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VEHICLE CLASSIFICATION PROCEDURE STUDY

Final Report

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16. Abstract

A procedure was developed that can be used to estimate vehicle mix and volumes on county roads in Arizona. The methodology involves short visual sampling periods for rapid and economical estimates.

Included are recommendations for updating and maintaining the data base. Expansion factors were developed from field data collections and the data base provided by the Automatic Traffic Recorders located on elements of the State Highway Systems.

Results show that a great deal of consistency exists on roads regardless of classification relative to hourly, weekly, and monthly factors. Vehicle mix, as a percentage of volume, is independent of volume and road classification.

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INTRODUCTION

Determining the impacts of vehicle emissions, energy consumption, and facilities usage requires that the fleet mix of vehicle types be known with reasonable accuracy. Data are currently inadequate to determine the fleet mix of vehicle types using urban and rural roads in Arizona counties. Vehicle registration shows the types of vehicles registered by county, but registration data do not adequately reflect vehicle miles of travel, either by total mileage or by type of vehicle in each county.

Each county has unique tourist, recreational and economic activities that attract various combinations of users (and vehicle types) that are not accurately reflected by registration records. A methodology is needed that will permit determination of the vehicle fleet mix using the roads in each county. The methodology should be easy to use, economical, and require a minimum of field data collection. In addition, the methodology must include a technique for yearly updates if required, to account for changes that will occur in each county's populations and economic activity.

The state highways under jurisdiction of the Arizona Department of Transportation (ADOT) have good volume documentation. Permanent counting stations (28) monitor traffic volumes on a 24 hour basis. ADOT also regularly monitors volumes at other locations on the state system.

The permanent counting stations (ATR) record vehicular volumes 24 hours a day, 365 days a year. The data from these stations were used to develop hourly, daily, and seasonal factors for determining Average Daily Traffic (ADT) on these particular highways.

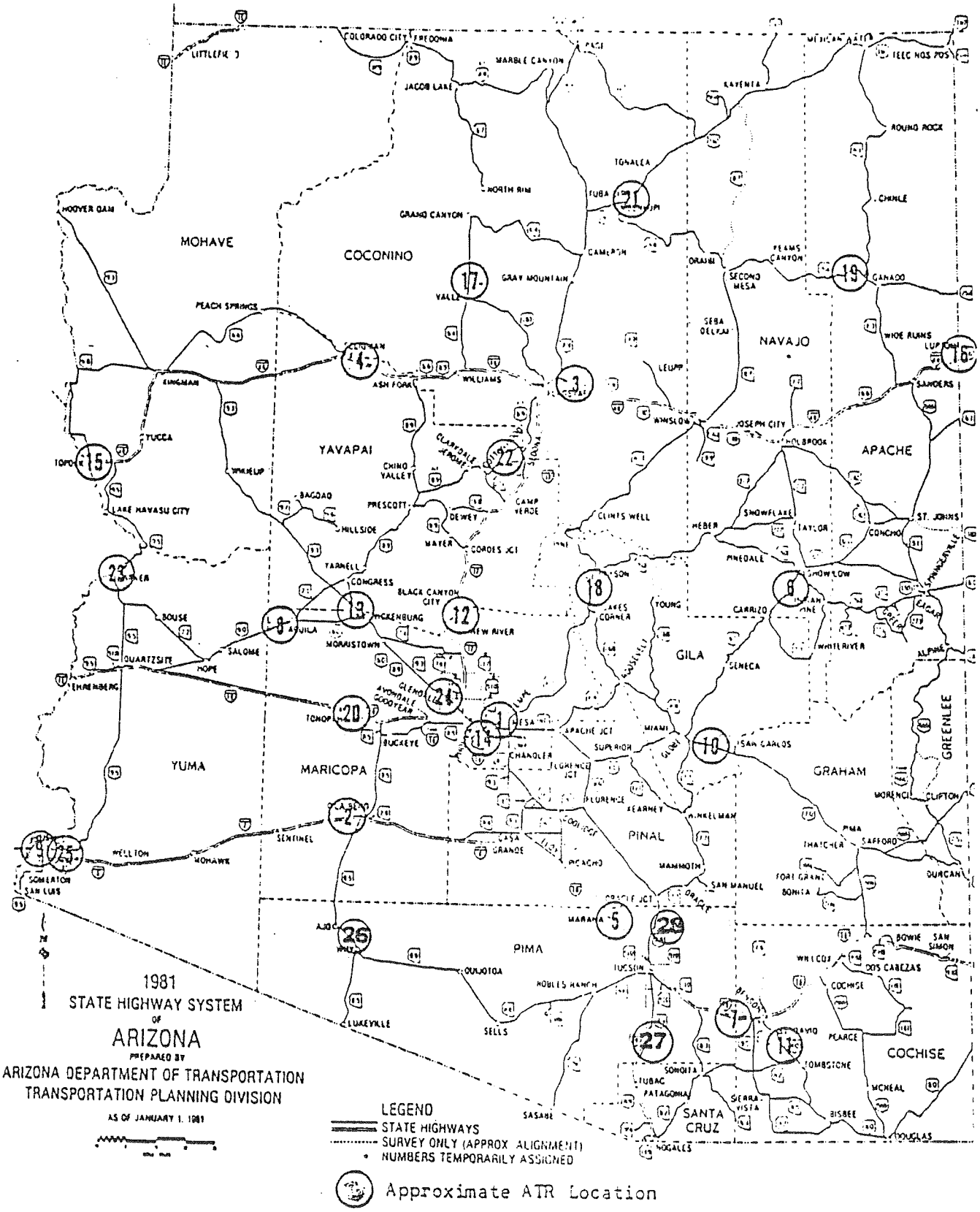

Figure 1. Approximate ATR Locations

These data provide basic volume factors that can be used to develop variation factors by hour, day of week, and season for selected highways. The locations of these permanent counting stations are dispersed throughout the state, as shown in Figure 1. Traffic volume data from these permanent counting stations were used in performing this study. The existing vehicle classification system used by ADOT (see Figure 2) was modified for use in performing this study.

A literature search revealed no similar research that could apply to this problem in Arizona. In order to be useful for Arizona's counties, the methodology developed by this study addresses specific conditions such as low rural population density and the large land areas of the counties.

Study Scope and Objectives

The primary objective of this research was to develop a methodology for use by ADOT or other agencies to determine the average fleet mix (vehicle classification) on urban and rural roads in each county. A second objective was to develop a method for annual updating of the data base using a low cost sampling procedure of sufficient accuracy for planning purposes.

Additional research questions concerned: (1) the adequacy of the number and location of permanent counting stations (ATR's) and (2) diesel powered vehicles as a percentage of all vehicles using various highways. If the ATR's are to be used to produce and maintain a permanent data base there should be adequate coverage of the highway system so that the entire state is monitored.

The research provides ADOT and other agencies with a means of estimating the average fleet mix by vehicle type on county roads with adequate accuracy for use in planning analyses; for example, functions such as energy consumption estimates and vehicle emission estimates.

VEHICLE CLASSIFICATION STUDY

Time Start_____ End_____ Road Name_____ Observer_____

Date _____ Counter: Start _____ End_____

Day M T W TH F SAT SUN Remark:_____

·Auto ·Station wagon ·Van with rear win. A	Motor-cycle B	Mobile Home C	·School Bus ·Transit Bus D	·Pickup ·Van with rear win. E	Single Truck 2 axle F	Single Truck 3 axle G	Trailer H	Truck and Trailer I	Train J	Others *

Traffic Direction ←
East
South
West
North

Traffic Direction →
East
South
West
North

Figure 2 Vehicle Classifications

METHOD OF STUDY

The approach utilized in this study began with a detailed analysis of volume data from the permanent counting stations located around the state on the state highway system. It was expected that certain patterns would be detected that could be used for establishing factors such as hourly, daily, and seasonal percentages of average daily traffic (ADT) for types of highways and areas of the state. Furthermore, it was anticipated that these factors would remain constant over time; that is, they would not vary significantly from year to year.

A set of figures was developed to show average hourly, daily, and seasonal (monthly) factors for determining ADT estimates based on data representative of each of the state's permanent counting stations for the years 1978, 1980, 1981, and 1982. These data were obtained from ADOT and represent average traffic volume. Average hourly, daily, and seasonal factors for each permanent counting station during 1982 were computed and are contained in Appendix A. It should be noted, however, that the number of counting stations increased during the time of the study. In 1978 there were 24 stations; in 1980, there were 25; and in 1981 and 1982, there were 28.

Examination of the data indicates that, as a general rule, the traffic volume factors were constant for each station from year to year. Where minor fluctuations in traffic volume factors did occur, they were usually in hourly factors representing the midnight to 5 a.m. time span.

Although not presented in this report, the data for each permanent counting station were analyzed using linear regression models available in the SAS program. Results of the analysis indicated that the data could be considered to be a straight line; that is, there was no significant variation from year to year. For this reason, the researchers decided to base this study

upon the latest available data, that obtained for the year 1982. Even though there might be small variations in the yearly factors, the researchers considered the most recent data preferable because it could better represent the actual traffic volume on the highway.

Hourly, Daily and Seasonal Factors

The hourly, daily, and seasonal factors for each permanent counting station were obtained using the following mathematical formulas:

$$\text{Hourly Percentage} = \frac{\text{average traffic volume for that hour}}{\text{average traffic volume for that day}} \times 100\% \quad \text{(Hour of Day)}$$

$$\text{Daily Percentage} = \frac{\text{average traffic volume for that day}}{\text{average traffic volume for the week}} \times 100\% \quad \text{(Day of Week)}$$

$$\text{Monthly (Seasonal) Percentage} = \frac{\text{average traffic volume for that month}}{\text{average traffic volume for the year}} \times 100\% \quad \text{(Month of Year)}$$

Corresponding hourly, daily, and monthly factors were determined from the hourly, daily, and monthly percentage values . The following example illustrates the procedure for determining the hourly factor. Initially, each hour of the 24 hour day is considered to constitute 1/24th of that day; that is, the fraction of the day each hour represents. Then, the average hourly volume is divided by the average daily volume for that day. The result is then expressed in terms of multiples of each 1/24th hour. Suppose one wants to determine the hourly factor for the 8th hour of a particular day, say Monday. Empirical data for the year indicate that the average daily volume between 8 and 9 a.m. was 592 and the average daily traffic was 5,892. Dividing 592 by 5892 indicates that, on the average, 0.1005 or 10.05% of the volume occurs from 8 to 9 AM. Since each hour is assumed to represent .0417 or (1/24) of the day, then the hourly factor is calculated as $\frac{.0417}{.1005}$ or 0.41. Thus, for this

example, the 8th hour value of 0.41 would be interpreted to mean that the average volume for this hour is higher than the average daily hourly volume. Furthermore, hourly factors greater than one indicate that the volume for that particular hour is less than the average daily volume.

Field Data Collection

Field data collection was done in order to determine vehicle mix on various types of highways. The ATR's provide data on volume but not on vehicle type. At present, this can only be done by human observers. Seven sites were selected for sampling based on functional classification and location. Figure 3 shows the approximate locations while Table 1 describes the type of highway. Williams Field Road is classified as a Major Rural Collector but is actually in the Phoenix Metropolitan Area and serves as a major access route from the Chandler/South Tempe Area to I-10.

Table 1 Sampling Sites

LOCATION	TYPE OF ROAD (Functional Classification)
Kohl's Ranch (S)*	Rural Minor Arterial
Rye (S)	Rural Minor Arterial
Wickenburg (S)	Rural Principal Arterial
Patagonia (S)	Major Rural Collector
Higley(C)**	Major Rural Collector
Williams Field (C)	Major Rural Collector
Rittenhouse Rd.(C)	Major Rural Collector

*S State System

**C County System

Local roads were not sampled.

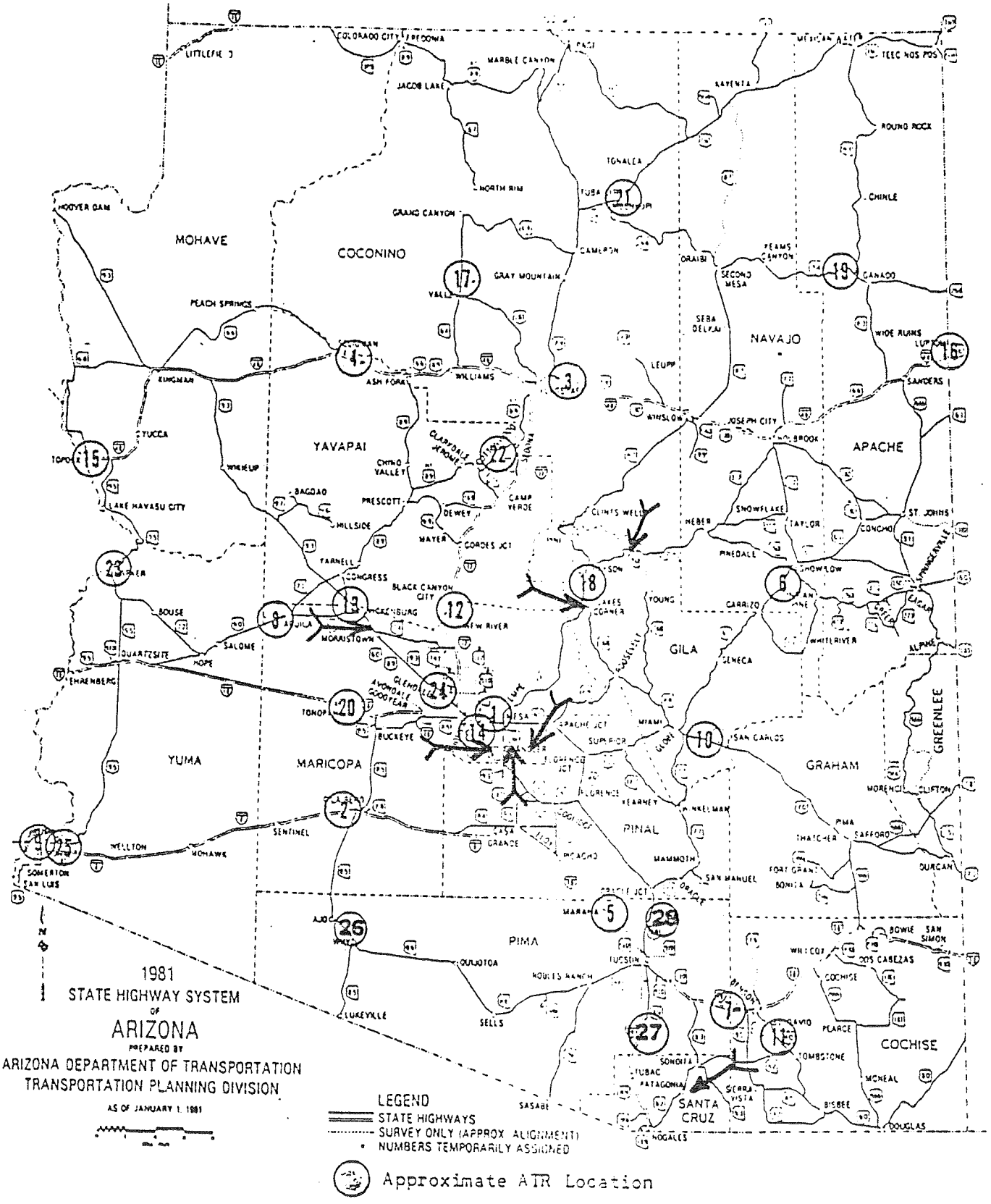

Figure 3 Approximate Sampling Sites

Development of the procedure for predicting hourly, daily, and seasonal variation factors on county roads was accomplished by obtaining empirical data from a count of the vehicle mix on several types of roads. These counts constituted a tabulation of data representing vehicle mix and volume for either 12 or 24 continuous hours. The data were taken on several roads on two different occasions in order to demonstrate that the proposed method of predicting vehicle mix as well as average daily traffic is valid and easy to implement. The recommended procedure is presented in the Conclusions and Recommendations section, below, of this report.

One of the objectives of this study was to recommend a data gathering procedure that would provide an accurate estimate of vehicle mix as well as total volume for any particular road. In arriving at the recommended procedure, it seemed reasonable that state agencies would, out of necessity, conduct vehicle classification and volume studies during regular work hours, that is, from 8 AM to 5 PM. Furthermore, during the late evening and early morning hours the volume of traffic diminishes considerably while the difficulty of correctly categorizing each vehicle becomes greater.

The recommended procedure is based upon a statistical analysis of the permanent counting stations dispersed throughout the state. It will be recalled that data were made available to ASU for each permanent counting station for the calendar years 1978, 1980, 1981, and 1982. Analyses of the data indicate that, on the average, the hourly, daily, and seasonal percentages were the same from year to year. This can be readily seen by an examination of the hourly, daily, and seasonal factors for each ATR in Appendix D. Furthermore, since the data can be shown to be constant (in a statistical sense) from year to year, it was decided to use the hourly 1982 data as the

baseline for this study. Empirical data collected during the study were then compared using this baseline data and conclusions drawn.

It was also of interest during the study to determine the total percent of ADT represented by selected 3 or 4 hour time segments. This part of the study was restricted to 1982 data for each of the 28 counting stations. Appendix A contains the data applicable to each station for the calendar year 1982 as a function of hourly, daily, and seasonal factors. The results of the study are presented in Table 2.

Table 2 Hourly Percent of ADT for Permanent Counting Stations

HOURS	AVERAGE	STANDARD DEVIATION
8-11 AM	18%	2%
8-12 AM	24%	2%
1-4 PM	21%	2%
1-5 PM	29%	3%

As shown in Table 2, approximately 18 and 21 percent of the ADT is represented during the three hour time intervals from 8-11 AM and from 1-4 PM, respectively. Four hour time intervals during the hours 8-12 AM or 1-5 PM represent 24 and 29 percent, respectively, of the ADT. Suppose now that it is desired to take 4 hours of vehicle classification data during a day. If the decision is made to obtain the vehicular data during the hours 1-5 PM, one would expect to observe 29 percent of the ADT during that time interval. Further examination of Table 2 indicates that three of the four interval considerations had a standard deviation of 2 percent, while one interval, from 1-5 PM, had a standard deviation of 3 percent. It will be recalled that the standard deviation indicates the amount of variation in the data. The larger the standard deviation, the greater the amount of variation. Since the

standard deviation is small in each case, one can conclude that the percentage of hourly volume is consistent from station to station for these time intervals.

A statistical analysis was conducted of the empirical data taken over each 24 hour interval in order to determine it similar percentages were observed during the prescribed time intervals. The average percentage deviation was accurate to within 1 percent for each of the four time categories, while the average standard deviation within each category was somewhat higher at 3.5 percent. Since it was difficult to obtain a large number of 24 hour counts, these values are exceptionally close to those obtained on a yearly basis from the permanent counting stations.

Approximately 80 percent of the traffic volume occurs between 6 AM and 6 PM on the monitored highways. Analyses of the empirical data representing twelve hours of data collection indicated hourly percent values very close to the 80 percent value. This finding reinforces the conclusion that permanent counting station data can be used to estimate vehicle mix as well as ADT on other highways.

In order to account for possible traffic pattern differences by location within the state, the ATR's were grouped into three distinct regions for analytical purposes (see Figure 4). Tables 3, 4, and 5 contain the average values for the hourly, weekly, and seasonal factors for the ATR's in the northern, southeastern, and southwestern regions respectively.

Field Testing

Field testing of the methodology was done next. It will be shown that there is a strong correlation between the data derived from actual counts and

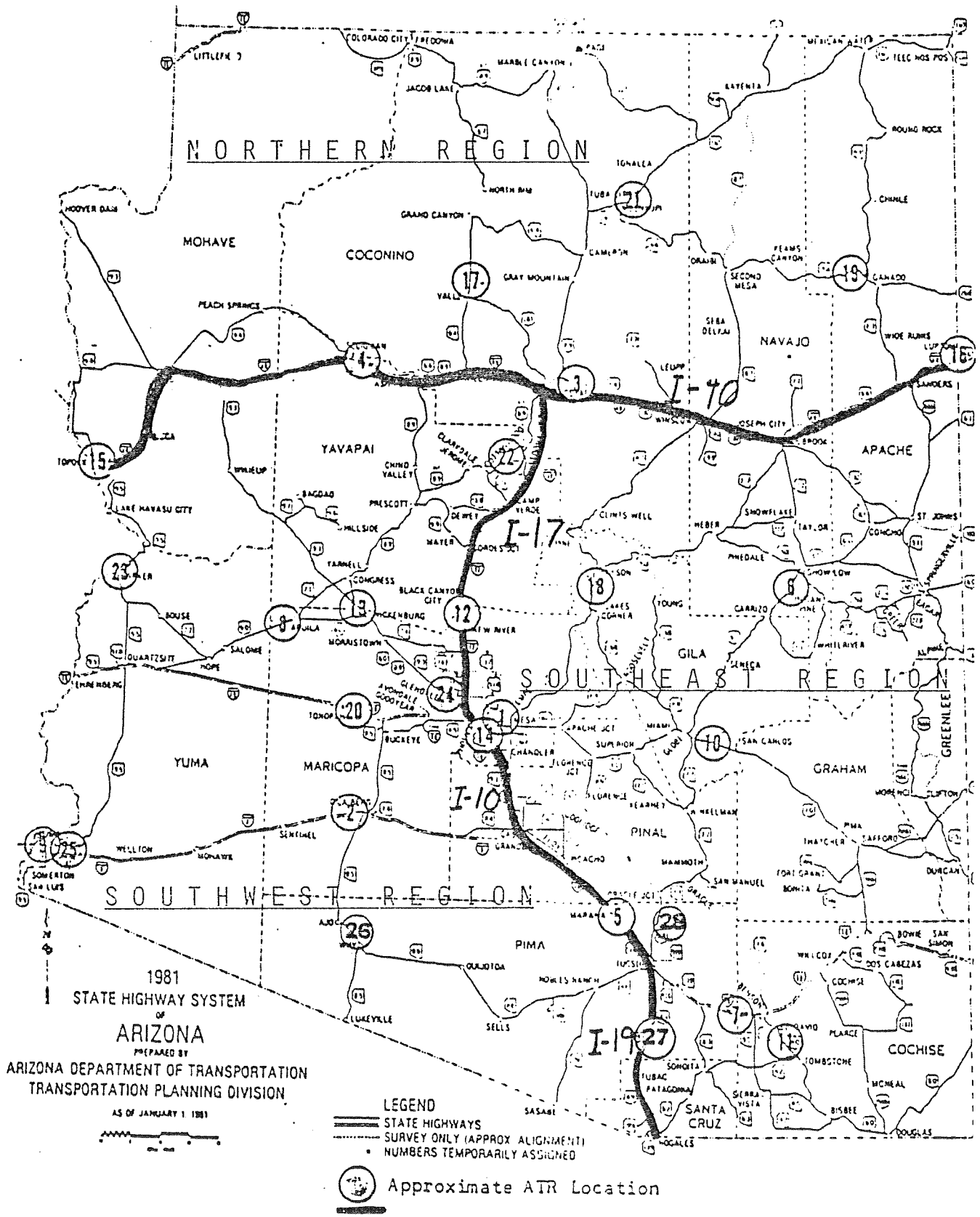

Figure 4 Approximate ATR Locations and Regional Boundaries

TABLE 3

HOURLY, DAILY AND SEASONAL ADT FACTORS
NORTHERN REGION

HOURLY VARIATION OF TRAFFIC VOLUME ON THE NORTHERN STATE HIGHWAY SYSTEM

Hour	Per Cent of Total 24 Hour Volume	Hour	Per Cent of Total 24-Hour Volume
12:00- 1:00 A.M.	0.47	12:00- 1:00 P.M.	7.40
1:00- 2:00 A.M.	0.30	1:00- 2:00 P.M.	7.57
2:00- 3:00 A.M.	0.20	2:00- 3:00 P.M.	7.83
3:00- 4:00 A.M.	0.20	3:00- 4:00 P.M.	8.07
4:00- 5:00 A.M.	0.33	4:00- 5:00 P.M.	8.20
5:00- 6:00 A.M.	0.97	5:00- 6:00 P.M.	7.43
6:00- 7:00 A.M.	2.33	6:00- 7:00 P.M.	5.80
7:00- 8:00 A.M.	3.90	7:00- 8:00 P.M.	4.20
8:00- 9:00 A.M.	0.55	8:00- 9:00 P.M.	3.13
9:00-10:00 A.M.	6.97	9:00-10:00 P.M.	2.10
10:00-11:00 A.M.	7.53	10:00-11:00 P.M.	1.37
11:00-12:00 P.M.	7.57	11:00-12:00 Midnight	0.77

DAILY VARIATION OF TRAFFIC VOLUME ON THE NORTHERN STATE HIGHWAY SYSTEM

Day	Per Cent of Total Weekly Volume	Per Cent of Average Day	Weekly Factor
Sunday	13.97	97.79	1.023
Monday	14.07	98.49	1.015
Tuesday	13.60	95.20	1.050
Wednesday	13.77	96.39	1.038
Thursday	13.67	95.69	1.045
Friday	15.83	110.81	0.902
Saturday	15.17	106.91	0.942

SEASONAL VARIATION BY MONTHS ON NORTHERN STATE HIGHWAY SYSTEM

Month	Per Cent of Total Yearly Volume	Monthly Factor	Month	Per Cent Total of Yearly Volume	Monthly Factor
January	5.10	1.6340	July	11.50	0.724b
February	5.83	1.4294	August	11.30	0.7375
March	6.93	1.2025	September	9.33	0.8932
April	8.27	1.0077	October	8.83	0.9438
May	8.93	0.9332	November	6.80	1.2255
June	11.17	0.7460	December	5.90	1.4124

TABLE 4

HOURLY, DAILY, AND SEASONAL ADT FACTORS
SOUTHEAST REGION

HOURLY VARIATION OF TRAFFIC VOLUME ON THE SOUTHEAST STATE HIGHWAY SYSTEM

Hour	Per Cent of Total 24 Hour Volume	Hour	Per Cent of Total 24-Hour Volume
12:00- 1:00 A.M.	1.03	12:00- 1:00 P.M.	7.15
1:00- 2:00 A.M.	0.77	1:00- 2:00 P.M.	7.12
2:00- 3:00 A.M.	0.40	2:00- 3:00 P.M.	7.33
3:00- 4:00 A.M.	0.38	3:00- 4:00 P.M.	7.68
4:00- 5:00 A.M.	0.50	4:00- 5:00 P.M.	7.80
5:00- 6:00 A.M.	1.08	5:00- 6:00 P.M.	7.23
6:00- 7:00 A.M.	2.55	6:00- 7:00 P.M.	5.60
7:00- 8:00 A.M.	4.62	7:00- 8:00 P.M.	4.38
8:00- 9:00 A.M.	5.08	8:00- 9:00 P.M.	3.38
9:00-10:00 A.M.	5.80	9:00-10:00 P.M.	2.82
10:00-11:00 A.M.	6.62	10:00-11:00 P.M.	2.17
11:00-12:00 P.M.	7.02	11:00-12:00 Midnight	1.52

DAILY VARIATION OF TRAFFIC VOLUME ON THE SOUTHEAST STATE HIGHWAY SYSTEM

Day	Per Cent of Total Weekly Volume	Per Cent of Average Day	Weekly Factor
Sunday	14.72	103.04	.9705
Monday	13.85	96.95	1.0315
Tuesday	12.93	90.51	1.1049
Wednesday	13.13	91.91	1.0880
Thursday	13.57	94.99	1.0527
Friday	16.80	117.60	.8503
Saturday	15.02	105.14	.9511

SEASONAL VARIATION BY MONTHS ON SOUTHEAST STATE HIGHWAY SYSTEM

Month	Per Cent of Total Yearly Volume	Monthly Factor	Month	Per Cent of Average Month	Monthly Factor
January	7.48	1.1141	July	9.08	0.9178
February	7.95	1.0482	August	8.82	0.9448
March	8.33	1.0004	September	8.43	0.9885
April	8.57	0.9724	October	8.33	1.0004
May	8.73	0.9546	November	7.78	1.0711
June	8.67	0.9612	December	7.88	1.0575

TABLE 5

HOURLY, DAILY, AND SEASONAL ADT FACTOR
SOUTHWEST REGION

HOURLY VARIATION OF TRAFFIC VOLUME ON THE SOUTHWEST STATE HIGHWAY SYSTEM

Hour	Per Cent of Total 24 Hour Volume	Hour	Per Cent of Total 24-Hour Volume
12:00- 1:00 A.M.	1.04	12:00- 1:00 P.M.	7.27
1:00- 2:00 A.M.	0.96	1:00- 2:00 P.M.	7.33
2:00- 3:00 A.M.	0.59	2:00- 3:00 P.M.	7.54
3:00- 4:00 A.M.	0.47	3:00- 4:00 P.M.	7.67
4:00- 5:00 A.M.	0.61	4:00- 5:00 P.M.	7.57
5:00- 6:00 A.M.	1.24	5:00- 6:00 P.M.	6.86
6:00- 7:00 A.M.	2.57	6:00- 7:00 P.M.	5.30
7:00- 8:00 A.M.	4.33	7:00- 8:00 P.M.	4.07
8:00- 9:00 A.M.	4.96	8:00- 9:00 P.M.	3.21
9:00-10:00 A.M.	6.07	9:00-10:00 P.M.	2.74
10:00-11:00 A.M.	6.86	10:00-11:00 P.M.	2.11
11:00-12:00 P.M.	7.10	11:00-12:00 Midnight	1.47

DAILY VARIATION OF TRAFFIC VOLUME ON THE SOUTHWEST STATE HIGHWAY SYSTEM

Day	Per Cent of Total Weekly Volume	Per Cent of Average Day	Weekly Factor
Sunday	14.21	99.47	1.005
Monday	14.20	99.40	1.006
Tuesday	13.47	94.29	1.061
Wednesday	13.56	94.92	1.054
Thursday	13.83	96.81	1.033
Friday	16.34	114.38	0.874
Saturday	14.40	100.80	0.9921

SEASONAL VARIATION BY MONTHS ON SOUTHWEST STATE HIGHWAY SYSTEM

Month	Per Cent of Total Yearly Volume	Monthly Factor	Month	Per Cent of Total Yearly Volume	Monthly Factor
January	7.90	1.0549	July	8.01	1.0404
February	9.00	0.9259	August	7.57	1.1008
March	9.07	0.9188	September	8.83	0.9438
April	9.36	0.8903	October	8.19	1.0175
May	8.89	0.9374	November	8.19	1.0175
June	8.21	1.0150	December	8.04	1.0365

the predicted vehicle mix and ADT based on statistical data from representative permanent counting stations by region.

The data representing vehicle mix and volume for each highway are contained in Appendix C. It will be observed that each hour of the data summary is expressed in terms of number and type of vehicles tallied during that hour. In addition, the total numbers of each type of vehicle are indicated. To illustrate the interpretation of these data, consider Table 17 in Appendix C, pertaining to Wickenburg. The data were taken on Friday, July 22, 1983, from 6 AM until 6 PM. The total number of vehicles counted during this time was 4662. The total number of Category A vehicles (autos, station wagons, and vans with rear windows) was 2950, representing 63.3 percent of all vehicles. Similarly, Category E vehicles (pickups and vans without rear windows) represented 23.7 percent of the total volume.

Analysis of the data collected in the field proceeded with calculation of the percentage contribution of each type of vehicle for each hour. Although there was some slight variation from hour to hour, the percentages remained relatively constant. This observation was independent of the volume experienced on the highway. When the data were first analyzed, the researchers attempted to fit a line to each set of hourly data percentages using linear regression methods. The linear regression method proved inappropriate because of the lack of hourly variation, leading to the conclusion that, for all practical purposes, the percentage of each type of vehicle could be considered to be a constant.

Vehicles classified in Category A, autos, station wagons, and vans with rear windows, and E, pickups and vans without rear windows, account for 89 percent of all traffic. This number is representative of all of the observational data taken during the study. In fact, the percentages of vehicle

mix on all the observed highways were surprisingly consistent. This consistency is shown in the Table 6.

Table 6 Vehicle Mix Percentages

Highway Location	VEHICLE TYPE									
	A	B	C	D	E	F	G	H	I	J
KOHL'S RANCH	54.5	0.7	5.6	0.5	32.3	2.0	0.4	3.0	0.6	0.5
RYE	57.5	0.8	4.9	0.1	30.1	1.4	0.4	3.8	0.4	0.4
WICKENBURG	63.3	0.9	3.2	0.6	23.7	2.7	0.3	4.1	0.9	0.1
WICKENBURG*	60.2	0.1	3.0	0.8	21.1	4.1	1.4	7.1	1.8	0.5
PATAGONIA	64.0	0.6	2.0	0.2	26.9	4.1	0.2	1.9	0	0
HIGLEY	58.2	1.4	0.5	0	33.2	3.2	2.3	1.1	0.1	0
HIGLEY*	58.9	1.2	0.4	0.5	34.0	2.0	0.9	0.9	1.2	0.1
WILLIAMS FIELD	58.4	1.5	0.5	0.1	29.3	3.2	2.2	3.7	0.8	0.1
WILLIAMS FIELD*	66.1	1.4	0.4	0.2	25.5	2.6	2.6	2.6	0.4	0.1
RITTENHOUSE ROAD	57.1	1.0	0.4	0.5	35.1	3.2	0.6	0.5	1.5	0.1
AVERAGE	60.8	1.1	1.8	0.3	27.9	2.8	1.0	3.3	0.8	0.2

*INDICATES AN ADDITIONAL DAY OF DATA ACQUISITION

As indicated in Table 6, vehicles in Category A ranged from a low of 54.5 percent to a high of 66.1 percent. For those roads where two independent samples were taken, the percentage deviation ranged from a maximum of 8 percent for Williams Field to a minimum of 0.7 percent for Higley road. For Category E vehicles, the overall average was 27.9 percent. The lowest percentage, 21.1, was observed at Wickenburg while a high of 35.1 percent was calculated for Rittenhouse Road.

DATA ANALYSIS

This section contains the results of the statistical analysis of vehicle type and volume data collected during the study. Each data set was collected during either a 12 or 24 hour segment. In several instances, data collections were repeated at the same location at a later date. These second collections

were for the purpose of validating the recommended methodology for determining vehicle mix and ADT.

At the onset of the study it was recognized that the recommended methodology should be one that provides reliable vehicle mix and ADT estimates yet is not difficult to implement.

ATR Locations and Regional Boundaries

The state was separated into three geographical regions in order to use data from the permanent counting stations more effectively. Figure 4 illustrates the division into three parts as a function of the interstate routes I-40, I-17, I-10, and I-19. The northern region is the area north of I-40 and contains ATR numbers 17, 19, and 21. The southeast section is the region south of I-40 and east of I-17, I-10, and I-19. It contains ATR numbers 1, 6, 10, 11, 18, and 28. Lastly, the southwest section is the area south of I-40 and west of I-17, I-10, and I-19. This section contains permanent counting station numbers 8, 9, 13, 22, 23, 24, and 26. The interstate ATR's were analyzed for informational purposes only; however, data applicable to these ATR's were not included in any of the 1982 baseline data used in constructing Tables 3, 4, and 5.

Proposed Method For Determining Hourly, Daily & Seasonal Factors

Hourly, daily and seasonal factors were determined by combining data from all of the permanent counting stations in each of the three regions. The method used to determine regional factors is presented in the following paragraphs.

For example, consider Table 4, for the southeast region, and, in particular, each of the hourly percentage values. Initially, the sum of the percentages for each hour at each station was obtained. This value was then

divided by the number of permanent counting stations in the region (in this case, six). The result is a set of percentage values applicable to each hour for highways located in the southeast region of the state.

Determining the daily and seasonal factors for Table 4 was accomplished in the same way. The daily percentage contribution of each counting station was summed and the resulting value divided by six. The monthly factor was computed using the same procedure.

The same procedure was performed to determine factors for the northern and southwest regions. The number of stations contained in the northern region is three, while the number of stations contained in the southwest region is seven.

Averaging the data from each permanent counting station in a region produced a set of tabular values for each geographical region in the state. Once data have been collected from a particular highway, the appropriate tabular values can be used to predict vehicle mix and ADT, following the procedures set forth in subsequent sections of this report.

Vehicle Mix Representative Values

The representative percentage values for each type of vehicle, indicated in Table 7, were used to develop the recommended procedure for predicting vehicle mix and ADT. The principal advantage of using representative percentages is their simplicity; all that is required to predict vehicle mix and ADT are data on the volume observed during the sampling interval. The possibility of making mathematical errors in computing percentages is precluded by using representative values. Furthermore, the need to collect data on vehicle mix data in the field is eliminated.

TABLE 7

AVERAGE VEHICLE MIX

	Vehicle Type	Percent of Total
A.	Auto Station wagon Van with rear window	60.8%
B.	Motorcycle	1.1%
C.	Mobile home	1.8%
D.	School bus Transit bus	0.3%
E.	Pickup Van without rear window	27.9%
F.	Single truck, 2 axle	2.8%
G.	Single truck, 3 axle	1.0%
H.	Trailer	3.3%
I.	Truck and trailer	0.8%
J.	Train	0.2%
	TOTAL	100.0%

Recommended Procedure for Determining Vehicle Mix and ADT

The procedure recommended for determining vehicle mix as well as ADT is presented in this section. The analysis is based upon the empirical data collected during the study. Counts were taken during either a 12 or 24 hour sampling interval. The data, expressed as a function of vehicle mix and volume applicable to each highway, are contained in Appendix C.

Table 8 compares predicted and actual vehicle mix and volume for one of the highways sampled during the study. The table also compares data collected during 3 and 4 hour sampling intervals and in the morning and afternoon. The intervals were chosen as potential sampling times available to the state. The method of analysis was identical for each road in the study; however, the hourly percentages were modified when data was collected during a 12, rather than 24, hour period or when data were not available for a particular hour. The modification of hourly percentages is discussed more fully in the following paragraphs.

Consider the Patagonia data comparisons presented in Table 8. The total vehicle volume observed during 12 hours of data collection was 931. In preparing this table and the others in Appendix B, the researchers assumed that one sample of vehicle mix and volume data was collected during each of the four intervals: 8-11 AM, 8-12 AM, 1-4 PM, and 1-5 PM. During the 12 hours of data collection, Type A vehicles made up 64% (596/931) of all vehicles. In the interval 8-11 AM, however, Type A vehicles made up 58% (132/226) of the total. During the 8-12 AM interval, type A vehicles were 61% (191/313) of the total. In the same way, Category A vehicles made up 58% and 60% of all vehicles in the sampling intervals of 1-4 PM and 1-5 PM, respectively. From these data, one can see that the percentage of type A vehicles may vary from interval to interval. It follows that percentages for the rest of the vehicle types will

TABLE 8

PATAGONIA DATA COMPARISONS

12 HOUR VOLUME: 931

Day: Wednesday
Date: 8-3-1983

HOURS	PERCENTAGE	ACTUAL VOLUME	PREDICTED 12 HR VOLUME	DIFFERENCE	PERCENT ERROR
8 - 11AM	22.14	226	1021	90	9.7
8 - 12AM	31.02	313	1009	78	8.4
1 - 4PM	27.99	277	990	59	6.3
1 - 5PM	37.86	371	980	49	5.3

Vehicle Type	8 - 11AM			8 - 12AM			1 - 4PM			1 - 5PM			12 HR VOLUME		
	Pred	Act	Δ	Pred	Act	Δ	Pred	Act	Δ	Pred	Act	Δ	Pred	Act	Δ
A	138	132	6	190	191	-1	169	160	9	226	222	4	567	596	-29
B	2	3	- 1	3	3	0	3	2	1	4	2	2	10	6	4
C	4	7	- 3	5	8	-3	5	6	- 1	6	7	0	16	19	- 3
D	1	0	1	1	0	1	1	0	1	1	0	1	3	2	1
E	63	60	3	87	84	3	77	92	-15	103	117	-14	260	250	10
F	6	16	-10	9	18	-9	8	12	- 4	10	15	- 5	26	38	-12
G	2	1	1	3	2	1	3	0	3	4	0	4	9	2	7
H	7	7	0	10	7	3	9	5	4	12	8	4	30	18	12
I	2	0	2	3	0	3	2	0	2	3	0	3	7	0	7
J	0	0	0	1	0	0	1	0	1	1	0	0	2	0	2

vary in a similar manner. This variation in percentages of vehicle types throughout the day is one of the primary reasons for using representative percentages. The percentages are based upon the entire set of data and more nearly represent each type of vehicle.

If a four hour sample were taken using a counter located on the Patagonia highway from 1-5 PM, the counter would tabulate data on the same day and in the same location that the 12 hour data were taken. In theory, the counter would indicate a traffic volume of 371 vehicles during the four hour count, identical to the actual number of observed vehicles. Using only the volume data provided by the counter, one can predict both the vehicle mix during this four hour interval and the vehicle mix and volume for the 12 hour interval from 7 AM to 7 PM. (Estimates for 24 hours of data could be made. Since no 24 hour count was taken, however, predicted data vs. actual data could not be compared with actual.)

Initially, the hourly percentages from 7 AM to 7 PM are added, using the data contained in Table 4. This gives a value of 79.05. Then, one must modify each hour's percentage contribution to a 24 hour volume, since the data represent a 12 hour interval. Consequently, each hourly percentage value from 7 AM to 7 PM is multiplied by 1.26502 (1.0/.7905). This procedure forces the sum of the hourly percentage values to one. It is now possible to compare the predicted 12 hour volume based on four hours of volume data obtained by the counter with the actual volume obtained by personal count.

The sum of the hourly percentages from 1-5 PM is 29.92 (from Table 4). Multiplying that sum by 1.26502 yields a value of 0.3786. This means that approximately 38% of the total volume of traffic occurs between 1 to 5 PM if the day were considered a 12 hour day from 7 AM to 7 PM. Using the counter value of 371 vehicles, the 12 hour volume is predicted:

$$\text{Predicted Volume/12 hours} = 371/0.3786 \qquad (1)$$

$$= 980 \text{ vehicles.}$$

This estimate compares favorably with the actual volume of 931 vehicles. The percent error is calculated:

$$\text{Percent Error} = \frac{\text{Pred. Volume} - \text{Actual Volume}}{\text{Actual Volume}} (100\%)$$

In this case, the percent error is calculated:

$$\text{Percent Error} = \frac{980 - 931}{931} (100\%)$$

$$= 5.3\%$$

This same procedure is followed to predict 12 hour volume estimates, by assuming that the counter provided data taken during each of the three intervals, 8-11 AM, 8-12 AM, and 1-4 PM. A percent error of 9.7%, obtained during the 8-11 AM interval, was the maximum percent error in the corresponding three estimates of 12 hour volume.

A 24 hour volume estimate could also be obtained by dividing the 12 hour volume by .7906. These values, however, could not be compared since 24 hour data are not available.

Table 8 also contains estimates of the predicted vehicle mix based upon the time of day the sample was taken. For this estimate, the representative percentage values applicable to each type of vehicle are used. Continuing with the 1-5 PM sample and the actual volume of 371 vehicles provided by the counter, the predicted number of Category A vehicles would be the product of 371 and 0.608, giving 226. The result is then compared to the actual number of Category A vehicles observed during this interval. Since it is known that there were 222 Category A vehicles observed during this time, a prediction

error of 4 has occurred. This error is indicated by the Δ symbol, representing the difference between predicted and actual values. If Δ is positive then the predicted value exceeds the actual; if negative, the predicted value is less than the actual value. Similarly, the predicted number of Category E vehicles would be obtained by multiplying 371 by 0.279. This prediction of 103 vehicles is compared to the actual number of 117 observed. The difference is 14 less than actually observed, resulting in a value equal to -14. The same procedure can be repeated for each vehicle type to determine the Δ value.

Table 8 also compares predicted and actual volume if the counter obtained data for the intervals 8-11 AM, 8-12 AM, and 1-4 PM. By comparing the value of Δ for each of the time intervals, one can see that the recommended procedure for determining vehicle mix (using the hourly data of Table 4 and representative percentage values of Table 7) in conjunction with the counter provides reliable estimates.

A different method was used to calculate the last comparison in Table 8. The objective of this comparison was to determine the predicted vehicle mix based upon the known volume of 931 vehicles. (We are, in effect, assuming that the counter was placed on the highway during the 12 hour interval.) The volume was multiplied by the representative percentage for each vehicle type and compared to the actual number observed. The largest value for Δ was -29 for Category A vehicles while the smallest value was 1 for Category D vehicles.

No attempt was made to compute a percent error for the separate vehicle types in each of the four time categories, because it would provide a misleading basis for decisions. For example, if 6 of a particular type of vehicle were expected and 10 were observed, the resulting Δ value would be -4. However, the percentage error would be 67% (6-10/6). Therefore, percentage error was computed only for the overall sampling interval.

Calculation of the percentage value for each time segment is a function of the hours the sample was taken. For example, some of the data collection started at 6 AM and terminated at 6 PM. To determine the correct multiplier for each percentage represented in the 12 hour segment, one would sum the percentages for the 6 AM to 6 PM time interval.

Turning to Table 9, for Rittenhouse Road, the total vehicle volume observed during the 24 hour data collection period was 3093. If a counter were placed on the highway during the time interval of 8-11 AM, it would indicate a volume of 570 vehicles during this time. The hourly percentage contribution for 8-11 AM is 17.5, determined from Table 4. There is no need to modify the percentage estimates since we are comparing data obtained during a 24 hour interval. The predicted volume of 3257 vehicles is obtained by dividing the counters volume count of 570 by 0.1750. This predicted value is in error by 164 vehicles, representing a 5.3 percent error. The same procedure would be followed if the counter collected volume data during the 8-12 AM, 1-4 PM, and 1-5 PM intervals. The percent error ranged from 2.1 (8-12 AM interval) to 7.5 (1-4 PM interval).

The lower section of Table 9 indicates the relative accuracy of the prediction methodology. Again using the 8-11 AM data provided by the counter, one would predict the vehicle mix by multiplying the volume of 570 vehicles by the appropriate percentage value for that particular type of vehicle. For specific vehicle types, ranges from a high of 61 to a low of -34; that is, over-predicting Category A vehicles and under-predicting Category E vehicles. The same situation occurs in the other time intervals and can be explained by the location of Rittenhouse Road. It is primarily an area of extensive agricultural use, where a larger percentage of trucks and a correspondingly smaller percentage of cars comprise the vehicle mix. Consequently, using the

TABLE 9

RITTENHOUSE DATA COMPARISONS

24 HOUR VOLUME: 3093

Day: Friday
Date: 2-10-84

HOURS	PERCENTAGE	ACTUAL VOLUME	PREDICTED 24 HR VOLUME	DIFFERENCE	PERCENT ERROR
8 - 11AM	17.50	570	3257	164	5.3
8 - 12AM	24.52	742	3026	- 67	2.1
1 - 4PM	22.13	633	2860	-233	7.5
1 - 5PM	29.93	905	3024	- 69	2.2

Vehicle Type	8 - 11AM			8 - 12AM			1 - 4PM			1 - 5PM			24 HR VOLUME		
	Pred	Act	Δ	Pred	Act	Δ	Pred	Act	Δ	Pred	Act	Δ	Pred	Act	Δ
A	347	286	61	452	376	76	385	352	33	551	502	49	1882	1766	106
B	6	2	4	8	2	6	7	7	0	10	11	- 1	34	31	3
C	10	1	9	13	2	11	11	1	10	16	3	13	54	11	43
D	2	2	0	2	4	- 2	2	8	- 6	3	8	- 5	10	15	- 5
E	159	193	-34	207	254	-47	176	229	-53	252	335	-83	862	1087	-225
F	16	44	-28	21	55	-34	18	25	- 7	25	33	-13	87	98	- 11
G	6	12	- 6	8	13	- 5	6	2	4	9	3	6	32	18	14
H	19	10	9	24	10	14	21	0	21	30	0	30	101	16	85
I	5	19	-14	6	25	-19	5	9	- 4	7	10	- 3	25	47	- 22
J	5	1	4	1	1	0	1	0	1	2	0	2	6	3	3

representative percentage values of 60.8 and 27.9 instead of the observed percentage values for that road of 57.1 and 35.1 for Category A and E vehicles, respectively, yields larger errors. One might argue that the estimates of vehicle mix for this road should be used instead of the overall percentage values. The argument is refuted by examining a 4 hour data collection interval from 8 AM to noon. Type A vehicles would be estimated to comprise 50.7 percent of the mix. One would then predict the number of Category A vehicles to be 1534, resulting in an under-prediction of 232 vehicles.

The remaining tables for each of the roads analyzed in the study are contained in Appendix B. Percentage error estimates for predicted volume range from a low of 0.2 percent for Wickenburg to a high of 29.8 percent for Williams Field road. Examination of the 12 hour Wickenburg data reveals that the hourly percentage mix is basically constant (see the Wickenburg data sheet in Appendix C). However, Williams Field Road exhibits considerable variation, not only in percentage mix, but also in hourly volume percentages. This particular road has high traffic volume during the early morning hours (from 6 to 8 AM) and mid-afternoon hours (from 2 to 6 PM). Attempting to estimate vehicle mix percentages using either of these time intervals could result in significant errors. Care must be exercised when interpreting prediction data on any highway exhibiting volume and vehicle mix fluctuations.

Prediction Methodology Accuracy

How good is the recommended technique is for predicting volume and vehicle mix? The average error was 10.2 percent for predicting either 12 or 24 hour volumes. If the 27.8 and 29.8 percent errors for Williams Field Road were deleted from the calculation, the average percent error for the 38 remaining points would be 9.2. Furthermore, deletion of the entire Williams Field Road data would provide an overall error estimate of 8.5 percent with a standard

deviation of 5.3 percent. It can be argued that the Williams Field Road data have a disproportionate effect upon the mean because of the high values, both shifting the overall percentage error higher and enlarging the standard deviation associated with the mean percent error.

One can conclude, therefore, that the recommended procedure for determining traffic volume and vehicle mix, based upon the sample data, provides estimates whose errors average at most 10.2 percent. This estimate is reduced to 8.5 percent if the Williams Field Road data are considered not representative of the remaining highways.

The preceding examples for the Patagonia and Rittenhouse Road highways have demonstrated that the recommended procedure for determining vehicle mix and volume for assumed sampling hours gives reasonable and accurate results. Additional calculations must be performed to determine ADT and yearly vehicle mix estimates. In order to accomplish this, an estimate of 24 hour volume on the selected highway must be available. Recall that the Patagonia highway was sampled for 12 hours, resulting in 931 vehicles. This volume would be divided by 0.7905, giving a 24 hour estimate of 1178 vehicles (931/0.7905). The Rittenhouse Road highway was sampled over 24 hours; consequently, the observed volume of 3093 vehicles is unchanged.

Determination of the ADT and yearly vehicle mix is straightforward once the 24 hour volume is known or estimated. The following calculations need to be made:

(1) Multiply the 24 hour volume by the appropriate weekly factor. This factor relates to the day of the week on which the data were collected. Tables 3, 4, and 5 contain the necessary information on hourly, weekly, and monthly factors. Select the table corresponding to the region where the highway is located, using Figure 4.

(2) Multiply the number calculated in (1) above by the appropriate monthly factor. This factor relates to the month of the year in which the data were collected. Again, it must be selected from Table 3, 4, or 5, depending on the region where the highway is located. This value provides an estimate of the ADT for this particular highway.

(3) Multiply the ADT value obtained in (2) above by the representative percentages for each vehicle type. These percentage values are contained in Table 7. The estimate of yearly vehicle mix by vehicle type is now available for this highway.

As an illustration of the above recommended procedure, consider Rittenhouse Road. The observed volume of 3093 vehicles was collected on a Friday during the month of February. The appropriate weekly and monthly factors, obtained from Table 4, are 0.8503 and 1.0482, respectively. Multiplying 3093 by 0.8503 gives an average daily volume of 2630 vehicles. This volume is now multiplied by 1.0482, resulting in an estimated ADT value of 2757 vehicles for Rittenhouse Rd. during the year. The vehicle mix estimates are easily obtained once the ADT is estimated. The ADT vehicle mix for Category A vehicles would be 1676 (2757 x 0.608) while for Category E vehicles it would be 769 (2757 x 0.279). Similar estimates for the remaining vehicle classifications could be made using the appropriate percentage contribution to vehicle mix.

For the Patagonia highway, where data were collected on a Wednesday in August, the appropriate weekly and monthly factors are 1.0880 and 0.9448, respectively. Performing the calculations in steps (1) through (3) on the 24 hour volume estimate of 1178 gives an ADT estimate for this highway of 1211

vehicles. The estimated number of Category A vehicles would be 736; of Category E vehicles, 338.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations of this study are contained in this section. Important conclusions drawn during the study and presented in the preceding sections are summarized below:

(1) Hourly, daily, and monthly traffic volume data are basically constant from year to year. Where minor fluctuations in traffic volume were observed, they were usually in the hourly factors during the midnight to 5 AM time span.

(2) Hourly, daily, and monthly factors for 1982 were used as the baseline data during the study. The research team chose to use the most current data since it could better represent the actual traffic volume on Arizona's highways.

(3) Traffic volume during the 6 AM to 6 PM interval constitutes approximately 80 percent of the volume. This percentage was observed at all the ATR's and was duplicated in the 24 hour counts taken by the research team.

(4) The recommended method for predicting vehicle mix and volume data was shown to have an average error of 10.2 percent. If the Williams Field data set were deleted from the statistical analysis, the average percent error in predicting traffic volume would be 8.5 percent with a standard deviation of 5.3 percent, based upon 38 sample points. Williams Field Road functions as an urban street

while the others sampled were rural in character. This may account for the percentage differences.

(5) Representative percentage values for each type of vehicle were used in the study. These percentages are based upon a volume of 46,176 vehicles. One could construct a 90% confidence interval for the percentage estimate of each vehicle; however, due to the large value of n (46176), the interval is very close to the estimated value. For example, the 90 percent confidence interval for category A vehicles is (60.45, 61.19). This means that one can be 90 percent confident that the actual percentage of category A vehicles, based on this study, is contained within the interval 60.49 to 61.19. The 90 percent confidence interval for category E vehicles is given as (27.56, 28.24). The equation used in determining the above 90 percent confidence intervals is given as

$$\hat{P} - 1.645\sqrt{\frac{\hat{P}(1-\hat{P})}{n}} < P < \hat{P} + 1.645\sqrt{\frac{\hat{P}(1-\hat{P})}{n}} \times 100\%$$

where $\hat{P} = \frac{\text{total number of Category "x" vehicles}}{n}$

n = total vehicles counted in all samples

P = actual percentage of Type "x" vehicles in the mix.

For type A vehicles we would have

$$\hat{P} = \frac{28086}{46176} \times 100\%$$

$$= 60.8\%$$

while, for type E vehicles, P is computed as

$$\hat{P} = \frac{12868}{46176} \times 100\%$$

$$= 27.9\%$$

One could easily construct 90 percent confidence intervals for the remaining vehicle percentages using the same formula. It can be shown, however, that the range of percentage variation is small in all cases due to the magnitude of the sample size n.

The recommended sampling hours, recommended method for maintaining an up to date data base, and a summary of the proposed method for determining vehicle mix and ADT estimates are presented in the following sections.

Recommended Sampling Hours

This study involved data collection by the ASU research team for either 12 or 24 continuous hours, during different days of the week and months of the year. Data were taken as far south as Patagonia, as far west as Wickenburg, and as far northeast as Kohl's Ranch. The vehicle mix and volume data collected during the study were separated into one hour increments. This would enable comparison between actual and predicted values if a counter were to be placed on the highway at the same time the count was made.

The counter would provide vehicle volume data during a 3 or 4 hour interval in the morning or in the afternoon. As a general rule, sampling during the afternoon hours resulted in more accurate volume estimates. The average percent error was 6.0 with a standard deviation of 3.8 percent if data were taken by the counter from 1-5 PM. However, if the counter were to take data from 8-11 AM, the average percent error and standard deviation would be 13.6 and 7.3, respectively. The 8-12 AM and 1-4 PM intervals had error estimates between the two discussed. The above error estimates include the

entire data set. The errors are reduced significantly if the Williams Field data are excluded from the statistical analysis. The average percent error for volume is reduced to 5.2 with a standard deviation of 3.4. The corresponding reduction in volume estimate for the 8-11 AM interval is 11.2 percent with a standard deviation of 5.5 percent. The vehicle mix estimates are based upon the volume estimates. If volume estimates are off by a certain percentage, the vehicle mix estimates will be in error by that same percent.

It is the recommendation of the research team that, if possible, data be collected during the afternoon hours, preferably from 1-5 PM. Sampling, however, during the 1-4 PM interval is almost as effective, the percent error and standard deviation increasing only one percent respectively.

Recommended Data Updating

It is recommended that the data comprising the data set be updated on an annual basis. This would both be cost effective and ensure that the data base accurately reflects vehicle mix percentages. At the present time, the estimated vehicle mix percentages, as a whole, appear to adequately reflect the vehicle mix.

The recommended updating procedure would be to maintain a cumulative data base of vehicle mix and volume as data are collected by actual counts throughout the state. The form used by the research team and illustrated in Figure 2 is easily implemented for data collection. At the end of the first year of data collection, the current data could be combined with data gathered during this study to recalculate the representative vehicle mix percentages. Alternately, the data could supercede this study's percentages, thus requiring new estimates of vehicle mix values. The equation defining p, presented in (5) in the summary above, would be used for determining the updated vehicle mix

percentages, whether the data set was based entirely on newly collected data or on a combination of newly collected data and data from this study.

It is recommended that at least 50 data sets of 4 afternoon hours each be taken during the year. This would exceed the 168 hours of data collected by the ASU research team. One would anticipate approximately 75000 vehicles counted, enabling the vehicle mix percentages to be updated. If, however, the number of data sets were reduced to 25, each of 4 hours duration, one would anticipate observing and classifying approximately 37500 vehicles. Manpower costs, scheduling, as well as other factors might dictate the number of times actual data counts are taken.

Lastly, the hourly, daily, and monthly factors contained in Tables 3, 4, and 5, should be updated on an annual basis. It is anticipated that there will be no significant change when 1983 data are compared to 1982 data. If this expectation proves correct, then the new hourly, daily, and monthly factors should be based on 1983 estimates. Updating these tables can be accomplished easily with only slight modification to computer programs available at ADOT.

Recommended Vehicle Mix and ADT Estimating Procedures

The recommended procedures for estimating vehicle mix and ADT were discussed fully in the preceding chapter. They are, however, summarized in the following step by step instructions:

(1) Estimate the traffic volume for the highway in question based upon a 24 hour day. In addition, identify the day and month on which the data were collected. If the data were taken during a time interval other than 24 hours, the individual hourly percentages applicable to that time interval are summed using hourly percentage values from Table 3, 4, or 5. The sum of the hourly percentages is then

divided into the volume count, resulting in a volume estimate for 24 hours.

(2) Multiply the 24 hour volume estimate by the appropriate daily factor from Table 3, 4, or 5.

(3) Multiply the product of the calculation in (2) above by the appropriate seasonal factor from Table 3, 4, or 5. This results in an estimated ADT for the highway in question.

(4) Multiply the ADT by the representative vehicle mix percentages contained in Table 7. This procedure enables an estimate to be made of each type of vehicle in the mix. Alternative estimates of vehicle mix could be made using percentage values other than those recommended if it was felt these values were not appropriate for the highway in question.

Identification of Diesel Powered Vehicles

It was determined early in the study that there was no effective method of identifying diesel powered vehicles strictly by visual observation. Diesel powered vehicles (except large trucks) could not be identified accurately, even during daylight hours, because diesel powered pick-ups and passenger cars are built on the same chassis as their gasoline powered counterparts. The researchers recommend assuming that the percentage of diesel powered vehicles on any type of road is the same as the percentage of diesel powered vehicles of that type indicated in state registration data.

Automatic Traffic Recorders

The number of ATRs needs to be increased to include more non-interstate, low volume, and urban area roads. The interstate system is well covered. The

non-interstate rural primary arterial system coverage is adequate. More coverage is needed for minor rural arterials, major rural collectors, and non-interstate urban arterials to improve the data base and provide proper coverage. No existing station should be eliminated. The existing stations have and continue to provide a data base that is extremely useful.

Specifically, the northwest quadrant lacks ATRs. The major urban areas should have more ATRs to provide better coverage of the arterial street systems. The smaller urban areas are lacking in coverage. Coordination of efforts by the cities and ADOT to build a data base using ATRs of all agencies should be encouraged.

RECOMMENDATION FOR FURTHER STUDY

This study addressed the development of a procedure that could be used to predict volume and vehicle mix on county highways.

While the volume factors appear to be constant with time based on (four years) data from the permanent counting stations, it is not known whether or not the vehicle mix percentages are constant. Only one year's data are available from this study. Further monitoring of vehicle mix percentages should be done.

The results of this study could be used to develop a methodology to calculate vehicle miles of travel (VMT) in each count. It could also be used to establish the VMT for the entire state. A study based on this research should provide information and monitoring techniques that could be used to better estimate VMT.

APPENDICES

Appendices under separate cover.