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EVALUATION OF ARIZONA'S FATALITY RATE

Final Report

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16. Abstract

A procedure is presented to estimate the State traffic fatality rate based on an alternative method of estimating statewide vehicle-miles of travel (VMT). The VMT model is based on fuel sales and a weighted miles-per-gallon (mpg) estimate for the state vehicle fleet. The weighted mpg value reflects vehicle mix by roadway functional classification, the driving environment, vehicle type mpg factors by vehicle model year, and a regional adjustment factor. The model considers four vehicle types and two roadway functional classifications each in the urban and rural travel environment. The model produced an estimate of 30,740 million VMT and a statewide fatality rate of 2.91 fatalities per hundred million vehicle miles for Arizona for 1985. The estimated VMT was 5 percent higher than the estimate generated by the existing State method, and significantly higher than the estimate based on the Highway Performance Monitoring System (HPMS) data.

"Federal Highway Administration has approved publication of this report with reservations. FHWA believes that the Highway Performance Monitoring System (HPMS) is capable of providing reliable estimates of VMT and agrees that updating of the HPMS sampling frame is important. However, FHWA will continue to require that VMT and related data submitted to FHWA be developed in harmony with HPMS and the recently distributed Traffic Monitoring Guide."

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1. INTRODUCTION

PROBLEM STATEMENT

The traffic accident fatality rate is a function of the number of fatalities and the vehicle-miles of travel in an area over a given period of time. Annual fatality rates are published by several sources, including the state highway agency, the Federal Highway Administration (FHWA) and the National Safety Council (NSC). While sources use the same formula for computing the fatality rate, the data inputs for the formula may differ. As a result, traffic accident fatality rates may differ by published source.

For the State of Arizona, the annual traffic accident fatality rate as published by several sources varies considerably. For example, the data in Table 1-1 shows a large discrepancy in the fatality rates reported for Arizona by the Arizona Department of Transportation (ADOT), the Federal Highway Administration (FHWA), and the National Safety Council (NSC).

TABLE 1-1. ARIZONA FATALITY RATE
(FATALITIES PER 100 MILLION VEHICLES-MILES)

Year	Reporting Agency		
	ADOT (a)	FHWA (b)	NSC (c)
1982	3.06	3.67	3.84
1983	2.64	3.44	2.60
1984	3.25	4.22	NA
1985	3.07	4.14	NA

NA = Not Available
Sources: (a) ADOT (1983, 1984, 1985, 1986)
(b) FHWA (1983, 1984, 1985, 1986)
(c) NSC (1983, 1984)

The importance of differences in the published fatality rates may be shown by comparing Arizona fatality rates with those for the nation. For example, the 1983 U.S. fatality rate was 2.58 fatalities per 100 million vehicle-miles (MVM) (FHWA, 1984). The difference between this value and ADOT rate (2.58 versus 2.64) may not be practically significant. However, a comparison between the FHWA published figures and the average national fatality rate (3.44 versus 2.58) shows a considerably larger difference. Similarly, the 1984 U.S. fatality rate was 2.58 fatalities per 100 MVM while the ADOT and FHWA published rates were 3.25 and 4.24, respectively. These differences may have a major impact on the credibility of fatality rate calculations and on economic decisions made in the State on issues such as vehicle and life insurance rates.

An investigation of fatality rates and their means of calculation revealed two primary points. First, the number of fatalities used by agencies in calculating the fatality rate is essentially the same. This is due to the use of a common data source for traffic fatality information. Agencies obtain their fatality data from the Fatal Accident Reporting System (FARS) files maintained by the National Highway Traffic Safety Administration (NHTSA). This database is checked and verified in cooperation with state and federal personnel on a periodic basis through the calendar year to assure consistency between the state and national records. A year-end matchup of fatality records is also performed to assure similarity in the data files. Little or no difference in the number of fatalities exist.

Second, the estimate of annual vehicle-miles of travel (VMT) for the State differ considerably between reporting agencies. For example, the data in Table 1-2 shows that the FHWA reported VMT was as much as 25.7 percent below the ADOT figure in 1985. The data also reveals that the discrepancy between the ADOT and FHWA figures has significantly increased from the 16.7 percent difference shown for 1982 using the ADOT figure as the base for comparison.

TABLE 1-2. ESTIMATES OF ARIZONA ANNUAL VMT
(MILLIONS OF VEHICLE-MILES)

Year	Reporting Agency		
	ADOT (a)	FHWA (b)	NSC (c)
1982	23,663	19,720	18,822
1983	25,561	19,611	NA
1984	26,700	20,613	NA
1985	29,050	21,580	NA

NA = Not Available
Sources: (a) ADOT (1983, 1984, 1985, 1986)
(b) FHWA (1983, 1984, 1985, 1986)
(c) NSC (1983)

The fatality rate investigation basically indicated that the difference in published fatality rates is due to major differences in VMT estimates. While some difference in VMT might be expected due to differences in source data and estimation procedures, the observed differences in VMT between published sources is significant. Due to the magnitude of the differences, a need to review current data sources, methods, and procedures for VMT estimation was identified. The purpose of this study was to evaluate the procedures used to calculate the Arizona fatality rate. As part of this evaluation, it was determined that procedures for estimating VMT was an intial factor that had to be addressed. Therefore, an effort was developed to identify a VMT estimation procedure which most reasonably reflects the actual VMT within Arizona.

GOALS AND OBJECTIVES

The primary goal of this study was to evaluate the procedures used to calculate the Arizona fatality rate. This activity identified the need to improve the procedure for estimating statewide VMT. This goal was achieved through the satisfaction of the following five objectives.

- o Investigate the estimation procedures for calculating vehicle-miles of travel by ADOT, FHWA, and NSC.
- o Assess the validity of the VMT estimation procedure used by each of the agencies.
- o Identify other valid VMT estimation procedures used throughout the country.
- o Propose and develop a recommended procedure for calculating vehicle-miles of travel given ADOT's available resources.
- o Prepare a procedural manual and report for highway agencies to assist in estimating vehicle-miles of travel.

STUDY METHODOLOGY

The study progressed through three general phases.

- o Review of existing VMT estimation procedures including a survey of other states.
- o Development of the proposed VMT algorithm
- o Data collection and model application

Review VMT Estimation Procedures

The details of this phase are contained in Chapter 2. The project team performed an extensive review of existing VMT estimation procedures which were designed for use in determining highway fatality rates. The current Arizona procedure is based on motor fuel sales and a statewide fleet MPG value. The MPG value is periodically updated based on national trends in fleet MPG. The Federal Highway Administration (FHWA) currently supports and recommends the use of the Highway Performance Monitoring System (HPMS) data base for estimating VMT. The HPMS is designed to sample roadway and traffic characteristics within each state and the samples are factored to represent regional totals.

A formal survey of each State Department of Transportation (DOT), excluding Arizona, plus Puerto Rico and the District of Columbia was conducted to identify procedures used to estimate VMT. The survey results were used to determine trends in the general structure of VMT estimation techniques and to evaluate alternatives

which might be applicable to this study. An extensive literature review was also performed to supplement and compliment the survey.

Development of Proposed VMT Algorithm

Several alternatives were evaluated prior to development of the proposed VMT algorithm. These procedures included:

- o Highway Performance Monitoring System (HPMS)
- o Fuel Sales with Fleet Miles per Gallon (mpg)
- o Fuel sales with weighted mpg value
- o ADT expanded count station
- o Vehicle inspection records data
- o Driver survey
- o Econometric models

The evaluation and decision making process was based on various criteria. The criteria included:

- o Key model inputs
- o Sources and availability of required data
- o Key model assumptions
- o Reasonableness/Validity of model assumptions
- o Manpower requirements for data collections, model development and updating.
- o Time requirements for data collection, model development and updating.
- o Equipment requirements for data collection, model development and updating.
- o Sources for, and the potential magnitude of errors in the VMT estimate.
- o Potential application and uses of model results.

Details of this analysis are contained in Chapters 2 and 3.

An enhanced fuel sales algorithm utilizing a weighted mpg factor, was identified as a desirable method for estimating VMT. The model was deemed capable of generating results with a desirable level of accuracy, it was sensitive to those factors that affect fleet mpg (e.g., vehicle mpg, vehicle mix, travel

environment, roadway type, and the distribution of vehicles by age), and was capable of being updated easily with a minimal expense. The model format was subsequently approved by ADOT for calibration and demonstration.

Data Collection and Model Development

The model was developed around primarily existing data. Collection of this information was accomplished through the review and synthesis of existing publications and ADOT data files. Data requirements and sources are summarized in Table 1-3. Some field data collection was necessary to establish statistics on vehicle mix by roadway functional class in urban areas and on weekends. These data were used to establish a statewide weighted mpg value for gasoline and diesel vehicles. Fuel sales data were subsequently converted to a state VMT figure. Details of this procedure are contained in Chapter 4. A step-by-step application of the procedure and results for 1985 are presented in Chapter 5.

TABLE 1-3. SUMMARY OF PRIMARY DATA REQUIREMENTS AND SOURCES

Data Element	Source
Vehicle mix by rural roadway functional class (weekdays)	ADOT Data Records
Vehicle mix by urban roadway functional class (weekdays)	Field collection
Vehicle mix by urban and rural roadway functional class (weekends)	Field collection
Automobile MPG data and correction factors.	EPA published reports
Truck MPG data	Truck census reports and EPA reports
Distribution of Arizona registered vehicles by model year	ADOT vehicle registration records
Miles logged by Arizona registered vehicles by vehicle age.	EPA published research reports
State fuel sales for highway motor vehicles	ADOT records

EPA = U.S. Environmental Protection Agency

2. VMT ESTIMATION PROCEDURES

The analysis of VMT estimation procedures was conducted in three general phases.

- o Review of the literature
- o Survey of States' procedures
- o Detailed evaluation of study procedures

The objectives of this analysis were to identify various procedures having merit in estimating statewide VMT, and to evaluate the effectiveness of these techniques in meeting the overall goal of this research.

REVIEW OF THE LITERATURE

The literature review revealed that VMT estimation procedures primarily fall into one of three categories.

- o Traffic count techniques
- o Fuel sales techniques
- o A combination of traffic count and fuel sales

The majority of the research literature focused on methods for estimating regional VMT based on traffic volume counts (Sharma (1981 and 1983), Bandy (1982), Ferlis and Bowman (1979), Levinson et. al. (1979), Drusch (1966)). In general, these previous efforts have evaluated sampling strategies for regional traffic counts, including such factors as the number of sampling sites, the duration of the sampling period, and the required frequency of sampling. This work appears to have supplied at least a part of the basis for the procedures recommended by the FHWA in the Highway Performance Monitoring System Manual (HPMS) (FHWA (1980)). The HPMS presents a detailed implementation procedure for establishing a statistically valid sampling mechanism for determining statewide VMT.

In 1979, the Oak Ridge National Laboratory (ORNL) surveyed all 50 states plus the district of Columbia to evaluate the procedures being used to determine VMT (Green and Loebl (1979)). The results indicated that 23 states and the District of Columbia were using traffic count procedures, 11 states based VMT estimates on fuel use, and 16 states used a combination of the two methods.

The ORNL study evaluated the variability of state VMT estimates across estimation procedures by comparing the VMT per household. It was concluded that:

o Estimates produced by traffic count showed a greater variability than those produced by the other two methods, but that this did not indicate that the method had a greater inherent error.

o States using a combination or comparison of traffic count and fuel use methods arrived at consistently lower estimates of annual VMT per household, other things being equal, than states using exclusively one or the other.

o Despite the above differences, there was no significant differences among groups of states in the relationship of a given year's VMT estimate to state income, gasoline prices, and the previous year's VMT estimate. This indicated a general consistency in VMT estimating procedures, and that no procedure was inherently better or worse than the others.

The ORNL study cautioned that while the three estimating procedures were reasonably consistent on the average, individual state estimates could still reveal large errors. The differences discovered among estimation procedures suggested that a uniform method should be adopted by all states, and that this method be carefully designed to minimize errors and still provide sensitivity to changes in travel activity.

SURVEY OF STATES

The purpose of the survey was to identify procedures and techniques currently used by state agencies in estimating VMT, and to define key applications and characteristics of the VMT data used by each state. A total of 51 surveys were distributed (one to each state DOT, excluding Arizona, plus Puerto Rico and the District of Columbia). Forty-seven responses were received from states shown in Figure 2-1. Details of the survey and the responses are contained in Appendix A.

The survey questions were directed at specific procedures and sources of data used for VMT estimation purposes. In addition, information on specific uses of the data (in particular, accident rates) was requested. Finally, the survey attempted to identify differences in the VMT outputs from different procedures.

FIGURE 2-1. STATE RESPONSES TO SURVEY-OF-STATES

Major Survey Findings

The major findings of the survey are summarized below:

o The primary means of estimating VMT is currently by traffic counting procedures, either as part of the HPMS program or as part of a statewide traffic counting program. Forty-three of the 47 responses indicated the use of one or both of these procedures in estimating VMT. The next most often used procedure, either singularly or as verification of another technique, was the fuel sales/fuel efficiency (mpg) approach. Nine agencies indicated use of this technique. Other techniques used only by an individual agency included an econometric model, the use of vehicle registration and mileage records, and the use of other state records such as truck travel logs.

o Of those agencies utilizing fuel efficiency and fuel sales data to estimate VMT, fuel sales records are obtained from the state agency collecting fuel taxes. Estimates of fuel efficiency (mpg) are typically based on state-adjusted data. In most cases, the fuel efficiency data are broken down by specific fuel type.

o Differences in VMT between the results of HPMS and other procedures performed within an agency are being experienced by many agencies. In general, HPMS estimates appear to be lower than the estimates derived by other procedures. Primary reasons (as stated by respondents) for the differences may be related to the sampling plan of the HPMS and the lack of volume data on local roads.

o Most responding agencies publish traffic accident and fatality accident rates. The primary source of VMT data used in rate calculations is state agency estimates. Accident data are obtained from statewide records. In most cases, the state highway agency is the sole source of publication for fatality rates.

These results indicate that a concensus has yet to be reached among state agencies regarding a uniform method of determining VMT. There has been a general trend away from the use of fuel sales models and towards traffic count procedures since the ORNL study. However, overall use of the HPMS sample data was not indicated.

EVALUATION OF VMT ESTIMATION PROCEDURES

Seven VMT estimation procedures were evaluated in this study. The procedures were identified primarily from review of the literature, ADOT input, and from survey responses. They included:

- o Highway Performance Monitoring System (HPMS)
- o ADT-Expanded Count Stations
- o Fuel Sales with Fleet mpg
- o Fuel Sales with Weighted mpg Factor
- o Vehicle Inspection Records
- o Driver Survey
- o Econometric Model

An eighth procedure was considered but is not included as an alternative. This procedure, adopted by the National Safety Council (NSC) is not actually a procedure in itself. Rather, it is a published source of VMT information. Using input from the FHWA (provided from the HPMS program), the NSC publishes a VMT figure as background for computation of other statistics, e.g. accident rates. In many cases, VMT data supplied by the states as part of HPMS program are not received for the previous year until approximately mid-year of the following year. As a result, NSC typically estimates the VMT based on historical trends of the previous several years. Once the data is received from the FHWA, statistics utilizing VMT are updated where possible. As a result, discrepancies may exist between data published at different times of the year.

The key features associated with the evaluation of the seven VMT procedures are displayed in Table 2-1. A description of each procedure and a general evaluation are presented below.

HPMS Procedure

The HPMS procedure is based on an expansion of volume counts obtained from a sample of roadway sections throughout a state. Initially, the entire state roadway system (excluding local streets) is divided into groups of roadways with similar functional classification and average daily traffic volumes (ADT). From this total list of segments, a sample of segments is randomly selected to define the traffic

TABLE 2-1. COMPARISON OF VMT ESTIMATION PROCEDURES

Criteria	HPMS	ADT–Expanded Count Stations	Fuel Sales with Fleet mpg	Fuel Sales with Weighted MPG
Key Input	o ADT for sample roadway segments. o Sample of roadway segments by functional classifications and traffic volume range.	o ADT for roadway segments. o Characteristics of roadway segments.	o Fuel sales records. o Fuel economy (mph) estimate.	o Fuel sales records. o Fuel economy by vehicles type. o Vehicle characteristics by classification.
Sources of Data	o ADOT–traffic volume measurements from ADOT and local agencies. o List of sample roadways–identified by ADOT at start of program and altered periodically.	o ADT–traffic volume measurements from ADOT and local agencies. o List roadway segments.	o Fuel sales records–fuel tax record supplied by Motor Vehicle Divisions o Fuel economy data–national statistics adjusted by ADOT.	o Fuel sales records–fuel tax record supplied by Motor Vehicle Division. o Fuel economy data–national statistics from SAE. o Vehicle classification data–from manual classification counts.
Key Assumptions	o Sampling plan (80% confidence level, 20% level of error) approx. actual population. o Random selection of sample sites represents unbiased samples. o Functional classification and traffic volume represent valid breakdown of VMT. o Volume data (ADT) updated on annual basis. o Sample sites updated annually to represent sampling within volume group and functional classification.	o ADT within specific section length adequately defines volume throughout section length. o Where data are expanded by control count stations, traffic characteristics of expanded section are the permanent count station(s).	o Fuel "sold" in-state and "used" out-of-state equals fuel "bought" out-of-state and "used" in-state. o All non-highway use is accounted for. o All fuel sold in year "X" used in year "X". o Fuel economy of vehicles traveling in-state representative of nationwide vehicle registration and adjustment factor.	o Fuel "sold" in-state and "used" out-of-state equals fuel "bought" out-of-state and "used" in-state. o All non-highway use fuel is accounted for. o All fuel sold in year "X" is used in year "X". o Fuel economy of vehicles sampled on roadways in-state representative of national fuel economy statistics.

TABLE 2-1. COMPARISON OF VMT ESTIMATION PROCEDURES (CONTINUED)

Criteria	Vehicle Inspection Records	Driver Survey	Econometric Model
Key Input	o Mileage data from vehicle emissions/ registration records for base year and previous year.	o Sample of drivers and vehicles by type, usage, and area. o Sample mileage by vehicle type, usage and area.	o Base year estimates and furture year projections of socioeconomic variables (population, personal income, etc.) o Base year fuel consumption and o Base year vehicle fleet description (vehicle type, model year and fuel economy). o Computer models to estimate base year characteristics and to forecast characteristics.
Sources of Data	o Vehicle emissions/registration inspection records by Motor Vehicle Division.	o Vehicle registration data by Motor Vehicle Division. o Driver survey.	o Vehicle registration data by Motor Vehicle Division. o Forecast planning data by MAG planning models. o Fuel economy data-FHWA. o Newly developed computer model.
Key Assumptions	o All vehicles used in-state are registered. o Vehicle miles traveled out-of-state by Arizona registered vehicles is equivalent to vehicle miles traveled in-state by out-of-state vehicles. o Travel patterns for vehicles registered in different months has no difference from year to year. o Vehicle registration dates are one year apart.	o Driver replies represent accurate data. o Driver/vehicle samples adequately represent "population." o Vehicle miles traveled out-of-state by Arizona registered vehicles is equivalent to vehicle miles traveled in-state by out-of-state vehicles.	o Forecast planning data is reasonable. o Development relationships between socioeconomic characteristics and vehicle ownership characteristics are reliable.

volume characteristics for the specific grouping (traffic volume range within a functional classification type). The multiplication of the ADT by sample segment length describes the daily VMT within the sample segment. The accumulation of the daily VMT within a specific grouping is then expanded by multiplying the daily VMT by a ratio of total statewide mileage to sample mileage. The daily VMT is then expanded to an annual VMT and accumulated for all groupings to obtain an annual statewide VMT, excluding the local street VMT. VMT on local streets is added using data from local transportation agencies. Traffic volumes for the sample segments and mileage expansion ratios are collected and updated annually.

The HPMS procedure represents a statistically sound method of determining VMT on the roadway functional classes that are sampled. However, the samplying procedure must be properly applied in order to establish an unbiased sample that generates a high level of confidence in the result. The sampling plan must be periodically updated to account for new roadway development, changes in highway functional classification, changes in highway link length characteristics, and changes in traffic volume.

Major sources of variability with the HPMS procedure (as applied in the state of Arizona) include the sampling plan, the update of data, and the accuracy of the volume count data. The criteria for site sampling for most functional groupings is typically based on the achievement of precision levels of 80 percent confidence level with a 20 percent level of error. Based on the planned uses of the data and the cost-effectiveness of obtaining additional data for increased accuracy, the sampling level is appropriate. The sampling plan does not, however, include local or residential streets. The VMT for this roadway classification is estimated by ADOT and included in the VMT estimate.

The update of data represents a second key source of variability. While the Arizona Department of Transportation (ADOT) supplied traffic volume counts are obtained annually, non-ADOT counts historically have been obtained on a less regular basis. For example, in the major metropolitan areas, i.e., Phoenix and Tucson, traffic counts are obtained every two or three years; however, other agencies have not updated their counts in the past seven to eight years. Based on 1984 statistics, 51.2 percent or 10,553 million vehicle miles of a statewide total of

20,613 million vehicle miles, (FHWA, 1985) of the annual VMT was on roadways under local jurisdiction. Since 91.2 percent of the roadway mileage in the state is under local jurisdiction, the need for accurate volume data on local roads is evident. While the impact of the lack of updated local road volumes is not precisely known, an estimate of VMT variability is 10 to 15 percent.

A second source of variability is associated with the identification of segment links and location of segments within groupings defined by the HPMS. The HPMS program uses the same sample links over several years. Over time, however, the link characterisitcs, i.e., geometrics, traffic characteristics, number of intersecting streets, etc., often change and the sampling plan may not be altered to account for these changes. For example, a link identified several years ago as a three-mile segment may now be comprised of three one-mile segments each with significantly different traffic characteristics. Similarly, a link previously classified as a rural link may, over time, become an urban link. A significant change in population mileage for urban principal and minor arterials was indicated from a review of the Arizona HPMS data for 1984 and 1985. An increase of 640 miles and 467 miles, respectively, was recorded for the principal and minor arterials. Also, a decrease in rural mileage was observed. However, with the volume ranges in the urban groups significantly greater than the rural groups, a large increase in VMT occurs. A preliminary estimate of this impact places the change in the range of approximately 2 million VMT. While the impacts of these difficulties cannot be defined easily, an estimated 10 to 15 percent variability is projected (particularly prior to the recent change in classification mileages).

The final source of variability is associated with the accuracy of the volume data itself. Reasons for variations include: placement of traffic counter within a segment, accuracy of traffic counter devices ($\pm$2 percent normally assocated with such devices), accuracy of medium (road tubing) in transmitting count data and impacts of multiaxle trucks, use of adjustment factors for the day of week and month of year and the accuracy of the recording devices. Overall, a 5 to 10 percent variability is projected.

While the variability sources associated with this procedure may not necessarily be additive, the variability associated with the HPMS procedure, as practiced in Arizona, was estimated as ±35 to 50 percent.

ADT-Expanded Count Station

The ADT-expanded count station procedure is similar in principle to the HPMS procedure with the following exceptions. First, the sampling plan is variable. That is, the user is able to sample roadway segments for count data on a basis consistent with available resources. For example, where available time, equipment, and manpower resources exist, a sample counting program can be planned to assure a 90 or 95 percent confidence level with a 5 to 10 percent level of error. Secondly, the use of select control stations are introduced to provide expansion of non-count locations. In this way, segments not counted in one year can be adjusted to represent current information. Thirdly, segments and segment lengths are reviewed on a regular basis. Since the primary purpose of the program is to provide a record of traffic volume data, the major effort is extended in this direction. Greater time and effort can be expended to achieve a reliable product. In addition, segments are regularly adjusted to reflect dynamic and changing traffic conditions. Finally, every roadway segment is taken into account. Rather than grouping segments into classes by volume and multiplying the population-to-sample ratio, the VMT from all segments are additive.

As in the case of the HPMS procedure, several major sources of variability exist. The first source is related to the sampling plan. While a 100 percent sample would yield the most reliable result, the resources required for this plan may not be available. A reasonable plan would allow a 90 to 95 percent confidence level with a 5 to 10 percent level of error.

A second source of variability is related to the updating of the volume data. In the worst case, a level comparable to the existing situation would occur. ADOT-supplied counts would continue to be obtained annually. In the Phoenix and Tucson metropolitan areas, volume counts would be obtained on a 2- to 3-year cycle. For the other agencies, scattered counts would be obtained. A 10 to 15 percent level of variability in the VMT estimate could be expected. However, in the positive sense,

with the development of a comprehensive ADT-expanded count station program, upgrading of the count program through increased ADOT-supplied resources or increased motivation to local agencies may result. As a result, a 5 to 10 percent level of variability associated with this factor would result.

A third source of variability is associated with the update of segment links and lengths to reflect current conditions. Since links are typically reviewed regularly, a low source of variability is associated with this factor. A 0 to 5 percent level of variability was projected.

The final source of variability is associated with the accuracy of the volume data itself. Similar causes for variation as stated for the HPMS procedure would exist. A 5 to 10 percent level of variability was projected.

While the variability sources associated with this procedure may not necessarily be additive, the variability associated with the ADT-expanded count station procedure (given current resources in Arizona) was estimated as $\pm$ 15-25 percent (assuming a 90 to 95 percent level of confidence and a 5 to 10 percent level of error).

Fuel Sales With Fleet mpg

The typical fuel sales procedure represents a much simpler approach to estimating VMT and is based on easily available data within the state. The procedure currently used by ADOT is one application. The total annual VMT for all roads in the state is based on fuel, gasoline, and diesel sales within the state and an estimated fuel efficiency factor, i.e., miles-per-gallon (mpg). The record of the total gallons of fuel sold within the state are obtained from Motor Vehicle Division records for fuel tax purposes. This record details the total gallons of fuel sold within the state and identifies an amount utilized by non-highway users. The subtraction of the "non-highway use" fuel from the total fuel sold within the state provides an indication of the amount of fuel used for highway travel.

Data for fuel efficiency characteristics are obtained from national figures supplied by the FHWA, Motor Vehicle Manufacturers Association (MVMA), and the Society of Automatic Engineers (SAE). These values all have a base in the Environmental Protection Agency (EPA) mpg figures that are generated annually for

the national vehicle fleet through laboratory testing of vehicles. Other agencies typically adjust the EPA results to represent on-road mpg values. Hence, the difference in mpg statistics reported in the literature. A fuel efficiency figure is selected by ADOT based on the "most reaonable" value. The currently used fleet average is 15.7 mpg. The mpg estimate is then multiplied by the gallons of fuel to obtain an estimate of the statewide VMT.

Major sources of variability with this procedure include the fuel efficiency characteristics and the estimate of non-highway use fuel (subtracted from the record of total fuel sales). For purposes of estimating a statewide VMT, the state of Arizona uses the fuel efficiency characteristics of a weighted average of fuel efficiencies for a population of vehicles representative of vehicle registration characteristics nationwide. These characteristics are based on the weighted average characteristics for the following three group types: passenger cars, light duty trucks, and heavy trucks. A comparison of 1985 statistics (Arizona vs. U.S.) is shown in Table 2-2. Only a slight difference exists between the state and U.S. vehicle characteristics.

TABLE 2-2. ARIZONA AND NATIONAL VEHICLE FLEET CHARACTERISTICS FOR 1985

Vehicle Type(c)	Fleet Mix (%) U.S.(a)	Arizona(b)
Passenger vehicles	73.0	71.0
Trucks (light duty)	22.0	26.4
Trucks (heavy)	5.0	2.6

Source: (reference).

(a) EEA (November 1985)
(b) ADOT Motor Vehicle Registration (database 7-13-86)
(c) Slight differences exist in the definitions of light and heavy duty trucks in the above sources.

A more important observation in the use of fuel efficiency characteristics is the type of driving (i.e., "urban" versus "rural") associated with an area. The state

of Arizona is primarily a "rural" state with much travel associated with the use of rural highways. This fact is exemplified by the percentage of urban VMT versus rural VMT within the state. For 1984, the statistics show that 51.2 percent of the estimated statewide VMT occurred on rural highways while 48.8 percent occurred on urban highways (FHWA (1985)). Nationwide, the statistics showed 41.9 percent of the estimated national VMT to have occurred on rural highways while 58.1 percent occurred on urban highways. These results appear to display a significant difference in travel characteristics statewide versus nationally.

A third source of variability of the national figures for fuel efficiency is the application of data on an overall basis. The fuel efficiency is applied to all functional classifications regardless of the vehicle composition utilizing the roadways within the specific classification. For example, the same fuel efficiency is applied to estimates of VMT for the rural interstate as well as the urban interstate. While the vehicle classification characteristics differ considerably between functional classifications, similar vehicle classification characteristics are assumed. An example of these differences is displayed in Table 2-3.

TABLE 2-3. ILLUSTRATION OF THE VARIABILITY OF WEIGHTED MPG BY ROADWAY CLASS

	Location		
	Rural (NB)	Urban (NB)	
Description	I-17 near Black Canyon City[a] (%)	I-17 Near McDowell Road[b] (%)	Vehicle[c] mpg
Passenger cars and motorcycles	60.3	71.3	17.05
Recreational units	0.8	0.2	8.60
Buses	0.2	0.1	5.90
Light trucks	27.5	22.2	14.30
Medium trucks	6.5	4.0	8.60
Heavy trucks	4.7	2.2	5.22
TOTAL	100.0	100.0	
Weighted mpg (1984)	15.1	15.8	

Source: ADOT Transportation Planning Division
(a) Data taken 7/10/84 from 8:00 a.m. to 11:00 a.m.
(b) Data taken 1/4/85 from 8:00 a.m. to 11:00 a.m.
(c) Source: FHWA (1985), Table VM-1.

The weighted mpg's were computed using 1984 statistics for fuel efficiency (FHWA (1985)). Owing to the difference in vehicle composition along the highways, a difference in fuel efficiency was shown to exist along roadways having different vehicle compositions. Since vehicle composition along highways (in particular, by functional classification) differs throughout the state, differences in fuel efficiency by roadway functional classification were shown to exist.

Another source of variability is the estimate of fuel sales. The fuel sales records as supplied by the ADOT Motor Vehicles Division provides data on the total gallons of fuel (gasoline and diesel) sold in the state. A portion of this fuel is used by vehicles other than highway users (e.g., aviation, agriculture, recreation-off-roadway use, and others). An estimate of this amount is obtained from a record of applications for fuel tax exempt status by businesses or agencies based on non-highway use. Not all non-highway-use fuel, however, is applied for as "tax exempt" status. Based on the literature review, the percentage of gasoline used for non-highway purposes has been shown to be as great as 13.8 percent of an individual state's gasoline sales (FHWA (1985, Table MF-21A)). This percentage, however, is highly dependent on the state's industrial and agricultural characteristics. A review of national trends for the year 1984, revealed the percentage of national gasoline sales which represented fuel used for non-highway purposes was approximately 3.7 percent. While the lone case of 13.8 percent represents an extreme case, the mean for all 50 states plus the District of Columbia was 4.5 percent with a standard deviation of 2.7 percent (FHWA (1985)). The error associated with the estimate of non-highway use of gasoline is unknown.

The variability in the ADOT procedure, associated primarily with the estimate of fuel efficiency characteristics and an estimate of non-highway use fuel, was estimated to be $\pm$ 10 to 20 percent.

Fuel Sales with "Weighted mpg" Characteristics

This VMT estimation procedure is similar to the fuel sales procedure. Fuel sales records would be used as base data. However, rather than use a general fuel efficiency (mpg) factor, a more refined mpg factor would be developed. The fuel efficiency factor would be obtained using "weighted mpg" characteristics based on the projected usage of fuel by vehicle type sampled along Arizona highways.

As in the case of the ADOT procedure, several key sources of variability in the VMT estimate exists. However, with the use of the "weighted mpg" fuel efficiency factor based on sampled vehicle types along Arizona highways, some of the variability would be reduced.

This procedure is an upgrade to the current ADOT procedure. By refining the specific fuel efficiency factors, a lower range of variability in VMT estimates would exist. A 5 to 15 percent range of variability was projected.

Vehicle Inspection Records

This procedure utilizes the mileage information obtained from vehicles at the time of vehicle emissions testing and registration. By comparing the mileage for a vehicle recorded in one year to that mileage recorded for the previous year, an account of approximately a 12-month VMT for the vehicle can be obtained. Summing the list of registered vehicles, or using a sample of vehicles and expanding the result, would provide an estimate of the 12-month VMT. It is important to note that the vehicle emissions testing program currently includes only vehicles registered in Maricopa and Pima counties and does not include diesel-powered vehicles or pre-1971 vehicle models. Mileage information for diesel-powered vehicles would be obtained from the state records of Vehicle Identification Numbers (VIN). Mileage information for vehicles registered outside Maricopa and Pima counties would be estimated based on historical mileage information. Three key assumptions in this procedure are:

1. The mileage traveled out-of-state by Arizona registered vehicles is equivalent to the mileage travelled in-state by non-Arizona-registered vehicles.
2. The 12-month mileage records of vehicles inspected during the year is representative of an annual VMT.

Key sources of variability associated with this procedure include: the comparison of travel in-state by out-of-state vehicles and out-of-state by in-state vehicles, the presence of non-registered vehicles within the state, the impact of mileage information for differing vehicle registration periods, and the mileage representation for vehicle registered outside Maricopa and Pima counties.

Of major significance is the assumption that the mileage of vehicles registered in Arizona and traveled out-of-state is equivalent to the mileage traveled in-state by non-Arizona registered vehicles. While a low to moderate range of variability in VMT may exist for in-state versus out-of-state passenger vehicles, a greater range of variability would be expected for trucks. Truck travel throughout the state represents a considerable amount of VMT; however, Arizona-registered trucks were expected to represent less than half of the truck travel within the state. A significant amount of interstate truck traffic is generated within California and other states, passing through Arizona. Therefore, a moderate to high range of variability in the VMT estimate is expected. This is estimated to be 10 to 15 percent.

It has been estimated by the Motor Vehicles Division that 5 to 10 percent of Arizona vehicles do not have a current vehicle registration. In addition, due to part-time residency vehicle registration requirements, the mileage recorded for certain vehicles will not accurately reflect in-state mileage travelled. Finally, under the vehicle inspection system, VMT associated with new vehicles is not recorded until one year after their initial registration. While the range of variability for these factors is difficult to assess, it was anticipated that a 5 to 10 percent variability in VMT could be expected.

Another key source of variability is the effect of the schedule for registration/emissions testing. Currently vehicle registrations are required annually on the month of the initial registration of the vehicle. As a result, vehicle registrations/emissions testing are distributed throughout the year. In summarizing mileage (VMT) information for the registered vehicles, the most recent available information would be used for each vehicle. VMT summaries would be accumulated for vehicles on mileage information for the 12-month period of January, 1984 through January, 1985 as well as vehicles for the 12-month period of December, 1984 through December, 1985. A mix of 12-month periods would be used. While in many cases, the variability in VMT estimates for a given year may be in the low to moderate range (particularly where economic impacts or impacts of factors affecting vehicle travel are comparable throughout the period), major economic impacts (e.g., oil embargo of mid-70's or a large increase or decrease in gasoline

prices during a portion of a period) can have a sizeable impact. Therefore, an estimate of the impact of this factor on the VMT range can be expected to be 10 to 50 percent.

The final primary source of variability is the use of a historical factor to identify VMT for vehicles registered outside the mileage/emissions recording area (i.e., outside Maricopa and Pima counties). Based on records of the Motor Vehicles Division, over 74 percent of vehicles registered in Arizona were registered in either Maricopa or Pima counties. Similar percentages were displayed for the 1982-1984 period. Therefore VMT related to aproximately 26 percent of Arizona-registered vehicles would require projection. Due to differing travel habits between the highly urbanized counties of Maricopa and Pima versus the rural counties of Yavapai, Pinal, and the other Arizona counties, use of a simple ratio (comparison of non-Maricopa and non-Pima counties registered vehicles to the Maricopa and Pima County registered vehicles) may not be accurate. Other techniques such as those used in transportation modelling would typically achieve a more desirable result. Therefore, a low to moderate (5 to 10 percent) range of variability in statewide VMT estimates could be expected.

Using vehicle inspection records supplemented with information from other sources as a means to estimate VMT would be expected to have a range of variability of approximately 30 to 85 percent. This wide range would be due primarily to the impact on VMT of vehicle registration/inspection records that are based throughout the calendar year.

Driver Survey

In this VMT estimation procedure, a sample of drivers (identified by vehicle type and, possibly, model year) would be surveyed regarding travel patterns. Use of statistically-based sampling procedures and a well-planned questionnaire would be vital components to the procedure. Based on the sample information, the data could be expanded to represent the total population. To date, this method has primarily been used on a regional basis.

The major sources of variability associated with this procedure would be the reliability of the information obtained and the amount of information on completed

surveys. It is estimated that a low to moderate (5 to 10 percent) variability in VMT estimates would result.

By far, the greatest source of variability would be due to the percent of survey responses received. In most questionnaire surveys, a return rate of 25 percent is considered good. A 10 to 25 percent return rate would be expected based on historical trends of survey returns. The return rate reflects the overall confidence level and precision level of the VMT estimate. Given a 10 to 25 percent return rate, a range of variability of 25 to 50 percent would exist.

With the use of driver surveys, an overall range of variability of 30 to 60 percent may be expected in the estimation of VMT. In addition, common problems associated with survey methods include misunderstanding of survey questions, biases in returned samples, and time related to processing and coding information. Overall, the application of this method on a statewide basis did not appear to be favorable.

Econometric Model

VMT estimation using an econometric model would require annual estimate of base vehicle registration data and socioeconomic variables (population, income, number of households, etc.) Inclusion of base year vehicle characteristics, travel data, and fuel consumption information, would be used to estimate VMT. This type of model is currently being used by the California Department of Transportation to project travel estimates and highway user revenues for both existing and projected time periods.

The range of variability associated with this procedure is highly dependent on the calibration efforts and the level of precision associated with the estimate of socioeconmic variables. Models are typically used to estimate socioeconomic variables, vehicle characteristics and areawide travel patterns. Therefore, the overall range of variability could be anywhere from approximately $\pm$ 10 percent to as great as 100 percent.

The range of variability associated with this procedure can be considerable depending on the level of accuracy of the individual models and the combination of the models. The development of this type procedure did not appear to be cost-effective to estimate statewide VMT.

3. RECOMMENDED VMT ESTIMATION ALGORITHM

The recommended VMT estimation procedure is based on fuel sales data and estimates of vehicle fuel consumption characteristics of specific vehicle types and driving environments, i.e., rural versus urban driving conditions. The recommended procedure is a refinement of the procedure currently used by ADOT to estimate statewide VMT. Improved estimates of vehicle fuel consumption rates were incorporated into the recommended model. The model also utilizes "weighted miles per gallon" factors to estimate statewide VMT from fuel sales records.

This algorithm was selected for several reasons:

o Most of the data required to calibrate the model were available from published sources or from ADOT records. This facilitated model development.

o Most of the data required to drive the model are collected annually by ADOT, or updated annually by other agencies. For example, fuel sales vehicle registration, and vehicle classification data are routinely collected by ADOT. Automobile mpg data is published annnually by EPA. Therefore, the model can be updated regularly and with relative ease.

o The model appears to supply a level of accuracy at least as good or better than the other procedures that were reviewed at a low implementation cost.

DESCRIPTION

The recommended statewide VMT algorithm follows the general format displayed in Figure 3-1. The algorithm form is:

Statewide VMT = (Gasoline Fuel Sales x Weighted Gasoline-Related mpg) + (Diesel Fuel Sales x Weighted Diesel-Related mpg)

where:

Weighted mpg for X = Weighted mpg i x Percent of VMT for i

i = functional classification type

X = fuel type, i.e. gasoline, diesel

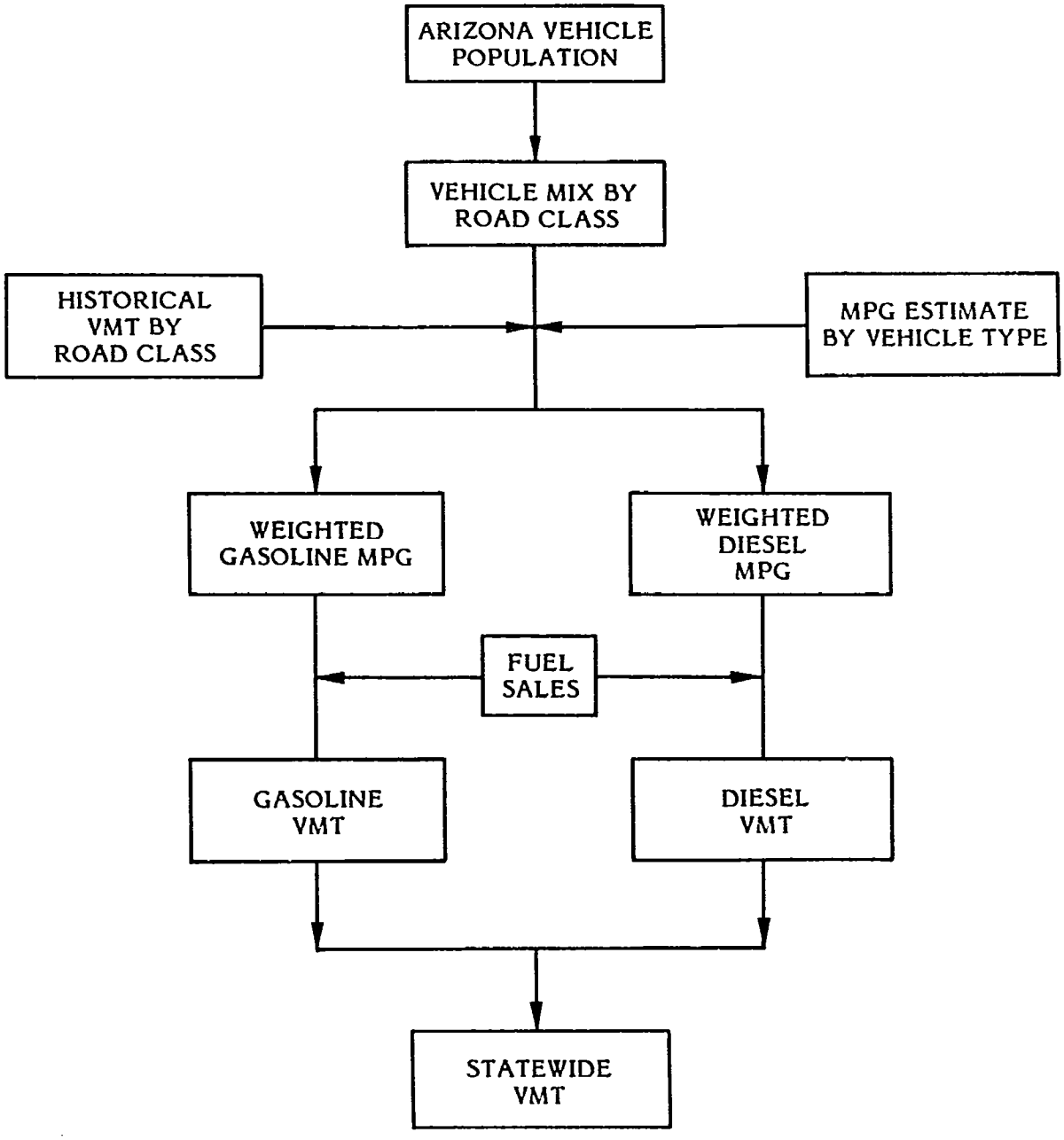


FIGURE 3-1. SUMMARY OF RECOMMENDED PROCEDURE FOR ESTIMATING STATEWIDE VMT

Separate "weighted mpg" factors were derived for both gasoline use and diesel fuel use. Since the trucking industry is the prime user of diesel fuel, an mpg factor representative of diesel use was developed to minimize bias in the overall VMT. Based on the samples of vehicle classification data collected in the field, average vehicle classification characteristics (i.e., vehicle types) were defined for each roadway functional classification. Using average mpg data for each vehicle type a "weighted mpg" factor for each roadway functional classification was developed.

Separate "weighted mpg" factors were derived for both gasoline use and diesel fuel use. Since the trucking industry is the prime user of diesel fuel, an mpg factor representative of diesel use was developed to minimize bias in the overall VMT. Based on the samples of vehicle classification data collected in the field, average vehicle classification characteristics (i.e., vehicle types) were defined for each roadway functional classification. Using average mpg data for each vehicle type a "weighted mpg" factor for each roadway functional classification was developed.

An overall "weighted mpg" factor (by gasoline and by diesel fuel use) was obtained by weighting the mpg factor for each functional classification based on the most recent VMT data by functional roadway classification. These data represented the previous year's VMT estimate.

DATA NEEDS

To apply the VMT estimation procedure, two key inputs are required: fuel sales and a "weighted mpg" factor. Fuel sales are typically obtained from the Motor Vehicles Division records and are separated into gasoline sales and diesel sales. From each group, non-highway use fuel is subtracted. Published data for Arizona show approximately a 2.7 percent level of non-highway use of gasoline while the national average was approximately 3.7 percent for 1984 (FHWA (1985)). The national average value could be used in the absence of better statistics. However, state specific values are highly recommended due to the large variability of this value between states. This factor would be subtracted from gasoline sales to obtain a reliable account of highway use of gasoline.

The non-highway use of diesel fuel remained an unknown parameter in this model. Statistics for 1985 for Arizona indicated that diesel fuel would account 14.8

percent of the total highway motor fuel if it were assumed that all diesel fuel were used on the highway. If it were assumed that the percent of diesel fuel consumed in non-highway uses were equivalent to that for gasoline, this would amount to less than 0.5 percent change in the total gallons of fuel consumed in highway use (see fuel statistics in Chapter 5). The lack of data on non-highway use of diesel fuel was not considered a significant problem when also considering that the majority of highway vehicles are gasoline powered.

Data used in obtaining an estimate of a "weighted mpg" factor included, vehicle classification data by functional roadway classification, base mpg data by vehicle type, the distribution of vehicle type by vehicle age, and recent VMT information by roadway functional classification. Details on the selection and use of this data is described in Chapter 4 of this report.

4. MODEL DEVELOPMENT AND APPLICATION

A number of key procedural issues required further study and resolution prior to finalization of the selected VMT algorithm. The issues included:

- o Vehicle classification study procedures
- o Vehicle class designations
- o Vehicle mix characteristics by road class
- o Development of mpg factors
- o Gasoline versus diesel fuel vehicles in the Arizona traffic population

A detailed description of the analysis of these issues follows.

REVIEW OF ADOT VEHICLE CLASSIFICATION STUDIES

The Arizona Department of Transportation (ADOT) has an ongoing program for collecting data on statewide vehicle classification. Vehicle classification data are periodically collected at 125 locations distributed throughout the state as shown in Figures 4-1, 4-2, and 4-3. Vehicles are classified by ADOT into the following categories:

- o Automobiles, station wagons, vans with rear windows and motorcycles.
- o Camper recreational vehicles and motor homes.
- o School and Transit buses.
- o Pickup trucks, pickups with shells or campers, panel trucks and vans without rear windows.
- o Single unit trucks with two axle dual tires or three axles.
- o Tractor-Semi Trailer with three, four, or five axles.
- o Truck and Trailer with four, five, or six axles.
- o Truck trains with five or six axles.

The number of ADOT data collection sites by roadway functional class in rural and urban areas is shown in Table 4-1 along with the number of miles of each functional class within the state. The precise locations of the ADOT sites and the highway functional class for each is given in Appendix B. For the years 1979 through 1984, 110 of the 125 sites were sampled at least once each year. These 110

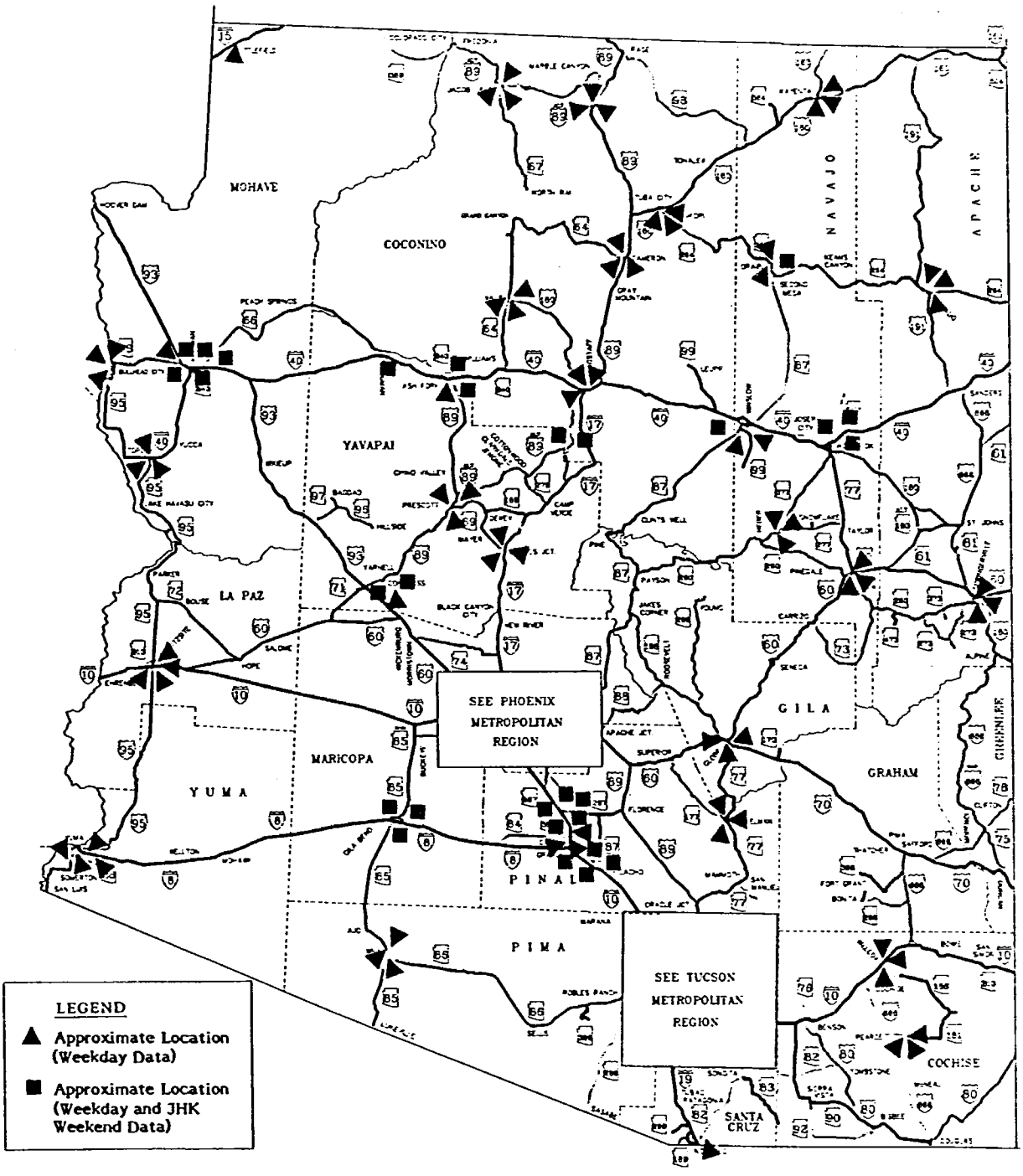


FIGURE 4-1. ADOT VEHICLE CLASSIFICATION DATA COLLECTION SITES

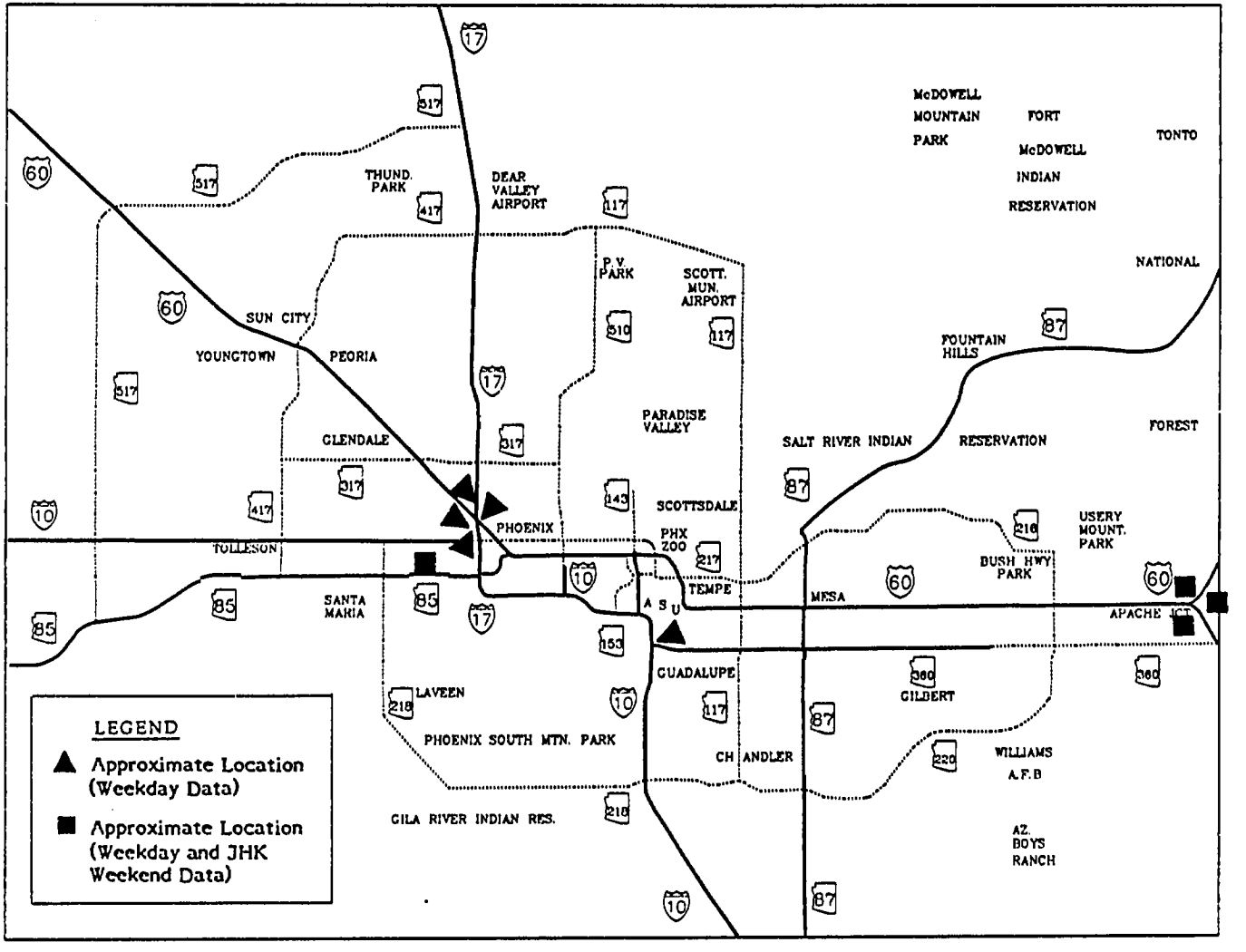


FIGURE 4-2. ADOT VEHICLE CLASSIFICATION DATA COLLECTION SITES IN PHOENIX

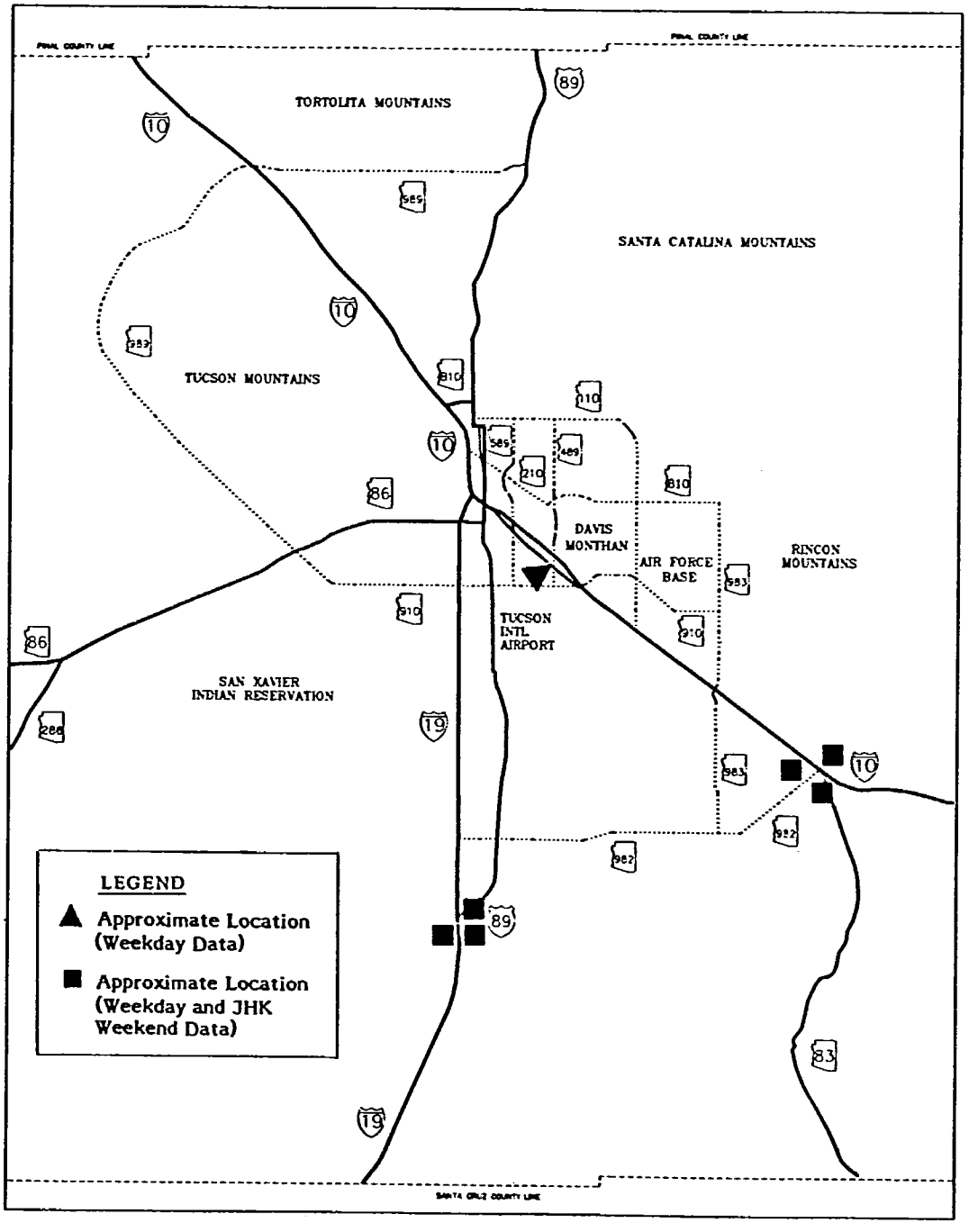


FIGURE 4-3. ADOT VEHICLE CLASSIFICATION DATA COLLECTION SITES IN TUCSON

TABLE 4-1. NUMBER OF ADOT VEHICLE CLASSIFICATION SITES, AND MILES OF ROADWAY BY ROADWAY FUNCTIONAL CLASSIFICATION

	Rural Highways		Urban Highways	
Functional Class	Number of Sites	Miles(a)	Number of Sites	Miles(a)
Principal Arterial--Interstate	28	1,021	3	129
Principal Arterial--Other	27	1,078	3	371
Minor Arterial	39	2,253	1	963
Major Collector	20	4,071	NA	NA
Minor Collector	2	3,825	NA	NA
Collector	NA	NA	2	924
Local	0	55,065	0	6,437
Total	116	67,313	9	8,824

NA = Not Applicable
(a) Source: FHWA (1985).

sites were used in an analysis of vehicle class distributions by road class. The study sample included 103 sites (93.6 percent) on rural roads and seven sites on urban roadways. The number of sites in the study sample, and the number of sampling periods is shown in Table 4-2 for each roadway functional class. For the rural roadways, 101 (98 percent) of the sites are located on the four most highly sampled functional classifications (principal arterial-interstate, principal arterial-other, minor arterial, and major collector) and were estimated to account for 81 percent of the rural VMT. The distribution of sites and the number of samples taken on each of these four rural classifications was sufficient for statistical analysis. The number of sites and samples on the remaining three rural functional classes and on all of the urban functional classes was considered inadequate to represent these for statistical analysis. The data collection and analysis performed by JHK to establish vehicle classification estimates for urban roadways is discussed later in this report.

Each of the ADOT sites was sampled between 10 and 14 times during the study period. The sample periods were three consecutive hours beginning between 7:00 a.m. and 2:00 p.m. A cursory review of the sample indicated that all the

TABLE 4-2. NUMBER OF STUDY VEHICLE CLASSIFICATION SAMPLE SITES AND SAMPLE PERIODS BY ROADWAY FUNCTIONAL CLASSIFICATION

Functional Classification	Rural Highways		Urban Highways	
	Number of Sites	Number of Samples	Number of Sites	Number of Samples
Principal Arterial-Interstate	25	294	2	24
Principal Arterial-Other	26	317	2	23
Minor Arterial	33	395	1	13
Major Collector	17	205	NA	NA
Minor Collector	2	24	NA	NA
Collector	NA	NA	2	26
Local	0	0	0	0
TOTAL	103	1,235	7	86

NA = Not Applicable

samples were obtained on weekdays. This could bias an analysis of vehicle classification if Saturdays and Sundays exhibited a significantly different vehicle mix. Therefore, a data collection and analysis effort was carried out to establish estimates of vehicle mix on rural and urban highways for weekend travel. These details are discussed later in this report.

A previous study for ADOT (Matthias and Dean (1984)) indicated that the hourly variation of vehicle class was minor and concluded that the percent of vehicles by class could be considered constant throughout the day on rural highways. Therefore, the sampling period and the rate of sampling for this study are considered more than adequate to base conclusions regarding vehicle class characteristics. The previous study did not evaluate the potential shift in vehicle mix by day of week.

The current ADOT program for sampling statewide vehicle classification data was adequate as a source of vehicle classification information for the following rural roadway classifications:

- o Principal arterial--interstate
- o Principal arterial--other

- o Minor arterial
- o Major collector

Since these classifications were estimated to contain over 80 percent of the rural VMT, current ADOT data provided an adequate database for analyzing and aggregating vehicle classes by rural roadway class.

ADOT vehicle classification data were insufficient for performing similar analyses on urban road classes and on weekends, and limited supplemental data was collected and analyzed as a part of this study. The current ADOT vehicle classification program should be altered to include a representative sample of vehicle classification data on urban road classes, and to monitor vehicle classification on weekends for application in this modeling procedure.

VEHICLE CLASS DESIGNATIONS

The objective of the analysis was to determine if selected classes of vehicles could be combined to reduce the number of vehicle classes in the VMT algorithm. Statistical analyses were performed on the ADOT vehicle classification database described in the previous section.

The vehicle classifications that were analyzed included the eight classes currently used in ADOT vehicle classification studies (refer to the list of vehicle types in the previous section). The criteria used to establish the vehicle types for use in the VMT algorithm were:

- o Physical characteristics must allow for the visual discrimination of vehicle types.
- o Vehicle type designations should conform to the existing classification scheme to allow the use of existing data and existing data collection procedures, if feasible.
- o Vehicle classes should represent significant portions of the vehicle population.
- o There should be significantly different fuel consumption characteristics between vehicle classes.
- o Vehicle classes should attempt to minimize the variance of fuel consumption characteristics within a particular vehicle class.

The analysis resulted in the aggregation of the following four classes of vehicles.

o Automobiles including: passenger cars, station wagons, vans with rear windows and motorcycles.

o Light trucks including: pickup trucks, pickups with shells or campers, panel trucks, and vans without rear windows.

o Medium trucks including: camper recreational vehicles, mobile homes, school and transit buses, and single unit trucks with two axle dual tires or three axles.

o Heavy trucks including: tractor-semi trailer with three, four or five axles, truck and trailer with four, five, or six axles, and trains with five or six axles.

The following comments are provided as justification for aggregation of the above vehicle classes.

o The automobile classification exhibits the largest within group variation in vehicle mpg. This is due to the large variation in vehicle mpg for passenger cars of different types, and due to the combining of vans with rear windows and motorcycles into the "automobile" classification. Vans with rear windows exhibit vehicle and mpg characteristics that are similar to those of light trucks and therefore should logically be grouped into the light truck classification. However, the existing ADOT vehicle classification scheme is based on the travel function (or purpose of vehicle utilization) and physical characteristics of the vehicle. Hence, vans with rear windows, which are typically used for carrying passengers, are grouped with other passenger vehicles. The proportion of vans within the automobile group was unknown, and could not be disaggregated from the ADOT data. The proportion of motorcycles within the ADOT data was also unknown. However, a previous ADOT study (Matthias and Dean (1984)) indicated that motorcycles accounted for a maximum of 1.5 percent and a minimum of 0.6 percent of the vehicles on rural roads, with a mean value of 1.1 percent. Thus, the influence of motorcycle mpg characteristics is not significant within the automobile classification on rural roads. Furthermore, the bias produced by motorcycles may be offset somewhat by the inclusion of the vans with rear windows in this group.

o Pickup trucks with campers are grouped with camper recreational vehicles in the ADOT classification schedule. ADOT procedures require data collectors to count pickups with campers in the classification with other pickups and vans without rear windows. Hence, the designation of this vehicle type in the light truck category. The light trucks satisfy all of the criteria for designation as a separate vehicle classification.

o Camper recreational vehicles and motor homes are, in general, single unit trucks with modified bodies. These vehicles generally have the weight and operating characteristics of single unit trucks as well. Therefore, it was logical to aggregate this vehicle type into the medium truck classification. This same reasoning was applied to the grouping of transit and school buses into the medium truck classification.

o A review of the available fuel consumption characteristics (see discussion of mpg values) indicated that above a weight of approximately 19,000 pounds, large trucks exhibit very similar mpg characteristics regardless of the other physical differences in the vehicles. Therefore, tractor-semi trailers, truck and trailers, and truck trains may be aggregated into a "heavy truck" classification.

RURAL ROADWAY VEHICLE CLASSIFICATION (WEEKDAYS)

The analysis of vehicle distributions concentrated on the four rural functional classifications for which there were sufficient data. These were:

- o Principal Arterial--Interstate
- o Principal Arterial--Other
- o Minor Arterial
- o Major Collector

There were 101 sample sites in the ADOT data for these functional classes. Statistical analyses were conducted to test for differences in vehicle mix between roadway functional classifications. Were statistical significance is indicated it was based on the Chi-Square Analysis of Variance at a 95th percentile level of confidence or greater, unless stated otherwise.

The objective of the analysis was to evaluate the distribution of vehicles by functional class to determine if sufficient variation existed betweeen classes to

prohibit grouping. The primary criteria for decision making in this analysis was the practical significance in the variation of the weighted mpg value generated for each functional classification. The statistical variation in the distribution of vehicle class by roadway class was also used as a guide.

The number of vehicles counted by vehicle class and roadway class is shown in Table 4-3. In general, such large sample sizes will result in high levels of statistical significance in the differences of vehicle type distribution even when these differences are minor.

The percent of vehicles by type for each roadway functional class is shown in Table 4-4. A statistically significant variation of vehicle mix was found to exist across all functional classes. Most significant was the obvious difference in vehicle mix between the interstate road class and the other rural classes. The distinctly lower percent of light trucks and higher percent of heavy trucks on the interstates was indicative of a unique roadway functional class. The vehicle type weighted mpg value for rural interstates, shown in Table 4-4, was also judged to be sufficiently different (7.8 percent) than the other rural highway classes to warrant maintaining this as a separate functional class.

The variation in vehicle mix by functional class was statistically significant for the three non-interstate classifications. However, the practical variation in the weighted mpg values was considered insufficient to prohibit aggregating these three functional classes. The difference in the weighted mpg between principal arterial, and major collectors was the largest at 0.5 mpg (2.6 percent). The maximum difference was only 0.3 mpg (1.6 percent) between the aggregate non-interstate classification and major collectors.

The vehicle distribution on rural interstates was very stable over the six year study period with very small fluctuations about the mean in the percent vehicles by vehicle type (See Figure 4-4). Vehicle distributions on rural non-interstates showed a similar time stability (See Figure 4-5). Adjustments in vehicle distribution for time series trends was not warranted.

The vehicle distribution by month of year by roadway functional classification was significantly different. The percent of all vehicle classes were shown to fluctuate significantly by month with the exception of medium trucks. Aggregation

TABLE 4-3. NUMBER OF VEHICLES (WEEKDAYS) BY VEHICLE CLASS AND RURAL FUNCTIONAL CLASS FROM 101 ADOT SITES

Rural Road Classification	Vehicle Class				
	Auto	Light Truck	Medium Truck	Heavy Truck	Total
Principal Arterial-Interstate	248,123	73,713	37,650	70,610	430,096
Principal Arterial-Other	163,556	87,723	22,904	13,611	287,794
Minor Arterial	135,515	80,177	19,995	5,652	241,339
Major Collector	97,631	52,469	9,698	4,767	164,565
TOTAL	644,825	294,082	90,247	94,640	1,123,794

TABLE 4-4. PERCENT OF VEHICLES (WEEKDAYS) BY VEHICLE CLASS AND RURAL FUNCTIONAL CLASS FROM 101 ADOT SITES

Rural Road Classification	Vehicle Class				
	Auto	Light Truck	Medium Truck	Heavy Truck	Weighted* MPG
Principal Arterial-Interstate	57.7	17.1	8.8	16.4	17.8
Principal Arterial-Other	56.8	30.5	8.0	4.7	19.0
Minor Arterial	56.2	33.2	8.3	2.3	19.2
Major Collector	59.3	31.9	5.9	2.9	19.5
Aggregated Non-Interstate	57.2	31.7	7.6	3.5	19.2

*Based on mpg values Auto (23.2), Light Truck (16.0), Medium Truck (9.0), Heavy Truck (5.1). See sections on Auto and Truck mpg values.

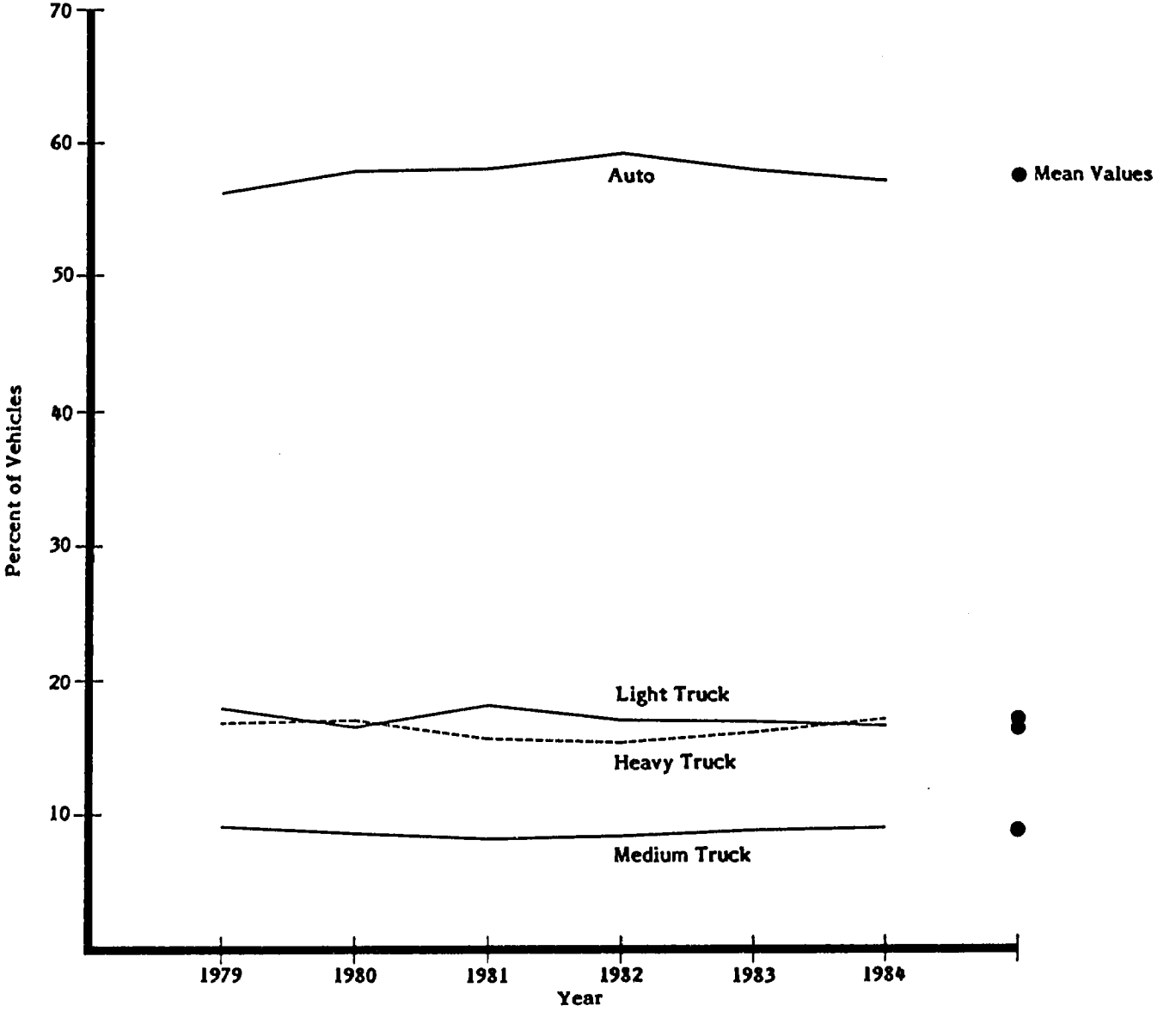


FIGURE 4-4. PERCENT OF VEHICLES BY YEAR FOR RURAL INTERSTATES

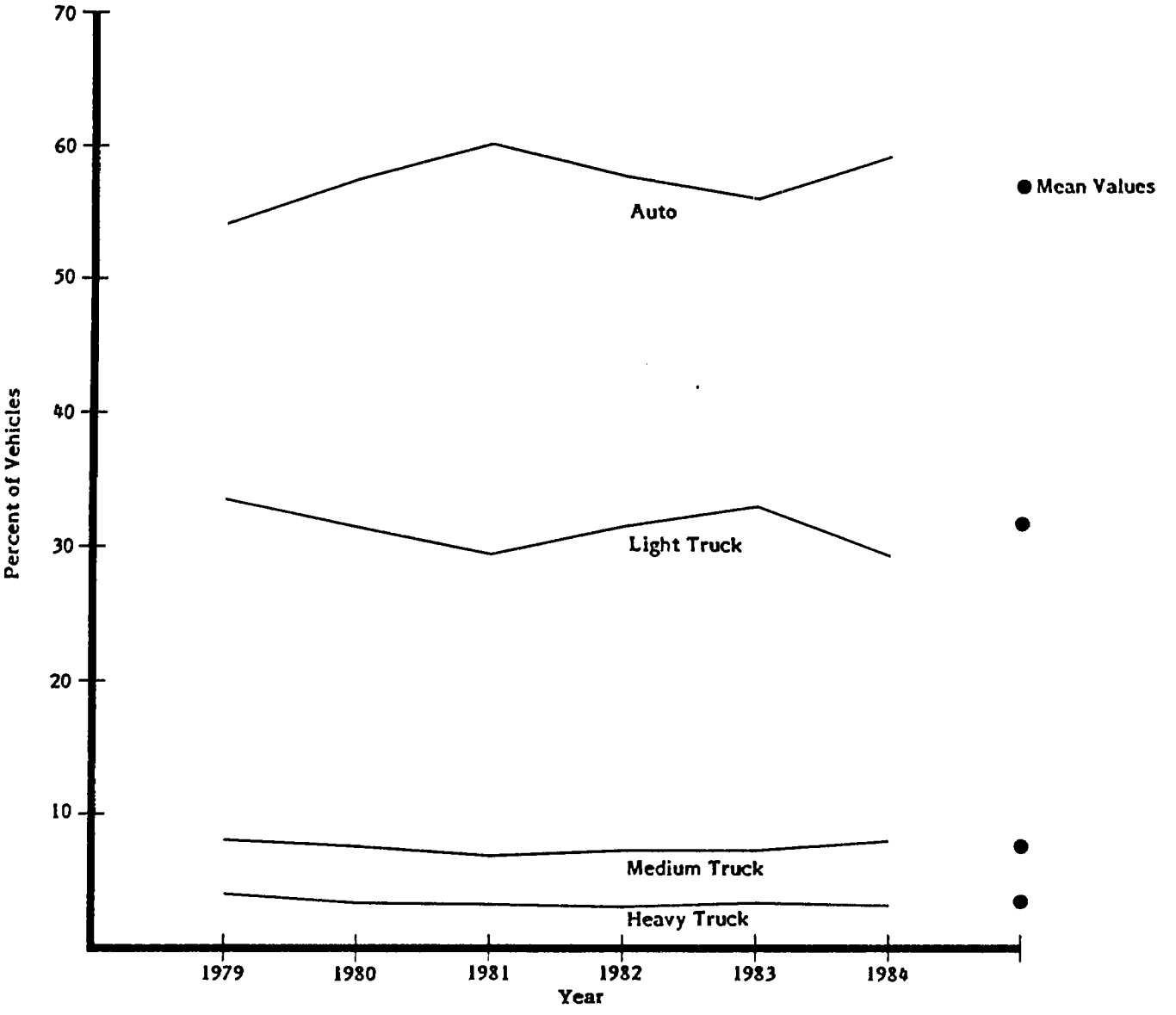


FIGURE 4-5. PERCENT OF VEHICLES BY YEAR FOR RURAL NON-INTERSTATES

of the data into the "rural interstate" and "rural non-interstate" classes verifies this finding (See Figures 4-6 and 4-7). The distribution of vehicle mix suggests seasonal variations in these characteristics.

The evaluation of the regional variation in vehicle mix was performed to determine if the application of a statewide mpg value for a defined roadway class was appropriate or if significant regional differences in vehicle class existed to result in region-specific mpg values. Regional boundaries used were identical to those used in a previous ADOT study (Matthias and Dean (1984)) as shown in Figure 4-8. The vehicle mix characteristics by region are given in Tables 4-5 and 4-6 for rural interstates and rural non-interstates, respectively.

Vehicle mix differences on rural roadways by region within the State were found to be statistically significant. However, practical significance regarding the weighted mpg value was not achieved as shown in Tables 4-5 and 4-6.

Statistically significant differences in vehicle mix were observed by region and season of year for the aggregation of rural interstates and rural non-interstate classifications. These differences, however, were not significant for fuel efficiency calculations. These characteristics are displayed in Tables 4-7 and 4-8. Seasonal designations were as follows:

Winter:	December, January, February
Spring:	March, April, May
Summer:	June, July, August
Fall:	September, October, November

Based on these findings, vehicle mix sampling should take into account the seasonal and regional variation within the state. However, the effect of these differences on the annual weighted mpg value was not considered significant.

Conclusions from this analysis regarding the VMT model were:

o The number of rural roadway functional classifications could be reduced to two -- interstate and non-interstate.

o The stability in the annual vehicle mix percentage allowed direct application of historical results without time series adjustment.

o Regional differences in vehicle mix had a negligable effect on the weighted mpg indicating the appropriate use of statewide averages by roadway functional class.

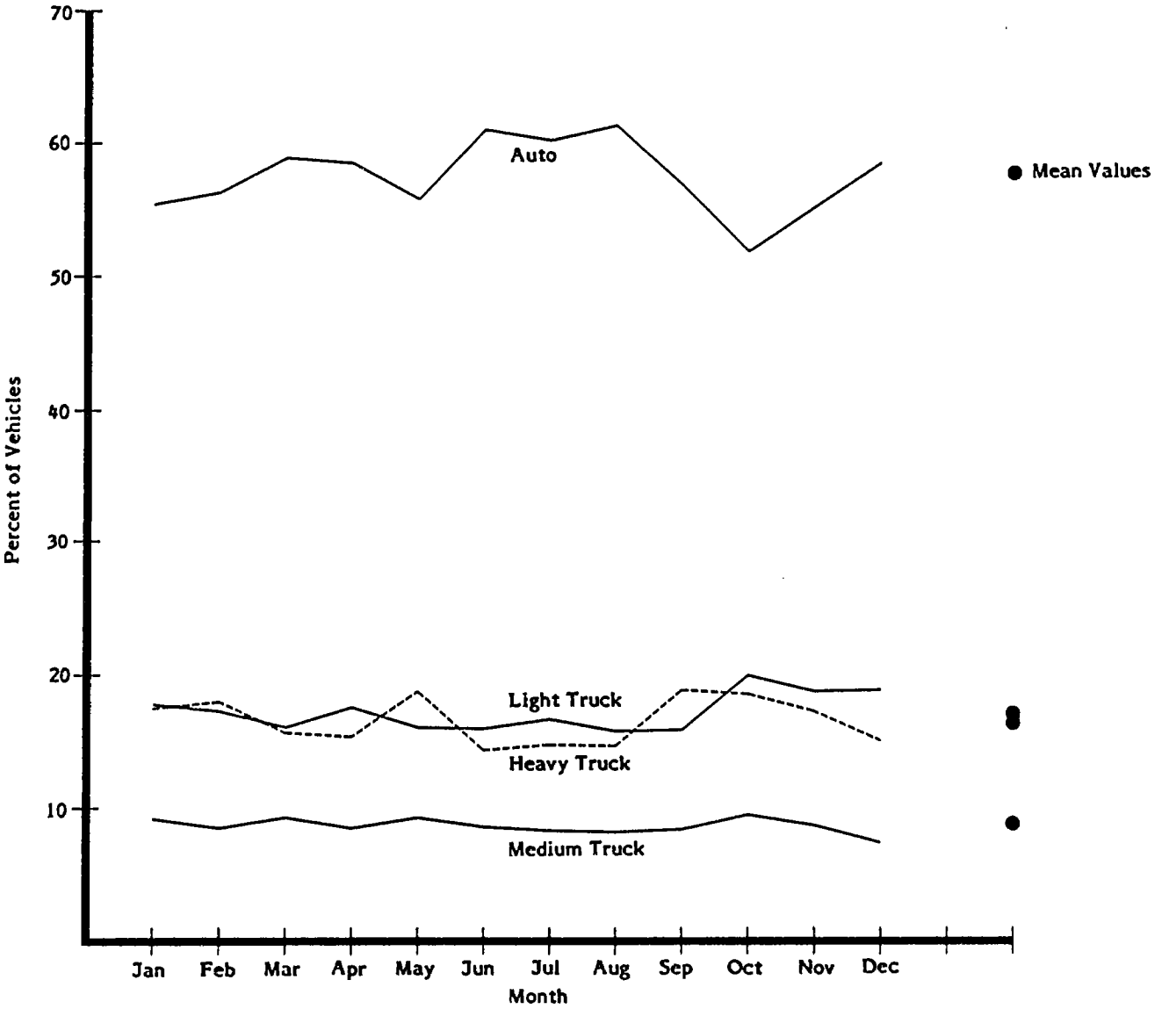


FIGURE 4-6. PERCENT OF VEHICLES BY MONTH FOR RURAL INTERSTATES

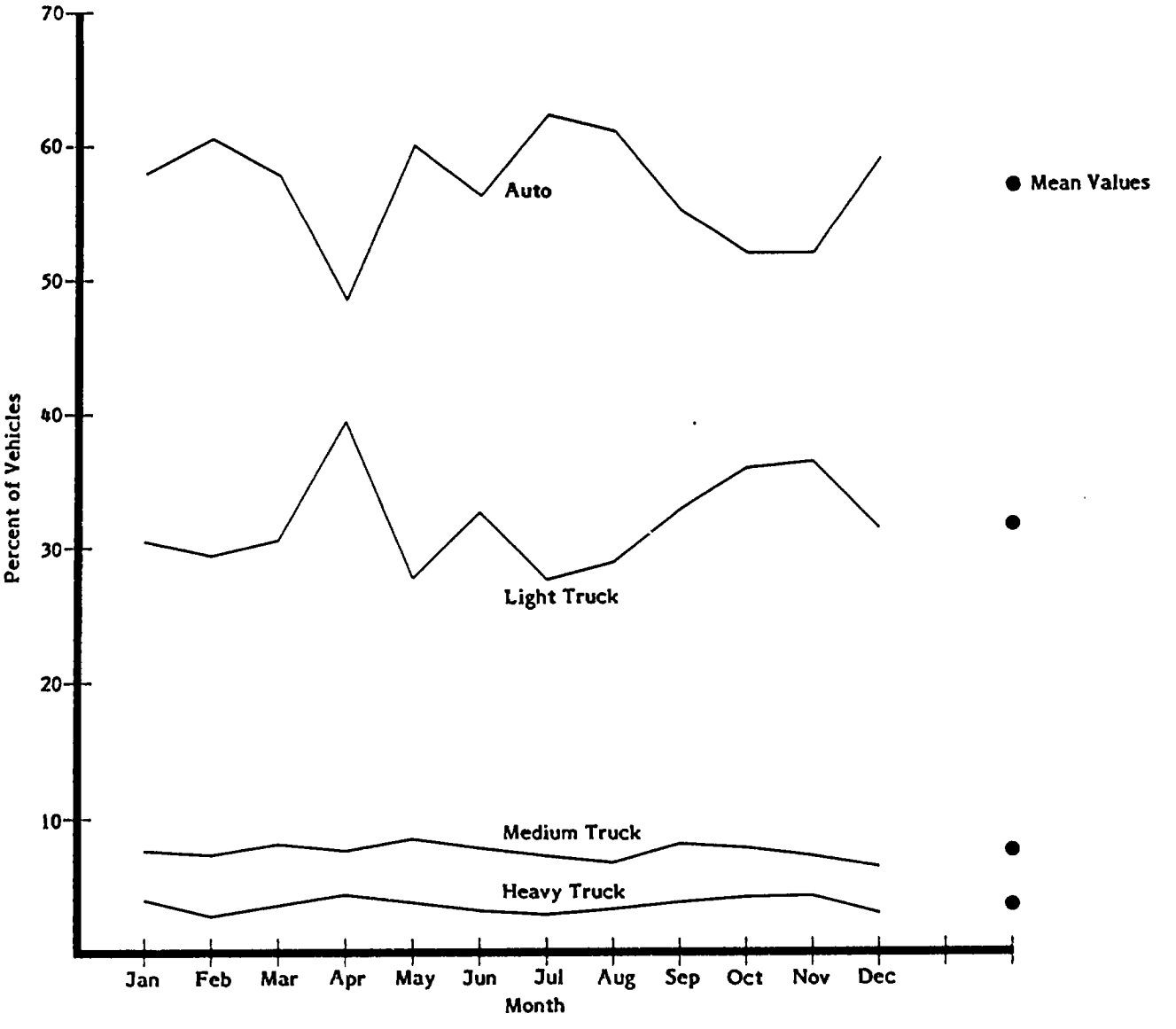


FIGURE 4-7. PERCENT OF VEHICLES BY MONTH FOR RURAL NON-INTERSTATES

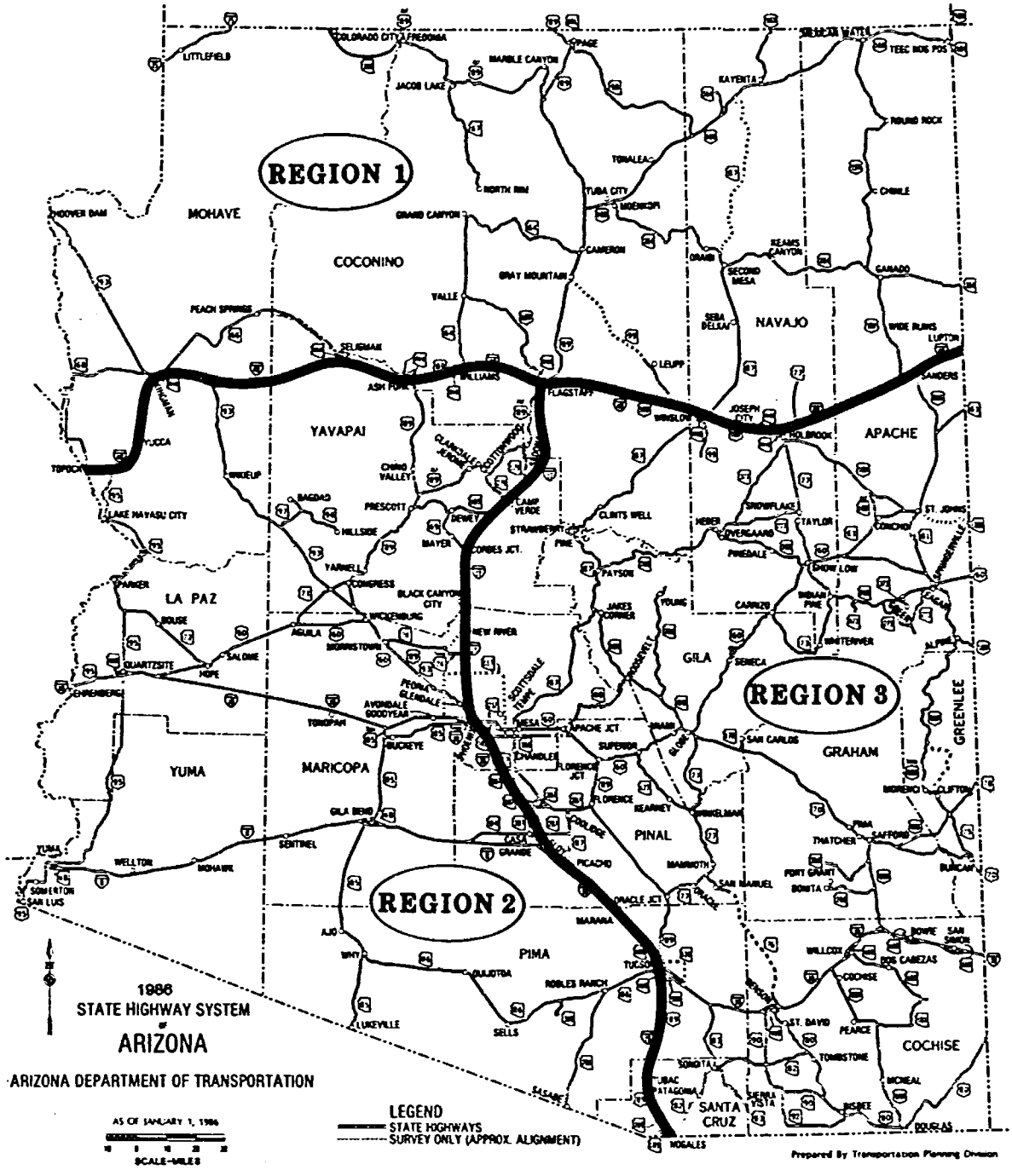


FIGURE 4-8. REGIONAL BOUNDARIES FOR VEHICLE MIX EVALUATION
SOURCE: MATTHAIS AND DEAN (1984)

TABLE 4-5. VEHICLE MIX (%) BY REGION FOR INTERSTATE HIGHWAYS (WEEKDAYS)

Region	Auto	Light Truck	Medium Truck	Heavy Truck	Weighted MPG
1	56.5	14.9	9.4	19.2	17.3
2	56.4	18.8	9.5	15.4	17.7
3	58.8	17.3	8.1	15.7	17.9
State Average	57.7	17.1	8.8	16.4	17.8

TABLE 4-6. VEHICLE MIX (%) BY REGION FOR NON-INTERSTATE HIGHWAYS (WEEKDAYS)

Region	Functional Class	Auto	Light Truck	Medium Truck	Heavy Truck	Weighted MPG
1	Principal Arterial-Other	54.9	31.6	8.5	4.9	18.8
	Minor Arterial	53.7	35.1	8.5	2.6	19.0
	Major Collector	62.9	29.1	5.8	2.2	19.9
	Region Average	56.0	32.4	8.0	3.6	19.1
2	Principal Arterial-Other	58.6	24.0	8.7	8.7	18.7
	Minor Arterial	59.1	30.3	8.4	2.2	19.4
	Major Collector	56.8	34.6	5.8	2.7	19.4
	Region Average	58.4	30.5	7.8	3,4	19.3
3	Principal Arterial-Other	58.0	31.0	7.3	3.6	19.3
	Minor Arterial	51.9	38.8	7.1	2.2	19.0
	Major Collector	58.8	31.5	6.0	3.6	19.4
	Region Average	57.4	32.3	7.0	3.4	19.3
	State Average	57.2	31.7	7.6	3.5	19.2

TABLE 4-7. VEHICLE MIX (%) BY REGION AND SEASON FOR INTERSTATE ROADWAYS (WEEKDAYS)

Region	Season	Auto	Light Truck	Medium Truck	Heavy Truck
1	Winter	54.3	15.1	7.8	22.8
	Spring	54.2	15.1	9.9	20.7
	Summer	60.0	14.4	9.4	16.2
	Fall	53.8	15.8	9.5	21.0
	Average	56.5	14.9	9.4	19.2
2	Winter	54.3	19.5	10.2	16.0
	Spring	56.1	19.7	10.1	14.1
	Summer	62.1	16.1	8.2	13.6
	Fall	53.5	19.9	9.3	17.2
	Average	56.4	18.8	9.5	15.4
3	Winter	57.2	17.3	8.3	17.2
	Spring	61.3	16.3	8.3	14.2
	Summer	60.8	17.7	7.5	13.9
	Fall	56.1	18.2	8.3	17.4
	Average	58.8	17.3	8.1	15.7

TABLE 4-8. VEHICLE MIX (%) BY REGION AND SEASON FOR NON-INTERSTATE ROADWAYS (WEEKDAYS)

Region	Season	Auto	Light Truck	Medium Truck	Heavy Truck
1	Winter	58.9	31.0	6.8	3.3
	Spring	54.6	33.1	8.4	4.0
	Summer	59.9	29.0	8.0	3.1
	Fall	50.0	37.8	8.2	4.0
	Average	56.0	32.4	8.0	3.6
2	Winter	57.7	30.6	8.4	3.3
	Spring	58.0	30.5	7.9	3.5
	Summer	60.6	29.7	6.8	2.9
	Fall	57.3	31.1	7.9	3.8
	Average	58.4	30.5	7.8	3.4
3	Winter	60.7	29.3	6.7	3.2
	Spring	55.7	33.3	7.4	3.6
	Summer	58.0	32.1	6.9	3.0
	Fall	52.4	36.3	7.0	4.2
	Average	57.4	32.3	7.0	3.4

o Monthly and seasonal fluctuations in vehicles mix were significant, indicating that seasonal adjustments are required of spot samples to reflect annual values.

o The recommended vehicle class distributions for interstates and non-interstates for weekdays are shown in Table 4-4.

URBAN ROADWAY VEHICLE CLASSIFICATION (WEEKDAYS)

The objective of this analysis was to determine the relationship between vehicle mix and urban roadway functional class for use in the VMT model. The data collection effort and analysis were necessitated because existing ADOT data files lacked urban vehicle mix information, and because urban travel makes up a substantial portion of state VMT.

Vehicle classification data were collected in the Phoenix and Tucson areas at 50 locations during March, 1987. The data collection sites are shown in Figures 4-9 and 4-10. The distribution of data collection sites by roadway functional class is given in Table 4-9. The precise location and roadway functional class for individual sites is given in Appendix C. The data were collected on weekdays during a single three-hour period between 7:00 a.m. and 3:00 p.m. The vehicle classifications used in the study were identical to those currently used by ADOT. Vehicle classification data were aggregated according to the results of the data analyses performed on the rural vehicle classification data (i.e., automobiles, light trucks, medium trucks, and heavy trucks).

The urban data were supplemented with limited ADOT data collected during the period 1979 through 1984 on urban interstate roadways. The ADOT data represented two sites in the Phoenix area. It was decided to include these data to increase the sample size of the database and account for possible seasonal fluctuations in the vehicle mix. The results of the data collection effort are shown in Table 4-10.

Analysis of variance procedures were performed to identify differences in the distribution of vehicle classification data by urban roadway class. A statistically significant difference was observed between vehicle class distributions for urban interstate and urban noninterstate classes. Table 4-11 indicates that a much higher

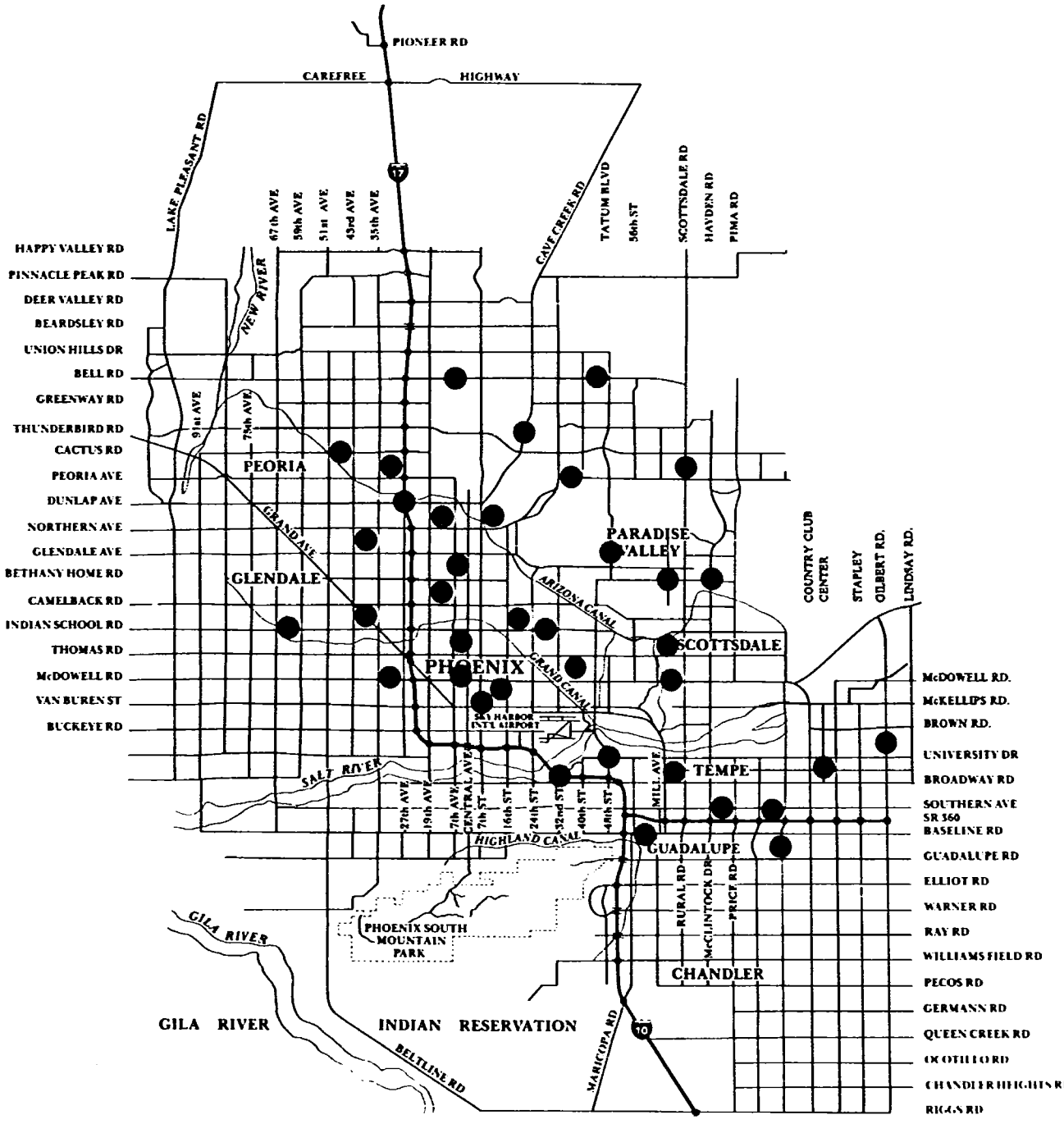


FIGURE 4-9. URBAN VEHICLE CLASSIFICATION DATA COLLECTION SITES - PHOENIX

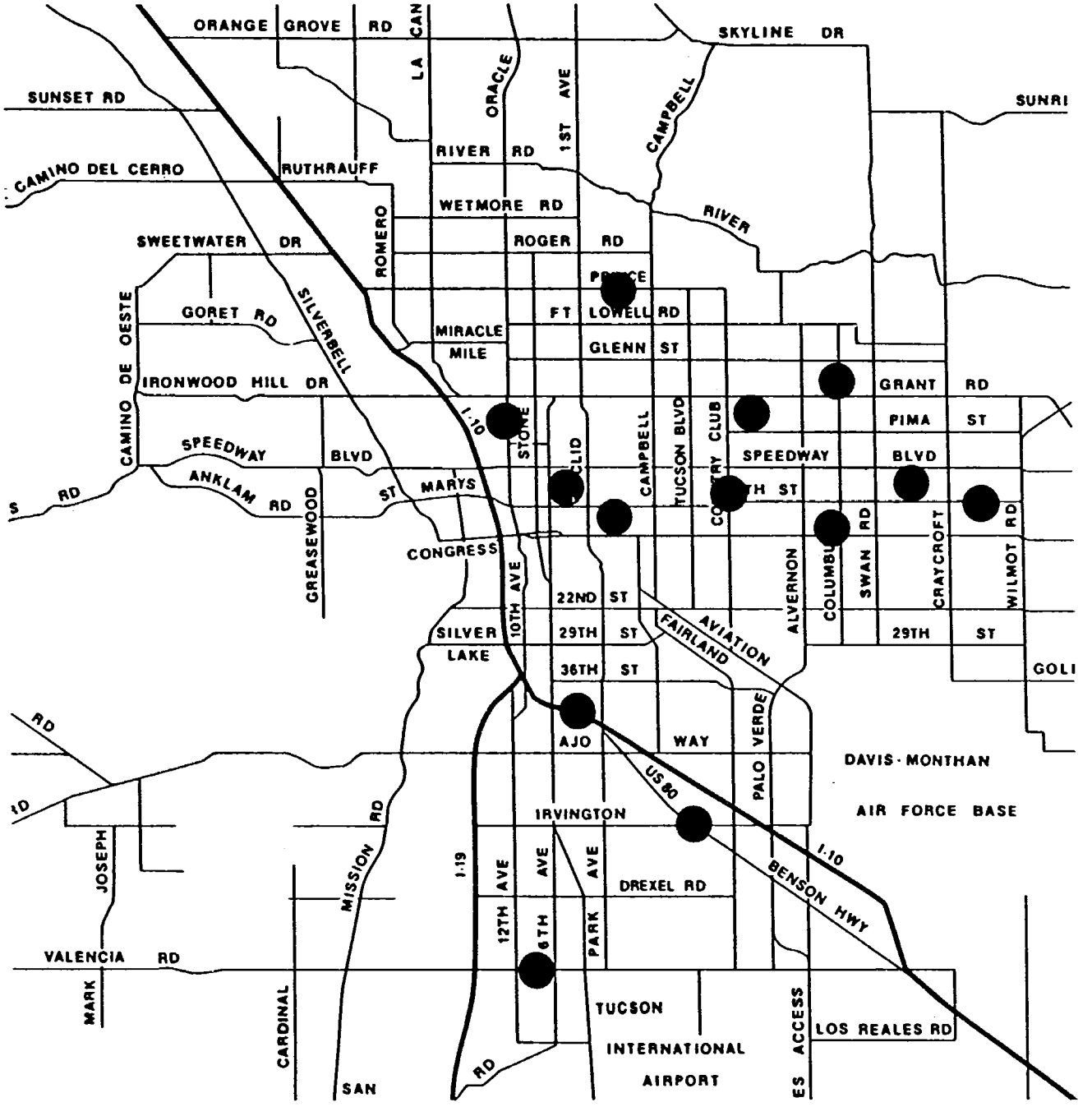


FIGURE 4-10. URBAN VEHICLE CLASSIFICATION DATA COLLECTION SITES - TUCSON

TABLE 4-9. DATA COLLECTION SITES BY URBAN ROADWAY FUNCTIONAL CLASS

Functional Class	Number of Sites
Principal Arterial -Interstate	3
Principal Arterial - Other	25
Minor Arterial	17
Collector	5
TOTAL	50

TABLE 4-10. NUMBER OF VEHICLES BY VEHICLE TYPE AND URBAN ROADWAY FUNCTIONAL CLASSIFICATION (WEEKDAYS)

	Vehicle Class				
Urban Roadway Classification	Auto	Light Truck	Medium Truck	Heavy Truck	Total
Interstate					
JHK Data	21,931	7,929	1,000	1,151	32,011
ADOT Data	248,493	98,583	28,284	17,131	392,491
Total	270,424	106,512	29,284	18,282	424,502
Non-Interstate (JHK Data)					
Principal Arterial - Other	77,031	22,257	1,747	501	101,536
Minor Arterial	36,235	8,822	670	79	45,806
Collector	2,702	595	69	4	3,370
Aggregated Non-interstate	115,968	31,674	2,486	584	150,712

proportion of medium and heavy trucks and a much lower proportion of automobiles exist on the urban interstates as compared to the non-interstate highways. This finding was consistent with similar analyses performed for vehicle class distributions on rural roadways. The observed statistical differences between interstate and non-interstate highways was further substantiated when weighted mpg values were estimated for the two road classes. The weighted mpg for interstate highways was estimated at 19.6 miles per gallon, while non-interstate highways exhibited a weighted mpg of 17.6 (combined for all non-interstate highways).

TABLE 4-11. VEHICLE CLASS DISTRIBUTION IN PERCENT BY URBAN FUNCTIONAL CLASS AND WEIGHTED MPG

Urban Roadway Class	Vehicle Class				Weighted* MPG
	Autos	Light Trucks	Medium Trucks	Heavy Trucks	
Interstate:					
JHK Data	68.5	24.8	3.1	3.6	20.3
ADOT Data	63.3	25.1	7.2	4.4	19.7
Combined	63.7	25.1	6.9	4.3	19.6
Non-interstate:					
Principal Arterial	75.9	21.9	1.7	0.5	17.6
Minor Arterial	79.1	19.3	1.5	0.2	17.7
Collector	80.2	17.7	2.0	0.1	17.7
Aggregate Non-Interstate	76.9	21.0	1.6	0.4	17.6

*Based on mpg values Auto (23.2 interstate, 18.3 non-interstate), Light Truck (16.0), Medium Truck (9.0), and Heavy Truck (5.1). See sections on Auto and Truck mpg values.

Analyses were also performed to identify differences within the non-interstate highway classes. Statistical comparisons resulted in observed differences between the non-interstate road classes. However, Table 4-11 indicates that the statistical difference between these road classes did not translate into a meaningful difference in the weighted mpg value. This finding was consistent with the results for rural roadways. As a result, it was concluded that the urban non-interstate roadways would be aggregated into a single urban non-interstate class.

The recommended vehicle class distributions for urban interstate and non-interstate roadways are summarized in Table 4-12. Comparison of the estimated rural and urban highway mpg volumes in Tables 4-4 and 4-11 supports firmly the disaggregation of roadways into rural and urban classifications.

TABLE 4-12. RECOMMENDED VEHICLE CLASS DISTRIBUTION IN PERCENT ON URBAN ROADWAYS (WEEKDAYS)

	Vehicle Class			
Urban Roadway Class	Autos	Light Trucks	Medium Trucks	Heavy Trucks
Interstate	63.7	25.1	6.9	4.3
Non-interstate	76.9	21.0	1.6	0.4

MPG ESTIMATES

The objective of this analysis was to determine the most appropriate values of vehicle mpg by vehicle and fuel type. This analysis considered those factors that were known to significantly affect vehicle mpg, and developed weighted mpg values for autos and truck tailored to Arizona. These values represent statewide averages for both gasoline and diesel powered vehicles.

Procedures For Determining Automobile mpg

Automobile mpg estimates were based on U.S. Environmental Protection Agency (EPA) values that are generated annually for the national vehicle fleet. Estimates of automobile mpg are developed by EPA for both city and highway driving based on EPA tests of individual vehicles. Mpg values are weigthed by national fleet sales data to obtain the the EPA fleet estimates shown in Figure 4-11. These mpg values provide the basis for most, if not all, mpg estimates that appear in the literature. The values for city and highway mpg used in the VMT model and given in Appendix D, Table D-1.

Research indicates that the laboratory mpg values are significantly different than those achieved under actual driving conditions (Crawford and Kaufman (1983) Hellman and Murrell (1984)). In addition, it has been observed that mpg values, are

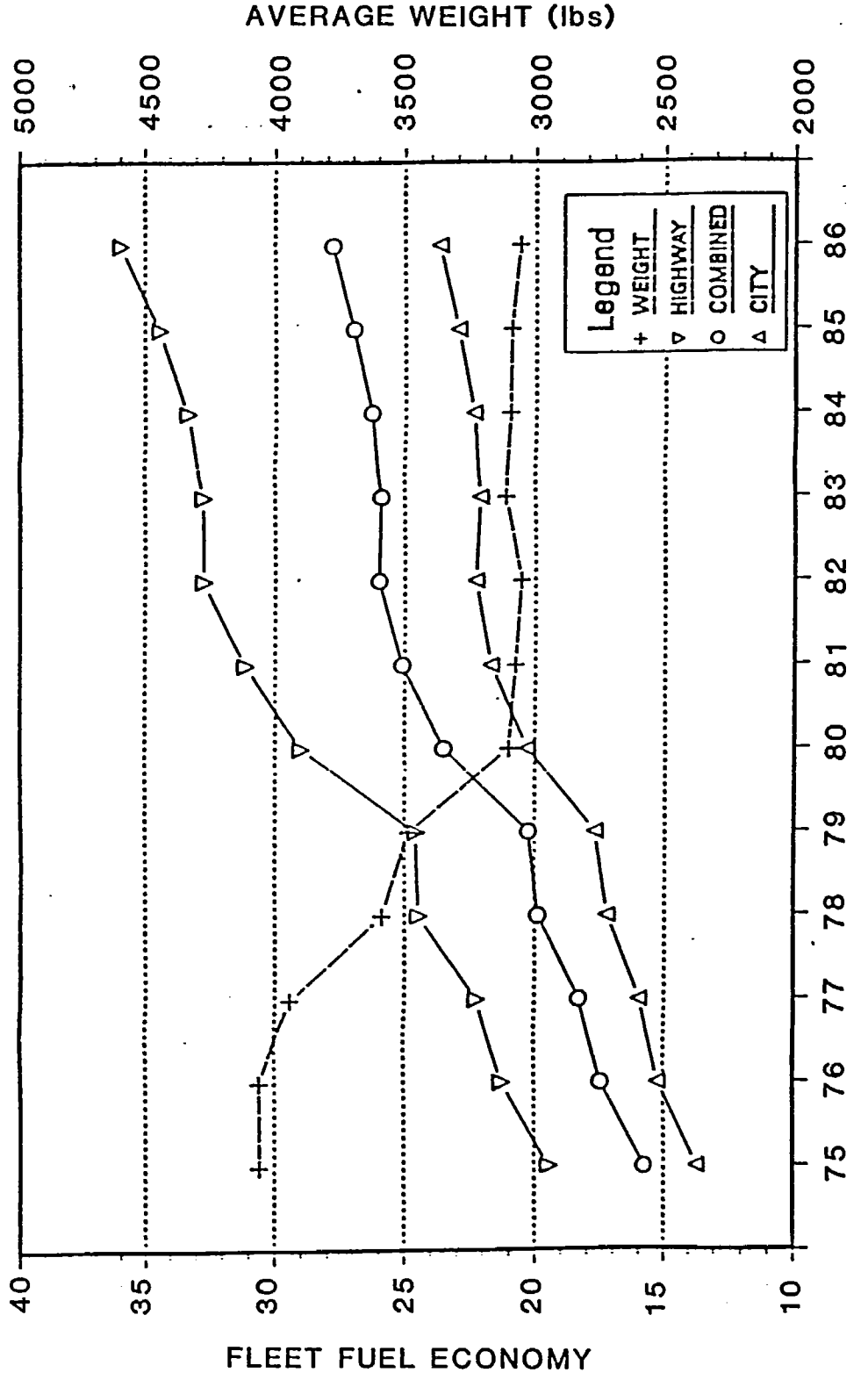


FIGURE 4-11. FLEET MPG BY MODEL YEAR
SOURCE: HEAVENRICH, et. al (1986)

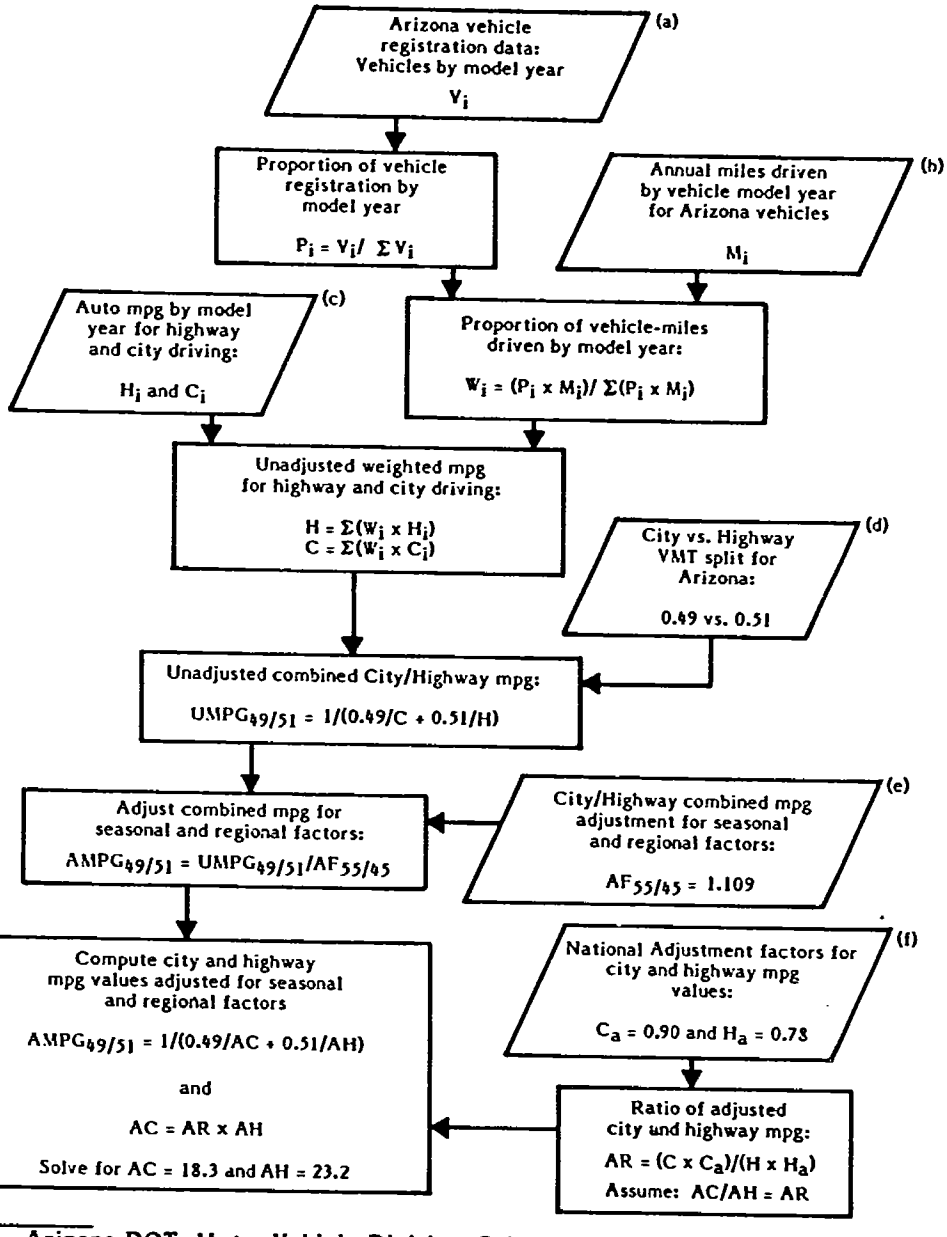
dependent on several factors including the following identified by Hellman and Murrell (1982):

- o Travel Environment (e.g. temperature, altitude, wind velocity, road gradient, road surface, and road curvature).
- o Travel Characteristics (e.g. trip length, average speed, cold starts, and acceleration).
- o Vehicle Condition (e.g. brake drag, wheel alignment, type of tire, tire pressure, weight load, engine tuning, and vehicle power accessories).
- o Simulation Variance (e.g. dynamometer load, tire effects, weight classification, and type of transmission).

Considerable research has been conducted to develop adjustment factors which bring fleet estimates into agreement with actual on-road mpg values. For example, Hellman and Murrell (1984) developed adjustment factors for city and highway mpg from a data base of 19,000 driver-reported mpg values. The adjustment factors developed in this study were 0.90 for EPA city estimates and 0.78 for EPA highway estimates.

Crawford and Kaufman (1983) developed adjustment factors to account for seasonal and regional impacts on mpg. The factors developed in this study were based on input from approximately 4,000 families regarding fuel purchases over a ten-month period during 1981. The study concluded that the U.S. could be divided into three broad zones relative to the EPA model year estimates. A review of these indicated that the most heavily populated areas of Arizona (including Phoenix, Tucson, and Yuma) fall into a single region. This region was observed to have an average adjustment factor of 1.109 for the combined city/highway EPA estimate. The adjusted mpg estimate using this factor is determined as the ratio of the EPA estimate to the adjustment factor.

The procedure used to estimate automobile mpg for use in the selected VMT model is shown in Figure 4-12. Arizona vehicle registration data (see Table D-2) were used to estimate the proportion of vehicles by model year in the Arizona fleet. These data were supplemented with information on the annual vehicle-miles of travel by model year of vehicle. The distribution of annual vehicle-miles as a function of model year was taken from a study performed by Energy and



Sources:
(a) Arizona DOT, Motor Vehicle Division, July 1986.
(b) Energy and Environmental Analysis, Inc., 1985.
(c) Heavenrich et. al., 1984 and 1986.
(d) FHWA, Highway Statistics -- 1984.
(e) Crawford and Kaufman, 1983.
(f) Hellman and Murrell, 1984.

FIGURE 4-12. AUTOMOBILE CITY AND HIGHWAY MPG CALCULATION PROCEDURE

Environmental Analysis, Inc. (EEA) (1985) for EPA. This study utilized a data base consisting of odometer readings collected within the state of Arizona as part of the vehicle emissions test program and vehicle registration process. Odometer readings were analyzed over a three-year period and the resulting mileage rates by model year are shown in Table 4-13. This study indicated a consistent decrease in mileage accumulation with the age of the vehicle. This finding was consistent with similar analyses conducted for Seattle, Washington, and in Connecticut.

TABLE 4-13. ARIZONA 1981-84 LIGHT DUTY VEHICLES
MILEAGE ACCUMULATION RATES (M.A.R) (IN THOUSANDS OF MILES PER YEAR)

		Period					
		1981-82		1982-83		1983-84	
Model Year	Sample Size	Age	M.A.R.	Age	M.A.R.	Age	M.A.R.
83							
82	35827					1	12.616
81	26859			1	12.127	2	11.413
80	11173	1	11.830	2	11.017	3	10.738
79	16348	2	11.031	3	10.389	4	10.274
78	16558	3	10.342	4	9.724	5	9.666
77	14617	4	9.731	5	8.974	6	9.156
76	11487	5	9.116	6	8.330	7	8.746
75	6958	6	8.621	7	7.815	8	8.345
74	7699	7	8.020	8	7.348	9	8.102
73	7444	8	7.446	9	6.921	10	7.621
72	5580	9	7.351	10	6.688	11	7.620
71	3006	10	7.212	11	6.502	12	7.428

Source: Energy and Environmental Analysis, Inc. (1985)

The EPA model year estimates of mpg were weighted by the proportion of annual vehicle-miles accumulated by vehicles of a given model year. Mileage accumulation rates for the period 1983 through 1984 (see Table 4-13) were used to

reflect the most recent available data. Both ends of the distribution were extrapolated slightly to cover the same range of model years represented by the vehicle registration and EPA mpg data (i.e. Pre-1968 through 1986). The mileage accumulation rates used in the model are given in Table D-3. The model year proportions were totaled to represent the unadjusted annual city and highway mpg values for automobiles in Arizona. These values were then used to calculate a combined city/highway mpg using a city/highway VMT ratio of 49 percent/51 percent in Arizona. This ratio was obtained from the Highway Statistics-1984 publication distributed by FHWA. This adjustment produced only a minor change to the EPA estimate for combined city/highway mpg values.

Futher adjustments were made for seasonal and regional factors. These factors were taken from the study conducted by Crawford and Kaufman (1983).

Finally, the resulting city/highway mpg estimate for Arizona was disaggregated into separate estimates for city and highway using the results of the research conducted by Hellman and Murrell (1984). This was accomplished by applying the ratio of EPA estimates for city and highway mpg to the Arizona combined city/highway estimate to obtain separate estimates for Arizona.

The reasons for calculating separate mpg estimates for city and highway travel in Arizona were (1) automobile traffic dominates the vehicle distribution for both urban (city) and rural (highway) travel and, therefore, dominates the weighted mpg estimate for each road class and (2) the proportion of automobiles in the traffic stream varies significantly for urban and rural highways and applying separate mpg estimates for urban (city) and rural (highway) travel would generate the most accurate estimate of the overall weighted mpg value.

Procedure For Determining Truck mpg Estimates

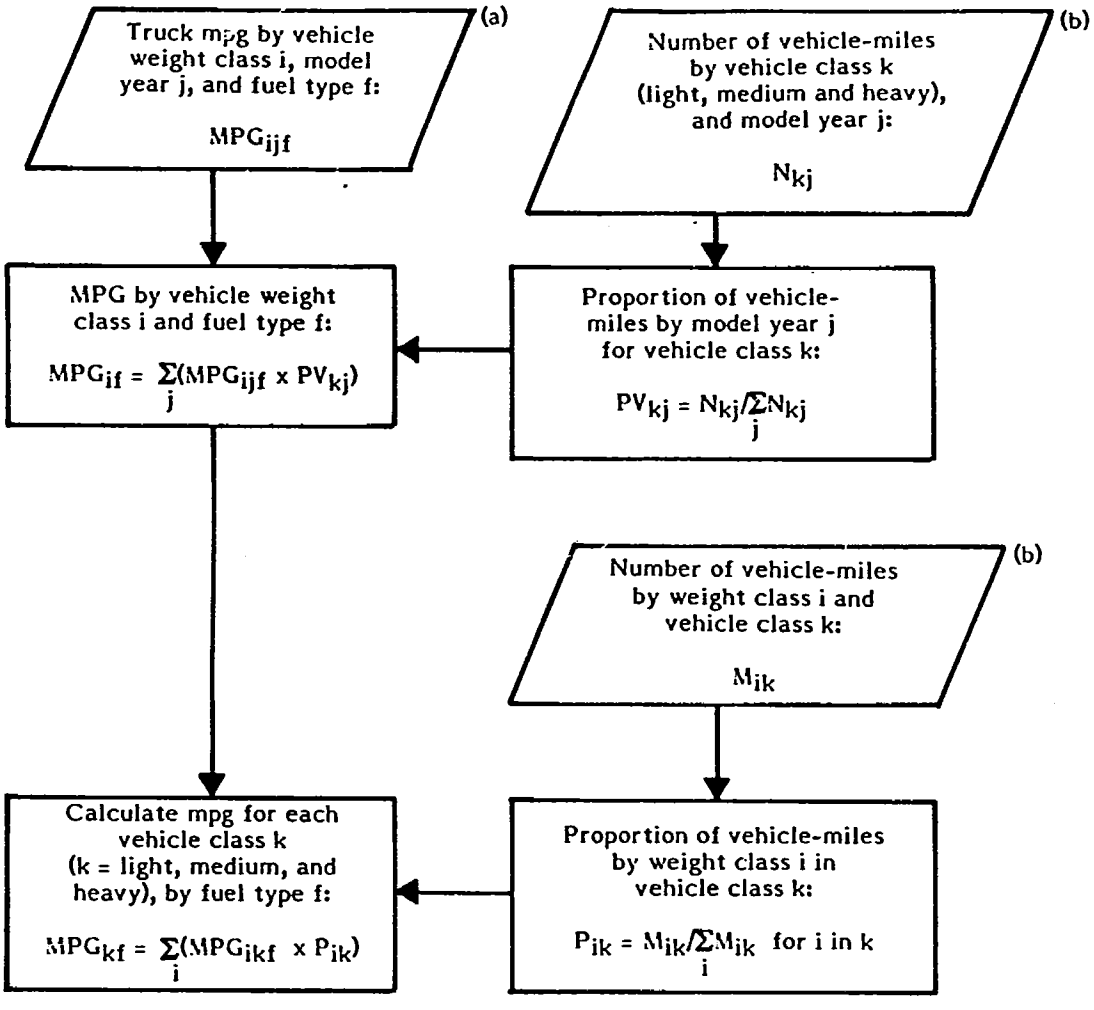
The primary source of information for establishing mpg estimates for trucks was the 1982 Census of Transportation Truck Inventory and Use Survey (TIUS). This was a large scale national survey that recorded owner-estimated mpg values by truck type and fuel type within each state. Annual vehicle-miles of travel by vehicle type and model year were also recorded.

The mpg data from the TIUS was tabulated by the Oak Ridge National Laboratory by vehicle weight and model year for medium and heavy trucks. Data tabulations are provided in Table D-4. The data shown in Table D-4 was supplied by the FHWA, Office of Policy Development, Transportation Studies Division. These data are used by FHWA in their Highway Revenue Forecasting System. This data base was selected for use over other published information because it represented comprehensive truck mpg values in a format well-suited to the requirements of this research.

Estimates of mpg for medium and heavy trucks from the TIUS data base were combined with similar information on light truck mpg based on national EPA estimates for combined city/highway travel. EPA estimates for light trucks were adjusted to account for differences between laboratory results and on-road experience. These adjustments were made by the Oak Ridge National Laboratory and were consistent with the adjustments for automobile mpg as described in the previous section of this report.

The procedure used to determine mpg estimates for trucks is shown in Figure 4-13. In this procedure, the mpg factors supplied by FHWA were weighted by the proportion of the vehicle-miles driven by model year and weight class of truck. The data on vehicle-miles were taken from published summaries in the TIUS (September, 1985) (See Tables D-5 and D-6). The proportion of vehicle-miles by model year for light, medium, and heavy trucks was used to determine an mpg estimate for each vehicle weight class and fuel type. It was assumed that the distribution of vehicle-miles by model year for a given weight class was the same for all weight classes which comprise a particular class of light, medium, or heavy trucks.

The mpg estimate for each weight class was multiplied by the percentages of vehicle-miles across all weight classes. The result was summed for the weight classes within light, medium, and heavy trucks to obtain an overall mpg factor for each fuel type. Estimates of the distribution of vehicle-miles by model year, vehicle class, and weight class were based on national estimates since similar data on the Arizona truck fleet were unavailable.



Sources: (a) FHWA Highway Revenue Forecasting System, Office of Policy Development, Transportation Studies Division, December 1986.

(b) U.S. Department of Commerce, Bureau of the Census, 1982 Census of Transportation -- Truck Inventory and Use Survey: United States, Washington, D.C., September, 1985.

FIGURE 4-13. TRUCK MPG CALCULATION PROCEDURE

RECOMMENDED MPG ESTIMATES

The mpg factors that were produced by the procedures described in the preceeding sections are shown in Table 4-14. These estimates are recommended for use in the selected VMT procedure. The following points provide additional insights into the recommendations shown in Table 4-14.

TABLE 4-14. RECOMMENDED MPG FACTORS

	Gas/Diesel MPG by Vehicle Class							
	Auto		Light Truck		Medium Truck		Heavy Truck	
Road Category	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel
City (Urban)	18.3	N/A	16.0	N/A	9.0	10.0	5.1	6.2
Highway (Rural)	23.2	N/A	16.0	N/A	9.0	10.0	5.1	6.2

N/A = Not Available

- A review of Arizona vehicle registration data indicated that less than two percent of the vehicles that comprise the automobile class are diesel powered. Therefore, an estimated gasoline mpg was assumed to be representative of the entire automobile class.
- Adjusted EPA estimates of city and highway mpg were assumed to be similar to mpg values experienced on urban and rural road classes in Arizona, respectively.
- The proportion of diesel-powered light trucks in the Arizona and national fleets was estimated to be less than two percent, as shown in Tables 4-15 and 4-16. Therefore, it was assumed that the gasoline-based mpg factor for light trucks would be representative of the entire light truck category.
- The recommended mpg values for light, medium, and heavy trucks represent an average mpg for city and highway travel. Insufficient data were available to disaggregate truck mpg estimates into city and highway values. This was not considered to be a serious limitation, given that automobiles dominate the amount of travel on every road class.
- The percentage of gasoline and diesel-powered vehicles in Arizona for the medium and heavy truck classes differ only slightly from the percentages for the

TABLE 4-15. COMPARISON OF ARIZONA AND NATIONAL TRUCK CLASS DISTRIBUTIONS BY FUEL TYPE

	Percent of Vehicles by Fuel Type from TIUS			
	Arizona		National	
Truck Class	Gas	Diesel	Gas	Diesel
Light	98.7	N/A	98.4	1.0
Medium	93.8	2.5	92.7	5.7
Heavy	47.0	51.2	46.2	52.4

N/A = Not Available
Source: TIUS, United States (September, 1985), and Arizona (June, 1985)

TABLE 4-16. DIESEL VERSUS GASOLINE FUEL TYPE USAGE AMONG ARIZONA-REGISTERED VEHICLES

		1985			1986		
Vehicle Type	Place of Registration	Total Vehicles	Diesel-Use Vehicles	% Diesel	Total Vehicles	Diesel-Use Vehicles	% Diesel
Light Duty Vehicles*	Maricopa County	914,576	13,699	1.50	935,657	14,117	1.51
	Pima County	285,696	4,331	1.52	287,442	4,366	1.52
	Yuma County	39,374	887	2.25	40,458	875	2.16
	Statewide	1,568,525	22,798	1.45	1,591,772	23,238	1.46
Light Duty Trucks	Maricopa County	280,493	5,349	1.91	294,334	5,776	1.96
	Pima County	90,958	1,595	1.75	93,054	1,770	1.90
	Yuma County	19,493	865	4.44	20,174	864	4.28
	Statewide	572,731	10,681	1.86	593,825	11,494	1.94
Heavy Duty Vehicles	Maricopa County	27,139	8,626	31.78	29,060	10,081	34.69
	Pima County	6,676	1,679	25.15	6,812	1,755	25.76
	Yuma County	1,754	340	19.38	1,737	348	20.00
	Statewide	51,618	16,293	31.56	57,594	19,316	33.54

*Passenger Vehicles
Source: ADOT Motor Vehicle Registration (database 6-30-85 and 7-13-86)

national fleet (see Table 4-15). Therefore, the use of national truck mpg estimates was appropriate for use in the VMT model for the Arizona truck fleet.

URBAN VEHICLE CLASSIFICATION FOR WEEKENDS

The objective of this data collection and analysis was to determine if sufficient differences existed between weekend and weekday vehicle type distributions to warrant adjusting the weighted urban mpg factors. Data was collected on weekends at the 50 urban sites previously described for weekday data collection (see Tables 4-9, C-1, and C-2). Sites were sampled on either Saturday or Sunday for a single three-hour time period beginning between 7:00 a.m. and 3:00 p.m. during the month of June 1987. Half of the sites were sampled on Saturdays and Sundays, with approximately half of the samples within each roadway functional class occurring on each day.

The results of the data collection effort are shown in Tables 4-17 and 4-18. A comparison of the vehicle type distributions for weekdays and weekends revealed a statistically significant difference for each roadway class and for the aggregated non-interstate class. However, a comparison of the results in Table 4-18 and 4-11 indicates that this did not translate into a meaningful difference in the weighted mpg values for any of the roadway classes. Note that the weekend data for interstates is only properly compared to the JHK data for interstates in Table 4-11. This is because the ADOT data in Table 4-11 is more representative of annualized percentages, while the spot samples have not been adjusted for possible seasonal fluctuations. The computed difference in the weighted mpg was less than 1 percent for each of the roadway classes. Therefore, it was concluded that an adjustment in the distribution of vehicles by type to account for differences in weekday and weekend travel was not necessary for the urban area.

RURAL VEHICLE CLASSIFICATION FOR WEEKENDS

The objective of this data collection and analysis was to determine if sufficient differences existed between weekend and weekday vehicle type distributions to warrant adjusting the weighted rural mpg factors. Data was collected on weekends at the 39 rural sites as indicated in Figures 4-1, 4-2, and 4-3. The precise location of these sites is indicated in Appendix B, Table B-1.

TABLE 4-17. NUMBER OF VEHICLES BY VEHICLE TYPE AND URBAN ROADWAY FUNCTIONAL CLASS (WEEKENDS)

Roadway Functional Class	Vehicle Class				
	Auto	Light Truck	Medium Truck	Heavy Truck	Total
Principle Arterial - Interstate	8,521	2,880	285	415	12,101
Principle Arterial - Other	61,623	18,502	2,117	533	82,775
Minor Arterial	26,793	6,121	577	117	33,613
Collector	1,489	354	19	0	1,862
Aggregated Non-interstate	89,910	24,977	2,713	650	93,273

TABLE 4-18. VEHICLE TYPE DISTRIBUTION IN PERCENT BY URBAN ROADWAY FUNCTIONAL CLASS WITH WEIGHTED MPG (WEEKENDS)

Roadway Functional Class	Vehicle Class				
	Auto	Light Truck	Medium Truck	Heavy Truck	Weight Mpg
Principle Arterial - Interstate	70.4	23.8	2.5	3.4	20.5
Principle Arterial - Other	74.4	22.4	2.6	0.6	17.5
Minor Arterial	79.7	18.2	1.7	0.4	17.7
Collector	80.0	19.0	1.0	0.0	17.8
Aggregated Non-interstate	76.0	21.1	2.3	0.6	17.5

TABLE 4-19. NUMBER OF RURAL WEEKEND DATA COLLECTION SITES BY ROADWAY FUNCTIONAL CLASS

Functional Class	Number of Sites
Principal Arterial--Interstate	17
Principal Arterial--Other	9
Minor Arterial	3
Major Collector	10
TOTAL	39

Each site was sampled on either a Saturday or Sunday for a single 3-hour time period beginning between 7:00 a.m. and 3:00 p.m. during the month of June 1987. Approximately half of the sites were sampled on Saturdays and Sundays, with approximately half of the samples within each roadway functional class occurring on each day. The number of sites in each roadway functional classification is shown in Table 4-19. The sites where approximately equally distributed throughout the three states regions defined in Figure 4-8.

The results of the data collection effort are shown in Tables 4-20 and 4-21. The comparable weekday data for the month of June is given in Tables 4-22 and 4-23. The weekday data is represented by 32 of the 39 sites where weekend data collection occurred. The weekday data is an aggregation of the information supplied by ADOT for the six-year study period.

A comparison of the vehicle type distribution for weekdays and weekends revealed a statistically significant difference for each roadway class and for the aggregated non-interstate class. However, a comparison of the results in Tables 4-21 and 4-23 indicates that this did not translate into a meaningful difference in the weighted mpg values for any of the roadway classes. The computed difference in the weighted mpg was a maximum of 5.3 percent for the minor arterial roadway class. Therefore, it was concluded that an adjustment in the distribution of vehicles by type to account for differences in weekday and weekend travel was not necessary for the rural area. The computed difference in the weighted mpg values for weekend and weekday travel becomes even less meaningful given that the weekend volumes on rural roads represents only approximately two-sevenths of the weekly total volume (Mattias and Dean (1984)).

TABLE 4-20. NUMBER OF VEHICLES BY VEHICLE TYPE AND RURAL ROADWAY FUNCTIONAL CLASS (WEEKENDS IN JUNE JHK DATA)

Roadway Functional Class	Vehicle Class				
	Auto	Light Truck	Medium Truck	Heavy Truck	Total
Principle Arterial - Interstate	12,883	4,245	2,017	3,270	22,415
Principle Arterial - Other	4,152	1,914	204	131	6,401
Minor Arterial	2,261	1,109	179	66	3,615
Major Collector	2,020	1,264	136	55	3,475
Aggregated Non-interstate	8,433	4,287	519	252	13,491

Table 4-21

VEHICLE TYPE DISTRIBUTION IN PERCENT BY RURAL ROADWAY FUNCTIONAL CLASS WITH WEIGHTED MPG (WEEKENDS IN JUNE JHK DATA)

Roadway Functional Class	Vehicle Class				Weight Mpg
	Auto	Light Truck	Medium Truck	Heavy Truck	
Principle Arterial - Interstate	57.5	18.9	9.0	14.6	17.9
Principle Arterial - Other	64.9	29.9	3.2	2.0	20.2
Minor Arterial	62.5	30.7	5.0	1.8	20.0
Major Collector	58.1	36.4	3.9	1.6	19.7
Aggregated Non-interstate	62.5	31.8	3.8	1.9	20.0

TABLE 4-22. NUMBER OF VEHICLES BY VEHICLE TYPE AND RURAL ROADWAY FUNCTIONAL CLASS (WEEKDAYS IN JUNE FROM ADOT DATA)

Roadway Functional Class	Vehicle Class				Total
	Auto	Light Truck	Medium Truck	Heavy Truck	
Principle Arterial - Interstate	12,943	3,277	1,895	3,141	21,256
Principle Arterial - Other	11,352	5,048	1,315	736	18,454
Minor Arterial	394	187	49	34	664
Major Collector	5,827	3,019	686	269	9,801
Aggregated Non-interstate	17,573	8,254	2,053	1,039	28,919

TABLE 4-23. VEHICLE TYPE DISTRIBUTION IN PERCENT BY RURAL ROADWAY FUNCTIONAL CLASS WITH WEIGHTED MPG (WEEKDAYS IN JUNE FROM ADOT DATA)

Roadway Functional Class	Vehicle Class				Weight Mpg
	Auto	Light Truck	Medium Truck	Heavy Truck	
Principle Arterial - Interstate	60.9	15.4	8.9	14.8	18.1
Principle Arterial - Other	61.5	27.4	7.1	4.0	19.5
Minor Arterial	59.3	28.2	7.4	5.1	19.0
Major Collector	59.5	30.8	7.0	2.7	19.5
Aggregated Non-interstate	60.8	28.5	7.1	3.6	19.5

5. MODEL APPLICATION

The procedure developed in this study for estimating statewide VMT was performed using actual data to demonstrate the use and application of the model. The application used historical data on vehicle classification from ADOT, vehicle classification collected as part of this study, fuel sales in 1985, EPA fuel consumption estimates, and Department of Motor Vehicle registration data. The demonstration produced an estimate of the 1985 VMT in Arizona. The following is a description of the procedural steps used in the application of the model and in the evaluation of model results.

STEP 1 - DETERMINE VEHICLE CLASSIFICATION DISTRIBUTIONS BY ROAD CLASS

The initial step in the procedure requires the establishment of vehicle class distributions by functional road class. As described earlier in this report, vehicle class distributions were established using historical data collected by ADOT in the rural areas of Arizona and supplemental urban data collected as a part of this study. Statistical analyses performed on these data resulted in the aggregation of Arizona roads into four functional classifications including rural interstates, rural non-interstates, urban interstates, and urban non-interstates. An analysis of fuel consumption characteristics resulted in the identification of four vehicle classes including automobile, light trucks, medium trucks, and heavy trucks. Table 5-1 illustrates the distribution of vehicle classification data by functional roadway type. Vehicle class distributions for rural interstate and non-interstates were determined from a relatively large data base, spanning several years. The distribution shown for these road classes were observed to be extremely stable over the six-year analysis period, and are appropriate for use in this application as well as future applications of the model. The vehicle class distributions for urban interstates and non-interstates are based on a 1-time sample collected in 1987. The collection of vehicle classification data on urban roadway types should be continued in the future and analyses should be performed to determine the stability and reliabilty of the distribution shown in Table 5-1.

TABLE 5-1. VEHICLE DISTRIBUTION BY ROAD CLASS IN PERCENT

Vehicle Class	Road Class			
	Rural Interstate	Rural Non-interstate	Urban Interstate	Urban Non-interstate
Auto	57.7	57.2	63.7	76.9
Light Truck	17.1	31.7	25.1	21.1
Medium Truck	8.8	7.6	6.9	1.6
Heavy Truck	16.4	3.5	4.3	0.4
TOTAL	100.0	100.0	100.0	100.0

STEP 2 - DISAGGREGATE VEHICLE CLASS DISTRIBUTIONS BY FUEL TYPE

Vehicle class distributions were disaggregated into type of fuel consumed (gasoline and diesel) using information received from the Arizona Department of Motor Vehicles and the Arizona data contained in the 1982 Truck Inventory and Use Survey (TIUS) (Bureau of Census (1985)). DMV data indicated that the percentage of automobiles and light trucks that use diesel fuel was less than 2 percent within the state of Arizona. Accordingly, it was decided that all vehicles within these classifications would be assigned as gasoline users. The 1982 census report indicated that for medium trucks, 97.4 percent used gasoline and 2.6 percent used diesel. For heavy trucks, 47.9 percent used gas and 52.1 percent used diesel. These factors were used to develop Table 5-2. Table 5-2 represents a disaggregation of the information contained in Table 5-1 using the gasoline and diesel use percentage described above and normalizing the distribution according to road class and fuel type.

TABLE 5-2. VEHICLE DISTRIBUTION BY ROAD CLASS AND FUEL TYPE IN PERCENT

	Road Class							
	Rural Interestate		Rural Non-interstate		Urban Interstate		Urban Non-interstate	
Vehicle Class	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel
Auto	63.2	--	58.3	--	65.3	--	77.1	--
Light Truck	18.7	--	32.4	--	25.7	--	21.2	--
Medium Truck	9.4	2.6	7.6	10.0	6.9	7.4	1.5	16.0
Heavy Truck	8.7	97.4	1.7	90.0	2.1	92.6	0.2	24.0
TOTAL	100.0	100.0	100.0	100.00	100.00	100.00	100.00	100.00

STEP 3 - DETERMINE FUEL CONSUMPTION FACTORS (MPG)

EPA estimates and the 1982 TIUS served as the principal sources of information for mpg estimates. The procedure is to develop the mpg figures used in this demonstration was described in detail earlier in this report. Table 5-3 summarizes the gasoline and diesel mpg estimates used in the application of the model.

STEP 4 - CALCULATED MPG BY ROAD CLASS FOR GASOLINE AND DIESEL FUEL

Weighted mpg was calculated separately for gasoline and diesel fuel for each road class. This was accomplished by multiplying the mpg figures shown in Table 5-3 by the appropriate percentage of each vehicle type which exists on a specific road class and for a given fuel type. For example, the following calculation was used to determine the weighted gasoline mpg for rural interstates.

Weighted gasoline mpg for rural interstates = 0.632 (23.2) + 0.187 (16.0) + 0.094 (9.0) + 0.087 (5.1) = 18.9 miles per gallon.

Table 5-4 summarizes the weighted mpg estimates for each road class and each fuel type.

TABLE 5-3. GASOLINE AND DIESEL MPG ESTIMATES

Vehicle Class	Gasoline MPG		Diesel MPG	
	Urban	Rural	Urban	Rural
Auto	18.3	23.2	--	--
Light Truck	16.0	16.0	--	--
Medium Truck	9.0	9.0	10.0	10.0
Heavy Truck	5.1	5.1	6.2	6.2

TABLE 5-4. WEIGHTED MPG ESTIMATES

Road Class	Weighted Gasoline MPG	Weighted Diesel MPG
Rural Interstate	18.9	6.3
Rural Non-Interstate	19.5	6.6
Urban Interstate	16.8	6.5
Urban Non-Interstate	17.7	6.8

TABLE 5-5. 1984 VMT ESTIMATES

Road Class	1984 MVMT	Percent of Total
Rural Interstate	3230	15.7
Rural Non-Interstate	7318	35.5
Urban Interstate	1250	6.0
Urban Non-Interstate	8815	42.8
TOTAL	20,613	100.0

Source: FHWA (1985).

STEP 5 - ESTIMATE THE DISTRIBUTION OF ARIZONA VMT BY ROAD CLASS

In order to obtain a weighted mpg by road class, an estimate is needed of the distribution of VMT by road classification. Historical VMT data published by FHWA for Arizona in 1984 was used to estimate this distribution. Table 5-5 shows the magnitude of VMT by road class (expressed in million vehicle miles of travel) and the proportion of VMT within each road class.

STEP 6 - CALCULATE WEIGHTED MPG BY ROAD CLASS

Wieghted mpg was calculated separately for gasoline and diesel fuel using the information contained in Table 5-4 and Table 5-5. This was accomplished by multiplying the weighted mpg for a particular fuel type and roadway class and summing this product over all road classes. The calculation for weighted gasoline and weighted diesel mpg is shown below.

Weighted gasoline mpg = 18.9 (0.157) + 19.5 (0.355) + 16.8 (0.060) + 17.7 (0.428) = 18.5 miles per gallon.

Weighted diesel mpg = 6.3 (0.157) + 6.6 (0.355) + 6.5 (0.060) + 6.8 (0.428) = 6.6 miles per gallon.

STEP 7 - DETERMINE FUEL SALES IN ARIZONA

The source of fuel sales data in Arizona for 1985 was the monthly report entitled "Motor Vehicle Fuel - Taxable Acquisitions and Refunds" maintained by the Arizona Motor Vehicle Division. This report provided both gasoline and diesel fuel sales in the state of Arizona by month for 1985. Gasoline sales, expressed in gallons, was the total gallons of gasoline sales less the gallons of gasoline refunded. Motor Vehicle Division personnel indicated that the refund gallons represent the gallons of gasoline bought for non-highway uses (for airplanes, tractors, etc.). Diesel fuel sales were taken directly from the form. Accumulations of monthly gasoline and diesel fuel sales for 1985 resulted in the following.

1985 gasoline sales = 1,568 million gallons

1985 diesel fuel sales = 273 million gallons

Total fuel sales = 1,841 million gallons.

STEP 8 - CALCULATE STATEWIDE VMT

Statewide VMT was calculated by summing the product of fuel sales and weighted mpg for each fuel type. Inputs for this calculation were determined in Steps 7 and 8. This calculation resulted in the following VMT.

Gasoline-related VMT = 1,568 million gallons x 18.4 miles per gallon = 28,851 million VMT

Diesel-related VMT = 273 million gallons x 6.6 miles per gallon = 1,802 million VMT

Total VMT = 30,653 million VMT

STEP 9 - CALCULATE FATALITY RATE

The statewide fatality rate for 1985 is calculated by dividing the number of fatalities in 1985 by the estimated statewide VMT calculated in Step 9. In 1985, the Arizona fatality frequency was 893. Dividing this frequency by the statewide VMT calculated in Step 9 produces a statewide fatality rate for 1985 of 2.91 fatalities per hundred million vehicle miles.

OBSERVATIONS

The following observations are made with regard to the VMT estimate and fatality rate calculation derived from the application of the model developed in this study.

o The VMT estimated by the procedure demonstration for 1985 was 30,653 million VMT. This estimate is 5.5 percent higher than the VMT estimated by ADOT using a fuel sales and fleet mpg procedure, the ADOT estimate was 29,050 million VMT. When compared to the FHWA estimate which is based on output from the HPMS, the procedure produced a VMT estimate that was 42.0 percent higher than the FHWA estimate of 21,580 million VMT.

o The Arizona estimate of VMT for 1985 utilized a fleet mpg value of 15.7 miles per gallon. This compares to a fleet mpg factor of 16.7 miles per gallon which can be calculated from the procedure demonstrated above by dividing total VMT (30,653 million VMT) by total fuel sales (1,841 million gallons). This indicates that

the weighted mpg produces a fleet average of approximately 1 mile per gallon higher than the figure used by ADOT in 1985. Assuming 893 fatalities in Arizona in 1985 the fatality rates produced by the model developed in this study, the ADOT procedure, and FHWA are as follows.

Fuel sales with weighted mpg = 2.91 fatalities per hundred million VMT

Fuel sales with fleet mpg (ADOT) = 3.07

FHWA (using HPMS) = 4.14 fatalities per hundred million VMT

6. CONCLUSIONS

The basic conclusions from this study are enumerated as follows.

1. In order to establish a meaningful basis for comparing fatality rates among states, standard inputs and procedures must be defined for the two elements that comprise the fatality rate equation; fatality frequency and vehicle-miles of travel (VMT). The number of fatalities can be determined with a high level of reliability from the Fatal Accident Record System (FARS) data base which should be established as the single source of data for fatality frequency. The predominant methods for estimating VMT are the Highway Performance Monitoring System (HPMS) and procedures which combine fuel sales and fuel consumption. With procedural enhancements and refinements, either method is capable of producing consistent estimates of VMT. Other VMT procedures evaluated in this study were determined not to be feasible for estimating statewide VMT on the basis of reliability, ease of implementation, and cost of implementation.

2. HPMS is capable of providing reliable estimates of VMT subject to the assurance that all states periodically update the HPMS sampling frame in response to changes in the character of the highway system and subject to improving the quality, accuracy, and coverage of traffic volumes on local roadway classes. Periodic updating of the HPMS sampling frame may be possible through FHWA mandates for procedure updating and monitoring of the updated systems by FHWA. The likelihood of improving the quality and coverage of traffic volume data on local roads is low due to the resource limitation at the local level and the expense associated with expanding state VMT volume counting programs to the local level.

3. In the absence of achieving the aforementioned enhancements to HPMS, other procedures should be considered for use in estimating VMT. Principle among these alternative procedures are methods that combine fuel sales and fuel consumption. Since fuel sales information is maintained in most states for taxation purposes, the application of these procedures is subject to the establishment of fuel consumption estimates. Typically, fuel consumption is expressed as either a fleet mpg or as a weighted mpg. Weighted mpg factors provide a more reliable estimate of VMT due to the ability of the weighted estimates to account for unique vehicle

type distributions, fuel consumption characteristics, and fuel sale characteristics within a particular state. This study demonstrates the recommended procedure for establishing a weighted mpg factor within the state of Arizona. This procedure produced an estimated VMT which was considered to be superior to either a VMT estimate based on a fleet mpg or on estimates produced by HPMS. Furthermore, the procedure for establishing weighted mpg requires a reasonable level of time and staff expenditures and is capable of being updated on an annual basis to reflect changes in the fuel consumption characteristics of the vehicle fleet within the state.

5. The existing ADOT data collection program for rural highway vehicle classification is more than adequate to support the rural data requirements of the VMT estimation procedure developed in this study. However, urban data collection should be expanded to generate a higher level of confidence in the urban vehicle classification statistics, and to account for the possible seasonal fluctuation in the results. Discrimination between weekday and weekend vehicle classification does not appear necessary for use in the VMT model. However, this result should be verified on an annualized basis.

7. RECOMMENDATIONS

ADOT should adopt the procedures and model developed in the study for use in calculating state-wide annual fatality rates and allocate sufficient resources and responsibilities to apply, update, and refine the elements of the model. Refinements to be made should include, but should not be limited to:

o Current ADOT data collection techniques including vehicle classes, data collection, period durations, and frequency of data collection are appropriate for providing necessary data to the model. However, it is recommended that a review the current ADOT program for collecting statewide vehicle classification data in light of the data requirements for the model developed in this study. Specifically, ADOT should reallocate current vehicle classification data collection resources from rural road classes to urban road classes, ensuring that data collected in both areas are representative of the population of urban and rural roads in the functional classifications which comprise these road systems.

o ADOT should coordinate with the Arizona Department of Motor Vehicles, the Arizona Department of Commerce, and the Environmental Protection Agency to ensure that data for performing annual updates to the model elements will be directed to the ADOT personnel who will be responsible for updating the model.

o ADOT should coordinate with FHWA to update the sampling frame of the HPMS in Arizona and establish agreements with local agencies to provide annual volume data on local roads according to a sampling plan to be established by ADOT.

o ADOT should encourage a study of national scope to examine the benefits and feasibility of establishing a nationwide procedure standard for calculating statewide fatality rates. Methods that should be considered should include (1) fuel sales with weighted mpg, (2) fuel sales with fleet mpg, (3) HPMS. The study should include the development of a procedural framework that is feasible for application in states throughout the U.S. The selected procedure should be sensitive to resource requirements, ease of application, ease of update, cost of application, and reliability of VMT estimate.

o In an effort to disseminate information on the model developed in this study and its relationship to VMT estimates produced from HPMS, ADOT should initiate a study to compare VMT estimates produced by both models over the past

several years. VMT estimates from HPMS are readily available from FHWA. Estimates from the model produced in this study could be obtained by applying the model using historical vehicle classification data and historical fuel consumption rates within the state of Arizona. Estimates will need to be made for urban vehicle classification distributions due to data limitations. The VMT estimates produced by these methods should be compared with other statewide data which have correlations with vehicle miles of travel in the state. Examples of such variables include vehicle registration, population, volume based VMT estimates for selected elements of the Arizona road system. VMT information from emissions test facilities, etc.

APPENDIX A. SUMMARY OF SURVEY RESULTS

STATE _____

AGENCY _____

DIVISION WITHIN AGENCY _____

DATE _____

SURVEY FORM

1. How does your State compute the statewide estimate of monthly and annual vehicle - miles of travel (VMT)? (If separate methods, specify monthly and annual procedures). Check all applicable procedures. Please provide documentation, where feasible.

a. 26 from HPMS (Highway Performance Monitoring System)
b. 9 from fuel sales records and mpg (miles per gallon) data
c. 1 from vehicle data records (emissions testing, license plate registration data)
d. 31 other (Please explain or supply documentation)

28 ADT-expanded
1 Econometric model
1 Vehicle records
1 Other

2. (If 1.b checked) What is the source(s) of the miles per gallon (mpg) data used in your computation? State-developed historical model (3), FHWA estimates (2), EPA and SAE adjusted data (2), nationwide mph data (1), econometric model (1)

If a nationwide miles per gallon figure is used, is an adjustment made where fleet mix within the state is expected to differ from national data? Yes 4 No 1 No response 4

Does the fleet mix travelling within your state compare well with the source's data from above? Yes 3 No 0 Not sure 2 No response 4
Why or why not? State comparison has not been conducted.

What is the source of the fuel sales records? State agency responsible for collection of fuel tax (8), No response (1)

Is total fuel sold in the state (minus that portion used for non-roadway use) used in the calculation of VMT (vehicle-miles of travel) or is the fuel sold broken down by type (e.g. diesel, leaded, unleaded) and divided by specific miles per gallon data by fuel type?

4 total fuel sales
5 fuel breakdown: How? gasoline, diesel, special fuel (4); gasoline and gasohol, diesel

3. (If I.c checked) What is the source of the vehicle record data?
Department of Motor Vehicles (1)

Is a sample of vehicle records or all vehicle records used in VMT calculations?
0 sample
1 all records:

How is the data used? Please explain. Provide documentation, where necessary. Used to compute travel by vehicle type

4. (If I.b, I.c, or I.d used) Does your annual VMT figures calculated by this method differ from the HPMS vehicle-miles of travel data? Yes 16
No 16 No response 4

Min.-0.1% Max.-35% Ave.-4.6%
If yes, how much? (Approx. percentage) 1983:____ 1984:____ 1985:____
No comparison made 4
If a difference exists, what are the key sources for differences?

Please define: HPMS sampling plan (12); Reliability of "local" data (6); Increased emphasis by State on urban sections (5); incomplete data (3)

5. (all respondees) Are there other sources of published vehicle-miles of travel data within your State? Yes 2 No 4 No response 2

If 'yes' to above question, what is the data source(s)? Travel models (2); Independent count programs (1)

Does the data differ from the data you use? Yes 1 No 1

If so, how much? 2-5% Please provide numerical example:

6. (all respondees) What are the primary uses of your VMT data by your agency?
Accident rate developed (27); Highway planning and programming (20); Federal reporting (13); Develop traffic trends (15); Funding allocation (13); State traffic statistics (10); Funding forecasts (5); Track performance (3); Speed study (2); Fuel consumption (2); EPA (2); Safety Program (2)

7. (all respondees) Are statewide accident rates published by your agency?
Yes 32 No 15

What source of VMT data is used in computing the rate published by your agency?

a. 9 HPMS data
b. 23 State-supplied estimate
c. ____ Other____

Does a difference exist in published statewide accident rates from various sources published in your state? Yes 0 No 29 No response 2 Unknown 2
If yes, please show extent of differences by showing actual rates for previous years: _____

Source:			
1982 Rates			
1983 Rates			
1984 Rates			

8. (all respondees) Is an annual traffic fatality rate figure published by your agency? Yes 36 No 11

What is the source of VMT and traffic accident data?
VMT: HPMS (8); DOT-supplied (25); No response (3)
Traffic Fatality Accidents: State accident records (36)

Is a traffic fatality rate published within the State by other agencies or organizations? Yes 12 No 22 No response 2

If yes, state source: State Police (6); Dept. of Motor Vehicles (1); Traffic Safety Commission (4); FARS group (1)
Does a difference in fatality rates exist within your State as published by the different agencies? Yes 2 No 9 No response 1

If yes, show actual rates for recent years:

Source:	DOT	VA Dep.Motor Veh.	KY Dep.Pub Safety	Trsp Res. Ctr.
1982 Fatality Rate	2.26	2.24	2.86	3.3
1983 Fatality Rate	2.15	2.15	2.61	3.0
1984 Fatality Rate	2.26	2.26	2.45	2.8

9. Name of individual completing form: _____

Title: _____

If additional information is necessary, may we contact you?
Yes _____ No _____

Telephone No. ( ) _____

Thank you for your time and cooperation.

Send survey form (envelope enclosed) to: JHK & ASSOCIATES
Attn: Mr. Mark Flak
2702 N. 44th St., Suite 102-A
Phoenix, Arizona 85008

APPENDIX B. RURAL DATA COLLECTION SITES

TABLE B-1. ADOT VEHICLE CLASSIFICATION PLACES LOCATION

Station	Site Number	Junction		Direction	Mile Post	Functional Class	Region
Goodyear	1*	U.S. 85	Litchfield Road	West	177.50	2	2
Flagstaff	2*	I-40	U.S. 66 (Flag East)	East	207.00	1	1
	3*	U.S. 89 "A"	Lake Mary Road	North	401.57	4	1
	4*	U.S. 89 "A"	Lake Mary Road	South	401.31	4	1
Phoenix	5	I-17	Thomas Road	South	201.83	7	3
	6	U.S. 60	27th Avenue	Southeast	160.60	8	3
	7	U.S. 60	19th Avenue	Northwest	161.63	8	3
	8	I-17	McDowell A	North	201.50	7	3
Apache Junction	9*	U.S. 60	State 88	East	198.62	2	3
	10*	U.S. 60	State 88	West	192.00	2	3
	11*	State 88	U.S. 60	North	200.00	4	3
Globe	12	U.S. 70	State 77	West	254.00	2	3
	13	U.S. 70	State 77	East	254.21	2	3
	14	State 77	U.S. 70	South	170.03	2	3
Gila Bend	15*	I-8	B-8	West	115.58	1	2
	16*	I-8	B-8	East	115.78	1	2
	17*	B-8	I-8	North	122.80	2	2
Tempe	18	U.S. 60	McClintock	East	175.19	8	3
Quartzsite	19	I-10	State 95	West	17.00	1	2
	20	I-10	State 95	East	17.50	1	2
	21	State 95	B-10	North	110.00	3	2
	22	U.S. 95	I-10	South	103.00	3	2
Wickenburg	23	U.S. 89	U.S. 93	North	258.00	2	2
	24*	U.S. 89	U.S. 93	South	257.89	2	2
	25*	U.S. 93	U.S. 89	North	193.70	2	2

TABLE B-1. ADOT VEHICLE CLASSIFICATION PLACES LOCATION (CONTINUED)

Station	Site Number	Junction		Direction	Mile Post	Functional Class	Region
Topock	26	I-40	State 95	West	9.65		
	27	I-40	State 95	East	9.85	1	1
	28	State 95	I-40	South	202.00	3	1
Kingman	29*	U.S. 66	I-40	South	56.50	2	1
	30*	U.S. 66	I-40	North	56.70	4	1
	31*	I-40	U.S. 66	East	53.60	1	1
Ashfork	32*	I-40	U.S. 89	West	143.00	1	1
	33*	I-40	U.S. 89	East	146.28	1	1
	34	U.S. 89	I-40	South	363.80	3	1
Show Low	35	U.S. 60	State 77	Southwest	342.20	2	3
	36	State 77	U.S. 60	North	342.50	2	3
	37	U.S. 60	State 77	East	343.10	2	3
Prescott	38	U.S. 89	State 69	North	313.30	3	2
	39	U.S. 89	State 69	Southwest	312.40	3	2
	40	State 69	U.S. 89	East	296.20	3	2
Yuma	41	I-8	B-8	East	9.50	1	2
	42	I-8	B8	Northwest	9.30	1	2
	43	B-8	I-8	West	12.00	2	2
Nogales	44	State 82	U.S. 89	Northeast	5.00	4	3
Mountain View	45*	I-10	State 83	West	281.50	1	3
	46*	I-10	State 83	East	282.00	1	3
	47*	State 83	I-10	South	58.20	4	3
Willcox	48	I-10	U.S. 666	East	356.00	1	3
	49	I-10	U.S. 666	West	352.30	1	3
	50	U.S. 666	I-10	North	67.00	4	3
Littlefield	51	I-15	F.A.S. 609	North	8.61	1	1

APPENDIX B. (CONTINUED)

TABLE B-1. ADOT VEHICLE CLASSIFICATION PLACES LOCATION (CONTINUED)

Station	Site Number	Junction		Direction	Mile Post	Functional Class	Region
Kingman	52*	U.S. 93	State 68	Southeast	67.25	2	1
	53*	U.S. 93	State 68	Northwest	67.00	2	1
	54	State 68	U.S. 93	West	27.15	3	1
Cordes Junction	55	State 69	I-17	Northwest	262.90	3	2
	56	I-17	State 69	South	262.39	1	2
	57	I-17	State 69	North	263.60	1	2
Yuma	58	U.S.95	Yuma County 14	South	16.90	3	2
Ajo	59	State 85	State 86	Northwest	52.50	3	2
	60	State 85	State 86	South	53.00	3	2
	61	State 86	State 85	East	52.90	3	2
Toltec	62*	I-8	I-10	West	178.00	1	3
	63*	I-10	I-8	North	199.00	1	3
	64*	I-10	I-8	Southeast	199.20	1	3
Casa Grande	65*	State 84	State 93	West	177.80	4	2
	66	State 84	State 93	East	178.40	4	2
	67	State 93	State 84	North	243.40	4	2
	68	State 287	State 93	East	111.80	4	3
	69*	I-10	State 93	Northwest	185.00	1	3
	70*	I-10	State 93	Southeast	186.00	1	3
	71*	State 93	I-10	South	235.20	4	3
	72*	State 187	State 87	South	192.00	4	3
	73*	State 387	State 187	East	.50	3	3
Tucson	74	I-10	G.S. Alvernon Way	Northwest	265.00	7	3
Tucson South	75*	I-19	U.S. 89	North	43.30	1	3
	76*	I-19	U.S. 89	South	42.50	1	3
	77*	U.S. 89	I-19	Northeast	43.90	3	3
Pearce	78	U.S. 666	State 181	South	38.00	4	3
	79	U.S. 666	State 181	North	38.20	4	3
	80	State 181	U.S. 666	East	38.30	5	3

TABLE B-1. ADOT VEHICLE CLASSIFICATION PLACES LOCATION (CONTINUED)

Station	Site Number	Junction		Direction	Mile Post	Functional Class	Region
Wickleman	81	State 77	State 177	Southeast	134.70	2	3
	82	State 77	State 177	Northeast	135.00	2	3
	83	State 177	State 77	Northwest	136.50	4	3
Eager	84	State 260	State 180B	West	396.00	3	3
	85	State 180B	State 260	North	396.20	3	3
	86	State 260	State 180B	East	396.15	3	3
Heber	87	State 277	State 377	Southwest	312.23	3	3
	88	State 277	State 377	East	312.63	4	3
	89	State 377	State 277	Northeast	.20	3	3
Winslow	90	State 87	State 99	North	340.90	3	1
	125*	State 87	State 99	Southwest	340.80	3	1
	91	State 99	State 87	Southeast	42.60	5	1
Holbrook	92*	I-40	State 77	Northeast	292.90	1	1
	93*	I-40	State 77	Southeast	292.70	1	1
	94*	State 77	I-40	North	395.20	4	1
Oraibi	95	State 264	State 87	East	384.31	3	1
	96	State 264	State 87	West	384.10	3	1
	97*	State 87	State 264	South	406.00	4	1
Kayenta	98	U.S. 160	U.S. 163	Northeast	394.00	2	1
	99	U.S. 160	U.S. 163	Southwest	393.50	2	1
	100	U.S. 163	U.S. 160	North	396.00	3	1
Tuba City	101	U.S. 160	State 264	West	321.00	2	1
	102	U.S. 160	State 265	Northeast	322.00	2	1
	103	State 264	U.S. 160	Southeast	323.00	3	1
Cameron	104	U.S.89	State 64	South	465.00	2	1
	105	U.S. 89	State 64	North	466.00	2	1
	106	State 64	U.S. 89	West	295.20	3	1

TABLE B-1. ADOT VEHICLE CLASSIFICATION PLACES LOCATION (CONTINUED)

Station	Site Number	Junction		Direction	Mile Post	Functional Class	Region
Flagstaff	107	State B-40	U.S. 180	East	196.20	10	1
	108	State B-40	U.S. 180	West	195.90	10	1
	109	U.S. 180	State B-40	North	215.50	9	1
Page	110	U.S. 89	U.S. 89 "A"	South	524.00	2	1
	111	U.S. 89	U.S. 89"A"	Northeast	524.50	2	1
	112	U.S. 89 "A"	U.S. 89	Northwest	525.00	3	1
Valle	113	State 64	U.S. 180	South	213.30	3	1
	114	State 64	U.S. 180	North	214.00	3	1
	115	U.S. 180	State 64	Southeast	265.80	3	1
Jacob Lake	116	U.S. 89 "A"	State 67	East	579.20	3	1
	117	U.S. 89 "A"	State 67	Northwest	579.50	3	1
	118	State 67	U.S. 89 "A"	South	581.00	4	1
Davis Dam	119	State 68	State 95 Y-LEG	East	1.50	3	1
	120	State 68	Sate 95 Y-LEG	West	.50	3	1
	121	State 95	State 68 Y-LEG	South	251.65	3	1
Ganado	122	State 264	U.S. 191	East	446.90	3	1
	123	State 264	U.S. 191	West	446.70	3	1
	124	U.S. 191	State 264	North	43.00	3	1

*Indicates location of JHK weekend data collection.

Functional Class Designation

1 = Rural Principle Arterial - Interstate
2 = Rural Principle Arterial - Other
3 = Rural Minor Arterial
4 = Rural Major Collector
5 = Rural Minor Collector
6 = Rural Collector
7 = Urban Principle Arterial - Interstate
8 = Urban Principle Arterial - Other
9 = Urban Minor Arterial
10 = Urban Collector

APPENDIX C. JHK URBAN DATA COLLECTION SITES

TABLE C-1. URBAN DATA COLLECTION SITES (PHOENIX)

Site Number	Interstate
9	Maricopa Freeway at 32nd Street
37	Black Canyon Freeway at Dunlap
	Principal Arterial
3	Southern Avenue at Country Club
4	Washington Street at 48th Street
5	Baseline Road at Hardy
6	Alma School at Medina
7	Main Street at Center
8	Gilbert Road at Adobe
12	McDowell at 70th Street
13	Hayden Road at McDowell
14	Tatum Boulevard at Clearwater
15	Scottsdale Road at Cholla
16	Shea Boulevard at 36th Street
17	Bell Road at 44th Street
18	Cave Creek Road at Sharon
24	7th Street at Washington Street
25	McDowell Road at 31st Avenue
26	Indian School at 28th Street
27	Grand Avenue at 36th Avenue
28	Indian School at 63rd Avenue
34	Bell Road at 15th Avenue
35	Cactus Road at 47th Avenue
36	7th Avenue at Maryland
	Minor Arterial
1	College Avenue at 15th Street
2	Longmore Street at Fiesta Mall
10	68th Street at 6th Street
19	Campbell Avenue at 20th Street
20	Oak Street at 36th Street
21	Roosevelt Street at 12th Street
22	3rd Avenue at Palm Lane
23	Osborn Drive at 6th Avenue
29	Missouri at 18th Avenue
30	15th Avenue at El Caminito
31	39th Avenue at Northview Avenue
32	39th Avenue at Northview Avenue
33	28th Drive at Laurel Lane
	Collector
11	Mockingbird at McDonald

TABLE C-2. URBAN DATA COLLECTION SITES (TUCSON)

Site Number	Interstate
38	I-10 south of 6th Avenue
	Principal Arterial
39	Miracle Mile/Ventura
40	Country Club Road/Third Street
41	Broadway Boulevard/Columbus Boulevard
42	Valencia Road/Mission Gale Road
	Minor Arterial
44	5th Street/Sahuara Street
46	Alvernon Way/Glenn Street
47	Prince Road/Mountain Avenue
45	Campbell Avenue/Irvington
	Collector
48	Rosemont Boulevard/2nd Street
49	Palo Verde Boulevard/Fairmont
43	9th Street/Highland Avenue
50	University Boulevard/3rd Avenue

APPENDIX D. DATA USED TO DETERMINE AUTO AND TRUCK MPG FACTORS

TABLE D-1. AUTOMOBILE FLEET MPG ESTIMATES FOR CITY AND HIGHWAY DRIVING BY MODEL YEAR

Model Year	City MPG	Highway MPG
1986	23.7	36.0
1985	23.0	34.4
1984	22.4	33.3
1983	22.1	32.7
1982	22.3	32.7
1981	21.7	31.1
1980	20.3	29.0
1979	17.7	24.6
1978	17.2	24.5
1977	16.0	22.3
1976	15.2	21.3
1975	13.7	19.5
1974	12.0	18.2
1973	12.0	18.0
1972	12.2	18.9
1971	12.3	18.2
1970	12.6	19.0
1969	12.6	18.6
1968	12.6	18.4
Pre - 1968	12.9	18.5

Source: Heavenrich et. al. (1984 and 1986).

TABLE D-2. ARIZONA REGISTRATIONS FOR LIGHT DUTY GAS VEHICLES

Year	Number of Vehicles	Percent
1986	90,296	5.76
1985	136,003	8.68
1984	125,854	8.03
1983	87,437	5.58
1982	84,645	5.40
1981	90,720	5.79
1980	98,353	6.28
1979	120,024	7.66
1978	116,654	7.44
1977	104,057	6.64
1976	80,221	5.12
1975	51,651	3.30
1974	59,352	3.79
1973	61,808	3.94
1972	49,392	3.15
1971	36,387	2.32
1970	33,021	2.11
1969	27,884	1.78
1968	21,828	1.39
Pre - 1968	91,748	5.85
TOTAL	1,567,335	100.00

Source: Arizona Department of Transportation Motor Vehicle Division, Data Base 7-13-86.

TABLE D-3. ASSUMED DISTRIBUTION OF ANNUAL MILES DRIVEN BY VEHICLE MODEL YEAR FOR ARIZONA LIGHT-DUTY VEHICLES

Year	Miles ($X10^3$)	
1986	13.445	Extrapolated from EEA Data
1985	12.616	
1984	11.413	
1983	10.738	
1982	10.274	
1981	9.666	EEA Data
1980	9.156	
1979	8.746	
1978	8.345	
1977	8.102	
1976	7.621	
1975	7.620	
1974	7.428	
1973	7.236	
1972	7.044	
1971	6.852	
1970	6.666	Extrapolated from EEA Data
1969	6.468	
1968	6.276	
Pre - 1968	6.084	

Source: Energy and Environmental Analysis, Inc. (1985).

TABLE D-4. TRUCK MPG BY VEHICLE WEIGHT

MILEAGE FILE AS USED FOR FY88 BUDGET ESTIMATES ADJUSTMENTS BASED ON

TELECON WITH SCNIA CONLY ON DEC. 5, 1986.

MILES PER GALLON

YEAR / VC	1	2	3	4	5	6	7	8	9	10	11	12	13	F
F10	25.5	23.76	23.76	14.6	14.6	7.5	6.7	6.4	5.3	4.9	4.8	4.8	4.8	1
F 9	25.8	23.14	23.14	14.4	14.4	7.5	6.7	6.3	5.3	4.9	4.8	4.8	4.8	
F 8	25.7	22.69	22.69	14.2	14.2	7.4	6.6	6.3	5.3	4.9	4.7	4.7	4.7	
F 7	25.6	22.34	22.34	13.7	13.7	7.4	6.6	6.2	5.2	4.8	4.7	4.7	4.7	
F 6	25.5	21.89	21.89	13.2	13.2	7.4	6.6	6.2	5.2	4.8	4.7	4.7	4.7	
F 5	25.4	21.45	21.45	12.8	12.8	7.3	6.5	6.2	5.2	4.8	4.7	4.7	4.7	
F 4	25.3	20.91	20.91	12.3	12.3	7.3	6.5	6.1	5.1	4.7	4.6	4.6	4.6	
F 3	25.2	20.56	20.56	12.5	12.5	7.2	6.4	6.1	5.1	4.7	4.6	4.6	4.6	
F 2	24.8	20.22	20.22	12.3	12.3	7.1	6.3	6.0	5.0	4.6	4.5	4.5	4.5	
F 1	24.4	18.06	18.06	12.1	12.1	7.0	6.3	6.0	5.0	4.6	4.5	4.5	4.5	
1&3	24.0	17.71	17.71	11.8	11.8	7.0	6.2	5.9	4.8	4.5	4.5	4.5	4.5	
1-2	24.2	17.8	17.8	11.8	11.8	6.9	6.2	5.8	4.9	4.6	4.5	4.5	4.5	
2-3	23.5	17.35	17.35	11.4	11.4	6.8	6.1	5.9	4.8	4.5	4.5	4.5	4.5	
3-4	22.1	17.35	17.35	9.7	9.7	6.8	6.0	5.7	4.8	4.5	4.5	4.5	4.5	
4-5	19.4	16.12	16.12	9.6	9.6	6.7	6.0	5.7	4.7	4.5	4.5	4.4	4.4	

VC = Vehicle Class
1 = Auto
2 = LT < 6K
3 = LT 6-10K
4 = MT 10-14K
5 = MT 14-16K
6 = MT 16-19.5K
7 = MT 19.5-26K
8 = MT 26-33K
9 = MT 33-50K
10 = MT 50-70K
11 = MT 70-75K
12 = MT 75-80K
13 = MT > 80K
F = Fuel Type
1 = Gasoline
2 = Diesel

TABLE D-4. TRUCK MPG BY VEHICLE WEIGHT (CONTINUED)

5-6	18.11	14.69	14.69	9.5	9.5	6.6	5.9	5.6	4.7	4.4	4.4	4.4	4.4
6-7	16.65	13.5	11.7	9.4	9.4	6.6	5.9	5.6	4.6	4.3	4.3	4.3	4.3
7-8	15.93	12.6	10.8	9.3	9.3	6.5	5.8	5.5	4.6	4.3	4.3	4.3	4.3
8-9	14.38	11.7	9.9	9.2	9.2	6.4	5.7	5.4	4.5	4.2	4.2	4.2	4.2
9-10	14.4	11.3	9.6	9.1	9.1	6.3	5.6	5.3	4.4	4.1	4.1	4.1	4.1
10+	14.12	11.3	9.6	9.0	9.0	6.2	5.5	5.2	4.3	3.9	3.6	4.0	4.0
F10	29.7	27.0	24.3	22.0	17.0	8.8	8.8	8.8	8.8	6.1	6.1	6.0	6.0 2
F 9	29.7	27.0	23.8	21.8	16.9	8.6	8.6	8.6	8.6	6.1	6.0	6.0	6.0
F 8	29.7	27.0	23.4	21.6	16.9	8.4	8.4	8.4	8.4	6.0	6.0	6.0	6.0
F 7	29.7	27.0	23.0	21.4	16.8	8.2	8.2	8.2	8.2	6.0	6.0	6.0	5.9
F 6	29.7	27.0	22.5	20.6	16.6	8.0	8.0	8.0	8.0	6.0	6.0	5.9	5.9
F 5	29.7	26.5	21.6	19.8	16.4	7.8	7.8	7.8	7.8	6.0	5.9	5.9	5.9
F 4	29.7	25.1	20.7	19.0	16.2	7.7	7.7	7.7	7.7	5.9	5.9	5.9	5.9
F 3	30.0	23.6	19.8	18.2	15.9	7.9	7.9	7.9	7.9	5.9	5.9	5.9	5.8
F 2	30.0	22.4	18.9	17.8	15.6	7.7	7.7	7.7	7.7	5.9	5.9	5.8	5.8
F 1	31.0	24.77	22.77	17.2	15.3	7.4	7.4	7.4	7.4	5.9	5.8	5.8	5.8
1983	32.1	25.57	23.57	16.6	14.9	7.1	7.1	7.1	7.1	5.8	5.8	5.8	5.8
1-2	28.1	25.2	23.29	15.0	14.7	6.9	6.9	6.9	6.9	5.7	5.7	5.7	5.7
2-3	27.1	24.9	22.94	15.4	14.3	12.0	9.1	7.3	5.9	5.6	5.4	5.2	5.1

TABLE D-4. TRUCK MPG BY VEHICLE WEIGHT (CONTINUED)

3-4	26.21	3[illegible].28	28.28	13.5	12.5	11.2	8.9	7.6	5.8	5.5	5.3	5.1	4.9
4-5	26.44	22.62	20.62	11.9	10.9	10.5	8.7	7.4	5.7	5.4	5.2	5.0	4.8
5-6	26.9	20.58	18.58	10.5	9.5	9.8	8.6	7.2	5.6	5.3	5.1	4.9	4.6
6-7	26.48	21.47	19.47	9.5	8.9	9.1	8.5	7.0	5.5	5.2	5.0	4.8	4.5
7-8	19.8	10.3	9.1	8.4	8.4	8.4	8.4	6.9	5.4	5.0	4.8	4.6	4.5
8-9	19.8	10.3	8.6	7.6	7.6	7.0	6.9	6.0	5.0	4.8	4.6	4.5	4.4
9-10	19.8	10.3	8.2	6.7	6.7	6.3	5.5	5.0	4.7	4.6	4.5	4.4	4.3
10+	19.8	10.3	8.1	6.6	6.6	6.2	5.4	4.9	4.6	4.5	4.4	4.3	4.2

MOTORCYCLE - 50.00

GASOLINE BUS - 7.35

DIESEL BUS - 4.50

Source: FHWA, Office of Policy Development, Transportation Studies Division, Washington, D.C.

TABLE D-5. MILLIONS OF VEHICLE-MILES OF TRAVEL BY TRUCK MODEL YEAR AND VEHICLE SIZE

Year	Light	Medium	Light-Heavy	Heavy-Heavy(a)
1983	606.1	N/A	N/A	71.0
1982	17,788.8	483.0	276.0	3,481.9
1981	27,261.4	1,040.3	513.6	5,539.1
1980	25,569.4	900.0	709.2	7,177.8
1979	40,440.9	1,262.4	966.4	9,476.7
1978	36,380.0	865.0	789.0	7,209.6
1977	30,123.2	1,067.5	623.0	6,123.8
1976	23,645.1	601.6	398.7	2,706.5
1975	13,764.5	711.2	502.3	2,906.5
1974	17,794.0	774.4	455.0	3,656.4
1973	14,025.5	788.1	389.5	3,104.6
Pre- 1973	52,034.4	2,775.0	1,932.5	7,369.4
TOTAL	299,433.3	11,268.5	7,555.2	58,823.2

(a) For this research Heavy = Light-Heavy + Heavy-Heavy
N/A = Not available
Source: TIUS, United States, (September, 1985), Table 11.

TABLE D-6. MILLIONS OF TRUCK MILES BY VEHICLE WEIGHT AND SIZE

Weight (Pounds)	Light	Medium	Light-Heavy	Heavy-Heavy
Less than 6,001	258,509.9			
6,001 - 10,000	41,022.7			
10,001 - 14,000		5,032.3		
14,001 - 16,000		2,937.7		
16,001 - 19,500		3,300.7		
19,501 - 26,000			7,555.4	
26,001 - 33,000				4,388.4
33,001 - 40,000				3,294.3
40,001 - 50,000				7,921.3
50,001 - 60,000				7,149.5
60,001 - 80,000				35,186.3
80,001 - 100,000				769.1
100,001 - 130,000				105.4
130,001 or more				78.3

(a) For this research Heavy = Light-Heavy + Heavy-Heavy
NA = Not Available
Source: TIUS, United States (September, 1985), Table 11.

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