Tennessee Department of Transportation
Project Planning Division

TRAFFIC MONITORING AND FORECASTING MANUAL

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Preface

Implementing the process of traffic monitoring and forecasting can lead to better planning, design, and operational decisions. The traffic data retrieved from the field is used for forecasting, evaluation of safety, cost projections, and compliance with requirements. After data collection, statistical analysis is performed and the information is refined. The analysis includes tabulation of data, which provides summarization and categorization. Interpretations of data based on known procedures and rules for a particular use, such as traffic engineering or transportation planning, is also part of the analysis. Data management involves the logical evaluation of database structures and interface structures that result in efficient and effective ways of storing and retrieving data. The presentation of data is an important aspect of project and program success.

Acknowledgments

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1 INTRODUCTION

1.1 Purpose

The purpose of this manual is to present simple and understandable guidelines for traffic monitoring and forecasting.

1.2 Chapters

Chapter 1 Introduction
This chapter describes the purpose of this manual, provides an overview of the chapters, and gives definitions of terms.

Chapter 2 Traffic Monitoring
This chapter describes the data collected and the traffic monitoring procedures used by the Tennessee Department of Transportation (TDOT) for the collection. It explains different types of traffic counts – continuous, coverage, classification, and special needs. It also describes truck weight surveys, vehicle occupancy surveys, and the Long Term Pavement Performance Program.

Chapter 3 Traffic Forecasting
This chapter explains traffic forecasting parameters. It gives procedures for forecasting Equivalent Single Axle Load (ESAL) and intersection turning movements. It also explains some basic traffic analysis, the Advanced traffic data Analysis and Management System (ADAM), traffic safety parameters, and highway capacity analysis.

1.3 Definitions

Advanced traffic Data and Analysis Management system (ADAM). An ORACLE relational database designed to aid in building and analyzing traffic information.

Arterial. Street that primarily serves through-traffic. Access to abutting properties is a secondary function. They provide a high operating speed and level of service.[1]

Automatic Traffic Recorder (ATR). Permanent count station where equipment is provided to count and record traffic volumes 24 hours a day, 365 days a year, year after year.

Automatic Vehicle Classifier (AVC). Equipment capable of automatically identifying vehicles of different type and recording data. The equipment is either portable or installed at permanent locations for continuous operation.

Average Annual Daily Traffic (AADT). Average 24-hour traffic volume at a given location. Raw traffic volume is adjusted by an axle correction factor and a traffic variation factor.

Average Daily Load (ADL). The loading on a pavement section resulting from all vehicles in the traffic stream computed by weighting the ESAL of each vehicle by its proportion in the traffic mix, usually on an average annual basis.

Average Daily Traffic (ADT). The total traffic volume during a given time period, more than one day and less than one year, divided by the number of days in that time period.[2]

Average Weekday Traffic (AWT). The average 24-hour volume occurring on weekdays for some period of time less than one year, such as for a month or a season.

Axle Correction Factor (ACF) or Truck Factor (TF). A factor developed to adjust a Base Count for the incidence of vehicles with more than two axles.

Base Count. A traffic count that has not been adjusted for vehicles with more than two axles or for daily/monthly variation in traffic volume.

Base Year. The initial year of the forecast period. The Base Year is equal to the Current Year plus five years.

Capacity. The maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions.[3]

Collector. Street that serves a dual function in accommodating shorter trips and feeding arterials. They provide some degree of mobility and also serve abutting property. They typically have an intermediate design speed and level of service.[4]

Corridor. A broad geographical band that follows a general directional flow connecting major origins and destinations of trips and may contain several alternate transportation alignments.

Count. Data collected as a result of measuring and recording traffic characteristics such as vehicle volume, classification, speed, weight, or a combination of these characteristics.

Current Year. The year traffic forecasting begins.

Design Hour. The 30th highest hour of traffic during the Design Year.

Design Hour Factor (K_{30}). The proportion of AADT occurring during the Design Hour.[5]

Design Hourly Volume (DHV). The traffic volume during the 30th highest hour of the Design Year. It is used frequently for planning and design. Based on prevailing traffic theory, the 30th highest hourly volume of the Design Year is a good cutoff point at which to design highways so that they are neither under designed nor overbuilt.[6]

Design Period. The number of years from initial application of traffic until the first planned major resurfacing or overlay, usually 20 years.[7]

Design Year. The year for which the roadway is designed, usually 20 years from the Base Year.

Directional Distribution. The portion of two-way traffic traveling in the Peak Direction.

Directional Factor (D_{30}). The proportion of two-way traffic in the 30th highest hour of the Design Year traveling in the Peak Direction.

Equivalent Single Axle Load (ESAL). The relative load on a pavement (produced by specific axle weight, group of axles, or mix of vehicles) compared to a single axle of 18,000 pounds.

Hazard Elimination Safety Program (HESP) (Section 152). The Hazard Elimination Program is intended to implement safety improvement projects to reduce the number and severity of crashes at hazardous highway locations. With the enactment of SAFTEA-LU, the Hazard Elimination Safety (HES)

Program (Section 152) was included along with the Railway-Highway Crossing Program (Section 130) in the Highway Safety Improvement Program (HSIP) (Section 148). The HSIP requires a Strategic Highway Safety Plan which defines goals and strategies to reach these goals. The program in Tennessee will concentrate on the reduction in the number of crashes that have resulted in fatalities and incapacitating injuries.

Highway Performance Monitoring System (HPMS). A database that reflects the extent, condition, performance, use, and operating characteristics of the Nation's highways. It is used for various assessments and apportioning Federal-aid funds back to the States.

High Occupancy Vehicle (HOV). Any vehicle carrying two or more passengers.

K-factor. *See* Design Hour Factor.

Level of Service (LOS). A quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience. Six LOS are defined for each type of facility that has analysis procedures available. Letters designate each level, from A to F, with LOS A representing the best operating conditions and LOS F the worst. Each level of service represents a range of operating conditions and the driver's perception of those conditions. Safety is not included in the measures that establish service levels.[8]

Local Road. A street that has relatively short trip lengths, and, because property access is their main function, there is little need for mobility or high operating speeds. This function is reflected by use of lower design speed and level of service.[9]

Oracle. A powerful relational database management system that offers a large feature set. Oracle is widely regarded as one of most popular full-featured database systems on the market.

Peak Direction. The dominant direction of travel for two-way traffic.

Peak Hour. The time period when the highest 60-minute traffic volume of the day occurs.

Peak Hour Factor (PHF). A measure of traffic demand fluctuation within the Peak Hour. It is the ratio of the Peak Hour volume to the number of vehicles during the highest 15-minute period multiplied by 4.[10,11]

Peak Season. The 13 consecutive weeks of the year with the highest traffic volume.

Tennessee Roadway Information Management System (TRIMS). An ORACLE relational database which contains information on over 88,000 miles of public roads in Tennessee. The interface allows users to query data in the form of inventory data, digital photographs, road mileage, documents, digital plans, and scanned documents. TRIMS also offers a graphical interface, which offers map-based queries, and displays information on maps.

Traffic Variation Factor (TVF). A factor developed to adjust a Base Count for travel behavior fluctuations by day of week and month of the year.

Vehicle Miles of Travel (VMT), The total number of vehicles multiplied by the total number of miles which are traversed by those vehicles.

Volume to Capacity Ratio (V/C), the ratio of demand traffic volume to capacity.

Weigh-In-Motion (WIM). Systems that use various devices and procedures for determining the weights of vehicles as they travel.

2 TRAFFIC MONITORING

2.1 Highway Performance Monitoring System

Tennessee participates in the Highway Performance Monitoring System (HPMS). HPMS provides data that reflects the extent, condition, performance, use, and operating characteristics of the Nation's highways. It was developed in 1978 as a national highway transportation system database. It includes limited data on all public roads, more detailed data for a sample of the arterial and collector functional systems, and certain statewide summary information. HPMS replaced numerous uncoordinated annual State data reports as well as biennial special studies conducted by each State. These special studies had been conducted to support a 1965 congressional requirement that a report on the condition of the Nation's highway needs be submitted to Congress every two years.

The HPMS data form the basis of the analyses that support the biennial Condition and Performance Reports to Congress. These reports provide a comprehensive, factual background to support development and evaluation of the Administration's legislative, program, and budget options. They provide the rationale for requested Federal-aid Highway Program funding levels, and are used for apportioning Federal-aid funds back to the States under TEA-21; both of these activities ultimately affect every State that contributes data to the HPMS.

These data are also used for assessing highway system performance under the strategic planning process by the Federal Highway Administration (FHWA). Pavement condition data, congestion-related data, and traffic data used to determine fatality and injury rates are used extensively by the Administration to measure FHWA's and the State's progress in meeting the objectives embodied in the Vital Few, FHWA's Performance Plan, and other strategic goals.

In addition, the HPMS serves needs of the States, MPOs, local government, and other customers in assessing highway condition, performance, air quality trends, and future investment requirements. Many States rely on traffic and travel data from the HPMS to conduct air quality analyses and make assessments related to determining air quality conformity, and are now using the same analysis models used by FHWA to assess their own highway investment needs, HERS-ST. As a result of these uses, States have an additional stake in assuring the completeness and quality of these data.

Finally, these data are the source of a large portion of information included in FHWA's annual Highway Statistics and other media and publications. They are widely used in both the national and international arenas by other governments, transportation professionals, and industry professionals to make decisions that impact national and local transportation systems and our transportation dependent economy. More information about HPMS is available online at http://www.fhwa.dot.gov/policy/ohpi/hpms/.

2.2 Traffic Monitoring in Tennessee – An Overview

The Short Range Planning and Data Office is maintained by the Planning Division of the Tennessee Department of Transportation (TDOT). The purpose of this office is to collect, process, summarize, and report traffic characteristics data.

Tennessee traffic counting consists of 31 existing and 27 proposed Automatic Traffic Recorder (ATR) stations, over 12,000 coverage count locations, and over 900 ramp count locations. In addition, there are approximately 600 classification locations. In order to monitor the traffic characteristics of over 88,000 miles of roadway in Tennessee, a program that utilizes the HPMS functional classification system is being used.

The road system in Tennessee is covered by continuous traffic counting and short-period traffic counting (coverage counts). The majority of these traffic counts are on HPMS classified roadways; however, some are located on the local system. The HPMS sample sections have 2,713 count locations with locations between each interchange on the Interstate System.

The structure of TDOT's traffic monitoring program can be summarized into these major elements:

- Continuous Count Program
- Coverage Count Program
- Classification Count Program
- Truck Weight Program
- Long Term Pavement Performance Program
- Special Needs
- Crash Studies

2.3 Traffic Monitoring Guide

Tennessee follows many of the recommendations in the Traffic Monitoring Guide (TMG)[12] published by the Federal Highway Administration (FHWA). The TMG offers suggestions to help improve and advance current programs with a view towards the future of traffic monitoring. A basic program structure for traffic monitoring is presented. The guide provides specific examples of how statewide data collection programs should be structured, describes the analytical logic behind that structure, and provides the information highway agencies need to optimize the framework for their particular organizational, financial, and political structures. The TMG is available online at http://www.fhwa.dot.gov/ohim/tmguide.

2.4 Traffic Data and Uses

Traffic data are the foundation of transportation. Of all the data collected by State agencies, traffic data are the most used and most important in virtually every decision-making process. Each decision is important and often involves the allocation of public funds. **Improved traffic data can lead to better decisions and designs.**

Data are collected during traffic counting, vehicle classification, and truck weighing. These data are used in all phases of highway transportation. Vehicle occupancy data are collected on demand. Table 1 shows some examples of how traffic data are used. Other State agencies, local government units, planning commissions, and private businesses also use this information for a variety of purposes.

Table 1. Examples of Traffic Data Uses.

Data Type	Use
Traffic Volume	Highway geometry. Benefit of improvements. Selection of highway routes. Location and design of highway systems. Design of traffic control systems. Location of service areas. Analyzing highway capacity. Determining LOS. Forecasting future traffic volumes.
Vehicle Classification	Pavement design. Cost of vehicle operation. Highway cost allocation. Speed limit and oversize vehicle policy. Forecasts of travel by vehicle type. Safety conflicts due to vehicle mix.
Truck Weight	Structural design. Benefit of truck climbing lane. Weight distance taxes. Permit policy for overweight vehicles. Resurfacing forecasts. Posting of bridges for load limits. Trends in freight movement.
Vehicle Occupancy	Mass transit studies. HOV lane studies. Intermodal transportation policy. Fuel efficiency.

2.5 Data Collection Equipment

2.5.1 Overview

Vehicle detection and surveillance technologies may be described as containing three components, the transducer, a signal processing device, and a data processing device. The transducer detects the passage or presence of a vehicle or its axles. The signal-processing device typically converts the transducer output into an electrical signal. The data-processing device usually consists of computer hardware and firmware that converts the electrical signal into traffic parameters. Typical traffic parameters include vehicle presence, count, speed, class, gap, headway, occupancy, weight, and link travel time. The data processing device may be a part of the sensor, as with devices that produce serial output data.[13]

2.5.2 Sensors

Intrusive sensors include inductive loops, magnetometers, microloop probes, pneumatic road tubes, piezoelectric cables, and other weigh-in-motion sensors. These devices are installed directly on the pavement surface, in saw-cuts, or holes in the road surface, by tunneling under the surface, or by anchoring directly to the pavement surface as is the case with pneumatic road tubes. The operation of these sensors is well understood as they generally represent applications of mature technologies to traffic surveillance. The drawbacks to their use include disruption of traffic for installation and repair and failures associated with installations in poor road surfaces and use of substandard installation procedures. Resurfacing of roadways and utility repair can also create the need to reinstall these types of sensors.[14]

TDOT relies on the use of pneumatic road tube, inductive loop, and piezoelectric sensors for the Traffic Monitoring Program. Sensors developed for the Road/Weather Information System (R/WIS) and non-intrusive, above-ground sensors developed for the Intelligent Transportation System (ITS) are being studied (especially regarding reliability) for future use.

2.5.2.1 Pneumatic Road Tube

The pneumatic road tube sends a burst of air pressure along a rubber tube when a vehicle's tires pass over the tube. The pulse of air pressure closes an air switch, producing an electrical signal that is transmitted to a counter. The pneumatic road tube is portable, using batteries as a power source. The road tube is installed perpendicular to the traffic flow direction.

Advantages of road tube are quick installation for temporary recording of data and low power usage. Road tubes are usually low cost and simple to maintain. Disadvantages include inaccurate axle counting when truck volumes are high, temperature sensitivity of the air switch, and cut tubes resulting from vandalism and wear produced by truck tires.[15]

2.5.2.2 Inductive Loop Detector

The inductive loop detector is the most common sensor used in traffic management applications. A small electrical current passes through a wire buried in the pavement. Its size and shape vary, including square loops, round loops, and rectangular configurations having a fixed width and variable length. When a vehicle stops on or passes over the loop, the inductance of the loop is decreased. The decreased inductance increases the oscillation frequency and causes the electronics unit to send a pulse to the controller, indicating the presence or passage of a vehicle. The operation of inductive loop sensors is well understood and their application for providing basic traffic parameters (volume, presence, occupancy, speed, classification, headway, and gap) represents a mature technology.[16]

As was the case with the pneumatic road tube, the equipment cost of inductive loop sensors is low when compared to non-intrusive sensor technologies. Another advantage of inductive loop sensors is their ability to satisfy a large variety of applications due to their flexible design. The drawbacks to the use of inductive loop sensors include disruption of traffic for installation and repair and failures associated with installations in poor road surfaces and use of substandard installation procedures. In many instances multiple detectors are usually required to count a location. In addition, resurfacing of roadways and utility repair can also create the need to reinstall these types of sensors. Also, wire loops are subject to stresses of traffic and temperature.[17]

2.5.2.3 Piezoelectric Sensors

Construction of the piezoelectric sensor is coaxial with a metal, braided core element, followed by a piezoelectric material and a metal outer layer. Piezoelectric materials generate a voltage when subjected to mechanical impact or vibration. Electrical charges of opposite polarity appear at the parallel faces and induce a voltage. The measured voltage is proportional to the force or weight of the vehicle. They are frequently used as part of weigh-in-motion (WIM) systems.[18]

Piezoelectric sensors offer the unique advantage of being able to gather information on the tire passing over the sensor, rather than on the passing of a vehicle. Piezoelectric sensors detect the passing of the tire over the sensor, thus creating an analogue signal that is proportional to the pressure exerted on the sensor. This unique ability of piezoelectric sensors allows them to differentiate individual vehicles with extreme precision. The drawbacks to the use of piezoelectric sensors are similar to those of inductive loop sensors in that they include disruption of traffic for installation and repair and failures associated with installations in poor road surfaces and use of substandard installation procedures. In many instances multiple detectors are usually required to count a location. In addition, resurfacing of roadways and utility repair can also create the need to reinstall these types of sensors. Also, piezoelectric sensors have been known to be sensitive to pavement temperature and vehicle speed.[19]

2.5.3 Data Processors

Data processors currently in use include the following:

Phoenix counter/classifier by Diamond Traffic Products.

The Phoenix is a multi-lane time interval counter/classifier designed for permanent installs or large portable applications. The Phoenix is capable of 1 to 8 lanes count using axle sensors, 16 lanes count with loops, classification for 1-8 lanes of traffic with gap, headway and speed by axle type studies. It can be fitted with 4 road tube sensors, 2 to 8 remote inputs, 4 to 16 presence inductive loop sensors, or 4 to 8 piezoelectric sensor inputs. Data is stored in onboard card memory that is expandable. A user manual is available online at http://www.diamondtraffic.com/PhoenixManual.pdf.

Unicorn counter/classifier by Diamond Traffic Products.

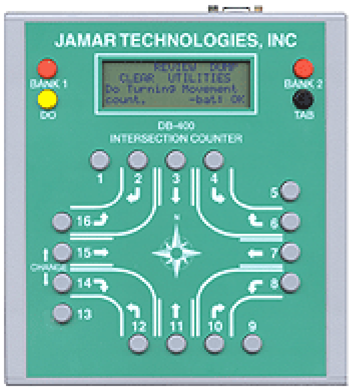
The Unicorn is a lightweight, compact vehicle classifier/counter. It will classify up to two lanes of traffic using road tube, piezoelectric, and/or loop presence sensors. The Unicorn also will count traffic up to four lanes. The Unicorn can be fitted with two or four road tube sensors, up to four remote inputs, two or four loop inputs, and two or four piezoelectric sensor inputs. Data is stored in onboard card memory that is expandable. A user manual is available online at http://www.diamondtraffic.com/Unicorn.pdf.

ADR-1000/2000/3000 counter/classifiers with Weigh-In-Motion by Peek Traffic, Inc.

The ADR-1000/2000/3000 versions have differing numbers of slots for sensor connections. Using one or two subsurface piezoelectric weighing sensors (with optional secondary sensors), the following types of data can be accurately collected: arrival time, vehicle speed and classification, gross vehicle weight, road surface temperature, volumetric flow, individual axle weights and spacing, overload indications, Equivalent Single Axle Loadings (ESALs), gap and headway, and per vehicle records. When short-term data is required, temporary stick-down sensors may be installed for cost-effective surveys. Site monitoring includes a four-lane capability on the ADR1000/2000 or an eight-lane capability on the ADR-3000. Data storage is provided by internal memory or removable

PCMCIA cards of up to 8 MB capacity. Sites are generally battery powered, but solar or line power backup extends monitoring time indefinitely. More information is available online at http://www.peek-traffic.com.

DB-400 Hand-held Manual Traffic Counter by JAMAR Technologies, Inc.



The DB-400 is designed to make collecting turning movement data easy and accurate. The buttons are arranged to simulate a standard intersection. There are 16 buttons, with 12 normally used for the left, through, and right movements from each of the four approach directions. The additional four buttons are user-defined; they can be used for bicycles, pedestrians, etc. While recording turning movements, there is the option to classify the vehicles recorded in up to three separate classes using the DB-400's 'Bank' buttons. Trucks and other heavy vehicles can be stored separate from passenger vehicles, and percentage breakdowns can be determined. The data can be transferred to a computer through the serial port. The DB-400 is battery-operated and has 32K of memory. A user manual is available online at http://www.jamartech.com/PDFs/DB-400%20Manual.pdf.

2.6 Continuous Count Program

The Continuous Count Program is designed to collect vehicular traffic volume data in one-hour increments 24 hours a day throughout the year. Permanent stations utilizing Diamond Phoenix with inductive loops, called Automatic Traffic Recorders (ATRs), collect this continuous data. By providing a data-intensive method of operation, a large database with enormous utility potential has been made available.

The primary purpose of continuous traffic counting is to obtain information that can be generalized or expanded on a system-wide, area-wide, or statewide basis. The ATR stations are representatively located. Because traffic over the course of a year exhibits considerable seasonality, coverage counts must be adjusted with factors to arrive at valid estimates of Average Annual Daily Traffic (AADT). The permanent, continuous ATR stations capture this seasonality which is an extremely efficient method of arriving at AADT estimates and perhaps the single most important purpose of continuous traffic counting.

2.6.1 Groups of ATR Stations

Five groups of ATR stations, representative of the different types of roadway functionality across the State, are monitored to develop factors for adjusting coverage counts. The groups are:

- Rural Interstate;
- Urban Interstate;
- Rural Non-Interstate;
- Urban Non-Interstate; and
- Recreational.

2.6.2 Number of ATR Stations

One of the most important issues related to continuous traffic monitoring is the number of stations needed for each group of ATR stations. It is assumed that the traffic data population has a normal distribution. Due to restraints, the number of ATR stations for a group must usually be small ($n \leq 30$). Also, the mean and variance in the data population are unknown. To determine the minimum sample size needed to obtain some selected level of accuracy, the t distribution is used. The general form of this equation is:

$$t_\alpha = \frac{\bar{x} - \mu}{s / \sqrt{n}}$$

where: t_α = (1 – α)th percentile of the t distribution with (n – 1) degrees of freedom;
α = 1 – (percent of confidence level chosen / 100);
$\bar{x}$ = sample mean;
μ = mean of the population;
s = standard deviation of the sample; and
n = sample size (i.e. number of ATR stations).

The shape of the t distribution is similar to the normal (bell curve) distribution; however, the t distribution has more probability in the tails than the normal distribution. As the number of degrees of freedom (n – 1) approaches infinity, the limiting form of the t distribution is the standard normal distribution. Table 2 shows values of the t distribution for 80% confidence (α = 0.20), 90% confidence (α = 0.10), 95% confidence (α = 0.05), 98% confidence (α = 0.02), and 99% confidence (α = 0.01). To be “95% confident” means that there is a 95% probability that the true population mean lies within the specified confidence interval.

If we set $(\bar{x} - \mu) = \varepsilon$ and solve for n, we obtain:

$$n = \left(\frac{t_\alpha \times s}{\varepsilon} \right)^2$$

where: n = sample size (i.e. number of ATR stations);
t_α = (1 – α)th percentile of the t distribution with (n – 1) degrees of freedom;
α = 1 – (percent of confidence level chosen / 100);
s = standard deviation of the sample; and
ε = error of the mean at the chosen confidence interval.

Table 2. Values of the *t* distribution (two-tailed).

Degrees of Freedom = (*n* -1)	α = 0.20	α = 0.10	α = 0.05	α = 0.02	α = 0.01
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	3.947
16	1.337	1.746	2.120	2.583	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.779
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
30	1.310	1.697	2.042	2.457	2.750
40	1.303	1.684	2.021	2.423	2.704
60	1.296	1.671	2.000	2.390	2.660
120	1.289	1.658	1.980	2.358	2.617
∞	1.282	1.645	1.960	2.326	2.576

This formula can be converted to the final form by expressing the standard deviation and probability of error in relative terms with respect to the mean of the sample. Using coefficient of variation (CV) instead of standard deviation and precision level (PL) instead of error of the mean, the equation for the number of stations is:

$$n = \left(\frac{t_\alpha \times CV}{PL} \right)^2$$

where: n = sample size (i.e. number of ATR stations);
t_α = (1 – α)th percentile of the t distribution with (n – 1) degrees of freedom;
α = 1 – (percent of confidence level chosen / 100);
CV = coefficient of variation; and
PL = precision level (i.e. ±error of the mean at the chosen confidence interval).

The procedure to calculate the coefficient of variation for each group of ATR stations during a year is as follows:

1) Calculate the ADT using 24-hours of count data and the appropriate ACF (see 2.8.3 Axle Correction Factors), such that:

$$ADT = (24\ Hour\ Count) \times (ACF)$$

2) Repeat Step 1 for all 365 days of the year, thus obtaining 365 ADTs throughout the year at an ATR station.
3) Calculate the average of the 365 ADTs and their standard deviation.
4) Divide the standard deviation by the average to get a coefficient of variation.
5) Repeat steps 1-4 for each ATR station in the group.
6) Calculate the average coefficient of variation for the group.

TDOT has a goal of at least a 10% precision level with 95% confidence for each ATR group, as recommended in the TMG. The following examples illustrate typical calculations.

Example 1. Determination of Precision Level
The average coefficient of variation of ADT values on the 11 Rural Non-Interstate ATR stations in a year was calculated to be 17.90%. Calculate the precision level of the ADT estimation in this group with 99% confidence.

Degrees of freedom = 11-1 = 10

α = 1 – (99 / 100) = 0.01

From Table 2: For degrees of freedom = 10, $t_{0.01}$ = 3.169

$$11 = \left(\frac{3.169 \times 17.90}{PL}\right)^2$$

$$PL = \frac{3.169 \times 17.90}{\sqrt{11}} = \underline{\underline{17.10\%}}$$

We can say that we are 99% confident that a 17.10% precision level on the Rural Non-Interstate ADT estimates was achieved that year.

Example 2. Calculation Number of ATR Stations
The latest year's data from 6 ATRs that make up a group was processed. The average coefficient of variation for the group was 16.38%. Calculate the number of ATR stations required for this group to achieve 10% precision with 95% confidence.

α = 1 – (95 / 100) = 0.05

Since we have a small, but unknown number of degrees of freedom, n must be determined by trial and error. To get a "ball park" estimate that will provide a starting point, we will assume an infinite number of degrees of freedom at 95% confidence:

From Table 2: For degrees of freedom = ∞, $t_{0.05}$ = 1.960

$$n = \left(\frac{1.960 \times 16.38}{10}\right)^2 = 10.31 = 11 \text{ ATR stations.}$$

We round 10.31 up because 10 stations will not provide enough data. 11 ATR stations is still just a rough estimate for the group to achieve a 10% precision level with 95% confidence – it represents a statistical minimum. To get a better estimate of how many stations are needed, we must make a guess and calculate the precision level. The calculations for the first guess are illustrated and the rest of the calculations are summarized in the table below:

Guess: $n = 11$

Degrees of freedom = 11-1 = 10

From Table 2: For degrees of freedom = 10, $t_{0.05}$ = 2.228

$$11 = \left(\frac{2.228 \times 16.38}{PL}\right)^2$$

$$PL = \frac{2.228 \times 16.38}{\sqrt{11}} = 11.00\%$$

n **(Guess)**	**Degrees of Freedom**	**t_α**	**PL (%)**	**Comment**
11	10	2.228	11.00	Too high.
12	11	2.201	10.41	Still too high.
13	12	2.179	9.90	OK (9.90<10)

As can been seen in the table, 13 ATR stations are needed to achieve 10% precision with 95% confidence. 7 new stations must be requested. The next year's data provided by the 13 stations should be evaluated to ensure that 10% precision with 95% confidence is actually achieved. A better estimate of variation will be possible because of the new stations. More stations may be required if the variation in the data is higher than the current estimate (16.38%).

2.6.3 Current ATR Stations in Operation.

The continuous traffic counting network in Tennessee consists of 31 ATR stations – five (5) Rural Interstate, five (5) Urban Interstate, eleven (11) Rural Non-Interstate, eight (8) Urban Non-Interstate, including one station on international airport, and two (2) Recreational. The ATR stations used by TDOT are listed by region in Table 3 and by group in Table 4. Recently, the old station numbering scheme was revised to a new scheme where the first digit of the new ATR station number reflects the TDOT region (1, 2, 3, or 4 from east to west, respectively) in which the ATR station is located. The old ATR station numbering scheme is still in use by field crews because of their familiarity with it. The Cycle station numbers shown in the tables are used in the ADAM program. Data from ATR station new#102/old#58 is faxed by the National Park Service and, therefore, is not available in the ADAM program. Station locations denoted by the new ATR numbering are shown in Figure 1 and by the old ATR numbering in Figure 2.

Table 3. Current ATR Stations by Region.

Region	New ATR Station #	Old ATR Station #	Cycle Station #	Group	County	Route	Log Mile	Year Established
1	101	38	990	Rural Int.	Anderson	I-75	5.76	1970
	102	58		Recreational	Blount	B483	0.69	1970
	103	25	990	Rural Non-Int.	Grainger	SR-92	6.71	1970
	104	26	991	Rural Non-Int.	Grainger	SR-1	13.13	1970
	105	37	990	Urban Int.	Knox	I-40	2.86 EB 2.48 WB	1970
	106	515	991	Rural Non-Int.	Knox	1256	1.41	1970
	107	3	990	Recreational	Sevier	SR-71	21.09	1970
2	201	35	990	Rural Int.	Coffee	I-24	19.05 EB 18.98 WB	1970
	202	30	990	Urban Int.	Hamilton	I-24	8.92 EB 8.91 WB	1970
	203	32	991	Urban Int.	Hamilton	I-124	1.05	1970
	204	540	992	Urban Non-Int.	Hamilton	SR-2	10.99	1970
	212	13	990	Rural Non-Int.	Cumberland	1174	0.81	2004
3	301	20	990	Urban Non-Int.	Davidson	SR-11	23.96	1970
	302	33	991	Urban Int.	Davidson	I-24	19.53	1970
	303	554	992	Urban Non-Int.	Davidson	SR-24	17.33	1970
	304	555	993	Urban Non-Int.	Davidson	SR-1	22.52	1970
	305	12	990	Rural Non-Int.	Hickman	SR-48	18.64	1970
	306	21	990	Rural Non-Int.	Humphreys	SR-1	22.99	1970
	307	15	990	Rural Non-Int.	Perry	SR-20	7.14	1970
	308	69	990	Rural Int.	Robertson	I-65	15.68 SB 15.58 NB	1970
	309	6	990	Rural Non-Int.	Rutherford	SR-2	2.58	1970
	310	34	990	Rural Int.	Wilson	I-40	6.38	1970
	347	516	990	Urban Non-Int.	Maury	5368	0.32	2005
4	401	61	990	Rural Non-Int.	Hardeman	SR-125	20.72	1970
	402	9	990	Rural Non-Int.	Haywood	SR-1	14.84	1970
	403	41	991	Rural Int.	Haywood	I-40	6.40 EB 6.81 WB	1994
	404	29	990	Rural Non-Int.	McNairy	SR-15	14.89	1970
	405	14	990	Rural Non-Int.	Madison	873	12.99	1970
	406	31	990	Urban Int.	Shelby	I-240	16.96	1970
	407	70	991	Urban Non-Int.	Shelby	Winchester	Airport	1970
	408	511	992	Urban Non-Int.	Shelby	SR-277	1.67	1970

Table 4. Current ATR Stations by Group.

Group	New ATR Station #	Old ATR Station #	Cycle Station #	Region	County	Route	Log Mile	Year Established
Rural Interstate	101	38	990	1	Anderson	I-75	5.76	1970
	201	35	990	2	Coffee	I-24	19.05 EB 18.98 WB	1970
	308	69	990	3	Robertson	I-65	15.68 SB 15.58 NB	1970
	310	34	990	3	Wilson	I-40	6.38	1970
	403	41	991	4	Haywood	I-40	6.40 EB 6.81 WB	1994
Urban Interstate	105	37	990	1	Knox	I-40	2.86 EB 2.48 WB	1970
	202	30	990	2	Hamilton	I-24	8.92 EB 8.91 WB	1970
	203	32	991	2	Hamilton	I-124	1.05	1970
	302	33	991	3	Davidson	I-24	19.53	1970
	406	31	990	4	Shelby	I-240	16.96	1970
Rural Non-Interstate	103	25	990	1	Grainger	SR-92	6.71	1970
	104	26	991	1	Grainger	SR-1	13.13	1970
	212	13	990	2	Cumberland	1174	0.81	2004
	305	12	990	3	Hickman	SR-48	18.64	1970
	306	21	990	3	Humphreys	SR-1	22.99	1970
	307	15	990	3	Perry	SR-20	7.14	1970
	309	6	990	3	Rutherford	SR-2	2.58	1970
	401	61	990	4	Hardeman	SR-125	20.72	1970
	402	9	990	4	Haywood	SR-1	14.84	1970
	404	29	990	4	McNairy	SR-15	14.89	1970
	405	14	990	4	Madison	873	12.99	1970
Urban Non-Interstate	106	515	991	1	Knox	1256	1.41	1970
	204	540	992	2	Hamilton	SR-2	10.99	1970
	301	20	990	3	Davidson	SR-11	23.96	1970
	303	554	992	3	Davidson	SR-24	17.33	1970
	304	555	993	3	Davidson	SR-1	22.52	1970
	347	516	990	3	Maury	5368	0.32	2005
	407	70	991	4	Shelby	Winchester	Airport	1970
	408	511	992	4	Shelby	SR-277	1.67	1970
Recreational	102	58		1	Blount	B483	0.69	1970
	107	3	990	1	Sevier	SR-71	21.09	1970

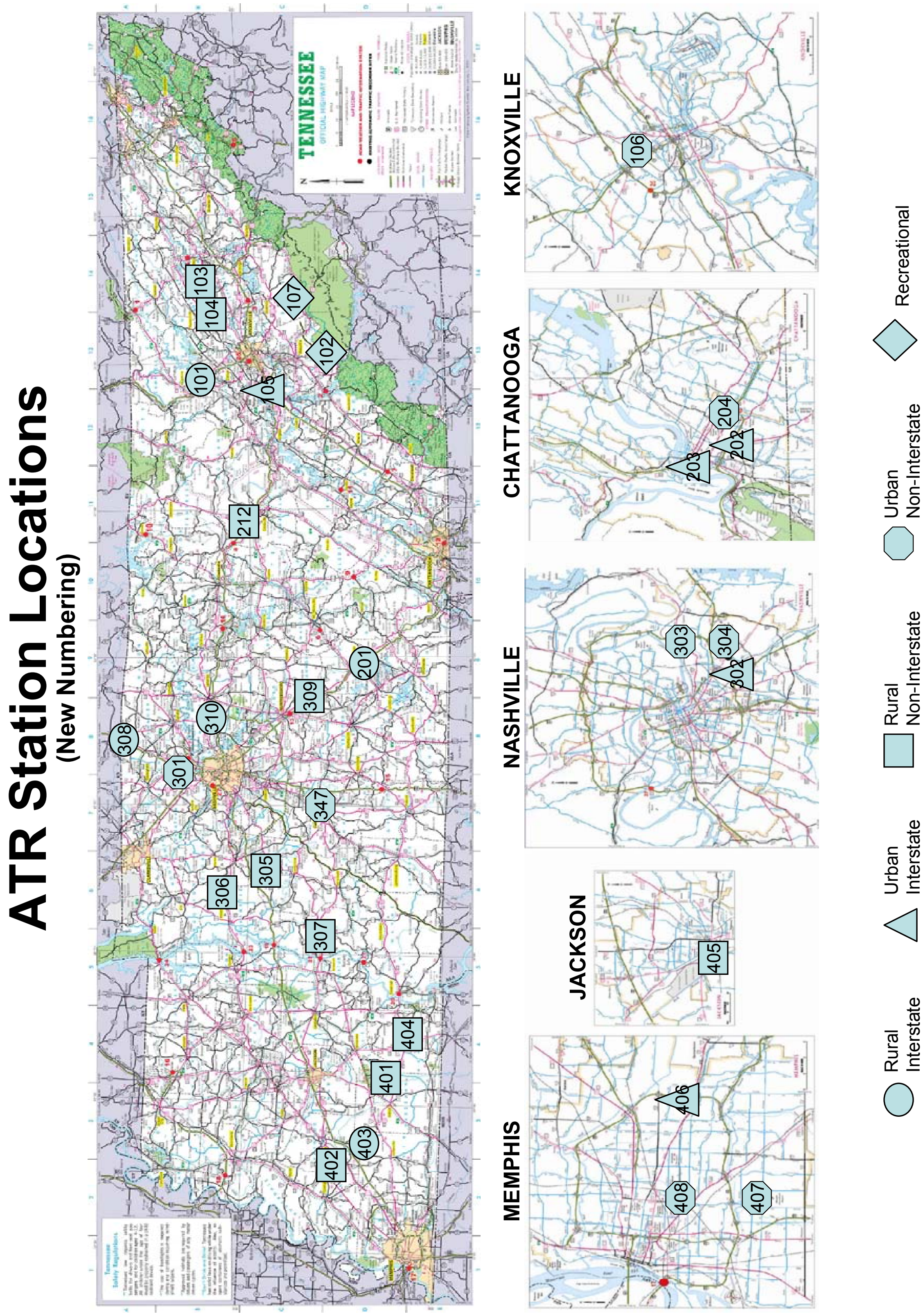


Figure 1. ATR Station Locations (New Numbering).

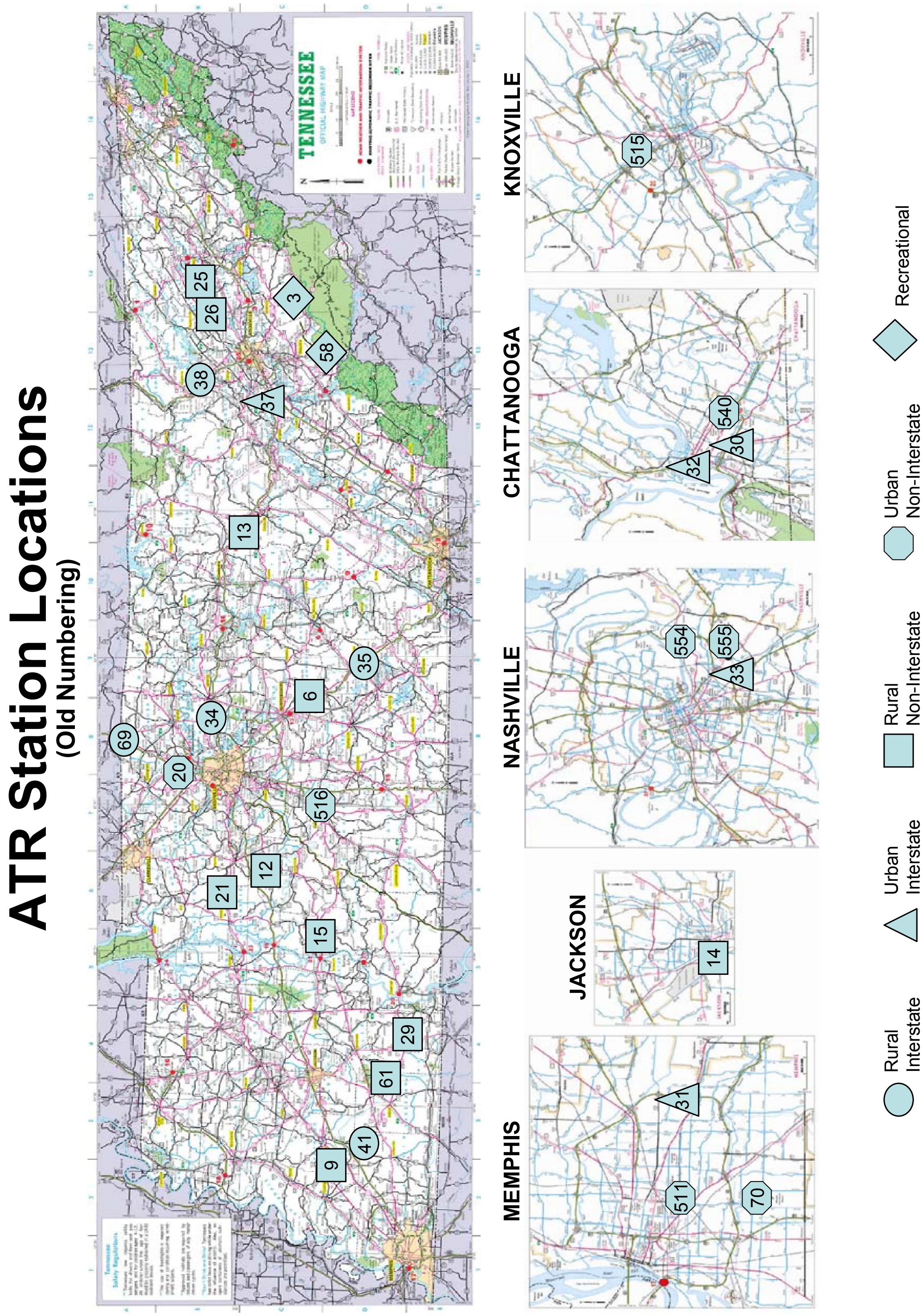


Figure 2. ATR Station Locations (Old Numbering).

2.6.4 Data Retrieval and Validation

After the continuous data is collected at the station, it is retrieved via telephone modem to a microcomputer at TDOT headquarters in Nashville. The data is imported into the Advanced traffic Data and Analysis Management (ADAM) system. Occasionally ATR stations malfunction, recording only a partial month's data. The TDOT policy is that seven (7) days of consecutive data is required before that month's data will be accepted. Also, when unusual disruptions, such as major construction projects, skew the data, it may be rejected. When the data is accepted for use, it is ready for factor development.

2.6.5 Traffic Variation Factors

Traffic Variation Factors (TVFs) represent monthly day-of-week variation in traffic volumes. They are used to adjust coverage (short term) counts to Annual Average Daily Traffic (AADT). TVFs are developed from the data collected by the ATRs. In developing the TVFs, Tennessee does not distinguish between the Urban Interstate and Urban Non-Interstate ATR groups. Those groups are combined to form the "Urban" group. TVFs are developed for the following groups:

- Rural Interstate;
- Rural Non-Interstate (sometimes labeled "Rural Other");
- Urban; and
- Recreational.

The factors are reported to two (2) places after the decimal. TVFs are calculated following these steps:

1) Calculate the average count for each day of the week (Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, and Saturday) for each month of the year for each ATR station of the TVF group.
2) Calculate the monthly averages (i.e. the average 24-hour count for the month) for the TVF group.
3) Calculate factors for each day of the week for each ATR station – each daily average is divided by the station's monthly average.
4) Average the factors of the group, producing a group factor for each day of the week of each month of the year.
5) Finally, average the factors with the previous years – each monthly day-of-week factor is averaged with the factors of the previous 4 years. (Extremely low or high factors are deleted before the averaging is done. TVFs were not calculated for years 1997 to 2002, so to produce the TVFs for 2005; the factors from 1995, 1996, 2003, 2004, and 2005 must be averaged.)

Table 5. Traffic Variation Factors.

2004 5-YEAR-AVERAGE MONTHLY VARIATION FACTORS, BY DAY OF WEEK

2004	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Rural Interstate												
Sunday	1.32	1.28	0.98	1.00	1.00	0.95	0.88	0.94	1.05	1.02	0.94	1.18
Monday	1.27	1.22	1.10	1.07	1.08	1.04	0.96	1.00	1.02	1.07	1.12	1.05
Tuesday	1.23	1.20	1.10	1.08	1.05	1.03	0.94	1.02	1.06	1.05	1.05	1.08
Wednesday	1.23	1.16	1.07	1.03	1.03	0.98	0.92	1.01	1.04	1.03	0.93	1.07
Thursday	1.24	1.09	0.98	0.96	0.97	0.93	0.88	0.92	0.99	0.98	1.04	1.03
Friday	1.24	1.04	0.85	0.81	0.83	0.80	0.79	0.83	0.88	0.88	0.91	0.95
Saturday	1.19	1.15	0.88	0.95	1.03	0.92	0.85	0.91	1.03	1.03	0.99	1.11
Rural Other												
Sunday	1.44	1.33	1.27	1.21	1.14	1.15	1.18	1.13	1.21	1.24	1.23	1.31
Monday	1.18	1.05	1.02	0.96	0.99	0.97	0.98	0.95	0.98	0.94	0.94	1.01
Tuesday	1.07	1.04	1.01	0.97	0.96	0.96	0.94	0.95	0.93	0.95	0.94	0.99
Wednesday	1.11	1.09	1.03	0.97	0.97	0.97	0.95	0.97	0.95	0.94	0.90	1.01
Thursday	1.08	1.05	1.00	0.94	0.93	0.93	0.92	0.92	0.91	0.90	0.98	0.97
Friday	1.00	0.95	0.90	0.87	0.86	0.87	0.86	0.86	0.83	0.84	0.88	0.89
Saturday	1.23	1.06	0.98	0.95	0.96	0.97	0.99	0.98	0.97	1.04	1.04	1.08
Urban												
Sunday	1.57	1.53	1.44	1.27	1.37	1.33	1.28	1.32	1.33	1.34	1.37	1.39
Monday	1.05	1.03	0.94	0.94	0.97	0.94	0.98	0.94	0.98	0.94	0.92	1.02
Tuesday	1.01	1.00	0.94	0.95	0.95	0.92	0.97	0.93	0.93	0.94	0.92	0.95
Wednesday	1.04	1.00	0.93	0.95	0.94	0.92	0.95	0.91	0.92	0.93	0.91	0.94
Thursday	1.03	0.99	0.90	0.91	0.90	0.91	0.97	0.91	0.91	0.91	0.94	0.90
Friday	0.98	0.94	0.85	0.82	0.85	0.87	0.87	0.86	0.88	0.84	0.90	0.87
Saturday	1.26	1.17	1.07	1.09	1.12	1.05	1.07	1.05	1.08	1.10	1.11	1.14
Recreational												
Sunday	1.69	1.17	1.08	0.98	0.77	0.77	0.68	0.70	0.71	0.67	0.89	1.16
Monday	2.14	1.95	1.64	1.33	1.07	0.89	0.64	0.87	0.95	0.70	1.34	1.18
Tuesday	1.87	2.21	1.65	1.31	1.23	0.87	0.67	0.92	1.12	0.79	1.24	1.15
Wednesday	1.99	2.20	1.67	1.31	1.20	0.86	0.70	0.93	1.11	0.87	1.23	1.37
Thursday	2.36	2.11	1.69	1.26	1.20	0.90	0.73	0.85	1.11	0.71	1.13	1.29
Friday	1.95	1.37	1.28	1.05	0.99	0.86	0.71	0.71	0.93	0.62	0.79	0.97
Saturday	1.50	0.88	0.96	0.86	0.79	0.75	0.63	0.61	0.68	0.57	0.68	0.87

For ease of use, the TVFs for the year are organized into tabular form (see Table 5). These yearly factor tables are not completed and ready for use until March or April of the following year. Thus, there is an offset in the factors' use – that in any one calendar year, coverage counts may be adjusted from two different yearly tables. However, this is not considered significant, since factors are developed as 5-year averages. An example of calculating TVFs is shown below.

Example 3. Calculation of Traffic Variation Factors.
Given the following data and the factors from previous years, calculate the Rural Interstate 5-Year-Average August 2004 TVFs.

Rural Interstate ATR August 2004 Data (Steps 1 and 2 Completed):

New/Old ATR Station	Sun Average	Mon Average	Tues Average	Wed Average	Thurs Average	Fri Average	Sat Average	Monthly Average
101/38	44,775	43,869	43,141	44,879	48,279	54,068	43,957	45,963
105/37	87,272	90,502	91,666	93,409	96,233	106,414	88,443	93,182
201/35	35,455	30,939	29,660	34,357	36,311	40,616	33,730	34,221
308/69	40,662	32,888	34,329	36,306	39,308	43,215	38,210	37,815
310/34	50,909	60,917	63,295	65,519	67,263	72,009	58,708	62,245
403/41	32,795	28,323	31,938	33,232	33,986	37,876	33,123	32,965

Factors from Previous Years:

	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
August 2003 Only	0.97	1.00	1.10	1.15	0.98	0.96	0.94
August 1996 Only	0.89	1.01	1.01	0.98	0.92	0.79	0.86
August 1995 Only	0.95	1.09	1.07	1.03	0.96	0.81	0.91
August 1994 Only	0.89	0.98	1.00	0.97	0.90	0.79	0.87

Step 3. *Calculate factors at each ATR station of the Group.*

Calculation for New/Old ATR Station 101/38 on Sunday:

$$\frac{44{,}775}{45{,}963} = 0.97$$

Calculation for New/Old ATR Station 101/38 on Monday:

$$\frac{43{,}869}{45{,}963} = 0.95$$

The results of the calculations are summarized in the following table:

New/Old ATR Station	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
101/38	0.97	0.95	0.94	0.98	1.05	1.18	0.96
105/37	0.94	0.97	0.98	1.00	1.03	1.14	0.95
201/35	1.04	0.90	0.87	1.00	1.06	1.19	0.99
308/69	1.08	0.87	0.91	0.96	1.04	1.14	1.01
310/34	0.82	0.98	1.02	1.05	1.08	1.16	0.94
403/41	0.99	0.86	0.97	1.01	1.03	1.15	1.00

Step 4. *Calculate the August 2004 Only Factors.*

Calculation for August 2004 Only on Sunday:

$$\frac{(0.97+0.94+1.04+1.08+0.82+0.99)}{6}=0.97$$

The results of the calculations are summarized in the following table:

	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
August 2004 Only	0.97	0.92	0.95	1.00	1.05	1.16	0.97

Step 5. *Calculate the 5-Year-Average August 2004 Factors.*

Calculation for 5-Year Average August 2004 on Sunday:

$$\frac{(0.97+0.97+0.89+0.95+0.89)}{5}=0.93$$

The results of the calculations are summarized in the following table:

	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
August 2004	0.93	1.00	1.03	1.03	0.96	0.90	0.91

2.6.6 Data Storage and Reporting

The continuous count data are archived in the Advanced traffic Data Analysis and Management system (ADAM) and can be printed or emailed as needed. As part of the Highway Performance Monitoring System (HPMS), data are prepared by the Travel Data and Operations Planning Section for submittal to the Federal Highway Administration in the record formats described in Section 6 of the Traffic Monitoring Guide. The continuous count data collected by the ATR stations is submitted monthly. Data files are e-mailed and printouts are sent, which are due within 20 days of the close of the month in which the data were collected. ATR station description records are sent annually or when there is a change.

The State maintains Monthly ATR Comparison Reports, Yearly ADT Summary Reports and Yearly ADT Variation Factor Reports. These reports also serve as “Quality Control of Data” for the ATRs.

2.7 Coverage Count Program

Continuous traffic counting is well suited to capturing seasonal variation in traffic, but it is an extravagant and inefficient way of arriving at Average Annual Daily Traffic (AADT) at all locations where values are needed. Short-period counts are a far more cost-effective method to estimate AADT. Any traffic volume count not taken continuously throughout the year, whether for hours, days, or weeks in duration, is a short-period “coverage count” (also often called a “cycle count”). TDOT makes coverage counts at over 12,000 locations and uses them to calculate AADT estimates.

The Traffic Monitoring Guide by the FHWA suggests using a 48-hour monitoring period on a three-year cycle, but TDOT has found that using a 24-hour monitoring period on an annual basis better meets the Department’s needs and abilities. This variation in monitoring is not considered to be significant in the accuracy of AADT estimates. The annual coverage counts are made at approximately the same time of the year. In cities with colleges, counts are scheduled when college is in session.

2.7.1 Data Collection Routine

To collect the short-period traffic data, field personnel are furnished with a map showing the locations and station numbers of the counts to be made. The personnel place a Diamond Unicorn with pneumatic road tubes attached to the roadway at the locations. The recorders count one vehicle for every two impulses from the road tubes. The recorders are left in place for a minimum of 24-hours before being picked up. In high traffic volume sections of Interstate routes, field personnel place the equipment on the ramps. This is done mainly for the safety of the field personnel, but the problem of tube undercounting due to simultaneous strikes on the tube is also eliminated. Installation of magnetic loops in the pavement is desirable, but the cost and time requirement is considered too high under present circumstances.

2.7.2 Data Retrieval and Validation

Once data is collected, it is transferred to a portable reader and then sent via telephone modem to a microprocessor at TDOT headquarters in Nashville. The data is imported into the ADAM system. The quality of data is controlled at several points and by different personnel. ADAM validates the traffic count by a data filtering process. The filtering process compares the count to previous and surrounding counts and checks for missing data due to equipment malfunctions. The Traffic Monitoring Guide recommends a maximum count variation of 10% high or low. Tennessee uses a 15% tolerance. This allows better utilization of field personnel and does not have a significant impact on traffic volumes since most sites are counted annually.

Comparing Tennessee's Interstate System counts with the bordering States does the most independent check. This comparison is done with the states of Kentucky, Virginia, North Carolina, Georgia, Alabama, Mississippi, Arkansas, and Missouri at thirteen (13) state borderline crossings.

The field personnel are notified by email or phone if any stations need to be recounted. This contact also allows the field personnel to inform the office personnel of any unusual factors that may have caused traffic volume changes. Common examples are road construction, business openings, crash sites and residential changes. After the raw count is accepted as “reasonable”, it is converted to an AADT estimate.

2.7.3 Estimating AADT

The Average Annual Daily Traffic (AADT) estimate is calculated by multiplying the 24-hour total of the coverage count (the Base Count) by the appropriate Traffic Variation Factor (derived from continuous counting) and the appropriate Axle Correction Factor (derived from classification counting):

$$AADT = ADT \times TVF \times ACF$$

where: $AADT$ = Average Annual Daily Traffic;
ADT = Average Daily Traffic (the Base Count);
TVF = Traffic Variation Factor; and
ACF = Axle Correction Factor.

Growth factors are not required to adjust the raw data since counts are made on an annual basis. All AADT estimates are rounded to the nearest ten because many of Tennessee’s counts are small.

2.7.4 Data Storage and Reporting

For reference and record keeping purposes, coverage count data is kept in several forms. The coverage count data are archived in ADAM and can be printed or emailed as needed. Printouts of the raw data are bound and filed by county and station number. The factors used to calculate AADT are shown on these sheets for audit purposes.

A “Trend Book” is kept for each county. Each station is placed on separate page with the station, county, route, and location information given in the heading. Below the heading, each year’s data is recorded by the date the count was made followed by the raw count Average Weekday Traffic (AWT) and the unrounded AADT volume. Space is also provided for important remarks about the count.

The rounded AADT volumes are imported on city and county maps. Interstate volumes are placed on a state map. All these maps are prepared and published annually in book form, called "Traffic Flow Maps" or "ADT Books". As these maps are prepared, another check of the AADT volumes is made. Hard copies may be ordered or digital Adobe PDF files may be downloaded online from http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_Planning/planning/mapping_&_statistics_office/adt.asp.

The Short Range Planning and Data Office generates several in-house reports from this data as well as sending the necessary information to the HPMS (compiles the data for reporting to the FHWA in Washington) and TRIMS (compiles the data for use by the State) sections. The coverage counts for the previous calendar year are sent to the FHWA in Washington by June 15th (as soon as Traffic Flow Maps is published) as a part of HPMS.

2.8 Classification Count Program

Vehicle classification is the observation of highway vehicles and the subsequent sorting of the resulting data into a fixed set of categories (vehicle classes). Vehicle classification data is extremely important as transportation agencies and the State Legislature grapple with the need to determine and allocate the costs associated with maintaining the highway system and in selecting the improvements that will be programmed. In 1987, when the classification stations were selected, the Rural Collectors were not separated, so Tennessee classifies on Rural Major Collectors, but not on Rural Minor Collectors.

2.8.1 Classification Data Collection Routine

Classification counts are performed annually in 3-year cycles using Peek ADR-1000/2000/3000 classifiers, called Automatic Vehicle Classifiers (AVCs). These classifiers are portable, battery-operated, solid-state machines with rubber tube/air switch detectors. They are conducted on roads with up to 2 directional lanes. They are tested for correct classification of vehicles by comparison with a 24-hour manual classification at the same location, date, and time. The procedure is not repeated on any regular schedule because the operator can view, in real time, all the traffic crossings at the road tubes. Any AVC not properly operating is removed from service until it is repaired. For facilities with 3 or more directional lanes, classification is done manually as a Special Need. Both machine and manual classification counts (also called "cycle counts") are conducted for 24-hour periods at approximately 600 locations (200 per year or cycle). Classification and truck weight stations are "nested" together; i.e., the truck weight stations are also used as classification stations (see Truck Weight Survey). These counts are made every month of the year between Monday morning and Friday afternoon, excluding holidays.

2.8.2 Data Retrieval and Sorting

Once the classification data are collected, they are retrieved from the AVCs by field personnel with a data retriever and sent by telephone modem to a microprocessor at TDOT headquarters in Nashville. The computer, with standard manufacturer's software, sorts the data into the standard 13 vehicle classifications as defined by the FHWA (see Figure 3 and Table 6). The sorted data is tabulated by office personnel into Microsoft Excel files, referred to as the "Machine Classification Forms" (see Figure 4).

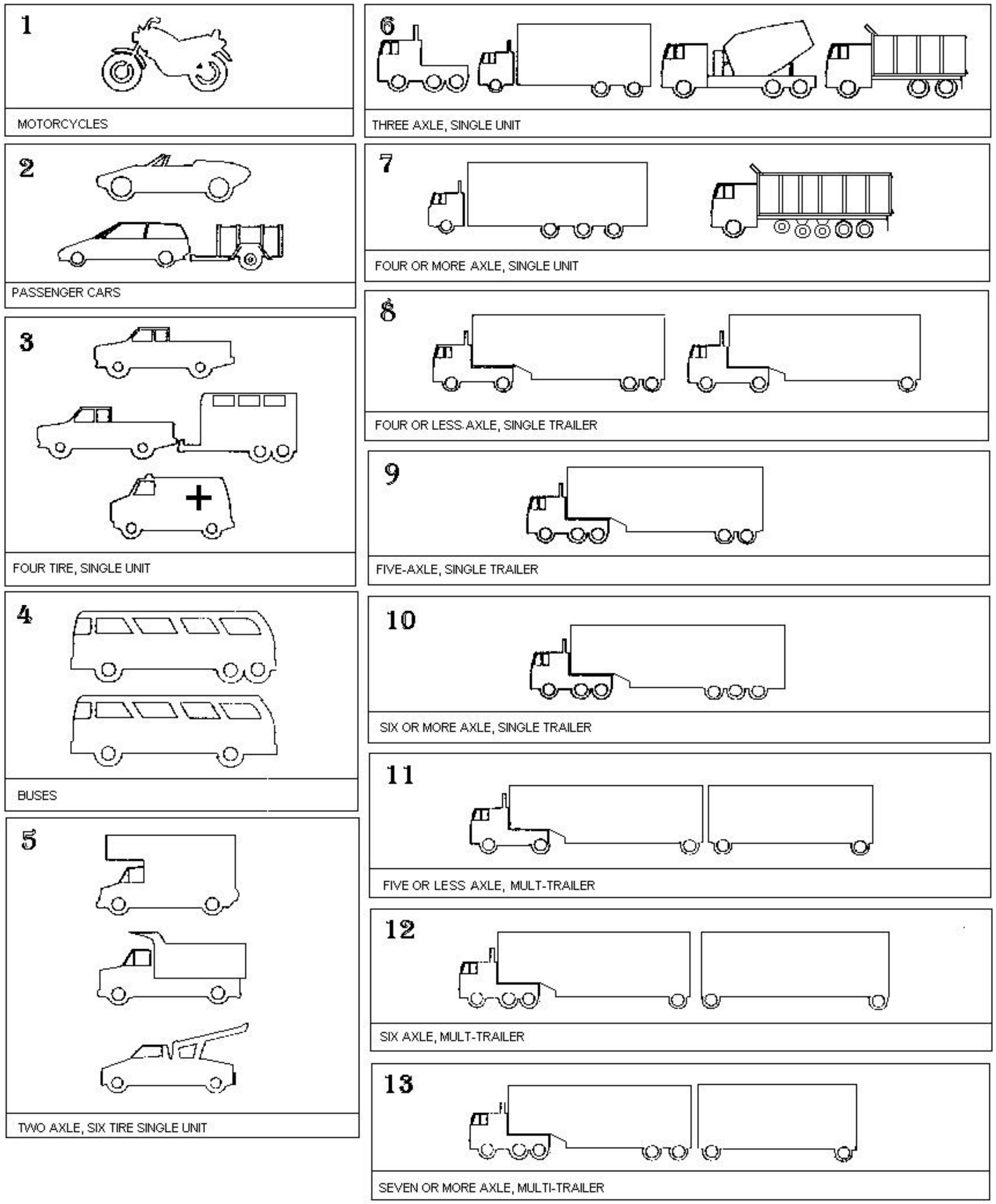


Figure 3. FHWA Vehicle Classifications.

Table 6. FHWA Vehicle Class Descriptions.

Class	Description
Class 1	**Motorcycles:** All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handlebars rather than wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheeled motorcycles.
Class 2	**Passenger Cars:** All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.
Class 3	**Other Two-Axle, Four-Tire Single-Unit Vehicles**: All two-axle, four-tire vehicles other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carryalls, and minibuses. Other two-axle, four-tire single-unit vehicles pulling recreational or other light trailers are included in this classification.
Class 4	**Buses:** All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered to be trucks and be appropriately classified.
Note: In reporting information on trucks, the following criteria should be used: **a.)** Truck tractor units traveling without a trailer will be considered single-unit trucks. **b.)** A truck tractor unit pulling other such units in a "saddle mount" configuration will be considered as one single-unit truck and will be defined only by axles on the pulling unit. **c.)** Vehicles shall be defined by the number of axles in contact with the roadway. Therefore, "floating" axles are counted only when in the down position. **d.)** The term "trailer" includes both semi- and full trailers.	
Class 5	**Two-Axle, Six-Tire, Single-Unit Trucks:** All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., with two axles and dual rear wheels.
Class 6	**Three-Axle Single-Unit Trucks:** All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., with three axles.
Class 7	**Four or More Axle Single-Unit Trucks:** All trucks on a single frame with four or more axles.
Class 8	**Four or Fewer Axle Single-Trailer Trucks:** All vehicles with four or fewer axles consisting of two units, one of which is a tractor or straight truck power unit.
Class 9	**Five-Axle Single-Trailer Trucks:** All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.
Class 10	**Six or More Axle Single-Trailer Trucks:** All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.
Class 11	**Five or Fewer Axle Multi-Trailer Trucks:** All vehicles with five or fewer axles consisting of three or more units, one of which is a tractor or straight truck power unit.
Class 12	**Six-Axle Multi-Trailer Trucks:** All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.
Class 13	**Seven or More Axle Multi-Trailer Trucks:** All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

Revised 8/25/05

MACHINE CLASSIFICATION

STATION NO.: 39
DATE: 8/31/2005
COUNTY: FRANKLIN
CITY: WINCHESTER
ROUTE: SR-15
LOG MILE: 15.750

CLASSIFICATION OF VEHICLE	DIRECTION OF TRAVEL		TOTAL	%	AXLE
**********************************	EAST	WEST	***************************		ADJUSTMENT
1. Motorcycles	67	68	135	1.59%	270
2. Cars	3,204	3,305	6,509	76.53%	13,018
3. Pick-up, Panel, Van	723	878	1,601	18.82%	3,202
Sub-total Passenger Vehicles	3,994	4,251	8,245	97%	16,490
4. Buses	4	4	8	0.09%	16
5. Dual Rear	27	26	53	0.62%	106
6. 3-Axle Truck	22	21	43	0.51%	129
7. 4-Axle Truck	4	6	10	0.12%	40
Sub-total Single-Unit Trucks	57	57	114	1%	291
8. 2S-1, 3S-1, 2S-2	32	23	55	0.65%	220
9. 3S-2, 2S-3	13	15	28	0.33%	140
10. 3S-3, 3S-4	1	4	5	0.06%	30
Sub-total Combination Trucks	46	42	88	1%	390
11. 2S-1-2	8	13	21	0.25%	105
12. 2S-2-2, 3S-1-2	0	1	1	0.01%	6
13. Any 7 Axle	25	11	36	0.42%	252
Sub-total Twin Trailers	33	25	58	0.68%	363
Total Combinations	79	67	146	2%	753
Total Trucks	136	124	260	3.06%	1,044
14. Other	0	0	0	0%	0
TOTAL ALL VEHICLES	4,130	4,375	8,505	100.0%	17,534

2005 A.D.T. = **7,740**

Truck Factor
0.97

$$\begin{array}{r} 8{,}505 \\ \times \quad 0.91 \\ \hline 7{,}739.55 \end{array}$$

Figure 4. Typical Machine Classification Form.

2.8.3 Axle Correction Factors

Axle Correction Factor (ACFs), also sometimes called truck factors, are derived from the classification counts to adjust the coverage counts. The factor is required since the use of pneumatic road tubes for coverage counting introduces error in the AADT estimates. The source of error is axle inflation (over-count) due to the way the equipment operates. The portable traffic counters using road tubes only count axles, not vehicles; so one vehicle is recorded for every two impulses. This obviously leads to over-count errors, which increase as the proportion of three-or-more axle vehicles increases in the traffic stream.

The Machine Classification Form is also used to develop the ACF. ACFs are reported to two (2) places after the decimal. To calculate the ACF, the following steps are used:

1) The number of vehicles is totaled.
2) The number of vehicles in each vehicle classification is multiplied by the corresponding number of axles for that classification.
3) The number of axles are added together and divided by 2 to give the number of vehicles if the sample only contained 2-axle vehicles.
4) The ACF is calculated according to the following:

$$ACF = \frac{Actual\ number\ of\ vehicles}{Number\ of\ vehicles\ if\ sample\ only\ contained\ 2-axle\ vehicles}$$

The calculations for an ACF are illustrated in Example 5.

Example 4. Calculation of Axle Correction Factor.

Revised 8/25/05

MACHINE CLASSIFICATION

STATION NO.: 39
DATE: 8/31/2005
COUNTY: FRANKLIN
CITY: WINCHESTER
ROUTE: SR-15
LOG MILE: 15.750

CLASSIFICATION OF VEHICLE	DIRECTION OF TRAVEL		TOTAL	%	AXLE
********************************	EAST	WEST	**************************		ADJUSTMENT
1. Motorcycles	67	68	135	1.59%	270
2. Cars	3,204	3,305	6,509	76.53%	13,018
3. Pick-up, Panel, Van	723	878	1,601	18.82%	3,202
Sub-total Passenger Vehicles	3,994	4,251	8,245	97%	16,490
4. Buses	4	4	8	0.09%	16
5. Dual Rear	27	26	53	0.62%	106
6. 3-Axle Truck	22	21	43	0.51%	129
7. 4-Axle Truck	4	6	10	0.12%	40
Sub-total Single-Unit Trucks	57	57	114	1%	291
8. 2S-1, 3S-1, 2S-2	32	23	55	0.65%	220
9. 3S-2, 2S-3	13	15	28	0.33%	140
10. 3S-3, 3S-4	1	4	5	0.06%	30
Sub-total Combination Trucks	46	42	88	1%	390
11. 2S-1-2	8	13	21	0.25%	105
12. 2S-2-2, 3S-1-2	0	1	1	0.01%	6
13. Any 7 Axle	25	11	36	0.42%	252
Sub-total Twin Trailers	33	25	58	0.68%	363
Total Combinations	79	67	146	2%	753
Total Trucks	136	124	260	3.06%	1,044
14. Other	0	0	0	0%	0
TOTAL ALL VEHICLES	4,130	4,375	8,505	100.0%	17,534

2005 A.D.T. = **7,740**

Truck Factor
0.97

8,505
x 0.91
7,739.55

- 135 x 2 = 270
- 6,509 x 2 = 13,018
- 1,601 x 2 = 3,202

- 8 x 2 = 16
- 53 x 2 = 106
- 43 x 3 = 129
- 10 x 4 = 40

- 55 x 4 = 220
- 28 x 5 = 140
- 5 x 6 = 30

- 21 x 5 = 105
- 1 x 6 = 6
- 36 x 7 = 252

Actual number of vehicles = 8,505

Total axles = 17,534

Number of vehicles if sample only contained 2-axle vehicles = 17,534 / 2 = 8,767

ACF = 8,505 / 8,767 = **0.97**

2.8.4 Classification Count Data Storage and Reporting

The digital classification files in Microsoft Excel format are made available on the TDOT Intranet at P:\PLANNING\Classification Counts. A printout of each file is also made and stored. ACFs are manually entered into ADAM for use in computing AADT estimates. ACFs and truck percents are placed on large State maps at the classification station locations. These maps are used for easy reference on truck usage of highways. The information is sent to the TRIMS section to make it readily available to TDOT employees and consultants.

The classification counts for the previous calendar year are sent in the report format outlined in the TMG to the FHWA in Washington by June 15th (as soon as the book "Vehicle Classifications Counts" is published) as a part of HPMS. This data is broken down according to roadway functional classes.

2.9 Truck Weight Program

The objective of the Truck Weight Program is to obtain a reliable estimate of the distribution of the vehicle and axle loads per vehicle for FHWA heavy vehicle classes (classes 4 through 13) within the functional roadway groups. These data provide valuable information that is used at the State, Regional and National levels in the consideration of transportation policies. Such information is needed to establish priorities for highway construction, pavement design, structural design loading, and frequency of pavement resurfacing. When coupled with information on available truck power, weight information is employed to determine highway gradients and need for climbing lanes. Weight information is also used to compute truck accident rates and allocate highway taxes equitability.

2.9.1 Data Collection Routine

From 1937 through 1976, the TDOT Bureau of Planning and Development conducted annual truck weight surveys at selected locations on highways in Tennessee. In 1976, the FHWA directed the State to classify vehicles at each survey station annually, but to weigh only in even numbered calendar years. In 1987, Tennessee began conducting annual surveys with Weigh-In-Motion (WIM) at 90 stations on a 3-year cycle complying with the TMG recommendations. Some of the Urban Interstates are not weighted because of concerns for the safety of the field crew and traffic congestion that would be caused. A 24-hour classification count is conducted at these locations.

Truck weight surveys are conducted using Peek ADR-1000/2000/3000 WIM equipment with piezoelectric sensors. The stations are operated 24 hours on weekdays. All vehicles are weighed and classified. If the route is 3 or more lanes in one direction or an undivided highway, then only the right lanes are weighed and all lanes are manually classified. The equipment is calibrated using an onboard software program. Field checks are randomly conducted by waiting for an empty flatbed semi-trailer truck to pass, which usually weighs 29,000-31,000 pounds.

The permanent truck weigh stations commonly seen on the interstates in Tennessee are not part of the Truck Weight Program. Those stations are operated by the Tennessee Highway Patrol (a division of the Tennessee Department of Safety). The stations are used for law enforcement and safety checks only. Data is not collected from these stations.

2.9.2 Data Retrieval

Once truck weight data is collected, it is transferred to a portable reader and then sent via telephone modem to a microprocessor at TDOT headquarters in Nashville.

2.9.3 Data Storage and Reporting

Printouts of the raw data files are made and filed. A consultant has been hired under contract to resolve digital file compatibility issues involved with inputting the data into the Vehicle Travel Information System (VTRIS) software package from the FHWA, so that reporting may be achieved. More information about VTRIS is available online at http://www.fhwa.dot.gov/ohim/ohimvtis.htm.

2.10 Long Term Pavement Performance Program

Understanding "why" some pavements perform better than others is key to building and maintaining a cost-effective highway system. That's why in 1987, the Long Term Pavement Performance (LTPP) program - a comprehensive 20-year study of in-service pavements - began a series of rigorous long-term field experiments monitoring more than 2,400 asphalt and portland cement concrete pavement test sections across the U.S. and Canada.

Established as part of the Strategic Highway Research Program (SHRP) and now managed by the Federal Highway Administration (FHWA), LTPP was designed as a partnership with the States and Provinces. LTPP's goal is to help the States and Provinces make decisions that will lead to better performing and more cost-effective pavements. More information about LTPP is available online at http://www.fhwa.dot.gov/pavement/ltpp/index.cfm.

Tennessee is one of many states taking part in the LTPP program by supporting 15 SHRP sites. These research sites are identified by a blue sign with the letters

"SHRP". The research sections are approximately 500 feet long and are composed of sections with various surfaces and base materials.

TDOT is committed to the goals and research objectives of the LTPP program. We understand the magnitude of research being performed and the benefits to be gained for those involved.

2.11 Special Needs

The need for traffic characteristics data not provided by the Continuous Count, Coverage Count, Classification Count, or Truck Weight Programs are considered "Special Needs". Special Needs traffic counts are of short duration, from one to twelve hours, but occasionally up to several days. The purpose of these counts is to supply specific data about a specific location. Special count data includes machine volume counts, manual turning movements, pedestrian counts, machine or manual classification counts, and origin and destination surveys.

The need for special data is carefully considered and clearly defined to insure that all other sources of data have been exhausted. This checking in advance of the actual collection activities reduces duplication of effort and time delays. The person in the Forecasting Unit requesting field data (project supervisor) is responsible for filling out a Request for Field Data Form (Figure 5) and attaching maps or diagrams as necessary to aid the field personnel. Requests are noted by location and scheduled to make the best use of the staff and equipment.

Because of the diversity of purposes for the data, collection activities are very flexible. The same equipment used in the regular count programs is used to make volume counts and classification counts, but manual counts are done by specialty personnel.

(REV. 3/8/05)

TENNESSEE DEPARTMENT OF TRANSPORTATION
SHORT RANGE PLANNING AND DATA OFFICE

TRAFFIC REQUEST FOR FIELD DATA

REQUESTED BY: TONY ARMSTRONG ______ DATE: ______
ASSIGNED TO: ______ DATE: ______
MADE BY: ______ DATE: ______
ANALYZED BY: ______ DATE: ______
RECEIVED BY: ______ DATE: ______

LOCATION OF TRAFFIC STUDY:
COUNTY: ______
CITY: ______
PROJECT NO.: ______

NUMBER OF COUNTS AND/OR STATIONS REQUESTED:
______

NUMBER OF COUNTS AND/OR STATIONS MADE:
______

MAPS PROVIDED: ______ DATE: ______

MAPS RETURNED: ______ DATE: ______

COMMENTS

Figure 5. Request for Field Data Form.

2.11.1 Turning Movement Counts

Turning movement counts are performed at intersections. The traffic volumes in each direction are recorded. Turning movement counts are performed by field personnel manually using the JAMAR DB-400. The counts are usually in a duration of 12 hours (from 6 A.M. to 6 P.M.), but are occasionally 8 hours capturing only the morning, noon, and evening peaks.

The field personnel classify the vehicles as they count them into 3 groups. The first group, cars, pick-ups, and panels (CPP), contains FHWA vehicle classes 1-3. The second group, other single units (OSU), contains FHWA vehicle classes 4-10. The third unit, combinations (C), contains FHWA vehicle classes 11-13.

After data is collected and with manufacturer's software, field personnel transfer the data to a microcomputer and convert it to Microsoft Excel files. Three Excel sheets are created for the turning movement count – one for each group of classes. The sheets display the data tabulated in 15-minute increments by each movement direction. The numerical identifier for each direction is as follows:

2 – From North, To Right;
3 – From North, Through;
4 – From North, To Left;
6 – From East, To Right;
7 – From East, Through;
8 – From East, To Left;
10 – From South, To Right;
11 – From South, Through;
12 – From South, To Left;
14 – From West, To Right;
15 – From West, Through; and
16 – From West, To Left.

Figure 6 shows an example of a Data Sheet for the CPP group of a turning movement count. Similar sheets are created for other two groups. These digital sheets are emailed to a microcomputer at TDOT headquarters in Nashville for further processing.

T.D.O.T. TURNING MOVEMENT SHEET

CARS, PICK-UPS & PANELS

PEAK	Total	PHF
AM	1637	1.063
PM	1684	0.975

TIME	2	3	4	6	7	8	10	11	12	14	15	16	SUB	TOTAL	PEAK	
6:00 - 6:15	0	16	0	0	0	0	0	14	2	4	0	5	41	42	242	
6:15 - 6:30	2	27	0	0	0	0	0	15	1	6	0	1	52	56	278	
6:30 - 6:45	3	34	0	0	0	0	0	12	5	8	0	3	65	71	315	
6:45 - 7:00	4	25	0	0	0	0	0	24	5	8	0	2	68	73	404	
7:00 - 7:15	3	26	0	0	0	0	0	20	7	12	0	7	75	78	492	
7:15 - 7:30	2	30	0	0	0	0	0	35	7	12	0	6	92	93	523	
7:30 - 7:45	6	65	0	0	0	0	0	52	9	14	0	11	157	160	532	
7:45 - 8:00	5	45	0	0	0	0	0	63	8	18	0	18	157	161	509	
8:00 - 8:15	6	32	0	0	0	0	0	36	10	7	0	10	101	109	481	
8:15 - 8:30	7	27	0	0	0	0	0	38	9	5	0	12	98	102	503	
8:30 - 8:45	9	42	0	0	0	0	0	54	5	7	0	12	129	137	548	
8:45 - 9:00	3	37	0	0	0	0	0	59	11	8	0	10	128	133	589	
9:00 - 9:15	1	60	0	0	0	0	0	50	6	5	0	6	128	131	612	
9:15 - 9:30	6	46	0	0	0	0	0	53	9	8	0	17	139	147	635	
9:30 - 9:45	8	60	0	0	0	0	0	65	11	11	0	17	172	178	662	
9:45 - 10:00	4	39	0	0	0	0	0	60	16	17	0	19	155	156	664	
10:00 - 10:15	6	54	0	0	0	0	0	46	13	17	0	14	150	154	721	
10:15 - 10:30	4	60	0	0	0	0	0	55	17	10	0	23	169	174	869	
10:30 - 10:45	6	50	0	0	0	0	0	59	16	20	0	23	174	180	1034	
10:45 - 11:00	7	62	0	0	0	0	0	75	25	16	0	23	208	213	1184	
11:00 - 11:15	24	87	0	0	0	0	0	117	28	20	0	25	301	302	1356	
11:15 - 11:30	24	110	0	0	0	0	0	107	40	22	0	31	334	339	1470	
11:30 - 11:45	23	101	0	0	0	0	0	106	37	27	0	32	326	330	1559	
11:45 - 12:00	35	122	0	0	0	0	0	111	40	40	0	30	378	385	1637	* #
12:00 - 12:15	30	128	0	0	0	0	0	115	51	42	0	49	415	416	1684	*
12:15 - 12:30	33	131	0	0	0	0	0	106	35	69	0	44	418	428	1633	
12:30 - 12:45	17	131	0	0	0	0	0	110	30	63	0	53	404	408	1463	
12:45 - 1:00	24	128	0	0	0	0	0	113	34	58	0	72	429	432	1354	#
1:00 - 1:15	16	116	0	0	0	0	0	112	17	53	0	47	361	365	1203	
1:15 - 1:30	16	83	0	0	0	0	0	79	16	29	0	31	254	258	1129	
1:30 - 1:45	19	100	0	0	0	0	0	80	25	29	0	40	293	299	1157	
1:45 - 2:00	12	87	0	0	0	0	0	85	22	34	0	35	275	281	1107	
2:00 - 2:15	8	83	0	0	0	0	0	94	33	33	0	34	285	291	1056	
2:15 - 2:30	12	93	0	0	0	0	0	76	18	40	0	44	283	286	1016	
2:30 - 2:45	13	82	0	0	0	0	0	63	19	31	0	30	238	249	993	
2:45 - 3:00	5	82	0	0	0	0	0	83	11	17	0	26	224	230	1027	
3:00 - 3:15	11	74	0	0	0	0	0	100	17	20	0	25	247	251	1049	
3:15 - 3:30	6	92	0	0	0	0	0	80	31	16	0	33	258	263	1166	
3:30 - 3:45	15	69	0	0	0	0	0	109	29	26	0	30	278	283	1195	
3:45 - 4:00	8	78	0	0	0	0	0	89	20	23	0	31	249	252	1228	
4:00 - 4:15	17	88	0	0	0	0	0	120	50	54	0	34	363	368	1279	
4:15 - 4:30	24	70	0	0	0	0	0	118	19	30	0	31	292	292	1205	
4:30 - 4:45	7	92	0	0	0	0	0	108	46	26	0	36	315	316	1187	
4:45 - 5:00	19	88	0	0	0	0	0	102	24	27	0	42	302	303	1148	
5:00 - 5:15	19	91	0	0	0	0	0	105	23	25	0	30	293	294	1125	
5:15 - 5:30	19	80	0	0	0	0	0	98	14	25	0	35	271	274		
5:30 - 5:45	25	94	0	0	0	0	0	73	34	30	0	20	276	277		
5:45 - 6:00	19	87	0	0	0	0	0	90	26	29	0	29	280	280		
SUBTOTAL	592	3504	0	0	0	0	0	3634	981	1151	0	1238	11100			
TOTAL	597	3589	0	0	0	0	0	3716	990	1162	0	1246		11300		

Station No.:	1		
Location:	RUTGERS AVE	AT	0
Date:	9/5-6/01		
Weather:	SUNNY		
Recorder:	DAVIS-ANDERSON		
County:	ANDERSON		
City:	OAK RIDGE		
Print Date:	10/28/2005		

*=Peak Hour
#=Peak 15 min

Figure 6. Typical Data Sheet for a Turning Movement Count.

Once received in Nashville, the data is reviewed against similar counts or nearby coverage and classification counts, as a quality control check. A copy of the data sheets is sent to the project supervisor to calculate an "expansion factor". The expansion factor is required to adjust the 12-hour turning movement count to a 24-hour value. To calculate the factor, raw/unadjusted data from a nearby coverage count for the same 12 hour period (6 A.M – 6 P.M.) as the turning movement count are retrieved from ADAM. The 12-hour totals for the turning movement volume and the coverage volume are calculated. The expansion factor is then calculated:

$$Expansion\ \ factor = \frac{12 - hour\ total\ \ from\ turning\ movement\ count}{12 - hour\ total\ \ from\ coverage\ count}$$

If an 8-hour count was conducted, then only the respective 8 hours from the coverage count are used. The expansion factor for 12-hour counts is typically near 1.33. The traffic volume on each approach is multiplied by the expansion factor to find the 24-hour ADT on each approach at the intersection. Percentages of the class groups are calculated for each approach.

The counted traffic volumes, expansion factor, calculated approach ADTs, and class group percentages are placed on a Summary Sheet. Figure 7 shows an example of a Summary Sheet.

The original Data Sheets and the Summary Sheet are labeled and filed for future use. This also creates a database to reduce the number of special counts in the future. The availability of turning movement counts that have been performed may be checked the intranet at http://home.tdot.state.tn.us/tmc.

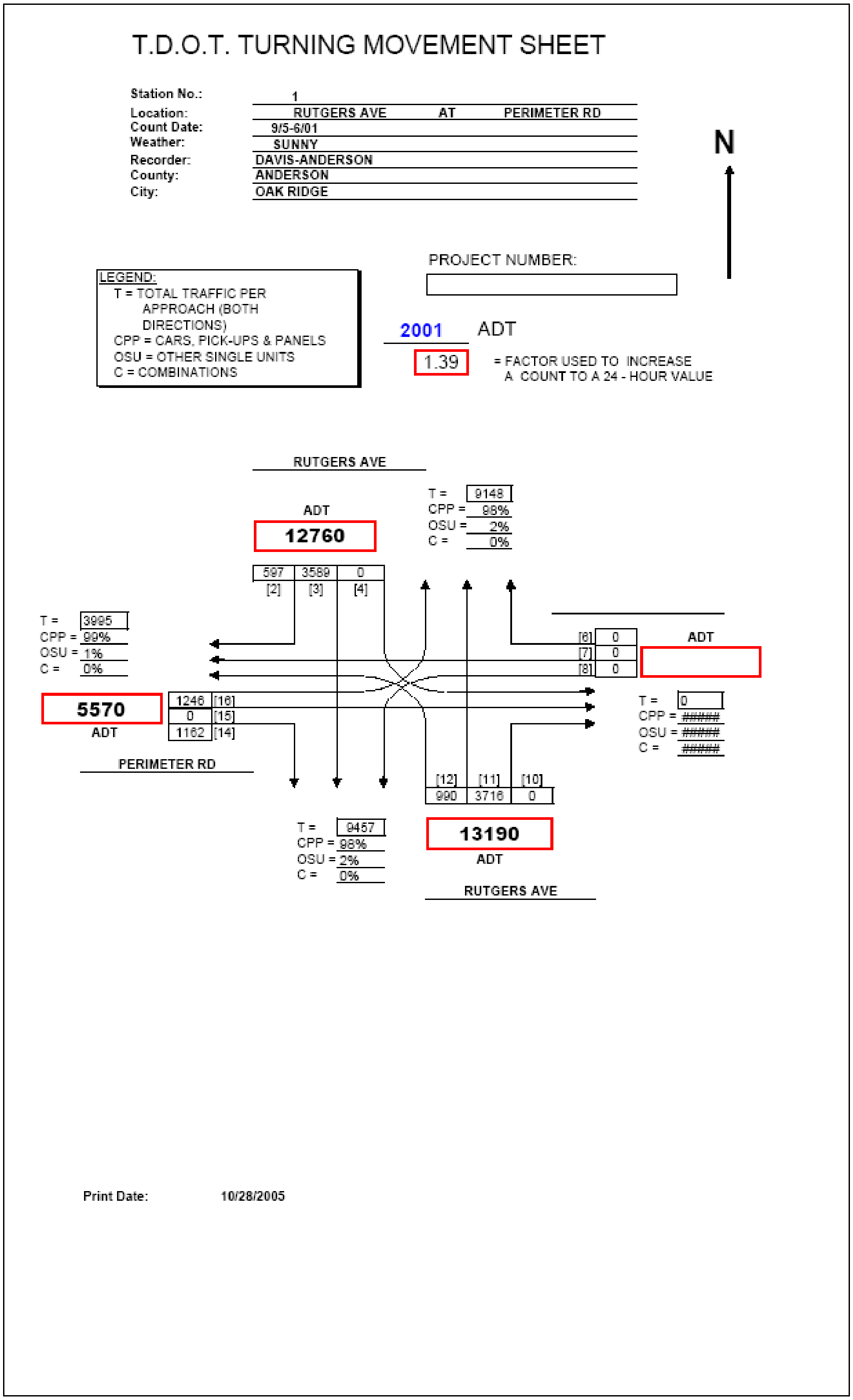


Figure 7. Typical Summary Sheet for a Turning Movement Count.

2.11.2 Vehicle Occupancy

Vehicle occupancy data are used for many purposes, including: monitoring the effectiveness of high-occupancy vehicle (HOV) programs, comparing the use of transportation modes, analyzing transport alternatives, and analyzing fuel efficiency. Occupancy data are collected manually. The data is recorded in 15-minute increments along with the type of vehicle utilized by the occupants. The 5 vehicle types include:

- Cars, pick-ups, and vans with only one driver;
- Single unit trucks (FHWA vehicle classes 4-10);
- Combinations (FHWA vehicle classes 11-13);
- Passenger vans with driver and at least one (1) passenger; and
- Busses.

An example of a Vehicle Occupancy Count Sheet is shown in Figure 8 below.

T.D.O.T. VEHICLE OCCUPANCY COUNT SHEET

Recorder: **Co./City:** Davidson County/Brentwood **Date:** 8/10/1998
Station No 1 **Route No.:** I-65 South **Period of Operation: 4:00 PM - 6:00 PM**

	TIME: 4:00 - 4:15				TIME: 4:15 - 4:30				TIME: 4:30 - 4:45				TIME: 4:45 - 5:00				
	Number of Occupants				**Number of Occupants**				**Number of Occupants**				**Number of Occupants**				
VEHICLE T	**1**	**2**	**3**	**4+**	**1**	**2**	**3**	**4+**	**1**	**2**	**3**	**4+**	**1**	**2**	**3**	**4+**	**Total**
Cars & Pic	63	68	5	7	58	59	9	4	69	55	13	1	72	97	8	5	593
Single Unit	4	0	1	0	2	0	1	0	1	1	1	0	2	2	0	1	16
Combinatio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Busses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Vehi	67	68	6	7	60	59	10	4	70	56	14	1	74	99	8	6	609
Total Pers	67	136	18	28	60	118	30	16	70	112	42	4	74	198	24	24	1021

	TIME: 5:00 - 5:15				TIME: 5:15 - 5:30				TIME: 5:30 - 5:45				TIME: 5:45 - 6:00				
	Number of Occupants				**Number of Occupants**				**Number of Occupants**				**Number of Occupants**				
VEHICLE T	**1**	**2**	**3**	**4+**	**1**	**2**	**3**	**4+**	**1**	**2**	**3**	**4+**	**1**	**2**	**3**	**4+**	**Total**
Cars & Pic	56	65	12	7	85	103	21	12	61	62	34	16	76	80	15	3	708
Single Unit	2	1	0	0	4	2	0	0	0	0	0	0	2	0	0	0	11
Combinatio	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
Passenger	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2
Busses	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Total Vehi	58	66	12	7	90	105	21	14	62	62	34	16	78	80	15	4	724
Total Pers	58	132	36	28	90	210	63	56	62	124	102	64	78	160	45	16	1324

Figure 8. Typical Vehicle Occupancy Count Sheet.

A troublesome problem with collecting occupancy data is the high-occupancy vehicles, such as vans. Occupancy is assumed for "four and more" because it is difficult for an observer to make an accurate count of persons in moving traffic. Although half, and sometimes more, of the vehicles in the traffic stream may be occupied by the driver only, high-occupancy vehicles are very important in computing the average occupancy. This can be illustrated by an example:

Example 5. Estimation of Average Vehicle Occupancy.
Assume that PV1 means "passenger vehicle with one occupant," etc., and that count is PV1 = 6, PV2 = 4, PV3 =2, and PV4+ = 2 for total of 14 vehicles. If the actual occupancy of PV4+ is actually 4 persons, then the total number of persons is 28 and average occupancy is 28/14 = 2.00. If the actual occupancy of PV4+ is 7 the total number of persons would be 34 for an occupancy of 34/14 = 2.428, a 21 percent error.

The effect of underestimating the occupancy of the relatively few high-occupancy vehicles can be substantial as the number of them increases. A special effort is worthwhile to obtain reliable estimates for vans. Transit bus occupancy often requires an on-board count.

Vehicle occupancy counts are more accurate if obtained at entrances to parking facilities. Vehicle occupancy can also be derived from home interview origin & destination data. Total person trips are divided by total driver trips to obtain average occupancy.

2.12 Crash Studies

Tennessee Department of Transportation in conjunction with the Federal Highway Administration (FHWA) is addressing locations with high injury rates and fatalities.
As result of passage of the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), the Highway Safety Improvement Program (HSIP) was elevated to a core program to achieve the significant reduction of hazards. Additionally, it introduced a new set-aside provision known as High Risk Rural Roads Program (HRRP) and Hazard Elimination safety Program. The purpose of the HSIP is to achieve significant reduction in traffic fatalities and serious injuries on public roads.

2.12.1 Data Sources

Identification of hazardous or potentially hazardous highway locations requires reliable, up-to-date crash data which will indicate the locations, types, and magnitudes of the problems at these locations. Crashes are not "accidents". Crash experience is the primary indicator of hazardous locations. Although crash data are supplied by the Tennessee Department of Safety (TDOS), the procedure for obtaining the data will be identified to provide a better understanding of the nature and quality of such data.

2.12.1.1 Crash Reporting

If a crash results in death or injury to any person, or in property damage to any one person in excess of $400, the driver is required to forward a written report to

TDOS within twenty days after the crash (T.C.A. 55-10-107). Every law enforcement officer in the state who investigates a motor vehicle crash, whether on a highway or on private property, is required by law to forward a written report of such crash to TDOS within 24 hours after the investigation (T.C.A. 55-10-107). It should be noted that the law does not require that every crash for which notification is received be investigated by a law enforcement officer. If an officer's report is not available, the amount of information about a crash is limited to the operator's report. In such cases, the data related to circumstances and contributing factors may be questionable or unavailable.

2.12.1.2 Crash Report Processing

All reports received by TDOS have a case or reference number assigned to the document. The reports are checked for completeness and coded by the Records Section of TDOS to facilitate data entry. Then, the reports are microfilmed, keypunched (except for location information), added to the driver's record file, and added to the statistical file. Checks are made for late reports and duplicate reports.

All reports are forwarded to TDOT. The Planning Division reviews the location description on each crash report to determine the type of highway on which the crash occurred. For crashes on the functionally classified highway system, a precise location is coded on the crash report for all crashes. This is also done for fatal and injury crashes on off system roads. The location code indicates county, route number, and log mile. The location information is entered into the crash statistics file by the Safety Planning Section. The records entered by TDOS within this file are accessed by the reference number. The original paper copies of the crash reports are stored until verified and then destroyed. TDOS furnishes TDOT with microfilm copies of crash reports.

2.12.1.3 Crash Record Processing by TDOS

The Tennessee Department of Safety produces crash data summaries on a monthly, semiannual, and annual basis. Three types of summaries are produced:

- Standard Summary of Motor Vehicle Traffic Crashes (National Safety Council format – for all investigated crashes involving death, injury, or property damage to any one person in excess of $400;
- Statewide Motor Vehicle Crash Experience – totals by county, Highway Patrol district, and state (all investigated crashes); and
- Statewide Daily Crash Activity Listing – statewide totals by day of month, month, and yearly total (all investigated crashes).

In addition, a daily report on fatal crashes is prepared. TDOS also has other capabilities for supplying data from their crash base.

2.12.1.4 Crash Record Processing by TDOT

The Tennessee Department of Transportation performs its own analyses of the data for engineering purposes. TDOT receives a duplicate copy of microfilm crash reports from TDOS for all crashes reported by a police officer. The microfilm data file is coordinated with the crash record file to enable retrieval and copying of individual crash reports.

The Planning Division processes crash data records using several computer programs to produce crash data summaries by specific location. The summaries produced and still in current use are as follows:

- Crash Data Listing;
- Statewide Average Crash Rates; and
- Hazard Location Listing.

These reports are reviewed and analyzed within the Planning Division and reviewed by the Program Development and Administration Division and the Highway Safety Program Committee.

To reduce fluctuations in the ranking of hazardous locations from year to year, the Hazardous Location Listing is made every two years using three years of crash data. This ranking is done on a statewide basis. A moving three-year average is computed using the three most recent calendar years on record. The system averages are expanded to reflect average rates for property damage, injury, and fatal crashes, as well as total crashes. Locations are added to the Hazardous Location Listing as projects eligible for Hazard Elimination Safety Program funds if their actual to critical crash ratio is greater than or equal to 3.50. The locations are ranked on the list by crash severity.

2.12.1.5 Other Data Sources

Indications of a potentially hazardous location are obtained from other sources, such as special safety studies, reports from local government agencies, and complaints from the public. Hazardous or potentially hazardous locations identified by any of these methods are brought to the attention of the Highway Safety Program Committee and the regional Traffic Engineers by the appropriate unit of the Department.

2.12.1.6 Crash File

The State's crash file contains one record for each crash that has occurred on the functional highway system. Reference is made to the coding manual for information concerning crash coding procedures.

2.12.2 Crash Data Analysis

The number of crashes observed at any location will vary from year to year due to chance alone even if conditions remain unchanged. Thus, statistical considerations are needed to determine that the number of crashes at any given location is not due to chance. To do that and to compare the relative degree of hazard, the following parameters are considered based on the latest 3-years of data:

- Crash Rate (R)
- Average Crash Rate ($\overline{R}$)
- Critical Crash Rate (R_c)
- Severity Index (SI).

2.12.2.1 Crash Rate Calculation

For the purposes of crash analysis, highway locations are defined as follows:

- Section – a highway segment longer than 0.1 mile with uniform characteristics, including geometry, surface type, number of lanes, access control, environment (rural/urban), and traffic volume;
- Spot – a non intersection highway segment with length equal to 0.1 mile or less; and
- Intersection – a junction of two or more highways, including turn lanes and approach legs up to 0.01 mile from the point of intersection of adjacent curb lines or pavement edge lines.

The Exposure Rate is measured in either number of vehicle-miles of travel or number of entering vehicles, depending on the location. The Exposure Rate is defined as:

For Sections:

$$E_{section} = \frac{V \times T \times L}{1{,}000{,}000}$$

where: $E_{section}$ = Exposure Rate (millions of vehicle-miles);
V = AADT volume (vehicles per day);
T = Time (days); and
L = Length of the section (miles, to the nearest hundredth).

For Spots:

$$E_{spot} = \frac{V \times T}{1{,}000{,}000}$$

where: E_{spot} = Exposure Rate (millions of entering vehicles);
V = AADT volume (vehicles per day); and

T = Time (days).

For Intersections:

$$E_{\text{int}} = \frac{\sum V_i \times T}{2 \times 1{,}000{,}000}$$

where: E_{int} = Exposure Rate (millions of entering vehicles);
$\sum V_i$ = Sum of AADT volumes for all legs of an intersection (vehicles per day);
T = Time (days); and
2 = A factor to avoid double counting of vehicles entering and leaving the intersection.

The Crash Rate for any highway location is determined by dividing the number of crashes that occur at that location in a specified time period by the Exposure Rate:

$$R = \frac{C}{E}$$

where: R = Crash Rate (crashes per million vehicle-miles or per million entering vehicles);
C = Number of crashes; and
E = Exposure Rate (millions of vehicle-miles or millions of entering vehicles).

2.12.2.2 Average Crash Rate Calculation

Determination of a Crash Rate for a specific location provides a basis for comparing that location with any other location. However, additional information is needed to access the importance of the rate. To provide a basis for determining the significance of Crash Rates, Average Crash Rates are needed for various roadway location classes. The standard types of location, highway, and environment used to define the classes are listed below:

Types of locations:

- Sections;
- Spots;
- Intersections;
- Bridges; and
- Railroad crossings.

Types of highways:

- Two-lane;
- Multi-lane, undivided;
- Multi-lane, two-way left turn lane;
- Multi-lane, divided; and
- Multi-lane, freeway.

Types of environment:
- Rural; and
- Urban.

In addition to these types, intersections are broken into a further subset:
- Signalized intersections;
- Full stop intersections; and
- Other intersections.

Average Crash Rates are determined for the previous three-year period for the different classes of highways. The first step in calculating the Average Crash Rate for a specific class (type of location, highway, and environment) is to sum all crashes and all vehicle-miles or entering vehicles for that class. Next, these sums are used in the appropriate equation to calculate the Average Crash Rate for the specific class, as follows:

For Sections:

$$\bar{R}_{section} = \frac{\sum C \times 1{,}000{,}000}{\sum (V \times T \times L)}$$

where: $\bar{R}_{section}$ = Average Crash Rate;
$\sum C$ =Sum of all crashes; and
$\sum (V \times T \times L)$ = Sum of all values of $V \times T \times L$.

For Spots:

$$\bar{R}_{spot} = \frac{\sum C \times 1{,}000{,}000}{\sum (V \times T)}$$

where: $\bar{R}_{spot}$ = Average Crash Rate;
$\sum C$ =Sum of all crashes; and
$\sum (V \times T)$ = Sum of all values of $V \times T$.

For Intersections:

$$\bar{R}_{\text{int}} = \frac{\sum C \times 2 \times 1{,}000{,}000}{\sum (\sum V_i \times T)}$$

where: $\overline{R}_{\text{int}}$ = Average Crash Rate;

$\sum C$ =Sum of all crashes; and

$\sum(\sum V_i \times T)$ = Sum of all values of $\sum V_i \times T$.

The Average Crash Rate should not be calculated by averaging the rates for individual sections, spots, or intersections. This would result in an unweighted average in which all locations of a given class are considered equal regardless of the volume of traffic at each location.

Average Crash Rates calculated with the Integrated Crash Analysis System computer program in 2005 are shown in Table 7 and Table 8.

Table 7. 2005 Average Crash Rates.

Tennessee Department of Transportation

Average Crash Rates

Average Crash Rates are calculated with a Confidence Level of 99% (Using Rates from Int/SR Analysis)

		Rural					Urban				
			Multi-Lane					Multi-Lane			
Location Type	**Crash Type**	**2-Lane**	**Undivided**	**Divided**	**Turn Lane**	**Freeway**	**2-Lane**	**Undivided**	**Divided**	**Turn Lane**	**Freeway**
Sections (1)											
	NonInjury	1.06	1.00	0.51	0.79	0.31	1.78	2.33	1.49	2.05	0.76
	Injury	0.61	0.48	0.28	0.30	0.14	0.72	0.85	0.57	0.76	0.29
	Fatal	0.03	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
	Total	**1.70**	**1.50**	**0.80**	**1.11**	**0.46**	**2.51**	**3.19**	**2.07**	**2.82**	**1.06**
Spots (2)											
	NonInjury	0.28	0.18	0.13	0.16	0.06	0.28	0.27	0.20	0.24	0.10
	Injury	0.17	0.09	0.07	0.06	0.03	0.11	0.10	0.08	0.09	0.04
	Fatal	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.46**	**0.27**	**0.20**	**0.22**	**0.09**	**0.39**	**0.37**	**0.28**	**0.33**	**0.14**
Intersections (3)											
	NonInjury	0.13	0.11	0.08	0.10	0.05	0.18	0.23	0.19	0.21	0.07
	Injury	0.07	0.05	0.05	0.04	0.02	0.07	0.08	0.07	0.08	0.02
	Fatal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.20**	**0.16**	**0.13**	**0.14**	**0.07**	**0.25**	**0.31**	**0.26**	**0.29**	**0.09**
Bridges (4)											
	NonInjury	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
	Injury	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	Fatal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**
Railroad Crossings (5)											
	NonInjury	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.02	0.00
	Injury	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
	Fatal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.04**	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**	**0.00**	**0.01**	**0.02**	**0.00**

Report Area: 2005 HES

(1) Crashes / Million Vehicle Miles

(2), (4), (5) Crashes / Million Vehicles

(3) Crashes / Million Entering Vehicles

Analysis Date: **09/08/2005**

Table 8. 2005 Average Crash Rates (Intersections Subset).

Tennessee Department of Transportation

Intersection Average Crash Rates

Average Crash Rates are calculated with a Confidence Level of 99% (Using Rates from Int/SR Analysis)

		Rural					Urban				
			Multi-Lane					Multi-Lane			
Location Type	**Crash Type**	**2-Lane**	**Undivided**	**Divided**	**Turn Lane**	**Freeway**	**2-Lane**	**Undivided**	**Divided**	**Turn Lane**	**Freeway**
Signalized Intersections (3)											
	NonInjury	0.34	0.44	0.22	0.40	0.00	0.56	0.62	0.67	0.66	0.02
	Injury	0.11	0.16	0.10	0.17	0.00	0.19	0.21	0.24	0.23	0.01
	Fatal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.45**	**0.60**	**0.32**	**0.57**	**0.00**	**0.75**	**0.83**	**0.91**	**0.89**	**0.03**
Full Stop Intersections (3)											
	NonInjury	0.37	0.36	0.18	0.16	0.00	0.27	0.76	0.05	0.38	0.00
	Injury	0.12	0.36	0.05	0.02	0.00	0.09	0.17	0.01	0.16	0.00
	Fatal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.49**	**0.72**	**0.23**	**0.18**	**0.00**	**0.36**	**0.93**	**0.06**	**0.54**	**0.00**
Other Intersections (3)											
	NonInjury	0.12	0.09	0.07	0.07	0.05	0.14	0.14	0.12	0.11	0.07
	Injury	0.06	0.04	0.05	0.03	0.02	0.05	0.05	0.05	0.04	0.02
	Fatal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.18**	**0.13**	**0.12**	**0.10**	**0.07**	**0.19**	**0.19**	**0.17**	**0.15**	**0.09**

Report Area: 2005 HES
(1) Crashes / Million Vehicle Miles

(2), (4), (5) Crashes / Million Vehicles — **Analysis Date:** **09/08/2005**
(3) Crashes / Million Entering Vehicles

2.12.2.3 Critical Crash Rate Calculation

To be reasonably certain that an observed Crash Rate differs significantly from the Average Crash Rate, a statistical technique is used. An upper limit is established in such a way that the probability of a Crash Rate being more than this limits by chance alone is very small. It is calculated with 99% confidence. This upper limit is referred to as the "Critical Crash Rate" because any Crash Rate larger than that value is most likely not due to chance, but to some unfavorable characteristic of the local conditions. The Critical Crash Rate is determined by the following formula:

$$R_c = \overline{R} + 2.327\sqrt{\frac{\overline{R}}{E}} + \frac{1}{2E}$$

where: R_c = Critical Crash Rate;

$\overline{R}$ = Average Crash Rate; and

E = Exposure Rate.

The ratio of the actual Crash Rate to the Critical Crash Rate is an indication of the relative hazard of that location. When $R/R_c \geq 4.0$, the site is placed on the Hazard Location Listing as a project eligible for Hazard Elimination Safety Program funds.

2.12.2.4 Severity Index Calculation

The Severity Index relates crashes with injuries and fatalities to the total number of crashes. A Severity Index as close to zero as possible is desirable. The Severity Index is defined as:

$$SI = \frac{I + F}{C}$$

where: SI = Severity Index;
I = Number of injury crashes;
F = Number of fatality crashes; and
C = Number of crashes.

If a site has been placed on the Hazard Location Listing, it will be ranked on the list with other sites from highest SI to lowest SI. The Hazard Location Listing prioritizes projects for use of funds in the Hazard Elimination Safety Program.

2.12.2.5 Crash Data Requests

Crash data is made available for public use, but most often crash data requests come internally from TDOT personnel for use in traffic engineering studies. A Crash Data Request form is shown in Figure 9.

TENNESSEE DEPARTMENT OF TRANSPORTATION
PROJECT PLANNING DIVISION
SAFETY PLANNING SECTION

CRASH DATA REQUEST

Requested by: Name: ____________ Date: ________
Division: ____________
Address: ____________ Telephone No.: ________
Project No.: ____________
Location: Region: ___ County: ________ City: ________
Route: ____________
Location on Route: ____________

Beginning Log Mile: ______ Ending Log Mile: ______

MAP SHOWING LOCATION MUST BE ATTACHED

TYPE OF CRASH DATA REQUESTED

	CHECK Yes	CHECK No	TIME PERIOD OR YEARS REQUESTED (3 Years or Specify)			
Crash Listing:	☐	☐	____	____	____	____
Collision Diagram:	☐	☐	____	____	____	____
Crash Rates:	☐	☐	____	____	____	____
High Hazard Rank:	☐	☐	____	____	____	____
Update Previous Request:	☐	☐	____	____	____	____
Special Request:	☐	☐	Describe Specifics: ____			

Request Analyzed By: ____________ Date: ________

Reviewed By: ____________ Date: ________
David Lollar, Transportation Specialist 1

____________ Date: ________
Harold Dilmore, Transportation Manager 1

____________ Date: ________
Charles Graves, Transportation Manager 2

Comments: ____________

(REV. 05/03/06)

Figure 9. Crash Data Request Form.

Example 6. Calculation of Crash Parameters for a Section.
A 5.13 mile section of two lane rural highway with AADT = 4,000 vehicles per day. The average statewide crash rate for this type of roadway is currently 1.70. The crashes over the last three-years on this roadway section included 2 fatality crashes, 18 injury crashes, and 14 property damage only crashes. Calculate the crash statistics for this roadway section.

$$V = 4{,}000$$

$$T = 3\ years \times 365\ days\ per\ year = 1{,}095$$

$$L = 5.13$$

$$E = \frac{4{,}000 \times 1{,}095 x 5.13}{1{,}000{,}000} = 22.5$$

$$C = 2 + 18 + 14 = 34$$

$$R = \frac{34}{22.5} = 1.51$$

$$R_c = 1.70 + 2.327\sqrt{\frac{1.70}{22.5}} + \frac{1}{2 \times 22.5} = 1.70 + 2.327 \times 0.29 + \frac{1}{36.2} = 1.70 + 0.67 + 0.03 = 2.40$$

$$SI = \frac{18+2}{34} = 0.59$$

Summary:
Crash Rate = 1.51 crashes per million vehicle-miles;
Critical Crash Rate = 2.40 crashes per million vehicle-miles; and
Severity Index = 0.59.

Since the Crash Rate is less than the Critical Crash Rate, we cannot conclude that anything other than chance has contributed to the number of crashes. Another way of making the same comparison is:

$$Crash\ Ratio = \frac{R}{R_c} = \frac{1.51}{2.40} = 0.63$$

Since 0.63 < 1, we cannot conclude that anything other than chance has contributed to the number of crashes.

Example 7. Calculation of Crash Parameters for a Spot.
A sharp, 500 foot long curve along a two lane rural highway has had 4 fatality crashes, 12 injury crashes, and 20 property damage only crashes over the last 3 years. AADT passing this spot is 6,000 vehicles per day. The average statewide crash rate for this type of roadway is currently 0.46. Calculate the crash statistics for this spot.

$$V = 6{,}000$$

$$T = 3\ years \times 365\ days\ per\ year = 1{,}095$$

$$E = \frac{6{,}000 \times 1{,}095}{1{,}000{,}000} = 6.6$$

$$C = 4 + 12 + 20 = 36$$

$$R = \frac{36}{6.6} = 5.45$$

$$R_c = 0.46 + 2.327\sqrt{\frac{0.46}{6.6}} + \frac{1}{2 \times 6.6} = 0.46 + 2.327 \times 0.26 + \frac{1}{13.2} = 0.46 + 0.61 + 0.08 = 1.15$$

$$SI = \frac{12 + 4}{36} = 0.44$$

Summary:
Crash Rate = 5.45 crashes per million entering vehicles;
Critical Crash Rate = 1.15 crashes per million entering vehicles; and
Severity Index = 0.44.

Since the Crash Rate is more than the Critical Crash Rate, we can conclude that something other than chance has contributed to the number of crashes at this spot. To determine if the spot should be placed on the Hazard Location Listing, we calculate the Crash Ratio:

$$Crash\ Ratio = \frac{R}{R_c} = \frac{5.45}{1.15} = 4.74$$

Since 4.74 > 3.50, this spot will be placed on the Hazard Location Listing. It will be eligible as a project for Hazard Elimination Safety Program funds and ranked in priority according to its Severity Index.

Example 8. Calculation of Crash Parameters for an Intersection.
A signalized urban intersection with 4 approach legs (both two lane roads) has had 1 fatality crash, 2 injury crashes, and 9 property damage only crashes during the 1.5 year period since the intersection was constructed. AADT on the legs has been determined: North leg = 3,500; East leg = 4,000; South leg = 3,250; and West leg = 5,250. The average statewide crash rate for this type of intersection is currently 0.75. Calculate the crash statistics for this intersection.

$$\sum V_i = 3{,}500 + 4{,}000 + 3{,}250 + 5{,}250 = 16{,}000$$

$$T = 1.5\ years \times 365\ days\ \ per\ \ year = 548$$

$$E = \frac{16{,}000 \times 548}{2 \times 1{,}000{,}000} = 4.4$$

$$C = 1 + 2 + 9 = 12$$

$$R = \frac{12}{4.4} = 2.73$$

$$R_c = 0.75 + 2.327\sqrt{\frac{0.75}{4.4}} + \frac{1}{2 \times 4.4} = 0.75 + 2.327 \times 0.41 + \frac{1}{8.8} = 0.75 + 0.95 + 0.11 = 1.81$$

$$SI = \frac{2+1}{12} = 0.25$$

Summary:
Crash Rate = 2.73 crashes per million entering vehicles;
Critical Crash Rate = 1.81 crashes per million entering vehicles; and
Severity Index = 0.25.

Since the Crash Rate is more than the Critical Crash Rate, we can conclude that something other than chance has contributed to the number of crashes at this intersection. To determine if the intersection should be placed on the Hazard Location Listing, we calculate the Crash Ratio:

$$Crash\ Ratio = \frac{R}{R_c} = \frac{2.73}{1.81} = 1.51$$

Since 1.51 < 3.50, this intersection cannot be placed on the Hazard Location Listing as a project for Hazard Elimination Safety Program funding. Other locations have priority for the funds. Some other means will have to be identified to address this situation.

3 TRAFFIC FORECASTING

The forecasting of future traffic volumes has significant effect on highway investment decision. Whether to increase the capacity of existing highways or to construct new facilities depends on future traffic. Traffic forecasting procedures should be:

- Reasonably easy and economical to perform;
- Sensitive to a wide range of policy issues and alternatives; and
- Understandable and useful for decision makers.

Developing future traffic estimates is not an exact science. This chapter presents the traffic forecasting process used by TDOT. The traffic forecasting process is divided into two main categories:

- Corridor Traffic Forecasting; and
- Project Traffic Forecasting.

Corridor traffic forecasting is used to determine the required number of lanes within a corridor or system to meet anticipated demands.

Project traffic forecasting estimates traffic conditions to determine the geometric design of a roadway and/or intersection and the loading that pavement will be subjected to over the design life. Project traffic forecasting is required for reconstruction, resurfacing, adding lanes, bridge replacement, new roadway projects and major intersection improvements. This type of forecasting process covers a limited geographic area and is more detailed.

To reflect the uncertainty of estimating, forecast volumes are reported according to the standard shown in Table 9:

Table 9. Forecast Volume Rounding.

Forecast Volume	Round to Nearest
less than 100	10
100 to 999	50
1,000 to 9,999	100
10,000 to 99,999	500
100,000+	1,000

3.1 Corridor Traffic Forecasting

The Corridor Traffic Forecasting (CTF) is used to determine the number of lanes within a corridor or system to meet anticipated traffic demands. CTF is more general than Project Traffic Forecasting.

3.2 Project Traffic Forecasting

The Project Traffic Forecasting Process is outlined in Figure 10.

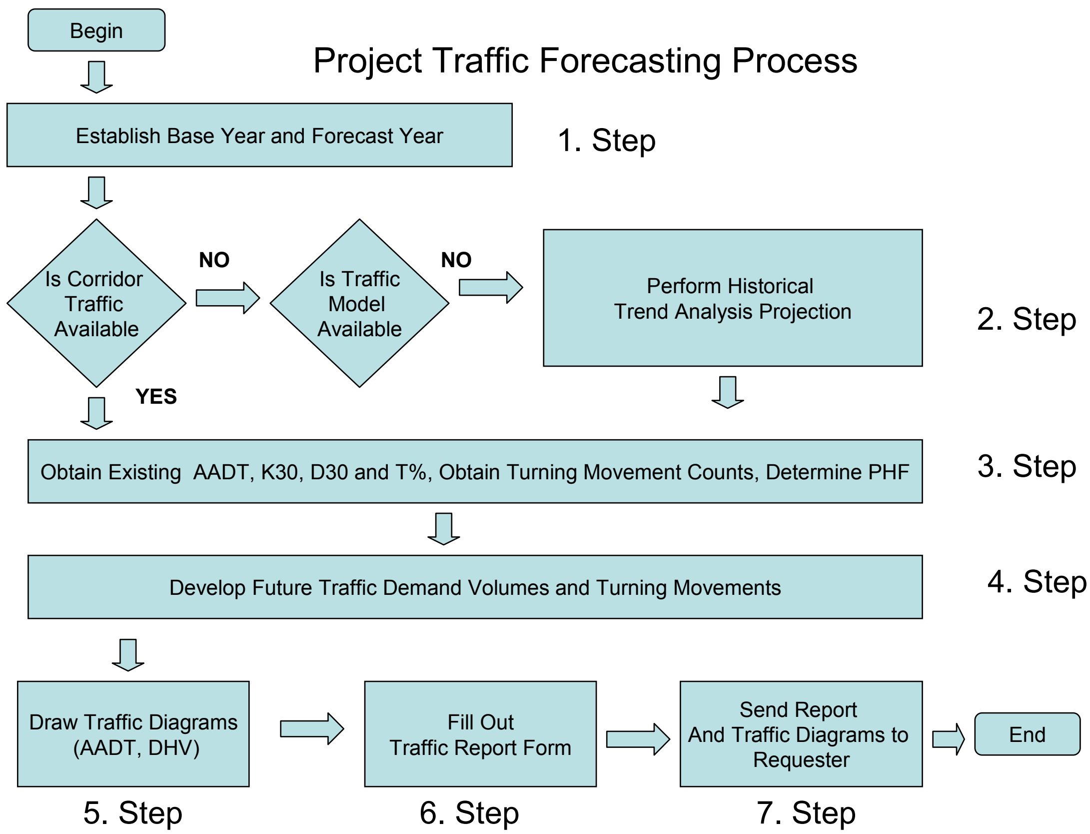


Figure 10. Project Traffic Forecasting Process.

3.2.1 Base Year and Forecast Year

The first step in Project Traffic Forecasting is to establish the Base Year and the Forecast Year. They are defined as:

$$Base\ Year = Current\ Year + 5\ Years$$
$$Forecast\ Year = Base\ Year + 20\ Years$$

The Current Year is the year when the traffic forecasting process begins.

Example 9. Determining Base Year and Forecast Year.
Forecast traffic volumes are requested in 2005 for a project. Determine the Base Year and the Forecast Year.

$$Base\ Year = 2005 + 5 = 2010$$
$$Forecast\ Year = 2010 + 20 = 2030$$

3.2.2 Traffic Models

The primary purpose of travel demand models has been to provide systems level traffic forecasts used to identify transportation needs in the development of long range transportation plans. Models can be useful tools in developing the traffic projections necessary for the project level traffic forecasting. However, the systems level traffic projections must be properly evaluated for reasonableness and consistency in light of current conditions and those indicated by trends. This manual primarily deals with traffic forecasting without traffic model.

3.2.3 Traffic Forecasting Parameters

Traffic parameters K_{30} and D_{30} are required to convert AADT into Design Hourly Volume (DHV).

3.2.3.1 Design Hour Factor (K30)

American Association of State Highway and Transportation Officials (AASHTO) generally recommend the 30th highest hourly volume of the year for highway design.[1] Researchers in the past have frequently studied the relationship between peak-hour traffic volume and AADT. Some of the main conclusions of those studies are as follows:[2]

- Economic considerations in the planning and design of highways make it impractical to design for the highest expected hourly volumes.
- In general, a pronounced break in curves that represent ratio of peak-hour volume and AADT has been thought to occur in the range from the 20th to the 50th highest hour.
- The studies have emphasized the difficulty in locating a pronounced break in curves. Where values of K-factor are based on the 30th highest hourly volumes, the following characteristics have been noted:
    - The value of K generally decreases as the AADT of the highway increases
    - The value of K decreases as development density increases
    - The highest values of K generally occur on recreational facilities, followed by rural, suburban, and urban facilities, in descending order.

3.2.3.2 Acceptable K30 Values

The value of K for the 30th highest hourly volume for main rural highways generally averages approximately 15% and varies in the range from 12% to 18%. For urban facilities, the average value of K for the 30th highest hourly volume is about 11%, with the range from 7% to 18%. The review of literature has shown that selection of the K-factor is widely based on individual judgment of transportation planners and designers. Little research work has been done to the analytical procedures to defining appropriate K-factor and corresponding DHV.

Data from 12 ATR stations located on different functional routes in Tennessee were analyzed. The highest 100 peak hour data as percentage of AADT were used to show relation between peak hour and AADT traffic volumes on rural and urban routes (respectively) in Tennessee. This relation is presented in Figure 11 and Figure 12. Table 10 shows the recommended K_{30} values for different functional routes used for project traffic forecasting if traffic data for project sites are unavailable.

Table 10 Recommended K_{30} Values

Road Type	K_{30} Range [%]	Recommended K_{30} [%]
Interstate Rural	8.0 – 9.0	8.0
Interstate Urban	7.0 – 9.0	8.0
Non-Interstate Rural	8.0 – 9.0	9.0
Non-Interstate Urban	8.0 – 10.0	10.0
Recreational	14.0 – 20.0	16.0

3.2.3.3 Calculation of K_{30} Factor from 24-Hour Count

When 24-Hour Count is available K factor can be calculated using the following formula:

$$K = \frac{V_{h(Max)}}{V_{24}} xF$$

Where: $V_{h(Max)}$ - Maximum Hourly Volume

V_{24} - Total 24-Hour Volume

F - Tennessee Adjustment Factor (1.2)

Example 10: Calculation of K_{30} Factor

COVERAGE COUNT DATA WITH 24 HOUR TOTALS

Station Number: 000084 **County:** 1 Anderson
Start Date: 06 / 01 / 2004 **End Date:** 06 / 02 / 2004
Start Time: 09 : 45 **End Time:** 09 : 45
Direction: 6

Time	
09:00	1,302
10:00	3,030
11:00	3,192
12:00	3,182
13:00	3,303
14:00	3,510
15:00	3,659
16:00	3,654
17:00	3,846
18:00	3,266
19:00	2,607
20:00	2,421
21:00	2,189
22:00	1,931
23:00	1,533
24:00	1,267
01:00	986
02:00	901
03:00	852
04:00	1,038
05:00	1,359
06:00	2,388
07:00	2,951
08:00	2,897
09:00	1,552

$$\boxed{K = \frac{3846}{58816} x1.2 = 0.078 = 8\%}$$

Total: 58,816 x Variation Factor: 1.00 = 58,816 x Truck Factor: 0.78 = AADT: 45876.48

Peak AM	Peak Total	Peak Percent	Peak PM	Peak Total	Peak Percent
11:45 - 12:45	3194	0.95	16:45 - 17:45	3876	0.97

Peak AM %	Dir Dist AM %	Peak PM %	Dir Dist PM %	Daily Peak %	Daily Dir Dist %
5	50	7	56	7	56

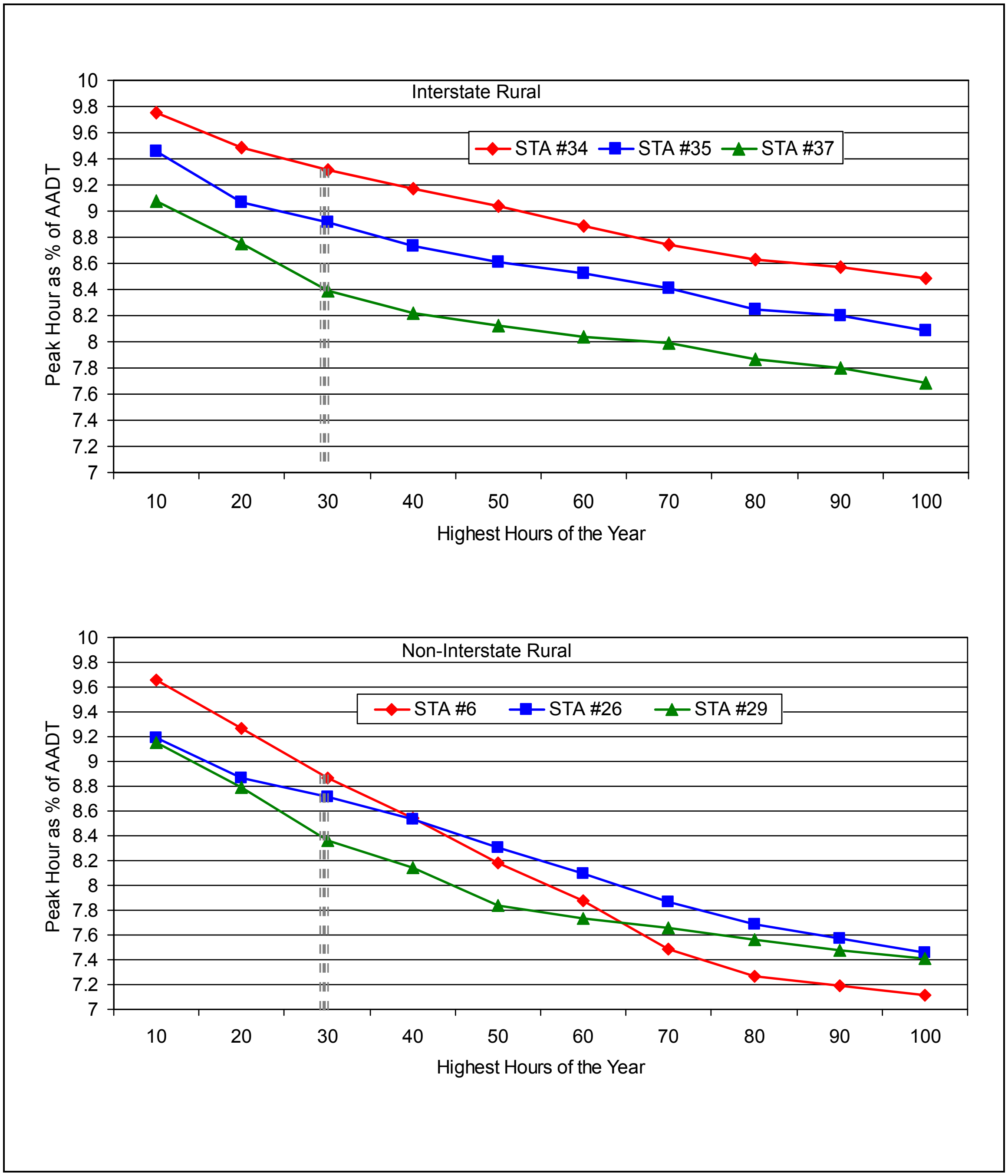


Figure 11. Peak Hour and ATD Relation on Rural Routes

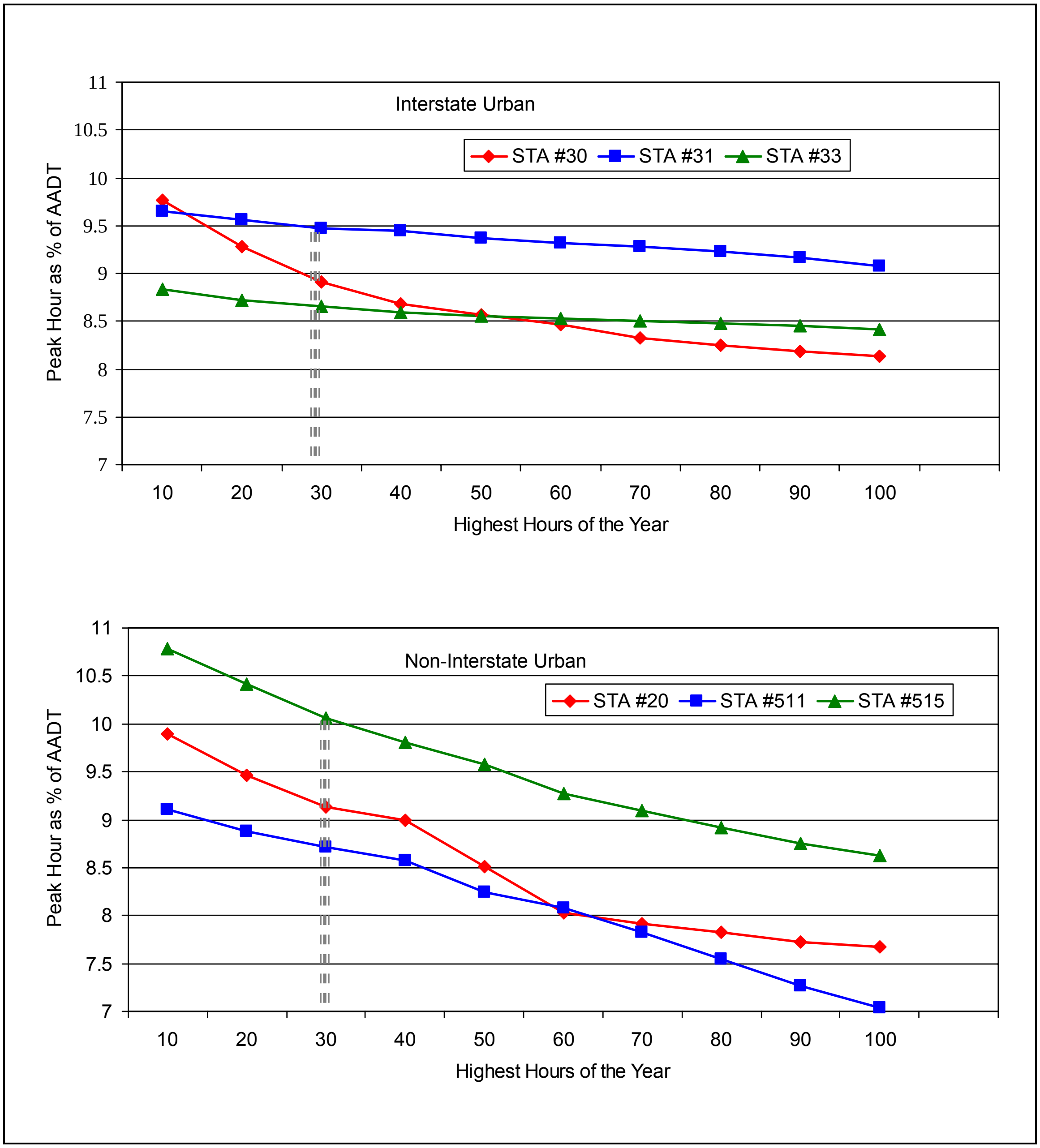


Figure 12. Peak Hour and ATD Relation on Urban Routes

3.2.3.4 Design Hourly Volume

The existing literature on the relationship between peak-hour traffic flow and average annual daily traffic (AADT) indicates that the 30th highest hourly volume of the year is generally most appropriate for planning, design and operational analyses. Customary practice in the United States is to base rural highway design on one hour between the 30th and 100th highest hour of a year[4]. This range generally encompasses the "knee" of the curve, which is the relationship between the hourly volume and AADT. The proportion of AADT in the design hour often is referred as a K-factor and traffic volume for that hour as Design Hourly Volume (DHV):

$$DHV = AADT \times K_{30}$$

3.2.3.5 Directional Distribution

The directional distribution is the percentage of the total two-way peak-hour traffic traveling in the peak direction. During any particular hour, traffic volume may be greater in one direction than the other. An urban route, serving strong directional demands into the city in the morning and out of it at night, may display as much as a 2:1 imbalance in directional flows. D_{30} is the proportion of traffic in the 30th highest hour of the design year traveling in the peak direction. The directional distribution is an essential parameter, used to determine the Directional Design hour Volume (DDHV) which is the basis for geometric design.

$$DDHV = DHV \times D_{30}$$

Figure 1.1 illustrates the directional distribution on an interstate in Tennessee (I-65, Station 202, Williamson County)

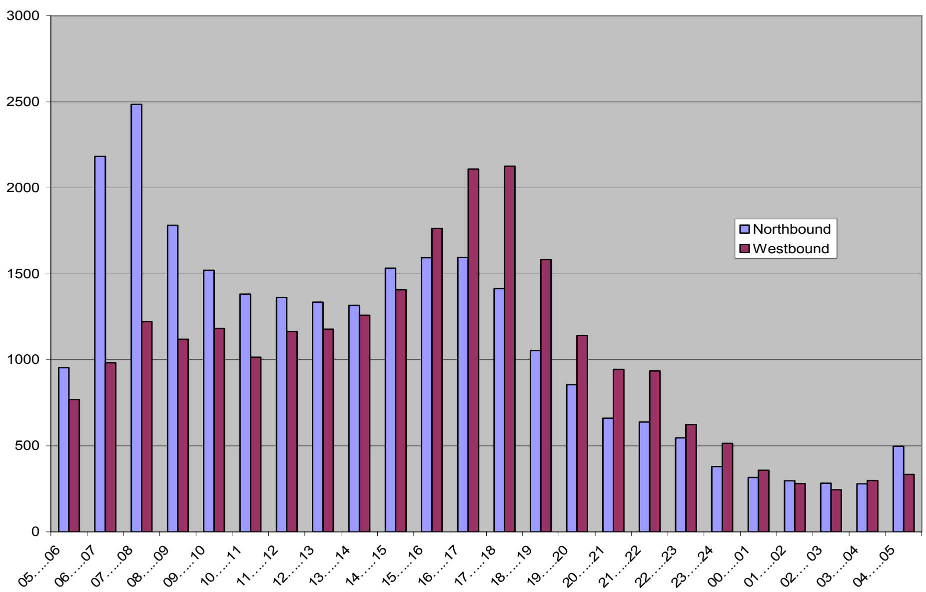


Figure 13. Directional Distribution of Peak-Hour Volumes

3.2.3.6 Peak Hour Factor

The most complex variation in traffic occurs by hour. The peak hour of traffic volume represents the most critical period for traffic operations. Capacity and other traffic analysis focus on the peak hour. The relationship between hourly traffic volume (Number of vehicles….) and the maximum rate of flow (Equivalent hourly rate…..) within the hour is defined as Peak Hour Factor (PHF).

$$PHF = \frac{HourlyVolume}{Max.RateofFlow} = \frac{HourlyVolume}{4xMax15\,\min.}$$

Peak hour factors in urban areas generally range between 0.80 and 0.98. Lower values signify greater variability of flow within the subject hour, and higher values signify little flow variation. Peak hour factors over 0.95 are often indicative of high traffic volumes, sometimes with capacity constrains on flow during the peak hour.

Example 11. Calculation of Peak-Hour Factor
For the given hourly traffic volume and rate of flow, calculate the Peak Hour Factor (PHF).

Time Period	Rate of Flow – Volume (Veh.)
5:01 – 5:15	1,800
5:16 – 5:30	1,950
5:31 – 5:45	**2,200**
5:46 – 6:00	2,050
Total:	**8,000**

$$PHF = \frac{HourlyVolume}{Max.RateofFlow} = \frac{8{,}000}{4x2{,}200} = \frac{8{,}000}{8{,}800} = 0.91$$

Example 12: Determination of Peak-Hour

Table 11. Determination of Peak-Hour and Peak Hour Factor

Time Period	Traffic Volume	Hourly Traffic Volume
6:00 - 6:15	76	-
6:16 - 6:30	72	-
6:31 - 6:45	78	-
6:46 - 7:00	80	306 (From 6 to 7)
7:01 - 7:15	82	312 (6:16 – 7:15)
7:16 - 7:30	81	321 (6:31 – 7:30)
7:31 - 7:45	79	322 (6:46 – 7:45)
7:46 - 8:00	88	330 (7:01 – 8:00)
8:01 - 8:15	85	333 (7:16 – 8:15)
8:16 - 8:30	90	342 (7:31 – 8:30)
8:31 - 8:45	**96**	359 (7:46 – 8:45)
8:46 - 9:00	**105**	376 (8:01 - 9:00)
9:01 - 9:15	**106**	397 (8:16 – 9:15)
9:16 - 9:30	**98**	**405 (8:31 – 9:30)**
9:31 - 9:45	90	399 (8:46 – 9:45)
9:46 -10:00	82	376 (9:01 – 10:00)

Answers: Peak Hour is between 8:30 and 9:30
Peak Hour Factor is:

$$PHF = \frac{405}{4x106} = \frac{405}{424} = 0.96$$

3.2.4 Equivalent Single Axle Load (ESAL)

Truck traffic and damage factors are essential information required to calculate axle load expressed as ESALs. It is very important to determine truck volume for the facility over the design period. The damage factor estimates are based on analysis of historical weight data collected from "Weigh in Motion" (WIM) surveys. The survey data is combined with other data such as highway location (rural/urban), highway type (freeway/arterial/collector), number of lanes. directional distribution, percent of trucks, lane factor, and truck equivalency factor to estimate accumulated 18-KIP (80kN) ESALs from the opening year to the design year of the project.

ESAL forecasting is required for all resurfacing, new construction, addition or reconstruction projects. It should encompass a period of twenty (20) years from the anticipated year the project is open to traffic, allowing the designer to select the appropriate design period for pavement design.

Example 13: Equivalent Single Axle Load (ESAL)

EQUIVALENT SINGLE AXLE LOAD (ESAL)

Purpose: To use in pavement design

TENNESSEE DEPARTMENT OF TRANSPORTATION
MAPPING AND STATISTICS OFFICE
TRAFFIC PLANNING AND SURVEYS SECTION (REV. 10/20/03)

PROJECT NO.: CM-STP-62 ROUTE: SR-62
COUNTY: KNOX CITY: KARNS
PROJECT PIN NUMBER:
PROJECT DESCRIPTION: INTERSECTION IMPROVEMENT AND SIGNALIZATION OF SR-62 AND HARREL RD.

DIVISION REQUESTING:

MAINTENANCE ☐ STRUCTURES ☒
PLANNING ☐ SURVEY & DESIGN ☐
PROG. DEVELOPMENT & ADM. ☐ TRAFFIC SIGNAL DESIGN ☐
PUBLIC TRANS. & AERO. ☐ OTHER ☐
YEAR PROJECT PROGRAMMED FOR CONSTRUCTION: 1999
PROJECTED LETTING DATE: APRIL 30, 1999

TRAFFIC ASSIGNMENT:

BASE YEAR		DESIGN YEAR					DESIGN ROADWAY % TRUCKS		DESIGN AVERAGE DAILY LOADS	
ADT	YEAR	ADT	DHV	%	YEAR	DIR.DIST.	DHV	ADT	FLEX	RIGID
16,360	1999	18,400	1,840	10	2004	50:50	3	5		
		26,620	2,662	10	2019	50:50	3	5		

1. **Step:** Calculate ADT which will be used for calculation of ESAL.
   ADT(ESAL) =(Present ADT + Future ADT) / 2 = (16,360 + 26,620) / 2 = 21,490

2. **Step:** Find the Ratio of Truck Percentage (RTP)
   RTP = (% of Trucks in Design ADT) / (% of Trucks in Classification) = 5 / 6.53 = 0.766

3. **Step:** Calculate number of trucks for ESAL
   Trucks (ESAL) = [(% of Trucks in Design ADT) / 100] x [ADT(ESAL)] = (5 / 100) x (21,490) = 1,075

4. **Step:** Find the percentage of trucks for each group
   T% = (RTP) x (% of Trucks in Classification) =
   (0.766) x (0.12) = 0.09%
   (0.766) x (1.12) = 0.76%
   (0.766) x (0.72 +0.04) = 0.58%.........ect.

MACHINE CLASSIFICATION

STATION NUMBER: 367 COUNTY OR CITY: KNOXVILLE

DATE: 5-5-98 ROUTE: SR-62

CLASSIFICATION OF VEHICLE	DIRECTION OF TRAVEL		TOTAL	%	
************************************	EAST	WEST	************	************	************
1. Motorcycles	5	1	6	0.03%	12
2. Cars	7363	7835	15198	80.77%	30396
3. Pick-up, Panel, Van	1192	1191	2383	12.66%	4766
Sub-total Passenger Vehicles	8560	9027	17587	93.47%	35174
4. Buses	12	10	22	0.12%	44
5. Dual Rear	101	109	210	1.12%	420
6. 3-Axle Truck	69	67	136	0.72%	408
7. 4-Axle Truck	2	5	7	0.04%	28
Sub-total Single-Unit Trucks	184	191	375	1.99%	900
8. 2S-1, 3S-1, 2S-2	335	170	505	2.58%	2020
9. 3S-2, 2S-3	90	72	162	0.86%	810
10. 3S-3, 3S-4	12	5	17	0.09%	102
Sub-total Combination Trucks	437	247	684	3.64%	2932
11. 2S-1-2	10	16	26	0.14%	130
12. 2S-2-2, 3S-1-2	37	13	50	0.27%	300
13. Any 7 Axle	35	59	94	0.50%	658
Sub-total Twin Trailers	82	88	170	0.90%	1088
Total Combinations	519	335	854	4.54%	4020
Total Trucks	703	526	1229	6.53%	4920
14. Other			0	0.00%	0
TOTAL ALL VEHICLES	9263	9553	$\boxed{18816}$	100.00%	40094
		20047	0.94		

EQUIVALENT SINGLE AXLE LOAD (ESAL) Continued

TENNESSEE DEPARTMENT OF TRANSPORTATION
MAPPING AND STATISTICS OFFICE
TRAFFIC PLANNING AND SURVEYS SECTION

PROJECT NO.: CM-STP-62 ROUTE NO.: SR-62
COUNTY: KNOX CITY: KARNS
PROJECT DESCRIPTION: INTERSECTION IMPROVEMENT AND SIGNALIZATION OF SR-62 AND HARREL RD.

FAP Rural

Pavement Structural Design

Calculation of Equivalent Daily 18 Kip Single Axle Loads

Type Vehicle		ADT (No. Counted)	Flexible 18-kip Factor	Flexible ADL	Rigid 18-kip Factor	Rigid ADL
Pass. cars and motorcycles (1-2)		17,643	0.001	18	0.001	18
Pick-up, Panel, Van (3)		2,772	0.005	14	0.004	11
Sing. Unit	Buses (4)	19	0.300	6	0.300	6
	2-axle, 6-tire (5)	185	0.240	44	0.310	57
	3-axle or more (6-7)	125	1.700	213	2.300	288
Comb.	4-axle (8)	441	1.110	490	1.500	662
	5-axle or more (9-13)	305	1.320	403	2.200	671
Totals (2009 ADT)		21,490		1,186		1,712

Suggested Percentages of Trucks in Design Lane

5,000 or less ADT	95%
5,000 - 10,000 ADT	90%
10,000 - 15,000 ADT	85%
15,000 - 20,000 ADT	80%
20,000 - 30,000 ADT	75%
30,000 - 40,000 ADT	70%
40,000 Plus	60%

No. of Lanes: 2
% Trucks in Design Lane: 75%
ADL in Design Lane:
FLEX: 0.5 X 0.75 X 1186.2 = 445
RIGID: 0.5 X 0.75 X 1711.8 = 642

ADL Calculations By: Date:
Reviewed By: Date:

5. Step: Find the number of trucks in each group T = (T% /100) x ADT(ESL)
(0.09 /100) x (21,490) = 19 in group [4]
(0.86 /100) x (21,490) = 185 in group [5]
(0.58 /100) x (21,490) = 125 in group [6] and [7]
(2.05 / 100) x (21,490) = 441 in group [8]
(1.42 / 100) x (21,490) = 305 in group [9], [10], [11]. [12] and [13]

Check: Sum of trucks in all groups = Total Number of Trucks
(19+185+125+441+305 = 1,075)

6. Step: Calculate the percentage of non-truck units (%NT)
%NT = 100 – 5 = 95%

7.Step: Calculate the ratio of non-trucks units %: 95 /93.47 = 1.016

8. Step: Find the number of non-trucks units
NT = (95 / 100) x (21490) = 20,415

9. Step: Find the percentage of non-truck units in each group
(1.016) x (12.66) = 12.9 % in group {3]
(1.016) x (80.80) = 82.1 % in group [1] and [2]

10. Step: Calculate the number of non-trucks units in each group
(12.9 / 100) x 21,490 = 2,772 in group [3] e.g. Pick-up, Panel, Van
(82.1 / 100) x 21,490 = 17.643 in group [1] 1nd [2] e.g. Passenger cars and motorcycles

Check: Sum of non-trucks in each group = Total number of non-truck units
(2,772 + 17,643 = 20,415

Check: Sum of non-truck units and truck units = ADT(ESAL)
(20,415 + 1,075 = 21,490)

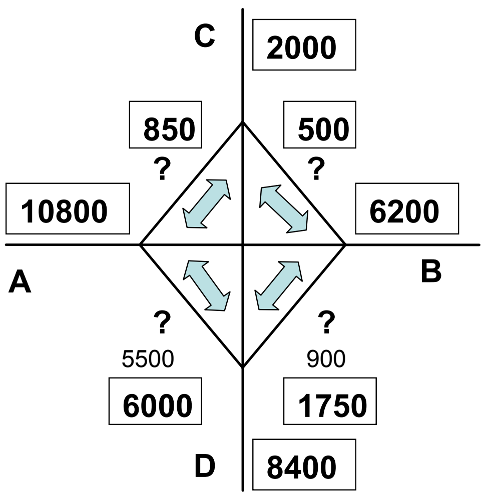
11. Step: Calculate Average Daily Loads in Design Lane (ADL-DL)
(0.5) x (75 / 100) x 1,186 = 445 FLEX
(0.5) x (75 / 100) x 1,712 = 642 RIGID

3.2.5 Intersection Turning Movements

Intersection turning movements are needed for the proper design of turning lanes, for level of service calculation in traffic impact studies, for air/noise calculation in environmental impact studies and for estimation of traffic diversion. Sound judgment must always be used when calculating turning movements. The duty of the analyst is to use as many sources of information as are practical for the task at hand and to keep the final product in mind when preparing turning movements. The following examples provide a framework or a starting point for estimation of turning movements. However, this method does not replace the analyst's need for creative thought and need for consideration of all possible sources of information.

Example 14. Turning Movement on Four Leg Intersection

ESTIMATION OF TURNING MOVEMENTS ON FOUR LEG INTERSECTION



1. Step: From larger number on AB axis subtract smaller number (A – B = 10800 - 6200 = 4600)

2. Step: From larger number on CD axis subtract smaller number (D - C = 8400 - 2000 = 6400)

3. Step: From the larger difference subtract the smaller difference (6400 – 4600 = 1800)

4. Step: The last difference divide by 2 (1800 : 2 = **900**)

5. Step: From the larger difference subtract the last calculated value (6400 - 900 = **5500**). The last two values are approximated minor turns volumes.

6. Step: Position the last two calculate diagonal turn-volume differences so that the original end volumes are satisfied if the two other turning movements are zero (10800 – 5500 + 900 = 6200)

7. Step: Calculate the Proration Factor (PF) as the ratio of the smallest original end volume and sum of the other three legs (PF = C / (A + B + D) = 2000 / (10800 + 6200 + 8400) = 2000 / 25400 = 0.079

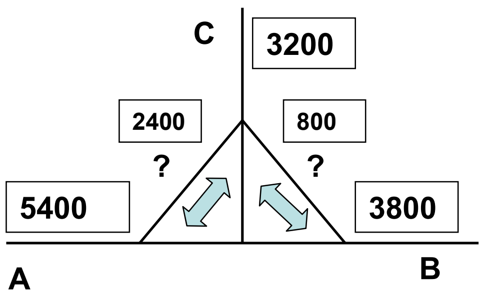
8. Step: Turns between A and C = PF x A = 0.079 x 10800 = **850**

9. Step: Turns between B and C = PF x B = 0.079 x 6200 = **500**

10. Step: To the approximated minor turns add the opposite diagonal –turn-volume-difference to obtain remaining turn volumes (5500 + 500 = 6000) and (900 + 850 = 1750)

Example 15. Turning Movement on Three Leg Intersection

ESTIMATION OF TURNING MOVEMENTS ON THREE LEG INTERSECTION ("T" OR "Y" INTERSECTION)



Rule: To find the volume moving between two legs of a three-leg intersection add the volumes on the two legs and subtract the volume on the third leg, then divide by two.

1. Step: Turning movement between A and C = (A + C – B) / 2 = (5400 +3200 -3800) / 2 = (5400 + 3200 – 3800) / 2 = 2400

2. Step: Turning movement between B and C = (B + C – A) / 2 = (3800 + 3200 – 5400) / 2 = 800

3.2.6 Capacity and Level of Service (LOS)

The capacity of facility is the maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions. Prevailing roadway, traffic and control conditions define capacity. These conditions should be reasonably uniform for any section of facility analyzed. Any change in the prevailing conditions changes the capacity of the facility. Level of Service (LOS) is a quality measure describing operational conditions within the traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions and comfort and convenience. Six LOS are defined for each type of facility that has analysis procedures available. Letters designate each level from A to F, with LOS A representing the best operating conditions and the driver's perception of those conditions. Safety is not included in the measures that establish service levels.

Example 16. Level of Service
(This example is taken from the Highway Capacity Manual 2000)
What is the LOS during the peak hour on existing four-lane rural freeway with 70 mph speed limit?

Input parameters:

- Two lanes in each direction
- 11-ft lane width
- 2-ft lateral clearance
- Commuter traffic

- 2,000 vph peak hour volume in one direction
- 5% trucks
- PHF = 0.92
- One interchange per mile
- Rolling terrain

Assumptions:

- Busses and RV's are not indicated
- Base Free Flow Speed (BFFS) = 75 mph
- The number of lane does not affect free flow speed since the freeway is in rural area
- Fp = 1.00 for commuter traffic

Solution:

1. **Step:** Convert volume (vph) to flow rate (pcphpl) – (use Equation 23-2 in Highway Capacity Manual 2000):

$$V_p = \frac{V}{(PHF)x(N)x(f_{hv})x(f_p)} = \frac{2{,}000}{(0.92)x(2)x(f_{hv})x(1.00)}$$

2. **Step:** Find f_{hv} (use Exhibit 23-8 and Equation 23-3 in HCM)

$$f_{hv} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} = \frac{1}{1 + 0.05(2.5 - 1) + 0} = 0.93$$

3. **Step:** Find V_P (use Equation 23-2)

$$V_P = \frac{2{,}000}{(0.92)x(2)x(0.93)x(1.00)} = 1{,}169\, pcphpl$$

4. **Step:** Compute free flow speed (use Exhibits 23-4, 23-5, 23-6, 23-7 and Equation 23-1)

$$FFS = BFFS - f_{lw} - f_{LC} - f_N - f_{ID} = 75 - 1.9 - 2.4 - 0.0 - 2.5 = 68.2 mph$$

5. **Step:** Determine LOS (use Exhibit 23-2)

   LOS = B

3.3 ADAM – (Advanced traffic Data and Analysis Management)

To further improve the efficiency of TDOT's traffic data collection and analysis effort, the University of Tennessee has helped streamline the activities associated with the collection, filtering, storage and analysis of field data through the implementation of a local area network (LAN) called ADAM. On one hand, traffic data from the field is uploaded onto one of several incoming nodes (computers equipped with data modems), where it can be filtered, pre-processed and made available to the host computer (server). The server houses the entire database, which can be modified only by a few authorized users. However, users on the network, e.g., TDOT planners, are able to view and use the data depending on their access privilege.

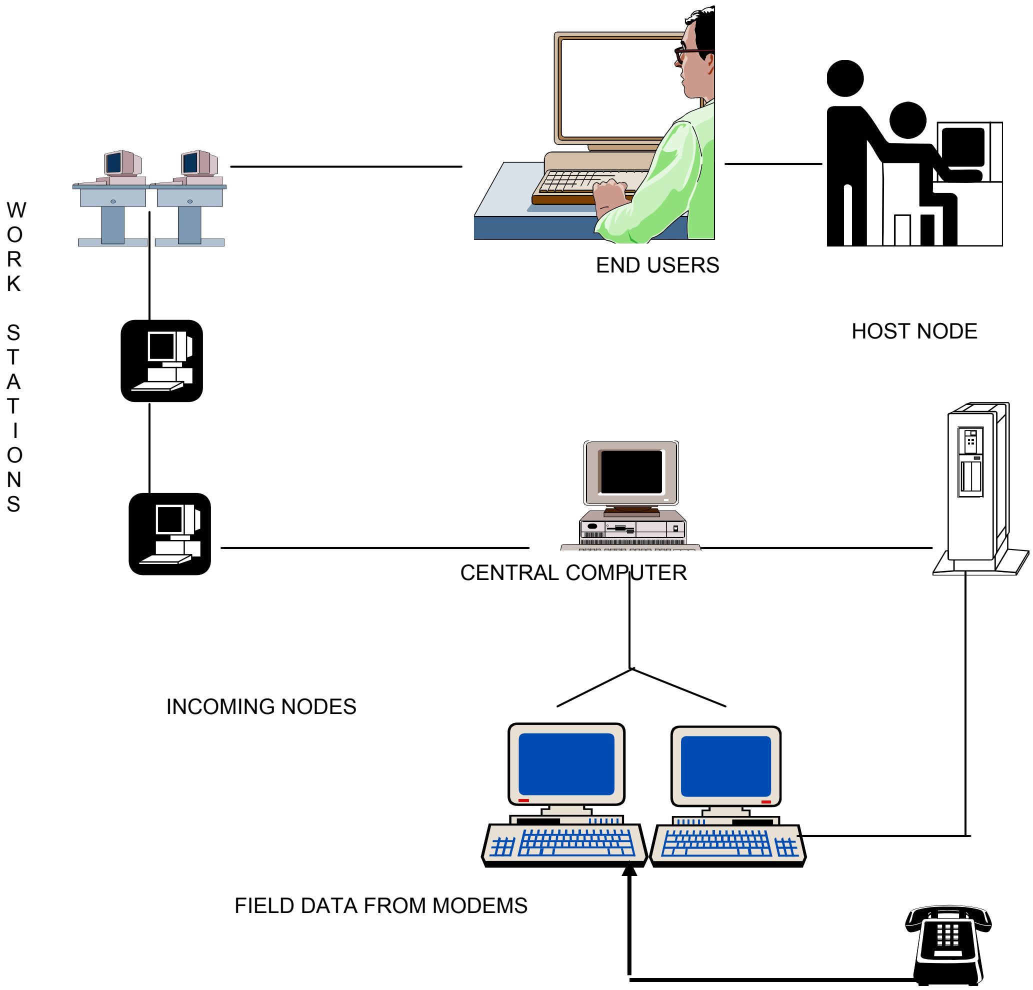


Figure 14. ADAM Local Area Network

Example 17. Traffic Forecast Using ADAM Software
Using ADAM software forecast AADT on Interstate 75 at station 84 (Figure 13) in Anderson County, Tennessee for the Base Year and Forecast Year if Current Year is 2004.

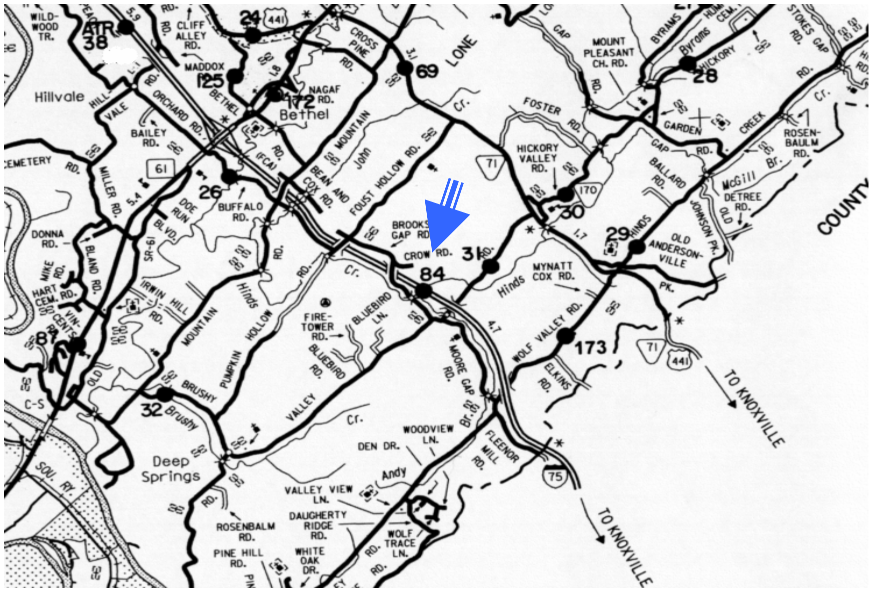


Figure 15. Location of Coverage Count Station

Solution:

1. **Step:** Establish the Base Year and Forecast Year
   Base Year = 2004 + 5 = 2009
   Forecast Year = 2009 + 20 = 2029
2. **Step:** Open ADAM software and select “Coverage” then “Trend Data” on ADAM tool bar
3. **Step:** Select Anderson County, Station Number 84
4. **Step:** Select “Graph” (Figure 14)
5. **Step:** Select “Trend Analysis” and type the Base Year and Forecast Year in the range years for forecasting AADT (Figure 15)
6. **Step:** Select “Print graph” and forecasted AADT (Figure 16)

Complete ADAM instructions can be found at http://home.tdot.state.tn.us/ADAM

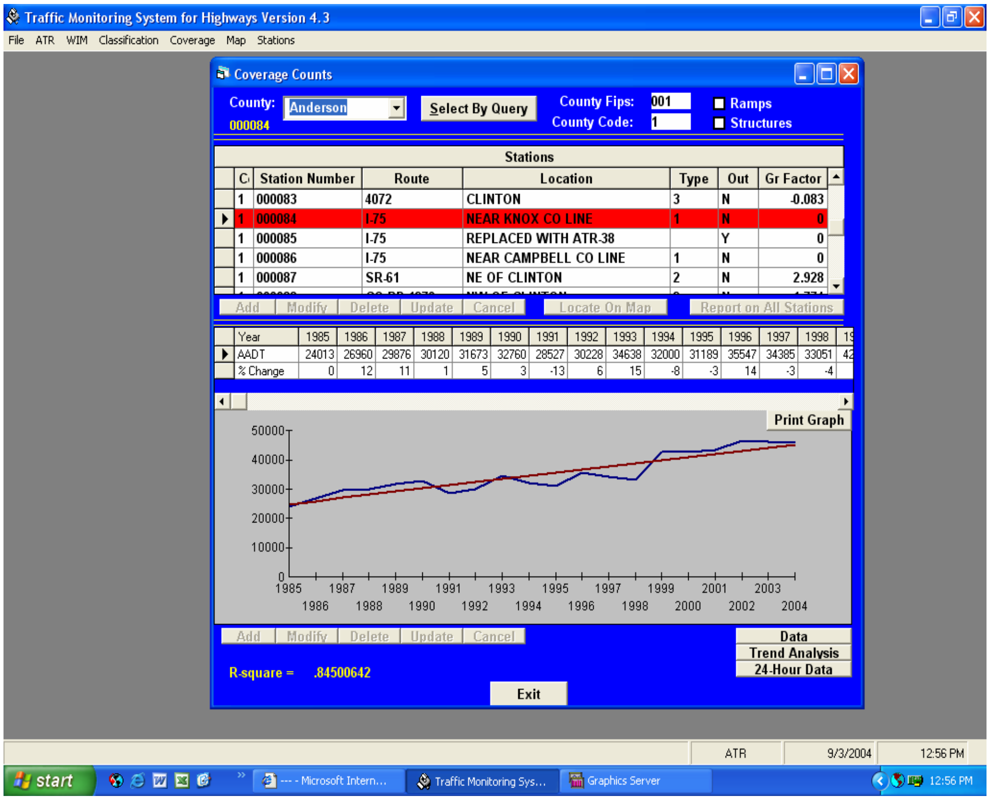


Figure 16. Trend Line Based on Data 1985-2004

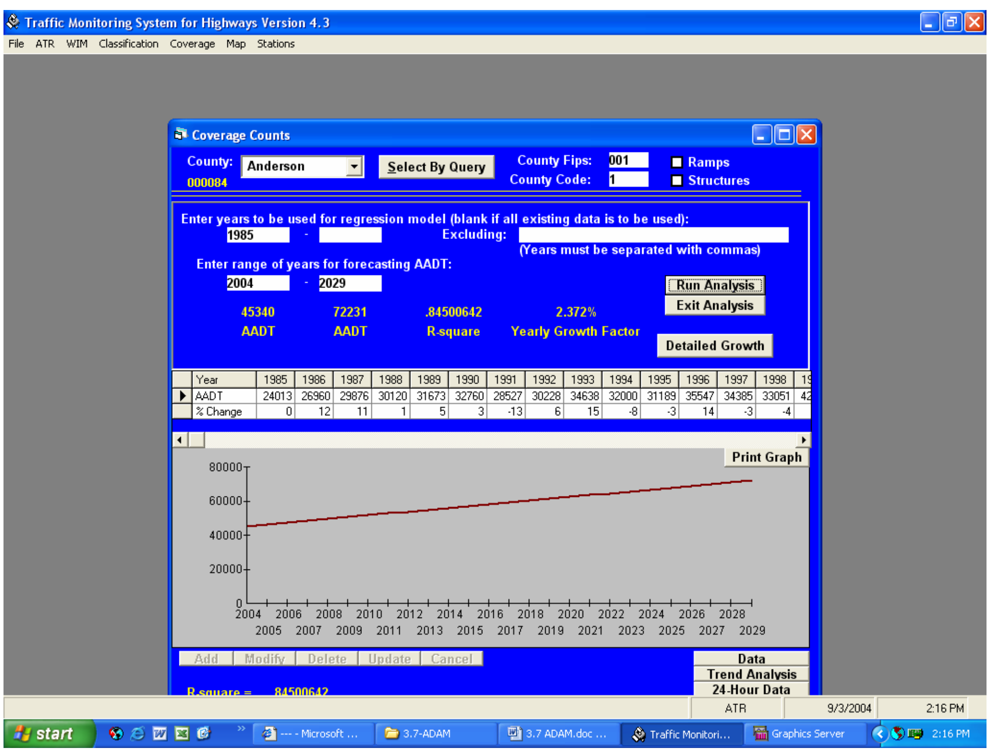
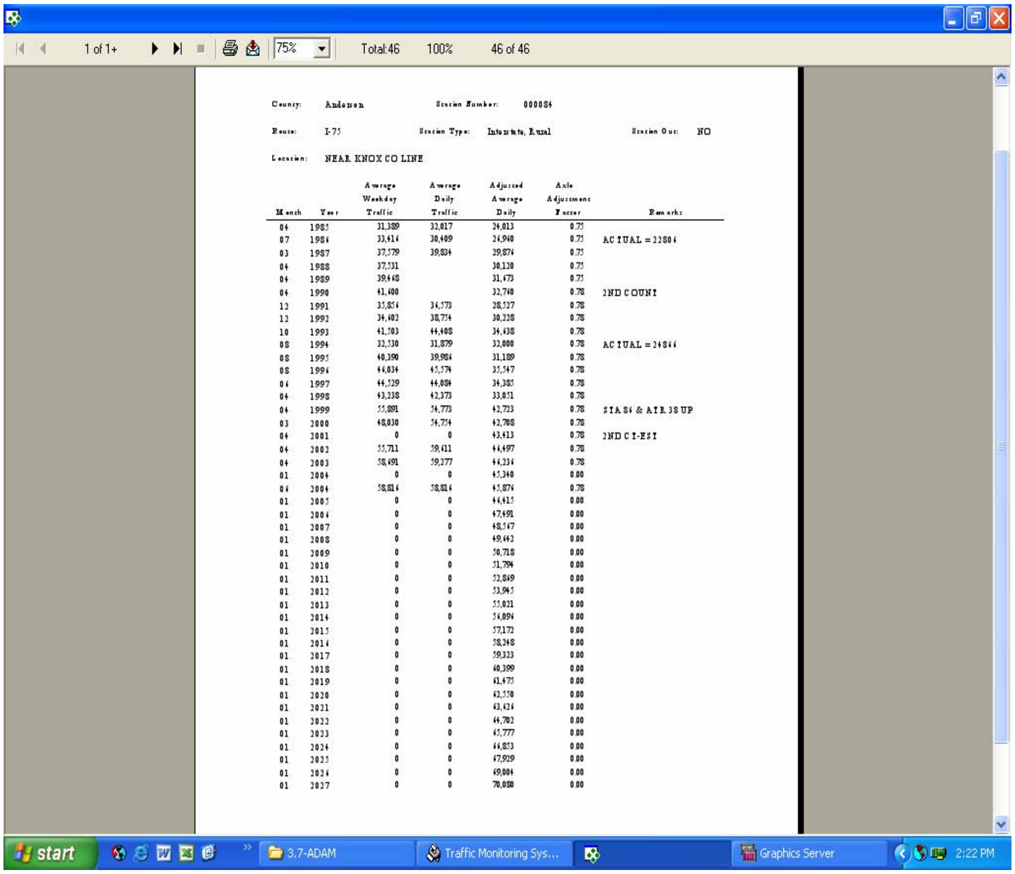


Figure 17. Trend Line From Current Year (2004) to Design Year (2029)

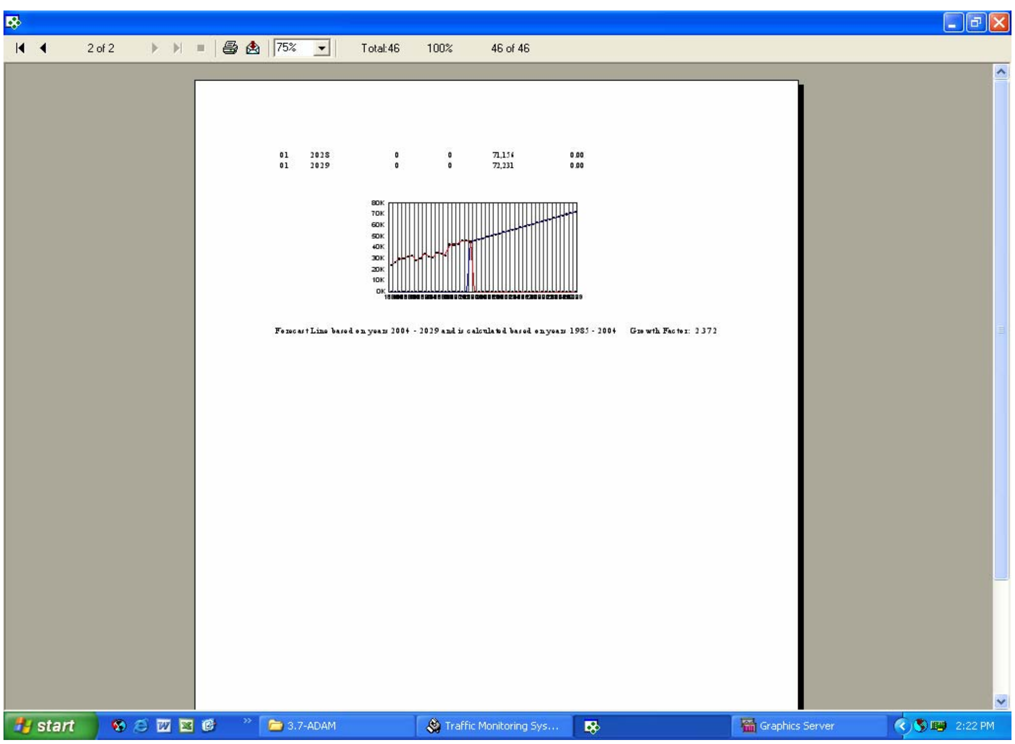


County: Anderson Station Number: 000084

Route: I-75 Station Type: Interstate, Rural Station Out: NO

Location: NEAR KNOX CO LINE

Month	Year	Average Weekday Traffic	Average Daily Traffic	Adjusted Average Daily	Axle Adjustment Factor	Remarks
04	1985	31,389	32,017	24,013	0.75	
07	1986	33,416	30,409	24,940	0.75	ACTUAL = 22806
03	1987	37,579	39,834	29,876	0.75	
04	1988	37,531		30,120	0.75	
04	1989	39,448		31,473	0.75	
04	1990	41,400		32,740	0.78	2ND COUNT
12	1991	35,856	36,573	28,527	0.78	
12	1992	34,402	38,754	30,228	0.78	
10	1993	41,503	44,408	34,638	0.78	
08	1994	32,530	31,879	32,000	0.78	ACTUAL = 24866
08	1995	40,390	39,986	31,189	0.78	
08	1996	44,034	45,574	35,547	0.78	
06	1997	44,529	44,084	34,385	0.78	
04	1998	43,238	42,373	33,051	0.78	
04	1999	55,891	54,773	42,723	0.78	STA 86 & ATR 38 UP
03	2000	48,030	54,754	42,708	0.78	
04	2001	0	0	43,413	0.78	2ND CT-EST
04	2002	55,711	59,611	46,497	0.78	
04	2003	58,691	59,277	46,236	0.78	
01	2004	0	0	45,340	0.00	
06	2004	58,816	58,816	45,876	0.78	
01	2005	0	0	46,415	0.00	
01	2006	0	0	47,491	0.00	
01	2007	0	0	48,567	0.00	
01	2008	0	0	49,642	0.00	
01	2009	0	0	50,718	0.00	
01	2010	0	0	51,794	0.00	
01	2011	0	0	52,869	0.00	
01	2012	0	0	53,945	0.00	
01	2013	0	0	55,021	0.00	
01	2014	0	0	56,096	0.00	
01	2015	0	0	57,172	0.00	
01	2016	0	0	58,248	0.00	
01	2017	0	0	59,323	0.00	
01	2018	0	0	60,399	0.00	
01	2019	0	0	61,475	0.00	
01	2020	0	0	62,550	0.00	
01	2021	0	0	63,626	0.00	
01	2022	0	0	64,702	0.00	
01	2023	0	0	65,777	0.00	
01	2024	0	0	66,853	0.00	
01	2025	0	0	67,929	0.00	
01	2026	0	0	69,004	0.00	
01	2027	0	0	70,080	0.00	



01	2028	0	0	71,156	0.00
01	2029	0	0	72,231	0.00

Forecast Line based on years 2004 - 2029 and is calculated based on years 1985 - 2004 Growth Factor: 2.372

Figure 18. Forecasted AADT and Graph

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