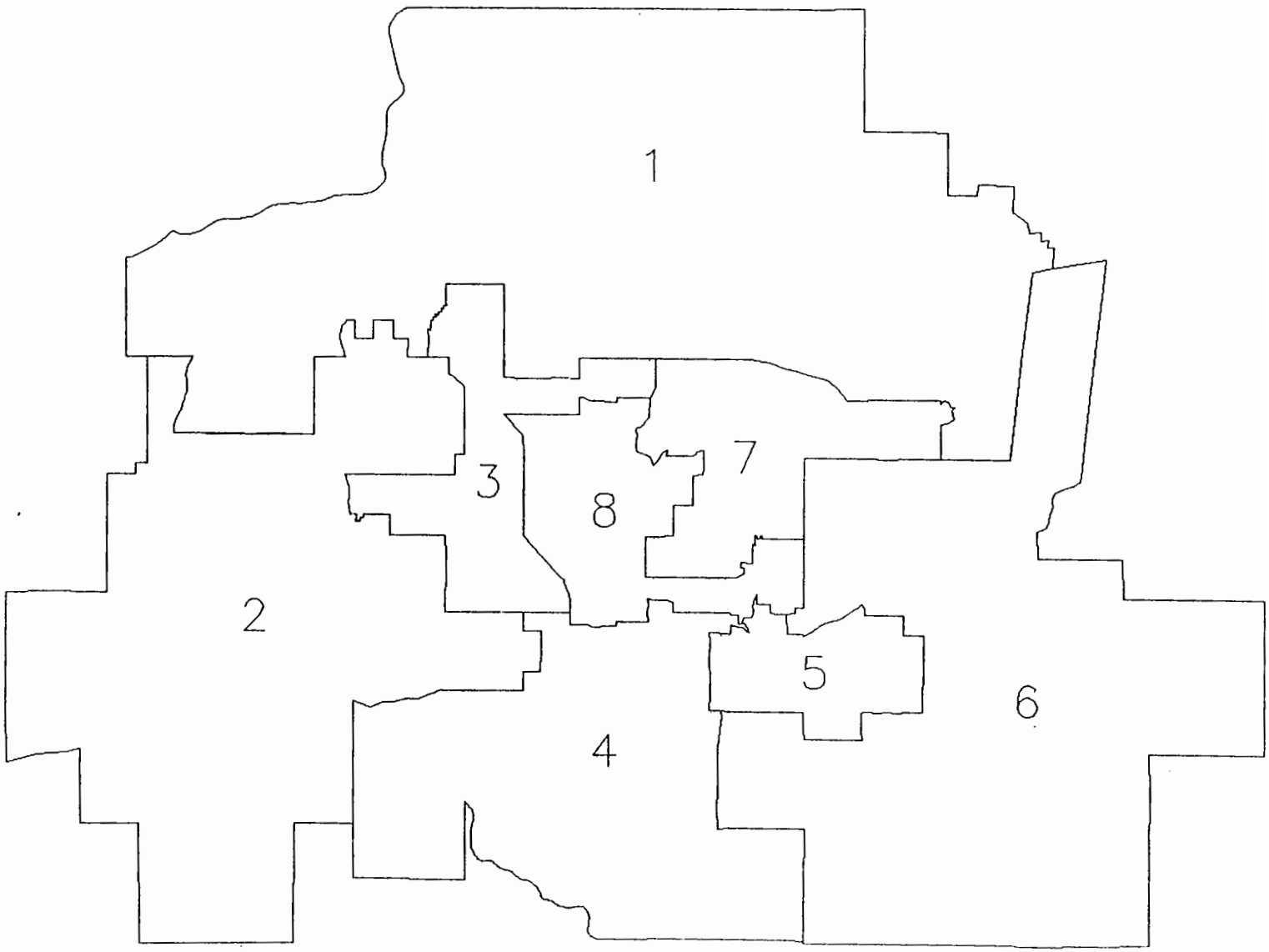


TABLE 19: AGGREGATION OF GEOGRAPHIC LOCATIONS INTO SUPERDISTRICTS

Superdistrict	Geographic Locations	1988 MAG Estimates
1	1-5	65,983
2	6, 7, 13, 22, 30-33	71,253
3	8, 9, 14, 23, 24	114,301
4	34, 25, 41, 46	53,932
5	36, 37	111,380
6	21, 38-40, 42-45, 47, 48	136,071
7	11, 12, 19, 20, 27	97,661
8	10, 15-18, 25, 26, 28, 29	189,735
TOTAL		840,316

TABLE 20: COMPARISON OF SAMPLED AND 1985 CENSUS HOUSEHOLDS BY QUOTA

Quota	Vehicle Availability/ Persons In HHlds	Sampled HHlds	% of 1988 HHlds*	1988 Estimate Of HHlds
1	0/1-5+	245	3.93	33,024
2	1/1-2	797	30.89	259,574
3	1/3-5+	220	7.05	59,242
4	2/1-2	270	18.13	152,349
5	2/3-5+	481	17.19	144,450
6	3+/1-2	227	7.58	63,696
7	3+/3-5+	753	15.23	127,980
Total	Households	2993		840,315

*Based on 1985 Census.

TABLE 21: FRATAR MATRIX EXPANSION

Input:

(Number of Households Sampled, Stratified by Superdistrict and Quota)

Superdistrict:		1	2	3	4	5	6	7	8	Total
Quota:	1	3	8	44	78	13	7	12	80	245
	2	77	116	72	24	103	156	77	172	797
	3	17	19	36	9	47	37	13	42	220
	4	32	28	37	8	30	47	27	61	270
	5	36	44	86	12	68	116	54	65	481
	6	21	18	22	7	32	34	31	62	227
	7	51	39	123	81	85	126	144	104	753
Total		237	272	420	219	378	523	358	586	2993
1988 MAG Estimate By Superdistrict:										
Target COL:		65,983	71,253	114,301	53,932	111,380	136,071	97,661	189,735	840,316
1988 MAG Estimate By Quota:										
Target Row:		33,024	259,574	59,242	152,349	144,450	63,696	127,980	0	840,315

RESULTS:

Superdistrict:		1	2	3	4	5	6	7	8	Total
Quota:	1	321	746	5106	11523	1839	330	1295	11866	33,024
	2	22242	31801	25305	10906	35132	43467	26408	64311	259,574
	3	4353	4290	10196	2527	13219	9225	3545	11888	59,242
	4	16148	13525	21432	5311	16672	23269	16147	39846	152,349
	5	10147	11183	25821	4893	21442	31881	16637	22447	144,450
	6	5122	4265	6134	2280	8968	8601	8709	19617	63,696
	7	7650	5444	20306	16492	14109	19298	24921	19760	127,980
Total		65,983	71,253	114,301	53,931	111,380	136,071	97,661	189,735	840,315

TM TM TM TM TM TM TM TM TM TM TM TM TM TM TM

R68/#38

TABLE 22: RESULTING EXPANSION FACTORS BY SUPERDISTRICT AND QUOTA

Superdistrict:		1	2	3	4	5	6	7	8
Quota:	1	105.156	98.266	119.422	147.344	120.078	103.156	120.766	133.125
	2	295.625	276.250	335.750	414.250	337.625	290.062	339.500	374.250
	3	243.500	227.531	276.500	341.250	278.062	238.906	279.625	308.250
	4	522.750	488.500	593.625	732.625	597.000	512.875	600.375	661.875
	5	266.625	249.125	302.750	373.625	304.437	261.562	306.187	337.562
	6	259.750	242.750	295.000	364.000	296.625	254.844	298.312	328.875
	7	148.937	139.156	169.125	208.687	170.062	146.094	171.031	188.531

4.4 Detailed Trip Frequency Tables

On the following pages are a series of trip frequency tables by household income, household size and vehicle ownership for three trip purposes -- home-based work, home-based non-work, and non-home based.

TABLE 23: HOME-BASED WORK TRIPS PER HOUSEHOLD BY INCOME AND VEHICLE OWNERSHIP

		Vehicles in Household			
Household Income:		0	1	2	3+
$15K:	Mean	.44	.85	1.40	1.83
	SE	.06	.08	.22	.24
	N	191	273	60	54
$15K - $24.9K:	Mean	1.18	1.29	2.02	2.44
	SE	.18	.08	.14	.20
	N	38	331	123	133
$25K - $34.9K:	Mean	.64	1.31	2.40	2.79
	SE	.24	.09	.12	.15
	N	11	235	194	184
$35K - $49.9K:	Mean	1.33	1.39	2.54	3.06
	SE	.67	.15	.11	.12
	N	3	109	200	238
$50K +:	Mean	2.50	1.10	2.29	3.27
	SE	.50	.20	.11	.11
	N	2	67	174	371

SE = Standard Error
N = Number of Households

TABLE 24: HOME-BASED OTHER TRIPS PER HOUSEHOLD BY INCOME AND VEHICLE OWNERSHIP

		Vehicles in Household			
Household Income:		0	1	2	3+
Under $15K:	Mean	.65	1.24	1.48	1.59
	SE	.10	.10	.30	.38
	N	191	275	60	54
$15K - $24.9K:	Mean	.74	1.45	2.19	2.19
	SE	.21	.11	.24	.22
	N	38	331	123	133
$25K - $34.9K:	Mean	1.27	1.66	2.21	2.22
	SE	.38	.15	.19	.22
	N	11	235	194	184
$35K - $49.9K:	Mean	.00	1.79	2.14	2.34
	SE	.00	.21	.20	.17
	N	3	109	200	238
$50K +:	Mean	1.50	1.60	2.80	2.75
	SE	1.50	.25	.25	.16
	N	2	67	174	371

TABLE 25: NON-HOME-BASED TRIPS PER HOUSEHOLD BY INCOME AND VEHICLE OWNERSHIP

Household Income:		Vehicles in Household 0	1	2	3+
Under $15K:	Mean	.45	1.30	1.32	2.56
	SE	.11	.11	.25	.57
	N	191	275	60	54
$15K - $24.9K:	Mean	.39	1.62	2.28	2.61
	SE	.13	.13	.24	.27
	N	38	331	123	133
$25K - $34.9K:	Mean	.91	1.79	2.65	2.85
	SE	.58	.15	.23	.24
	N	11	235	194	184
$35K - $49.9K:	Mean	.00	2.36	3.00	3.50
	SE	.00	.28	.24	.23
	N	3	109	200	238
$50K +:	Mean	1.50	2.13	3.43	3.97
	SE	1.50	.31	.26	.19
	N	2	67	174	371

TABLE 26: HOME-BASED WORK TRIPS PER HOUSEHOLD BY INCOME AND HOUSEHOLD SIZE

		Persons in Household					
Household Income:		1	2	3	4	5	6+
Under $15K:	Mean	.45	.83	1.79	1.04	2.19	2.38
	SE	.05	.10	.30	.16	.36	.47
	N	2.73	166	47	47	26	21
$15K - $24.9K:	Mean	1.06	1.37	2.18	2.17	2.88	2.73
	SE	.08	.12	.18	.18	.34	.49
	N	178	203	101	70	43	30
$25K - $34.9K:	Mean	1.17	1.35	2.90	2.87	2.81	2.79
	SE	.11	.11	.20	.21	.20	.26
	N	109	201	91	93	88	42
$35K - $49.9K:	Mean	1.14	1.95	2.90	3.06	3.00	2.92
	SE	.13	.15	.17	.17	.18	.25
	N	58	135	101	113	92	51
$50K +:	Mean	1.07	1.93	2.91	2.93	3.21	3.78
	SE	.15	.16	.17	.16	.17	.32
	N	45	123	112	122	140	72

TABLE 27: HOME-BASED OTHER TRIPS PER HOUSEHOLD BY INCOME AND HOUSEHOLD SIZE

Household Income:		Persons in Household					
		1	2	3	4	5	6+
Under $15K:	Mean	.79	1.34	1.53	1.49	1.23	1.38
	SE	.07	.17	.31	.37	.41	.43
	N	273	166	47	47	26	21
$15K - $24.9K:	Mean	1.01	1.82	1.95	2.07	2.26	2.67
	SE	.10	.15	.27	.29	.43	.58
	N	178	203	101	70	43	30
$25K - $34.9K:	Mean	.79	1.89	1.65	2.53	2.44	4.19
	SE	.09	.14	.24	.32	.33	.75
	N	109	201	91	93	82	42
$35K - $49.9K:	Mean	.91	1.96	1.84	2.32	2.79	3.12
	SE	.14	.17	.24	.27	.33	.46
	N	58	135	101	113	92	51
$50K +:	Mean	1.07	1.60	1.93	3.11	3.41	4.14
	SE	.20	.17	.18	.31	.29	.48
	N	45	123	112	122	140	72

TABLE 28: NON-HOME-BASED TRIPS PER HOUSEHOLD BY INCOME AND HOUSEHOLD SIZE

		Persons in Household					
Household Income:		1	2	3	4	5	6+
Under $15K:	Mean	.70	1.16	1.32	2.36	2.92	1.33
	SE	.08	.13	.44	.45	.99	.64
	N	273	166	47	47	26	21
$15K - $24.9K:	Mean	1.61	1.55	2.05	3.01	2.49	1.80
	SE	.18	.16	.27	.35	.48	.44
	N	178	203	101	70	43	30
$25K - $34.9K:	Mean	1.63	2.19	1.91	3.15	2.78	3.29
	SE	.19	.20	.24	.37	.35	.31
	N	109	201	91	93	88	42
$35K - $49.9K:	Mean	1.93	3.06	3.03	3.16	3.88	2.88
	SE	.28	.28	.36	.31	.42	.46
	N	58	135	101	113	92	51
$50K +:	Mean	1.98	2.30	3.80	4.32	4.29	4.00
	SE	.31	.26	.34	.35	.33	.41
	N	45	123	112	122	140	72

TABLE 29: HOME-BASED WORK TRIPS PER HOUSEHOLD BY VEHICLE OWNERSHIP AND HOUSEHOLD SIZE

Vehicles in Household:		Persons in Household					
		1	2	3	4	5	6+
0	Mean	.37	.81	.88	.70	1.25	1.00
	SE	.06	.14	.27	.37	.37	.45
	N	133	64	24	10	8	6
1	Mean	.93	.94	2.18	1.79	1.92	2.24
	SE	.05	.08	.17	.17	.23	.44
	N	446	351	100	78	25	17
2	Mean	1.05	1.96	2.69	2.46	2.61	2.51
	SE	.13	.11	.14	.12	.16	.21
	N	65	205	159	184	93	45
3+	Mean	1.05	1.93	3.08	3.31	3.24	3.47
	SE	.21	.11	.15	.15	.13	.21
	N	19	208	169	173	263	148

TABLE 30: HOME-BASED OTHER TRIPS PER HOUSEHOLD BY INCOME AND HOUSEHOLD SIZE

Vehicles in Household:		Persons in Household					
		1	2	3	4	5	6+
0	Mean	.47	.84	1.54	.90	.25	1.00
	SE	.08	.16	.47	.71	.25	.68
	N	133	64	24	10	8	6
1	Mean	.98	2.00	1.33	1.54	2.56	3.35
	SE	.06	.12	.20	.30	.58	.94
	N	446	351	100	78	25	17
2	Mean	1.05	1.73	2.13	2.90	2.85	3.20
	SE	.16	.13	.21	.26	.36	.51
	N	65	205	159	184	93	45
3+	Mean	.84	1.55	1.85	2.49	2.84	3.61
	SE	.19	.14	.15	.19	.19	.33
	N	19	208	169	173	263	148

TABLE 31: NON-HOME-BASED TRIPS PER HOUSEHOLD BY INCOME AND HOUSEHOLD SIZE

Vehicles in Household:		Persons in Household					
		1	2	3	4	5	6+
0	Mean	.30	.55	1.17	1.00	.00	.00
	SE	.06	.13	.75	.47	.00	.00
	N	133	64	24	10	8	6
1	Mean	1.42	1.81	1.54	2.42	2.28	2.76
	SE	.09	.14	.22	.30	.60	.66
	N	446	351	100	78	25	17
2	Mean	2.22	2.27	2.79	3.35	3.05	2.60
	SE	.31	.18	.24	.27	.38	.51
	N	65	205	159	184	93	45
3+	Mean	2.11	2.43	3.25	3.95	3.97	3.32
	SE	.59	.22	.28	.27	.24	.28
	N	19	208	169	173	263	148

4.5 Survey Sampling, Inc.

Statistical Characteristics of Random Digit Telephone Samples Produced by Survey Sampling, Inc.

I. Summary

By utilizing a massive data base, specialized computer programs and classical statistical techniques, Survey Sampling has developed a method by which highly efficient and unbiased samples of telephone numbers can be drawn along recognized geographic boundaries. Well-conducted telephone surveys using these samples can be reliably projected, on a national basis, to some 79 million American households.

The statistical characteristics of these samples can be described by five criteria proposed by Prof. Leslie Kish, a well-known sampling statistician:

1. The method produces epsem samples in which all telephone households in the geographic sampling frame are given, within the limits of available data, equal probability of selection.

2. The method produces element samples rather than clustered samples.

3. The samples are stratified to all counties in the geographic frame such that the number of telephone households drawn from a county for the sample is proportional to that county's share of telephone households.

4. Samples are drawn systematically from an array of counties and an array of working telephone blocks within each county.

5. The method employs double sampling with the final sample drawn from the county-stratified first phase sample.

A detailed description of the selection process and related data bases follows.

II. The Universe: 79 Million American Households with Telephones

According to a series of excellent national health surveys conducted by the federal government, by 1980 some 93 percent of American households contained telephones. According to the most recent estimates published by Sales & Marketing Management, there are about 85.063 million households in the nation, so that perhaps 79.1 million homes can be accessed by a telephone survey employing random digit techniques.

If the sampling frame was restricted to households listed in published telephone directories, perhaps 30 percent or more of the telephone households would be excluded from a survey. At present, about 63 million households are listed in directories. However, each year about 19 percent of American households move. And when one considers that it may take two or three months to publish and distribute a new directory, it is not surprising that from 12 to 15 percent of the residential numbers in a typical directory are disconnected when called. Thus, directory-based surveys only include some 56 million of the 79 million telephone homes.

If the remaining 23 million telephone households were a random subset of the sampling frame, there would be little need to employ random digit techniques. However, numerous studies have shown that unlisted homes are different: they are younger, more urban, etc. Thus, because of known differences, no serious telephone survey of the population can be based on directory numbers alone.

III. Creation of the Sampling Frame

Before any random sample can be drawn, it is necessary to construct a "frame"--a set of operations which permits selection of specific elements of the population with known probability. In this case, frame construction consisted of a series of steps to narrow the search for 79 million operating residential phone numbers from a pool of 330 million possibilities to a pool of approximately 134 million. Care was taken to minimize the elimination of actual residential listings while at the same time increasing their probability of selection from .24 to .59 or higher.

A list of about 36,000 area code-exchange combinations currently operative in the United States is maintained by the Long Lines division of AT&T and is updated monthly. However, not all these exchanges are used for residential purposes. Some are devoted to internal telephone company use; some held for future expansion;

others are assigned exclusively to large companies or government agencies.

To eliminate non-residential exchanges from the frame, a special proprietary data file was developed to include all apparent residential listings from every known telephone directory in the country.

After the names, street addresses, and telephone numbers are transferred to computer tapes, they are geographically coded so that the correct mailing post office and zip code are added to each record. In urbanized areas, the address is also related to Census tracts, block groups or enumeration districts. About 20 percent of the addresses, those located in more rural areas, are identified only by town and county. At present, the file contains more than 63 million households.

Survey Sampling, Inc. developed specialized computer programs which performed the following operations on the file:

---Added the appropriate area code and time zone to each telephone number.

---Sorted all numbers to area code, exchange, and phone number sequence.

---Tabulated the county(ies) of residence for all the listed residential numbers of each exchange.

---Tabulated which ZIP codes were associated with each exchange and the number of listings in each ZIP.

---Counted the number of listings in each exchange.

---Identified the "working blocks" of each exchange, where a block is a group of 100 contiguous numbers (e.g., 1700-1799) and a working block is one which contains three or more listed residential numbers.

This analysis permitted elimination of 12 percent/4,000 of the AT&T exchanges from the sampling frame. This number was chosen to screen out erroneous phone numbers due to key-entry errors. Most eliminated exchanges had no residential listings. In a few instances, Survey Sampling has checked the status of eliminated exchanges with local telephone companies and in each case the exchange was described as "an internal telephone company exchange."

180 Post Road East, Westport, Connecticut 06880, (203) 226-7558

Next, non working "blocks" of numbers were eliminated from working exchanges. Again, a block is considered to be 100 contiguous numbers with each exchange having 100 blocks (e.g., the telephone number 226-7558 is found in block 75 of exchange 226). Examination of patterns of listed numbers supports the widely-held belief that most telephone companies systematically assign groups of numbers for use rather than randomly select them. This practice has to do with the characteristics of switching equipment in rotary exchanges (and a majority of telephones still rely on rotary rather than electronic switching). A component of this practice involved the reassignment of disconnected numbers to new subscribers so that active numbers are densely compressed in a relatively small number of blocks.

Frequency distributions of block density were tabulated by state. Patterns do vary by state, particulary between urban and rural states. The density distribution curves were approximately normal in shape, though skewed to the right towards high density. State modes varied between 55 and 65 percent. That is, the typical listed residential number occurred in blocks in which about 60 of the 100 possible numbers were listed telephone residences. Thus, the chance of encountering a listed household is around 60 percent.

The general pattern of these closely resembles one derived from a national random digit telephone survey conducted at the Survey Research Center of the University of Michigan (Robert M. Groves, "An Empirical Comparison of Two Telephone Sample Designs," Journal of Marketing Research, November, 1978 pp.622-31). This study estimated national block density of both listed and unlisted residential phones and showed a mode of about .75. The ratio of all telephones to listed phone households is 1.23. Applying this adjustment to .6 (the approximate mode of listed residential density) produces an estimated chance of hitting a phone household of .74.

The close correspondence between the Survey Sampling curves, based on listed residences, and the Groves curve, based on all telephone households, lends empirical support to an important assumption required by the new sampling model:

> The assignment of numbers to households is made independently of their publication status in the directory.

If this is true, then unlisted numbers will tend to be found in the same blocks as listed numbers. Further, blocks heavily used for listed households will also tend to have a higher incidence

of unlisted numbers, except for those blocks totally filled with listed numbers.

This assumption squares with common sense. If, for example, telephone companies intentionally segregated unlisted residential numbers in certain blocks, the risk of inadvertent disclosure would be heightened. Also, it would be more complicated and expensive for telephone service personnel to process number assignments in two different ways.

The effect of eliminating non-working blocks is quite important. About 60 percent of the possible blocks have not a single listed residential number. This reduces the pool of possible numbers in working blocks to fewer than 134 million and increases the probability of encountering a telephone household to an estimated .6.

At this point, a cautious statistician might well inquire as to the probability of encountering working residential numbers in the "non working" blocks. Due to the constant assignment of new numbers and growing populations, it is quite likely that a small number of telephone residences are contained in the non-working blocks. However, it seems reasonable to believe that their number would be relatively small and that their inclusion in a survey would have little chance of altering its results. It would be expensive to include such households, and money spent for that purpose would generally be better spent on other aspects of the survey project.

IV. Method of Stratification

In this model, the sampling frame is accessed in such a way as to produce proportionate stratified systematic random samples from working blocks of exchanges located within specified geographic boundaries. The method of stratification is highly important to the control of bias that might be introduced through improper use of the sampling frame.

The problem is that the incidence of unlisted numbers is quite variable from one area of the country to another. Generally, the use of unlisted numbers is much more an urban phenomenon than a rural one. But great variation is found even among large cities and in certain rural areas. For example, in Minneapolis and St. Paul, 90 percent of residents list their number in the directory, but in nearby Chicago, perhaps 35 percent of the numbers are unpublished. Thus, without adjustment, the sampling frame would tend to under-represent Chicago and over-represent Minneapolis.

To equalize the probability of telephone households being selected anywhere in the country, samples are first systematically stratified to all counties in proportion to each county's share of telephone households in the survey area. To obtain reasonable estimates of telephone households by county, a special data base was developed, beginning with county estimates of telephone incidence measured in the 1980 Census of Population and Housing. These figures are then applied annually to household estimates calculated by Market Statistics for Sales & Marketing Management magazine to produce estimates of total telephone households by county.

After a geographic area has been defined as a combination of counties, the total of telephone households is calculated and divided by the desired sample size to produce a sampling interval. The counties are then ordered (normally by alphabetic state and county within state). A random number between one and the sampling interval is generated and a cumulative count of telephone households is calculated. At the point at which the accumulation reaches the random starting point, a specific county is selected. The second point is one interval away from the first point. Counties whose population is greater than the sampling interval of telephone households will be selected repeatedly and counties whose population is less than the sampling interval have some chance of being skipped. In this way, the sample is distributed across all counties in proportion to their share of the total population of telephone homes.

A second level of stratification occurs when specific working block within a selected county are selected. Two methods of systematic selection are available. In Method A, the total number of working blocks is calculated and that sum is divided by the number of sampling points assigned to the county. This produces a sampling interval in which all blocks have an equal chance of being selected. Blocks within a county are ordered in ascending order by exchange and block number within exchange.

From a random start within the first interval, one or more blocks are selected in a systematic fashion. Once a specific block has been selected, two random digits in the range 00-99 are generated and added to the block and its exchange to form a complete telephone number. Next, that telephone number is tested against Survey Sampling's data base of 8.4 million Yellow Page telephone listings of businesses. If a match occurs, the number is discarded and replaced by a new number from the same block. Thus, in Method A, all working blocks are given equal probability of selection regardless of their utilization for listed residential numbers.

180 Post Road East, Westport, Connecticut 06880. (203) 226-7558

Method B offers an optional variation and generally produces noticeably more efficient samples than Method A. In this approach, the sampling interval is calculated by summing the number of listed residential numbers in each working block and dividing that sum by the desired quantity of numbers. Thus, each block's chance of being selected is proportional to its share of listed homes so that more active blocks have a greater probability of selection. Yellow Page business listings are eliminated from the sample in Method B just as they are in Method A. Method B has proven markedly more efficient than Method A, adding typically ten points to the chance of encountering a working residential number. Although exhaustive tests of possible bias that might be introduced by Method B have not been completed, tentative evidence does not suggest that bias is present.

The methods of stratification described in this section have been developed primarily to equalize the probability of selection for all telephone homes in the United States. To the extent that this has been successful, the resulting samples resemble epsem samples in which all population elements have equal probability of selection. Such samples have the advantage of being self-weighting (assuming the sample is expertly executed as the survey proceeds).

These samples are also element samples in the extreme, since careful steps are followed to avoid clustering of sampling points in any fashion. The use of clustering, though usually necessary when personal interviewing is required in the field, almost always has adverse affects on the statistical efficiency of a survey. For example, Groves reports that the use of 9-element clusters in a national telephone survey increased error estimates from 17 to 40 percent. Stated another way, this modest use of clustering (employing the well-known Waksberg method) would require a sample 37 to 59 percent larger than a simple element sample.

Finally, upon selection, samples are ordinarily ordered by time zone, area code and exchange and then systematically divided into a number of subsamples or replicates. When administered in replicate order, it is a simple matter to control the geographic distribution of a telephone survey as interviewing proceeds.

180 Post Road East, Westport, Connecticut 06880. (203) 226-7558