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Arizona Department of Transportation
Arizona Transportation Research Center

February, 1992

Final Report

Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area

Research Project No. HPR-PL-1(35)314
Report No. FHWA-A292-314

Prepared by

Cambridge Systematics, Inc.

with

O'Neil Associates, Inc.

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16. Abstract

The primary objectives of the Phoenix urban truck travel model project were to conduct a travel survey of commercial vehicles operating within the Phoenix metropolitan area and to use the data collected in this survey to develop commercial vehicle trip generation, distribution, and traffic assignment models. The models are designed to be incorporated into the UTPS-based travel model system maintained by the Maricopa Association of Governments Transportation and Planning Office (MAGTPO), which predicts highway and transit system usage throughout the Phoenix metropolitan area.

This report describes the entire urban truck travel model project, including the methods used to collect commercial vehicle travel data, summaries of the survey results, and model development using the survey data. The report also discusses the issue of the transferability of the results of this project to other urban areas. Thus, the commercial vehicle travel patterns identified in Phoenix, and the travel forecasting models based on these patterns, may also be useful in other urban areas which have similarities to Phoenix with respect to their mix of commercial and industrial activities, and their history of growth and development into major metropolitan regions.

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1.0 Introduction

The Phoenix urban truck travel model project was conducted for the Arizona Transportation Research Center, Arizona Department of Transportation. The Maricopa Association of Governments Transportation and Planning Office (MAGTPO), the metropolitan planning organization for the Phoenix area, provided technical monitoring of the project. The primary objectives of the project were to conduct a travel survey of commercial vehicles operating within the Phoenix metropolitan area and to use the data collected in this survey to develop commercial vehicle trip generation, distribution, and traffic assignment models. The models are designed to be incorporated into MAGTPO's UTPS-based travel model system which predicts highway and transit system usage throughout the metropolitan area. The project was conducted by Cambridge Systematics, Inc., Cambridge, Massachusetts, with support for data collection provided by O'Neil Associates, Inc., Phoenix, Arizona.

This report documents the entire urban truck travel model project, including both data collection and model development. The remaining sections describe the survey methods used (2.0), provide a statistical summary of the survey results (3.0), and document the travel models developed (4.0). The final section (4.4) discusses the issue of the transferability of the results of this project to other urban areas, particularly in Arizona. Thus, the commercial vehicle travel patterns identified in Phoenix, and the travel forecasting models based on these patterns, may also be useful in other urban areas such as Tucson which have similarities to Phoenix with respect to their mix of commercial and industrial activities, and their growth and development into major metropolitan regions.

This report concludes with four appendices which provide additional detail on the survey forms used (Appendix A), the computerized files of commercial vehicle and trip data collected in the survey (Appendices B and C, respectively), and the UTPS procedures for model implementation as part of the MAGTPO forecasting system (Appendix D). The information in these appendices, plus the data and procedure files transmitted separately to MAGTPO, will allow transportation planners in Phoenix to obtain additional survey summaries and to integrate the new models into the MAGTPO travel forecasting process.

2.0 Survey Methods

The Phoenix commercial vehicle survey provides detailed information on 3,402 trips made by 606 commercial vehicles registered in Maricopa County or used by the US Postal Service in the county. Each surveyed trip has both its origin and its destination within the Maricopa Association of Governments (MAG) transportation study area. The survey does not include any commercial vehicles registered outside Maricopa County. In the Phoenix travel forecasting system, most of the trips made by these vehicles are included in external commercial vehicle trip tables. The purpose of this survey was to develop new models for internal commercial vehicle trips only.

Two sources of data were used to determine the total population of commercial vehicles to be sampled in the survey. The first was a computerized file of approximately 157,000 commercial vehicles registered in Maricopa County in 1989. This file, obtained from the Department of Motor Vehicles, contains truck type identifiers and owners' names and addresses. The second was a listing, by garaging location in Maricopa County, of the 2,300 vehicles owned by the US Postal Service, but not registered in Arizona. The procedures used to select vehicles for the survey sample from these sources are described in Section 2.2, below.

The data collection procedure used for vehicles selected from the DMV file was a combined telephone/mail method. This approach was adopted after obtaining low response rates in an initial pretest which relied entirely on a mailout/mailback method. The following general procedure was used:

- **Telephone Contact:** Vehicle owners for which telephone numbers could be obtained were called, initial screening questions were asked, and cooperation was requested in the mail portion of the survey.

- **Mail Contact:** A mail-back questionnaire including a one-day trip diary was mailed, both to those who agreed to participate in the survey and to selected owners who could not be contacted by telephone.

For Postal Service vehicles, with the assistance of the Manager of Fleet Operations for the Phoenix Postal District, vehicles were sampled by weight class and garaging location. Then, for the sampled vehicles, USPS forms detailing daily itineraries were obtained and translated into the format of the trip diary used for vehicles obtained from the DMV files.

2.1 Data Collection Forms

During the telephone portion of the survey, a script was used to introduce vehicle owners to the survey, to elicit their cooperation, and to obtain the following information on their registered vehicle which was selected to be included in the survey:

- For vehicles leased by another firm or individual, name and address of the lessor.
- For vehicles not used on a specified survey day:
  - The reason for no usage: no work, vehicle not operational, or other; and
  - The registration number for a replacement vehicle, if any.
- Person to whom the mailout questionnaire should be sent.

An example of the mailout questionnaire used for the truck survey is provided in Appendix A of this report. It was designed to obtain the following data for each surveyed commercial vehicle:

- Starting and ending addresses on survey day;
- Vehicle type, based on number of axles and body style;
- Estimated gross weight;
- Vehicle usage for transportation between home and work, and for work-related purposes; and
- Total number of one-way trips on the survey day.

The DMV file also provides data items which were used along with the survey data. These items include the zip code of the owner and the registered vehicle weight.

In addition, the travel diary requests the following information on the first ten one-way trips made by each vehicle on the selected survey day:

- Start and stop times;
- Stop odometer reading;
- Name and address of stop;

- Driver/vehicle activity at stop;
- Land use at stop; and
- Vehicle type and total axles during trip (to determine trailer pick-up and drop-off locations.)

It should be noted that the potential biases due to the limitation to the first ten daily trips were felt to be unavoidable if cooperation was to be obtained from the required number of vehicle operators. The magnitude of these biases was felt to be minimized because over 80 percent of the vehicles make ten or fewer trips per day, and vehicles making more than ten trips per day tend to make many similar trips (for example, a number of pairs of a warehouse to delivery location trip followed by a return trip to the warehouse, or a number of stops on a multi-pickup tour) which would be sampled sufficiently by the first ten daily trips. Furthermore, the trip weighting or expansion process discussed later was designed to eliminate biases related to the number of trips reported per day.

The survey forms included in Appendix A evolved as the survey procedures were developed. Initial versions were reviewed by the MAGTPO staff monitoring the project. Then, as the pretest and a pilot survey were conducted, changes were made to accommodate the final telephone/mail survey procedures. In addition, minor changes in wording were made for clarification.

As stated previously, a small mail-only pretest indicated that more work was required to identify vehicle owners and drivers and to obtain their cooperation in the survey. Since this work was beyond the original project scope, a pilot survey was conducted to refine the telephone/mail procedures and to determine the additional costs involved. This pilot survey used one-sixth of the entire DMV sample. The results of the pilot survey were the following:

- The new telephone/mail survey procedures proved to be workable;
- Survey responses reached an acceptable level; and
- Survey costs per valid response increased by 27 percent compared with the original estimates for the costs of a mailout/mailback survey.

Based on these findings, authorization was given by ADOT to complete the survey using the telephone/mail procedures developed in the pilot survey.

2.2 Sample Design

DMV-Registered Vehicles

Stratified samples were selected from the DMV registration file and from the list of Postal Service vehicles. In both cases, the stratification was on the basis of vehicle weight. This variable was used for stratification because separate travel models were desired for three or more weight classes, and the number of heavy vehicles is much smaller than the number of light and medium vehicles. In the DMV's 1988 Maricopa County file, for example, commercial vehicles were distributed as follows:

Vehicle Weight (lbs)	Percentage of Total Commercial Vehicles
0-8,000	82
0-28,000	13
28-64,000	3
64,000+	2

This distribution represents the 155,000 registrations in the file for all motorized vehicles (trailers were excluded) in the following three vehicle categories used by the DMV:

- C – Commercial vehicles;
- D – Buses; and
- S – Commercial pick-ups and station wagons.

The survey pretest was conducted using a random sample of 120 vehicle owners selected from the 1988 DMV file. Following the pretest, subsamples for use in the remainder of the survey were selected from the 1989 DMV file which included the same vehicle types and vehicle categories. These subsamples were designed to provide a total of at least 4,000 vehicles distributed by vehicle weight as follows:

Vehicle Weight (lbs)	Percentage of Total Sample
0-8,000	40
8-28,000	20
28-64,000	20
64,000+	20

Subsamples meeting these requirements were obtained from the DMV file by selecting every Nth record within a particular weight category. The following values of N were used:

Vehicle Weight (lbs)	Records Selected
0-8,000	Every 79th record
8-28,000	Every 24th record
28-64,000	Every 5th record
64,000+	Every 4th record

By sorting the entire DMV file by zip code prior to sample selection, subsamples were obtained in which all geographic areas are represented in proportion to their vehicle weight category-specific distribution in the total population. The sizes of the resulting subsamples were as follows:

Vehicle Weight (lbs)	Total Vehicle Records
0-8,000	1,613
8-28,000	810
28-64,000	966
64,000+	1,237
Total	**4,626**

Postal Service Vehicles

The Postal Service vehicles to be included in the survey were selected by the Postal Service's Manager of Fleet Operations. All Postal Service vehicles in Phoenix fall in the two lightest weight categories used in this

project. The selection process involved the listing of all vehicles within the two relevant weight categories in order by garaging location. Then, every Nth vehicle was selected from these lists, with N equal to 40 for vehicles weighing less than 8,000 pounds and equal to 10 for vehicles weighing more than 8,000 pounds. The resulting subsamples, and the populations from which they were selected, are as follows:

Vehicle Weight (lbs)	Total Vehicles	Selected Sample Size
0-8,000	2,180	53
8-28,000	101	9
Totals	**2,281**	**62**

2.3 Data Collection

The Pretest Survey

The initial pretest, involving mailout/mailback procedures only, was conducted in September, 1989. The survey forms were mailed to a total of 120 registered vehicle owners from DMV's 1988 commercial vehicle file for Maricopa County. The disposition of the pretest sample was as presented in Table 2.1. The overall response rate was 17 percent, two-thirds of the expected rate of 25 percent. However, only 8 percent of the total sample reported making commercial trips on the survey day, and half of the responses were from unqualified vehicles or indicated that no commercial trips were made in Maricopa County on the survey day. The combination of the low response rate and the large fraction of responses from vehicles which were unqualified or did not make commercial trips indicated that the mailout/mailback survey strategy would not provide a valid sample of commercial vehicle travel in Maricopa County.

The Pilot Survey

Revised Procedures

Recognizing that an improved surveying technique would be required, and that the new technique would be likely to require more surveying resources per response, a pilot survey was next designed to test the new procedures and to determine the change in resource requirements. The

Table 2.1 Pretest Sample Disposition

Category	Number	Percentage
1. Total mailing	120	100
2. Unsuccessful contacts – returned by Postal Service	10	8
3. No responses	90	75
4. Total responses	20	17
a. Vehicle not qualified – no trips made[a]	10	8
b. Vehicle qualified – trips made	10	8

Note: Subtotals and totals may be inconsistent due to rounding.

[a] Includes vehicles not used for commercial purposes, vehicles located outside Maricopa County, and vehicles no longer owned by addressee.

improved technique, which involves both telephone and mail procedures, was designed to identify, for each commercial vehicle, an individual who would accept responsibility for receiving the survey form, arranging for the vehicle driver to complete the form, and returning the form. In many cases, this identification process was necessary because the registered vehicle owner was a business concern or individual who was not directly involved in day-to-day vehicle operation. This identification process, conducted by telephone, was combined with preliminary questions on vehicle location and usage to determine the vehicle's suitability for inclusion in the survey. By thus eliminating unqualified vehicles and obtaining promises of cooperation from vehicle owners' representatives, the survey team expected to increase the response rate per mailed out survey form and to minimize non-response biases.

The pilot survey was carried out in October and November, 1989, using a subsample of 771, one-sixth of the 1989 DMV file discussed in Section 2.2.

Telephone Survey Results

The results of the pilot survey indicated the effectiveness of the revised surveying strategy. These results are summarized in Tables 2.2 and 2.3. Forty-two percent of the registered vehicles could not be contacted by telephone; most because no number was available from directories or information services. Other reasons for failure to make telephone contacts were disconnected telephones, locations outside Maricopa County, and no answers after repeated tries. Of the owners' representatives contacted, 156 (20 percent) were not qualified to receive the survey for a variety of reasons shown in Table 2.2. In addition, 48 of the representatives of qualified vehicles would not agree to participate. Surveys were mailed to the remaining 247 (32 percent) owners' representatives. In addition, to determine the validity of the pretest results, surveys were also mailed to 406 of those who did not agree to participate.

Mail Survey Results

Table 2.3 summarizes the results of the mail portion of the pilot survey. Even though 247 owners' representatives agreed to participate, only 55 percent mailed back a completed survey form. This response rate, however, was much better than the 14 percent rate for those who did not agree to participate. Overall, 30 percent of the 653 surveys mailed were returned; of these, 109 (56 percent) reported qualifying trips on the survey day.

Table 2.2 Pilot Survey Results – Telephone Portion

Category	Number	Percentage
Total subsample	771	100
No telephone contact possible	320	42
Vehicles not qualified	156	20
No work/no alternative vehicle	22	3
No information available	30	4
Non-commercial vehicle	36	5
Lessee name not available	53	7
Out of state owner	15	2
No agreement to participate	48	6
Agreement to participate – surveys mailed	247	32

Note: Subtotals and totals may be inconsistent due to rounding.

Table 2.3 Pilot Survey Results – Mail Portion

Category	Number	Percentage
1.1 Total surveys mailed to those agreeing to participate	247	100
1.2 Not returned or not completed	110	45
1.3 Responses	137	55
a. Trips made	96	39
b. No trips made	41	17
2.1 Total surveys mailed to other vehicle owners	406	100
2.2 Not returned or not completed	348	86
2.3 Responses	58	14
a. Trips made	13	3
b. No trips made	45	11
3.1 Total surveys mailed (1.1 + 2.1)	653	100
3.2 Not returned or not completed (1.2 +2.2)	458	70
3.3 Responses (1.3 + 2.3)	195	30
a. Trips made	109	17
b. No trips made	86	13

Note: Subtotals and totals may be inconsistent due to rounding.

The Main Survey

Procedures

Based on the results of the pilot survey, its procedures were extended to the remaining five-sixths of the 1989 DMV sample during the period from January to March, 1990. However, due to the poor response and few trips reported by those who did not agree via telephone to participate in the remainder of the survey, only 300 survey forms were mailed to these registered owners.

Telephone Survey Results

Tables 2.4 and 2.5 provide the results obtained in this final portion of the truck survey. The telephone results summarized in Table 2.4 show improvements in all general categories except agreements to participate. Those not agreeing to participate in the survey increased from 6 to 13 percent of the total subsample. In spite of this result, however, 37 percent of the total subsample did agree to participate, a favorable comparison with the 32 percent in the corresponding category of the pilot test.

Mail Survey Results

The results for the mail portion of the main survey (Table 2.5) show that, although the response rate dropped from 55 to 29 percent for those who agreed to participate, the overall response rate to the mailed questionnaires remained at 30 percent. The difference represents responses from 105 (35 percent) of 300 surveys sent out to owners' representatives who were identified by name in the telephone portion of the survey, but did not initially agree to participate. Apparently, many of these representatives saw, when the survey form arrived by mail, that it could be completed without an excessive amount of effort. The result was a higher response rate from this group than from those who initially agreed to participate.

Prior to geocoding, the total number of survey responses was 720; 195 from the pilot survey and 525 from the main survey. Of these 720 responses, 527 (73 percent) represent vehicles which made commercial trips on the survey day.

Postal Service Vehicle Survey

Data collection for Postal Service vehicles was much simpler than for the DMV file, because the cooperation of the Manager of Fleet Operations was obtained prior to subsample selection. Travel diary data for the 62 selected vehicles was obtained from existing Postal Service forms and transferred directly to vehicle and trip data sets used in this project.

Table 2.4 Main Survey Results – Telephone Portion

Category	Number	Percentage
1. Total subsample	3855	100
2. No telephone contact possible	1393	36
3. Vehicles not qualified	538	14
a. No work/no alternative vehicle	214	6
b. No information available	103	3
c. Non-commercial vehicle	169	4
d. Lessee name not available	35	1
e. Out of state owner	17	0
4. No agreement to participate	498	13
5. Agreement to participate – surveys mailed	1426	37

Note: Subtotals and totals may be inconsistent due to rounding.

Table 2.5 Main-Survey Results – Mail Portion

Category		Number	Percentage
1.1	Total surveys mailed to those agreeing to participate	1426	100
1.2	Not returned or not completed	1006	71
1.3	Responses	420	29
	a. Trips made	358	25
	b. No trips made	62	4
2.1	Total surveys mailed to other vehicle owners	300	100
2.2	Not returned or not completed	195	65
2.3	Responses	105	35
	a. Trips made	60	20
	b. No trips made	45	15
3.1	Total surveys mailed (1.1 + 2.1)	1726	100
3.2	Not returned or not completed (1.2 +2.2)	1201	70
3.3	Responses (1.3 + 2.3)	525	30
	a. Trips made	418	24
	b. No trips made	107	6

Note: Subtotals and totals may be inconsistent due to rounding.

2.4 Data Coding and Factoring

Data Coding

As the DMV and Postal Service responses were received, they were edited, coded, and entered in vehicle and trip data sets. All addresses were coded fully as provided by respondents. The resulting data sets were then transmitted to MAGTPO for geo-coding using the department's LandTrak computer program. Addresses which could not be coded automatically were processed manually to increase the number of geo-coded records. Following all coding and editing of both non-geographic and geographic data fields, a total of 606 vehicles making 3,402 trips were available for use in statistical summaries and model development.

Data Factoring

Overview

In order to expand the successfully coded vehicle and trip records to represent total commercial vehicle travel by vehicles registered in Maricopa County, expansion factors were developed for each data record. Due to the complexities of the subsample selection process and the limited number of trips for which information was requested in the survey questionnaire, these factors depend on a number of variables. The expansion factors for trucks registered with the DMV depend on the following variables:

- The percentage of vehicles in use for commercial purposes within the Phoenix metropolitan area on a typical weekday;
- Vehicle weight class; and
- Zip code of vehicle owner.

The expansion factors for Postal Service vehicles depend on vehicle weight class and postal garaging location.

Expansion factors for trips were developed by increasing the corresponding vehicle factors to account for the following:

- The number of usable trip records per vehicle versus the reported total number of daily trips; and
- Whether or not the trip represented travel to or from the vehicle's overnight garaging location.

The details of the data factoring process are described in the subsections which follow.

Vehicle Factors

The 1989 DMV file used to obtain a survey sample contained 156,645 commercial vehicle registration records, and the Phoenix postal district reported a total of 2,281 vehicles. The breakdown by vehicle weight class is shown in Table 2.6.

The telephone portion of the survey revealed that only 75.7 percent of the vehicle owners contacted via the DMV data set reported that their vehicle is available for use for commercial purposes within the Phoenix metropolitan region on the typical travel weekday. This fraction was used to obtain an initial estimate of the total population of qualified vehicles, subject to adjustment in later stages of the project (see Section 4.3). Thus, the survey data was expanded to represent 118,645 DMV vehicles in operation, plus 2,281 Postal Service vehicles.

Expansion factors for the DMV vehicles were developed separately by vehicle weight class and by owner's zip code as contained in the DMV file. Two sets of factors were developed, one to match the DMV totals by weight/zip category, and the other to match the DMV totals by weight class. The latter factors take into account weight/zip categories for which trucks exist in the DMV file but not in the final survey sample. Post Office vehicles were weighted using a similar strategy, expanding to match the Post Office totals by weight/postal garaging location category and to match totals by weight class. The average factors by vehicle type and weight class are provided in Table 2.7. Overall, the survey represents a 0.5 percent sample of all commercial vehicles based in Maricopa County.

Trip Factors

Because the commercial vehicle drivers responding to the survey were asked to report individual information for a maximum of ten trips on their survey day, additional truck-specific expansion factors were required to account for each truck's unreported trips. These factors were defined as follows:

- For trips to or from the truck's overnight garaging location, when the total number of usable trip records was more than two, the additional truck factor was set equal to 1.0.

Table 2.6 Total Population of Commercial Vehicles Registered In Maricopa County

Vehicle Type	Vehicle Weight (lbs) 0-8,000	8-28,000	28-64,000	64,000+	Total
DMV Vehicles	127,427	19,440	4,830	4,948	156,645
Postal Service Vehicles	2,180	101	0	0	2,281
Total Vehicles by Class	129,607	19,541	4,830	4,948	158,926
Percentage of Total Vehicles	81.8%	12.3%	3.0%	3.1%	100.0%

Table 2.7 Average Vehicle Expansion Factors

Vehicle and Factor Types	Vehicle Weight (lbs) 0-8,000	8-28,000	28-64,000	64,000+	Total
DMV Vehicles					
To match by weight and zip	619.5	107.3	18.9	9.8	127.0
To match by weight	1,084.5	175.3	25.9	16.3	218.1
Postal Service Vehicles					
To match by weight and zip	27.5	10.4	--	--	25.0
To match by weight	41.1	11.2	--	--	36.8

- For trips to or from the truck's overnight garaging location, when only one or two usable trip records were available, the additional truck factor was set equal to the following ratio:

  $$\frac{\text{reported number of total daily trips}}{\text{number of usable trip records}}$$

- For all other trips, the following ratio was used as the additional truck factor:

  $$\frac{\text{reported number of total daily trips - 2}}{\text{number of usable trip records - 2}}$$

The factors account for the reporting of trips to and from the overnight garaging location, which generally was available for each truck, and for the partial reporting of all other trips by trucks making more than ten trips per day. The factors also correct for unusable trip records.

Final total trip factors were formed as the products of the additional factors defined above and the truck factors, described in the previous subsection, which match DMV and Postal Service vehicle totals by weight class. The average total trip factor is 284.5, implying an average additional trip factor of 1.43. The average factors by vehicle weight class are provided in Table 2.8. When these trip factors are applied to the 3,402 usable reported commercial vehicle trips, an estimate of 967,835 total daily trips is obtained. The numbers and percentages of trips by weight class are provided in Table 2.9. Both the largest and the smallest weight classes have smaller percentages of trips than of commercial vehicles (see Table 2.6). The trucks in the middle weight categories – 8,000 to 64,000 pounds – reported making more trips per day than do those in the smallest and largest weight categories.

2.5 Sample Accuracy

All surveys based on the sample of a population for which statistics are desired are subject to sampling error. Sampling errors are the differences between the results obtained from a sample and those which would be obtained if the entire population were to provide the information requested in the survey. The size of sampling error depends both on the number of survey responses obtained and on the range of responses to a particular question.

For the Phoenix commercial vehicle survey, estimates of the sampling error range can be determined, both for vehicle data and for truck data. These

Table 2.8 Average Trip Expansion Factors

Factor Type	Vehicle Weight (lbs) 0-8,000	8-28,000	28-64,000	64,000+	Total
Additional trip factor	1.08	2.33	1.50	1.11	1.43
Total trip factor	751.7	371.9	39.0	18.1	284.5

Table 2.9 Estimated Total Commercial Vehicle Trips by Weight Category

Vehicle Weight (lbs)	Daily Commercial Vehicle Trips	Percentage of Total
0-8,000	726,889	75.1
8-28,000	188,545	19.5
28-64,000	32,659	3.4
64,000+	19,742	2.0
Total	**967,835**	**100.0**

Note: These totals represent initial estimates, prior to the traffic assignment and calibration stage of the project. See Sections 4.2 and 4.3 for final refinements of the values provided here.

estimates have been calculated for observed percentages at the 95 percent confidence level, a common value frequently used to state the accuracy of survey data. The values of sampling error are also maximum values, valid when the survey data is divided evenly between two possible responses. Survey responses which are more unevenly divided have lower sampling errors than those presented in this section.

For statistics based on all vehicles, the maximum sampling error is 4.0 percent. The corresponding value for statistics based on all trips is 1.7 percent. Table 2.10 presents the sampling errors for statistics based on fewer cases, for both vehicles and trips.

Table 2.10 Approximate Sampling Errors

Percentage of Total Sample	Vehicles		Trips	
	Sample Size	Sampling Error(%)[a]	Sample Size	Sampling Error(%)[a]
10	61	12.5	230	5.3
25	152	7.9	851	3.4
50	303	5.6	1,701	2.4
75	455	4.6	2,552	1.9
100	606	4.0	3,402	1.7

[a] Plus or minus tolerance of sample-based percentages at a 95 percent confidence level.

3.0 Summary of Survey Results

All of the statistics reported in this section represent results of the weighted commercial vehicle survey. In all cases, non-responses to a particular question are omitted from the statistical tabulations. Two data sets – a commercial vehicle file and a trip file – were used to obtain these tabulations. Copies of these data sets have been transmitted to MAG; their formats are documented in Appendices B and C, respectively.

3.1 Characteristics of Commercial Vehicles

Average Vehicle Weights

Table 3.1 provides reported average vehicle weights by vehicle weight category and for all vehicles. For all commercial vehicles, the average weight is six tons.

Vehicle Types

Overall, pickups constitute over half of all commercial vehicles, followed by single trucks (20 percent), autos and vans (10 percent), and panel trucks (10 percent). Table 3.2 shows the distribution for the remaining vehicle types, as well as separate distributions by vehicle weight category.

Vehicle Usage

In total, 41.9 percent of the vehicles are used for travel between home and work as well as for other commercial purposes. Also, 79.4 percent of the vehicles are used for commercial purposes on a typical day. These percentages vary significantly by vehicle weight class, as shown in Table 3.3.

Table 3.1 Average Vehicle Weights

Vehicle Weight Category (lbs)	Average Vehicle Weight (lbs)
0-8,000	7,960
8-28,000	15,520
28-64,000	43,600
64,000+	74,080
All vehicles	**12,010**

Table 3.2 Vehicle Types

Vehicle Type	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
Autos and vans	11.7[a]	3.6	0.0	0.0	10.1
Campers	4.4	0.0	0.0	0.0	3.6
Buses	0.0	0.8	1.7	0.0	0.2
Pickups	63.8	15.0	0.4	0.0	54.3
Panels	10.3	8.0	0.0	0.0	9.5
Single trucks	9.8	69.7	85.5	51.8	20.3
Tractor/semi-trailer	0.0	0.7	7.4	13.3	0.7
Truck/trailer	0.0	2.2	4.9	38.5	1.3

[a] Percentage of total vehicles by class.

Table 3.3 Vehicle Usage

	Vehicle Weight (lbs)				
	0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
Used for home-work travel	48.5[a]	14.4	1.3	1.8	41.9
Used for commercial purposes	77.1	86.2	95.9	96.6	79.4

[a] Percentage of total vehicles by class.

Table 3.4 Time of First Trip

	Vehicle Weight (lbs)				
	0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
Before 6 AM	12.9[a]	17.9	30.1	51.8	15.5
6-9 AM	65.2	44.5	54.8	35.2	61.0
9 AM-2 PM	20.0	31.0	10.2	11.1	20.9
After 2 PM	1.9	6.6	5.0	1.9	2.7

[a] Percentage of total vehicles by class.

Time of First Trip

Most vehicles are first used between 6 and 9 AM on a typical weekday, but the pattern of the time of first usage varies significantly by weight category. Lighter vehicles are less likely to start before 6 AM, and more likely to be used first after 9 AM. These variations are apparently due to differences in working schedules for the commercial activities which make use of the different vehicle sizes, and differences in the intensity of vehicle usage by vehicle size. Table 3.4 provides the details of these time patterns.

Vehicle Trips Per Day

The average vehicle surveyed reported making 7.7 trips per day. The distribution of vehicles by number of trips, and the averages by weight class, are provided in Table 3.5. Vehicles ranging from 8-28,000 pounds make the most trips per day (12.1), and vehicles in the heaviest category make the fewest (4.7). Both of the remaining vehicle categories have averages similar to the overall average.

Vehicle Mileage Per Day

Vehicle mileage per day by vehicle category, when measured using odometer readings at the start and end of the day, is inversely related to the number of trips made (see Table 3.6). This apparently anomalous result is explained by the differences in average miles per trip by vehicle category. Vehicles in the 8-28,000 pound category make many short trips, typically for such activities as refuse pickup and package delivery. Vehicles in the heaviest category make a few long trips and in so doing generate many more vehicle miles per day than are generated by the lighter vehicles. As in the case of trips per day, the remaining vehicle classes exhibit average vehicle mileage and trip lengths similar to the overall averages. These averages are 78.5 miles traveled per day, and 10.2 miles per trip. It should be noted that when trip lengths are determined using either odometer readings for individual trips (see Section 3.2 and Table 3.6) or zone-to-zone distances or times obtained from MAGTPO's highway network (see Section 4.2), different values by vehicle category are likely to be obtained for two reasons:

- Minimum paths in the highway network may differ from actual paths used by commercial vehicle operators.

- A number of survey responses did not include starting and/or final odometer readings. The statistics shown in Table 3.6 do not include these responses.

Table 3.5 Vehicle Trips per Day

Range of Trips per Day	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
0	17.6[a]	6.9	4.7	3.7	15.4
1-10	63.6	68.4	69.3	92.8	65.2
11-20	15.3	15.6	21.8	3.5	15.2
21+	3.5	9.1	4.2	0.0	4.2
Averages	**7.2**	**12.1**	**8.0**	**4.7**	**7.7**

[a] Percentage of total vehicles by class.

Table 3.6 Vehicle Mileage per Day

Range of Miles per Day	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
1-20	14.6[a]	20.8	13.7	8.0	15.3
21-40	25.3	17.5	27.6	3.3	23.6
41-60	10.6	20.9	12.6	7.6	12.0
61-80	9.4	19.8	8.6	11.8	10.9
81-100	13.4	14.5	8.1	12.1	13.3
101-150	19.1	4.4	17.6	32.8	17.4
151+	7.6	2.1	11.8	24.4	7.5
Averages[b]					
Miles per day	79.0	56.2	74.0	156.8	78.5
Miles per trip[c]	11.0	4.7	9.2	33.4	10.2

[a] Percentage of total vehicles by class.

[b] These averages are based on vehicles' starting and ending odometer readings on their survey day. Because many drivers failed to provide this information, the averages shown are not as accurate as the statistics provided in other tables. See also Table 3.16.

[c] Calculated as miles per day from this table divided by trips per day from Table 3.5.

3.2 Characteristics of Commercial Vehicle Trips

Trips by Vehicle Weight

The average vehicle weight per commercial vehicle trip is 11,870 pounds, just one percent lower than the weight of the average commercial vehicle (see Table 3.1). The averages by weight class are provided in Table 3.7.

Trips by Vehicle Type

Table 3.8 provides distributions of commercial vehicle trips by type of vehicle. For all trips, pickups remain the predominant vehicle type, but due to a lower than average trip rate, these 54 percent of total commercial vehicles make just less than half of total trips. The results for autos and vans are similar – 10 percent of total vehicles in this category make just 8 percent of total trips. The fraction of trips made by single trucks (22 percent) and panel trucks (17 percent) exceed the corresponding fractions of vehicles, indicating that these vehicle types have higher than average trip rates.

Time of Day Distributions

In order to obtain time-of-day information from the survey results, it was necessary to consider only the trips reported by vehicles which made ten or fewer trips and thus provided details such as trip start and stop time for each trip made. (Vehicles making more than ten trips were only asked for detailed information on their first ten trips of the day.) Table 3.9 displays the distribution of time spent in travel by all vehicles which reported details for all of their trips on the survey day.

These distributions indicate that, for each vehicle weight class, the time-of-day pattern for commercial vehicles is much different than that for private autos. Rather than AM and PM peaks, truck travel typically increases steadily to a single peak hour, and then begins decreasing steadily. The peak hour by vehicle type ranges from the hour ending at 9 AM to the hour ending at 2 PM, and the percentage of total daily travel occurring in the peak ranges from 11 to 15 percent. The category consisting of the largest trucks is the only one with two peak hours separated by a period of lower volumes, but these peaks are separated by just two hours with slightly lower volumes; the peaks for this category are in the hours ending at 11 AM and 2 PM.

Table 3.7 Trips by Vehicle Weight

Vehicle Weight Category (lbs)	Average Weight Per Vehicle Trip (lbs)
0-8,000	7,980
8-28,000	14,700
28-64,000	44,600
64,000+	74,020
All vehicles	**11,870**

Table 3.8 Trips by Vehicle Type

Vehicle Type	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
Autos and vans	13.1[a]	0.4	0.0	0.0	8.2
Campers	2.4	0.0	0.0	0.0	1.8
Buses	0.0	0.7	1.1	0.0	0.2
Pickups	61.3	9.8	1.1	0.0	48.5
Panels	16.0	26.8	0.0	0.0	17.3
Single trucks	9.6	60.1	89.1	51.1	22.5
Tractor/semi-trailer	0.0	0.5	7.6	9.5	0.5
Truck/trailer	0.0	1.7	1.1	39.3	1.1

[a] Percentage of total vehicle trips by class.

Table 3.9 Time of Day Distributions

Hour Ending	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
1 AM	-	-	-	-	-
2 AM	-	1	1	-	-
3 AM	1[a]	2	1	-	1
4 AM	-	-	1	-	-
5 AM	2	2	2	1	2
6 AM	5	4	5	4	5
7 AM	4	6	9	7	5
8 AM	5	7	11	9	6
9 AM	5	10	12	8	7
10 AM	8	9	10	10	9
11 AM	8	11	11	11	9
12 Noon	10	13	8	10	11
1 PM	14	11	8	9	13
2 PM	15	8	8	11	13
3 PM	6	7	6	9	7
4 PM	5	4	2	6	5
5 PM	3	2	1	4	3
6 PM	3	1	-	1	2
7 PM	1	1	2	-	1
8 PM	1	-	1	-	1
9 PM	1	-	1	-	1
10 PM	1	-	-	-	1
11 PM	-	-	-	-	-
12 Midnight	-	-	-	-	-

[a] Percentage of daily vehicle-hours occurring in the specified hour for all vehicles reporting each of their daily trips.

For all sampled commercial vehicles, the peak period extends over two hours, from 12 noon to 2 PM. During both of these hours, 13 percent of daily commercial vehicle travel occurs. Table 3.10 provides the percentages of commercial vehicle travel occurring during the peak periods for all vehicles, 6 to 9 AM and 3 to 6 PM. These values can be compared with the percentages of total private vehicle travel occurring in the same periods.[1] These values are 18 percent in the AM peak and 24 percent in the PM peak. Thus, the AM peak period is as important for commercial vehicles as for private vehicles, but during the PM peak period, when traffic volumes are greatest in total, commercial vehicles' percentage of daily traffic is only two-fifths of that for private vehicles.

Activities at Trip Ends

Table 3.11 provides the distribution of activities at the stops made by commercial vehicles. These results reflect the varying uses of different sized vehicles, beyond the cargo pick-ups and deliveries which are important for all vehicles. The smallest vehicle category is also used heavily for service calls and personal business. Vehicles in the 8-28,000 lb category are used most often – and more frequently than are other size categories – for combined pick-ups and deliveries. An example would be a small package service such as UPS. Vehicles larger than 28,000 lbs are used most predominantly for separate pick-ups and deliveries, probably of full loads in most cases.

Land Uses at Trip Ends

Eleven land use categories were included on the survey form. For reporting purposes and in order to match the land use data forecasted as part of the travel forecasting process for the Phoenix metropolitan area, these were grouped into the eight categories shown in Table 3.12, which provides the distribution of land uses reported by truck drivers at their stops. Three land uses – residential, retail and manufacturing/warehousing – account, overall, for approximately equal shares of all trip ends. Together, these three land uses represent nearly two-thirds of the trips. It is important to note that, due to the orientation of the survey to long-range travel forecasting and the resulting limitations in future land use data availability, information was not requested on detailed land uses such as schools, restaurants, and grocery stores which have particularly low or high trip generation rates.

1/ Cambridge Systematics, Inc. Analysis of Temporal Demand Shifts to Improve Highway Speed Modeling, prepared for Arizona DOT, 1988.

Table 3.10 Truck Travel During Peak Periods for All Vehicles

Time Period (%)	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
AM Peak (6-9 AM)	15[a]	22	32	23	17
PM Peak (3-6 PM)	11	7	3	11	10

[a] Percentage of daily vehicle-hours for all vehicles reporting each of their daily trips.

Table 3.11 Activities at Trip Ends

Activity at Stop	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
Loading, cargo pickup	14.4[a]	14.2	30.6	21.4	15.1
Unloading, cargo drop-off	27.6	23.7	39.4	51.4	27.7
Loading and unloading	21.0	32.7	5.3	5.6	22.4
Service calls	16.1	9.4	9.3	0.5	14.2
Vehicle maintenance	1.3	2.2	1.2	0.8	1.5
Personal business	11.8	1.6	1.2	2.1	9.2
To/from garaging location	7.8	16.3	13.1	18.2	9.9

[a] Percentage of all commercial vehicle trips.

Table 3.12 Land Uses at Trip Ends

Land Use at Stop	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
Residential	19.5[a]	35.8	18.6	26.7	22.9
Retail	20.0	18.5	22.9	7.4	19.5
Manufacturing, Warehousing	22.2	15.8	23.6	16.6	20.8
Transportation, Utilities, Communications	2.0	1.6	3.7	9.6	2.2
Medical, Government	4.0	0.4	4.0	6.4	3.4
Office, Services	11.2	3.2	1.8	1.2	9.0
Garaging locations	9.3	18.4	13.1	19.0	11.5
Other	11.8	6.3	12.3	13.1	10.7

[a] Percentage of all commercial vehicle trips.

Activity/Land Use Linkages at Trip Ends

Table 3.13 displays all trip end activity/land use linkages which account for eight percent or more of the total vehicle trips by weight category. Loading at manufacturing and warehousing sites is important for all vehicle sizes. Vehicles in the smallest weight category are unique in the importance of residential service calls. Vehicles in the second weight category (8-28,000 lbs) are unique in the importance of combined loading and unloading operations, at both residential and retail locations. Loading at residential locations – largely solid waste pick-ups, for example – is important for trucks weighing 28-64,000 lbs. For the largest trucks, the most important activities are loading, as noted above, and unloading at a number of land uses. The preponderance of unloading at residential locations reflects, to a large extent, the delivery of construction materials including lumber and ready-mixed concrete. In a more detailed study, residential construction sites would be considered in a separate land use category. In this study, however, it was necessary to be consistent with the outputs of land use forecasting and to consider such sites as residential land.

Stop Locations

Overall, over one-third of commercial vehicle stops are made on-street. As indicated in Table 3.14, there is considerable variation in this statistic for the separate vehicle weight categories. Vehicles in the 8-28,000 pound weight category make half of their stops on-street, while for heavier vehicles the percentages are 11 and 18 percent, respectively. The percentage for the lightest vehicles is nearly the same as the overall average.

Trips by Time Duration

The distributions of vehicle trip times, and the corresponding averages, are shown in Table 3.15. These distributions are based on the times between successive vehicle stops; they include time spent stopping. For this reason, they exceed the more relevant trip times discussed in Section 4.2, which reflect only origin to destination travel times over minimum paths, as determined from the offpeak highway network. Overall, the average trip time is 28.1 minutes. Generally, average trip times increase with increasing vehicle weight.

Table 3.13 Activity/Land Use Linkages at Trip Ends

Vehicle Weight (lbs)	Activity at Trip End	Land Use at Trip End	Percentage of all Trips by Weight Category
0-8,000	Loading	Manufacturing, Warehousing	10
"	Unloading	Retail	11
"	Unloading	Manufacturing, Warehousing	8
"	Service calls	Residential	10
8-28,000	Loading	Manufacturing, Warehousing	8
"	Loading and unloading	Residential	34
"	Loading and unloading	Retail	9
28-64,000	Loading	Residential	10
"	Loading	Manufacturing, Warehousing	12
"	Unloading	Retail	17
"	Unloading	Manufacturing, Warehousing	9
64,000+	Loading	Manufacturing, Warehousing	10
"	Unloading	Residential	30
"	Unloading	Transportation, Utilities Communication	9
"	Unloading	Hospitals, Government	8

Note: Only activity/land use linkages which account for eight percent or more of all trips by weight category are included in the table.

Table 3.14 On-Street Stops

Vehicle Weight (lbs)	Percentage of Vehicle Trips Stopping On-Street
0-8,000	36.8
8-28,000	50.2
28-64,000	10.9
64,000+	17.5
All Vehicle Trips	**38.3**

Table 3.15 Distributions of Trip Durations

Time Range (minutes)	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
0-5	18.5[a]	37.7	13.3	1.8	20.4
5-10	17.2	16.6	17.2	2.8	16.1
10-15	17.3	10.5	20.5	5.8	15.3
15-20	8.6	10.6	8.5	5.7	8.5
20-25	6.1	3.2	4.4	6.5	5.3
25-30	9.6	7.9	8.5	13.6	9.0
30-45	8.8	3.6	8.5	15.5	7.8
45-60	3.6	4.1	5.5	9.2	3.7
60-75	4.8	0.2	2.6	9.2	3.9
75-90	2.1	0.2	2.0	5.3	1.7
90-105	0.1	0.5	0.7	4.3	0.3
105-120	0.8	0.2	1.4	5.8	0.8
120+	2.6	4.7	6.8	14.5	7.2
Average (min.)	**23.9**	**18.8**	**30.1**	**57.6**	**28.1**

Note: These trip durations include time for loading, unloading, etc., at each stop. See Table 4.6 for estimates of time spent traveling per trip.

[a] Percentage of all commercial vehicle trips.

Trips by Travel Distance

Table 3.16 provides distributions of trip distances, based on starting and ending odometer readings for individual trips. The trip-based average values show major differences from the vehicle-based averages in Table 3.6 both due to the difference in weighting and due to the large number of data records of both types with missing odometer data. The poor reporting of odometer data as probably due to the difficulty in obtaining cooperation from vehicle drivers to provide more odometer information than they normally must provide. Because network-based distances can be estimated for all reported trips, the lack of complete odometer data was not critical. For most purposes, the information shown in Table 3.16 is more relevant; it is also more consistent with the network-based values discussed in Section 4.2.

Table 3.16 also provides the average speeds by vehicle implied by the average times and distances from Tables 3.15 and 3.16, respectively. The results indicate a reasonable range of average speeds by vehicle size.

Table 3.16 Distributions of Trip Distances

Distance Range (miles)	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28-64,000 (%)	64,000+ (%)	Total (%)
0-1	10.9[a]	32.3	15.8	2.2	14.7
1-3	17.6	17.9	17.1	3.1	17.4
3-5	17.1	9.7	12.3	4.3	15.4
5-10	18.2	21.9	16.1	12.0	18.7
10-20	19.8	9.5	21.7	36.6	18.3
20-40	9.4	3.9	11.1	27.5	8.8
40-60	1.9	2.7	1.7	3.9	2.0
60-80	0.8	0.6	1.2	1.9	0.8
80-100	0.2	0.0	1.2	1.0	0.2
100+	4.1	1.5	1.9	7.4	3.6
Average (miles)	14.1	8.5	13.3	27.1	13.3
Speed (miles/hour)[b]	35.4	27.2	26.5	28.2	28.4

[a] Percentage of all commercial vehicle trips.

[b] Calculated as miles per trip from this table divided by time per trip (including stopped time) from Table 3.15.

4.0 Urban Commercial Vehicle Travel Models

4.1 Trip Generation

Trip File Processing

One of the primary files for trip generation model development consisted of 32 district-weighted totals of trip ends by weight class (four categories) and by trip end activity (eight categories: loading, unloading, loading and unloading, service calls, vehicle maintenance, personal business, to/from the garaging location, and total for all activities). The survey data was aggregated to the district level in an attempt to reduce the random sampling variability due to the small sample size of 3,400 trips. The trip file was merged at the zonal level with the MAG zonal data for 1990 prior to its aggregation to the district level. The district level file also contains summations of each of the following variables from the MAG file:

- Number of households (four categories plus total);
- Number of employees (five categories plus total);
- Average household income;
- Total developable land area; and
- Total vehicles.

The second file used for trip generation model development was the weighted trip file used for statistical analysis of the survey trip data. It provides trip totals by weight class and land use category, as discussed in Section 3.2 and presented in Table 3.12. These totals, for all land use categories except garaging locations, could be used together with household and employment totals for the entire MAG study area to obtain land use/employment based trip rates.

Alternative Model Forms

Linear Regression Models

The activity-based trip end totals by district developed in the first file described above and summations of these totals by vehicle weight class were used to estimate a wide range of models using stepwise and standard linear regression.

Trip totals by trip end activity were used in an attempt to obtain models sensitive to the unique mixes of these activities by vehicle weight class, and to the potentially unique independent variables related to each activity. The final models, however, were always seen as being specific only to vehicle weight class, not also to trip end activity. Thus, a number of candidate models were developed using the activity-specific trip end totals, but these were subsequently aggregated to provide totals by vehicle weight class before comparisons were made between alternative model formulations.

The first step in developing candidate linear regression models was the use of stepwise regression to estimate all 32 activity/weight class-specific models both with and without estimated intercept values. Models without estimated intercepts are preferable to avoid problems in transferring the results from the district to the zonal level of aggregation and in estimating trip ends accurately in small zones and districts. Review of the initial estimation results revealed that the specification of models without intercepts did not change coefficient values or reduce goodness of fit measures significantly, so all subsequent estimation efforts were limited to models without estimated intercepts.

The second step in developing candidate linear regression models was the specification and estimation of five sets of five weight class-specific models using the following specification strategies:

- **Strategy 1** – Summation over trip end activities of the 32 zero-intercept models obtained using stepwise linear regression to provide five models: four for vehicle weight classes 1 to 4, respectively, and one for the total of vehicle weight classes 3 and 4.

- **Strategy 2** – Direct estimation using stepwise linear regression of five weight class-specific models.

- **Strategy 3** – Stepwise estimation of 32 models in which the first two variables included in the models are forced to be total households and total employment; followed by summation of the results over activities to provide five weight class-specific models.

- **Strategy 4** – Direct estimation of five weight class-specific models using stepwise linear regression starting with total households and total employment variables.

- **Strategy 5** – Direct estimation using standard linear regression of five weight class-specific models with the specifications found for each weight class in each of the previous strategies, followed by selection of the model having the correct signs for its coefficients and the highest R-square of the tested alternatives.

The results obtained for all five strategies are summarized in Table 4.1, which provides the number of variables and R-squared statistic for each weight category.

Generally, the best of these models provide acceptable goodness of fit measures, given the small sample size available in the commercial vehicle survey. There are potential problems, however, due to the lack of consistency in the variables used to estimate each of the 25 candidate models. Furthermore, the number of variables included in 14 of the models is fewer than five; these models are not able to capture many of the potential factors affecting commercial vehicle trip generation.

Land Use-Based Rate Models

Because the commercial vehicle survey includes information on land uses at trip ends and the MAG zonal data includes the number of residents and employment by land use category, it was possible to determine trip rates by land use category. As defined for use in this project, these rates have the following form:

$$\text{truck trip rate for land use category } i = \frac{\text{total study area trips to land use category } i}{\text{total study area employment at land use category } i}$$

The five categories of land use available in the MAG zonal data, and the corresponding categories used in the truck survey, are shown in Table 4.2.

An additional land use category, residential land, was included in the survey. For trips to and from this category, the trip rate was defined as follows:

$$\frac{\text{total study area trips to residential land}}{\text{total study area households}}$$

It should be noted that each of the trip rates defined above includes a minor mis-specification error, since the reported trips include those made to construction sites, but the land use data do not identify these sites explicitly. However, since construction activity is also not predicted

Table 4.1 Summary of Linear Regression Model Results

Model Specification Strategy	Vehicle Weight (lbs)				
	0-8,000	8-28,000	28-64,000	64,000+	28,000+
1	12/0.66[a]	6/0.36	7/0.59	8/0.40	8/0.60
2	4/0.76	2/0.43	1/0.59	3/0.63	3/0.76
3	9/0.66	3/0.15	5/0.58	5/0.37	7/0.60
4	2/0.74	2/0.25	3/0.74	2/0.58	2/0.74
5	8/0.77	2/0.43	3/0.74	3/0.63	8/0.76

[a] In each cell, the first value is the number of variables in the selected model. The second value is the R-squared statistic for the model.

Table 4.2 Correspondence Between Employment and Land Use Categories

MAG Zonal Employment Category	Truck Survey Land Use Category
Retail	Retail
Industrial	Manufacturing, warehousing
Public	Medical, government
Office	Office, services
Other	Transportation, utilities, communication, other

explicitly for future years and all present and future commercial vehicle trips must be accounted for, this mis-specification cannot be avoided as part of a long-range travel forecasting model.

Although the land use-based trip rates defined above account for most truck trips reported in the survey, they do not include trips to and from garaging locations. Information on land uses at these locations was not requested in the travel survey. To overcome this data limitation, the equations estimated for trips to and from garaging locations in Strategy 1 were added to equations based on the trip rates defined above. The characteristics of the final land use-based models for the five vehicle weight categories are summarized in Table 4.3.

These models have the advantage of a consistent set of independent variables. Like the regression models, they have no constant term and thus are well-suited for application at both the zonal and the district level. Finally, their R-squared statistics are comparable with those of the alternative regression models.

Model Selection

Based on the considerations discussed above, the land use-based model for each weight class was evaluated against the corresponding best regression model, mainly with respect to the models' accuracy in replicating the district-level survey results. Table 4.4 summarizes this evaluation.

Those results indicate that the land use rate models have lower coefficients of variation, and thus are to be preferred over the linear regression models for statistical reasons as well as for reasons related to consistency and numbers of variables, as discussed previously.

The modeling results obtained for the two heaviest vehicle weight classes combined indicate that, from the standpoint of predicting trip generation, this classification strategy is preferable to keeping these weight categories separate. A final decision on this issue was not made, however, until the average travel times, based on MAG's network data, were determined for each category and preliminary distribution model results were obtained. Thus, models based on both classification strategies were developed and used at the beginning of the trip distribution modeling task.

The final estimated trip generation models are presented in Table 4.5, which contains the coefficients associated with each independent variable for each model. The following equation, for commercial vehicles less than 8,000 pounds, illustrates how the rates shown in Table 4.5 are used in the trip generation models:

Table 4.3 Summary of Land Use-Based Model Results

Vehicle Weight (lbs)	Number of Variables	R-Squared Statistic
0-8,000	7	0.64
8-28,000	7	0.29
28-64,000	7	0.57
64,000+	8	0.29
28,000+	9	0.55

Table 4.4 Coefficients of Variation for Regression and Land Use-Based Models

	Coefficients of Variation[a]	
Vehicle Weight (lbs)	Linear Regression Models	Land Use Rate Models
0-8,000	0.89	0.78
8-28,000	2.28	1.10
28-64,000	0.92	0.81
64,000+	0.99	0.98
28,000+	0.82	0.81

[a] Coefficient of Variation = Standard Error of Estimate divided by the mean value of the dependent variable

Table 4.5 Final Trip Generation Models

Independent Variable	Vehicle Weight (lbs)				
	0-8,000	8-28,000	28-64,000	64,000+	28,000+
Total households	0.15433[a]	0.06859	0.00671	0.00590	0.01260
Retail employment	0.59091	0.13253	0.03075	0.00609	0.03685
Industrial employment	0.64087	0.09972	0.03210	0.01781	0.04991
Public employment	0.29491	0.00596	0.01349	0.01049	0.02398
Office employment	0.30925	0.02119	0.00225	0.00095	0.00320
Other employment	0.76348	0.10567	0.04026	0.03500	0.07527
Resident households	0.04004	--	0.00288	--	0.00288
Group quarter households	--	7.52348	--	--	--
Total area (acres * 100)	--	--	--	0.00365	0.00365
Vehicles	--	--	--	0.00062	0.00062

[a] Commercial vehicle one-way trips per one unit of the independent variable.

Note: The coefficients shown here do not reflect the results of the traffic calibration/assignment phase of the project. See Section 4.3 for a discussion of the final regional factors used to estimate total commercial vehicle trip generation.

$$TRIPS_i = 0.15433 * TOTHH_i + 0.59091 * RETEMP_i + 0.64087 * INDEMP_i + 0.29491 * PUBEMP_i + 0.30925 * OFFEMP_i + 0.76348 * OTHEMP_i + 0.04004 * RESHH_i$$

where:

$TRIPS_i$ = total average weekday commercial vehicle trips for vehicles less than 8,000 pounds originating in (and the total destined for) zone or district i.
$TOTHH_i$ = total households in zone or district i.
$RETEMP_i$ = total retail employees in zone or district i.
$INDEMP_i$ = total industrial employees in zone or district i.
$PUBEMP_i$ = total public employees in zone or district i.
$OFFEMP_i$ = total office employees in zone or district i.
$OTHEMP_i$ = total other employees in zone or district i.
$RESHH_i$ = total resident (non-group quarters, non-temporary, and non-seasonal) households in zone or district i.

4.2 Trip Distribution

Network-Based Average Trip Times

Six zonal level trip tables were developed using the weighted truck travel survey data. Four of these tables represent the trips made by vehicles in the four weight classes used throughout the project. The fifth table combines the two heaviest weight classes and the sixth table includes all weighted survey trips.

A table of zone-to-zone off-peak highway skimmed travel times for Phoenix's existing highway system was obtained from MAG. This table was combined with the six truck trip tables described above to obtain travel time distributions and average times by vehicle class. These results, plus the trip totals per table, are shown in Table 4.6. The averages by vehicle weight category are much less than those obtained from vehicles' reported stopping times per trip (see Table 3.16), reflecting the elimination of stopped time from the averaging process and reflecting differences between times based on minimum paths in a highway network and times reported by vehicle drivers.

Table 4.6 Characteristics of Zone-to-Zone Trip Tables Based on Survey Data

	Vehicle Weight (lbs)					
	0-8,000	8-28,000	28-64,000	64,000+	28,000+	All Trucks
Total Weekday Daily Trips[a]	702,377	187,855	31,944	19,430	51,377	941,613
Average Trip Time (minutes)	16.4	11.9	16.2	23.1	18.8	15.6
Trip Time Distribution (percentages)						
0 - 15 minutes	21.2 [b]	42.3	27.8	17.2	23.8	25.5
6 - 10	20.4	20.2	17.1	5.7	12.8	20.0
11 - 15	19.2	10.3	15.1	5.8	11.6	17.0
16 - 20	12.4	9.4	8.5	16.6	11.6	11.8
21 - 25	6.5	5.1	8.2	16.7	11.4	6.5
26 - 30	8.2	1.9	7.4	8.9	8.0	7.0
31 - 40	6.1	7.9	10.6	17.5	13.2	6.8
41 - 50	2.3	1.8	3.8	6.3	4.7	2.3
51 - 60	1.5	0.6	1.1	4.1	2.2	1.3
61 - 70	2.2	0.6	0.6	0.9	0.7	1.8
71 - 80	-	-	-	0.3	0.1	-
81 - 90	-	-	-	-	-	-
91 - 100	-	-	-	-	-	-
101 - 110	-	-	0.1	-	-	-

[a] These totals do not reflect the results of the calibration/assignment phase of the project. See Section 4.3 for additional factors applied to the trip totals shown here.

[b] Percentage of total commercial vehicle trips by vehicle weight category.

Model Structure

For consistency with MAGTPO's person trip models and with the state of the modeling practice in many US metropolitan areas, the standard gravity-type model structure was selected for commercial vehicle trip distribution modeling in the Phoenix metropolitan area. This structure is one in which trips for a particular category (in this case, commercial vehicle trips by weight category) between a production zone i and an attraction zone j are directly proportional to the total number of trip productions in zone i, attractions in zone j, an attractiveness factor based on the impedance (in this case, offpeak highway travel time) from i to j (although this factor decreases for larger values of impedance as an attractiveness measure should, it is termed a friction factor in the transportation literature; to avoid confusion, the standard terminology will be used in the remainder of this section) and, optionally, an adjustment factor (K-factor) which varies by origin and destination superdistrict (no K-factors are included in these commercial vehicle models). Because a share formulation is used, the number of trips between zones i and j is inversely proportional to the numbers of attractions in all other zones, to the friction factors from i to each of these zones, and, optionally, to K-factors from zone i to each of these zones. The friction factors are normally estimated iteratively for each trip category using a gravity model calibration program which attempts to match the observed impedance distributions.

Gravity Model Calibration

Number of Vehicle Classes

The average trip times for the two heaviest vehicle categories are quite different, but a final decision to combine these into a single heavy vehicle category was not made until initial gravity model calibration results were obtained. These initial results were obtained by running the TRANPLAN calibration program for three trip tables, representing the following vehicle weight ranges:

- 28-64,000 pounds;
- 64,000 pounds and greater;
- 28,000 pounds and greater – the summation of the two heavy-vehicle categories.

The observed and predicted average trip times for these three models, and the corresponding percentage errors, are provided in Table 4.7. The average trip time for the combination of the two heaviest vehicle classes is

Table 4.7 Initial Calibration Results for Alternative Heavy Vehicle Categories

Vehicle Weight (lbs)	Average Trip Times (minutes)		Percentage Error
	Observed	Predicted	
28-64,000	16.2	15.9	-1.3
64,000+	23.1	23.9	+3.5
28,000+	18.8	18.9	+0.5

Table 4.8 Observed and Predicted Average Trip Times for The Final Distribution Models

Vehicle Weight (lbs)	Average Trip Times (minutes)		Percentage Error
	Observed	Predicted	
0-8,000	16.4	16.1	-2.0
8-28,000	11.9	12.2	+2.6
28,000+	18.8	18.8	+0.2

predicted much more accurately than are the corresponding averages for the separate classes. Based on these results, and the small sizes of both of the heavy-vehicle trip tables, the gravity model for a single heavy vehicle category, 28,000 pounds and greater, was selected rather than the two models for 28-64,000 pounds and 64,000 pounds and greater. This selection does not imply that vehicles in these two weight categories have the same trip patterns; only that more accurate models can be developed when the two categories are combined then when they are not.

Final Distribution Models

Comparisons of the predicted and observed trip time distributions from initial calibration runs for all three vehicle weight categories revealed significant variations, even when average trip times were very nearly matched. Furthermore, increases in the number of calibration iterations did not improve these initial results. A careful review of the calibration algorithm used in the TRANPLAN package revealed that its friction factor smoothing process was apparently responsible for these results – by fitting a smooth log-linear function to the adjusted friction factors, the required adjustments were being cancelled out on each iteration.

This problem with the available gravity model calibration program was overcome by switching to an iterative application of the TRANPLAN gravity model calculation program, supplemented by a spreadsheet to assist in making manual friction factor adjustments. As in the TRANPLAN calibration process prior to smoothing, the manual adjustments involved re-estimating each friction factor using a correction term equal to the desired fraction of trips in a travel time range divided by the previously estimated fraction in this range. Rather than using constant travel time ranges of one minute, the travel time ranges were selected to ensure that the resulting friction factors would always decrease as travel times increase. This procedure converged after just 3-5 iterations (beginning with the results of a five-iteration run of the calibration program) to models with acceptable travel time averages and distributions. Tables 4.8 and 4.9 provide comparisons of the observed and predicted averages and distributions for these final models. Appendix D lists the corresponding friction factors for each model.

Table 4.9 Observed and Predicted Trip Time Distributions for The Final Distribution Models

Trip Time (minutes)	Vehicle Weight (lbs)					
	0-8,000		8-28,000		28,000+	
	Observed (%)	Predicted (%)	Observed (%)	Predicted (%)	Observed (%)	Predicted (%)
0 - 5	21.2[a]	21.0	42.3	41.3	23.8	21.8
6 - 10	20.4	20.8	20.2	19.4	12.8	13.4
11 - 15	19.2	19.1	10.3	10.8	11.6	12.2
16 - 20	12.4	12.6	9.4	9.7	11.6	12.6
21 - 25	6.5	7.6	5.1	5.4	11.4	11.8
26 - 30	8.2	6.6	1.9	3.8	8.0	10.0
31 - 40	6.1	6.3	7.9	5.7	13.2	10.4
41 - 50	2.3	2.9	1.8	2.6	4.7	4.7
51 - 60	1.5	1.8	0.6	0.9	2.2	2.4
61 - 70	2.2	0.9	0.6	0.3	0.7	0.7
71 - 80	-	0.3	-	-	0.1	0.1
81 - 90	-	0.1	-	-	-	-
91 - 100	-	-	-	-	-	-
101 - 110	-	-	-	-	-	-

[a] Percentage of total vehicle trips by weight category.

4.3 Calibration and Traffic Assignments

The Current Internal Commercial Vehicle Travel Forecasting Process

MAG's current travel modeling process, as updated in 1988, includes a trip generation model for a single category of internal truck trips representing all weight classes, plus a single gravity model. The trip generation model was borrowed from the forecasting system developed for the Detroit metropolitan area by the Southeast Michigan Council of Governments transportation staff. The gravity model was developed using Phoenix data collected more than 15 years ago. The internal commercial vehicle trips estimated by this gravity model are added to all other vehicle trips, including external truck trips which are estimated based on a recent external vehicle trip survey, and assigned to the Phoenix highway network using a network equilibrium procedure.

During the 1988 model updating process, these internal truck generation and distribution models were considered as temporary "place holders", to be replaced by the models developed in this project. However, they were also used to perform the final adjustments required to calibrate the complete vehicle trip modeling system to match current vehicle-miles of travel (VMT) data for the entire Phoenix metropolitan region. Thus, a regionwide factor of 1.38 was applied to the results of the current trip generation and distribution models as these trips were added to all other vehicle trips prior to the traffic assignment step. The overall adjustment of 38 percent provided by this factor represents the total effect of each of the following components of changes in internal truck travel:

- The expansion of truck vehicle trips to the equivalent number of two-axle counts, as measured by the automatic traffic recorders used to estimate the total VMT in the Phoenix area.

- The adjustment of internal truck travel estimated with the current models used in Phoenix to represent the actual internal truck travel in the Phoenix area.

- The expansion of Phoenix internal truck travel to compensate for any under-reporting in the latest Phoenix travel survey or under-estimation in the updated non-truck Phoenix models.

Only the first component, accounting for internal truck axles rather than trucks, can be determined accurately using the available data. The other two factors cannot be isolated to determine the relative importance of the adjustments due to model transfer and those due to under-reporting of non-truck travel.

Adjustments of the New Truck Models

It was necessary to incorporate the first and third adjustment components listed above also in the calibration process for the new models. In addition, although no adjustments are required due to model transfer, an adjustment was required to account for the fact that only the trips made by commercial vehicles registered in Maricopa County are included in the models developed in this project. As these models are integrated into the MAG forecasting system, they must be adjusted to represent all internal commercial vehicle trips, including those made in the study area by vehicles registered outside Maricopa County. As in the case of the current models, the net effect of the factors due to vehicle registration location and under-reporting can be determined, but the separate factors making up this total adjustment cannot be isolated. Thus, the calibration process for the new models consists of two steps:

- Expanding the commercial vehicle trips by weight class to account for the average number of axles per vehicle in each class.

- Expanding total commercial vehicle trips so that total estimated and observed VMT in the Phoenix region are equal. This expansion factor represents the net effect of internal trips by all commercial vehicles versus those by vehicles registered in Maricopa County, and of any under-reporting or under-estimation in any of the Phoenix models which affect the number of truck and non-truck vehicle trips.

The subsections which follow describe these two steps.

Axles per Vehicle Trip Factors

Table 4.10 summarizes the information obtained in the commercial vehicle survey concerning axles per vehicle trip by weight category. In the light vehicle category, all vehicle trips are made using vehicles having two axles. Only 3.7 percent of medium vehicle trips have more than two axles; the average number of axles for this group is 2.056. In the heaviest group, most vehicle trips are made by vehicles with three axles; the average is 3.124. When each of these averages are divided by two, factors are obtained which can be used to increase the number of medium and heavy vehicle trips to account for those made by vehicles with more than two axles. Overall, this adds 3.3 percent more vehicle trips and vehicle-miles of travel to that provided by the unadjusted vehicle trip models.

Combined Registration and Under-Reporting Factor

When the average travel time statistics by weight class and the overall average speed for the entire expanded Phoenix travel survey are applied to the survey's total commercial vehicle equivalent two-axle trips, an

Table 4.10 Axles per Vehicle Trip

Number of Axles	Vehicle Weight (lbs) 0-8,000 (%)	8-28,000 (%)	28,000+ (%)	All Vehicles (%)
2	100[a]	96.3	24.1	95.6
3	-	1.9	57.5	3.2
4	-	1.6	2.4	0.4
5	-	0.2	14.0	0.7
6	-	-	2.0	0.1
Averages	**2.000**	**2.056**	**3.124**	**2.066**

[a] Percentage of total commercial vehicle trips by weight class.

estimated of 7.182 million vehicle-miles is obtained.[1] This value compares with 11.659 million VMT, the difference between the total observed two-axle VMT in the Phoenix area and the total estimated by all current Phoenix models except the temporary internal truck trip model.[2] Thus, the combined registration/under-reporting factor, the ratio of the latter number to the former, is 1.623.

Model Implementation

The adjustment factors described above were combined with the trip generation models listed in Table 4.5, the trip distribution models described in the previous section, and MAG's current vehicle trip assignment procedure to fully implement the new commercial vehicle models as an integral part of the total Phoenix travel forecasting system. Appendix D lists these changes, which have also been provided to MAG in computer-readable format.

4.4 Model Transferability

Because travel patterns are often found to vary to a large extent from one urban area to another, the safest means of using the results of this project in another city would be to repeat the travel survey and model development tasks using the procedures found to be most effective in this project. The information requirements of this strategy would be within the usual capabilities of local and regional agencies responsible for transportation planning. These requirements include:

- A file from the Arizona Department of Motor Vehicles, or corresponding agencies in other states, of all commercial vehicles registered to owners in the planning agency's study area;
- The ability to geo-code street addresses to traffic analysis zones;
- Current zonal data on households and employment by type, on vehicles, and on land area;

1/ Table 4.6 provides trip totals by weight class. The predicted average trip times for all trips is provided in Table 4.8, and the average speed in Table 3.16.

2/ As reported by Priscilla Johnson, MAGTPO, July 30, 1991.

- A matrix of zone-to-zone offpeak highway travel times in the year of the commercial vehicle travel survey;
- An existing model system to which truck travel models can be added, or in which existing truck travel procedures can be replaced; and
- Estimates of regional vehicle-miles of travel by commercial vehicle type and by private automobiles.

Although the information requirements of this strategy for transfering the procedures used in this project to other areas are reasonable, the costs of doing so will be significant. Thus, it is important to explore less costly means of transfering the modeling strategies developed in this project to other urban areas. Recognizing the inherent tradeoffs between the reductions in costs and possible reductions in precision and accuracy involved in alternative approaches, a number of possible approaches are described briefly in this subsection. They are ordered from the least costly in terms of resource requirements and development time to the most costly.

Complete Transfer of the Phoenix Models

If planners in another urban area have no current tools to predict commercial vehicle travel, they would be able to use the models developed in this project, including its modeling strategies, model parameters, and UTPS travel forecasting procedures and setups. In this way they could implement a complete new set of commercial vehicle models. To the extent that commercial vehicle travel patterns in Phoenix are representative of local conditions, this approach would provide a useful tool for local planning at a relatively small cost.

This approach would be a reasonable one for Tuscon, for example, which is likely to be highly similar to Phoenix in terms of both current and expected future travel behavior. It might also be appropriate in other large and growing southern and western cities with either current or expected future levels of commercial vehicle travel similar to those in Phoenix.

Adjusting the Phoenix Models to Match Local Data

The previous strategy could be improved at low cost by adjusting the Phoenix models to match local information on commercial vehicle registrations and/or vehicle-miles of travel for the entire study area, following the strategies used for Phoenix. As discussed in Section 2.4, information on total vehicles registered by weight class was used to provide preliminary expansion factors for both vehicles and trips. Changes in registrations per employee could thus be used to adjust the Phoenix trip generation models

for application in other cities. Similarly, changes in the resulting models could be adjusted to match total commercial vehicle-miles of travel, as discussed in Section 4.3. As in the case of Phoenix, vehicle-miles of travel data can be obtained from local vehicle classification counts. Thus, after revising the Phoenix trip generation models, a set of commercial vehicle models calibrated to local regionwide data can be obtained.

The Phoenix trip distribution models could also be adjusted, if local data on average commercial vehicle trip lengths are available. However, this information is not likely to be available unless a recent commercial vehicle travel survey has been conducted.

If any model parameters are revised to reflect local conditions in other urban areas, changes of various types will be required in the programs which implement the models. These changes include the following:

- Revisions to the trip generation models implemented in Fortran to reflect coefficient changes required to match local measures of vehicle registrations and/or vehicle-miles of travel; and

- Revisions of the friction factors input to the trip distribution models implemented in AGM to reflect changes required to match local data on average trip lengths.

Development of a "National Model"

Perhaps the ultimate extension of the models developed in this project to other urban areas would involve their generalization to create a "national model", taking the Quick Response System[3] as a pattern. This would involve combining the existing models with information in the UMTA reports "Characteristics of Urban Travel Demand" and "Characteristics of Urban Travel Supply" to provide tables of each of its parameters as these are likely to vary by urban area type and size. Although this would involve a significant amount of effort, it would provide all urban areas with versions of the models developed in this project which, in the absence of local data and model estimation, could be used to estimate commercial vehicle travel with acceptable levels of accuracy for sketch planning purposes, such as performing initial feasibility assessments of new highway facilities with or without features designed for exclusive use by either autos or commercial vehicles.

3/ Sosslau, A.B., et al, "Quick-Response Urban Travel Estimation Techniques and Transferable Parameters, User's Guide", NCHRP Report 187, Washington, D.C., 1978.

Appendix A

■ Mail-Out Travel Survey Forms

The pages which follow provide a copy of the complete survey package mailed, with a postage paid return envelope, to selected commercial vehicle owners in the Phoenix metropolitan area.

MARICOPA•ASSOCIATION•OF•GOVERNMENTS
Transportation & Planning Office
1739 West Jackson Street
Phoenix, Arizona 85007
(602) 255-7867

Dear Truck Owner,

Enclosed you will find a Vehicle Trip Record designed to study commercial vehicle transportation and travel activity. The survey will play an important part in planning for future transportation needs here in the Valley. We are interested in learning more about the day-to-day travel behavior of commercial vehicles in Maricopa County. We need your help. The vehicle with the license plate number listed on the label attached to the survey is the vehicle that should have its travel activity recorded on this Vehicle Trip Record. **By having the driver of that vehicle fill out a travel log for just one day, you will help us learn more about how to help address Arizona's transportation concerns.** We need the travel activity of that vehicle for Tuesday, October 3, 1989.

ABOUT MAG

The Maricopa Association of Governments (MAG) is a voluntary association of local governments that does transportation planning for Maricopa county. Research studies about transportation are conducted so that we can learn more about how to solve traffic problems that affect the Valley. We also maintain computer programs that help us to project future traffic patterns.

ABOUT THE STUDY

This Vehicle Trip Record is being filled out by several hundred commercial vehicle drivers in Maricopa county. Vehicles are randomly selected to participate in the study, and yours is one that has been selected. **The information about the use of your vehicle will enable MAG to understand "a day in the life" of this county's fleet of commercial vehicles.** We want to know what the vehicle is used for and where it goes. We are interested in the vehicle, but we need your help. By filling out the Vehicle Trip Record, your driver will be giving us information that we cannot get anywhere else. Through your record, we will learn more about that vehicle and others like it.

ABOUT THE RESULTS

All information gathered for this study is coming from individuals just like your drivers who are filling out identical Vehicle Trip Records. All of the information will be treated with the utmost confidentiality. We will use the information only for MAG purposes, to help us prepare future transportation improvement programs. Programs that we hope will help you.

You really count to us. Can we count on you? In expectation of getting your help with this study, I thank you. If you have any concerns about participating in the research, please call our Survey Information telephone line at 967-4441.

To proceed, the addressee should complete the first page of the Vehicle Trip Record and then forward the record to the driver of the appropriate vehicle as indicated on Page 1.

Yours appreciatively,

Roger Herzog

Roger Herzog
MAG Transportation & Planning
Office Manager

ADOT COMMERCIAL VEHICLE TRIP RECORD

***** A Personal Message To The Driver Or Drivers *****

If you have any questions, please call our Survey Information telephone line 967-4441.

Who should we contact if we have questions about your Vehicle Trip Record?

NAME _____

TELEPHONE NUMBER _____

X X

INSERT LABEL HERE

X X

1. What is the starting address for the vehicle listed on the label above on the survey date (the first Tuesday, Wednesday or Thursday after you received this survey)? Please be specific! Indicate St., Ave., North, South, East or West, nearest intersection if street address is unknown.

Street Address:_____

City:_____ Zip Code:_____

2. Please look at Figure 1 and determine which vehicle looks most like this vehicle. In the space provided below, write in the letter next to the picture of the vehicle which looks most like this vehicle. (If this vehicle normally operates with one or more trailers, write in the letter of the most common tractor/trailer configuration usually used.)

Letter of Vehicle From Figure 1: _____

3. If this vehicle, when used as shown in Figure 1, has more than six tires, please write in an estimate of what you think is its gross weight. If the vehicle has six tires or less, go on to Question 4.

Gross weight _____

4. How will you be using the vehicle today? Please circle "yes" or "no" for each item below to tell us whether you will use the vehicle for that activity today.

a. Transportation between home and work ..... YES NO

b. Any work-related purpose other than commuting .... YES NO->COMPLETION OF DIARY IS NOT REQUIRED. RETURN FORM IN POSTAGE PAID ENVELOPE.

V

PLEASE COMPLETE TRAVEL DIARY.

Before you go on to the Travel Diary on the next page, we want to give you an idea of what we consider to be a trip or trips to be recorded on these pages. We will use the example of a ten-wheel tractor which is normally used with an eight-wheel semi-trailer to deliver building supplies:

Trip 1 Loaded tractor-trailer goes from warehouse to first delivery site, a new residential development under construction.

Trip 2 Empty tractor-trailer returns to warehouse to drop off for re-loading.

Trip 3 Tractor only goes to truck stop (transportation land use) to be refueled.

Trip 4 Tractor goes to restaurant (retail land use); driver has lunch.

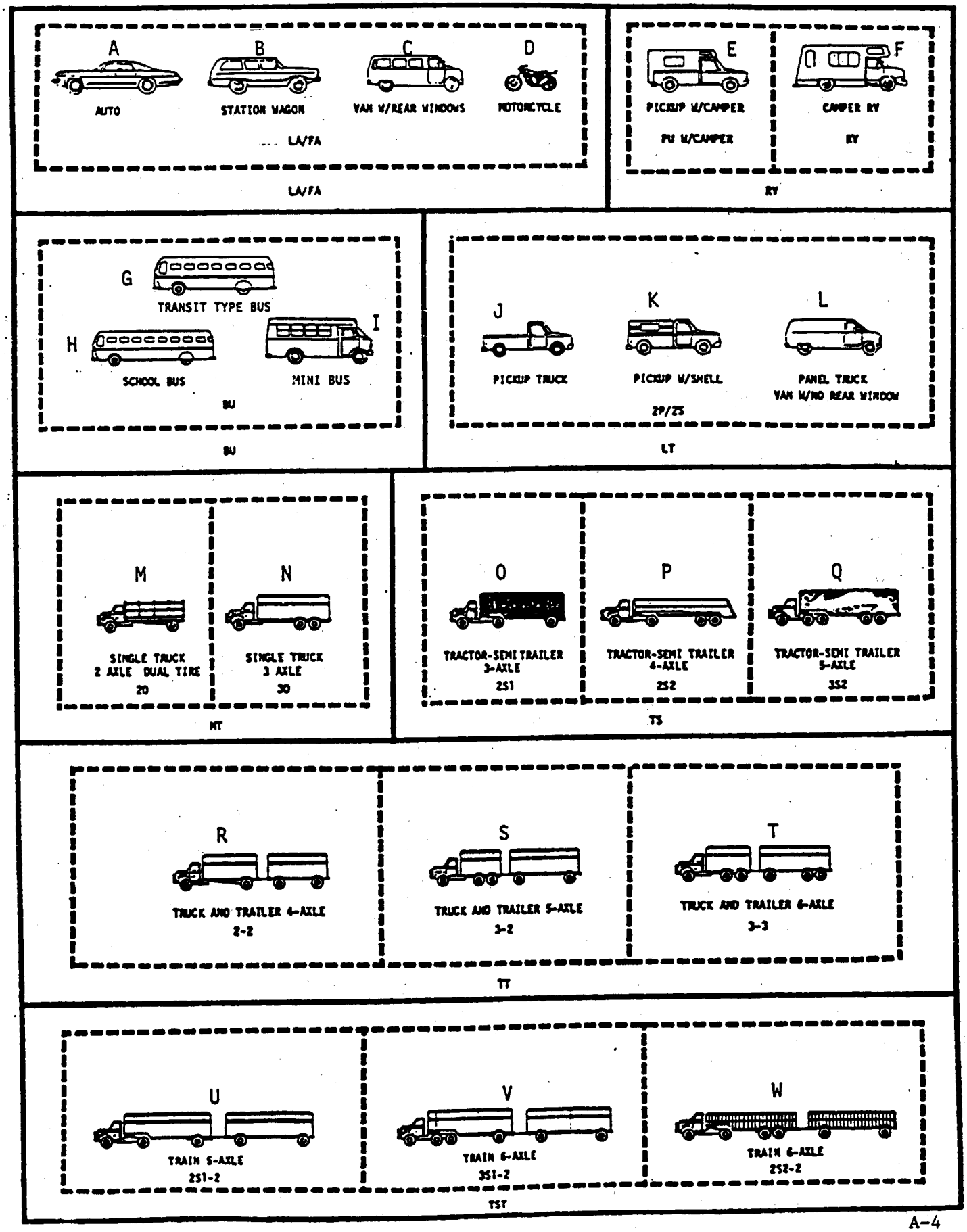
Trip 5 Tractor returns to warehouse to pick up loaded trailer.

Trip 6 Loaded tractor-trailer goes from warehouse to second delivery site, where a hospital is being expanded.

Trip 7 Empty tractor-trailer returns to warehouse where it is parked overnight.

Figure 1

VEHICLE CLASSIFICATIONS



Start time: ____ :__ A.M./P.M.
Start Odometer: _____

TRAVEL DIARY

Please record each trip in the order you make it.

Trip #	Start Time (circle A.M./P.M.)	Stop Time	Stop Odometer	Name & Address of stop Please give EXACT street address, St. vs Ave., etc.	Zipcode of stop	Activity at stop see below.	Stop ON or OFF street	Land Use at stop see below.	Vehicle Type see below.	Total # axles
EXAMPLE TRIP: (TRIP #5 IN PREVIOUS EXAMPLE)										
5	12:45 AM (PM)	1:15 AM (PM)	5082.3	1345 N. 10th Street Warehouse #2, Phoenix	85014	1	ON (OFF)	3	4	3
1.	AM PM	AM PM					ON OFF			
2.	AM PM	AM PM					ON OFF			
3.	AM PM	AM PM					ON OFF			
4.	AM PM	AM PM					ON OFF			
5.	AM PM	AM PM					ON OFF			
6.	AM PM	AM PM					ON OFF			
7.	AM PM	AM PM					ON OFF			
8.	AM PM	AM PM					ON OFF			
9.	AM PM	AM PM					ON OFF			
10.	AM PM	AM PM					ON OFF			

If your vehicle made more than 10 trips during the day, write in the total number of trips here: _____

Write in your final odometer reading here: _____

What was your final stop address? _____

ACTIVITY AT STOP
1. Pick up, Load
2. Drop off, Unload
3. Load & Unload
4. Service call
5. Gas up vehicle
6. Meal/Other personal

LAND USE AT STOP
1. Residential
2. Retail
3. Manufacturing, Warehousing, etc.
4. Transportation
5. Utilities
6. Communications
7. Hospitals
8. Public/Government
9. Office/Services
10. Other (write in)

VEHICLE TYPE
1. Straight Truck
2. Tractor/ semitrailer
3. Tractor/ Trailer
4. Bobtail
5. Commercial Auto

At the end of the travel day for this vehicle, please fold and return the Vehicle Trip Record by mail. Postage is paid.

Please return to:

O'NEIL ASSOCIATES, INC.
412 East Southern Avenue
Tempe, AZ 85282

Appendix B

The Vehicle Data File

Table B.1 documents the vehicle data file developed from the responses to the Phoenix commercial vehicle travel survey. The file consists of 606 individual vehicle records, each containing 21 fields or variables. The SAS statistical analysis system was used during the project for all data processing; the transmitted file is a "flat" ASCII data set which can be used as input to all microcomputer or mainframe based statistical or data base programs. The file name is 'VEHICLE.DAT'.

Table B.1 Vehicle Data File Format

Field Number	Variable Name	Column Location	Format[a]	Description and Codes
1	ID	2-6	I	Survey identification number; matches with variable ID in the Survey Trip File (C.1)
2	DMVZIP	8-12	I	Zip code of mailing address from DMV file
3	DMVWT	14-19	I	Vehicle weight from DMV file (lbs)
4	CLASS	21	I	Vehicle weight class: 1 = 0-8,000 lbs 2 = 8-28,000 lbs 3 = 28-64,000 lbs 4 = 64,000+ lbs
5	SRTADD	23-62	A	Address at start of first trip on survey day
6	SRTZIP	64-68	I	Zip code at start of first trip
7	SRTTAZ	70-73	I	Traffic analysis zone at start of first trip
8	SRTTIME	75-79	R.2	Starting time in the format xx.yy, where xx = hours (12-hour clock) and yy = minutes
9	SRTAMPM	81	A	Starting time AM or PM code: 1 or A = AM 2 or P = PM
10	SRTODOM	83-92	R.1	Starting odometer reading (miles)
11	FNLADD	94-133	A	Address at end of last trip on survey day
12	FNLZIP	135-139	I	Zip code at end of last trip
13	FNLTAZ	141-144	I	Traffic analysis zone at end of last trip

Table B.1 Vehicle Data File Format (continued)

Field Number	Variable Name	Column Location	Format[a]	Description and Codes
14	FNLODOM	146-155	R.1	Ending odometer reading (miles)
15	VEHTYPE	157	A	Vehicle type code; codes shown in Figure 1, Appendix A
16	COMMUTE	159	I	Vehicle usage for travel between home and work: 1 = yes 2 = no
17	WORKREL	161	I	Vehicle usage for any work-related purpose other than commuting: 1 = yes 2 = no
18	TRIPS	163-165	I	Total trips made on survey day
19	VEHDIST	167-176	R.1	Total daily vehicle distance (miles)
20	VFACT1	178-187	R.3	Vehicle factor 1: to match population totals by DMVZIP and CLASS
21	VFACT2	189-198	R.3	Vehicle factor 2: to match population totals by CLASS

[a] The following codes are used:
I = Integer variable: no decimal included
A = Alphanumeric variable
R.n = Real variable: decimal included; n digits to the right of the decimal

Appendix C

■ Trip Data Files

This appendix documents two trip data files developed from the responses to the Phoenix commercial vehicle travel survey. Each file is a "flat" ASCII data set which can be used as input to all microcomputer or mainframe based statistical, data base or transportation planning programs. These files are:

- **Survey Trip File.** The information obtained in the trip diary portion of the travel survey on 3,402 commercial vehicle trips was merged with selected vehicle data. The resulting file includes 29 fields or variables. The file name is 'SRVTRIPS.DAT'.

- **Generation Data File.** The survey trip file was aggregated to the district of origin and destination level to provide 100 records for use in trip generation model development. A number of variables from MAG's TAZ master file were also aggregated to the district level and merged into this file. The resulting file includes 55 fields or variables. The file name is 'GENDATA.DAT'.

The record formats for each of these files are provided in Tables C.1 and C.2.

Table C.1 Survey Trip File Format

Field Number	Variable Name	Column Location	Format[a]	Description and Codes
Section 1.	**Vehicle Data**			
1	ID	2-6	I	Survey identification number; matches with variable ID in the Vehicle Data File (B.1)
2	DMVWT	11-16	I	Vehicle weight from DMV file (lbs)
3	CLASS	18	I	Vehicle weight class: 1 = 0-8,000 lbs 2 = 8-28,000 lbs 3 = 28-64,000 lbs 4 = 64,000+ lbs
4	VEHTYPE1	20	A	Vehicle type code as registered; codes shown in Figure 1, Appendix A
5	COMMUTE	22	I	Vehicle usage for travel between home and work: 1 = yes 2 = no
6	WORKREL	24	I	Vehicle usage for any work-related purpose other than commuting: 1 = yes 2 = no
7	TRIPS	26-28	I	Total trips made on survey day
8	VEHTYPE2	30	I	Vehicle type code as used for current trip: 1 = Straight truck 2 = Tractor/semi-trailer 3 = Tractor/trailer 4 = Bobtail 5 = Commercial, auto
9	AXLES	32	I	Number of axles for vehicle as used for current trip

Table C.1 Survey Trip File Format (continued)

Field Number	Variable Name	Column Location	Format[a]	Description and Codes
Section 2.	**Origin Data**			
10	OZIP	34-38	I	Zip code at origin
11	OTAZ	40-43	I	Traffic analysis zone at origin
12	OTIME	45-49	R.2	Trip start time in the format xx.yy, where xx=hours (12-hour clock) and yy=minutes
13	OAMPM	51	A	Trip start time AM or PM code: 1 or A = AM 2 or P = PM
14	OODOM	53-62	R.1	Starting odometer reading (miles)
15	OACT	64-65	I	Activity at origin code: 1 = Pick up, load 2 = Drop off, unload 3 = Load and unload 4 = Service call 5 = Gas up vehicle 6-8 = Meal/other personal 11 or 12 = Garaging location
16	OLU	67-68	I	Land use at origin code: 1 = Residential 2 = Retail 3 = Manufacturing, warehousing, etc. 4 = Transportation 5 = Utilities 6 = Communications 7 = Hospitals 8 = Public, government 9 = Office, services 10 = Other 11 or 12 = Garaging location
17	OPARK	70-72	A	Parking location at origin code: 'ON' or 'OFF'

Table C.1 Survey Trip File Format (continued)

Field Number	Variable Name	Column Location	Format[a]	Description and Codes
Section 3. Destination Data				
Note: The codes, formats, and units for variables 18-25 match those for the corresponding variables in Section 2.				
18	DZIP	74-78	I	Zip code at destination
19	DTAZ	80-83	I	Traffic analysis zone at destination
20	DTIME	85-89	R.2	Trip end time
21	DAMPM	91	A	Trip end time AM or PM code
22	DODOM	93-102	R.1	Ending odometer reading
23	DACT	104-105	I	Activity at destination code
24	DLU	107-108	I	Land use at destination code
25	DPARK	110-112	A	Parking location at destination code
Section 4. Trip Data				
26	TRIPNO	114-115	I	Trip number: specific to vehicle number ID
27	TIME	117-119	I	Trip time (minutes)
28	DIST	121-125	R.1	Trip distance (miles)
29	TFACT	127-136	R.3	Trip factor

[a] The following codes are used:
I = Integer variable: no decimal included
A = Alphanumeric variable
R.n = Real variable: decimal included; n digits to the right of the decimal

Table C.2 Generation Data File Format

Field Number	Variable Name	Column Location	Format[a]	Description and Codes
Section 1.	**Record Identifier**			
1	DISTRICT	2-4	I	MAG district number
Section 2.	**Trips For Weight Class 1: 0-8,000 lbs**			
2	TRIPS11[b]	6-15	R.1	Total trips; weight class 1, activity 1
3	TRIPS12	17-26	R.1	Total trips; weight class 1, activity 2
4	TRIPS13	28-37	R.1	Total trips; weight class 1, activity 3
5	TRIPS14	39-48	R.1	Total trips; weight class 1, activity 4
6	TRIPS15	50-59	R.1	Total trips; weight class 1, activity 5
7	TRIPS16	61-70	R.1	Total trips; weight class 1, activity 6-8
8	TRIPS17	72-81	R.1	Total trips; weight class 1, activities 11-12
9	TOTAL1	83-92	R.1	Total tips; weight class 1
Section 3	**Trips For Vehicle Weight Class 2: 8-28,000 lbs**			
Note:	Variables TRIPS21-TRIPS27 correspond to TRIPS11-TRIPS17 with respect to their activities;[b] all have format R.1.			
10	TRIPS21	94-103		
11	TRIPS22	105-114		
12	TRIPS23	116-125		
13	TRIPS24	127-136		
14	TRIPS25	138-147		
15	TRIPS26	149-158		
16	TRIPS27	160-169		
17	TOTAL2	171-180		

Table C.2 Generation Data File Format (continued)

Field Number	Variable Name	Column Location	Format[a]	Description and Codes
Section 4. Trips For Vehicle Weight Class 3: 28-64,000 lbs				
Note: Variables TRIPS31-TRIPS37 correspond to TRIPS11-TRIPS17 with respect to their activities;[b] all have format R.1.				
18	TRIPS31	182-191		
19	TRIPS32	193-202		
20	TRIPS33	204-213		
21	TRIPS34	215-224		
22	TRIPS35	226-235		
23	TRIPS36	237-246		
24	TRIPS37	248-257		
25	TOTAL3	259-268		
Section 5. Trips For Vehicle Weight Class 4: 64,000+ lbs				
Note: Variables TRIPS41-TRIPS47 correspond to TRIPS11-TRIPS17 with respect to their activities;[b] all have format R.1.				
26	TRIPS41	270-279		
27	TRIPS42	281-290		
28	TRIPS43	292-301		
29	TRIPS44	303-312		
30	TRIPS45	314-323		
31	TRIPS46	325-334		
32	TRIPS47	336-345		
33	TOTAL4	347-356		

Table C.2 Generation Data File Format (continued)

Field Number	Variable Name	Column Location	Format[a]	Description and Codes
Section 6. Trips For Vehicle Weight Classes 3 and 4: 28,000+ lbs				
Note: Variables HEAVY1-HEAVY7 correspond to TRIPS11-TRIPS17 with respect to their activities;[b] all have format R.1.				
34	HEAVY1	358-367		
35	HEAVY2	369-378		
36	HEAVY3	380-389		
37	HEAVY4	391-400		
38	HEAVY5	402-411		
39	HEAVY6	413-422		
40	HEAVY7	424-433		
41	TOTAL34	435-444		
Section 7. District Data				
42	RESHH	446-451	I	Resident households
43	GQHH	453-458	I	Group quarters households
44	TRANSHH	460-465	I	Transient households
45	SEASHH	467-472	I	Seasonal households
46	TOTHH	474-479	I	Total households
47	PUBEMP	481-486	I	Public/quasi-public employment
48	RETEMP	488-493	I	Retail employment
49	OFFEMP	495-500	I	Office employment
50	INDEMP	502-507	I	Industrial employment
51	OTHEMP	509-514	I	Other employment
52	TOTEMP	516-521	I	Total employment

Table C.2 Generation Data File Format (continued)

Field Number	Variable Name	Column Location	Format[a]	Description and Codes
53	AREA	523-528	I	Land area (acres*100)
54	INCOME	530-535	I	Mean household income (1988 $)
55	VEHICLES	537-542	I	Vehicles

[a] The following codes are used:
I = Integer variable: no decimal included
A = Alphanumeric variable
R.n = Real variable: decimal included; n digits to the right of the decimal

[b] In general, variable TRIPSij refers to trips made by weight class i for activity group j. The activity codes included in each activity group j are described in the description and codes column for the Weight Class 1 variables (Section 2). See variable OACT in Table C.1 for definitions of these activity codes. Activity codes were assigned by allocating half of each weighted observed trip to its origin activity (OACT) and half to its destination activity (DACT).

Appendix D

■ Model Implementation Procedures

Tables D.1-D.3 provide listings of all changes required to incorporate the models presented in Section 4.0 into the current Phoenix travel forecasting system. This material has also been transmitted to MAG as an ASCII text data set for ease of use in modifying MAG's current travel forecasting procedures. The file name is 'PROCS.NEW'.

Tables D.1 and D.2 provide the changes required in MAG's current trip generation and trip distribution procedures, respectively. Table D.3 consists of a modified vehicle trip table accumulation procedure.

No changes are required to MAG's current traffic assignment model. The prior steps create a single trip table for assignment containing all vehicle trips, including internal truck trips by three vehicle weight classes. These truck trips are estimated in the prior steps provided in this appendix using adjusted versions of the trip generation and trip distribution models developed in this project.

Table D.1 Trip Generation Models

Insert the following code in place of the current Fortran program in STEP1 of the TRUCK set-up:

```
//PAN.SYSIN  DD  *
++INSERT WORK
C
C     Phoenix Internal Commercial Vehicle Trip Generation Model
C
C     Developed by Cambridge Systematics, Inc.
C     August 1, 1991
C
      INTEGER*4 ZONE, TRIPS(3), TTRIPS(4)
      REAL*4 HHS(4), EMP(5), AREA, VEHS, RFACT, AFACT(3), C(3, 10)
C
      DATA TTRIPS /3*0/, RFACT /1.623/, AFACT /1.000, 1.028, 1.562/
      DATA C /0.15433, 0.06859, 0.01260,
     *        0.59091, 0.13253, 0.03685,
     *        0.64087, 0.09972, 0.04991,
     *        0.29491, 0.00596, 0.02398,
     *        0.30925, 0.02119, 0.00320,
     *        0.76348, 0.10567, 0.07527,
     *        0.04004, 0.00000, 0.00288,
     *        0.00000, 7.52348, 0.00000,
     *        0.00000, 0.00000, 0.00365,
     *        0.00000, 0.00000, 0.00062/
C
C     IVWC = Vehicle weight class:
C            1 - 0-8,000 lbs
C            2 - 8-28,000 lbs
C            3 - 28,000+ lbs
C            4 - Total, all weight classes
C
C      TRIPS(IVWC) = Trip origins/destinations for current zone
C     TTRIPS(IVWC) = Total trip origin/destinations for all zones
C                    1 - ZONE
C      AFACT(IVWC) = Axle factor: average axles by VWC divided by 2
C
C     IVAR = Variable number:          Associated variable:
C            1 - Total households          TOTHHS
C            2 - Retail employment         EMP(3)
C            3 - Industrial employment     EMP(5)
C            4 - Public employment         EMP(2)
C            5 - Office employment         EMP(4)
C            6 - Other employment          EMP(1)
C            7 - Resident households       HHS(1)
C            8 - Group quarter households  HHS(2)
C            9 - Total area                AREA
C           10 - Vehicles                  VEHS
```

Table D.1 Trip Generation Models (continued)

```
C     C(IVWC,IVAR) = Model coefficient
C
C     IH = Household type:
C          1 - Residents
C          2 - Group quarters
C          3 - Transient
C          4 - Seasonal
C
C          HHS(IH) = Households in current zone of type IH
C           TOTHHS = Total households in current zone
C
C     IE = Employment type:
C          1 - Other
C          2 - Public
C          3 - Retail
C          4 - Office
C          5 - Industrial
C
C          EMP(IE) = Employment in current zone of type IE
C
C             AREA = Total zonal area (acres * 100)
C             VEHS = Total vehicles in zone
C
C            RFACT = Regional adjustment factor to match
C                    total VMT
C
C-------------------------------------------------------------
C
 100  READ (1, 101, END = 300) ZONE, HHS, EMP, VEHS, AREA
 101  FORMAT (5X, I4, 29X, 4F5.0, 5F6.0, 43X, F5.0, 1X, F6.0)
C
      TOTHHS = HHS(1) + HHS(2) + HHS(3) + HHS(4)
C
      DO 200 IVWC = 1, 3
      TRIPS(IVWC) = IFIX (RFACT * AFACT(IVWC) * (C(IVWC,1) * TOTHHS
     *              + C(IVWC, 2) * EMP(3) + C(IVWC, 3) * EMP(5)
     *              + C(IVWC, 4) * EMP(2) + C(IVWC, 5) * EMP(4)
     *              + C(IVWC, 6) * EMP(1) + C(IVWC, 7) * HHS(1)
     *              + C(IVWC, 8) * HHS(2) + C(IVWC, 9) * AREA
     *              + C(IVWC, 10) * VEHS + 0.5))
      TTRIPS(IVWC) = TTRIPS(IVWC) + TRIPS(IVWC)
 200  CONTINUE
C
C     Output adjusted model results to production and attaction files
```

Table D.1 Trip Generation Models (continued)

```
      WRITE (2, 102) ZONE, TRIPS
 102  FORMAT (I4, 4X, 3I6)
      WRITE (3, 102) ZONE, TRIPS
      GO TO 100
C     Output totals and close-out
C
 300  TTRIPS(4) = TTRIPS(1) + TTRIPS(2) + TTRIPS(3)
      WRITE (6, 301) TTRIPS
 301  FORMAT (10X, 'TOTAL INTERNAL COMMERCIAL VEHICLE TRIPS:' /
     *        15X,       ' 0 - 8,000 LBS', I10 /
     *        15X,       '8 - 28,000 LBS', I10 /
     *        15X,       '   28,000+ LBS', I10 /
     *        15X,       '-------------------------' /
     *        15X,       '          TOTAL', I10)
      STOP
      END
/*
```

Table D.2 Trip Distribution Models

Insert the following control data in the place of the current data in the AGM step of the TRUCK set-up:

```
//AGM.A3  DD  *
   1    9999999999999999
   2    4280008930009460 00
   3    2040008470007530 00
   4     84500  7330605000
   5     22600  4080217000
   6     17800  3420 53000
   7     10900  1520 51000
   8      7790  1140 41800
   9      5650   916 27900
  10      4880   682 14800
  11      4370   486 14600
  12      3900   352 14100
  13      3410   259 13300
  14      2770   246 12000
  15      2280   230 10900
  16      1900   215  9880
  17      1590   201  9020
  18      1340   176  8310
  19      1120   140  7840
  20       941   113  7410
  21       798  92.3  7020
  22       683  76.4  6660
  23       588  64.8  6340
  24       586  58.3  5930
  25       580  53.0  5590
  26       573  48.7  5280
  27       543  45.1  5020
  28       515  42.1  4780
  29       488  39.8  4580
  30       447  38.0  4400
  31       384  36.3  4190
  32       331  35.1  3710
  33       288  33.6  3290
  34       268  32.2  2910
  35       250  31.0  2570
  36       233  30.1  2260
  37       218  29.4  1990
  38       207  28.9  1730
  39       197  28.4  1690
  40       189  27.7  1660
  41       182  25.3  1640
  42       176  23.0  1630
  43       170  21.1  1610
```

Table D.2 Trip Distribution Models (continued)

44	167	19.2	1590
45	164	17.3	1580
46	161	15.5	1540
47	159	13.9	1480
48	158	12.6	1430
49	156	11.5	1370
50	155	10.2	1320
51	154	9.1	1260
52	153	8.3	1210
53	152	8.4	1160
54	152	8.5	1110
55	151	8.5	1060
56	151	8.6	1020
57	150	8.6	989
58	149	8.5	952
59	149	8.5	914
60	148	8.3	875
61	146	8.1	834
62	145	8.0	792
63	143	7.0	714
64	142	6.1	605
65	139	5.2	505
66	137	4.4	415
67	134	3.5	333
68	131	2.9	280
69	127	2.3	262
70	123	1.7	243
71	119	1.3	224
72	115	0.9	205
73	110	0.5	186
74	105	0.3	168
75	99.2	0.1	150
76	93.7	0.0	133
77	87.9	0.0	117
78	82.0	0.0	102
79	76.1	0.0	88.6
80	70.2	0.0	75.9
81	64.3	0.0	64.4
82	58.6	0.0	54.2
83	52.9	0.0	45.1
84	47.5	0.0	37.2
85	42.3	0.0	30.3
86	37.4	0.0	24.5
87	32.8	0.0	19.5
88	28.5	0.0	15.4
89	24.6	0.0	12.1

Table D.2 Trip Distribution Models (continued)

```
  90      21.0    0.0    9.3
  91      17.8    0.0    7.1
  92      14.9    0.0    5.3
  93      12.5    0.0    4.0
  94      10.3    0.0    2.9
  95       8.3    0.0    2.1
  96       6.7    0.0    1.5
  97       5.4    0.0    1.1
  98       4.3    0.0    0.7
  99       3.3    0.0    0.5
 100       2.5    0.0    0.3
 101       2.0    0.0    0.2
 102       1.5    0.0    0.2
 103       1.1    0.0    0.1
 104       0.8    0.0    0.1
 105       0.6    0.0    0.0
 106       0.4    0.0    0.0
 107       0.3    0.0    0.0
 108       0.2    0.0    0.0
 109       0.1    0.0    0.0
 110       0.1    0.0    0.0
/*
//AGM.SYSIN  DD  *
 1991 INT COMML VEH TRIP DISTRIBUTION MODELS FOR 3 WEIGHT CLASSES
 &PARAM  ZONES=1272,AITER=3,MAXT=110,TABOUT=3  &END
 &OPTION  A=T  &END
 &SELECT  REPORT=1,-8  &END
/*
```

Table D.3 Vehicle Trip Table Accumulation

Insert the following control data in the place of the current data in the UMCON and UMATRIX steps of the VEHO&D set-up:

```
//UMCON.SYSIN  DD  *
 EXPAND & BLOCK ALL VEHICLE TRIP TABLES
 &PARAM  ZONES=1272,1272,1272,1288,1288,1288,1288,1272,1272,1272,1272,
         ROUT=1288,COUT=1288,
         TABLES=1003,2003,2009,3001,4001,4002,4003,5001,6001,6002,6003,
         OUTPUT=4,NAME1='HBW VEH',NAME2='NHB VEH',NAME3='HBO VEH',
         NAME4='E/E VEH',NAME5='E/I AUTO',NAME6='EXT MED TRK',
         NAME7='EXT HVY TRK',NAME8='AIR PASS',NAME9='INT LT TRK',
         NAME10='INT MED TRK',NAME11='INT HVY TRK'  &END
 &DATA
99999999
 30013001    1 1288    11288*   1.42
/*
//UMATRIX.SYSIN  DD  *
 CONVERT 1991 MODEL VEHICLE TRIPS TO O&D FORMAT
 &PARAM  SIZE=1288,
         J9001.VEH TRIPS='0.5*(T1001+T1002+T1003+T1004+T1005+T1006+T1007
                          +T1008+T1009+T1010+T1011)+TR(0.5*(T1001+T1002
                          +T1003+T1004+T1005+T1006+T1007+T1008+T1009+T1010
                          +T1011))'  &END
/*
```

Table D.3 Vehicle Trip Table Accumulation

Insert the following control data in the place of the current data in the UMCON and UMATRIX steps of the VEHO&D set-up:

```
//UMCON.SYSIN  DD  *
 EXPAND & BLOCK ALL VEHICLE TRIP TABLES
 &PARAM  ZONES=1272,1272,1272,1288,1288,1288,1288,1272,1272,1272,1272,
         ROUT=1288,COUT=1288,
         TABLES=1003,2003,2009,3001,4001,4002,4003,5001,6001,6002,6003,
         OUTPUT=4,NAME1='HBW VEH',NAME2='NHB VEH',NAME3='HBO VEH',
         NAME4='E/E VEH',NAME5='E/I AUTO',NAME6='EXT MED TRK',
         NAME7='EXT HVY TRK',NAME8='AIR PASS',NAME9='INT LT TRK',
         NAME10='INT MED TRK',NAME11='INT HVY TRK'  &END
 &DATA
99999999
 30013001    1 1288    11288*   1.42
/*
//UMATRIX.SYSIN  DD  *
 CONVERT 1991 MODEL VEHICLE TRIPS TO O&D FORMAT
 &PARAM  SIZE=1288,
         J9001.VEH TRIPS='0.5*(T1001+T1002+T1003+T1004+T1005+T1006+T1007
                          +T1008+T1009+T1010+T1011)+TR(0.5*(T1001+T1002
                          +T1003+T1004+T1005+T1006+T1007+T1008+T1009+T1010
                          +T1011))'  &END
/*
```