Traffic Monitoring Guide

September 2013

U.S. Department of Transportation
Federal Highway Administration
Office of Highway Policy Information

NOTICE

QUALITY ASSURANCE STATEMENT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

TMG EXECUTIVE SUMMARY

ES.1   BACKGROUND

This edition of the *Traffic Monitoring Guide (TMG)* is intended to provide the most up to date guidance to State highway agencies in the policies, standards, procedures, and equipment typically used in a traffic monitoring program. The *TMG* presents recommendations to help improve and advance current programs with a view towards the future of traffic monitoring and with consideration for recent transportation legislation resulting from MAP-21. The needs for traffic data at both the Federal and State levels will continue to require that States have a well-designed traffic monitoring program to support all business areas. Traffic data and information is needed to assess current and past performance and to predict future performance. Improved traffic data, including data on ramps, is needed for reporting in the Highway Performance Monitoring System (HPMS) and there are now opportunities to utilize traffic data from Intelligent Transportation Systems (ITS) to support coordination of planning and operations functions at the Federal and State levels.

Improvements in traffic data collection technology since the publication of the *TMG* in 2001, has allowed States to improve their data collection processes and to streamline QA/QC procedures, thereby replacing manual procedures with new automated ones. New technology also now enables States to collect data on non-motorized travel including bicycle and pedestrian traffic. This new capability is addressed in more detail in Chapter 4. The use of non-motorized travel data and information supports analysis regarding the impact to the transportation network (from a volume and safety perspective), resulting from the use of bicycles as an alternative method for travel compared to the traditional motor vehicle. The new technologies and procedures for traffic monitoring presented in this *Guide* are supplemented (in the appendices) with practical examples from actual State experiences in improving traffic monitoring programs.

The guidance presented in the *TMG* should be used to help States manage and improve their traffic monitoring programs, with consideration for overall business needs for traffic data and information. Chapter 2 explains the importance of having a well-designed traffic monitoring program to support typical business needs. This *Guide* is written to assist both experienced traffic data collection personnel and those who are less-experienced, or who are new to traffic data collection. Quick references to topics are available in the Index and may also be found in the Table of Contents. Other reference material that may benefit traffic data collection personnel and traffic program managers is found in Appendix M, References.

This edition of the *TMG* also includes new data formats as an option for reporting traffic data. These new formats are known as the Per Vehicle Formats for reporting volume, speed, vehicle classification, and vehicle weight data. Data formats are also provided for reporting non-motorized data for those States with capabilities to collect this type of data. This edition of the *TMG* has been developed with considerable input from State traffic data program managers and the vendors who design and build traffic data collection equipment. This approach has resulted in a guidance document that FHWA anticipates will continue to be beneficial to States in improving their business processes, technology, and equipment used to successfully manage their traffic monitoring programs.

ES.2   SCOPE

The scope of State traffic monitoring programs has grown over the last decade to now include the capability to collect speed data, which is critical for analysis in supporting State highway safety programs. While the collection of volume, classification, and weight data continues to be the

foundation of a State's traffic monitoring program, the addition of speed data greatly enhances the capabilities of the traffic programs to meet additional business needs, particularly in the area of improving performance measures related to safety. New requirements for performance monitoring based on MAP-21 legislation will also be supported by the guidance presented in this *Guide*. Traffic data from the States continues to be required to meet the reporting requirements of the Federal Highway Administration (FHWA) under United States Code of Federal Regulations (CFR) title 23, 420.105(b), which requires States to provide data that supports FHWA's reporting responsibilities to Congress and to the public. Traffic data reported under this Federal regulation is submitted as part of the annual Highway Performance Monitoring System (HPMS) report from each State.

ES.3   USERS

Traffic data is typically used to support highway agency activities including design, maintenance, operations, safety, environmental analysis, finance, engineering economics, and performance management. Each State has its own traffic data collection needs, priorities, budgets, geographic and organization constraints. These differences cause agencies to select different equipment for data collection, use different data collection plans, and emphasize different data reporting outputs. This *Guide* is intended to provide guidance to highway agencies in some of the successful approaches in data collection, analysis, and reporting based on best practice examples, which are highlighted in the appendices.

ES.4   MANUAL ORGANIZATION

The organization of the material presented in this *Guide* begins with explaining the theory, technology, and concepts typically used in a traffic monitoring program (Chapter 1). The *Guide* also highlights the business needs for traffic monitoring programs (Chapter 2) and provides comprehensive guidance on the methodologies used for motorized (Chapter 3) and non-motorized traffic monitoring practices (Chapter 4). The importance of traffic data in supporting transportation management and operations activities is also discussed in Chapter 5, with HPMS reporting requirements for traffic data explained in Chapter 6. The final chapter (Chapter 7) defines the record formats used for submitting traffic data for both motorized and non-motorized data, along with a table explaining the deadlines for submitting traffic data to the FHWA Office of Highway Policy Information.

Several appendices are also included as part of the *Guide* to provide a glossary of terms, list of acronyms, Frequently Asked Questions (FAQs), and best practice examples from States and the private sector in designing statewide traffic monitoring programs, establishing data QA/QC criteria, and setting up and calibrating data collection equipment. Other appendices include guidance on the use of traffic data for pavement design purposes, guidance on length-based classification, and the QC checks performed on the traffic data by the Travel Monitoring Analysis System (TMAS) software. This *Guide* also includes an appendix of References and an Index for quick location of a particular topic related to traffic monitoring.

The chapters and appendices in this *Guide* include the following:

Chapter 1 – Traffic Monitoring Theory, Technology, and Concepts – This chapter discusses the terminologies used in traffic monitoring and defines the types of traffic counts conducted (i.e., continuous, short duration), explains factor computations, and defines data products derived from the collection of traffic data.

Chapter 2 – Traffic Monitoring Program – Business Planning and Design – This chapter explains how data business planning can be used to support and improve the design of a traffic monitoring program in accordance with the Code of Federal Regulations.

Chapter 3 – Traffic Monitoring Methodologies – This chapter is the most comprehensive chapter in the *TMG*. It provides guidance on the following:

- Methods used to determine the number of data collection sites needed;

- How factor groups are assigned;

- How to derive Daily, Monthly, Weekly and Annual Average Daily Traffic values;

- Recommended methodologies and steps used to establish Continuous Count and Short Duration Count programs to collect volume, speed, vehicle classification, and weight data; and

- Estimating motorcycle Vehicle Miles Traveled (VMT).

Chapter 4 – Traffic Monitoring for Non-Motorized Traffic – This chapter provides basic guidance on non-motorized traffic volume monitoring. The term non-motorized pertains to bicycles, pedestrians, and other non-motorized road and trail users. The chapter highlights the challenges in collecting non-motorized data compared with traditional collection of motorized traffic data. It also provides several examples of the types of data collection equipment available and describes procedures that can be used to collect this type of data.

Chapter 5 – Transportation Management and Operations – This chapter provides guidance and examples on coordinating activities for transportation management and operations functions within State DOTs. The specific types of functions covered include:

- Traffic management and operations (freeway, freight, arterial) including traveler information, incident management, and planning for operations (including performance measures);

- Special monitoring for evacuations/emergency/planned events;

- Commercial vehicle enforcement;

- Safety; and

- Planning (including access management, modeling and long range planning).

Chapter 6 – HPMS Requirements for Traffic Data – This chapter provides guidance to State DOTs in meeting the reporting requirements for the Highway Performance Monitoring System (HPMS). Traffic data represents a significant portion (25%) of the HPMS data reported to FHWA annually. Much of this data is provided from a State's traffic monitoring program. The traffic data items reported in HPMS are identified and the uses of this data are also explained in this chapter.

Chapter 7 – Traffic Monitoring Formats – This chapter defines the data record formats and data submittal frequency to be used for reporting volume, speed, vehicle classification, and weight data for motorized data and also describes the data formats for reporting non-motorized data. It includes new formats now available, known as Per Vehicle Formats, as an alternative method for submitting traffic data to FHWA. The traffic data formats described in this chapter are in addition to the traffic data which is required to be submitted annually to FHWA as part of the HPMS submittal.

Appendices: There are also several appendices included in the *TMG* to provide additional guidance to the user. Of particular significance, this edition of the *TMG* includes best practice examples in traffic monitoring in appendices D, E, F, and L.

The appendices in the *TMG* include the following:

Appendix A – Glossary of Terms

Appendix B – Acronyms

Appendix C – Vehicle Types

Appendix D – Compendium of Designing Statewide Traffic Monitoring

Appendix E – Compendium of Data Quality Control Criteria

Appendix F – Compendium of Equipment Calibration Procedures, Current Practices, and New Procedures

Appendix G – North Carolina Department of Transportation Clustering Methodology for NC Traffic Data Inputs for MEPDG

Appendix H – Traffic Data for Pavement Design

Appendix I – Frequently Asked Questions (FAQs)

Appendix J – TMAS 2.0 QC Checks

Appendix K – Length Based Class Memo

Appendix L – Additional State Traffic Monitoring Program Examples

Appendix M – References

Appendix N – An Index is also included in the *TMG* to assist users with quickly locating information on a particular topic

Chapter 1   TRAFFIC MONITORING THEORY, TECHNOLOGY AND CONCEPTS

1.1   INTRODUCTION

Traffic monitoring is performed to collect data that describes the use and performance of the roadway system. This chapter describes the types of data that should be collected, the technologies that are currently available for collecting those data, how agencies should examine those technologies for meeting their traffic monitoring needs, and the characteristics of traffic data that should be incorporated into the design of a strong and effective traffic monitoring program.

Background information on the science and concepts used in traffic monitoring is discussed to guide the States in developing a traffic monitoring program that not only meets their needs, but also supports the need for traffic data at the national and local levels.

This chapter is organized into the following four sections:

1.2 Terminology – introduces the technical terms used in the *Traffic Monitoring Guide (TMG)*.

1.3 Detection Theory – introduces the theoretical concepts behind current traffic monitoring technologies and compares the strengths and weaknesses of each.

1.4 Detection Technology – describes the types of data useful to a traffic monitoring program and introduces the sensors used for traffic monitoring.

1.5 Variation of Traffic Data – provides background information about what variation occurs in the traffic stream, and how that variation shapes the design of a strong traffic monitoring program.

1.2   TERMINOLOGY

The purpose of this section is to frame the basic definitions of terms for the remainder of the *TMG*, and it is supplemented with a more comprehensive Glossary of Terms in Appendix A.

There are many different terms used in the *TMG* to discuss the development and implementation of a traffic monitoring program. It is recognized that some of these terms are used in different manners by the various States. For the purposes of the *TMG*, the terms will be used as described below.

Each term is listed, followed by a brief explanation of its meaning/use within a traffic monitoring program. The terms are organized in the following categories: methods, equipment, location, count types and programs, factors and data products.

Unless otherwise noted most of the text in this chapter refers to *motorized* vehicles.

1.2.1   METHODS

There are two general methods used to collect traffic data: automatic and manual.

Automatic – Refers to the collection of traffic data with automatic equipment designed to continuously record the distribution and variation of traffic flow in discrete time periods (e.g. by 5 min., 15 min., hour of the day, day of the week, and month of the year from year to year). Automatic methods may include both permanent and portable counters.

Manual – Refers to visually observing number, classification, vehicle occupancy, turning movement counts, or direction of traffic. Methods include using tally sheets or electronic counting boards. These methods are not described extensively in this version of the *TMG*.

1.2.2   EQUIPMENT

Traffic Counter – Any device that collects vehicular characteristics data (such as volume, classification,

speed, weight).

Automated Traffic Recorder (ATR) or Counter – This is a traffic counter that is placed at specific locations to record the distribution and variation of traffic flow by hour of the day, day of the week, and/or month of the year. The ATR may be used to collect data continuously at a permanent site or at any location for shorter periods.

Continuous Count Station (CCS) – permanent counting site provides 24 hours a day and 7 days a week of data for either all days of the year or at least for a seasonal collection.

Portable Traffic Recorder (PTR) or Counter – This is a traffic vehicle counter or classifier that is portable/mobile (can be moved to different locations) and not permanently installed in the infrastructure.

NOTE – These terms (ATR, PTR) are often used together and in different contexts. For example, some States refer to an ATR as a site where traffic is collected continuously. However, according to the strict definition an ATR is simply an automated traffic recorder. To further describe the type of count, one should indicate whether the count is continuous or short duration.

Weigh-In-Motion (WIM) – The process of measuring the dynamic tire forces of a moving vehicle and estimating the corresponding tire loads of the static vehicle. A WIM detector is a device that measures these loads and forces.

1.2.3 LOCATION

Traffic counts are recorded at a specific point on the roadway. This point is referred to as a "count station" or "site." The point often represents the characteristics of a road segment. For example, a count location is often assigned to a segment of road. The definition of a segment varies by State; here it refers to a section of roadway defined by the State. Since collecting traffic data is not feasible on every possible point within a segment, traffic data collected and representing a point on a segment is extrapolated to represent the entire segment. The extrapolation of point data to the line segments is known as the traffic data and linear referencing system (LRS) integration process. All States should extrapolate point data to a common linear referencing system that is for Highway Performance Monitoring System (HPMS) reporting purposes. The word "segment location" may also be known as LRS location or HPMS location.

1.2.4 COUNT TYPES AND PROGRAMS

Count – Refers to how the data is collected to measure and record traffic characteristics such as vehicle volume, classification (by axle or length), speed, weight, lane occupancy or a combination of these characteristics. These characteristics are defined in more detail in other parts of the *TMG*.

There are two primary categories of traffic count programs: continuous and short duration. They are described in detail below.

Continuous

Continuous Count Station – A site that uses an automated traffic counter and is recording traffic distribution and variation of traffic flow by hour of the day, day of the week, and/or month of the year. It is recording the data 24 hours a day, 7 days a week. The goal of a continuous count site is to capture data for 365 days of the year. On occasion due to equipment failure, construction, special event detours, etc., there can be gaps in the data that occur. Some stations only collect continuous count data for part of the year due to weather and road closings. These sites can also be considered continuous count stations.

The word "continuous" may also be known as permanent. The word "count" may also be known as monitoring. The word "station" may also be known as site.

Continuous Counts – Continuous counts are volume counts derived from permanent counters for a period of 24 hours each day over 365 days (except for leap year) for the data-reporting year.

Continuous Data Program – Refers to the program management aspects of maintaining, storing, accessing, and reporting data from continuous counters within an overall travel monitoring program. In some States, this is referred to as "permanent count program." For the purposes of the *TMG*, the program will be referred to as the "continuous data program." Chapter 3 provides more detail.

Short Duration

Short Duration Count Station – A site that uses an automated traffic counter and is recording traffic distribution and variation of traffic flow for a specified period (less than 365 days per calendar year.) The counter may be permanently installed or moved to accommodate count locations. The goal of a short-duration count station is to collect data that can be adjusted by factoring and creating an annual average daily traffic (AADT) number that representing a typical traffic volume number any time or day of the year. Short-duration count stations typically are defined as stations where 24-hour, 48-hour, or one week of data is collected.

The word "duration" may also be known as term. Some States refer to these count stations as "portable" because they may have permanent loops in the pavement that connects a portable counting device to the loops.

Short Duration Counts – Counts that are collected on less than a continuous basis (i.e., may be a period of 24, 48 or 72 hours).

Short Duration Count Program – Refers to the non-continuous data collection program management aspects of an overall travel monitoring program. Provides the majority of the geographic diversity needed to generate traffic information on the State roadway system. Short duration provide more spatial/geographic count coverage (in addition to the continuous program) for HPMS or for special traffic studies and are taken for various periods on roadway segment-specific locations, typically on a rotating schedule over time. A State's overall travel monitoring program typically includes both a short-duration count and a continuous count program. The counts within a short duration count program are taken for 48 or 72 hours or at times as long as a week.

Some States also refer to their short duration program as the "coverage count program" and some include a subsection of the short duration program as special needs counts. Other States refer to the short duration count program as "portable."

1.2.5 FACTORS

Factors are used to process the data collected. A factor is a number that represents a ratio of one number to another number. K, D, T, and peak hour factor are factors best computed from data collected at continuous count stations and are used in engineering analyses.

Axle, seasonal, monthly, and day-of-week (DOW) factors are computed from continuous count station data for use in adjusting short count data to estimates of AADT.

Axle Factor/Axle Correction Factors – Factors developed to adjust axle counts into vehicle counts. Axle correction factors are developed from classification counts by dividing the total number of vehicles counted by the total number of axles on these vehicles. However, the prevalence of data collection equipment that is dependent on pneumatic tubes that count axles rather than vehicles requires adjustments by applying an axle correction factor to represent vehicles. Equipment that detects vehicles directly (such as inductive loops or vehicle classification counters) does not require axle adjustment. In general, the higher the percentage of multi-axle vehicles on a road, the more error you will introduce into the data by not using axle correction factors.

Axle correction factors can be applied at either the individual point or the system level; specifically, from either specific vehicle classification counts at specific locations or from a combination of vehicle

classification counts averaged together to represent an entire system of roads. This is an example of creating axle factor groups. Another example is described below.

Because truck percentages (and consequently axle correction factors) change dramatically from road to road, even within functional classes and HPMS strata, the *TMG* recommends that axle correction factors be developed for specific roads from vehicle classification counts taken on that road whenever possible.

Where possible, the axle correction factor applied to an axle count should come from a classification count performed nearby, on that same road, and from a vehicle classification count that was taken during the same approximate period as the volume count. For roads where these adjustment factors are not available, a system wide factor is recommended. The systemwide factor should be computed by averaging all of the axle correction factors computed in the vehicle classification count sample within a functional classification of roads. However, other methods can also be used. Where State highway agencies have developed a truck route classification system, this classification system may be substituted for the functional class strata.

Computation of Axle Correction Factors

Emphasis on the collection of classification data should minimize the need for axle correction. Whenever possible, axle correction factors needed to convert axle counts to vehicles should be developed from vehicle classification counts taken on the specific road. In addition, the classification count should be taken from the same general vicinity and on the same day of week (a weekday classification count is usually sufficient for a weekday volume count) as the axle count it will be used to adjust. Where a classification count has not been taken on the road in question, an average axle correction factor can be estimated from the WIM and continuous classification sites. Methods used should be detailed in the traffic count metadata. The computation is the same whether the data comes from a single short duration count or from a continuous WIM scale.

Table 1-1 illustrates the process. In the table, vehicle volume is computed by dividing the total number of axles counted by the average number per vehicle. The table provides a conservative estimate of the number of axles per vehicle for the FHWA 13 vehicle category classes. Appropriate numbers should be computed at each site. States have different axle class systems. Some States have automated software to create these factors by axle factor groups; not all States are the same; and not all States group axle factors the same way.

TABLE 1-1   EXAMPLE CALCULATION OF THE NUMBER OF AXLES PER VEHICLE

Road ID	Daily Vehicle Volume Count (A)	Daily Number of Axle Count (B)	Average Number of Axles Per Vehicle (K)=B/A
R200B	54,267	135,124	2.5
R120A	1,968	4,546	2.3
R280K	240,656	579,019	2.4

Seasonal Factors – The seasonal factor is used to correct for seasonal bias in short duration counts. Directions on how to create and apply seasonal factors are provided in the general discussion of factoring in Chapter 3. States may choose to select alternative seasonal adjustment procedures if they have performed the analytical work necessary to document the applicability of their chosen procedure.

Monthly Factors – The monthly factor is used to correct for month of year bias in short duration counts. Directions on how to create and apply monthly factors are provided in the general discussion

of factoring in Chapter 3. Those procedures are recommended for the HPMS reporting, discussed further in Chapter 6. States may choose to select alternative monthly adjustment procedures if they have performed the analytical work necessary to document the applicability of their chosen procedure.

Day of week factors are used to correct for bias according to the day of the week.

Other Factors

K-Factor (K) – The proportion of AADT occurring in the peak hour is referred to as the peak hour proportionality K-factor. It is the ratio of peak hour to annual average daily traffic. It is used in design engineering for determining the peak loading on a roadway design that might have similar traffic volumes. For example, by applying the K-factor to a volume, a design engineer can estimate design hour volume. The K30 is the 30th (K100 is the 100th) highest hour divided by the annual average daily traffic.

D-Factor (D) – The directional distribution factor. It is the proportion of traffic traveling in the peak direction during a selected hour, usually expressed as a percentage. For example, a road near the center of an urban area often has a D-factor near 50% with traffic volumes equal for both directions.

Peak Hour Factor (PHF) – The hourly volume during the maximum traffic volume hour of the day divided by 15-minute volume multiplied by four, a measure of traffic demand fluctuation within the peak hour. It represents one hour of data at the peak time.

1.2.6 DATA PRODUCTS

ADT – Average Daily Traffic – The total volume during a given time period (in whole days), greater than one day and less than one year, divided by the number of days in that time period. Also known as raw data and unadjusted or non-factored data.

AADT – Annual Average Daily Traffic – The total volume of vehicle traffic of a highway or road for a year divided by 365 days. It is meant to represent traffic on a typical day of the year.

There are two basic procedures for calculating AADT:

- A simple average of all days; and

- An average of averages (the American Association of State Highway Transportation Officials (AASHTO) method).

In the first of these techniques, AADT is computed as the simple average of all 365 days in a given year (unless a leap year). When days of data are missing, the denominator is simply reduced by the number of missing days.

The advantage to this approach is that it is simple and easy to program. The disadvantage is that missing data can cause biases (and thus inaccuracy) in the AADT value produced. In particular, blocks of missing days of data (for example, data from June 15 to July 15) can bias the annual values by removing data that have specific characteristics. On a heavy summer recreational route, missing data from June 15 through July 15 would likely result in an underestimation of the true AADT for that road.

When the simple average is used to compute average monthly traffic, the missing data can bias the results when an unequal number of weekday or weekend days are removed from the dataset. Because continuous count stations may have some equipment down time during a year and miss a considerable numbers of days, AASHTO adopted a different approach for calculating AADT. The AASHTO approach first computes average monthly days of the week. These 84 values (12 months × 7 days) are then averaged to yield the AADT. This method explicitly accounts for missing data by weighting each day of the week the same, and each month the same, regardless of how many days are actually present within that category; however, there must be between one and five records for each day of the week in each month. For example, if only two Saturdays and two Sundays are present

for June, but there are three days of data for all five weekdays, in the simple average technique the weekdays would be over-represented in the average June day computation. In the AASHTO procedure, the first computation of the seven average days of the week allows the two Saturdays to be used to estimate the average June Saturday, while three Mondays are used to compute the average June Monday. When these seven values are then averaged to compute the average June day, the proper balance between weekdays and weekend days can be maintained.

The resulting two versions of AADT are very close to each other. The study, *Traffic Count Estimates for Short-Term Traffic Monitoring Sites: A Simulation Study* (Wright, et al.), indicates that the differences are so small as to be unimportant. The simple average method is certainly easier to compute. However, where data is likely to be missing the AASHTO method will provide a more reliable and accurate value.

The AASHTO method for computing AADT is recommended. This is because it allows factors to be computed accurately even when a considerable number of data is missing from a year at a site, and because it works accurately under a variety of data conditions (both with and without missing data). Conversely, the simple average works accurately only when the data set is complete, or when little bias is present in the missing data. Because a common method should be used for all AADT computations, the AASHTO method is preferred.

The AASHTO formulation for AADT is as follows:

$$AADT = \frac{1}{7} \sum_{i=1}^{7} \left[\frac{1}{12} \sum_{j=1}^{12} \left(\frac{1}{n} \sum_{k=1}^{n} VOL_{ijk} \right) \right]$$

Where:

VOL	=	daily traffic for day *k*, of DOW *i*, and month *j*
i	=	day of the week
j	=	month of the year
k	=	1 when the day is the first occurrence of that day of the week in a month, 4 when it is the fourth day of the week
n	=	the number of days of that day of the week during that month (usually between one and five, depending on the number of missing data)

AADTT – Annual Average Daily Truck Traffic – The total volume of truck traffic on a highway segment for one year, divided by the number of days in the year. Computation of AADTT (by vehicle class) from a short duration count requires the application of one or more factors that account for differences in time-of-day, DOW, and seasonal truck traffic patterns.

AAWDT – Annual Average Weekday Traffic – The estimate of typical traffic during a weekday (Monday through Friday) calculated from data measured at continuous monitoring sites.

AVDT – Annual Vehicle Distance Traveled – The number of miles that vehicles are driven in one year. AVDT is one of the values used in the Federal apportionment formula, and is calculated in distance units reported in HPMS for the roadway segment, usually in miles. This definition was added for accommodating distance measurements in the metric system.

The annual vehicle distance traveled (AVDT) is computed by multiplying the daily vehicle distance traveled (DVDT) by the number of days in the year. The HPMS software calculates the DVDT, and the AVDT is computed manually by FHWA.

The DVDT is calculated by multiplying the section AADT by the section length to compute section-specific DVDT. (A roadway section or subsection is a State-owned or off-system roadway identified

by an eight-digit code. Each roadway section is defined by a beginning and ending milepost in the Roadway Characteristics Inventory (RCI)). These are then summed for an entire stratum to compute DVDT. Aggregate estimates at any stratification level (volume group, functional class, area type, statewide, or other combinations of these) can be derived by summing the DVDT of the appropriate strata. For example, to obtain estimates of rural interstate DVDT, sum the DVDT estimates for each volume group strata within the rural interstate functional system group.

Estimates of DVDT or AVDT for specific HPMS vehicle classes also can be derived by multiplying DVDT strata figures by the appropriate percentages derived from the vehicle classification counts and aggregating to the strata totals as done for volume.

An estimate of the standard error of a stratum DVDT estimate is given by the following equation:

$$S_h = \sqrt{\frac{N_h(N_{h-}n_h)}{n_h(n_h-1)}\left[\sum D_{hi}^2 + \left(\frac{\sum D_{hi}}{\sum L_{hi}}\right)^2 \left(\sum L_{hi}^2\right) - 2\left(\frac{\sum D_{hi}}{\sum L_{hi}}\right)\sum D_{hi}\, L_{hi}\right]}$$

Where:

S_h =   standard error of DVDT estimate in stratum h

N_h =   number of full extent sections in stratum h

n_h =   number of sample sections in stratum h

D_{hi} =   DVDT of section i in stratum h

L_{hi} =   length of section i in stratum h.

Example:

If:

N_h =   10

n_h =   5

D_{hi} =   5.00 miles

L_{hi} =   1.00 mile

Then:

S_h =   ± 5%

This equation is presented in *Sampling Techniques* (Cochran). A complete discussion of ratio estimation procedures is included in the reference. The estimates produced by this process are conservative since the errors introduced by using factors to develop AADT estimates have been ignored. The assumption is that these errors are normally distributed and therefore will cancel out when aggregated. The equation shows that estimates of the standard error of aggregate VDT for HPMS strata are derived by summing the squared standard errors of the appropriate strata and taking the square root of the total. Coefficients of variation and confidence intervals can be derived by standard statistical procedures.

As a rule of thumb, the precision of statewide DVDT estimates (excluding local functional class) is expected to approximate ±5 percent with 95 percent confidence, although the analysis assumed that the AADT values reported were exact. Because of this assumption, precision estimates are conservative. Computation of annual DVDT estimates with the complete HPMS standard sample by using the AADT from each HPMS standard sample would be expected to approximate the stated precision. It is important to note that precision and accuracy are different concepts from variability. For example, you can have variable traffic volumes from year-to-year but still have accurate volumes.

The HPMS standard sample sizes are defined in terms of AADT within strata (described in the *HPMS Field Manual*). To estimate the precision of DVDT estimates, a complex procedure is needed to account for the variation in AADT and for the variation in section length. The equation to estimate the

sampling variability of aggregate DVDT estimates is given in *Sampling Techniques*. In an early HPMS study, the precision of statewide estimates of interstate DVDT approximated ±2-3 percent with 95 percent confidence, but these results considered only sampling variability and ignored error introduced by equipment or the factoring process used to estimate sample section AADT.

MADT – Monthly Average Daily Traffic – This can be computed by adding the daily volumes during any given month and dividing by the number of days in the month. For MADT, most of the calendar month of data should be included with a a minimum of at least one Monday, Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday .

MAWDT – Monthly Average Weekday Daily Traffic – The MADT for Monday through Friday are summed and then divided by five.

MAWET – Monthly Average Weekend Daily Traffic – The MADT for Saturday and Sunday are summed and then divided by two.

VDT – Vehicle Distance Traveled – The distance traveled by all vehicles for a given period, usually measured in miles and reported as vehicle miles traveled (VMT) for a geographic region. There is a relationship between VDT and VMT, although each is distinctly different. While VDT is measuring a distance traveled, VMT is counting the number of vehicles traveled over a distance. Depending upon the formulas used, these numbers may be the same.

VMT – Vehicle Miles Traveled – Indicates how many vehicles have traveled over the distance of a route or functional classification or geographic area in one day. VMT is calculated by multiplying the AADT value for each section of road by the section length (in miles) and summing all sections to obtain VMT for a complete route. VMT is not the same as daily vehicle distance traveled (DVDT), which measures the distance traveled by vehicles in a day, not how many (VMT) vehicles traveled over a given distance in a day. Depending upon the formulas used, these numbers may be the same.

1.2.7   OTHER TERMS

Vehicle – Vehicles include one powered unit and may include one or more unpowered full-trailer or semi-trailer units (*ASTM E17.52*).

Vehicle Length – This refers to the overall length of a vehicle measured from the front bumper to the rear bumper including permanent equipment that may extend beyond the rear bumper such as that used to improve aerodynamic performance.

Vehicle Axle – The vehicle axle is the axis oriented transversely to the nominal direction of vehicle motion and extending the full width of the vehicle about which the wheel(s) at both ends rotate (*ASTM E17.52, E1318-09*).

Axle Spacing – For each vehicle axle, the horizontal distance between the center of that axle and that of the preceding axle is the vehicle axle spacing (*ASTM E17.52, E1572-93*).

Vehicle Counts

Vehicle counting is the activity of measuring and recording traffic characteristics such as vehicle volume, classification, speed, weight, or a combination of these characteristics (*ASTM E17.52, E1442-94*).

Speed (Vehicle) – Measurement of how fast a vehicle is traveling in miles/hour (mph).

Weigh In Motion – Gross-vehicle weight of a highway vehicle is due only to the local force of gravity acting upon the composite mass of all connected vehicle components, and is distributed among the tires of the vehicle through connectors such as springs, motion dampers, and hinges. Highway WIM systems are capable of estimating the gross weight of a vehicle as well as the portion of this weight, called load, that is carried by the tires of each wheel assembly, axle, and axle group on the vehicle.

FHWA Vehicle Classes

The FHWA vehicle classification system separates vehicles into categories depending on whether they carry passengers or commodities. Non-passenger vehicles are further subdivided by the number of axles and the number of units, including both power and trailer units. Note that the addition of a light trailer to a vehicle does not change the classification of the vehicle.

Axle-based automatic vehicle classifiers rely on an algorithm to interpret axle spacing information and correctly classify vehicles into these classes. The FHWA does not endorse any specific algorithm or system for interpreting axle spacings. Axle spacing characteristics for different vehicle classes are known to change from State to State, by region of the country. As a result, no single algorithm is best for all cases. It is the responsibility of each agency to develop, test and calibrate the classification algorithm they use. FHWA vehicle classes with definitions are identified in Appendix C of the *TMG*.

1.3 DETECTION THEORY

This section reviews the theory of vehicle detection, including the physics and electronics used with the various types of sensors.

The theory and operation of vehicle sensors is discussed in detail in the sensor technology chapter of the *Traffic Detector Handbook* (FHWA-HRT-06-108). The handbook also discusses the operation and uses of the following types of modern vehicle presence technologies:

- Inductive Loop Detectors – A sensor capable of detecting vehicle passage and presence. Advanced signal processing can be used to derive certain vehicle class characteristics. It consists of four parts, namely one or more turns of wire embedded in the pavement, a lead-in wire running from the wire loop in the pavement to the pull box, and a lead-in cable spliced to the lead-in wire at the pull box, which connects to the inductive loop detector electronic circuit on a card or device within the equipment cabinet or traffic counter.

- Magnetic Sensor – Passive devices that detect the presence of a ferrous metal object through the perturbation (known as a magnetic anomaly) it causes in the Earth's magnetic field. Its output is connected to an electronics unit. The two types of magnetic sensors are fluxgate magnetometers and induction magnetometers, referred to as magnetic detectors as described in the *Traffic Detector Handbook*.

- Magnetic Detector (Induction or Search Coil Magnetometer) – A device that detects changes in the Earth's magnetic field caused by the movement of a ferrous metal vehicle in or near its detection area. It is placed under or in the roadway to detect the passage of a vehicle over the sensor. These sensors generally detect only moving vehicles. Their output is connected to an electronics unit.

- Microwave Radar Sensors – Vehicle detection devices that transmit electromagnetic energy from an antenna towards vehicles traveling the roadway. When a vehicle passes through the antenna beam, a portion of the transmitted energy is reflected back towards the antenna. The energy then enters a receiver where the detection is made and traffic flow data, such as volume, speed, and vehicle length are calculated.

- Microwave Doppler – The constant frequency signal (with respect to time) allows vehicle speed to be measured using the Doppler principle. Accordingly, the frequency of the received signal is decreased by a vehicle moving away from the radar and increased by a vehicle moving toward the radar. Vehicle passage or count is denoted by the presence of the frequency shift. Vehicle presence cannot be measured with the constant frequency waveform since only moving vehicles are detected.

- Passive Infrared Sensors – Transmit no energy of their own. Rather they detect energy from two sources: 1) energy emitted from vehicles, road surfaces, and other objects in their field of view;

and 2) energy emitted by the atmosphere and reflected by vehicles, road surfaces, or other objects into the sensor aperture. The energy captured by passive infrared sensors is focused by an optical system onto an infrared-sensitive material mounted at the focal plane of the optics.

With infrared sensors, the word "detector" takes on another meaning, namely the infrared sensitive element that converts the reflected and emitted energy into electrical signals. Real-time signal processing is used to analyze the signals for the presence of a vehicle. The sensors are mounted overhead to view approaching or departing traffic. They can also be mounted in a side-looking configuration. Infrared sensors are used for signal control; volume, speed, and class measurement; detection of pedestrians in crosswalks; and transmission of traffic information to motorists.

- Passive Acoustic Array Sensors – Measure vehicle passage, presence, and speed by detecting acoustic energy or audible sounds produced by vehicular traffic from a variety of sources within each vehicle and from the interaction of a vehicle's tires with the road. When a vehicle passes through the detection zone, an increase in sound energy is recognized by the signal-processing algorithm and a vehicle presence signal is generated. When the vehicle leaves the detection zone, the sound energy level drops below the detection threshold, and the vehicle presence signal is terminated.

- Ultrasonic Sensors – Transmit pressure waves of sound energy at a frequency between 25 and 50 kHz, which is above the human audible range. Most ultrasonic sensors operate with pulse waveforms and provide vehicle count, presence, and occupancy information.

- Laser Radar Sensors – Active sensors that transmit energy in the near infrared spectrum. Models are available that scan infrared beams over one or two lanes or use multiple laser diode sources to emit a number of fixed beams that cover the desired lane width. Laser radars provide vehicle presence at traffic signals, volume, speed, length assessment, queue measurement, and classification.

- Video Detection Systems – Typically consist of one or more cameras, a microprocessor-based computer for digitizing and analyzing the imagery, and software for interpreting the images and converting them into traffic flow data. A video detection system can replace several in-ground inductive loops, providing detection of vehicles across several lanes.

- Sensor Technology Combinations – Various types of sensors in combination used for traffic management, including ultrasonic-infrared-microwave Doppler.

Table 1-2 describes the strengths and weaknesses of the types of technology used for presence detection. Presence detection refers to the ability of a vehicle detector to sense that a vehicle, whether moving or stopped, has appeared in its zone of detection.

TABLE 1-2 STRENGTHS AND WEAKNESSES OF COMMERCIALLY AVAILABLE SENSOR TECHNOLOGIES FOR MOTORIZED TRAFFIC

Technology	Strengths	Weaknesses
Inductive loop	• Flexible design to satisfy large variety of applications • Mature, well-understood technology • Large experience base • Provides basic traffic parameters (e.g., volume, presence, occupancy, speed, headway, and gap) • Insensitive to inclement weather	• Installation requires pavement cut • Improper installation decreases pavement life • Installation and maintenance require lane closure • Wire loops subject to stresses of traffic • Multiple loops usually required to monitor a location • Detection accuracy may decrease when design requires detection of a large

Technology	Strengths	Weaknesses
	such as rain, fog, and snow • Provides best accuracy for count data as compared with other commonly used techniques • Common standard for obtaining accurate occupancy measurements • High frequency excitation models with advanced signal processing can provide axle classification data	variety of vehicle classes • Does not detect axles in commonly used configurations
Piezo/ Quartz	• High accuracy in vehicle classification • Insensitive to inclement weather such as rain, fog, and snow • Common standard for obtaining axle count and classification • Can be used to collect weight classification data (WIM); quartz performance comparable to bending plates • Mature, well-understood technology	• Installation requires pavement cut • Improper installation decreases pavement life • Installation and maintenance require lane closure • Piezo sensitive to temperature • Does not detect vehicle overall length • Does not work well in slow or stopped traffic
Air switch/ Road tube	• Common standard for obtaining axle count and classification in portable applications • Mature, well-understood technology	• Installation may require lane closure • Does not detect vehicle overall length • Does not work well in high volume or slow or stopped traffic
Magnetometer (two-axis fluxgate magnetometer)	• Less susceptible than loops to stresses of traffic • Insensitive to inclement weather such as snow, rain, and fog • Some models transmit data over wireless radio frequency (RF) link	• Installation requires pavement cut • Improper installation decreases pavement life • Installation and maintenance require lane closure • Models with small detection zones require multiple units for full lane detection • Cannot detect stopped vehicles, axles
Magnetic (induction or search coil magnetometer)	• Can be used where loops are not feasible (e.g., bridge decks) • Some models are installed under roadway without need for pavement cuts; however, boring under roadway is required • Insensitive to inclement weather such as snow, rain, and fog • Less susceptible than loops to stresses of traffic	• Installation requires pavement cut or boring under roadway • Cannot detect or classify stopped vehicles or axles unless special sensor layouts and signal processing software are used
Microwave radar	• Typically insensitive to inclement weather at the relatively short ranges encountered in traffic management applications • Direct measurement of speed • Multiple lane operation available • Detects stopped and slow-	• Detector can miss occasional vehicles traveling side-by-side (occlusion) • Calibration and sensor position are crucial to proper operation • Does not detect axles

Technology	Strengths	Weaknesses
	moving vehicles • Lane assignment and changes can be accommodated for at a location	
Microwave doppler	• Typically insensitive to inclement weather at the relatively short ranges encountered in traffic management applications • Direct measurement of speed	• Cannot detect stopped vehicles, axles
Active infrared (laser radar)	• Transmits multiple beams for accurate measurement of vehicle position, speed, and class • Multiple lane operation available • Good motorcycle detection • Non-intrusive installation	• Operation may be affected by fog when visibility is less than ≈ 20 feet (6 meters) or blowing snow is present • Installation and maintenance, including periodic lens cleaning, require lane closure (should not require a lane closure for cleaning and maintenance of a side-fired laser) • Side fire axle detection will not work with roads that have a substantial crown or median obstructions
Passive infrared	• Multizone passive sensors measure speed • Good motorcycle detection • Non-intrusive installation	• Passive sensor may have reduced vehicle sensitivity in heavy rain, snow, and dense fog • Some models not recommended for presence detection • No accurate vehicle length or axle detection (requires periodic lens cleaning)
Ultrasonic	• Multiple lane operation available • Capable of overheight vehicle detection	• Environmental conditions such as temperature change and extreme air turbulence can affect performance; temperature compensation is built into some models • Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles traveling at moderate to high speeds • Cannot detect stopped vehicles, axles
Acoustic	• Passive detection • Insensitive to precipitation • Multiple lane operation available in some models	• Cold temperatures may affect vehicle count accuracy • Specific models are not recommended with slow-moving vehicles in stop-and-go traffic • Cannot detect stopped vehicles, axles
Video detection system	• Monitors multiple lanes and multiple detection zones/lane • Easy to add and modify detection zones • Rich array of data available • Generally cost effective when many detection zones within the camera field of view or specialized data are required	• Installation and maintenance, including periodic lens cleaning, require lane closure when camera is mounted over roadway (lane closure may not be required when camera is mounted at side of roadway) • Performance affected by inclement weather such as fog, rain, and snow; vehicle shadows; vehicle projection into adjacent lanes; occlusion; day-to-night

Technology	Strengths	Weaknesses
		transition; vehicle/road contrast; and water, salt grime, icicles, and cobwebs on camera lens • Reliable nighttime signal actuation requires illumination • Requires 30- to 50-ft (9- to 15-m) camera mounting height (in a side-mounting configuration) for optimum presence detection and speed measurement • Cannot detect axles • Some models susceptible to camera motion caused by strong winds or vibration of camera mounting structure

Source: Adapted from Traffic Detector Handbook*, 2006.*

The *Traffic Detector Handbook* summarizes the comparison of in-roadway and over-roadway sensors and indicates that good performance of in-roadway sensors such as inductive loops, magnetic, and magnetometer sensors is based, in part, on their close location to the vehicle. Thus, in-road sensors are insensitive to inclement weather due to a high signal-to-noise ratio. Their main disadvantage is their in-roadway installation, necessitating physical changes in the roadway as part of the installation process. Over-roadway sensors often provide data not available from in-roadway sensors and some can monitor multiple lanes with one unit.

In traffic monitoring applications, in-road sensors can effectively discriminate vehicle characteristics (e.g. axle spacing, class, length) on a lane by lane basis, without being subject to errors introduced by multiple vehicles simultaneously in the field of view of the sensor.

The following table adapted from the *Traffic Detector Handbook* lists and describes the traffic flow sensor technologies and their capabilities. Most measure count, presence, and occupancy. Some single detection zone sensors, such as the range-measuring ultrasonic sensor and some infrared sensors do not measure speed. Continuous wave Doppler radar sensors do not detect stopped or slow moving vehicles.

TABLE 1-3   MOTORIZED SENSOR COMPARISON

Sensor Technology	Count	Presence	Speed	Output Data	Classification[l]	Multiple Lane, Multiple Detection Zone Data	Communication Bandwidth	Sensor Purchase Cost
Inductive Loop	X	X	X[a]	X	X[b]		Low to moderate	Low[h]
Magnetometer (2-Axis Fluxgate)	X	X	X[a]	X			Low	Moderate[h]
Magnetic Induction Coil	X	X[c]	X[a]	X			Low	Low to moderate[h]
Microwave Doppler								
Microwave Radar	X	X[d]	X	X[d]	X[d]	X[d]	Moderate	Low to moderate
Active Infrared	X	X	X[e]	X	X	X	Low to moderate	Moderate to high
Passive Infrared	X	X	X[e]	X			Low to moderate	Low to moderate
Ultrasonic	X	X		X			Low	Low to moderate
Acoustic Array	X	X	X	X		X[f]	Low to moderate	Moderate
Video Detection System	X	X	X	X	X	X	Low to high[g]	Moderate to high

Source: Federal Highway Administration.

[a] Speed can be measured by using two sensors a known distance apart or estimated from one sensor, the effective detection zone and vehicle lengths[b] with specialized electronics unit containing embedded firmware that classifies vehicles.
[c] With special sensor layouts and signal processing software.
[d] With microwave radar sensors that transmit the proper waveform and have appropriate signal processing.
[e] With multi-detection zone passive or active mode infrared sensors.
[f] With models that contain appropriate beam-forming and signal processing.
[g] Depends on whether high-bandwidth raw data, lower-bandwidth processed data, or video imagery is transmitted to the TMC.
[h] Includes underground sensor and local detector or receiver electronics. Electronics options are available to receive multiple sensors, multiple lane data.
[l] *There are different types of classification schemes (axle-based, length-based and visual schema)*

1.4 DETECTION TECHNOLOGY

This section describes the kinds of technologies that are available to support traffic monitoring programs at the State level, including the technology and equipment used for collecting counts and the general strengths and weaknesses of each of those technologies. This section summarizes a large amount of previously published material and acknowledges that additional literature continues to be published as vendors bring new technologies to market and update existing technologies. An additional excellent source of information on the selection of traffic monitoring equipment can be found in Chapter 3 of the report *AASHTO Guidelines for Traffic Data Programs* (2009).

Traffic monitoring technology is evolving quickly due to a combination of the availability of modern, low cost computing and communications technology, but is also driven by the need for more timely information. Not all equipment vendors produce equipment of equal quality. Some equipment has been heavily tested and operates very robustly. Even within a single technology, equipment performance can vary widely from vendor to vendor based on each vendor's internal software algorithms and the components that make up their equipment.

The reason different vendor's equipment can produce different results for any given sensor technology is that the data collection electronics and the software that resides in those electronics may perform in different ways. (For example, two different video image-counting devices may produce very different results if one uses a robust image-processing algorithm, while the other does not.)

Consequently, as agencies make decisions on what type of hardware and supporting software to purchase, they should continue to consult the available and more detailed literature (such as from pooled funds, FHWA Highway Community Exchange, and FHWA Long Term Pavement Performance (LTPP)) that describes the performance of specific technologies. They should work cooperatively with their peers to share their working experience with specific equipment. Using these resources effectively is a key to selecting the best data monitoring equipment for each agency's needs. A very good source of additional information on traffic data collection technologies is available on the FHWA's Travel Monitoring Policy website. A variety of other excellent technical resources are included in Appendix L.

It is also important that agencies carefully test equipment before they purchase specific devices from a vendor, and once they have purchased devices that meet their needs, they should routinely calibrate and continue to test the performance of their equipment in the field. The first of these steps ensures that the equipment they purchase performs as advertised. The second step ensures that the equipment they are using is being correctly installed in the field, and that the performance of the sensors and electronics has not degraded over time due to use and changing environmental conditions. Careful site selection, use of high quality materials, and rigorous attention to detail during the installation process will facilitate the reliable collection of high quality traffic data on a continuous basis.

1.4.1 TRAFFIC ATTRIBUTES

A good way to categorize traffic monitoring devices is based on the type of data they collect. Given the goals of the *Traffic Monitoring Guide*, traffic monitoring equipment can be categorized as being able to collect several different types of data:

- Non-Motorized:
    - Bicycle volumes;
    - Pedestrian volumes; and
    - Bicycle and pedestrian total volumes.

- Motorized:
  - Vehicle volumes;
  - Vehicle classification (including motorcycles);
  - Speed;
  - Axle spacing;
  - Vehicle and axle weight;
  - Gap;
  - Headway; and
  - Lane occupancy.

The technology used to sense the passing traffic stream determines what each data collection device physically counts. The electronics connected to that sensor interpret the sensor's signal, processes the signal (usually using a proprietary algorithm specific to that equipment's vendor), and produces some subset of the data items listed in the bullets above. The next paragraphs describe the different types of data that are collected by traffic data collection equipment.

Non-Motorized Traffic Programs

Chapter 4 provides basic guidance related to the state of the practice in non-motorized traffic monitoring. It includes discussion of the following:

- Various technologies that are commonly used to count non-motorized (i.e., bicycles and pedestrians) traffic volumes at fixed locations;
- Discussion of non-motorized traffic variability;
- Process for collecting continuous non-motorized traffic data; and
- Non-motorized short-duration counts.

Motorized Traffic Programs

Vehicle Volume

A wide variety of technologies can count vehicles. Some technologies actually count each passing object, where in most cases an object is a vehicle, whether it is a car or multi-unit truck. Other sensors do not detect a vehicle, but instead count the axles of those vehicles. Additional information is then used to convert the axle count data into measures of vehicle volume. In many cases, this extra information comes from a second sensor. But for simple, single sensor, axle-based counters, an adjustment factor (the axle correction factor) is applied against the total axle count in order to provide an estimate of vehicle volume. Table 1-4 summarizes which of the currently available traffic monitoring technologies directly count vehicle volumes, and which count axles requiring conversion of that data to vehicle volume estimates.

TABLE **1-4**   **C**OMMON **T**ECHNOLOGIES **U**SED FOR **C**OUNTING **V**EHICLES **V**ERSUS **A**XLES
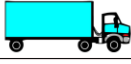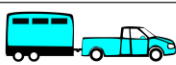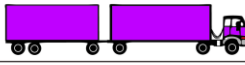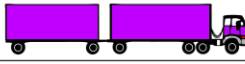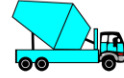
Presence Sensing Technologies	Axle Sensing Technologies
Inductive loops	Infrared
Magnetic	Laser (most)
Video detection system	Piezo-electric
Acoustic	Quartz sensor
Ultrasonic	Fiber optic
Microwave radar	Capacitance mats
Laser radar	Bending plates
Passive infrared	Load cells
	Inductive Signatures
	Contact switch closures (e.g., road tubes)

This table shows the most common application of this technology. In some cases, specific implementations of the technologies can be used in different ways. For example, one very specific implementation of loop sensors has been shown to be able to count axles very accurately. However, most loop installations are not capable of detecting axles.

Vehicle Classification

Collecting traffic volume data by vehicle classification differs from simple volume counting in that each vehicle is not only recognized as a vehicle, but that vehicle is also classified into one of several defined categories. Adding to the difficulty of categorizing vehicles is the fact that different users have different definitions into which they would like vehicles classified. In traffic monitoring, the most commonly used vehicle classification system is the 13 vehicle category classification system developed by FHWA and is used in each State's HPMS submittal. Figure 1-1 provides representative examples that depict the 13 vehicle categories.

FIGURE 1-1   FHWA'S 13 VEHICLE CATEGORY CLASSIFICATION

Class 1 Motorcycles		Class 7 Four or more axle, single unit	
Class 2 Passenger cars			
		Class 8 Four or less axle, single trailer	
Class 3 Four tire, single unit			
		Class 9 5-Axle tractor semitrailer	
Class 4 Buses		Class 10 Six or more axle, single trailer	
		Class 11 Five or less axle, multi trailer	
Class 5 Two axle, six tire, single unit		Class 12 Six axle, multi- trailer	
		Class 13 Seven or more axle, multi-trailer	
Class 6 Three axle, single unit			

Source: Federal Highway Administration.

Certain truck configurations utilize axles that can be lifted when the vehicle is empty or lightly-loaded. The position of these axles—sometimes called lift axles, drop axles, or tag axles—affects the classification category into which the vehicle falls. To maintain consistency between visual and axle-based counts, the *TMG* recommends that only axles that are in the dropped position be considered when classifying the vehicle. While this promotes consistency, it may induce difficulty when interpreting summary classification statistics at certain locations. For example, a site may exhibit directional differences in vehicle classification even though the same trucks may be travelling one direction loaded (with axles down) and the other direction empty (with axles lifted).

This recommendation was developed as a compromise between a wide variety of competing interests. It is really a visual system. Most vehicles can be easily classified into this system by a human

observer. However, work performed by John Wyman and others at Maine DOT (Wyman, Gary, and Stevens, 1985) resulted in computer algorithms that allow most vehicles to be correctly classified into these categories based on the number and spacing of their axles. This system has been refined over time by a wide variety of researchers, State agencies, and vendors to help it function effectively in their respective States. These modifications from the original system were necessary because truck size and weight laws vary from State to State and, consequently, common truck dimensions and configurations can change slightly from State to State. In addition, some States permit specific vehicle types that are not legal in other States. (For example, some western States allow tractors to pull three trailers, while most States do not allow more than two trailers.) States often wish to track these unusual vehicle types, and therefore add additional vehicle categories to FHWA's 13 categories that meet their specific traffic monitoring needs. When these States purchase vehicle classification counters, they require that the vendors install their State-specific classification algorithms in the data collection electronics or post processing software.

However, these modified FHWA classification systems are not the only classification systems of interest. Many engineering and planning analyses do not require data in the detailed FHWA 13 categories, but do require information on truck volumes versus car volumes. Thus, many engineering and planning analyses use either a simple car/truck split or they use a very simplified truck classification system; commonly a 3- or 4-bin classification system based on vehicle length.

The most common length classification systems essentially consist of four generalized length bins that approximate the following four categories of vehicles: cars, small trucks, large trucks, and multi-trailer trucks. States that use only three truck classes combine the large truck and multi-trailer truck classes. (These States tend to be States where multi-trailer trucks are rare.) Unfortunately, unlike the FHWA 13 vehicle category classification, there is no common definition across the States that indicates the vehicle length at which a car becomes a truck. The States, therefore, set their own length definitions for these classification systems.

Besides its simplicity, one advantage of the length classification systems is that vehicle length can be easily calculated by a number of sensor technologies that do not require axle sensors. Thus, many of the sensor technologies that can collect volumes by vehicle length can be placed above or beside the roadway, limiting or eliminating the need for staff placing those sensors to work in the lane of travel.

The primary disadvantage of the length-based classification is that they do not correlate as well as the FHWA 13 vehicle category classification system to several of the key vehicle attributes used in specific types of analyses. For example, a major input to pavement design is traffic load, and that in turn is driven by the number and weight of axle loads being applied. The FHWA 13 vehicle category classification system directly accounts for the number of axles within the classification system. The FHWA classification system also does a good job of identifying specific vehicle types (e.g., classes 7 and 10) that are often particularly heavy. This results in better traffic load estimation and thus better pavement analysis.

Jurisdictions should adopt classification systems that are compatible with the 13 vehicle category classification system. Systems with fewer categories should be combinations of the FHWA classes, and systems with more categories should be subdivisions of the FHWA classes.

Length-based classification systems do not account for specific axle configurations, and thus the connection between the number and weight of axles within the different length classifications is far more nebulous. Similarly, the FHWA axle-based system does a good job of differentiating the number of multi-unit vehicles on the roadway, while the length-based systems are not able to track the number of vehicles pulling one or more other units. The number of units in a given vehicle is a key variable being tracked for safety purposes, thus the length classification systems are much less useful for the kinds of safety analyses that are interested in the exposure rates associated with multi-unit vehicles.

Some State agencies use some combination of both FHWA's 13 vehicle category classification system and a simpler length-based system. The length-based system is used in those physical road segments

where it is not possible to place axle sensors. Length-based is also used when the advantages of simplicity outweigh the loss of detail and precision that comes from using the more sophisticated axle-based classification system. Approval is required by a State's FHWA office for use of length class in any data submitted to FHWA.

Table 1-5 describes which vehicle counting technologies can also classify vehicles.

TABLE 1-5   COMMON TECHNOLOGIES FOR CLASSIFYING MOTORIZED VEHICLES

Technologies for Axle-Based Vehicle Classification	Technologies for Length-Based Vehicle Classification
Infrared (passive)	Dual inductive loops
Laser radar	Inductive loops (loop signature)
Piezo-electric	Magnetic (magnetometer)
Quartz sensor	Video detection system
Fiber optic	Microwave radar
Inductive Loop Signatures	CW Doppler sensors
Capacitance mats	
Bending plates	
Load cells	
Contact switch closures (e.g., road tubes)	
Specialized inductive loop systems	
Any of the above combined with inductive loops	

Speed

Vehicle speed is also a commonly desired traffic monitoring attribute. Interest in monitoring and reporting roadway performance is growing at the State and Federal levels. This means that States are being asked to collect and report on where, how often, for how long, and to what extent roads are becoming congested. At the same time, safety and environmental studies are interested in the relative distribution of vehicle speeds, and the number and type of vehicles that are speeding.

Most modern traffic monitoring technologies produce a measure of speed as part of their routine traffic monitoring function. Roadway agencies are well advised to consider collecting and reporting speed data that can be used by their agency.

The selection of equipment to collect speed data should consider the fact that some technologies are particularly well suited for reporting individual vehicle speeds (that is tracking how fast each specific vehicle is moving), while others are designed to provide average facility speed over a given reporting interval. Although both data represent speed information, the usefulness of those data is very different.

How the speed data is collected is as much a function of the equipment connected to the sensor as it is of the sensor technology itself. For example, the traditional method for estimating speeds when using a single inductive loop is to measure total sensor on time (lane occupancy) over a set period, along with the total number of vehicle observations during that period. By dividing the lane occupancy by the volume and multiplying by a constant that represents the average vehicle length for that location, average speed for that reporting period can be computed and reported. However, more modern electronics can take the same basic single loop signal, and by analyzing that signal, directly calculate vehicle speed from the shape of the loop signature. Another approach to using loop technology is to place two loops in the lane at a known distance apart configured one after the other, thus forming a speed trap. When these loops are properly calibrated, the distance between the

leading edge of the two detectors (d_{12}) divided by the difference in time it takes for the passing vehicle to activate the second loop after it activates the first loop ($T_2 - T_1$) yields the speed of the vehicle ($d_{12} / (T_2 - T_1)$).

The key to collecting speed data is that the agency needs to understand both what use they need from the data, and what their available equipment can supply.

Speed data can also be obtained from other sources. One such source is vehicle probe data; however, guidance on how to combine speed data collected from vehicle probes within the overall roadway performance-monitoring program of an agency is not covered in this edition of the *TMG*. FHWA now has a speed format that allows for flexibility with a minimum of 15 speed bins to a maximum of 25 speed bins (all in 5 mph increments).

Vehicle and Axle Weight

The final traffic attributes that should be addressed as part of a traffic monitoring program is axle weights and spacings. A specific subset of traffic monitoring devices is capable of weighing vehicles while they travel down the road. These devices are commonly referred to as weigh-in-motion (WIM) scales. The sensors used are designed to not only detect the presence of an axle, but to measure the force being applied by that axle during the duration of the time the axle is in contact with the axle sensor. Sophisticated analysis is then applied to the signal produced by each sensor in order to establish the weight of each passing axle. Weights for all axles associated with a given vehicle are then combined to estimate total vehicle weight. Axle spacings are also recorded.

The most common of WIM technologies used in the U.S. are piezo-electric and bending plate systems. There are a variety of different piezo-electric and quartz sensor technologies, each of which has specific strengths and weaknesses. In addition, other technologies such as fiber optic cables, load cells (both hydraulic and mechanical), capacitance mats, and strips, along with bridges and culverts instrumented with strain gauges can also be used as weight sensors.

In almost all cases, secondary sensors (e.g., inductive loop detectors) are used in combination with the primary axle and weight sensors to provide information on presence. Combining vehicle speed and presence information with the time between axle weight measurements allows the WIM system to correctly assign specific axles to specific vehicles and to group the axles correctly (that is, are the observed axles single axles, tandem axles, tridems, or even larger groups of axles), and thus correctly classify each vehicle and compute its total weight. It is important to note that WIM measures the dynamic axle weights, and these are different from static axle weights.

Motorcycle Counting

The relatively small amount of metal in many motorcycles combined with the fact that many motorcyclists ride near lane lines in order to give themselves more time to avoid cars moving into their lanes means that inductive loop detectors and half lane axle sensors often undercount motorcycles. When motorcycles ride in closely spaced groups, the closely spaced axles and cycles often confuse available traffic monitoring equipment, which have not been designed to identify the resulting pattern of closely spaced axles and vehicles. Guidance for how to address these issues is included in Chapter 3.

1.4.2 LOCATION OF THE SENSOR

For much of the 20th century, most traffic monitoring devices were placed on top of or in the pavement (e.g., road tubes versus inductive loops). These sensors are commonly referred to as "intrusive" sensors. Micro loops are placed in a tube below the ground (shuttle).

As traffic volumes have grown over time, it has become both increasingly difficult and costly to quickly and safely place sensors on, or in, the travel lane. The most common reasons for not wanting to place sensors in or on the lane of travel are as follows:

- It may be unsafe for data collection crews to place the sensor in position;

- It is too expensive to supply the traffic control needed to place and/or maintain intrusive sensors;

- When pavement condition is poor, intrusive sensors often perform poorly and have a greatly shortened life span;

- If the intrusive sensor is not properly installed, it can shorten the life of the pavement where it is placed;

- Disruption of traffic occurring with the placing of sensors introduces safety as well as performance issues; and

- It may be difficult to close the lane because of high traffic volumes.

As a result, considerable work has been done during the last 20 plus years to bring to market non-intrusive sensors that can be put in place and/or maintained without personnel having to enter the travel lane. Table 1-6 describes which sensors are intrusive and which are non-intrusive.

TABLE 1-6   INTRUSIVE AND NON-INTRUSIVE TECHNOLOGIES

Intrusive	Non-Intrusive
Inductive loops	Infrared (passive)
Piezo-electric	Video detection system
Quartz sensor	Microwave radar (overhead or side mounted)
Fiber optic	CW Doppler sensor
Magnetic (most sensor designs)	Acoustic
Contact closures	Ultrasonic
WIM scales (bending plates, load cells, capacitance mats and strips)	Laser radar

Non-intrusive sensors can be further divided into overhead mounted sensors and side-fired sensors. Side-fired sensors have the advantage of being mounted beside the road. This makes them easy to install, access, and maintain. The drawback is that on multi-lane roadways, traffic using the roadway lanes farthest away from the sensor location can be obscured from the side-fired sensors by vehicles (and particularly trucks) traveling in the lanes closer to the sensor. This is called occlusion. Occlusion results in undercounting of total volume and can bias speed estimates if the traffic on the inside of the roadway is traveling at a different speed than traffic on the outside lanes.

Generally, the higher above the roadway the non-intrusive sensor is placed, the smaller the problem with occlusion. However, raising the sensor vertically can 1) increase the cost of installation and maintenance; 2) decrease the resolution with which the sensor detects vehicles in the road; and 3) create movement in the sensor (as the pole on which the sensor sits sways), which may result in other forms of accuracy degradation.

Mounting the sensor directly above the lane of travel is one way of significantly reducing the opportunity for occlusion to occur. Thus, overhead mounted sensors tend to be more accurate than side-fired sensors of that same technology. The disadvantage of overhead mounted sensors is that the lane of travel must normally be shut down in order for the sensors to be installed and then again each time maintenance is performed because of fears that material could be dropped onto the roadway during those activities. This can be problematic for some high volume roadways. Axle weights are the one form of data that cannot be collected non-intrusively. (Some bridge WIM systems are designed to operate without sensors being placed in the lane of travel. But to date, these systems only work on a very limited set of bridges and are still primarily in the research phase.)

1.4.3 OTHER CONSIDERATIONS

Selecting Motorized Traffic Monitoring Technologies

In addition to the basic functional requirements discussed above, roadway agencies should consider a variety of other functionalities when selecting traffic monitoring technologies. These topics include:

14. Number of lanes of data collection performed by any one piece of equipment and/or sensor;

15. Cost of the equipment (initial cost, placement cost, operating cost, and expected maintenance costs);

16. Expected life of the sensors and data collection electronics;

17. Warranties supplied by the manufacturer/vendor;

18. Environmental conditions under which the equipment is expected to operate relative to the strengths and weaknesses of each specific technology;

19. Whether the agency staff has the required knowledge and equipment for placing, calibrating, and maintaining the equipment;

20. Available communications capabilities (i.e., what options does the agency have for retrieving data from the data collection electronics, and how do those options fit within the agency's current or planned traffic data processing procedures?);

21. Type of power source to be used (AC/DC, solar, luminary, internal battery);

22. Ability of the vendor to supply data outputs in a format that works seamlessly with the agency's existing or planned data processing system (ability to integrate data into a centralized system and utilize information to calculate and summarize statewide year-end statistics);

23. Vendor agreement for software support, equipment maintenance, warranty work;

24. Pavement condition for surface sensor like piezos and WIM; and

25. Installation materials and methods.

The first four of these issues are straightforward and provide the reviewer with the ability to trade-off cost and performance. Of particular importance is the warranty provided by the vendor, as it provides an important level of assurance that the first three cost estimates are accurate.

The fifth topic relates to the fact that some technologies work better in some specific environmental and traffic conditions than others. Some equipment might work very well in specific instances while work poorly in other circumstances. For example, road tubes generally work well for short duration counts (48 hours) on lower volume, rural roadways. However, they do not work effectively on higher volume, multi-lane urban roadways. While vendors can create product modifications/versions to help technologies function in conditions for which they are generally not suited, when selecting technologies, agencies should be very aware of the increased likelihood of count issues/failures from those technologies in those conditions.

The answer to the sixth topic determines whether the agency needs to purchase additional equipment to place, operate, and maintain new technologies, as well as have staff undergo new training in order to perform those tasks.

Finally, the last six topics describe how efficiently and reliably the vendor's implementation of the selected technology will work within the existing or planned data processing system of the roadway agency. Collection, calibration, processing, reporting, accessing, and storing of traffic monitoring data can be resource intensive and roadway agencies should consider how much effort would be required for any given device.

Optimizing Motorized Traffic Monitoring Efforts

Regardless of the traffic monitoring technology selected, every roadway agency should routinely perform the following tasks to ensure that the equipment they purchase works to the best of its capability:

- The equipment should be tested and meet the users accuracy level before being placed into service;

- The equipment should be routinely calibrated as it is placed in service;

- The equipment performance should be validated periodically to ensure that it continues to perform as intended;

- The collected data should be routinely subjected to quality assurance tests;

- The data should be analyzed and then quickly and routinely supplied to users so that data quality concerns not caught by the primary data quality process can be quickly identified by users; and

- A feedback process should be in place so that the traffic monitoring group obtains this feedback from users, and effectively responds to improve the quality of the data.

These tasks, described in more detail in Chapters 2 and 3, ensure active management from those collecting and using the data so that the technology performs well.

Equipment that is not actively monitored for quality performance eventually goes out of calibration, regardless of a vendor's assurances of self-calibration capabilities. Validation checks when equipment is initially installed are an essential first step in that process. Following a formal quality assurance and field maintenance program and providing resources to fix problems that are identified by that process ensures that funding available for collecting data is spent on collecting valid, useful information.

The next section describes the concepts regarding variability in traffic patterns, which should be considered when establishing traffic data collection programs.

1.5   VARIATION OF TRAFFIC DATA

This section discusses the concepts of different types of variability found in traffic patterns and describes how this variability affects the design of a strong traffic monitoring program. Traffic volumes typically vary over time and space. That is, traffic volumes are different at 8 a.m. than they are at 8 p.m. Similarly, traffic patterns are different on urban freeways and on rural farm to market roads. A good traffic monitoring program collects data to meet many needs; therefore, a roadway agency should design data collection efforts that provide the roadway agency with an accurate understanding of exactly what these patterns are and how they are changing over time.

The next paragraphs introduce the concepts of traffic variability and describe the program and technology designs that are used to account for this variability.

1.5.1   TRAFFIC VARIABILITY

Technology allows agencies to collect enough data to accurately describe how traffic varies over time and space (Wright et al., 1997). Traffic varies over a number of different time scales, including:

- Time of day (year-to-year, event-driven);

- Day of week;

- Month (season) of the year; and

- Year to year.

Traffic varies from place to place and directionally too. Not only do roads carry different volumes of traffic, but also the characteristics of the vehicles using those roads change from facility to facility. One road with 5,000 vehicles per day may have very little truck traffic, while another road with the same volume of vehicles may have 1,000 trucks per day mixed in with 4,000 cars. Similarly, one road section may be traversed by 1,000 heavily loaded trucks per day while a nearby road is used by 1,000 partially loaded trucks. Directional variations also exist.

Time-Of-Day Variation

Since the early development of roads, it has been known that the use of a road changes during the course of the day. In most locations, traffic volumes increase during the day and decrease at night. A 1997 study for the Federal Highway Administration (Hallenbeck, et al., 1997) determined that most truck travel falls into one of two basic time-of-day patterns; one pattern is centered on travel during the business day, and the other pattern shows almost constant travel throughout the twenty-four-hour day.

Most passenger car travel also falls into one of two time-of-day patterns, but these patterns are different from those of trucks. These four patterns are illustrated in Figure 1-2.

FIGURE 1-2   BASIC TIME OF DAY PATTERNS
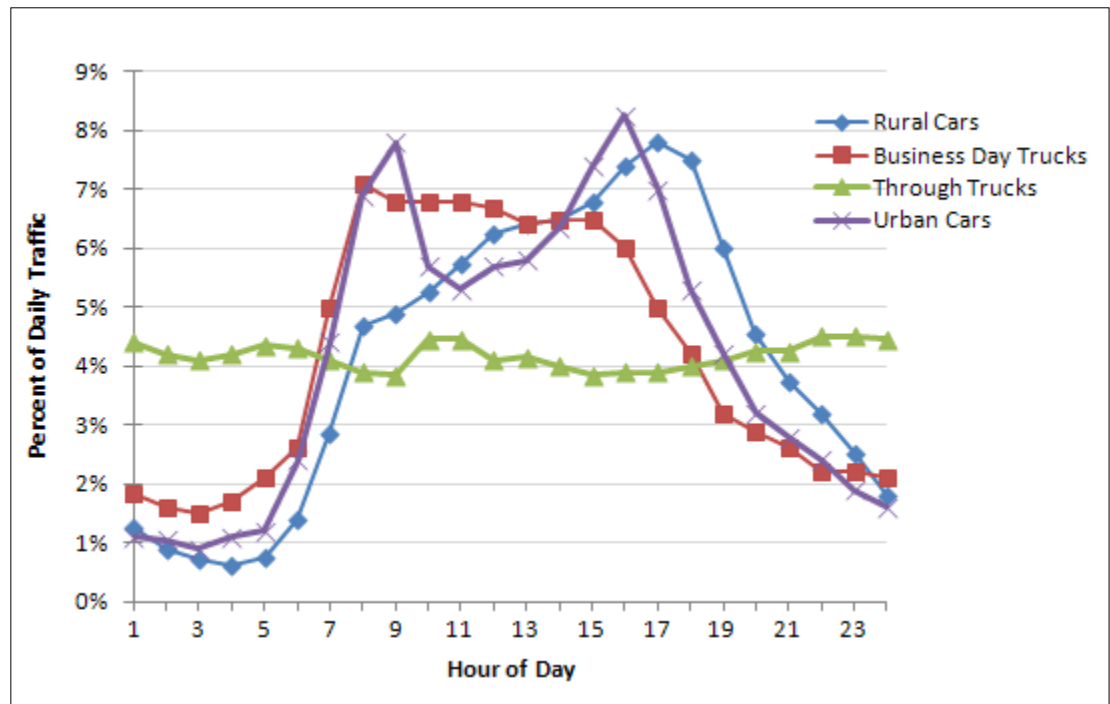
Source: *Hallenbeck, et al.,* Vehicle Volume Distributions by Classification*, 1997.*

As can be seen in Figure 1-2, cars tend to follow either the traditional two-humped urban commute pattern or the single-hump pattern commonly seen in rural areas, where traffic volumes continue to grow throughout the day until they begin to taper off in the evening. Trucks also exhibit a single mode. However, the truck pattern differs from the rural car pattern in that it peaks in the early morning (many trucks make deliveries early in the morning to help prepare businesses for the coming workday) and tapers off gradually, until early afternoon, when it declines quickly. The other truck pattern (travel constantly occurring throughout the day) is common with long haul trucking movements.

The traffic at any given site comprises some combination of these types of movements. In addition, at any specific location, time-of-day patterns may differ significantly as a result of local trip generation patterns that differ from the norm. For example, Las Vegas, Nevada, generates an abnormal amount of traffic during the night because that city is very active late at night. In heavily congested urban areas, the commute period traffic volume peaks flatten out and can last three or more hours. Local patterns also have a significant effect on the directional time-of-day pattern for any given road. On some urban roadways, there is very heavy directional traffic movement – inbound to the central city in the morning and outbound to the suburbs in the afternoon. On other roadways, especially freeways serving multiple suburban cities, traffic can be equally strong in both directions during both commute periods.

Because the volumes of cars and trucks are very different from one site to another, the effect of these different time-of-day patterns on summary statistics such as percent trucks, percent bicycles, percent pedestrians, and total volume can be unexpected. Often, in daylight hours, car volumes are so high in comparison to truck volumes that the car travel pattern dominates and the percentage of trucks is very low. However, at night on that same roadway, car volumes may decrease significantly while through-truck movements continue so that the truck percentage increases considerably and total volume declines less than the car pattern would predict. Figure 1-3 shows how typical values of truck percentages change during the day for urban and rural settings on both weekdays and weekends.

Because these changes can be so significant, it is important to account for them in the design and execution of the traffic monitoring program as well as in the computation and reporting of summary statistics.

FIGURE 1-3   WEEKDAY/WEEKEND TRUCK PERCENTAGES
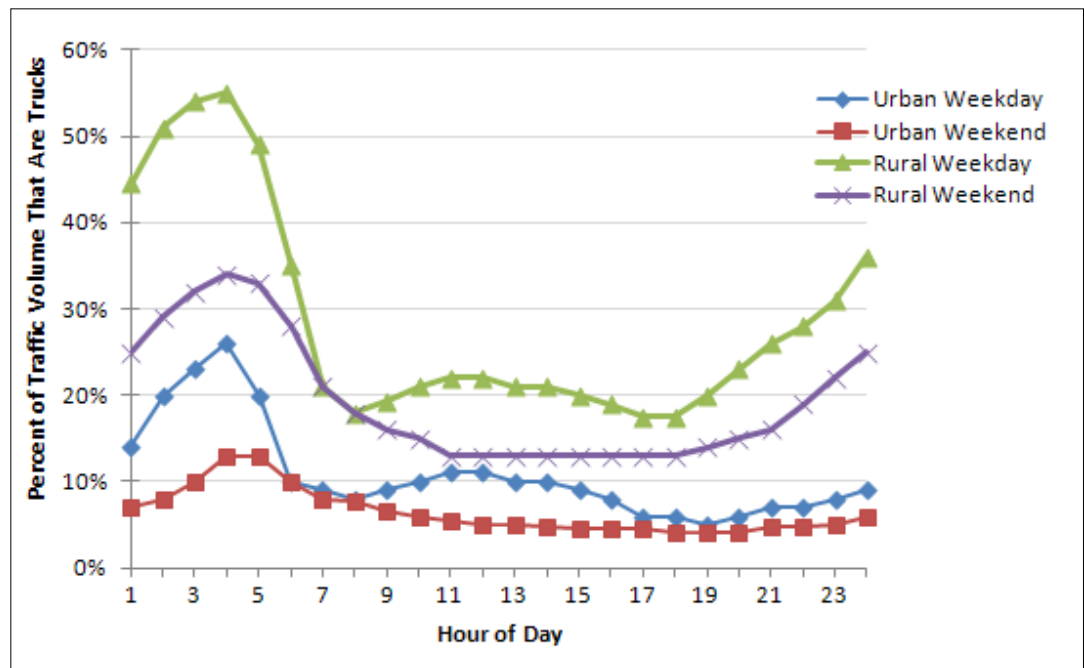
Source: Hallenbeck, et al., Vehicle Volume Distributions by Classification, *1997.*

Day-Of-Week Variation

Time-of-day patterns are not the only way car and truck patterns differ. DOW patterns also differ in large part because of the use of cars for a variety of non-business related traffic, whereas for the most part, trucks travel only when business needs require.

Similar to the time-of-day patterns, DOW patterns for cars fall into one of two basic patterns as shown in Figure 1-4. In the first pattern (traditional urban), volumes are fairly constant during weekdays and then decline slightly on the weekends, with Sunday volumes usually being lower than Saturday volumes. This pattern also exists on many rural roads. The alternate pattern, usually found on roads that contain recreational travel, shows constant weekday volumes followed by an increase in traffic on the weekends.

FIGURE 1-4 TYPICAL DAY-OF-WEEK TRAFFIC PATTERNS
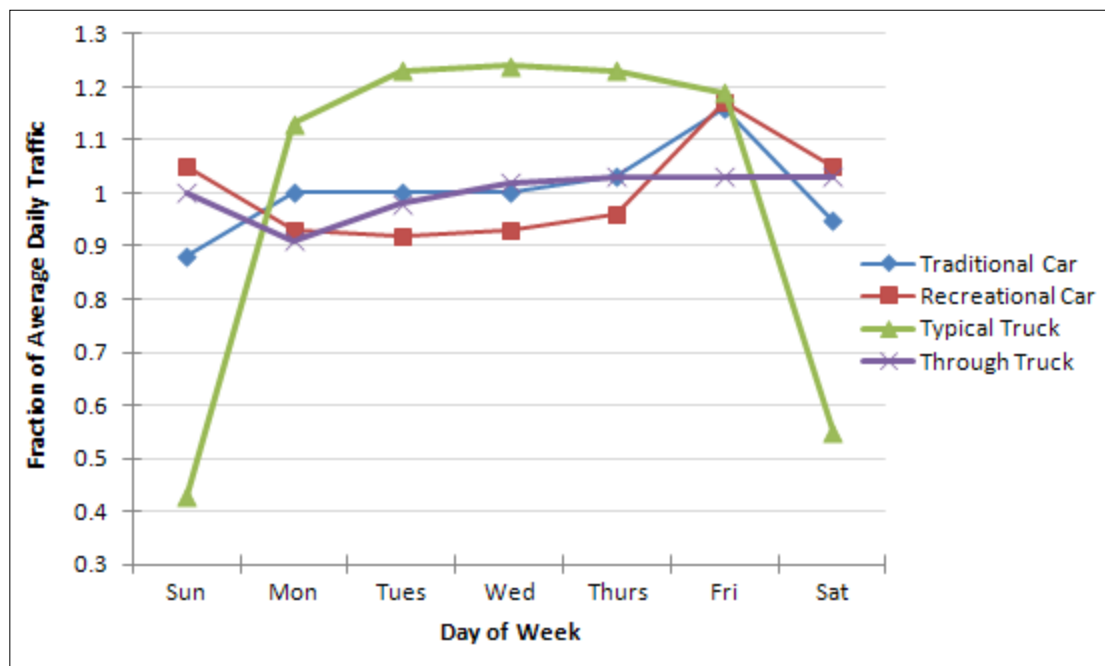
Source: Hallenbeck, et al., Vehicle Volume Distributions by Classification, *1997.*

Trucks also have two patterns that are both driven by the needs of businesses. Most trucks follow an exaggerated version of the traditional urban car pattern. That is, weekday truck volumes are constant, but on weekends, truck volumes decline considerably more than car volumes (unlike cars, the decline in truck travel caused by lower weekend business activity is usually not balanced by an increase in truck travel for other purposes). However, as with the time-of-day pattern, long haul through trucks often show a very different DOW pattern. Since long-haul trucks are not concerned with the business day (they travel as often as the driver is allowed), they travel equally on all seven days of the week. Thus, roads with high percentages of through-truck traffic often maintain high truck volumes during the weekends, even though the local truck traffic declines. Note that through-truck traffic is still normally generated during normal business hours. Thus, through-traffic generated from any one geographic location has the same 5-day on, 2-day off pattern seen in the local truck pattern. Where a road carries through-truck traffic from a single dominant area, the two-day lag in truck volumes is often apparent. However, the lag appears at some other time in the week. This pattern is

visible in truck volume counts only when through-truck traffic is a high percentage of total truck volume. What happens more commonly is that weekend truck volumes do not drop as precipitously as they do at sites where little through-truck traffic exists.

These significant changes in traffic volumes during the course of the week have several effects on the traffic monitoring program. Most importantly, the monitoring program should collect data that allow a State to describe these variations. Second, the monitoring program should allow this knowledge to be shared with the users of the traffic data and applied to individual locations. Without these two steps, many of the analyses performed with traffic monitoring data will be inaccurate. Pavement designers need to account for reductions in truck traffic on the weekends if they are to accurately predict annual loading rates. Likewise, accident rate comparisons for different vehicle classifications are not realistic unless these differences are accounted for in estimates of vehicle miles traveled by class.

Monthly (Seasonal) Variation

Further complicating the analysis of temporal variation in traffic patterns is the fact that both car and truck traffic change over the course of the year. Monthly changes in total volume have been tracked for many years with permanent counters, traditionally called Continuous Count Station. Total volume patterns from these devices show a variety of patterns, including common patterns such as the flat urban and rural summer peak shown in Figure 1-5.

FIGURE 1-5   TYPICAL MONTHLY VOLUME PATTERNS
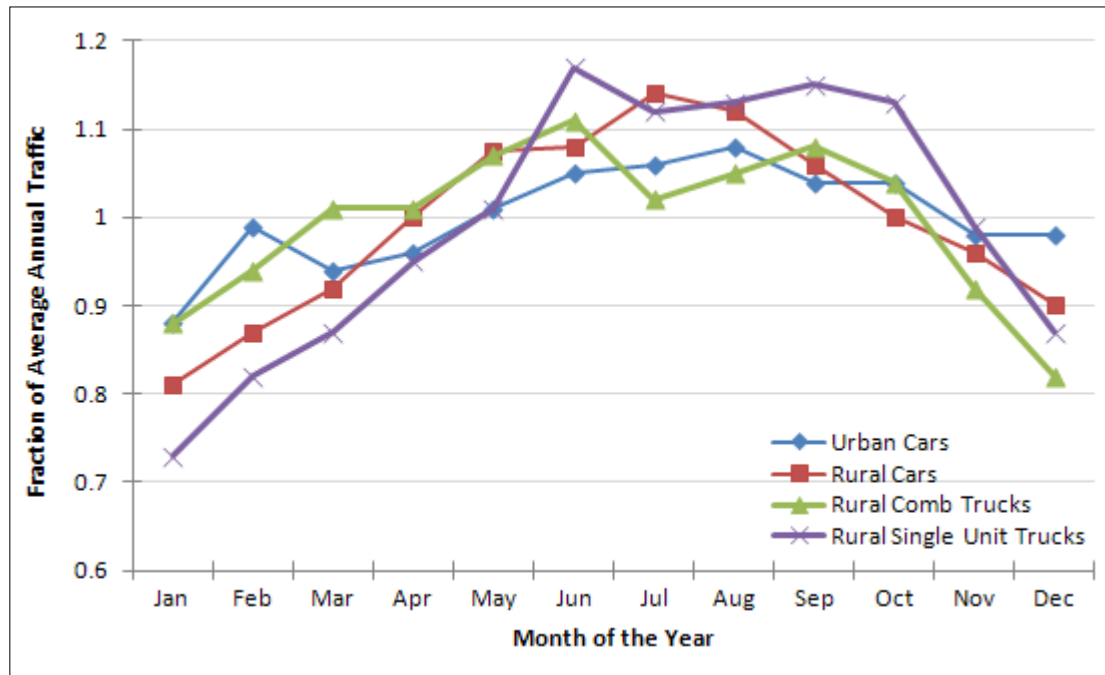
Source: Hallenbeck, et al., Vehicle Volume Distributions by Classification, *1997.*

Most States track four or more monthly patterns and they base the patterns being followed on some combination of functional classification of roadway and geographic location. Geography and functional classification are used as readily available surrogate measures that describe roads that follow that basic pattern. Geographic stratification is particularly important when different parts of a State experience very different travel behavior. For example, travel in areas that experience heavy

recreational movements follow different travel patterns than those in areas without such movements. Even in urban areas where travel is more constant year round, cities with heavy recreational activity have different patterns than cities in the same State without heavy recreational movements.

Not surprisingly, truck traffic has monthly patterns that are different from automobile patterns. Some truck movements are stable throughout the year. These movements are often identified with specific types of trucks operating in specific corridors or regions. Other truck movements have high monthly variability, for example, in agricultural areas. It has even been shown that the weights carried by some trucks vary by season. This is particularly true in States where monthly load restrictions are placed on roads and where weight limits are increased during some winter months.   Where this happens, States should track monthly changes for the development of adjustment factors.

As with day-of-week patterns, tracking of monthly changes in volumes is useful to calculate adjustments needed for various analyses. If annual statistics are needed for an analysis, it is necessary to adjust a short duration traffic volume count taken in mid-August to account for the fact that August traffic differs from the annual average condition.

Research has shown that monthly monitoring and adjustment should be done separately for trucks and cars (Hallenbeck, et al., 1997). Truck volume patterns can vary considerably from car volume patterns. Roads that carry significant volumes of through-trucks tend to have very different monthly patterns than roads that carry predominately local freight traffic. Roads that carry large volumes of recreational traffic often do not experience similarly large increases in truck traffic, but do often experience major increases in the number of recreational vehicles, which share many characteristics with trucks but have significant differences in weights.

Thus, it is highly recommended that States monitor and account for monthly variation in truck traffic directly, and that these procedures be independent of the procedures used to account for variations in car volume.

Directional Variation

Most two-way roads exhibit differences in flow by direction by time of day. The traditional urban commute involves a heavy inbound movement in the morning and an outbound movement in the afternoon. On many suburban roads, this directional behavior has disappeared, replaced by heavy peak movements in both directions during both peak periods. When these directional movements are combined, the time-of-day pattern shown in Figure 1-2 is still evident, but when looked at separately, new time-of-day patterns become apparent.

In areas with high recreational traffic flows, directional movements change the DOW traffic patterns as much as the time-of-day patterns. Travelers often arrive in the area starting late Thursday night and depart on Sunday.

Truck volumes and characteristics can also change by direction. One example of directional differences in trucks is the movement of loaded trucks in one direction along a road, with a return movement of empty trucks. This is often the situation in regions where mineral resources are extracted. Volumes by vehicle classification can also change from one direction to another, for example when loaded logging trucks (classified as 5-axle tractor semi-trailers) move in one direction, and unloaded logging trucks (which carry the trailer dollies on the tractor and are classified as 3-axle single units) move in the other.

Tracking these directional movements as part of the statewide monitoring program is important for not only planning, design, and operation of existing roadways, but as an important supplement to the knowledge base needed to estimate the impacts that new development will generate in previously undeveloped rural lands.

Geographic Variation

The last type of variation discussed is spatial variation. That is, how volumes change from one roadway to another, or from one location on a road to another location on that same road. This type of differentiation is taken for granted for traffic volumes. Some roads simply carry more vehicles than others do. This concept is readily expanded to encompass the notion discussed above, that many of the basic traffic volume patterns are geographically affected (e.g., California ski areas have different travel patterns than California beach highways). It is important to extend these concepts even further to recognize that truck travel also varies from route to route and region to region. It is just as important to realize that differences in truck travel can occur irrespective of differences in automobile traffic.

One important area of interest in traffic monitoring is the creation of truck flow maps and/or tonnage maps. These maps (analogous to traffic flow maps) show where truck and freight movements are heaviest. This is important for the following:

- Prioritizing maintenance and roadway improvement funding;

- Instituting geometric and pavement design and maintenance guidelines that account for expected truck traffic; and

- Studying the effects of regulatory changes in freight and goods movements (such as the abandonment of existing freight rail lines).

When these truck flow maps are developed, they often reveal that truck routes exist irrespective of the total traffic volume and/or the functional classification of the roads involved. Trucks use specific routes because those roads lead from the truck's origin to their destination, and the route has sufficient geometric capacity to accommodate them. Truck drivers do not select a route because it is designated as a rural principal arterial. They select a route because of how it serves their route purposes. Consequently, functional classification is a very poor predictor of truck volume or percentage. As an example, interstates that serve major through truck movements (even in urban areas) tend to have high truck volumes, but interstates that do not service major freight movements tend to have low truck volumes. While both of these are functionally classified as interstates, they do not have the same truck flow characteristics.

Because truck flows (both truck volumes and weights) play such an important (and growing) role in highway engineering functions, it is vital that States collect truck volume data that describe the geographic changes that exist. Which roads carry large freight movements? Which roads carry large truck volumes, even if those volumes are a small percentage of total traffic volume? Which roads restrict or carry light volumes of freight?

1.5.2 PROGRAM AND TECHNOLOGY DESIGNS THAT ACCOUNT FOR TRAFFIC VARIABILITY

The variability described in the previous paragraphs should be measured and accounted for in the data collection and reporting program that a State designs and implements. The data collection program should also identify changes in these traffic patterns as they occur over time. To meet these needs in a cost effective manner, statewide traffic monitoring programs generally include:

- A large number of short duration data collection efforts; and

- A smaller number of permanent, continuously operating, data collection sites.

The short duration counts provide the geographic coverage needed to understand traffic characteristics on individual roadways, as well as on specific segments of those roadways. They provide site-specific data on the time-of-day and DOW variation in travel, but are mostly intended to provide current general traffic volume information throughout the larger monitored roadway network. However, short duration counts cannot be directly used to provide many of the required data items desired by users. Statistics such as annual average traffic or design hourly volume cannot be accurately measured during a short duration count. Instead, data collected during short duration

counts are factored or adjusted to create these estimates. The procedures to develop and apply these factors are discussed in Chapter 3 of the *TMG*.

To develop those factors, an agency should have a modest number of permanently operating traffic monitoring sites. Permanent data collection sites provide data on seasonal and day-of-week trends. Continuous count summaries also provide very precise measurements of changes in travel volumes and characteristics at a limited number of locations.

Importantly, while the basic traffic variables required for short- and permanent-duration counts is the same (i.e., volume, volume by class, speed, weights), these two types of data collection efforts place different demands on data collection technology, and thus the equipment well suited for short duration counts is not always well suited for permanent counting and vice-versa. The implications of these different types of data collection durations on equipment selection are discussed in the following sections.

1.5.3 SHORT-TERM TEMPORARY COUNTS

The key to short duration counts is that they should be easy and inexpensive to perform, while the sensors should remain in place and function properly for the duration of the count. Because they are designed to give wide geographic coverage, most highway agencies typically perform a large number of short duration counts, each being performed at a new location. As a result, short count programs tend to be staff intensive, with the data collection staff working frequently within the roadway right-of-way to place and retrieve data collection sensors and equipment. This leads to two major priorities when selecting the appropriate technologies for performing short duration counts (in addition to the issues discussed in the previous paragraphs, and the accuracy and price of the equipment). Technologies used for short duration counts should:

- Be easy and quick to put in place and calibrate (because this saves large amounts of staff time when even small savings are multiplied by a large number of counts); and

- Allow placement of the traffic sensors safely.

Other attributes that are less dependent on sensor technology but also very important when selecting short duration count equipment include:

- The data collection electronics should contain a sufficiently large power source to allow the device to operate until it is retrieved.

- The data collection sensors should stay in place, and operate correctly for the duration of short count, usually between 24 and 72 hours, but sometimes extending to one week.

- The data collection equipment should be theft and vandalism resistant. (Traditionally, this has meant that the data collection electronics have been stored in a rugged case that can be chained to a permanent fixture to prevent theft.)

- The data collection electronics should have a robust mechanism for transferring data from the data collection electronics to the central traffic data repository.

- Software should be intuitive and allow for calibration of the equipment to ensure it is working properly before the technician leaves the site.

The speed of sensor placement and related equipment set up and calibration is important because staff usually perform a large number of short duration counts. As a result, considerable cost is involved in the placement and retrieval of equipment. The faster sensors and data collection equipment can be placed, the more count locations a given staff member can place in a day and the lower the cost of collecting that data. Nevertheless, at the same time, the placement (and pick up) of those sensors must not endanger the staff placing that equipment. This need to safeguard data collection staff, without having to go to the cost of applying full-scale traffic control, is one of the reasons so much effort has been spent on exploring non-intrusive data collection technologies.

However, on lower volume roads where low cost road-tube axle sensors can be easily placed, intrusive sensors are still commonly used.

Where intrusive sensors cannot be safely and easily placed, agencies either use non-intrusive sensors or accept the cost of substantial traffic control each time a sensor must be placed in the roadway. Where short counts are used routinely at such locations, but the agency is not interested in investing permanent equipment, another option is to place permanent intrusive sensors in the roadway but not to connect those sensors to permanent power and communications. Instead, to use these sensors, the agency simply connects portable data collection electronics to the sensor leads, which are stored in a weatherproof enclosure until they are needed again. This approach saves the agency both the initial capital expenditure of bringing power and communications to the site, and the cost of traffic control during subsequent site visits. However, this approach is only cost effective if the permanent sensors are long lived, and if that location is to be visited for data collection routinely.

If non-intrusive sensors are the desired option, U.S. DOT has worked with several State highway agencies to develop new ways of deploying modern non-intrusive traffic monitoring technologies for short duration counts (Kotzenmacher, Minge, and Hao, 2005). The most common of these approaches is to affix the non-intrusive sensors to an extendable pole, which is placed on a trailer. The trailer is then towed to the roadside locations, placed in a safe position behind a barrier, and the pole raised. The sensors are then calibrated and the entire trailer system left in place for the duration of the count.

Short counts are commonly made for all of the traffic attributes, including volume, volume by classification of vehicle (including bicycles), speed, and axle weights. (Note that axle weights can only be collected with a high degree of accuracy using intrusive technologies that cannot be put in place quickly (Hallenbeck and Weinblatt, 2004). This means that most roadway agencies collect axle weight data from permanent data collection sites.) Table 1-7 describes the sensor technologies that are commonly used for short duration counts and the motorized vehicle attributes they routinely collect.

TABLE 1-7   SENSORS FOR MOTORIZED VEHICLE DATA COLLECTION FOR SHORT DURATION COUNTS

Technology	No. Sensors Needed for Speed Data Collection	Types of Vehicle Classifications Collected	Number of Lanes of Data Collected by Each Sensor	Environmental Issues/Concerns	Other Issues/Concerns
Road Tubes – traditional	2 (One lane only)	Axle Based (FHWA 13+)	1 per pair of sensors (Only lanes bordering shoulders)	Not suited to snowy conditions	Accuracy limitations under very heavy traffic volumes or stop-and-go conditions
Road Tubes – multi-lane design	2 per lane	Axle Based (FHWA 13+)	1 per pair of sensors	Not suited to snowy conditions	Accuracy limitations under very heavy traffic volumes or stop-and-go conditions
Tape Switches	2 per lane	Axle Based (FHWA 13+)	1 per pair of sensors	Placement difficulties in wet conditions	Needs protection of lead wires if placed on lanes not adjacent to shoulders
Magnetometer (several different variations on this technology exist)	2 per lane	Length-Based (for most sensor designs)	1 per sensor (2 sensors per lane if speed or vehicle length is needed)	Most magnetic technology sensors require a short lane closure for sensor placement	Some magnetic sensors are placed in the pavement, others on the pavement, and others under the pavement
Video Detection System	1 camera	Length-Based	Multiple	Does not work well in snow, fog, or dust storms	Short duration counter is mounted on an extendible pole on a trailer pulled to the count site; generally slow to set up
Piezo-sensors (piezo-film, piezo-cable)	2 per lane	Axle Based (FHWA 13+)	1 per pair of sensors	Very cold weather may affect performance	Needs protection of lead wires if placed on lanes not adjacent to shoulders
Infrared	1 (transmitter + receptor)	Axle Based (FHWA 13+)	Multiple	Fog and heavy snow can degrade performance and large crown in road will block beams; Occlusion	
Microwave radar	1 per direction (side-fired), 1 per lane (overhead)	Length-Based	Multiple	Can have occlusion issues with heavy or stop-and-go traffic and multiple lanes	Short duration counter is mounted on an extensible pole on a trailer pulled to the count site
Acoustic	1 sensor	None	Multiple	Background noise/sound may interfere	Short duration counter is mounted on an extensible pole on a trailer; the sensor should be mounted higher than 25 feet
Laser Radar	1 sensor	13+	Maximum of 4	Snow, fog, heavy rain	No in-road installation required

Source: Hallenbeck and Weinblatt, 2004.

1.5.4 PERMANENT COUNTS

Permanent, continually operating traffic monitoring equipment is used to provide both current measures of traffic flow and to provide a time series record of traffic flow attributes that describe how traffic flow changes over time at that location. Permanent traffic monitoring locations should have:

- Long lived sensors that can withstand the harsh roadway environment;

- Power sources (either electrical power or solar power with battery backup);

- Communications (land lines or cellular communications); and

- Environmental protection (temperature, moisture, dirt, electrical surge protection on power and communications lines, and protection against animal and insect infestation).

Permanent sensors represent both a large financial investment and a large data resource. As a result, the selection, installation, and calibration of that equipment is particularly important. Sensors that are poorly installed, inadequately calibrated, or that fail quickly because of poor design or construction, not only do not generate useful data, they waste resources (both money and staff time) that are needed for other data collection tasks. In part, this is because the funds spent on equipment and installation could be used elsewhere, but also because it requires considerable staff time to determine that the data being provided by poorly performing sensors are not an accurate representation of the traffic stream.

Unlike short duration counts, the speed of sensor installation is much less of an issue for selecting permanent count technology and equipment. The real key for permanent count technologies is that once installed, the equipment should operate accurately for long periods, with only a modest level of maintenance. In high volume locations, maintenance of an intrusive sensor may not actually be possible unless lane closures are planned for some other purpose. (In a growing number of urban areas, traffic lane closures are very limited due to the size and scope of traffic congestion those closures cause, even at night.)

One of the great advantages of non-intrusive detectors as permanent traffic monitoring devices is the ability of the roadway agency to work on that equipment when it starts to have performance problems. Of course, not all non-intrusive equipment has this advantage, and in other instances, non-intrusive equipment can be placed either beside the roadway (fully accessible) or above the roadway (requiring lane closures for maintenance), but the side-fired equipment positions come with penalties to the accuracy with which the devices work.

Table 1-8 summarizes the technologies currently used for permanent vehicular traffic monitoring.

TABLE 1-8   SENSORS FOR MOTORIZED VEHICLE DATA COLLECTION FOR PERMANENT COUNT LOCATIONS

Technology	Intrusive or Non-intrusive	Types of Vehicle Classifications Collected WIM?	Number of Lanes of Data Collected by Each Sensor	Environmental Issues/Concerns	Other Issues/Concerns
Piezo-Electric Cable	Intrusive	Axle Based (FHWA 13+) Can be used for WIM	1 per pair of sensors	Susceptible to damage from mill and resurface and oversized trucks Susceptible to snowplow damage, if not flush with surface	Temperature sensitive (for weight classification); doesn't work well in stop-and-go traffic
Piezo-Polymer Film	Intrusive	Axle Based (FHWA 13+) Can be used for WIM	1 per pair of sensors		Temperature sensitive (for weight classification); doesn't work well in stop-and-go traffic
Piezo-Quartz Cable	Intrusive	Axle Based (FHWA 13+) A good WIM sensor	1 per set of sensors		Piezo-Quartz sensors are typically ½ lane in width, so a site may require 4 sensors/lane; it is possible to instrument only on wheel path, with modest loss of volume and classification accuracy
Other Pressure Sensors	Intrusive	Axle Based (FHWA 13+)	1 per pair of sensors		Doesn't work well in stop-and-go traffic
Inductive Loop (conventional)	Intrusive	Length-Based	1 per pair of sensors	Freeze/thaw can break loops	Single loops can be used to collect volume and lane occupancy, from which speed can be estimated
Inductive Loop (undercarriage profile)	Intrusive	Various[a]	1 per set of sensors		New technology, not currently in widespread use
Side-Mounted Microwave Radar	Non-intrusive	Length-Based	Multiple		Not as accurate as overhead-mounted, forward-, or rear-facing radar (getting close)
Overhead Microwave Radar	Non-intrusive	Length-Based	1 per sensor		
Doppler Radar	Non-intrusive	None	Multiple		Generally used only for speed data collection, often not accurate as a volume counting device
Infrared	Non-intrusive 1 (transmitter + receptor)	Axle Based (FHWA 13+)	Multiple	Fog and heavy snow can degrade performance	Most common device requires equipment on both sides of the right of way
Magnetometer (3-axis flux gate)	Intrusive[b]	Length-Based	1 per pair of sensors		

Technology	Intrusive or Non-intrusive	Types of Vehicle Classifications Collected WIM?	Number of Lanes of Data Collected by Each Sensor	Environmental Issues/Concerns	Other Issues/Concerns
Magnetometer (magnetic imaging)	Intrusive	Length-Based	1 lane		
Video Detection System (trip wire)	Non-intrusive	Length-Based	Multiple	Can be affected by heavy fog, snow, glare, dust	Requires proper mounting height
Video Detection System (object analysis)	Non-intrusive	Various[c]	Multiple	Can be affected by heavy fog, snow, glare, dust	Requires proper mounting height; new technology, not currently in widespread use
Ultrasonic	Non-intrusive	Length-Based	1 per pair of sensors	Temperature variation and air turbulence can affect accuracy	New technology, not currently in widespread use
Acoustic	Non-intrusive	None	1 per pair of sensors		Must be carefully calibrated
Bending Plate	Intrusive	Axle Based (FHWA 13+) A good WIM sensor	1 per set of sensors		Too expensive unless used as a WIM scale
Bridge WIM	Non-intrusive	Axle Based (FHWA 13+) a WIM scale			Only works on specific types and sizes of bridges and culverts; not really a conventional traffic monitoring device
Load Cell	Intrusive	FHWA 13+	1 per wheel path	Large upfront cost	Maintenance costs are yearly and require lane closure

Source: Hallenbeck and Weinblatt, 2004.

[a] *There are two basic undercarriage loop classifier technologies. One uses the "signature" from existing loops to determine classification by matching the shape of that loop to expected profiles. The other uses specific types of loops to detect changes in inductance associated with wheels, and uses that information to detect and measure axles. This device can classify by "axle," while the other defines classes that relate strongly to axle-based classes but are not specifically based on the number and spacing of axles.*

[b] *Overhead-mounted, non-intrusive detectors require a structure (usually a bridge or gantry) upon which to be mounted. The expense of sensor installation increases dramatically where these do not already exist.*

[c] *Video image analysis will define classes based on the features the software can detect. The simplest detection algorithms are based on length. More complex algorithms can detect and classify using axle information, provided the camera angles are capable of "seeing" different axles.*

This chapter discussed the theory, technology, and concepts that are used as the basis for developing a traffic monitoring program. The strengths and weaknesses of the various types of technology and equipment were also presented. The States should consider which combinations of technology and equipment best suit their needs when establishing their traffic data collection programs.

Chapter 2 TRAFFIC MONITORING PROGRAM – BUSINESS PLANNING AND DESIGN

2.1 INTRODUCTION

This chapter addresses the high-level design of a traffic monitoring program and how data business planning can be used to support the design and development of the program at State highway agencies. It provides guidance on designing a traffic monitoring program and explains the importance of having such a program from three perspectives: statewide, regional/sub-area, and roadway facility/corridor-specific traffic monitoring. It also describes recommendations for a traffic program evaluation to be conducted by States every five years. More detail regarding guidance and examples of traffic monitoring programs are provided in Chapter 3 and the Appendices.

2.2 PROGRAM DESIGN

Many transportation agencies have recognized that traffic data programs support a growing variety of functions and critical decision processes within their agencies. The need for data and the benefits that result from the required data must be balanced against available and potential resources to implement an effective and efficient traffic monitoring program.

Therefore, in planning and designing a traffic monitoring program it is critical to consider one's customer needs and the benefits that result from the timely delivery of quality traffic data for decision support. The customers of traffic data programs generally fall into the following categories:

- National Agencies – Such as FHWA for supporting national transportation policy development and in compiling national reports such as traffic volume trends or *Highway Performance Monitoring Programs (HPMS)*, or the *National Condition and Performance Report*;

- State DOT Partners – Such as State operations, safety, bridges, planning, design, construction, maintenance, environmental, enforcement, and freight offices;

- Local Agencies – Local governments and metropolitan planning organizations (MPOs); and

- Public – Including public requests.

The components of traffic data programs include planning, design, calibration, collection, distribution, analysis, reporting, and maintenance. Uses of traffic data include project and resource allocation programming; performance reporting; operations and emergency evacuation; capacity and congestion analysis; traffic forecasts; project evaluation; pavement design; safety analyses; emissions analysis; cost allocation studies; estimating the economic benefits of highways; preparing vehicle size and weight enforcement plans; freight movement activities; pavement and bridge management systems; and signal warrants, air quality conformity analysis, etc.

The following table is a useful resource detailing some of the uses of traffic data collection that includes traffic counting, vehicle classification, vehicle weighing, and speed monitoring.

TABLE 2-1   EXAMPLES OF HIGHWAY TRAFFIC DATA USES

Highway Activity	Traffic Counting	Vehicle Classification	Vehicle Weighing	Speed Monitoring
Design	• Highway geometry	• Pavement design, bridge design	• Pavement design, bridge design, and monitoring	• Highway geometry
Engineering Economics	• Benefit of highway improvements	• Cost of vehicle operation	• Benefit of truck climbing lane	• Costs associated with congestion
Finance	• Estimates of highway revenue and toll revenue	• Highway cost allocation	• Highway cost allocation	• User travel time costs
Legislation	• Selection of highway routes	• Speed limits and oversize vehicle policy		• Speed limits
Maintenance	• Selecting the timing of maintenance, by lane volume for lane closure policies	• Selection of maintenance activities	• Pavement management, bridge management	• Work zone safety measures
Operations	• Signal timing, by lane volumes • Traveler information emergency evaluation	• Development of control strategies and speed by class • Freight	• Weight enforcement activities • Freight	• Setting speed limits and speed by class • Traveler information
Planning	• Location and design of highway systems	• Forecasts of travel by vehicle type	• Truck lanes • Truck ramps • Freight	• Congestion measurement systems
Environmental Analysis	• Air quality analysis, noise impact analysis	• Forecasts of emissions by type of vehicle	• Emissions by type of vehicle	• Project-level analyses
Safety	• Design of traffic control systems and accident rates	• Safety conflicts due to vehicle mix and accident rates	• Weight limits and regulations	• Design of safety systems
Statistics	• Average daily traffic	• Travel by vehicle type	• Average weight by vehicle class	• 85th percentile
Private Sector	• Location of service areas • Development planning	• Marketing keyed to particular vehicle types	• Trends in freight movement • Truck lanes	• Accessibility to service areas
Administration, Other	• Performance measurement, resource allocation, emergency operations, asset management	• Lane use • Tax administration	• Enforcement	

The *TMG* is designed to provide guidance to States, MPOs and local agencies in establishing and maintaining a traffic monitoring program. Other national reference material includes the *AASHTO Guidelines for Traffic Programs* and the *ASTM Loop Detector Handbook*. Many States have developed their own statewide versions of traffic monitoring guidelines including Florida, California, and Texas (Appendix D, Case Study 1).

The following text describes the purpose and framework for establishing a traffic monitoring program. These programs are designed to collect traffic data and monitor travel within a defined geographic area for a State, region, or at the roadway-specific level. The types of data collected primarily consist of volume, classification, weight, and speed data. Many traffic programs are also adding bicycle and pedestrian counting. In the *TMG*, motorized programs include traditional traffic and non-motorized refers to bicycle and pedestrian counting programs. Chapter 4 is dedicated to guidance on bicycle and pedestrian counting.

2.2.1 STATEWIDE TRAFFIC MONITORING PROGRAM DESIGN

A traffic monitoring program is important from a statewide perspective to meet Federal and State requirements and is used to monitor travel primarily on State system roads. Traditionally, statewide traffic monitoring programs were designed to collect primarily three types of data: volume, classification, and weight. Speed data has now been included to address the need for data related to travel times and to determine the impact of speed on traveler safety. Each type of data can be used for many purposes, including tracking traffic volume trends on important roadway segments; providing input to traffic management and traveler information systems; determining truck travel patterns; providing input for safety and design studies along with roadway performance monitoring; and for providing data for programs such as the Highway Performance Monitoring System (HPMS). Traffic data reported to FHWA is used to apportion funding to States from the U.S. Highway Trust Fund. Proper support and funding of traffic counting programs is critical to ensure the State data collection remains up to date and is providing the best possible data.

The information obtained from statewide traffic monitoring programs is also the primary information resource for almost all general queries about road use in a State. Many users, both inside and outside of State highway agencies, periodically need basic traffic statistics, and those statistics should be readily available and comparable throughout the State. The statewide traffic monitoring program is responsible for collecting and providing that information. Requests for statewide data can range from how vehicle miles of travel are changing in order to compute carbon emissions to whether specific roads carry enough volume to warrant new retail construction activity. Having a strong statewide counting program allows an agency to answer a wide range of key policy and business questions confidently and effectively. Roadway agencies that cannot provide direct, timely, and accurate answers to these basic queries risk losing their credibility and subsequently the support of decision makers and the taxpaying public.

Traffic counts are fundamental to almost every task a highway agency performs and critical to a comprehensive performance measurement system. The timely delivery of high quality data can serve as a critical framework for effective decision making. The ability to describe how much traffic is using a road reflects positively on the agency's ability to effectively perform its responsibilities and manage its budget. Consequently, collecting, summarizing, using, and reporting this data is a critical task for any roadway agency, delivering more relevant and cost effective data for operations, construction, and maintenance decisions and planning with benefits across the transportation system. Additional information with an example of the design of a statewide traffic monitoring program is found in Appendix D.

The measurement of traffic volumes and its composition (class, weight, speed) is one of the most basic functions of highway planning and management. Traffic volume counts are the most common measure of roadway use and count data is needed as input to nearly all traffic engineering analyses. While several traffic volume statistics are used in traffic analyses, of primary interest for the design of statewide traffic monitoring programs are annual average daily traffic (AADT) and average daily

vehicle distance traveled (DVDT). Because DVDT is computed by multiplying the roadway segment AADT by the length of that segment, the primary goal of most traffic monitoring programs is to develop accurate AADT estimates, which can then be expanded to estimates of travel.

The recommended framework for a traffic monitoring program consists of two basic components:

1. Continuous counts (temporal); and
2. Short-duration counts (spatial) including periodic coverage counts and special needs counts.

Continuous Count Program (Volume, Speed, Classification, and Weight)

All highway agencies should have access to data collected from continuous counters. Agencies should work with each other to ensure that enough data is collected and shared to allow calculation of accurate adjustment factors needed to convert short-duration traffic counts into estimates of AADT. Chapter 3 in the *TMG* provides considerable guidance on how to structure continuous count programs, how to determine the appropriate number of counters for adjustment factor development, and how to apply those factors.

The continuous counts help the agency understand temporal (time-of-day, DOW, month-of-year and multi-year) changes in traffic volume, speed, class, and weight and allow development of the mechanism needed to convert short-duration counts into accurate estimates of annual conditions. Adjustments to short-duration count data are normally required to remove temporal bias from data used for AADT computation.

Short-Duration Count Program Design (Volume, Speed, Classification, and Weight)

Highway agencies perform short-duration counts for a variety of purposes including meeting Federal reporting needs (HPMS), supplying information for individual projects (pavement design, planning studies, etc.), and providing broad knowledge of roadway use. The portable short-duration counts also ensure geographic diversity and coverage. The short-duration counting program is most efficient if these various data collection efforts are coordinated so that one count program meets multiple needs. Examples of coordination include: sharing counting schedules with city/county/MPO staff; putting technology solutions in place that include access to software that encourages the integration/dissemination/conversion of schedules/data collected from city/county/MPO and State agencies; and establishing a data governance committee that crosses agency jurisdictions including national, State, county, city, and MPO boundaries.

The two types of short duration counts are described in the following sections.

Short-Duration Coverage Counts and Special Needs Counts

The coverage count subset covers the roadway system on a periodic basis to meet both point-specific and area needs, including the HPMS reporting requirements. The *TMG* recommends that the short-count data collection consist of a periodic comprehensive coverage program over the entire system on a maximum six-year cycle. The coverage plan includes counting the HPMS sample and full-extent sections on a shorter (maximum) three-year cycle to meet the national HPMS requirement.

The coverage program is supplemented with a special needs element where additional counts are performed as needed to meet other more specific data needs. The special needs program represents many different operations and may include the following:

- Pavement design counts performed to provide data for pavement design, maintenance, repair, rehabilitation, and reconstruction;

- Traffic operations counts performed to provide inputs to traffic control studies (e.g., the creation of new signal timing plans);

- Traffic counts for other special purpose studies; and

- Lane closure policies, corridor studies, inclement weather, and construction management.

The specific requirements (what is collected, when and where it must be collected) for these and other special needs studies vary from agency to agency. The ways in which agencies balance the benefits and costs of addressing these all-encompassing needs against their limited traffic counting budgets lead to the very different data collection programs that exist around the country.

Classification Data Needs

Vehicle classification data is a critical component of a well-designed traffic monitoring program because substantial amounts of classification data are needed to understand motorcycle, bus, and truck travel on highways. To address the need for classification data, the *TMG* recommends a coverage program structure for both volume and vehicle classification programs. More detail is provided in Chapter 3.

2.2.2 REGIONAL AND SUB-AREA TRAFFIC MONITORING DESIGN

A traffic monitoring program is used at the regional and sub-area level to address information needs on roads that are not met as part of a general statewide program. Traffic monitoring at this level is generally more detailed than the statewide program, and may include roads that are not part of the statewide program.

Regional or sub-area monitoring plans are generally designed to answer specific questions of regional importance. They often provide additional detail on traffic movements that cross-jurisdictional borders (e.g., they may provide data that are used to allocate State resources between jurisdictions within the region), or provide data needed to answer key scoping questions for upcoming regional projects. For example, urban areas often collect congestion and travel time reliability data. Similarly, geographic areas that depend on recreational traffic movements often collect data in different ways or times than would otherwise be collected for general State traffic monitoring purposes. Detailed regional traffic counts can be vital to maintaining or improving the economic vitality of communities that depend on recreational movements. Additional information with an example of the design of a regional traffic monitoring program is found in Appendix D, Case Study 4.

2.2.3 ROADWAY FACILITY SPECIFIC TRAFFIC MONITORING DESIGN

Facility-specific monitoring plans are the most detailed level of the three types of traffic monitoring programs. Roadway facility-level monitoring provides data needed at the project level. A minimum of four data items are typically produced as part of these monitoring efforts: AADT, K-Factor, D-Factor, and truck percentages. However, monitoring efforts may also collect data items that are needed for specific project purposes such as vehicle speed distributions and turning movements.

Facility-specific traffic monitoring programs are designed to provide the site-specific traffic statistics needed for roadway improvement and planning studies. They are also used to collect the detailed data needed to design, implement, and refine traffic operations plans (e.g., traffic signal timing or event planning). Well-designed facility monitoring plans are fundamental to the effective management and operation of heavily used roadways.

2.3 PROGRAM EVALUATION

It is in a DOT agency's best interest to strategically conduct a comprehensive evaluation of their traffic monitoring program at a minimum of once every five years. This comprehensive evaluation should include all aspects of the program including equipment inventories, site selection procedures, data collection practices, validation, quality control, analyzing data, and data dissemination practices. A comprehensive travel monitoring program evaluation should provide an agency with a strategic business plan that documents program strengths and deficiencies with targeted recommendations

for minimizing deficiencies and leveraging data program assets for a broad range of agency needs. A comprehensive program evaluation is recommended every five years because travel monitoring equipment and technology, as well as Federal regulations requiring travel monitoring data, can change over time, ultimately requiring travel monitoring program changes.

Conducting a program evaluation can benefit a DOT agency by saving the agency time, resources, and money by implementing newly recommended business practices that eliminate unnecessary or inefficient processes or data management practices. Examples include (but are not limited to) the following:

- Sharing of data with partner agencies and eliminating duplication of data collection efforts;

- Eliminating of travel monitoring sites by consolidating data sources that are overlapping within an agency;

- Implementing of automated software technologies to eliminate manual or electronic processing of data as well as eliminating inefficient or unnecessary business process steps;

- Purchasing and integrating private sector data to supplement existing data sources within the program;

- Upgrading site equipment to include cellular (preferred)/dial-up modems or establishing fiber network access eliminating the need for site visits to download data; and

- Integration of travel monitoring program data with Intelligent Transportation Systems (ITS) data eliminating duplication of efforts within an agency – this requires coordination and standardization of data collection efforts (time of collection 24 hours without gaps), resources, data export formats, etc.

Many agencies already rely on obtaining advice from partner Federal, State, and local agencies related to budgeting, monitoring equipment, resource allocations, etc. When conducting a comprehensive program evaluation a similar industry practice is advised.

Managing a travel monitoring program requires many different skills including budgeting; resource allocations; statistical analyses and quality evaluation of the travel monitoring program's data. The travel monitoring program industry currently lacks the ability to evaluate and rank data programs based on a national standardized performance matrix. Although the Federal Highway Administration (FHWA) has the ability to evaluate continuous count programs by the number and quality of continuous count station data by State, currently there are no metrics for other travel monitoring program aspects such as short-duration counts programs, weigh-in-motion, etc. The remainder of this section describes the steps for conducting the program evaluation.

The program evaluation review should include the following elements.

1. Goals and Objectives – Identify a clear statement of goals and objectives of the traffic monitoring program and how it fits into the planning process at the agency, and supports other agency needs.

2. Stakeholders – Identify all stakeholders and customers of the data. Customers of the traffic data program should include internal customers, external partners (MPOs, local governments and the public) and FHWA (for reporting purposes). The stakeholders should include both data collectors and users. (See Appendix D.)

3. Benefits of the Traffic Monitoring Program – Document the benefits of a traffic monitoring program for a State transportation agency and all of the internal and external stakeholders. This can include fiscal decision-making abilities and resource benefits.

4. Documentation of Federal, State, Local Requirements and Guidelines for Traffic Monitoring Program – Document any Federal, State, and local requirements and guidelines that must/should be followed in establishing traffic monitoring programs. Federal guidelines are contained in the *TMG*. State-specific requirements should be documented separately. In some States, a manual or

handbook documenting existing State traffic program equipment and resources is also developed.

5. Documentation of Existing Processes – Document the physical infrastructure of existing data programs. This documentation serves as customer data supply and demand documentation helping all stakeholders including the managers, the collection staff, analysts, and customers of the statewide traffic database. Some States apply use-case diagrams or other forms of diagramming and flowcharting to indicate which data elements are collected, how they are processed, analyzed and reported, who is involved, and which databases are integrated and published. Staffing responsibilities should also be documented for future planning.

This documentation is extremely important in succession planning. It should (minimally) include the following elements:

- Calibration protocols and procedures for all data types;

- Standardized specifications for factoring process;

- Data distribution and delivery methods;

- Reporting requirements and methods;

- Number of counts and samples taken and the logic used with how they are done;

- Inventory and age of equipment; Database management and storage procedures including data archiving, retrieval, network connectivity/access/security and storage; Data retention methods and what formats are employed; and

- Personnel and worker's technical and safety training.

6. Review of Stakeholder Needs – This review can be accomplished through surveys, informal discussions, meetings, or focus groups. The objective is to determine stakeholder needs (data demand) with respect to the following dimensions of traffic data quality (data supply):

- Accuracy – The measure or degree of agreement between a data value or set of values and a source assumed to be correct.

- Completeness (also referred to as availability) – The degree to which data fields and respective values are present in the attributes database (e.g., volume and speed are database fields that have values such as a volume (AADT) of 1500 or a speed value of 55 miles per hour attributes of traffic) that require them. Completeness can refer to both the temporal and spatial aspect of data quality, in the sense that completeness measures how much data is available compared to how much data should be available.

- Validity – The degree to which data values satisfy acceptance requirements of the validation criteria or fall within the respective domain of acceptable values.

- Timeliness – The degree to which data values or a set of values are provided at the time required or specified. Examples are real-time data, near-real time, and annual or historical data. The data collection/usage purpose and context may or may not require real-time data.

- Coverage – The degree to which data values in a sample accurately represent the whole of that which is to be measured.

- Accessibility (also referred to as usability) – The relative ease with which data can be delivered or retrieved and manipulated by data consumers to meet their needs.

- How the data is being used.

- Formats of data (storing, reporting, exporting, integrating, converting).

7. Identification of Gaps – Includes a review of resources and allocation of resources to priorities, identification of gaps, and overlaps in the data program. These can include the number of

collection devices, processes, data gaps, and resources. For example, a State may identify that the factor groups they are using are not adequate, or there may be a need to add more ramp counts. Other gaps could include the need for more or different report formats. An example of an overlap may be the identification of an opportunity to share traffic data with a local agency or duplicated count locations. The key in this step is to document all needs and carefully prioritize them against available or potential resources. This step allows for the provision of expectations regarding needs and a vision of the State's future traffic monitoring programs.

8. Review Program Components – Chapter 3 of the *TMG* contains specific guidance related to traffic data programs. During the program evaluation (recommended at least every five years) States should review all steps documented to determine if they are meeting the requirements. The figures in Chapter 3 outlining steps for establishing elements of traffic data programs will be particularly useful in the assessment (Steps for Establishing a Continuous Data Program, Steps For Creating and Maintaining a Continuous Data Collection Program, and Steps for Creating and Maintaining a Continuous Data Program).

FIGURE 2-1   STEPS FOR ESTABLISHING A CONTINUOUS DATA PROGRAM
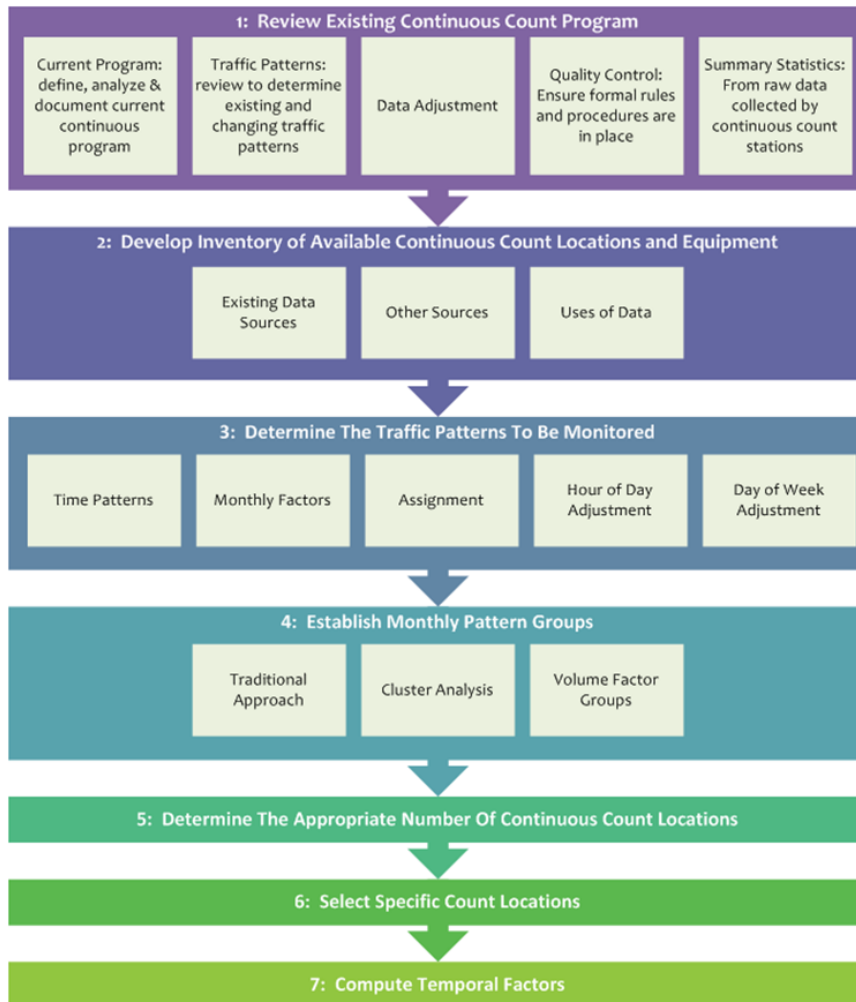
Source: Federal Highway Administration.

9. Implementation Plan – Develop an implementation plan to make the improvements identified in Step 7 and deemed necessary in Step 8. In documenting improvement needs, the traffic monitoring staff may wish to conduct a benefits analysis and risk assessment. This assessment

would involve identifying the benefits accruing from traffic monitoring program data and products, and the risks of not providing the traffic data at the desired level of quality. More information related to risk assessment and corresponding risk management programs can be found in *NCHRP Report 666: Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies, Volume II*, and in *Assessing the Value of the ADOT&PF Data Programs White Paper*, September 2009. These steps are illustrated in Figure 2-2.

FIGURE 2-2   TRAFFIC MONITORING PROGRAM BUSINESS PROCESS REVIEW STEPS

1: Develop Goals & Objectives

2: Identify Stakeholders

3: Quantify Benefits of the Traffic Monitoring Program

4: Document Federal, State, Local Requirements & Guidelines for Traffic Monitoring Program

5: Document Existing Processes

6: Review Stakeholder Needs

7: Identify Gaps

8: Review Program Components (Chapter 3)

9: Develop Implementation Plan
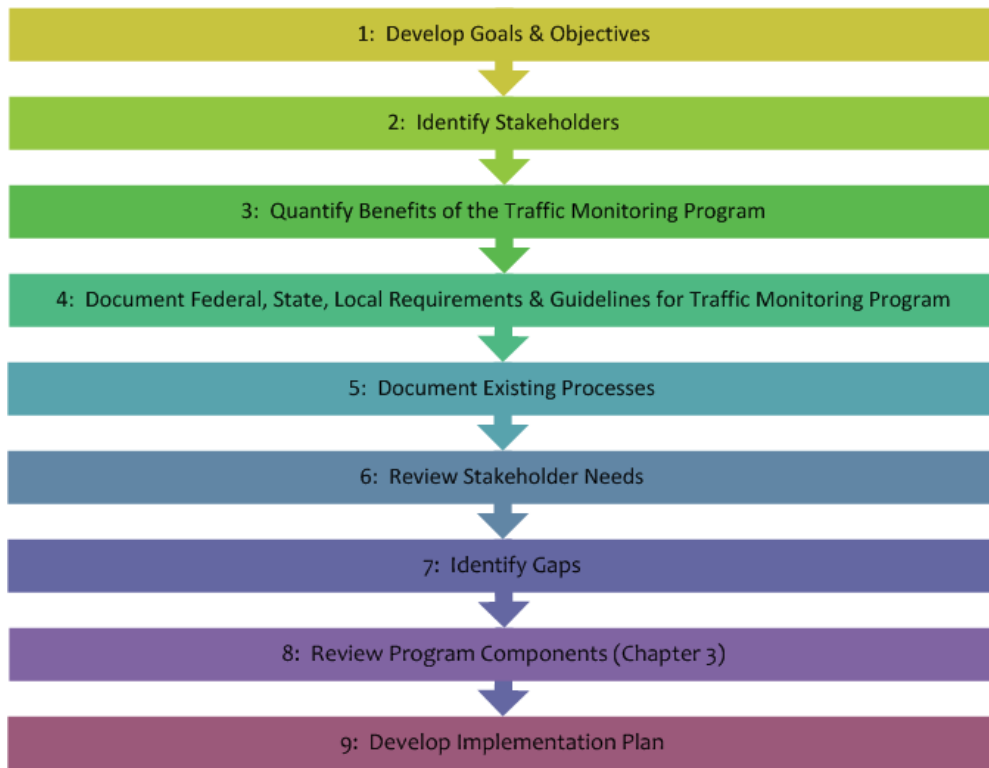
Source: Federal Highway Administration.

This business process review should be updated annually to ensure the optimum use of resources with respect to stakeholder needs. States have embarked on business process reviews to document their processes, identify gaps, and improve their traffic monitoring programs. Good examples are provided in Appendix K for Georgia DOT and Colorado DOT.

Data Business Planning is an important component of any State DOT traffic monitoring program because it ensures that customer needs are met and the most efficient methods are deployed. It also provides accountability, transparency, and other strategic management benefits such as answering "what does your data program staff do?" Several States including Texas, Florida, Colorado, Virginia and Ohio have well-documented programs and can be used as references (see Appendices D, E, and K).

2.4   COORDINATING COUNT PROGRAMS AND SHARING DATA

This section recommends best practices in coordinating count programs between State highway agencies and external agencies, and the methods used for sharing data.

Access to data collected from continuous counters is encouraged for all highway agencies. Considerable benefit can be obtained by sharing these data collection resources. Access to additional counts will provide data for quality assurance, filling of count gaps, saving money, and ease of reporting because all data can be integrated into one platform. On the other hand, the challenges to sharing data among agencies can be many, but are not insurmountable. For example, data may exist in different formats or be collected with different standards (e.g., 24-hour versus 48-hour counts). With carefully planned and implemented management strategies in place, (such as creating a data governance committee, implementing QA/QC data procedures, and having a scalable enterprise-wide data warehousing solution) an agency can not only overcome data sharing challenges, but benefit significantly through data sharing best practices.

Agencies should work together to reduce duplication in the number and location of permanent, continuous data collection devices. Agencies should share the data they collect (e.g., a State DOT could use monthly and DOW information collected at permanent sites operated by a county or city as part of developing adjustment factors for a specific urban area). A single count location can supply information for many purposes (e.g., permanent, continuous weigh-in-motion scales supply weight, classification, speed, and volume data). Opportunities to share data exist not only among agencies but also *within* agencies. Ensuring that planning, operations, maintenance, and construction groups share the data they collect can substantially increase the availability of traffic monitoring data and benefits derived, while reducing the overall cost of data collection.

A key source for urban traffic data is the traffic surveillance systems used for traffic management and control. The Intelligent Transportation System (ITS) program (see more information in Chapter 5) offers highway agencies the ability to collect continuous traffic monitoring data at high volume locations. Access to these data requires proactive efforts by the traffic monitoring groups, as archiving and analysis of surveillance data are traditionally less important to the operations groups that build, operate, and maintain these ITS systems. Without proactive efforts by the traffic monitoring groups, the benefits of ITS data can be lost because operations groups spend their scarce resources on operational improvements rather than on the archiving and analysis software needed to convert surveillance data into useful traffic statistics. Traffic monitoring assets can also supplement ITS assets and when configured appropriately can also provide critical information for operations.

Examples of best practices related to sharing traffic data can be found in Appendix D.

2.5   TRAFFIC MONITORING CALIBRATION, PROCESSING, AND COMPLIANCE REVIEWS

This section describes the use of calibration procedures (explained more fully in Appendix F), the processing of data, and the use of compliance reviews to assess how well the State's traffic monitoring program is performing in meeting MPO, State, and Federal requirements. This combination of tasks ensures that the traffic data collection equipment is working correctly, and that the data collected in the field is correctly processed to ensure that the summary statistics being reported accurately reflect the traffic conditions that are occurring on the roadway.

On-site and in-office calibration and tracking of site information should occur regularly (daily, monthly, and annually as needed). Having a robust traffic monitoring calibration program in place includes:

- Implementing software tools that help automate the process;
- Performing daily diligence activities such as business processes that ensure checking the quality of data as it is collected/processed/stored in the master (centralized or distributed) traffic database;
- Evaluating data using monthly trends and yearly trends to determine validity;
- Conducting field calibration;

- Collecting manual counts and comparing counts against portable equipment collected counts; and

- Performing manual and electronic calibration of classification, weigh-in-motion, volume, speed, and portable hardware annually.

Calibration includes performing a variety of tests on equipment to ensure that it functions as intended and correctly collects, processes, and reports the traffic data. The calibration process can identify both major errors (such as failed sensors) and minor errors (such as errors in site set-up, or the wrong classification algorithm installed on a shipment of devices) that can result in the collecting, processing, storing, and disseminating of inaccurate traffic statistics. The entire traffic monitoring program credibility is at stake when erroneous data is collected, processed, stored and disseminated. To avoid the risk of producing and disseminating erroneous data, traffic data programs should calibrate often.

Errors associated with calibration inaccuracies significantly increase the cost and decrease the usability of data from the entire traffic monitoring program.

However, once the data have been physically collected, more work remains to be done. To convert data into published statistical information, an agency must process (integrate, convert, calculate, QA/QC, store, manage, and provide access, etc.) the data consistently and correctly. Correct and consistent data processing ensures that AADT estimates produced from a simple axle counter can be accurately compared with AADT estimates collected using a sophisticated vehicle classifier. Consistent processes also ensure that agency credibility which allows an agency to easily defend their reported statistics and show through transparent audit processes that their data accurately reflect current traffic conditions. This allows States to pass Federal compliance reviews used to ensure that reported VMT statistics, a key variable used in funding allocation, are being accurately reported, and assures decision-makers the data deliverables are appropriate for critical decisions.

2.6 QUALITY ASSURANCE – STARTS WITH THE DATA QUALITY ACT (DQA) REQUIREMENTS

Data quality assurance processes are a critical component of any well-designed traffic monitoring program. The *TMG* recommends that each agency improve the quality of reported traffic data by establishing quality assurance processes for traffic data collection and processing. Each highway agency should have formal, documented rules and procedures for their quality control efforts.

The Data Quality Act (DQA) directs the Office of Management and Budget (OMB) to issue government-wide guidelines that provide policy and procedural guidance to Federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by Federal agencies.

A comprehensive and quality documented process will also assist in a smooth succession when there is turnover in staff.

2.7 DOCUMENTATION AND METADATA

Another critical factor of a well-designed traffic monitoring program is thorough and complete documentation. States are encouraged to maintain adequate documentation to support the decisions made and to allow future reexamination of those decisions as experience is gained in such areas as the factoring process. Documentation, such as the HPMS annual report which includes a requirement for reporting of metadata pertaining particularly to traffic and pavement data, is also recommended for any processes or methods used in data collection and analysis that may affect the outcome of the traffic data reported.

Metadata is documentation used to describe specific data items and datasets. HPMS recommends reporting of metadata that contains data that captures and explains variability in the collection and

reporting of traffic (and pavement) data. For example, the traffic metadata may be used to describe if AADT values have been seasonally adjusted, if AADT values are directly (raw unadjusted data) from vehicle count data, or if AADT is adjusted by annual growth/change.

NCHRP Report 666: Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies also explains that it is becoming more common for documentation of data programs to be a shared responsibility between IT divisions and business units within the organization. The business units have a responsibility to document the business needs and benefits for the traffic programs so that executives internally, as well as external entities such as legislatures, are aware of the importance of continued funding and resource allocation to support these critical programs. Establishing structured documentation procedures includes having well defined change tracking mechanisms to ensure that the prioritization of requested system changes is in accordance with the primary goals and objectives of the agency (NCHRP 666, 2010).

All types of documentation that are used to support traffic monitoring programs become a significant part of the repository of information about the program. This important information can be used at the national level for modeling travel trends, conducting highway safety and weight studies, as well as supporting State needs and uses for the data. Appendix D contains an example case study from Texas that demonstrates the importance of documentation in supporting its statewide traffic monitoring program.

Chapter 3   TRAFFIC MONITORING METHODOLOGIES

3.1   INTRODUCTION

This chapter describes Federal guidelines for establishing and maintaining traffic monitoring programs. Detailed guidance is provided for traffic monitoring methodologies ranging from determining the number of data collection stations, to how to assign factor groups using cluster analysis as one of the tools.

This chapter is organized into the following sections:

- Continuous Data Program;

- Short Duration Data Program; and

- Calculations and Computations.

The Figure 3-1 is a chapter map showing how the sections relate to each other. Please note that some of the sections repeat certain information and guidance. This is to ensure all relevant points are made in every relevant section.

FIGURE 3-1   CHAPTER MAP


```
3.2.1
Volume
Page 3-3

3.2.2
Speed
Page 3-17

3.2.3
Classification
Page 3-18

3.2.4
Weight
Page 3.35

3.2.5
Lane Occupancy
Page 3-62

3.2
Continuous
Page 3-3

3.3.1
Volume
Page 3.63

Continuous
or Short
Duration?

3.3.2
Speed
Page 3-68

3.3
Short Duration
Page 3-63

3.3.3
Classification
Page 3-68

3.3.4
Occupancy
Page 3-74

3.3.5
Motorcycles
Page 3-74

Methodology
or
Calculation?

Methodology          Calculation

3.4.1
AADTT
Page 3-78

3.4.2
Daily Volumes
from Less-than-
Daily Counts
Page 3-78

3.4.3
AADTV from
More Than 24-
Hour Counts
Page 3-79

3.4.4
Axle Correction
Factors
Page 3-80

3.4.5
Convert Daily
Counts to
AADTT
Page 3-80
```

Source: Federal Highway Administration.

3.2 CONTINUOUS DATA PROGRAM

In most States, the continuous count stations form the basis for the overall traffic monitoring program. The definitions related to continuous count programs are included in Chapter 1. A continuous count is a volume count derived from permanently installed counters for a period of 24 hours each day over 365 days (except for leap year) for the data-reporting year. There is an attempt to collect 365 days of data per year, but sometimes data is not available for some of those days. In some States, this is referred to as the permanent count program. In the *TMG*, the program will be referred to as the continuous count program.

The objectives of continuous count programs are many and vary from State to State. Continuous count stations can be used to develop adjustment factors, track traffic volume trends on important roadway segments, and provide inputs to traffic management and traveler information systems. The number and location of the counters, type of equipment used, array, sensor technology, and the analysis procedures used to manipulate data supplied by these counters are functions of these objectives. As a result, it is of the utmost importance for each organization responsible for the implementation of the continuous count program to establish, refine, and document the objectives of the program. Only by thoroughly defining the objectives, and designing the program to meet those objectives, will it be possible to develop an effective and cost-efficient program.

3.2.1 VOLUME

Volume data is normally collected as part of a State's continuous count program. The primary objective of the program is to develop hour of day (HOD), day of week (DOW), month of year (MOY) and yearly factors to expand short-duration counts to AADT. This objective is the basis for establishing the number and location of continuous count sites operated by the State highway agency. Secondary objectives of the continuous count program include the following:

- Provide peak hour, 30th highest hour, and directional distribution data used by traffic forecasters and roadway designers;

- Track volume trends on specific roadway sections on the State highway system;

- Provide an anchor point for using ramp-balancing methods;

- Understand geographic differences in travel trends;

- Integrate with the HPMS volume sample; and

- Collect data on roadway sections where it is not possible or prohibitively expensive to collect data with portable counters.

Each agency develops its own balance between having larger numbers of continuous count stations (increasing the accuracy and reliability of analyses that depend on data supplied by those counters) and reducing the expenditures required to operate and maintain those counters. The *TMG* recommendations provide sufficient flexibility for each agency to find an appropriate compromise among objectives.

When determining the balance point, the objectives of the continuous count program should be statewide in nature, and the focus should reflect this statewide perspective (see Appendix D, Case Studies #1 and #2). As a result, the continuous count program should be developed to meet the minimum requirements of the State highway agency for ensuring statistical validity. Sub-area and roadway-specific data collection needs should be secondary considerations in the design of the continuous count program as desired by the appropriate agency.

Consequently, the *TMG* recommends that the division responsible for factor development operate at least the minimum number of continuous count locations needed to meet the accuracy and reliability requirements of the factoring program. Expansion of the data available through the program should come from other available count programs. That is, data available through other count programs

such as intelligent transportation systems (ITS), MPOs, cities, counties and WIM programs (if separate), where the funding for the installation and operation of the counters comes from other sources, should be considered to supplement and expand the continuous count database (See Chapter 5, Case Studies #1 through #5). However, while the cost of equipment installation and operation of these supplemental continuous count programs is the responsibility of those other programs, the statewide traffic monitoring division should be responsible for ensuring its accuracy and making this data available to users. Determining how best to obtain, summarize, and report this data is an issue best addressed at the State level. Data management best practices can be learned from advanced travel monitoring programs. These examples are provided in Appendices D, E, and L.

Several steps should be followed in establishing and evaluating a continuous count program for statewide traffic monitoring. The results of those steps will allow for benchmarking and improving the monitoring program. The lists were designed for 1) developing a new program; 2) checking to ensure compatibility with the guidance; and 3) evaluating a program.

The following figure shows the steps to be followed in establishing a volume program.

FIGURE 3-2   CONTINUOUS DATA PROGRAM
VOLUMES
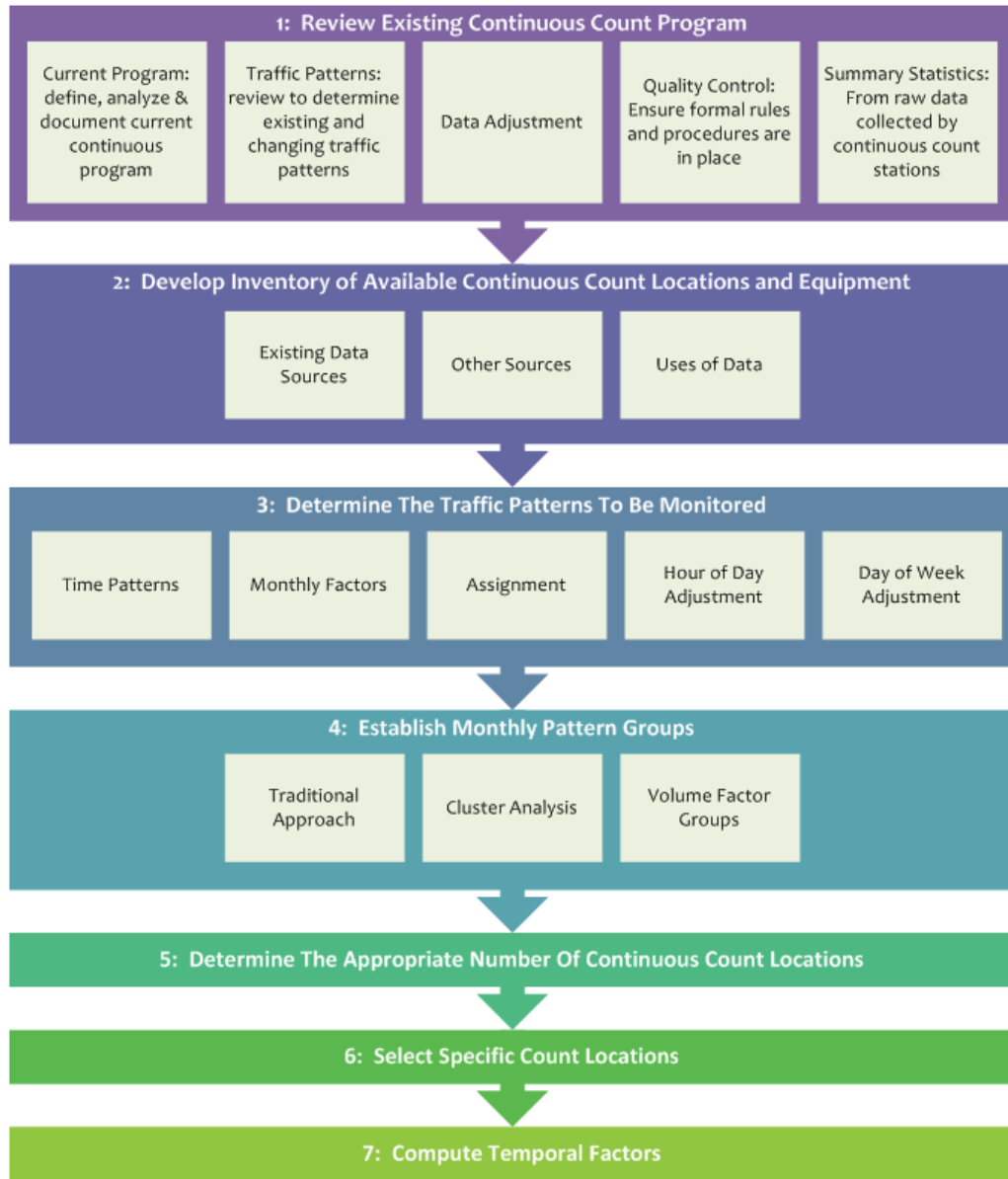
Source: Federal Highway Administration.

Step 1: Review the Existing Continuous Count Program

A.   Current Program – The first step in refining the continuous count system is to define, analyze, and document the current continuous count program. A clear understanding of the current program will increase confidence in later decisions to modify the program. The review should explore the historical design, procedures, equipment, personnel, objectives, and uses of the information. This review should start with an inventory of the continuously operating traffic data collection equipment available (this would include features, limitations, age, and repair/failure rates). It should then progress to determining how the data is being used, who is using it, and how it would be used if tools for using it in new ways were available.

B. Traffic Patterns – Next, the data should be reviewed to determine hourly, daily, and monthly traffic patterns that exist in the State and whether previous patterns have changed in order to establish whether the monitoring process should also change.

C. Data Adjustment – The next step is to review how the data is being adjusted, and whether those data adjustment steps can be improved or otherwise made more efficient. Of considerable interest in this review is how the quality of the data being collected and reported is maintained. Establishing the quality of the traffic data reported by the system and the outputs of the analysis process is a prerequisite for future improvements. Continuous traffic data is subject to discontinuities due to equipment malfunctions and errors. The way a State identifies and handles errors or anomalies (i.e., due to weather, construction, special events, etc.) in the data stream is a key component of the program. Data adjustment should be made according to ASTM E27-59 Standard Practice for Highway Traffic Monitoring Truth-In-Data. The emphasis is on documenting the process and implementing of the documented process.

D. Quality Control – Each State highway agency should have formal rules and procedures for these important quality control efforts. Truth-in-data implies that agencies maintain a record of how data is adjusted, and that each adjustment has a strong basis in statistically rigorous analysis. Data should not be discarded or replaced simply because they appear atypical. Instead, each State should establish systematic procedures that provide the checks and balances needed to identify invalid data, control how those invalid data are handled in the analysis process, and identify when those quality control steps have been performed.

E. Finally, the State highway agency should periodically review whether these procedures are performed as intended or need to be revised. For States that currently do not have formal quality control procedures, Appendix E provides several examples of how States use data quality control procedures.

F. Summary Statistics – The last portion of the review process should entail the steps for creating summary statistics from the raw data collected by continuous counters. These procedures should be consistent from year to year, be replicable, and should accurately account for the limitations (such as gaps in data) that are often present in continuous count data.

Step 2: Develop an Inventory of the Available and Needed Continuous Count Locations and Equipment

A. Existing Data Sources – The inventory of existing (and planned) continuous count sites ensures that the State's traffic monitoring effort obtains all of the continuous count data that are available. As noted earlier, the key to the inventory process is for the agency to identify not just the traditional continuous count sites but also other data collection devices that can supply continuous volume data. These secondary sites include, but are not limited to:

- Continuous classification counters;
- Continuous weigh-in-motion sites;
- Traffic management systems;
- Regulatory monitoring sites such as international border crossings and toll plazas;
- NPS Counters;
- MPO, City, and Town Counts; and
- Signalized intersections and ramp metering.

Other Sources – Posing more challenges are devices operated by other divisions within the State highway agency. Obtaining this data can be difficult, particularly when internal cooperation within the agency is limited. However, the current emphasis on improved cost-efficiency in government means that in most States there is strong upper management support for full utilization of data resources, wherever they exist. The key to taking advantage of this support is

to make the transfer of the data as automated as possible, so that little or no staff time need be expended outside of the continuous count data collection group to obtain the data.

The State highway agency should also look for data outside of its own agency. While it may not be possible to obtain this data at the level provided by standard continuous count devices (i.e., hourly records by lane for all days of the year), it is often possible to obtain useful summary statistics such as AADT and seasonal volume patterns from these locations. These summary data can be used to supplement the State's data at those locations and geographic areas. The accessibility of data from supplemental locations reduces the cost of collecting and increases access to useful data. Local data can also be provided to FHWA. To obtain this data, the State highway agency may have to acquire software that automatically collects and reports this data. The intent is to reduce the operating agency's staff time needed to collect and transmit the data. The easier this task is for the agency collecting the data, the more likely that this data can be obtained and integrated.

B. Uses of Data – This step involves determining how the continuous count data is currently being used, who the customers are for those data, and which data products (raw data? summary statistics? factors?) are being produced. Data should be collected for a purpose, and the users and uses of those data should be prioritized. Data has benefit when it answers important questions. Understanding by whom and how the data is being used creates a clear understanding of what value the data collection effort has to the organization. Understanding this value, and being able to describe it, is crucial to defending the data collection budget when budget decisions are made.

Several State DOTs find the use of a data business plan to be a useful tool for documenting the business needs for data and information (Chapter 2). Data business plans help to document how data systems support current business operations, identify data gaps (i.e., where new data and information are needed to support current needs), and provide a structured plan for the development of enhanced data systems to meet future **needs and include life cycle costs to make best use of limited resources.**

Step 3: Determine the Traffic Patterns to Be Monitored

One of the tasks integral to the existence of the continuous counter program is the monitoring of traffic volume trends. Foremost among these trends is the monitoring of AADT at specific highway locations, and the tracking of seasonal and DOW patterns around the State. The Traffic Monitoring Analysis System (TMAS) is a good way to evaluate volume trends over time. The inventory process should document how the continuous count program is being used to create and apply adjustment factors to short duration traffic counts to estimate AADT, as well as which highway locations require continuous counters simply because of the importance of tracking volume with a high degree of confidence.

The collection of continuous data to determine AADT should only be necessary at a limited number of locations.

A. Time Pattern Variations – Monthly and DOW patterns are of much greater concern in the refinement of the continuous count program, since the effectiveness of the seasonal factoring process (and consequently the accuracy of most AADT counts) is a function of the seasonal patterns observed around the State. Understanding what patterns exist, how those patterns are distributed, and how they can be cost-effectively monitored is a major portion of the factor review process. Obtaining data from other sources (both volumes and speeds) and integrating the data with existing sources can be beneficial for monitoring traffic and congestion patterns for factoring.

The review of monthly patterns can be undertaken using one of a number of analytical tools. Two of the most useful are cluster analysis (that can be performed using any one of several major statistical software packages such as SAS or SPSS) and graphic examination (that uses GIS tools) of seasonal pattern data from individual sites.

The intent of the MOY pattern review is to assess the degree of seasonal (monthly) variation that exists in the State as measured by the existing continuous count data and to examine the validity of the existing factor grouping procedures that produces the seasonal factors. The review consists of examining the monthly variation (attributed to seasonality) in traffic volume at the existing continuous count locations, followed by a review of how roads are grouped into common patterns of variation. The goal of this review is to determine whether the State's procedures successfully group roads with similar seasonal patterns, and whether individual road segments can be correctly assigned to those groups.

B. Monthly Factors – The review process begins by computing the monthly average daily traffic (MADT) and the monthly factors at each continuous count location. The monthly factors are then used as input to a computerized cluster analysis procedure. The patterns for individual sites can also be plotted on paper or electronically so that patterns from different sites can be overlaid to visually test for similarities and/or differences. If the groups of roads reported by the cluster analysis are similar to the groups of roads already in use, or if the visual patterns of all continuous counts in each factor group are similar, then it can be concluded that the factor groups are reasonably homogeneous. Specifically, all of the continuous counts that make up each factor group have the same or reasonably similar MOY pattern.

Factor groups are not necessary to be identical to the cluster analysis output for two reasons. For any given year, the cluster output is likely to be slightly different, as minor variations in traffic patterns are likely to be reflected in minor changes in the cluster analysis output. In addition, the cluster analysis output will require adjustment to create identifiable groups of roads.

C. Assignment – The remaining review step is to make sure that the groups are defined by an easily identifiable characteristic that allows complete assignment of all short duration counts to a factor group. The definition of each group must be complete so that analysts can correctly select the appropriate factor for every applicable roadway section.

D. HOD Distribution – The repeatability of hourly variability is of great importance. Typical hourly variation in traffic volume on the traffic monitoring sites from Arizona DOT is shown in the figure below. The typical morning and evening peak hours are evident for urban routes on weekdays. The evening peak generally has somewhat higher volumes than the morning peak. Rural routes do not show two prominent peaks, while recreational routes shows a single daily peak (as travelers go to their recreational destination). Figure 3-3 shows an example of the HOD distribution.

FIGURE 3-3   HOUR OF DAY FOR URBAN, RURAL, AND RECREATIONAL SITES
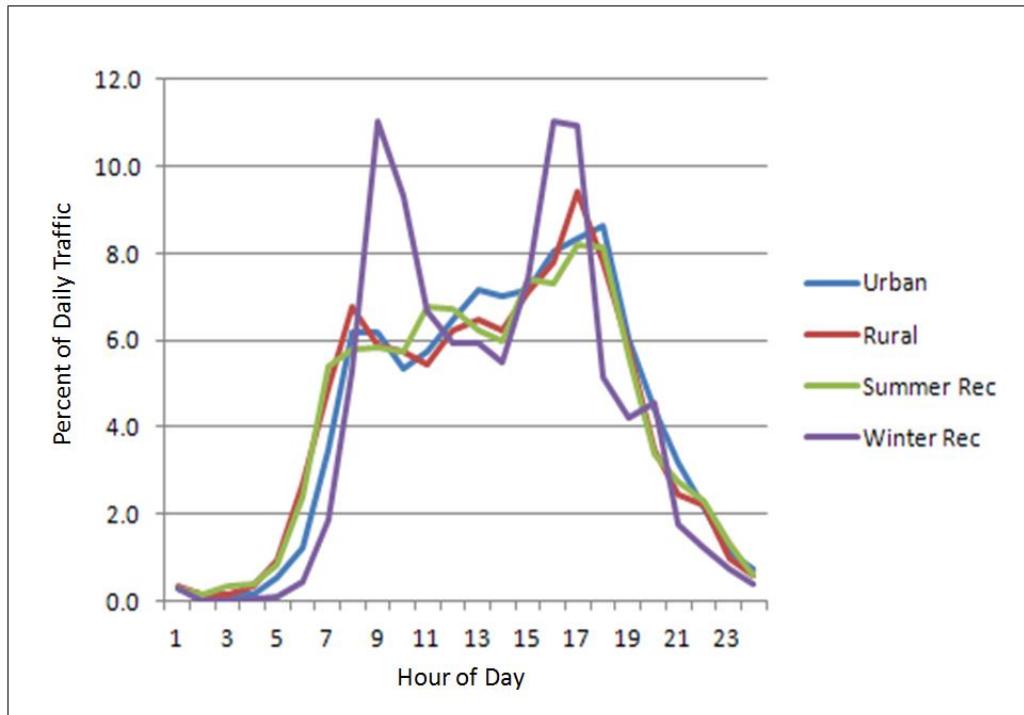
Source: Federal Highway Administration.

E. DOW distribution – Volume variation by day of the week is also related to site location (urban or rural) and the type of highway on which observations are made. Typical DOW variation in traffic volume on the traffic monitoring sites from Arizona DOT is shown in the figure below. Monday to Thursday traffic is similar and close to an average while the weekend traffic is generally lower than weekday traffic on urban routes. Friday traffic is generally higher than the rest of the days. States are allowed flexibility in how they design their DOW adjustment factor process to account most effectively for their own traffic patterns and data analysis process. At a minimum, weekday and weekend factors should be developed. However, individual DOW factors may be more appropriate in many cases due to the variability in traffic volumes from Friday through Monday on many roads.

FIGURE 3-4   DAY OF THE WEEK FOR URBAN, RURAL, AND RECREATIONAL SITES
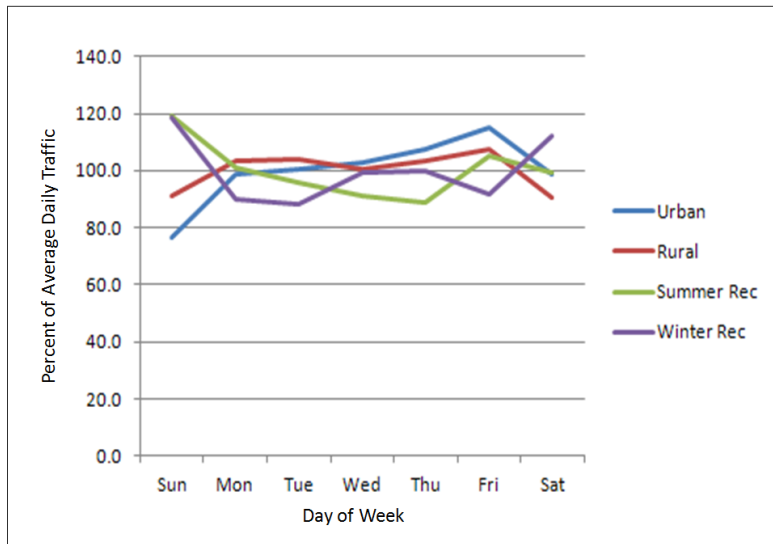
Source: Federal Highway Administration.

Step 4: Establish Monthly Pattern Groups

If the factor groups are not reasonably homogeneous, the definition of the groups is not clear, or new traffic patterns are emerging, it may be necessary to re-form the monthly factor groups.

The basic statistic used to create factor groups can be either the ratio of AADT to MADT, or the ratio of AADT to MAWDT. In many States there are patterns of variation related to rural roads, urban roads, and recreational areas. However, in some States, significant geographic differences in travel need to be accounted for in the seasonal factoring process. For example, rural roads in the northern half of the State may have different travel patterns than rural roads in the southern half of the State. In addition, in some States clear patterns have failed to emerge.

The three prominent types of analysis are described as follows:

A. Traditional Approach – The more subjective traditional approach to grouping roads and identifying like patterns is based on a general knowledge of the road system combined with visual interpretation of the monthly graphs. The advantage of the traditional approach is that it allows the creation of groups that are easier for agency staff to identify and explain to users. This happens because the grouping process starts by defining road groups that are expected to behave similarly. The hypothesis is then tested by examining the variation of the seasonal patterns that occur within these expected groups.

    The initial groups of roads that behave similarly could consist of roads of the same functional classification, or a combination of functional classifications. The groups should be further modified by the State highway agency to account for the specific characteristics of the State. Note that these are simply examples; there are other ways to accomplish this. Expected revisions include the creation of specific groups of roads that have travel patterns driven by large recreational activities, or that exhibit strong regional differences.

    Deciding on the appropriate number of factor groups should be based on the actual data analysis results and the analyst's knowledge of specific, relevant conditions. As a general guideline, a minimum of three to six groups is usually needed. More groups may be appropriate if a number of recreational patterns need to be monitored or if significant regional differences exist.

B. Cluster Analysis – The cluster procedure is illustrated by an example in Appendix G where the monthly factors (ratio of AADT to MADT) at the continuous count stations are used as the basic

input to the statistical procedures. An understanding of the computer programs used for statistical clustering procedures is helpful but not required to interpret the program results.

The cluster analysis procedures have two major weaknesses. One is the lack of theoretical guidelines for establishing the optimal number of groups. Determining how many groups should be formed is difficult. The cluster analysis process starts with all continuous counts in a single group, and proceeds until each continuous count is in an individual group. The difficulty is in determining at what point to stop this sequential clustering process. Unfortunately, the optimal number of groups cannot be determined mathematically.

The second weakness in the cluster analysis approach is that the groups that are formed often cannot be adequately defined, since the cluster procedure considers only variability at the continuous counts, not applicability to the short counts. Plotting the sites that fall within a specific cluster group on a map is sometimes helpful when attempting to define a given group output by the cluster process, but in some cases, the purely mathematical nature of the cluster process simply does not lend itself to easily identifiable groups.

Two advantages of cluster analysis are that it allows for independent determination of similarity between groups, therefore making the groups less subject to bias, and it can identify travel patterns that may not be intuitively obvious to the analyst. Accordingly, it helps agency staff investigate road groupings that might not otherwise be examined, which can lead to more efficient and accurate factor groups and provide new insights into the State's travel patterns.

C. Volume Factor Groups – Because of the importance and unique inter-regional nature of travel on the interstate system, States should consider maintaining separate volume factor groups for the interstate functional categories. When interstate intrusive continuous count stations are not fiscally or logistically feasible, agencies utilize non-intrusive technologies to collect data. The interstate system will always be subject to higher data constraints because of its national emphasis and high usage levels. Most States maintain many continuous counts on the interstate system; therefore, separate interstate groups are easily created.

The following table shows the advantages and disadvantages of seasonal factor groups.

TABLE 3-1   ADVANTAGES AND DISADVANTAGES OF SEASON PATTERN GROUP TYPES

Type	Advantages	Disadvantages
Traditional	1 – Creation of groups is easier 2 – Application for factoring can be explained 3 – Easier to assign short-term count to a group	1 – May not stand statistical scrutiny
Cluster Analysis	1 – Independent determination of similarity of groups without bias 2 – Traffic pattern can be found which may not be intuitively obvious 3 – Efficient and accurate factor groups	1 – Lack of guidelines for establishing optimal number of groups 2 – Groups that are formed often cannot be adequately defined 3 – Difficult to assign short-term count to a group
Volume Factor Group	1 – Consistent national framework for comparison among the State 2 – The precision of the seasonal factors can be calculated	1 – Functional or road classification may not be based on travel characteristics 2 – May not stand

Type	Advantages	Disadvantages
	3 – Easier to assign short-term count to a group	statistical scrutiny

The *TMG* recommends the groups illustrated in Table 3-2 as a minimum.

TABLE 3-2   **MINIMUM RECOMMENDED VOLUME FACTOR GROUPS**

Recommended Group	HPMS Functional Code
Interstate Rural	1
Other Rural	2, 3, 4, 5, 6, 7
Interstate Urban	1
Other Urban	2, 3, 4, 5, 6, 7
Recreational	Any

The first four groups are self-explanatory. The recreational group relies on subjective judgment and knowledge of the travel characteristics of the State. Usually, recreational patterns are identifiable from an examination of the continuous count data. The existence of a recreational pattern should be verified by knowledge of the specific locations and the presence of a recreational travel generator. A roadway is likely a recreational road when the difference between the ratio of the highest hourly volume to AADT and the ratio of the thirtieth highest hourly volume to AADT is greater than one. No single method exists for determining recreational patterns. A typical commuter pattern roadway can operate as a recreational pattern on weekends or a weekday depending on events, etc. The best way to determine trip purpose absolutely is to conduct intercept surveys.

Distinct recreational patterns cannot be defined based simply on functional class or area boundaries. Recreational patterns are obvious for roads at some locations but non-existent for other, almost adjacent, road locations. The boundaries of the recreational groups should be defined based on subjective knowledge. The existence of different patterns, such as for summer and winter, further complicates the situation. Therefore, the recommendation is to use a strategic approach to determine subjectively the routes or general areas where a given recreational pattern is clearly identifiable, establish a set of locations, and subjectively allocate factors to short counts based on the judgment and knowledge of the analyst. The road segments where these recreational patterns have been assigned should be carefully documented so that these recreational factors can be accurately applied and periodically reviewed.

While this may appear to be a capitulation to ad hoc procedures, it is a realistic acknowledgement that statistical procedures are not directly applicable in all cases. However, recreational areas or patterns are usually confined to limited areas of the State and, in terms of total vehicle distance traveled (VDT), are small in most cases. The direct statistical approach will suffice for the majority of cases.

The procedure for recreational areas is then to define the areas or routes based on available data (as shown by the analysis of continuous and control data) and knowledge of the highway systems to subjectively determine which short counts will be factored by which continuous count (recreational) location. The remaining short counts should be assigned based on the groups defined by the State.

The minimum group specification can be expanded as desired by each State to account for regional variation or other concerns. However, more groups result in the need for more continuous count stations, with a corresponding increase in program cost and complexity. Each State highway agency will have to examine the trade-offs carefully between the need for more factor groups and the cost of operating additional continuous count stations.

The above definition of these seasonal patterns based on functional class provides a consistent national framework for comparisons among States and more importantly, provides a simple procedure for allocating short duration counts to the factor groups for estimating annual average daily traffic (AADT). It also provides a direct mechanism for computing the statistical precision of the factors being applied.

The precision of the seasonal factors can be computed by calculating the mean, standard deviation, and coefficient of variation of each adjustment factor for all continuous count locations within a group. The mean value for the group is the adjustment factor that should be applied to any short count taken on a road section in the group. The standard deviation and coefficient of variation of the factor describe its reliability. The error boundaries can be expressed in percentage terms using the coefficient of variation, where the error boundaries for 95 percent of all locations are roughly twice the coefficient of variation.

Typical monthly variation patterns for urban areas have a coefficient of variation under 10 percent, while those of rural areas range between 10 and 25 percent. Values higher than 25 percent are indicative of highly variable travel patterns, which reflect recreational patterns but which may be due to reasons other than recreational travel.

Step 5: Determine Appropriate Number of Continuous Count Locations

Having analyzed the data, established the appropriate seasonal groups, and allocated the existing continuous count locations to those groups, the next step is to determine the total number of locations needed in each factor group to achieve the desired precision level for the composite group factors. To carry out this task, statistical sampling procedures are used. Since the continuous count locations in existing programs have not been randomly selected, assumptions may be made. The basic assumption made in the procedure is that the existing locations are equivalent to a simple random sample selection. Once this assumption is made, the normal distribution theory provides the appropriate methodology. The standard equation for estimating the confidence intervals for a simple random sample is:

$$B = \overline{X} \pm T_{1-\frac{d}{2},n-1} \frac{s}{\sqrt{n}}$$

Where:

B =   upper and lower boundaries of the confidence interval

$\overline{X}$ =   mean factor

T =   value of student's T distribution with $1-\frac{d}{2}$ level of confidence and n-1 degrees of freedom

n =   number of locations

d =   significance level

s =   standard deviation of the factors

The precision interval is:

$$D = T_{1-\frac{d}{2},n-1} \frac{s}{\sqrt{n}}$$

Where:

D = absolute precision interval

s = standard deviation of the factors

Since the coefficient of variation is the ratio of the standard deviation to the mean, the equation can be simplified to express the interval as a proportion or a percentage of the estimate.

The equation becomes:

$$D = T_{1-\frac{d}{2},n-1} \frac{C}{\sqrt{n}}$$

Where:

D = precision interval as a proportion or percentage of the mean

C = coefficient of variation of the factors.

Note that a percentage is equal to a proportion times 100, i.e., 10 percent is equivalent to a proportion of 1/10.

Estimating the sample size needed to achieve any desired precision intervals or confidence levels is possible using this formula. Specifying the level of precision desired can be a difficult undertaking. Very tight precision requires large sample sizes, which translate to expensive programs. Very loose precision reduces the usefulness of the data for decision-making purposes. Traditionally, traffic estimates of this nature have been considered to have a precision of plus or minus 10 percent. A precision of 10 percent can be established with a high confidence level or a low confidence level. The higher the confidence level desired, the higher the sample size required. Furthermore, the precision requirement could be applied individually to each seasonal group or to an aggregate statewide estimate based on more complex, stratified random sampling procedures.

The reliability levels recommended are 10 percent precision with 95 percent confidence for each individual seasonal group, excluding recreational groups where no precision requirement is specified. When these reliability levels are applied, **the number of continuous count locations needed is usually five to eight per factor group**, although cases exist where more locations are needed. The actual number of locations needed is a function of the variability of traffic patterns within that group and the precision desired; therefore, the required sample size may change from group to group.

Recreational factor groups usually are monitored with a smaller number of continuous counters, simply because recreational patterns tend to cover a small number of roads; it is not economically justifiable to maintain five to eight stations to track a small number of roads. The number of stations assigned to the recreational groups depends on the importance assigned by the planning agency to the monitoring of recreational travel, the importance of recreational travel in the State, and the different recreational patterns identified.

Step 6: Select Specific Count Locations

Once the number of groups and the number of continuous count locations for each group have been established, the existing locations can be modified if revision is necessary. The first step is to examine how many continuous counters are located within each of the defined groups. This number is then compared to the number of locations necessary for that group to meet the required levels of factor reliability. If the examination reveals a shortage of current continuous count locations, the agency should select new locations to place continuous counters within that defined group. Since the number of additional locations may be small, the recommendation is to select and include them as soon as possible. Additional issues that should be considered when selecting locations to expand the sample size are reviewed in the following paragraphs.

If a surplus of continuous counters within a group exists, then redundant locations are candidates for discontinuation unless needed for ramp balancing and anchors. If the surplus is large, the reduction should be planned in stages and after adequate analysis to ensure that the cuts do not affect

reliability in unexpected ways. For example, if 12 locations are available and six are needed, then the reduction could be carried out by discontinuing two locations annually over a period of three years. The sample size analysis should be recomputed each of the three years before the annual discontinuation to ensure that the desired precision has been maintained. Location reductions should be carefully considered. Maintaining a few (two to three) additional surplus locations may help supplement the groups and compensate for equipment downtime or missing data problems.

Matters for consideration are as follows:

- Other uses of existing information or other reasons the sites are important – As mentioned previously, seasonality is not the only objective for use of continuous count data. Each State should ensure that these other criteria are met before discontinuation. It should be clear that additional locations increase the reliability of the data.

- Quality of the traffic data – Continuous counter data is subject to many discontinuities due to downtime, which results in missing data, and to the issues of data adjustment and imputation.

- Existing locations – Available locations from control or other programs may be candidates for upgrading to continuous status.

- Location on or near HPMS sites – Because of the direct linkage to the HPMS sample sections, these locations should be given priority.

- Tie-in to the classification, speed, or weight programs – Coordination with other programs is essential.

- Distribution over geographical areas of the State.

- Distribution by functional class system.

- Random selection to reduce bias – New locations should be randomly selected.

- Quality of continuous count equipment of sites – Older or malfunctioning equipment should be given higher priority for discontinuation.

Step 7: Compute Temporal Factors

MOY factors are most accurately developed and applied on a year-by-year basis. That is, a short count taken in 2009 should be adjusted with factors developed exclusively from continuous count data collected in 2009. This allows the adjustment process to account for economic and environmental conditions that occurred in the same year the short count was taken.

This recommendation creates problems for the timing of factor computation and application. That is, if a short count is taken in the summer of this year, the true adjustment factor for this year cannot be computed until January of next year at the earliest, which may not be timely enough for many users. The recommendation is to compute temporary adjustment factors for estimating AADT before the end of the year, and then to revise that preliminary estimate once the year's true adjustment factors can be computed in January.

Temporary factors can be developed in one of three ways:

- Applying last year's factors;

- Computing an average of the three previous year's factors; and

- Computing a monthly rolling average (for example, the temporary July 2009 factor would be computed as the factor for the 12 consecutive months from August 2008 through July 2009).

The first of these approaches is the easiest but also the least accurate, because the effects of this and last years' economic/environmental conditions are likely to be different. The second approach reduces the biases that occur from using a single year's factors. The last approach produces the most accurate adjustment factor but also requires the most labor-intensive data handling and processing

effort. (See Appendix D, Case Study #6 for an example of computing monthly rolling average.)

The procedures for developing and using monthly factors to adjust short volume counts to produce AADT estimates follow directly from the structure of the program. The individual monthly factors for each continuous count station are the ratio of the AADT to MADT. Alternatively, the State can combine the DOW adjustment and monthly adjustment into a single factor, for example the ratio of annual average daily traffic to monthly average weekday traffic (AADT / MAWDT). This term, or a similar seasonal adjustment, can be substituted directly for the ratio of AADT / MADT in the factor grouping and application process if desired.

For a counter site that operates 365 days per year without failure, the AADT can be computed by adding all of the daily volumes and dividing by 365. Similarly, the MADT can be computed by adding the daily volumes during any given month and dividing by the number of days in the month.

Challenges with this approach are that few continuous count stations operate reliably during any given year. Most suffer at least small amounts of downtime because of power failures, communications failures, and other equipment or data handling problems. These missing hours or days of data can cause biases and other errors in the calculations, particularly when a moderate amount of data is lost in a block. As a result, a modified formula for computing these types of statistics that directly accounts for missing data has been adopted.

The following methodology has been adopted by AASHTO, has been researched and verified by FHWA, is used by many States, and is recommended by FHWA.

$$AADT = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n}VOL_{ijk}\right)\right]$$

Where:

VOL	=	daily traffic for day *k*, of DOW *i*, and month *j*
i	=	day of the week
j	=	month of the year
k	=	1 when the day is the first occurrence of that day of the week in a month, 4 when it is the fourth day of the week
n	=	the number of days of that day of the week during that month (for which you have data).

This formula computes an average DOW for each month, and then computes an annual average value from those monthly averages, before finally computing a single annual average daily value. This process effectively removes most biases that result from missing days of data, especially when those missing days are unequally distributed across months or days of the week. The method used should be detailed in the Traffic Monitoring System (TMS) that States keep on record with the local FHWA district office.

The calculation of MADT is similar to that of AADT. An average DOW is first computed for a given month, and then all seven-day values are averaged. MAWDT is similarly computed. However, each State can define the specific days present in the MAWDT calculation. For example, some States do not count Fridays for routine short duration traffic counts and therefore, choose not to include Fridays in the computation of MAWDT.

Monthly factors for each continuous count are computed by the ratio of AADT to MADT or AADT to MAWDT. Group monthly factors are computed as the average of the factors for all continuous counter locations within the group. Both the individual continuous count and the group factors

should be made available to users in tabular and computer accessible form. (See Appendix K for examples of these computations. See Appendix D, Case Study #5 for an example from Alabama regarding incorporating data collected by local governments.)

3.2.2 SPEED

Measurements of vehicle speeds are used for a wide variety of studies, but particularly for safety studies and roadway performance monitoring. The data needed for these two types of studies are highly related but can be significantly different in both content and format. Safety studies rely on statistically valid measures of vehicle speed distributions during the study periods. Of particular interest in most safety studies is the speed distribution that occurs under free flow conditions (e.g., how many vehicles are speeding and how fast are they going? Is there a large difference in speed between the fastest and slowest vehicles in the traffic stream?). On the other hand, those conducting roadway performance monitoring are more interested in how the average speed of the facility changes by time of day and from one day to the next (e.g., is congestion forming, and if so, how often, how badly, and how long does it last?).

Consequently, speed data for most safety studies are gathered with traditional traffic monitoring devices, which collect speed data for all vehicles passing a selected point in the roadway over a defined period. Speeds are then reported either as individual vehicle observations or as summary data that indicate the volume of vehicles moving within defined speed ranges (speed bins).

Conversely, speed data for performance monitoring purposes traditionally come from sensors used for traffic management purposes. Average facility speeds are the primary reporting statistic calculated with data from these sensors, and individual vehicle speeds are often not collected. Recent decreases in the cost of both GPS equipment and wireless communications costs have also meant that privately collected vehicle probe data sets can now also meet many performance-monitoring needs. Unfortunately, these probe vehicle data only include a small sample of vehicles using a roadway, which can be used to estimate average facility speeds along entire roadway corridors across all days of the year. These data sets are less useful for most safety studies because they do not capture an unbiased measure of the distribution of speeds.

This edition of the *TMG* provides guidance on the collection and submission of speed data that are of particular use for safety studies. It does not contain guidance on the collection and use of vehicle probe based speed data useful for more general, area-wide, or corridor long roadway performance monitoring.

Travel speed data is used to determine travel time reliability, and is important for planning, program effectiveness evaluation, and investment analysis. Many other divisions within State DOTs need speed data for travel time, performance measures, safety studies, and other analysis. Multiple divisions within an agency could consider funding a permanent site, collecting the data once and using it many times across divisions/agencies.

Many continuous traffic-monitoring devices are deployed specifically to collect vehicle speed data; others collect speed data as a by-product of some other traffic data collection function. By taking advantage of all of their devices collecting speed data—whether intentionally or as a by-product—highway agencies frequently have access to a wealth of vehicle speed data. Many continuous counters are equipped with dual loops simply because the cost of the second loop is low in comparison to the initial investment at that site, and the provision of the second loop both provides redundancy in volume data collection and allows that location to be used for other purposes (speed monitoring and length classification).

The deployment of continuous equipment specifically to collect vehicle speed data is becoming popular in States. In an effort to leverage the capabilities of the current equipment, FHWA investigated speed data collection practices of States and found that 94 percent have speed data; all of the States collect speed data themselves, and five of the States use third parties to collect speed data.

Chapter 5, Transportation Management and Operations discusses ideas for sharing resources with other offices to collect speed data.

Data already collected at States are as follows:

- By lane;

- In 5 mph bins;

- Counter location identified by latitude/longitude; and

- Reported every 15 minutes (FHWA will accept one hour intervals).

This flexible structure would enable the reporting of spot speed without changing the data collection methodology currently being used by States. The final format for submission is identified in Chapter 7.

A well-designed monitoring program stores, summarizes, and makes available the speed data already collected by these devices for both internal agency use and submittal to U.S. DOT.

3.2.3 VEHICLE CLASSIFICATION (AXLE AND LENGTH)

This section discusses the process for establishing a continuous vehicle classification count program and presents two alternative methods for the development of factor groups for classification. **The continuous vehicle classification data collection program is related to, but can be distinct from, the traditional continuous count program.** In addition, factoring of vehicle classification counts (i.e., heavy vehicle volume counts) may be performed independently from the process used to compute AADT from short duration volume counts. Highway agencies should collect classification data (which also supply total volume information) in place of simple volume counts whenever possible.

Figure 3-5 shows the steps for the classification process and are explained in the following paragraphs.

FIGURE 3-5   STEPS FOR CREATING AND MAINTAINING A CONTINUOUS DATA COLLECTION PROGRAM
FOR DEVELOPING AND USING KNOWLEDGE OF THE TRAFFIC PATTERNS FOR EACH CLASS OF VEHICLE

> 1: Review The Existing Continuous Vehicle Classification Count Program
>
> 2: Develop An Inventory Of Available Continuous Vehicle Classification Count Locations & Equipment
>
> 3: Determine The Vehicle Traffic Patterns To Be Monitored
>
> 4: Establish Pattern Groups
>
> 5: Develop Factors
>
> 6: Determine The Appropriate Number Of Continuous Vehicle Classification Count Locations
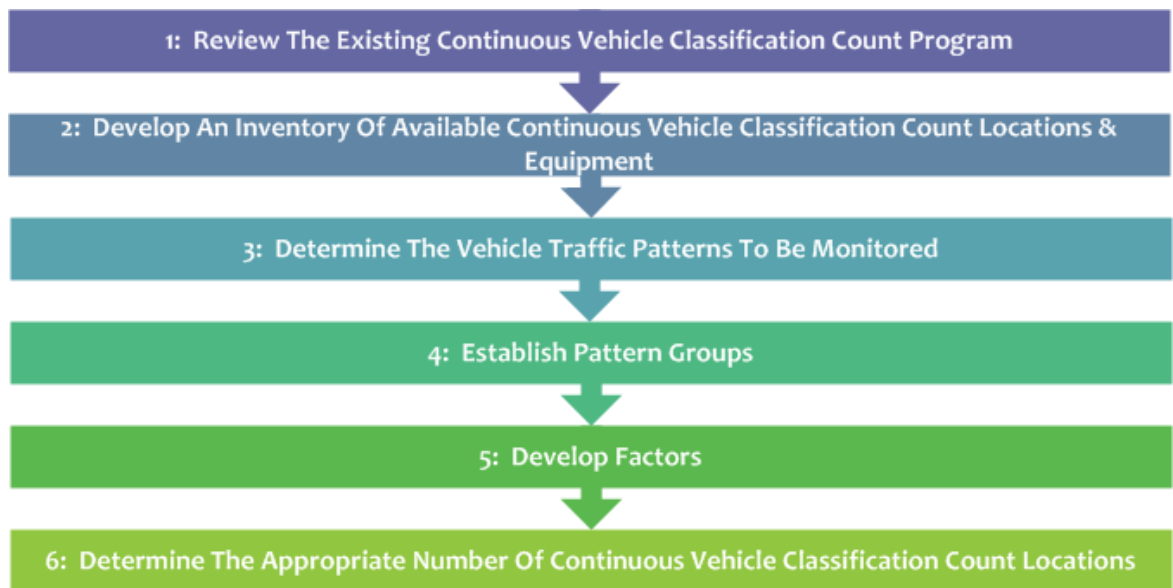
Source: Federal Highway Administration.

Step 1: Review the Existing Vehicle Continuous Classification Count Program

A. Current Program – The first step in developing the continuous vehicle classification count program is to define, analyze, and document the current program. This assessment should include the historical design, procedures, equipment, personnel, objectives, and uses of the information. This review should begin with an inventory of the State's continuous vehicle classification data collection equipment. The uses of the data should be identified, as well as who is using it and how it might be used if additional application tools were available.

B. Traffic Patterns – The data should be reviewed to determine what unique traffic patterns exist for each major classification of vehicle in the State and whether previously identified patterns have changed in order to establish whether the monitoring process should be adjusted.

C. Data Adjustment – The details of the data adjusted/processed should be reviewed with attention to whether the data adjustment steps can be improved or otherwise made more efficient. Of considerable interest in this review is how the quality of the data being collected and reported is maintained. Establishing the quality of the vehicle classification data reported and the outputs of the data analysis process is a prerequisite for future improvements. Continuous traffic data collection is subject to discontinuities due to equipment malfunctions and errors. The way a State identifies and handles errors in the data stream is a key component of the vehicle classification program. Subjective editing procedures for identifying and imputing missing or invalid data is discouraged, since the effects of such data adjustments are unknown and may bias the resulting estimates. Instead, the quality control procedures listed below should be followed to ensure that invalid data is appropriately and consistently identified and replaced.

D. Quality Control – Each State highway agency should have formal rules and procedures for these important quality control efforts. The implementation of truth-in-data concepts as recommended by the AASHTO Guidelines for Traffic Data Programs will greatly enhance the analytical results and help in establishing objective data patterns. Truth-in-data implies that agencies maintain a record of how data is manipulated, and that each manipulation has a strong basis in statistically rigorous analysis. Data should not be discarded or replaced simply because they appear atypical. Instead, each State should establish systematic procedures that provide the checks and balances needed to identify invalid data, control how those invalid data are handled in the analysis process, and identify when those quality control steps have been performed.

E. Finally, the State highway agency should periodically review whether these procedures are performed as intended or need to be revised. For States that currently do not have formal quality control procedures, Appendix E provides several examples of how States use data quality control procedures. In addition, AASHTO has also provided guidance on how to develop and implement a quality control process for traffic data collection.

F. Summary Statistics – The last portion of the review process should entail the steps for creating summary statistics from the raw data collected by vehicle classification equipment. These procedures should be consistent and should accurately account for the limitations that are often present in continuously collected classification data.

Step 2: Develop an Inventory of Available Vehicle Classification Count Locations and Equipment

Correctly manipulating continuous vehicle classification count data after they have been collected is vital.

A. Existing Data Sources – The inventory of existing (and planned) continuous vehicle classification ensures that the State's traffic monitoring effort is comprehensive and effective. As noted earlier, the key to the inventory process is for the agency to identify not only the traditional continuous

vehicle classification, but also other data collection devices that can supply continuous class data. These secondary sites include, but are not limited to:

- Continuous weigh-in-motion sites;
- Traffic management systems; and
- Regulatory monitoring sites (such as international border crossings and toll plazas).

B. When available, data collection devices operated by the same group that operates the vehicle classification sites are the easiest from which to obtain data, but a number of State highway agencies do not make use of this data as part of their vehicle classification process.

C. Other Sources – Posing more challenges are devices operated by other divisions within the State highway agency. Obtaining this data can be difficult, particularly when internal cooperation within the agency is limited. However, the current emphasis on improved cost-efficiency in government means that in most States there is strong upper management support for full utilization of data resources, wherever they exist. The key to taking advantage of this support is to make the transfer of the data as automated as possible, so that little or no staff time is expended outside of the traffic data collection group to obtain the data.

D. The State highway agency should also seek data outside of its own agency. (See Chapter 5, case study examples.) While it may not be possible to obtain this data at the level provided by continuous vehicle classification equipment, it is often possible to obtain useful summary statistics from these locations. These summary data can be used to supplement the State's data at those locations and geographic areas. The availability of data from supplemental locations reduces the cost of collecting and increases access to useful data. To obtain this data, the State highway agency may have to acquire software that automatically collects and reports this data. The intent, once again, is to reduce the operating agency's staff time needed to collect and transmit the data. The easier this task is for the agency collecting the data, the more likely it is that this data can be obtained. However, data should only be used from calibrated sites (all sites including classification should be calibrated yearly).

E. Uses of Data – Another element is to inventory data uses and users. This step involves determining how the vehicle classification data is currently being used, who the customers are for those data, and which data products are being produced. Data should be collected for a purpose, and the users and uses of those data should be prioritized. Data only have value when they answer important questions. By understanding how the data is being used, it is possible to develop a clear understanding of what value the data collection effort has to the organization. Understanding this value, and being able to describe it, is crucial to defending the data collection program when budget decisions are made.

F. States should be checking the accuracy of their class data and taking appropriate action to evaluate and adjust their vendor-specific classification algorithm to correctly classify all of the vehicle types on their roadways (within 10% by class).

G. This inventory process may uncover the circumstance that some data and/or summary statistics are not being used. If that is the case, then those data and statistics may be eliminated in favor of the collection of data or production of statistics that will be used. This results in better use of available resources, makes the data collection system more focused on products actively desired by agency users, and results in more support for the data collection program from others in the agency. Several State DOTs find the use of a data business plan to be a useful tool for documenting the business needs for data and information (Chapter 2). Data business plans help to document how data systems support current business operations, identify data gaps (i.e., where new data and information are needed to support current needs), and provide a structured plan for the development of enhanced data systems to meet future needs.

Step 3: Determine the Traffic Patterns to Be Monitored

If sufficient data is available, it should be evaluated to determine what unique traffic patterns exist for each of the different classes of vehicles. For example, motorcycles have different DOW and monthly travel patterns than single unit trucks. The development of factor groups and factor procedures for different classes of vehicles should be undertaken. At a minimum, States should investigate whether they need different factor groups and processes for six aggregate classes of vehicles: motorcycles (MC), passenger cars (PV), light duty trucks (LT), buses (BS), single unit trucks (SU), and multi-unit combination trucks (CU). In some cases, two or more classes of vehicles may be included in one set of factors when these vehicles can be shown to have similar travel patterns.

The inventory process should document whether and how the continuous vehicle classification program is being used to create and apply adjustment factors to short duration vehicle classification traffic counts to estimate annual average volumes by type of vehicle. The inventory review process should also determine which highway locations require continuous vehicle classification equipment to capture the travel patterns effectively of all vehicle classes with a high degree of confidence.

The review of seasonal patterns can be undertaken using one of a number of analytical tools. Two of the most useful are cluster analysis, which can be performed using any one of several major statistical software packages such as SAS or SPSS, and the graphic examination, using GIS tools, of seasonal pattern data from individual sites.

The intent of the seasonal pattern review is to assess the degree of seasonal (monthly) variation that exists in the State as measured by the existing vehicle classification data and to examine the validity of the existing factor grouping procedures that produce the seasonal factors. The review consists of examining the monthly variation (attributed to seasonality) in vehicle traffic volume for each class of vehicles (at a minimum of MC, PV, BS, LT, SU and CU) at the existing vehicle classification locations, followed by a review of how roads are grouped into common patterns of variation. The goal of this review is to determine whether the State's procedures successfully group roads with similar seasonal patterns, and whether individual road segments can be correctly assigned to those groups.

It is not necessary for the factor groups to be identical to the cluster analysis output for two reasons. For any given year, the cluster output is likely to be slightly different, as minor variations in traffic patterns are likely to be reflected in minor changes in the cluster analysis output. In addition, the cluster analysis output will require adjustment to create intuitively rational and identifiable groups of roads. The use of cluster analysis is explained in further detail in Appendix G.

The remaining review step is to make sure that the groups are defined by an easily identifiable characteristic that allows easy assignment of short counts to the group. The definition of each group must be complete enough to allow analysts to select the appropriate factor for every applicable roadway section.

Step 4: Establish Monthly Pattern Groups

Each State highway agency should operate a set of continuous classification counters to measure vehicle-travel patterns and provide the factors to convert short classification counts to annual averages. As an example of one vehicle type, research has shown that truck travel does not follow the same time-of-day, DOW, and seasonal patterns as total volume (Schneider and Tsapakis 2009, Hallmark and Lamptey 2004, Hallenbeck and Kim 1993, Weinblatt 1996, Hallenbeck et al 1997). For example, see Figures 3-6 and 3-7 below.

Analysis of continuously collected data sets also indicates that truck volumes on many roads (even high volume interstate) can change significantly due to changes in the national and local economy. Similarly, continuous count data have shown that motorcycle traffic follows different patterns than other passenger vehicles with much more travel occurring on weekends than weekdays, especially on some rural roads used for recreational travel by motorcyclists. Continuously operating classification counters are needed to monitor these travel patterns so that these patterns can be detected and

accounted for in engineering and planning analyses. For example, if the large increases in weekend motorcycle travel are not accounted for, short duration classification counts will significantly underestimate the number of miles traveled annually on motorcycles, thus biasing national and State safety analyses.

FIGURE 3-6   EXAMPLE OF DIFFERENCES IN DOW TRAVEL BY VEHICLE CLASS IN IOWA
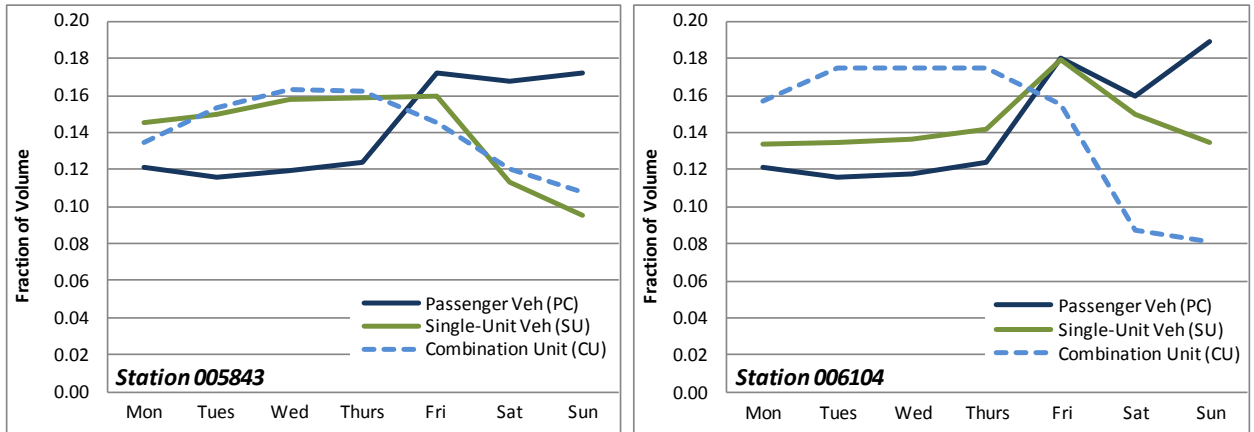
Source: Federal Highway Administration.

FIGURE 3-7   EXAMPLE OF DIFFERENCES IN MONTHLY TRAVEL PATTERNS BY VEHICLE CLASS IN IOWA
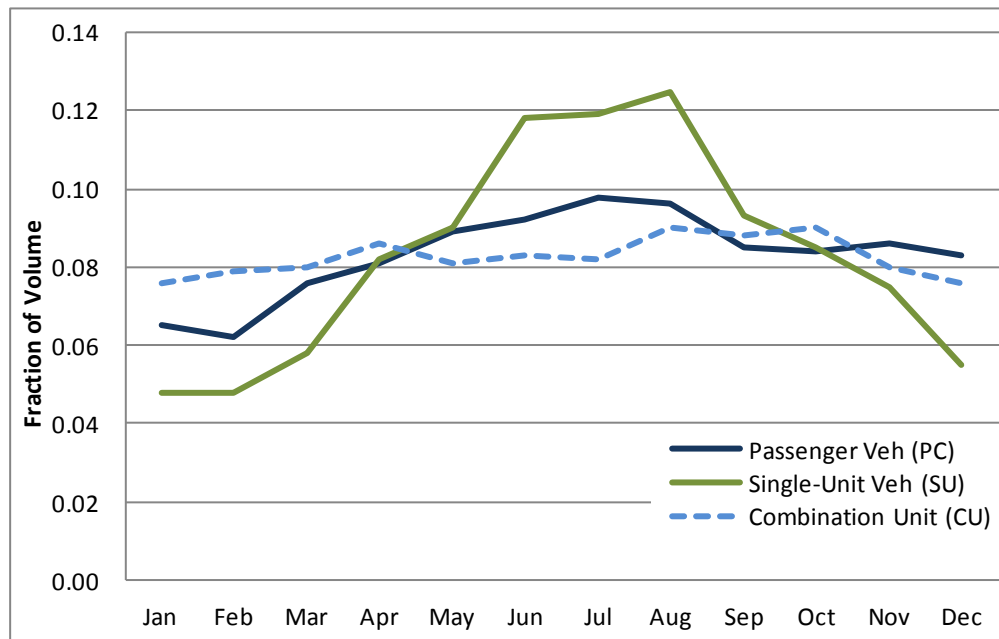
Source: Federal Highway Administration.

All State highway agencies have been operating permanently installed continuous count stations (CCS) (commonly referred to as ATRs) for many years. It has only been since the mid-1980s that

technology allowed the installation and operation of similar counters to collect continuous classification data. A significant increase in the number of these counters has taken place since 1990 because of the start of traffic data collection for the Strategic Highway Research Program's (SHRP) Long Term Pavement Performance (LTPP) project. Many States have also converted continuous installations to classification as the old equipment was replaced.

Data from these continuous classification devices have shown that motorcycle, single unit truck, and combination unit truck volumes have time-of-day, DOW, and by month variations that are different from those of cars. In addition, sources of continuous classification data may be obtained from installations from regulatory, safety, and traffic management systems installed to operate and manage the infrastructure. To obtain these existing data, highway agencies often need to establish working relationships with other public agencies, including MPOs, county and regional planning councils, to coordinate count programs and sharing of data. The effort may result in considerable improvement to the available classification data. FHWA is working on establishing length-based classification (see Appendix J, FHWA Memo on Establishing Length Based Classification).

The objective of seasonal factor procedures is to remove the temporal bias in current estimates of vehicles with unique temporal variances that are different from the total volume. Four primary reasons for installing and operating permanent, continuously operating, vehicle classifiers for traffic monitoring purposes include the ability to:

- Provide a highly accurate measure of MC, PV, LT, BS, SU, CU volumes at a limited number of specific sites around the State;

- Track the changes in those volumes over time with a high degree of accuracy;

- Determine the travel patterns of different vehicle types on different roadways across the State; and

- Create adjustment factors and factor groups that allow application of the factors for converting short duration classification counts into annual average estimates of vehicle volume by vehicle type.

Vehicle Classes Used for Factoring

Regardless of the approach taken for the computation and application of factors, it is recommended that adjustment factors be computed for a maximum of six generalized vehicle classes (see VM-1 and HPMS Summary types). These are:

- Motorcycles (MC)

- Passenger vehicles under 102" (PV)

- Light trucks over 102" (LT)

- Buses (BS)

- Single-unit trucks (SU)

- Combination trucks (tractor-trailers) (CU)

Table 3-3 compares the six-vehicle class groupings used in one of the HPMS datasets to the FHWA 13 vehicle category classes.

TABLE 3-3   HPMS VEHICLE CLASS GROUPS/FHWA VEHICLE CLASSES

HPMS Summary Table Vehicle Class Group*	FHWA 13 Vehicle Category Classification Number
Group 1: Motorcycles (MC)	1
Group 2: Passenger Vehicles equal to or under 102" (PV)	2
Group 3: Light trucks over 102" (LT)	3
Group 4: Buses (BS)	4
Group 5: Single-unit vehicles (SU)	5,6,7
Group 6: Combination Unit (CU)	8,9,10,11,12,13

These groupings are used to report travel activity by vehicle type in the Vehicle Summaries dataset for HPMS.

Highway agencies may adjust these categories to reflect their vehicle fleets and travel patterns best, as well as the capabilities of the classification equipment in their programs. (Note that where data shows similar patterns, the passenger car and light truck categories can be combined into one set of factor groups.)

Several reasons support these recommendations. The factoring process does not work well with low traffic volumes. With low volumes, even small changes result in high-percentage changes that make the computed factors highly unstable and unreliable. Even on moderately busy roads, many of FHWA's 13 category vehicle classes (illustrated in Appendix C) will have mathematically unstable vehicle flows simply because their volumes are low. Aggregating the vehicle classes provides for more stable and reliable factors.

A second reason is that computing factors for the individual 13 vehicle classes may introduce too much complexity. There is no gain in separately annualizing extremely variable and rare vehicle classification categories.

Some issues presenting challenges to the factor development and application process remain unanswered, such as adequate editing procedures, resolution of the assignment of vehicles to classification categories, inability of equipment to collect a standard set of vehicle classes in all conditions, and disparities in the available equipment. Unnecessary complications at this stage of development should be avoided.

Alternative Factor Procedures

The following alternative truck volume factor procedures both have advantages and disadvantages. Both are complementary and can be combined as appropriate. States are encouraged to develop these alternative factor procedures or other alternatives that effectively remove temporal bias.

The first procedure involves the use of roadway-specific factors. The second is an extension of the traditional traffic volume factoring process involving the creation of groups and the development of average factors for each of the groups.

Either applying factors to a road or fitting road segments into groups involves making decisions to resolve difficulties. A factor process may result in one set of factors for cars, another set of factors for trucks, and the combination of both to arrive at a total volume. A factor process may also require more than one set of factors for trucks where different truck types are factored separately. Some roads could conceivably fit in one factor group for cars, a second factor group for single unit trucks, and a third factor group for combination trucks. Resolutions should be made by each State between the need for accuracy and reductions in unnecessary complexity in the approach to removing temporal bias.

Two basic elements to the factoring process are the computation of the factors to apply to the short counts and the development of a process that assigns these factors to specific counts taken on specific roadways. The roadway-specific and the traditional procedures approach these two aspects of the factoring process differently. The result is two different mechanisms for creating and applying factors, each with its own strengths and weaknesses.

Alternative #1: Roadway-Specific Factors

One option is the process that was developed by the Virginia Department of Transportation (VDOT) in the late 1990s. VDOT operates continuous counters on all major roads and the counters are used to develop road-specific factors. A short classification count taken on a specific road is adjusted using factors taken from the nearest continuous classification counter on that road. A factor computed for a specific road is not applicable to any other road.

As a result, a continuous classification counter should be placed on every road for which an adjustment factor is needed. This requires a large number of continuous vehicle classification counters and substantial resources. However, it ensures that a road can be directly identified with an appropriate factor and provide considerable insight into the movement of freight and goods within the State. The rule for assigning factors to short counts is simple and objective.

Identifying a specific road with a specific factor removes a major source of error in the computation of annual traffic volumes by removing the spatial error associated with applying an adjustment factor. Further, it produces factors that are applicable to all trucks using that road. The fact that different truck classes (single-unit versus combination trucks) exhibit different travel patterns is irrelevant, since all patterns are computed for that road. Having road-specific continuous classification counters also greatly reduces the number of short duration counts that are needed, since the continuous counters provide classification data for road sections near the count locations. The quality of data from continuous classification counters is superior to that of short counts.

Finally, this approach has the advantage of simplifying the calculation of adjustment factors, the application of those factors, and the maintenance of the program. For example, there is no need to develop groups and the application is performed one road at a time. Problems with continuous counters only apply to the affected roads and prioritization of counter problem correction can be based on road priority.

The most important disadvantage with this approach is cost. It is expensive to install, operate, and maintain large numbers of continuous traffic counters. The larger the system to be covered, the larger the cost. Even for smaller States, the cost to install a large counter base may be prohibitive. However, this approach may apply effectively to the interstate, where sufficient continuous counters may be available. It can also be applied to roads where current counters are installed.

A second disadvantage is that many roads are quite long and the character of any given type of vehicle traffic over their length can change drastically. This is why short count short duration programs are valuable. An adjustment factor taken on a road segment may not be applicable to another segment a few (two to three) miles down the road, particularly if a significant vehicle generation activity takes place along that stretch of roadway. Traffic patterns change because of economic activity, traffic generators, or road junctions. Not only does this further increase the number of continuous counters required, it also creates difficulty in selecting between the two continuous classification counters when a short count falls in between.

That is, specific road factors may be used for the most important truck roads and the traditional factor groups for routes without continuous classification counters. When continuous counters fail, traditional factoring techniques can then be used to provide adjustment factors on those roads. This combination of the traditional and roadway-specific factors may be an effective compromise between these two techniques.

One final consideration with the roadway-specific technique is that there is no mathematical mechanism that allows computation of the accuracy/precision of the factors as they are applied to a given roadway section. Caution is recommended when significant traffic generators in the intervening space between the count and the continuous counter exist. When these factors are applied to count locations that are close to the continuous counter, they can be assumed to be quite accurate. However, as the distance between the short count and the continuous counter grows, and particularly as more opportunity exists for trucking patterns to change, the potential for error in the factor being applied grows, and at an unknown (but potentially substantial) rate.

Alternative #2: The Traditional Factor Approach

The traditional factor process involves categorizing roads that have similar individual vehicle traffic patterns. A sample of data collection locations is then selected from within each group of roads, and factors are computed and averaged for each of the data collection sites within a group. A definition is provided for each group to describe characteristics that explain the observed pattern, which is used to allow the objective assignment of short counts to the groups. For example, a group might be defined as all roads in counties that experience heavy beach traffic, as these roads have unique seasonal and DOW recreational traffic. Similarly, for truck factors a logical grouping might be all roads serving heavy north/south or east/west through trucking movements, versus those roads that serve primarily local delivery movements.

For traffic volume, the traditional characteristics for grouping roads have been the functional class of the road (including urban or rural designation) and geographic location within the State. These groups are then supplemented with an occasional recreational (or geographic) designation for roads that are affected by large recreational traffic generators.

This same technique can be applied to truck traffic patterns. However, the characteristics that need to be accounted for can be different. Functional class of roadways has been shown to have an inconsistent relationship to truck travel patterns (Hallenbeck et al 1997, Schneider and Tsapakis 2009). Instead, truck travel patterns appear to be governed by the amount of long distance truck through-traffic versus the amount of locally oriented truck traffic, the existence of large truck traffic generators along a road (e.g., agricultural or major industrial activity), and the presence or absence of large populations that require the delivery of freight and goods. Understanding how these and other factors affect truck traffic is the first step toward developing truck volume factors. Developing this understanding requires analysis of the existing continuous vehicle classification data already being collected by the State, and analyzing it within the context of the commodity movements happening in the State. The steps required to gain this understanding are described below.

Create Initial Factor Groups

The creation and application of adjustment factor groups (time of day, DOW, and monthly) by class of vehicle is a topic that is still new. Most State DOTs have yet to develop these factoring procedures, and considerable research still needs to be accomplished.

States should depend on available classification data and knowledge to begin the development of truck traffic patterns. Truck traffic patterns are governed by a combination of local freight movements and through-truck movements. Extensive through-truck movements are likely to result in higher night truck travel and higher weekend truck travel. Through-traffic can flatten the seasonal fluctuations present on some roads while creating seasonal peaks on other roads not associated with the economic activity occurring in the land abutting that roadway section. Similarly, a road primarily serving local freight movements will be highly affected by the timing of those local freight movements. For example, if the factory located along a given road (not subject to significant amounts of through-traffic) does not operate at night, there may be little freight movement on that road at night.

Functional road classification can be used to a limited extent to help differentiate between roads with heavy through-traffic and those with only local traffic. Interstates and principal arterials tend to have higher through-truck traffic volumes than lower functional classes. However, there are interstates and principal arterial highways with little or no through-truck traffic, just as some roads with lower functional classifications can carry considerable through-truck volumes. Therefore, functional classification of a road by itself is a poor identifier of truck usage patterns. To identify road usage characteristics, additional information should be obtained from either truck volume data collection efforts or the knowledge of staff familiar with the trucking usage of specific roads. The truck volume data patterns, especially time of day patterns from short counts and DOW and monthly patterns from continuous classifiers, identify travel patterns for different types of vehicles. These patterns should then be discussed with staff working on freight planning activities to understand and help identify trucking patterns in ways that allow both grouping of continuous counters and assignment of short count location to those groups.

Among the types of patterns that can be identified through this combination of data and communication with staff are various local, regional, and through travel patterns. For example, local truck traffic can be generated by a single facility such as a factory, or by wider activity such as agriculture or commercial and industrial centers. These point or area truck-trip generators create specific seasonal and DOW patterns, much as recreational activity creates specific passenger car patterns. Truck trips produced by these generators can be highly seasonal (such as from agricultural areas) or constant (such as flow patterns produced by many types of major industrial plants). Where these trips predominate on a road, truck travel patterns tend to match the activity of the geographic point or area that produces those trips. In addition, changes in the output of these facilities can have dramatic changes in the level of trucking activity. For example, a labor problem at a West coast container port may produce dramatic shifts in container truck traffic to other ports. This results in significant changes in truck traffic on major routes serving those ports. Expansion or contraction of factory production at a major automobile plant in the Midwest can cause similar dramatic changes on roads that serve those facilities.

Truck trip generators can also affect the types of trucks found on a road. Specific commodities tend to be carried by specific types of trucks. However, State-specific truck size and weight laws can mean that trucks typical in one State may not be common in others. For example, multi-trailer trucks are common in most western States, while they make up a much smaller percentage of the trucking fleet in many eastern States. Understanding the types of trucks used to carry specific commodities is critical to understanding the trucking patterns on a road and how those patterns are likely to change (e.g., coal trucks in Kentucky and Pennsylvania).

Many other elements affect truck travel. For example, construction trucks operate in an area's roads until the construction project is completed and then they move somewhere else. This type of truck movement is difficult to quantify. Roads near truck travel generators, such as quarries or trash dumps, carry consistent truck traffic and the type of truck is well known. Summarizing the different patterns in a way that allows creation of accurate factor groups is difficult. Obviously, the more knowledge that exists about truck traffic on a road, the easier it is to characterize that roadway.

Geographic stratification and functional classification can be used to create truck factor groups that capture the temporal patterns and are reasonably easy to apply. An initial set of factor groups might look something like that shown in Table 3-4. However, the two keys to the creation of groups is that the data should show that traffic patterns within grouped sites are in fact similar, and those groups should be designed in such a manner that short counts can be easily and accurately assigned to the correct factor groups. Therefore, as groups are formed, specific roads may need to move from one group to another to ensure that both of these constraints remain true.

Definitions like those above group roads with as homogenous truck travel patterns as possible, and provide easy identification of the groups for application purposes. They present a starting point to begin the identification process necessary to form adequate groups.

Performing a cluster analysis using truck volumes (as illustrated in Section 3.2.1 for total volume) will help to identify the natural patterns of variation and to place the continuous counters in variation groups. This will help in identifying which groups may be appropriate and in determining of how many groups are needed. One of strengths of the cluster analysis is that it identifies groups only by variation. The weakness is that it does not describe the characteristics of the group that allow application of the resulting factors to other short counts. The example definition in Table 3-2 does exactly the opposite. It clearly establishes group characteristics but cannot indicate whether the temporal variation is worth creating separate groups or not. As is the case for AADT group procedures, a combination of statistical methods and knowledge should be used to establish the appropriate groups.

TABLE 3-4   EXAMPLE COMBINATION UNIT TRUCK (CU) FACTOR GROUPS

Rural	Urban
Interstate and arterial major through-truck routes	Interstate and arterial major truck routes
Other roads (e.g., regional agricultural roads) with little through traffic	Interstate and other freeways serving primarily local truck traffic
Other non-restricted truck routes	Other non-restricted truck routes
Other rural roads (e.g., mining areas)	Other roads (non-truck routes)
Special cases (e.g., recreational, ports)	

Step 5. Develop Monthly Factors

All roads within the defined factor groups should have similar types of vehicle volume patterns. To verify this condition, the continuous counter data available within the groups should be examined. For each continuous classification counter in a group, compute the temporal adjustment factors of interest (DOW, month, or combined) for each of the vehicle types desired, and then compute the mean and standard deviation for the group as a whole. Plots of the volumes and the factors over time can also help to determine whether the travel patterns at the continuous sites are reasonably similar.

In most cases, only a few roads within each group will have sufficient data (continuous classification counters) needed to estimate travel patterns. The assumptions this analysis makes are similar to those made for AADT factors. The implication is that the continuous counters typify the existing temporal variation. Then the continuous counter variation reflects the variation existing at locations where no continuous counters exist. A combined monthly and weekday factor is computed as follows (This formulation assumes a multiplicative application. AADTT is equal to the average 24-hour count times the adjustment factor. Many States use the inverse of this formula and apply the resulting factor by dividing the average 24-hour volume obtained from their short count by the adjustment factor. See Table 3-9 for example):

$$\textit{Adjustment Factor}_{C, June} = AADTT_C \, / \, MAWDTT_{C, June}$$

Where:

Adjustment Factor$_{C, June}$ = a multiplicative factor for a specific vehicle type C used to convert a 24-hour count taken on any weekday in June to an estimate of annual average daily traffic

$AADTT_C$ = annual average daily (truck) traffic volume for a specific vehicle type C

$MAWDTT_{C, June}$ = monthly average weekday (truck) traffic volume for the month of June for a specific vehicle type C

An example of how these monthly adjustment factors differ by vehicle class is shown below in Table 3-5.

TABLE 3-5   EXAMPLE OF MONTHLY FACTORS BY VEHICLE CLASS AT A SINGLE SITE

	MC	Car and Light Trucks	Buses	Single Unit Trucks	Combination Trucks	Total Volume
MADT$_{Vehicle\_Class}$	35	4,874	52	227	1,639	6,826
AADT$_{Vehicle\_Class}$	33	5,499	57	288	1,653	7,530
Monthly Factor (AADT$_c$/MADT$_c$)	0.95	1.13	1.10	1.27	1.01	1.10

Computing the mean (or average) for the June factor for all sites within the factor group yields the group factor for application to all short counts (weekdays in June) taken on road segments within the group. The standard deviation of the factors within the group describes the variability of the group factor. The variability can be used to determine whether a given factor group should be divided into two or more factor groups, to compute the precision of the group factor, and to estimate the number of continuous classification counter locations needed to compute the group factor within a given level of precision. An example of this is in Table 3-9.

The variability of each statistic computed for the factor group will have a different level of precision. For example, the June factor will have different precision than the July factor. The precision will also vary for each of the vehicle types analyzed.

Test the Quality of the Selected Groups

The information on variability must be reviewed to determine whether the roads grouped together have similar individual vehicle travel patterns. A number of methods can be used to determine whether various sites belong together. A statistically rigorous approach to testing the precision of the selected groups requires the use of fairly complex statistics, an examination of all the truck classes used, and the comparison of statistical reliability for all the different types of statistics produced, with the reliability users need for those statistics. This is a complex and difficult analysis. The analysis can be simplified by concentrating on the most important vehicle classes and statistics produced. However, even with the simplifications suggested, trade-offs are necessary. No designed group will be optimal for all purposes or apply perfectly to all sites. For example, in one group of roads, the single tractor-trailer volumes on roads within each group may have similar travel characteristics, but the single-unit truck volume patterns are quite different from each other. By changing the road groups, it may be possible to classify roads so that all roads have similar travel patterns for single-unit trucks, but then the single tractor-trailer patterns become highly variable.

At some point, the analyst will need to determine the proper balance between the precision of the group factors developed for these two classes of trucks, or they will have to accept different factor groups for different vehicle classes. Each road may end up in multiple factor groups depending on what vehicle classification volume is being factored. Use of multiple groups may result in a more accurate factor process but will certainly result in a more complicated and confusing procedure.

The trade-offs between alternative factor groups can only be compared by understanding the value of the precision of each statistic to the data user. In most cases, this is simply a function of determining the relative importance of different statistics. For example, if 95 percent of all trucks are

single tractor-trailer trucks, then having road groups that accurately describe tractor-trailer vehicle patterns is more important than having road groups that accurately describe single-unit truck patterns. Similarly, if single-unit trucks carry the predominant amount of freight (this occurs in mineral extraction areas), then the emphasis should be on forming road groups that accurately measure single-unit truck volume patterns.

The quality of a given factor group can be examined in two ways. The first is to examine graphically the traffic patterns present at each site in the group. Figure 3-8 is an example of a set of monthly truck volume patterns for a group of sites in Washington State that could be considered a single factor group. Graphs like these give an excellent visual description of whether different data collection sites have similar travel patterns. The second method is to compute the mean and standard deviation for various factors that the factor group is designed to provide. If these factors have small amounts of deviation, the roads can be considered to have similar characteristics. If the standard deviations are large, the road groupings may need to be revised.

FIGURE 3-8 **RATIO OF AVERAGE WEEKDAY TRAFFIC PER MONTH TO ANNUAL AVERAGE DAILY TRAFFIC FOR COMBINATION TRUCKS (FHWA CLASSES 8-10) AT INTERSTATE SITES**
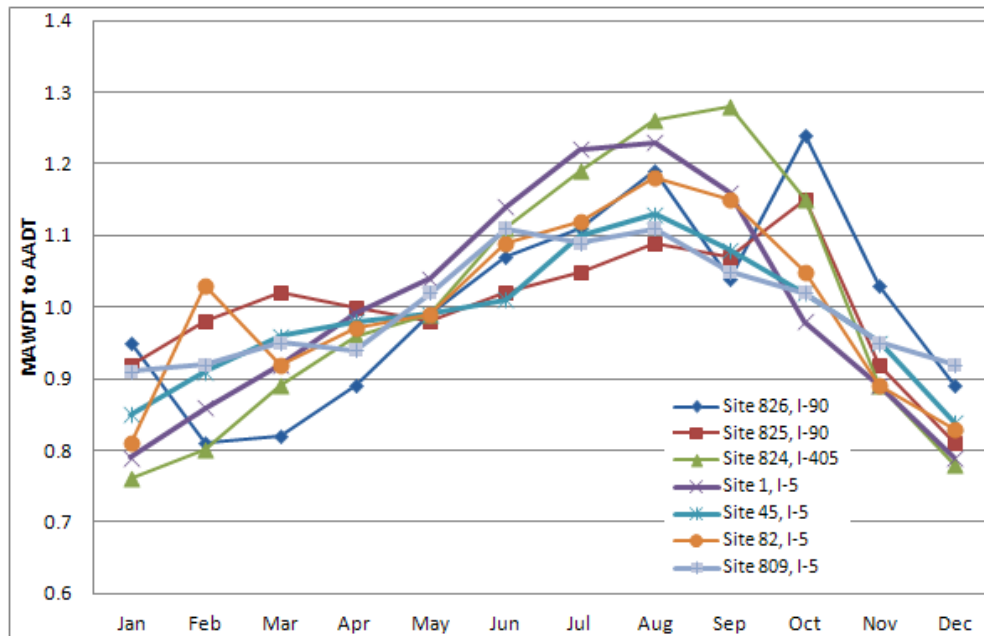
Source: *Federal Highway Administration.*

Determine the Precision of the Factor

An estimate of the precision of the group factor can be derived from the standard deviation. For example, the precision of the June adjustment factor computed above can be estimated using the standard deviation of that estimate. The precision of the group factor can be estimated with 95 percent confidence as approximately plus or minus 1.96 times the standard deviation divided by the square root of the number of sites in the group. (This is a relatively crude approximation because it assumes that the standard deviation calculated from the seven sample sites is equal to the actual standard deviation of the population of the group of roads. The value 1.96 should be used only for sample sizes of 30 sites or more. A more statistically correct estimate would use the student's *t* distribution, which for six degrees of freedom (seven classification sites) is 2.45. The calculation also assumes that the factors are normally distributed and that sites are randomly selected.)

Increasing the number of continuous counter locations within a group will improve the precision of the group factor. However, increasing the number of continuous classification counter locations only marginally improves the precision of the group factor application at specific roadway sections. That is, increasing the sample size makes the group factor itself a better measure of the mean for the group, but the mean value may or may not be a good estimate of the pattern at any given roadway section within that group. The standard deviation of the group factor measures the diversity of the site factors within the group.

There can be cases where the factors will not improve the annual volume estimates, particularly in high variability situations. An alternative is to take multiple site-specific classification counts at different times during the year to measure seasonal change. This can be an effective way to estimate annual individual vehicle traffic accurately for high profile projects that can afford this additional data collection effort. This alternative can also be used to test the accuracy of the annual estimates derived from the group factors.

Refine the Factor Groups

If the factor groups selected have reasonably homogenous travel patterns (i.e., the variability of the factors is low), then the groups can be used for factor development and application. If the factors for the group are too variable, then the groups may need to be modified. These modifications can include the creation of new groups (by removing the roads represented by some continuous classification counters from one group and placing them in a new group), and the realignment of counters within existing groups (by shifting some classification counters and the roads they represent from one existing factor group to another). This process continues until a judgment is made that the groups are adequate.

Be aware, as noted earlier, that if precise adjustment factors are desired, it is possible that the factor process will require different factor groups for each vehicle class. That is, traffic patterns for combination trucks may be significantly different (and affected by different factors) than the traffic patterns found for smaller, short-haul trucks. These patterns may in turn be sufficiently different from passenger vehicle patterns that three different factor groupings may need to be developed. In such a case, passenger car volumes may need to be adjusted using the State's existing factor process since total volume tends to be determined by passenger car volumes in most locations, while single unit trucks are factored with data obtained from different groups of counters. Combination trucks are factored with counts obtained from those same counters but aggregated in a different fashion. Then the three independent volume estimates will need to be added to produce the total AADT estimate.

Step 6. Determine the Appropriate Number of Continuous Vehicle Classification Locations

Once groups have been established and the variability of the group factors computed, it is possible to determine the number of count locations needed to create and apply factors for a given level of precision. Note that because each statistic computed for a group has a different level of variability, each statistic computed will have a different level of precision.

The first step in determining the number of sites per group is to determine which statistics will guide the decision. In general, the key statistics are those that define the objective of the formation of groups, that is, the correction for temporal bias in truck volumes. The combined DOW and monthly factor, computed for the truck-trailer combination vehicles during the months when short duration counts are taken, may well be the most appropriate statistic to guide the group size for the interstate/arterial groups. For other groups, the single-unit truck may be more appropriate.

If counts are routinely taken over a nine-month period, the one month with the most variable monthly adjustment factor (among those nine months) should be used to determine the variability of the adjustment factors and should thus be used to determine the total sample size desired. In that way, factors computed for any other month have higher precision.

For most factor groups, at least six continuous counters should be included within each factor group. This is an initial estimation based on AADT factor groups. If it is assumed that some counters will fail each year because of equipment, communications, or other problems, a margin of safety may be achieved by adding additional counters.

Collect Additional Data and Refine the Established Process

States are encouraged to convert as many of their continuous counters to classification as possible and to analyze the available data to understand individual vehicle travel patterns and variation. A substantial continuous vehicle classification program allows States to refine the classification count factoring process as needed. The addition of new continuous count locations allows the comparison of newly measured truck travel patterns with previously known patterns. This is true even for the road-specific factoring procedure, since traffic patterns along a road can change dramatically from one section to another. One way of adding new count locations is to move counter locations when equipment or sensors fail and need replacement at an existing continuous site.

If a new data collection site fits well within the expected group pattern, that site can be incorporated into the factor group. However, if a new site shows a truck travel pattern that does not fit within the expected group pattern, a reassessment of the truck volume factoring procedures may be appropriate. Modifications include moving specific roads or road sections from one factor group to another, creating new factor groups, and even revising the entire classification factoring process.

The factoring process should be reviewed periodically to ensure that it is performing as intended. For the first few years after initial development or until the process has matured, these evaluations should be conducted every year. After that, the classification process should be reviewed periodically every three years (or the same review cycle used for the AADT group factor process).

Motorcycle Correction Factors

Current practice applies seasonal adjustments to the total volume and then estimates volumes for vehicle types using the observed classification proportions. This will work fine if the traffic profile of all vehicle types is the same as the total volume profile. Otherwise, traffic volume for some vehicle types will be under-estimated or over-estimated.

The day of week traffic pattern for motorcycles differs from that of other vehicle types, so short counts for motorcycles should be factored. The *TMG* allows flexibility in the creation of DOW factors. It suggests that factors may be computed on an individual basis (seven daily factors) or as combined weekday and weekend factors. The definition of "weekday" and "weekend" is a function of traffic patterns. In urban areas, Fridays are more similar to weekdays than weekends. In some rural areas, they are closer to weekends. It is also permissible to treat weekdays as Monday – Thursday; treat weekends as Saturday and Sunday, and treat Fridays as a third factor adjustment group.

In practice, few short duration counts are taken on weekends, unless the State performs seven day short duration counts, so the only data available for weekends are from continuous traffic counters and classifiers. This is a problem for correctly estimating motorcycle VMT, as motorcycles may have significant weekend travel on routes or areas that are not near a continuous classifier, therefore underestimating annual motorcycle VMT, which is an important statistic for evaluating the safety of motorcycle travel. The solution is to: 1) install additional continuous vehicle classifiers; 2) make sure that at least some of the available permanent classifiers are placed on roads that are used for recreational motorcycle travel; or 3) take classification counts that include some weekdays and extend over weekends where recreational motorcycle travel is expected to occur in order to account for differences in DOW motorcycle travel on those roads.

The following example shows how to estimate correctly the annual average daily motorcycle traffic (AADMT). First, take the data from a continuous automatic vehicle classifier and determine the monthly average daily traffic (MADT) for the total volume. The seasonal (monthly) factors are the ratio of the MADTs with the AADT.

TABLE 3-6   MOTORCYCLE TRAFFIC ESTIMATION

Month	Monthly ADT	Monthly Factor
January	47,376	1.05
February	45,285	1.10
March	50,574	0.99
April	51,040	0.98
May	51,662	0.97
June	52,320	0.95
July	51,320	0.97
August	52,416	0.95
September	50,824	0.98
October	51,564	0.97
November	49,188	1.02
December	45,806	1.09
AADT	49,948	1.00

Next, calculate the average daily traffic by vehicle type for each day of the week for the year. Then compute DOW motorcycle correction factors (MCF) as the ratio of the annual ADMT and the DOW ADMT. Table 3-7 shows an example of the annual ADMT by day of week.

TABLE 3-7   ADMT BY DAY OF WEEK

Day	ADMT	Resulting MC DOW Factors
Monday	396	1.26
Tuesday	403	1.24
Wednesday	405	1.23
Thursday	428	1.17
Friday	655	0.76
Saturday	725	0.69
Sunday	483	1.03
ADMT	499	

1. Compute the Monday MCF = $ADMT_M$/Monday ADMT
in this case 499/396 = 1.26

2. Compute the Tuesday MCF = $ADMT_{Tu}$/Tuesday ADMT
in this case 499/403 = 1.24

3. Compute the Wednesday MCF = $ADMT_W$/Wednesday ADMT
in this case 499/405 = 1.23

4. Compute the Thursday MCF = $ADMT_{Th}$/Thursday ADMT
in this case 499/428 = 1.17

5. Compute the Friday MCF = $ADMT_F$/Friday ADMT
in this case 499/655 = 0.76

6. Compute the Saturday MCF = ADMT$_{Sa}$/Saturday ADMT
in this case 499/725 = 0.69

7. Compute the Sunday MCF = ADMT$_{Su}$/Sunday ADMT
in this case 499/483 = 1.03

Therefore, a short class count would first be factored for seasonality and then for the day of week. As an example, at a short term monitoring site on the same route as the above site 10 miles to the south, two class counts were taken on weekdays in August with the following results for motorcycles.

TABLE 3-8   ADT CALCULATION EXAMPLE

Date	ADMT	ADT
Aug. 14 (Tues)	518	50,761
Aug. 15 (Wed)	494	51,231
Average	506	50,996

Since we are using separate DOW factors, we will do the adjustments and then average the adjusted values. The two counts are adjusted using both the seasonal (monthly) factor for August, which is 0.95, and the appropriate DOW factors (1.24 and 1.23 respectively).

$518 \times 0.95 \times 1.24 = 610$

$494 \times 0.95 \times 1.23 = 577$

These two AADMT estimates are then averaged to provide the estimate of AADMT.

$(610 + 577) / 2 = 594$

Because of the special DOW MC factors, weekday motorcycle counts are increased to more accurately estimate the average annual daily motorcycle travel. This takes into account the likelihood of higher weekend motorcycle travel. The other vehicle classes would need to be adjusted for the day of week, too, so that the total volume is correct.

This same process should be performed with each of the vehicle classes. At the end of the process, the total of the different vehicle classes should then be compared against the AADT computed for the volume only factor and the various volumes adjusted proportionately to account for any differences in those two AADT estimates. (The AADT computed from volume only will be the more accurate estimate of total volume and should serve as the control total.)

A simplified example is shown in Table 3-9 below. (Note that this table shows the different day of week and monthly adjustments for each class.)

TABLE 3-9   MOTORCYCLE ADT EXAMPLE

Date	MC Volume	PV Volume	LT Volume	Bus Volume	SU Volume	CU Volume	ADT
Aug. 14 (Tues)	518	30,705	11,215	58	4,103	4,162	50,761
Aug. 15 (Wed)	494	31,689	11,834	48	3,697	3,469	51,231
Tuesday Factor	1.24	1.02	1.02	1.06	0.88	0.8	
Wednesday Factor	1.23	1.00	1.00	1.03	0.89	0.79	
August Factor By Class	0.95	0.97	0.97	0.81	0.84	0.91	
AADT Based	610	30,380	11,096	50	3033	3030	48,199

Date	MC Volume	PV Volume	LT Volume	Bus Volume	SU Volume	CU Volume	ADT
on Tuesday							
AADT Based on Wednesday	577	30,738	11,479	40	2764	2,494	48,092
Average	594	30,559	11,288	45	2898	2,762	48,145
AADT computed from total volume = (50,761 + 51,231) × 0.95 × 0.98 DOW factor) =							47,477
Difference of average computed from total volume minus average computed by class specific factors and then summed							-668
Fraction of Traffic	0.012	0.635	0.234	0.001	0.060	0.057	
Proportional Adjustment (Fraction of Vehicles × Error)	-8	-424	-157	-1	-40	-38	
Final AADT by Class (Volume + Proportional Adjustment)	585	30,135	11,131	44	2,858	2,724	47,477

This example illustrates the need for adjusting vehicle classification volumes if applicable. Section 3.3.5 discusses the important reasons for collecting motorcycle data and describes the uses of this data.

3.2.4 WEIGHT

This section examines the alternatives for collecting truck weight information and introduces truck weight data collection technology and data collection strategies. The basic user needs for truck weight data are identified and recommendations are made for a truck weight data collection program to meet those needs. Additional information regarding equipment validation for weigh-in-motion (WIM) equipment is found in Appendix F.

Gathering truck weight data is the most difficult and costly of the four primary data collection activities. However, in many respects this data is the most important.

Data on the weight carried by trucks is used as a primary input to a number of a State highway agency's most significant tasks. For example, traffic loading is a primary factor in determining the depth of pavement sections. It is used as a primary determinant in the selection of pavement maintenance treatments. The total tonnage moved on roads is used to estimate the value of freight traveling on the roadway system and is a major input into calculations for determining the costs of congestion and benefits to be gained from new construction and operating strategies. Vehicle classification and weight information is also a key component in studies that determine the relative cost responsibility of different road users. The number, weight, and configuration of trucks are also major factors in bridge design and the analysis of expected remaining bridge life.

Figure 3-9 summarizes the steps for creating and maintaining the weight portion of the continuous data program.

FIGURE 3-9 STEPS FOR CREATING AND MAINTAINING A CONTINUOUS DATA PROGRAM
WEIGHT

1: Review Existing Weight Data Collection Program

2: Develop Inventory Of Available Weight Data Collection Locations & Equipment

3: Determine Roadway Weight Groups To Be Monitored

4: Establish Roadway Weight Groups

5: Determine Appropriate Number Of Weight Data Collection Locations

6: Determine The Number Of Days That Should Be Counted At A Given WIM Site

7: Select WIM Sites

8: Integrate WIM Sites With Remaining Count Program

Source: Federal Highway Administration.

Step 1. Review the Existing Weight Data Collection Program

Of all the traffic monitoring activities, WIM requires the most sophisticated data collection sensors, the most controlled operating environment (strong, smooth, level pavement in good condition), and the most costly equipment set up and calibration. (An excellent introduction to WIM is provided in the reference, *State's Successful Practices Weigh-in-Motion Handbook* by McCall, Bill, and Vodrazka, Walter, FHWA, December 1997.) It is important that the review take into account these complex requirements.

Heavy Vehicle Weight User Needs

In addition to reviewing the physical requirements for WIM systems, the needs of the users should be taken into account.

Heavy vehicle weight data is used for a wide variety of tasks. (In the *TMG*, heavy vehicle refers to buses and heavy trucks, not light trucks such as pick-ups. However, the term "truck" often references these vehicles as well, so often the terms are interchangeable.) These tasks include, but are not limited to, the following:

- Pavement design;
- Pavement maintenance;
- Bridge design;
- Geometric design;

- Air quality;

- Pavement and bridge loading restrictions;

- Development and application of equitable tax structures;

- Determination of the need for and success of weight law enforcement actions;

- Determination of the need for geometric improvements related to vehicle size, weight, and speed;

- Determination of the economic value of freight being moved on roadways; and

- Determination of the need for and effect of appropriate safety improvements.

Truck Weight Data Summaries

State highway agencies summarize and report truck weight data in many ways. Three types of summaries are commonly used including:

- Gross vehicle weight (GVW) per vehicle (usually by vehicle class);

- Load spectra, which are axle load distribution by type of axle (singles, tandems, tridems, quads) for specific vehicle types, are used as inputs to the *Mechanistic-Empirical Pavement Design Guide* for pavement design and pavement analysis; and

- Equivalent single axle load (ESAL) values, which are developed from load spectra data and are used to both summarize and simplify those load spectra, are used as key inputs to the traditional AASHTO pavement design procedures. ESALs are most commonly reported for specific vehicle types. (ESALs are a measure of pavement damage developed by AASHTO researchers in the 1960s that are used for pavement design by many current design procedures. They are computed from load spectrum. For an example of this computation, see Table 3-11. Because of limitations in their use for pavement design, the use of ESALs is being phased out of many pavement design analyses. While ESALs have limitations as a measure of traffic loading for pavement design, they are still a very useful way of comparing the relative pavement damaging potential of different load spectrum. Consequently, they are a useful measure for grouping "like" load spectrum. Other summary statistics, such as GVW or the percent of axles equal to or greater than the legal limit, can also be used in place of ESALs to group or compare load spectrum. Each has limitations, and at the time of this writing, no single statistic has been widely adopted at the national level to replace the traditional ESAL as a way of describing a load distribution. Thus, ESALs are used to simplify the grouping and description of load spectrum in this chapter.)

Finally, it is important to note that for roads with separated right-of-way for different directions of travel, the two different directions of travel can be placed in different groups. For example, the loaded direction might be assigned to a group with a heavy loading pattern, while the other direction of travel (the side carrying primarily empty trucks) might be assigned to a light group. When the two directions share a single pavement design, the entire road should be assigned to the heavier group for pavement design purposes.

Summary statistics such as the GVW or ESAL for a given vehicle classification can be expressed as distributions, as mean values, or as mean values with specified confidence intervals, depending on the needs of the analysis that will use this information. Each of these summary statistics can be developed for a specific site, a group of sites, or an entire State or geographic region, depending on the needs of the analysis and the data collection and reporting procedures.

The role of the traffic-monitoring program is to provide the user with the data summaries needed. The summaries can be required for any one of several levels of summarization. For example, it may be appropriate to maintain axle-loading distributions for each of the FHWA heavy vehicle classes (classes four through thirteen, see Appendix A for definitions of the FHWA 13 vehicle classes) so that these statistics are available when needed for pavement design – such as with the new AASHTO

Mechanistic-Empirical Pavement Design Guide (MEPDG). It is recommended that the per vehicle record axle loading (all or 4-13) be stored since it offers the most detail for later reporting. However, even if a more aggregated classification system is used for most analyses by an agency, the more detailed data collected by WIM systems should be retained for later use, as this raw data is the only source of other key statistics needed for some key analyses – such as the headway between trucks, or studies looking at changes in the truck characteristics like average tandem axle spacing – which are used as engineering design assumptions.

The primary truck weight summary statistics can be computed with FHWA's TMAS software, with software supplied by the WIM system vendor, or with software developed specifically for use by the State highway agency as part of its traffic database. Less commonly used statistics (e.g., the MEPDG uses as an input the percentage of heavy truck axle spacings greater than 12 feet but less than 15 feet) can be extracted from the individual vehicle records obtained from a WIM system with other commonly available analytical software packages.

A single statewide average statistic such as ESAL per truck may not be applicable to all parts of the State. Trucking characteristics can vary significantly by type of road or by geographic area within a State. When a single statewide summary is not representative of all roads, it is important to collect data and maintain summary statistics for different regions or roads in the State. For example, the truck traffic in urban areas often has different truck weight characteristics than those in rural areas. Roads that serve major agricultural regions often have different loading characteristics than roads that serve resource extraction industries. Roads that serve major industrial areas within an urban area tend to carry much heavier trucks than roads that serve general urban and suburban areas. Roads that serve major through-truck movements often experience different truck weights than roads that serve primarily local truck traffic. An effective truck weight program must identify these differences and include a data reporting mechanism to provide users with data summaries that correctly describe specific characteristics.

Truck Loading Estimates

The basis for all truck loading estimates is the axle load distribution table, also called a load spectrum (or the plural form called spectra). A load spectrum is produced from the data collected by WIM systems. It describes the distribution of axle weights by type of axle (single, tandem, tridem, or quad) for each class of vehicles. Load spectra are frequently normalized so that the table shows the fraction of axles within specific weight ranges for a given class of vehicles. A load spectrum can be produced for one specific WIM site or as an average of several WIM sites. Table 3-10 shows an example of normalized load spectra for single and tandem axles for class 9 trucks. It shows the specific axle weight ranges into which axles are binned and the fraction of axles in each of those bins.

Once developed, load spectra are often converted into other statistics. For traditional pavement design efforts, ESAL values are computed per truck, by classification of the truck. However, many States are moving towards use of the new *AASHTO Mechanistic-Empirical Pavement Design Guide* for many of their more significant pavement analyses. The MEPDG does not use ESALs, but instead directly uses normalized load spectra as inputs. Thus, agencies should use their WIM data to develop the normalized load spectra needed for pavement design, and make sure those load spectrum are given to their pavement design offices.

TABLE 3-10   EXAMPLE OF A NORMALIZED LOAD SPECTRUM FOR VEHICLE CLASS 9 SINGLE AND TANDEM AXLES

Single Axles			Tandem Axles		
Lower Bound (Pounds)	Fraction of Single Axles	Upper Bound (Pounds)	Lower Bound (Pounds)	Fraction of Tandem Axles	Upper Bound (Pounds)
0	0.00	3,000	0	0.00	6,000
3,001	0.00	4,000	6,001	0.00	8,000
4,001	0.01	5,000	8,001	0.01	10,000
5,001	0.01	6,000	10,001	0.02	12,000
6,001	0.01	7,000	12,001	0.03	14,000
7,001	0.01	8,000	14,001	0.05	16,000
8,001	0.01	9,000	16,001	0.06	18,000
9,001	0.05	10,000	18,001	0.07	20,000
10,001	0.22	11,000	20,001	0.08	22,000
11,001	0.34	12,000	22,001	0.08	24,000
12,001	0.18	13,000	24,001	0.08	26,000
13,001	0.05	14,000	26,001	0.08	28,000
14,001	0.02	15,000	28,001	0.10	30,000
15,001	0.02	16,000	30,001	0.14	32,000
16,001	0.03	17,000	32,001	0.13	34,000
17,001	0.02	18,000	34,001	0.06	36,000
18,001	0.01	19,000	36,001	0.02	38,000
19,001	0.00	20,000	38,001	0.00	40,000
20,001	0.00	21,000	40,001	0.00	42,000
21,001	0.00	22,000	42,001	0.00	44,000
22,001	0.00	23,000	44,001	0.00	46,000
23,001	0.00	24,000	46,001	0.00	48,000
24,001	0.00	25,000	48,001	0.00	50,000
25,001	0.00	26,000	50,001	0.00	52,000
26,001	0.00	27,000	52,001	0.00	54,000
27,001	0.00	28,000	54,001	0.00	56,000
28,001	0.00	29,000	56,001	0.00	58,000
29,001	0.00	30,000	58,001	0.00	60,000
30,001	0.00	31,000	60,001	0.00	62,000
31,001	0.00	32,000	62,001	0.00	64,000
32,001	0.00	33,000	64,001	0.00	66,000

These normalized load spectra will not only be useful within the MEPDG, they are also used to compute a variety of other key weight statistics. They are the basis for computing the ESAL/truck values used in the traditional (1993) *AASHTO Guide for Design of Pavement Structures*. They also allow the computation of statistics such as the average GVW per truck.

Load spectra and the resulting ESAL and GVW statistics can be derived directly only from WIM sites. Because WIM equipment is expensive to install and maintain, WIM data is available at only a few

locations in the State. Thus, at most road sites, truck weight data items cannot be measured directly. Instead, the needed data is obtained by combining a representative, normalized axle load spectra collected elsewhere in the State and a site-specific count of volume by vehicle classification. Multiplying the truck volumes taken from the site specific count (adjusted for DOW and seasonal variation) by the load spectra and other factors associated with the load spectra, which describe the number of axles carried by each type of truck, yields the required site-specific estimate of traffic loading for that site.

That is, the site-specific classification count is used to determine how many trucks of a particular type travel on the road. The WIM data determines how many axles of each type are present for each class of trucks and how heavy each of those axles is likely to be. For example, if a road section carries 100 Class 9 trucks in a day, it experiences approximately 100 single axles and 200 sets of tandem axles. (Directions for developing and applying representative load spectra are given later in this chapter.)

Multiplying the number of trucks within a given class by the average GVW for vehicles of that class yields the total number of tons applied by that class on that roadway. (Note that this value is the total tons of load carried by the roadway, not the total net tonnage of goods carried over that road (i.e., gross weight applied, not net commodity weight carried.)) Adding these values across all vehicle classes yields the total number of tons carried by that road. These values can be plotted graphically, creating an image similar to a traffic volume flow map (Figure 3-10). (The accuracy of these estimates is a function of the quality of the volume by vehicle classification estimate and the degree to which the GVW/vehicle value represents the trucks using that roadway. Like all flow maps, extrapolation is required to produce the map, and users should not assume high levels of precision when reading directly from such a map.)

The graphics are useful for both public presentations and as an information tool for decision makers. Map displays allow decision makers to graphically compare roads that carry large freight volumes with roads with light freight movements. The information can also be used to help prioritize potential road improvement projects.

The axle distribution by axle weight range can also be easily converted into equivalent single axle loads (ESAL), the most common pavement design loading value currently used in the United States. To make this conversion, an ESAL (ESAL varies with pavement characteristics, flexible (asphalt) or rigid (Portland cement) pavement) value is assigned to each axle weight category for each type of axle (single, tandem, tridem, quad). This value times the number of axles within that weight range yields the total ESAL load for that type and weight range of axles. Summing these values across all axle types and weight ranges yields the total number of ESALs applied to that roadway (Table 3-11).

Finally, understanding and accounting for monthly variations in vehicle weights is becoming increasingly important for both economic analyses and pavement design procedures. New pavement design procedures being developed and refined require traffic-loading data for specific times of the year. For example, in many colder regions proposed pavement design procedures will require the average daily loading rate during the spring thaw period because the pavement will be designed to withstand loads when the roadway structure is at its weakest. Since pavement strength changes with many environmental conditions, the pavement designers are likely to require data on loads at different sites at different times during the year. The traffic data collection process should be able to detect and report differences if loads vary (because the number of trucks or the weights of individual trucks vary) during the year. Otherwise, the pavement design procedures will be unreliable.

FIGURE 3-10   EXAMPLE GVW FLOW MAP

Greater than 10M tons per year ————

5 to 10 M tons per year ————

Less than 5 M tons per year ————

Source: Federal Highway Administration.

TABLE 3-11   EXAMPLE DAILY LOAD DISTRIBUTION TABLE (ALL VEHICLE CLASSES COMBINED) AND COMPUTATION OF TOTAL (FLEXIBLE) ESAL LOADING

SINGLE AXLES			TANDEM AXLES			TRIDEM AXLES		
Upper Weight Range (Pounds)	ESAL Per Axle	Number of Axles	Upper Weight Range (Pounds)	ESAL Per Axle	Number of Axles	Upper Weight Range (Pounds)	ESAL Per Axle	Number of Axles
3,000	0.000	5	6,000	0.000	4	12,000	0.000	0
4,000	0.000	7	8,000	0.000	16	15,000	0.000	0
5,000	0.000	51	10,000	0.000	24	18,000	0.000	0
6,000	0.000	31	12,000	0.000	36	21,000	0.000	0
7,000	0.014	37	14,000	0.020	34	24,000	0.048	0
8,000	0.026	75	16,000	0.036	37	27,000	0.079	0
9,000	0.044	99	18,000	0.061	33	30,000	0.126	0
10,000	0.071	97	20,000	0.097	28	33,000	0.191	0
11,000	0.108	78	22,000	0.148	23	36,000	0.278	0
12,000	0.158	56	24,000	0.217	19	39,000	0.393	0
13,000	0.224	40	26,000	0.309	20	42,000	0.539	0
14,000	0.310	22	28,000	0.425	22	45,000	0.722	1
15,000	0.416	16	30,000	0.572	29	48,000	0.947	0
16,000	0.547	16	32,000	0.752	29	51,000	1.217	0
17,000	0.706	13	34,000	0.757	30	54,000	1.537	2
18,000	0.894	13	36,000	1.229	25	57,000	1.912	1
19,000	1.115	11	38,000	1.532	17	60,000	2.346	3
20,000	1.371	10	40,000	1.884	15	63,000	2.843	1
21,000	1.664	7	42,000	2.288	8	66,000	3.408	0
22,000	1.999	6	44,000	2.747	7	69,000	4.046	0
23,000	2.376	5	46,000	3.267	5	72,000	4.763	0
24,000	2.801	3	48,000	3.850	2	75,000	5.563	0
25,000	3.275	1	50,000	4.502	3	78,000	6.453	0
26,000	3.804	1	52,000	5.229	1	81,000	7.441	0
27,000	4.390	1	54,000	6.035	1	84,000	8.534	0
28,000	5.039	1	56,000	6.927	1	87,000	9.740	0
29,000	5.756	0	58,000	7.913	0	90,000	11.070	0
30,000	6.546	0	60,000	8.999	0	93,000	12.532	0
31,000	7.416	0	62,000	10.194	0	96,000	14.138	0
32,000	8.371	0	64,000	11.506	0	99,000	15.900	0
33,000	9.419	0	66,000	12.947	0	102,000	17.831	0
34,000	10.567	0	68,000	14.525	0	105,000	19.942	0
35,000	11.824	0	70,000	16.253	0	108,000	22.250	0
36,000	13.197	0	72,000	18.140	0	111,000	24.769	0
37,000	14.696	0	74,000	20.201	0	114,000	27.514	0
38,000	16.331	0	76,000	22.448	0	117,000	30.503	0

SINGLE AXLES			TANDEM AXLES			TRIDEM AXLES		
Upper Weight Range (Pounds)	ESAL Per Axle	Number of Axles	Upper Weight Range (Pounds)	ESAL Per Axle	Number of Axles	Upper Weight Range (Pounds)	ESAL Per Axle	Number of Axles
39,000	18.111	0	78,000	24.895	0	120,000	33.753	0
40,000	20.047	0	80,000	27.556	0	123,000	37.283	0
41,000	22.149	0	82,000	30.446	0	126,000	41.111	0
Total ESAL by type of axle (ESAL/axle × Total Axles)	169.8				269.7			15.6
Total ESAL (all axle types combined)	455.1							

Source: Federal Highway Administration.

Step 2. Develop An Inventory Of Available Weight Data Collection Locations And Equipment

The State should conduct a detailed inventory of its WIM assets. WIM systems are designed to measure the vertical forces applied by axles to sensors in the roadway even while the truck continues to travel down the highway. This measurement helps estimate the weight of those axles if the truck being weighed were stationary. The task is complicated by a number of factors, including the following:

● Each sensor feels the vertical force of each axle for only a brief time.

● The weight reported by the WIM scale based on that measurement is approximately equal to the static weight of that axle. It varies because while the vehicle is in motion, the truck and its components bounce up and down. If the truck mass is moving upward when an axle crosses the WIM sensor, the weight applied by that axle is lower than the static value. If the truck mass is landing, the weight applied is greater than the static value. (In addition, truck components such as shock absorbers are also in motion, affecting the axle weight at any given instant in time.) The scale systems are designed to account for this variation, but can only account for modest vertical truck movements.

● Some sensors (strip sensors) feel only a portion of the tire weight at any given time. Because the sensor is smaller than the footprint of the tire, the pavement surrounding the sensor physically supports some portion of the axle weight throughout the axle weight measurement.

● Sensors should be capable of weighing more than one axle in quick succession. That is, the sensor should be able to recover quickly enough so that one axle weight does not affect the measurement of the following axle.

● Roadway geometries such as grade, slope, horizontal and vertical curves can cause shifts in vehicle weight from one axle to another, which would not be present if the truck was at rest on a flat scale platform.

● Vehicle acceleration or braking, torque from the drive axles, wind, the style and condition of vehicle's suspension system, and a variety of other factors can also cause shifts of weight from left to right and one axle to another.

The effects of many of these factors can be minimized through careful design of the WIM site. The site should be selected and designed to reduce the dynamic motion of passing vehicles. However, achieving these design controls requires restrictions on site selection, which means that WIM systems

cannot be placed as easily or as universally as other traffic monitoring equipment. In particular, they should not be placed in rough pavement or pavement that is in poor condition. To help States identify those locations where pavement conditions are conducive to the placement and operation of WIM equipment, the FHWA-LTPP program has developed a software module called the Optimal WIM Locator (OWL) that is part of the Profile Viewing and Analysis (ProVAL) software system. The OWL software uses pavement profile information to identify optimal WIM sensor locations. Both ProVAL and the OWL module are free. Information on both ProVAL and the OWL module can be obtained through the LTPP Customer Support Service Center. WIM scales work most accurately when they are placed flush with the roadway. Sensors that sit on top of the roadway cause two problems with WIM system accuracy: 1) They induce additional short wave length dynamic motion in the vehicle; and 2) They can cause the sensor to measure the force of tire deformation (which includes a horizontal component not related to the weight of the axle) in addition to the axle weight. This means that permanent installation of the sensors and/or frames that hold the sensors is normally better for consistent, accurate weighing results. The use of permanently installed WIM sensors is recommended as a means of improving the quality of the data. (This recommendation does not prevent the use of less accurate portable equipment.)

Step 3. Determine The Roadway Groups To Be Monitored

The objective of the weight data collection program is to obtain a reliable measure of the axle weights and inter-axle spacings per vehicle.

The data collection plan for truck weight accounts for:

- The statistical needs of State and Federal agencies;

- The capabilities and limitations of WIM equipment;

- The resource constraints found at many State highway agencies; and

- The variability of truck weight data, as examined in the literature and as observed in data submitted to the FHWA.

The weight data collection program is based on collecting accurate axle weights for at least all heavy trucks that can be applied with confidence and statistical precision to all roads in a State. The procedure is to group the State's roads into categories, so that each of those groups experiences freight traffic with reasonably similar characteristics and/or which are subject to reasonably similar axle weight and GVW limits (and the seasonal variations of these limits). For example, roads that experience trucks carrying heavy natural resources should be grouped separately from roads carrying only light, urban delivery loads. The weight data collection program is analogous to the continuous count programs for collecting seasonal and DOW pattern information for volume and vehicle classification data. The primary difference is that some of the truck weight data collection sites do not need to be operated in a continuous manner. It is acceptable if they are in operation only periodically during the year to confirm the truck weight patterns occurring at that location.

Within each of these groups of roads, the State should operate a number of WIM sites. These sites will be used to identify weight patterns that apply to all roads in the group. Where possible (given budget and staffing limitations), at least two WIM sites within each group should be monitored continuously to provide more reliable measures of seasonal change. The proper number of continuous sites that a State should operate is primarily a function of:

- Each State's ability to supply the resources needed to monitor the sites to ensure the provision of accurate data throughout the year.

- The proven need to monitor differences in seasonal weight characteristics. (If extensive data collection shows that a group of roads has a very stable seasonal pattern, then relatively few continuous counters are needed to monitor the pattern. However, if the State has limited data on

seasonal weight patterns or if prior data collection has shown the pattern to be inconsistent, then a larger number of continuous counters may be needed.)

● Performing additional vehicle weighing, both by operating continuous WIM sensors and by collecting data at more than the minimum number of sensor sites, will allow a State to determine whether the initial groups selected carry similar truck traffic. Where new data collection shows that monitored roads do not carry traffic with loading characteristics similar to those of other roads in the group, the State should either create new road groups (and collect more truck weight information) or revise the existing road groups to create more homogeneous groups.

Step 4. Establish Roadway Weight Groups

Figure 3-11 illustrates the reason why roads should be stratified into road groups. It shows the distribution of tandem axle weights for Class 9 trucks from three different truck weight sites. Each of these three sites exhibits a significantly different set of loading conditions, ranging from heavily loaded to very lightly loaded. Use of loading information from one of these sites at either of the other two sites would result in poor load estimates. If the heaviest of these load spectra were used as input to the new mechanical-empirical pavement design guide, it would result in predicted pavement damage that is more than three times the amount of damage that would be predicted if the lightest of these load spectrum were used.

The key to the design of the truck weight data collection effort, and the use of the data that results from that process, is for the highway agency to be able to successfully recognize these differences in loading patterns, and to collect sufficient data to be able to estimate the loads that are occurring under these different conditions.

FIGURE 3-11   TANDEM AXLE LOAD DISTRIBUTIONS AT THREE SITES WITH DIFFERENT LOADING CONDITIONS
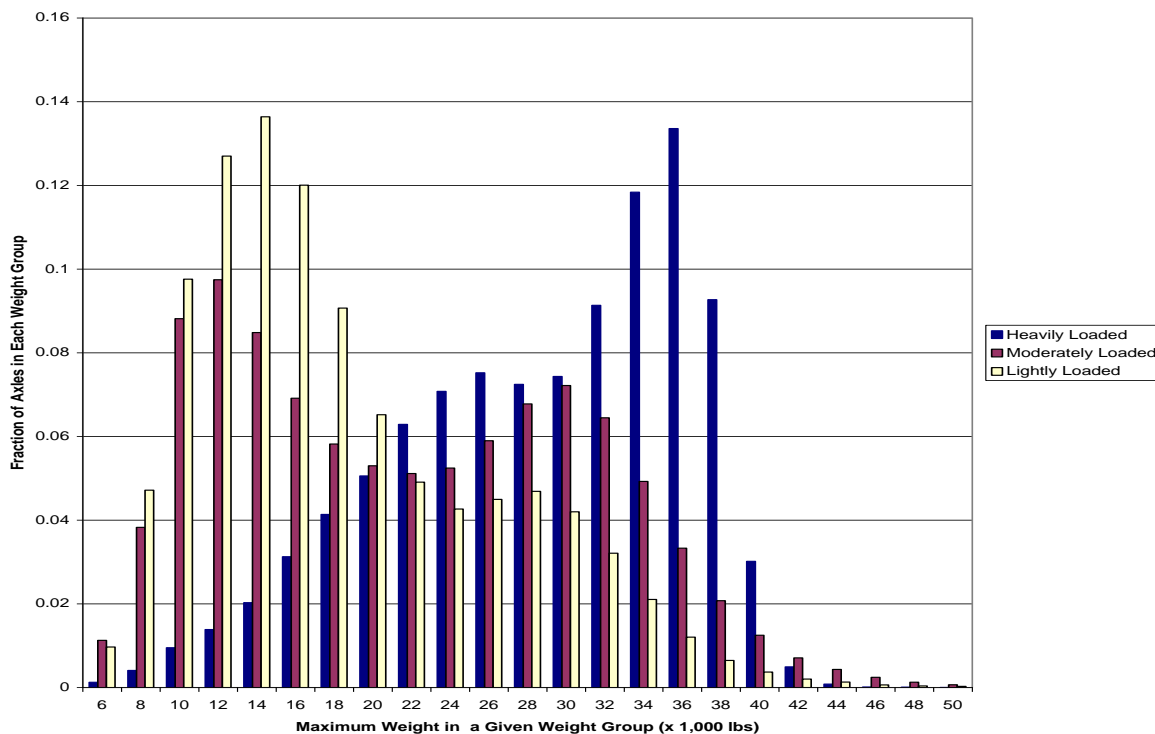
Source: Federal Highway Administration.

One important consideration when creating truck weight road groups is whether different road groups will be created for each class of heavy vehicle (meaning a specific road segment can be assigned to nine different groups – one for each class of heavy vehicle), or whether each road segment is assigned to only one group that is primarily formed based on the loads of the most common or voluminous heavy vehicles. The most common approach historically has been to assign each roadway to one and only one truck weight road group. However, the FHWA Long Term Pavement Performance (LTPP) project recently completed a report in 2012, *MEPDG Traffic Loading Defaults Derived from LTPP Pooled Fund Study*, which grouped WIM sites differently for each class of vehicles. By grouping each set of WIM sites differently for each class of heavy vehicles, the LTPP study team was able to create more standardized groups for each type of vehicle.

Regardless of whether a single road segment is assigned to one or more groups, two key aspects of group formation are:

- The truck loading patterns at sites within each group should be similar; and

- It should be relatively easy to accurately and consistently assign each road in the State to a group so that the group values can be applied as needed.

Finally, it is important to note that for roads with separated right-of-way for different directions of travel, the two different directions of travel can be placed in different groups. For example, the loaded direction might be assigned to a group with a heavy loading pattern, while the other direction of travel (the side carrying primarily empty trucks) might be assigned to a light group. Where the two directions share a single pavement design, the entire road should be assigned to the heavier group for pavement design purposes.

For the LTPP project's approach of assigning each site to multiple groups (one group per class of vehicle), the development of the groups is performed entirely mathematically. Analysis sites are then assigned to these groups based on professional knowledge. Because the assignment process has considerable error associated with it, users of the LTPP weight groups are strongly encouraged to apply sensitivity tests to their analyses that use these group load spectra (i.e., analysts are encouraged to perform their analyses at least twice, using two different load groups, to test the effects of potential errors caused by improper assignment of the roadway being analyzed to the wrong truck weight load groups).

Alternative Approaches to Forming Groups

As with the factor grouping processes described earlier for both vehicle classification and total volume, the basis for the group formation process can be either intuitive or mathematical, or some combination of these two approaches. The intuitive approach is where descriptive information is used along with professional knowledge to create groups of roads that should have similar truck loading patterns due to the nature of the truck traffic they carry. This approach is the easiest to apply but often produces groups that are more variable. The mathematical approaches (most commonly based on cluster analysis) generally create more homogeneous groups, but tend to result in groups that are harder to define, making assignment of roadway sections to groups more difficult. As a result, combination approaches are often tried that start with basic intuitive groups (e.g., geographic stratifications or geographic stratification along with descriptive road classifications such as urban/rural or interstate/non-interstate) and then apply cluster analysis within the initial groups to determine more uniform sub-groups within the basic geographic/roadway classifications.

Local Traffic Knowledge Grouping

With this approach, the initial roadway groups used to summarize truck weight characteristics should be based on a combination of known geographic, industrial, agricultural, and commercial patterns, combined with knowledge of the trucking patterns and legal weight limits that occur on specific roads. These initial concepts should then be tested by examining the actual truck weight data collected at WIM sites operated by the State to determine if roads that are expected to have similar

loading patterns have similar patterns. The intent is simply to identify those roads that trucks are heavily loaded versus those routes where large numbers of trucks are not carrying very heavy weights.

The resulting road groups for truck weight data should be easily identified by users of truck weight data within the State. They must provide a logical means for discriminating between roads that are likely to have very high load factors and roads that have lower load factors (i.e., between roads where most trucks are fully loaded and roads where a large percentage of trucks are either partially loaded or empty). In addition, States should incorporate knowledge about specific types of very heavy vehicles into their weight grouping process so that roads that carry those heavy trucks are grouped together, and roads that are not likely to carry those trucks are treated separately. For example, roads leading to and from major port facilities might be treated separately from other roads in that same geographic area, simply because of the high load factor that is common to roads leading to/from most port facilities.

In the 1990s, Australia proposed a similar grouping technique in the chapter on traffic data collection in its pavement design guide (Update of the *AUSTROADS Pavement Design Guide – Traffic Design Chapter, Final Draft Working Document*, September 1998.) In the Australian guide, 25 different truck-loading patterns are identified nationwide. These patterns are structured by type of trucking movement, and the infrastructure linkages being served. The Australian guide uses the following categories of haul activities:

- General Freight;
- General Freight in a Heavy Vehicle Increased Mass Permit Environment;
- Predominately Industrial;
- Quarry Products;
- Predominately Farm Produce;
- Live-Stock; and
- Logging Products.

NCHRP Project 1-37A, *Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures: Phase II* developed a similar set of truck weight loading groups from data available in the Strategic Highway Research Program's Long Term Pavement Performance project Central Traffic Database. The NCHRP project identified 17 different loading conditions and described them with terms similar to the short Australian list noted above.

For a State, it is reasonable to start with less detailed truck weight stratification than these approaches. In fact, unless State data suggests the need for a definitive grouping process, it is recommended that initial intuitive groups be based on a more simplistic approach. For example, insight into geographic differences in truck travel can be used along with the percentage of through-trucks that exist on a road to define roads where loading patterns are dominated by local industry or long haul truck traffic.

Other professional knowledge based criteria that can be used to create truck load groups include:

- The presence of agricultural products that create specific loading patterns and are carried in specific types of trucks. For example, wheat growing areas might need to be grouped separately from those that grow cherries because these two products have different densities, different weights on a truck, and because their harvest and hauling seasons are different.
- The types of industrial areas, such as resource extraction operations that ship large amounts of material by truck. For example, roads serving coal truck movements may be grouped separately from roads that experience few coal trucks.

- The distance over which the trucks are likely to travel. For example, roads where trucks deliver cargo over long distances across multiple States, or roads with truck travel between cities within a region where drivers can make a round trip in one day, or roads with truck travel within a general urbanized area where drivers make multiple trips in a day. Trucks traveling longer distances are more likely to be full, and thus heavier, than trucks operating within half a day of their base, which are likely to be full leaving their depot but are often empty when returning.

- Urban or rural roads, because urban areas often have considerably higher numbers of partially loaded trucks and trucks that travel empty after unloading at urban destinations. Note that some roads functionally classified as rural that are located between two large cities (say within 300 km or 180 miles of each other) may experience urban rather than rural trucking patterns because trucks routinely make day-trips between those cities, traveling full in one direction and possibly empty in the other.

This simplistic approach would then be improved (as needed) over time as more weight data is collected and analysis carried out. A State may also be interested in discriminating between roads because of the industrial activities they serve. For example, roads leading into and out of major seaports may experience far heavier traffic (higher load factors) than other roads in the same area. Much information can be extracted from existing truck weight databases and planning programs to determine logical and statistical differences that can be accounted for in the formation of truck weight groups.

As an example of a weight factor group, Washington State developed five basic truck-loading patterns as part of a study to determine total freight tonnage carried by all State highways. These five groups were defined as:

- Group A – Serves major statewide and interstate truck travel. These routes are the major regional haul facilities;

- Group B – Serves primarily intercity freight movements, with minor amounts of regional hauling. These routes also serve as produce transfer routes, serving rail and barge loading facilities;

- Group C – Serves farm to market routes and regional commerce;

- Group D – Serves suburban industrial activity; and

- Group E – Serves primarily local goods movement and specialized products.

A starting point for developing truck weight groups is shown in Table 3-12. The example begins with the groups identified in the vehicle classification section. The truck loading groups defined should be coordinated with the vehicle classification groups identified earlier. Differences in the two sets of groups are likely since the groups are defined to meet different purposes (seasonal differences in truck volume and loading variation). However, they both reflect truck travel characteristics that are directly related. A similar group definition will greatly simplify the understanding and applicability of the patterns. The groups may need further redefinition over time as information is gained.

TABLE 3-12   EXAMPLE TRUCK LOADING GROUPS

Rural	Urban
Interstate and arterial major through-truck routes	Interstate and arterial major truck routes
Other roads (e.g., regional agricultural with little through trucks)	Interstate and other freeways serving primarily local truck traffic
Other non-restricted truck routes	Other non-restricted truck routes
Other rural roads (mining areas)	Other roads (non-truck routes)
Special cases (e.g., recreational, ports)	

These are examples. Each State highway agency should select the appropriate number and definition of truck groups based on its economic and trucking characteristics and the need for heavy vehicle travel patterns in their State.

Cluster Analysis

The 2012 report, *MEPDG Traffic Loading Defaults Derived from LTPP Pooled Fund Study*, contains very detailed instructions on how to use cluster analysis to group load spectra. This document only summarizes that material.

The cluster process consists of the following steps:

1. Develop a normalized load spectrum from well-calibrated WIM scales for each WIM site.

2. Compute a single statistic for each load spectrum that represents the nature of that spectrum. For example, if the primary reason the group is being created is for pavement design, then convert the normalized load spectrum to some form of estimate of the average damage caused per axle. An ESAL is this type of statistic. One ESAL value should be computed for each normalized load spectrum. If the main use of the truck weight road group is for estimating total tonnage on State routes, then mean axle weight may be used as the best single statistic that represents each normalized load spectrum.

3. If the load spectra for all heavy vehicle classes at a WIM site are to be assigned to only one truck weight road group, determine how different loading patterns for each class of vehicle will be weighed. (This step is not necessary if groups will be formed for each type of axle for each class of vehicle.)

4. Perform a cluster analysis, stopping when clusters reach the point where the difference between clusters becomes large enough that the use of different clusters causes statistically different outcomes when used in planned analyses.

Steps 3 and 4 are discussed in more detail below. Step 1 requires no additional explanation. Step 2 has been demonstrated already in Table 3-11 above.

Step 3 determines how to handle grouping because different classes of trucks will have different patterns at any given site. That is, some classes of trucks will be heavier at one site (Site A) than at other sites (e.g., Sites B through G), while a different set of vehicle classes will be lighter at Site A than at the remaining sites. Finally, other vehicle classes will have very similar patterns. The difficult task in grouping these sites is determining how to weigh the relative importance of these different vehicle classification weight patterns.

For example, at Site A, the Class 9 truck weight pattern may be dominated by urban delivery trucking patterns where Class 9 trucks are equally split between load, unloaded, and partially loaded conditions. At the same site, Class 7 and Class 10 vehicles may all be carrying very heavy loads. At Site B, the majority of Class 9 trucks are fully loaded, while Class 7 and Class 10 are also carrying heavy loads. At Site C, the original Class 9 urban pattern is present, but the Class 7 and 10 vehicles are much lighter than elsewhere. In step 3, it is necessary to determine if these three sites should be grouped together or kept separately. (If groups are formed differently for each class of vehicles, Sites A and C would be grouped together for Class 9 trucks with Site B kept as a different group, but Sites A and B would be grouped together for Classes 7 and 10, with Site C separate this time.) If only one group can be formed, Step 3 should be used to determine which of these patterns is most important to the formation of the group.

If all vehicle classes are treated equally, a statistically based cluster analysis might group all three of these test sites or it might separate all three sites, depending on the criteria set when applying the clustering approach. However, not all trucks are equal. Some truck classes are heavier than others (Class 5 is considered a truck, but is generally so light it creates little pavement damage, while Classes 7 and 10 tend to always be heavy and can be extremely heavy.) Similarly, while some trucks are very heavy, there are often less of them compared to other moderately heavy trucks. Thus, while trucks in Classes 7 and 10 tend to be very heavy, in most States and on most roads, these classes are a very small percentage of truck traffic, and contribute a relatively modest amount of total pavement damage. On some roads, these trucks are very prevalent and drive the pavement design equation. In most cases, however, Class 9 tends to produce the vast majority of pavement loading from traffic. These trucks tend to be less damaging per vehicle, but they tend to constitute a very large percentage of truck volumes. Therefore, when deciding how to balance the importance of different truck classes to the grouping process, a combination of how heavy each class is and how frequently they are observed are important considerations.

While considerably more research is needed on the best methods for grouping truck-loading patterns, the recommendation in this report is to identify the one or two most significant truck patterns. This can be computed by multiplying the volume of that class of trucks times their average weight. Any truck class that provides more than 40 percent of the total load on a pavement should be considered in the grouping process.

This simplifies the grouping process, although it downplays the importance of lower volume truck classes in that process. States can always refine their grouping process to better account for lower volume classes as they refine their traffic-monitoring program.

In Step 4, the data that represents the vehicle class loading conditions being used to group sites are entered into a statistical clustering program. The output of that process can then be tested to determine the reliability of the groups created. (See subsection, "Testing the Quality of Selected Truck Weight Groups" on page 3-51.)

Combining the Intuitive and Clustering Approaches

The last approach described in this report combines features of the Intuitive and Clustering Approaches. In this approach, professional judgment is used to initially segregate roads into specific categories or groups. For example, based on data from classification counts, the State may know that specific roads carry large volumes of Class 7 and Class 10 trucks due to the nature of industry served by those roads (e.g., coal or other heavy natural resources.) These roads may be segregated from roads that carry more diverse heavy vehicle traffic prior to running cluster analyses. These roads may be used as one group, or a cluster analysis may be performed using only data from WIM sites on these special roads – using Class 7 and Class 10 loading conditions as the key cluster variable. A separate cluster analysis may then be applied – using Class 9 loading conditions as the cluster variable – for all other roads in the State.

This hybrid approach to truck weight road group creation is intended to improve the group creation process by allowing application of professional knowledge in limited ways, while preserving the statistical integrity of the group creation as much as possible with the clustering approach whenever current knowledge does not provide clear definition of truck load groups.

Testing the Quality of Selected Truck Weight Groups

Just as with the formation of groups used for factoring volume and classification counts, the initial formation of heavy vehicle weight groups should be reviewed to determine whether the road segments grouped together have similar truck weight characteristics. Examining available data from the existing truck weight sites is the first step. A substantial amount of judgment is required since the data is likely to be limited to that currently available from existing WIM sites.

For example, a State highway agency may find that in one group of roads, the Class 9 trucks all have similar characteristics, but the Class 11 truck characteristics are very different from each other. By changing the road groups, it may be possible to classify roads so that all Class 9 and Class 11 trucks within a road group have similar characteristics. More likely it will not be possible to form homogenous groups for different truck classes, and trade-offs will have to be made. The type of vehicle considered the most important should be given priority.

The trade-offs can be made based on the relative importance of each weight statistic to the data user. In many cases, this is simply a function of determining the relative importance of different truck statistics. For example, if 95 percent of all trucks are in Class 9, then having truck weight road groups that accurately describe Class 9 truck weight characteristics may be more important than having road groups that accurately describe Class 11.

Determining the Precision of Estimates from Truck Weight Groups

An estimate of the precision of the mean of a variable that any truck weight road group will provide can be found by computing the standard deviation when computing the mean statistic for that variable. For example, the precision of the mean gross vehicle weight for a Class 9 truck within a truck weight group can be calculated while computing the mean GVW per Class 9 truck from all of the WIM sites within that group. The standard deviation of the estimate and the number of sites provide an approximate measure of the precision of the mean of the group.

An example of this computation is shown below. In the example, assume that a State has determined that all rural interstate roads have similar truck weight characteristics based on seven WIM sites. Statistics from those WIM sites are shown in Table 3-13. Based on this data, it can be assumed that all rural interstate roads in the group have a mean gross vehicle weight of 25,000 kg for Class 9 trucks. To determine an estimate of precision of this group with respect to pavement design, the mean ESAL value for flexible pavements is also computed for these sites in Table 3-13. As can be seen, the average Class 9 truck in this group of sites applies an average of 1.63 ESAL. (When comparing ESAL values between sites, the ESAL computations assume the same pavement type and structure. All ESAL examples in this document are computed assuming flexible pavements. ESALs are used in this chapter as the measure of pavement damage because they are still in common use in most States. While they have limitations as a measure of traffic loading for pavement design, and are being phased out of many pavement performance analyses, they are still a very useful single statistic for comparing the load spectrum in terms of the amount of pavement damage that those load spectrum will cause. Other summary statistics can be used in place of ESALs to simplify the comparison between load spectrum.)

The precision of the group mean, referred to as the standard error of the mean, can be estimated with 95 percent confidence as approximately plus or minus 1.96 times the standard deviation divided by the square root of the number of sites. (This is a relatively crude approximation. The value 1.96 should be used only for sample sizes of 30 sites or more. A more statistically correct estimate would use the student's t distribution, which for six degrees of freedom (seven weigh sites) is roughly 2.45.)

TABLE 3-13   EXAMPLE OF STATISTIC COMPUTATION FOR PRECISION ESTIMATES

Site	Mean Class 9 GVW	Mean Class 9 ESAL
1	50,000 lb	1.64
2	57,000 lb	1.72
3	64,000 lb	1.84
4	46,000 lb	1.45
5	45,000 lb	1.34
6	55,000 lb	1.65
7	62,000 lb	1.78
Group Mean	54,000 lb	1.63
Group Standard Deviation	7,500 lb	0.18
Coefficient of Variation	0.14	0.11
Standard Errors of Mean	2,800 lb	0.07

In the above example, note that the coefficient of variation for the two statistics (GVW/vehicle and ESAL/vehicle) are different, even though both variables come from the same set of vehicle weights. Each statistic computed for a truck weight group is likely to have different statistical reliability because of the different levels of variation found in axle weights, GVW, and the various other statistics computed from weight records.

To complicate matters further, each statistic has a different level of precision for each different vehicle class. Accordingly, the precision of the ESAL/vehicle value for Class 9 trucks will be different from that of the ESAL/vehicle value for Class 11 trucks.

Step 5. Determine The Appropriate Number Of Weight Data Collection Locations

The precision calculations can be used to determine how many WIM systems should be included within each truck weight group. The State highway agency should determine what statistic it wants to use as the key to the analysis, select how precisely it wishes to estimate that statistic, and compute the number of WIM locations needed to obtain the desired degree of confidence.

This step involves several decisions:

- The State highway agency should determine whether the heavy vehicle weight groups would be developed to produce mean statistics within each group with a given level of precision (e.g., the mean ESAL/Class 9 truck for rural interstates is 1.56 + .15 with 95 percent confidence). This decision primarily affects the grouping process.

    - If the intention is to develop precise mean values for the group as a whole, the key tends to be the number of data collection locations included in each group.

    - If the intention is to develop good default values for individual sites, the key to the grouping process is to have more and very homogenous groups (groups in which truck weights are very similar for all sites within the group, making standard deviations very small).

- States that emphasize predicting mean values for groups will have fewer groups but larger numbers of data collection sites within each group, whereas States that emphasize site-specific estimates will have more truck weight groups but fewer sites within each group.

- The second decision that affects the grouping process is the selection of the statistic to be the basis for the precision estimates. Because the precision of each statistic will vary, the State should

select a single statistic to use as its benchmark. Normally, this means selecting a specific vehicle classification and a specific weight variable. The recommended statistics for use in selecting sample sizes are either the mean ESAL (ESAL varies with pavement characteristics, thus the ESAL formulation used for this purpose should be a generic formulation using default pavement characteristics)/Class 9 trucks or a better option would be the mean GVW for Class 9 trucks. Class 9 trucks are recommended because they are the most common throughout the country, and they tend to carry a high percentage of the loadings on most major roads.

- The two most likely weight variables that can be used are the average gross weight (by class) and the average loaded per tandem (by class). Both measures are acceptable statistics for this purpose. GVW is easily understood by technical and non-technical people and does not change. It is reasonably well correlated to pavement damage and is commonly used as a measure of the size of commodity movements. ESAL are a much better measure of pavement damage than GVW. However, ESAL are not easily converted to measures of commodity flow, and current pavement research is not emphasizing their use in the design process.

- The next decision is how precise to estimate the target statistic. Precision levels are normally stated in terms of percentage of error within a given level of confidence (e.g., the GVW/vehicle estimate is within plus or minus 15 percent with 95 percent confidence). Decreasing the size of the acceptable error or requiring higher levels of confidence both increase the number of samples required. Conversely, accepting lower levels of precision and/or confidence allows smaller sample sizes and lower data collection costs.

- Selecting the acceptable level of error is an iterative process. First, the desired target precision is selected. Next, the variability of data in the truck weight groups is examined. This examination may result in the need to collect more data or to adjust the assignment of roads within heavy vehicle weight groups. If the State cannot meet the initially selected precision levels (either because it cannot create sufficiently homogenous groups or because it cannot collect data at enough sites), the desired precision levels have to be relaxed to reflect the quality of the estimates that can be obtained. The last step is to compute the number of weighing locations needed to meet the desired precision level. The number of WIM sites within a group is estimated as:

$$n = (t_{(\alpha/2)})^2 (C^2) / (D^2)$$

Where:

n =   the number of samples taken (in this case, the number of sites in the group)

t =   the student's t distribution for the selected level of confidence (α) and appropriate degrees of freedom (one less than the number of samples, n)

α =   the selected level of confidence

C =   the coefficient of variation (COV) for the sample as a proportion

D =   the desired accuracy as a proportion of the estimate

- This equation can be manipulated to solve for any variable. COV (the ratio of the standard deviation to the mean) is usually computed from available truck weight data. D is selected as part of the previous step (see above). The number of sites, n, can be computed after selecting the value for alpha (α) and looking up the appropriate term for $t_{\alpha/2}$ with $n-1$ degrees of freedom. Similarly, if n is given, it is possible to solve directly for the value of $t_{\alpha/2}$ and therefore (α). The example given below illustrates the basic process of comparing sample size with the precision levels each sample size achieves.

Table 3-14 shows the same truck weight statistics used in Table 3-13, except two additional weight sites have been added. These two sites experience heavy vehicle weights and consequently have increased the mean values for GVW/vehicle and ESAL/vehicle for the group.

TABLE 3-14   STATISTICS USED FOR SAMPLE SIZE COMPUTATION

Site	Mean Class 9 GVW	Mean Class 9 ESAL
1	50,000 lb	1.64
2	57,000 lb	1.72
3	64,000 lb	1.84
4	46,000 lb	1.45
5	45,000 lb	1.34
6	55,000 lb	1.65
7	62,000 lb	1.78
8	77,000 lb	2.01
9	75,000 lb	1.95
Group Mean	59,000 lb	1.71
Group Standard Deviation	11,600 lb	0.22
Coefficient of Variation	0.197	0.13
Standard Error of Mean	3,900 lbs	0.07

Using this table the following can be determined:

- The average GVW of Class 9 trucks for this group is 59,000 lb; and

- This estimate is + 8,900 lb with 95 percent confidence (3,900 multiplied by 2.306). (This table uses the student's *t* distribution for eight degrees of freedom because of the small number of sample sites within the truck weight road group.)

Increasing the number of WIM stations included in the sample to 15 sites (and assuming that those stations do not change the standard deviation of the sample) would change the standard error of the mean to 3,000 kg (11,600 divided by the square root of 15). This would improve the confidence in the mean value of the GVW/vehicle estimate for the truck weight group to 59,000 lb +/- 6,400 lb with 95 percent confidence. The improvement comes from two sources. The first is the increased precision in the mean value provided by the increase in the number of samples. The second is the decrease in the value of $t_{a/2}$ used to compute the multiplier in the confidence interval by having a greater sample size upon which to perform the statistical computation.

Table 3-15 shows the effect of different sample sizes and confidence intervals estimates of the group mean. Note that increases beyond about six sites in the group sample size have only a marginal effect on the precision of the group mean.

TABLE 3-15   EXAMPLE EFFECTS OF SAMPLE SIZE ON THE PRECISION OF GVW ESTIMATES

Number of Weigh Sites[1]	Mean Value	Precision of the Mean Value Itself (Standard Error)	
		80% Level of Confidence[2]	95% Level of Confidence[3]
3	59,000 lb	12,600 lb	28,800 lb
5	59,000 lb	8,000 lb	14,400 lb
9	59,000 lb	5,400 lb	8,900 lb
15	59,000 lb	4,000 lb	6,400 lb
30	59,000 lb	2,700 lb	4,200 lb
60	59,000 lb	1,900 lb	2,900 lb
90	59,000 lb	1,600 lb	2,400 lb

This table uses the student's t distribution because of the small number of sample sites in the group.

The value of $t_{\alpha/2}$ for each sample size using the student's t distribution for a two-tailed confidence interval of α = 80% (t.1) is as follows: n = 3, $t_{\alpha/2}$ = 1.886, n = 5, $t_{\alpha/2}$ = 1.533, n = 9, $t_{\alpha/2}$ = 1.397, n = 15, $t_{\alpha/2}$ = 1.345, n = 30, $t_{\alpha/2}$ = 1.282.

The value of $t_{\alpha/2}$ using the student's t distribution for a two-tailed confidence interval of α = 95% ($t_{.025}$) is: n = 3, $t_{\alpha/2}$ = 4.303, n = 5, $t_{\alpha/2}$ = 2.776, n = 9, $t_{\alpha/2}$ = 2.306, n = 15, $t_{\alpha/2}$ = 2.145, n = 30, $t_{\alpha/2}$ = 1.960.

If tighter confidence intervals are deemed necessary, it is always possible to modify the truck weight road groups. Looking at Table 3-14, it is apparent that sites eight and nine have much higher loads than the remaining seven sites. If these sites are removed from the truck weight group, the computed standard deviation of the GVW per vehicle computed for sites in the group drops from 11,600 lb to 7,500 lb. This has a dramatic impact on the precision of the estimates computed for the group.

Table 3-16 shows the precision level of the truck weight group after removal of these sites. However, note that to remove these two sites from the truck weight road group, they should represent some identifiable set of roads. For example, they could be located on the State's only north/south rural interstate, while the remaining seven sites are on east/west interstates. Therefore, the rural interstate truck weight grouping could be divided into two separate truck weight groupings, rural east/west interstate and rural north/south interstate.

TABLE 3-16   **EXAMPLE EFFECTS OF SAMPLE SIZE AND CONFIDENCE INTERVAL ON PRECISION OF GVW ESTIMATES FOR THE REVISED TRUCK WEIGHT GROUP**

Number of Weigh Sites[1]	Mean Value	Precision of the Mean Value Itself (Standard Error)	
		80% Level of Confidence[2]	95% Level of Confidence[3]
3	54,000 lb	+8200 lb	+18600 lb
5	54,000 lb	+5100 lb	+9300 lb
9	54,000 lb	+3500 lb	+5800 lb
15	54,000 lb	+2600 lb	+4200 lb
30	54,000 lb	+1800 lb	+2700 lb
60	54,000 lb	+1200 lb	+1900 lb
90	54,000 lb	+1000 lb	+1600 lb

This table uses the student's t distribution because of the small number of sample sites within the truck weight road group.

The value of $t_{\alpha/2}$ for each sample size using the student's t distribution for a two-tailed confidence interval of α = 80% (t.1) is as follows: n = 3, $t_{\alpha/2}$ = 1.886, n = 5, $t_{\alpha/2}$ = 1.533, n = 9, $t_{\alpha/2}$ = 1.397, n = 15, $t_{\alpha/2}$ = 1.345, n = 30, $t_{\alpha/2}$ = 1.282

The value of $t_{\alpha/2}$ for each sample size using the student's t distribution for a two-tailed confidence interval of α = 95% (t.025) is as follows: n = 3, $t_{\alpha/2}$ = 4.303, n = 5, $t_{\alpha/2}$ = 2.776, n = 9, $t_{\alpha/2}$ = 2.306, n = 15, $t_{\alpha/2}$ = 2.145, n = 30, $t_{\alpha/2}$ = 1.960

The key to correctly creating these truck weight groups is that sites should only be removed from a truck weight group when they can be readily identified with a specific set of roads that experience those loads. All of those roads should be moved to the new truck weight group.

From the above examples, it is possible to see that changing the number of sites included in a truck weight road group has three effects:

1. It changes the computed sample standard deviation for the group (which serves as the estimate of the standard deviation for the entire road group).

2. **It changes the denominator used to compute the standard error, which is the statistic used to determine how well the mean value computed from that group of roads estimates the mean value for the population being sampled.**

3. **It changes the value of t used to compute the size of the confidence interval applied to estimates produced for that group.**

In general, the more sites included in a group, the better the estimates produced by that group, although the benefit of adding sites decreases as the number of sites within a group increases. The effect of using the student's t distribution to compute confidence intervals means that a significant decrease in the value of t can be obtained by simply adding locations up to a sample size of six. A sample size of six sites has a 10 percent smaller confidence interval at the 95 percent level of confidence than a sample size of five sites, all other things being equal. Beyond six sites, the benefits gained by adding sites begin to decrease quickly. More than six sites in a group may be appropriate, particularly if the State is unsure of its truck weight patterns.

Based on this analysis, six sites per group are recommended. The exception to the six-site rule is for truck weight road groups that contain very few roads. These will tend to be specialty roads (e.g., roads leading into and out of gravel pits) that have unusual loading conditions but that are not applicable to many other roads in the State. If improvements in precision are needed beyond what affordable increases in sample size will achieve, the primary option is to change the make-up of the truck weight groups, i.e., create new subsets of roads that will serve as the truck weight groups. If this change produces a significant decrease in the standard deviation that offsets the increase in $t_{\alpha/2}$ caused by the lower sample size, then the State will benefit from an improvement in the precision of its weight estimates along with a smaller data collection sample size.

Step 6. Determine the Number of Days that Should be Counted at a Given WIM Site

All of the statistics presented previously start with the critical assumption that each WIM site in a truck weight group produces an accurate estimate of vehicle weights for that location, so that the mean value calculated for the group is accurate. The accuracy assumed for the data provided by each WIM scale is not just that the scale weighs the passing trucks correctly, but that those weight estimates are representative of weights at that site throughout the year.

For WIM sites where less than a year of data is collected, the assumption is that the period measured gives an accurate measurement of weights for the entire year. If the weight data collection period is only 48 to 72 hours, the assumption is that there is no DOW difference in the loading condition of trucks passing the site. That is, that trucks traveling on weekends carry the same distribution of payloads as trucks traveling on weekdays, as well as the hypothesis that there are no seasonal differences in truck loading patterns. At some WIM sites in some States, extensive data collection has shown that these assumptions are reasonable (Butler 1993). At other sites and in other States, these assumptions are incorrect (Hallenbeck and Kim, 1993). Where truck weights are not stable across days of the week or seasons, the weight monitoring effort has to be extended to account for these differences. For example, the count duration may be extended from two days to seven days to incorporate DOW differences. Seasonal differences can be detected and incorporated in the annual estimates by collecting data at each site more than once per year, such as once per quarter.

While it is mathematically possible to obtain load spectra information through factoring of short duration WIM data to account for variations in seasonal changes in truck loading patterns, this process is not recommended due to the limited data available to create and apply those adjustments. Where seasonal differences in load spectra are known or suspected (for example, seasonal load restrictions occur in that area), States are encouraged to collect sufficient data to measure those changes rather than trying to factor short duration WIM measurements to estimate those changing patterns. If a State chooses to factor the load spectra information from short duration WIM for pavement design purpose, formal consultation should be carried out with the Federal Highway Administration.

To date, little work has been published on the seasonal differences in axle weight distributions found in the nation's truck fleet, nor on the weight characteristics of particular trucking movements found in individual States. However, these seasonal and DOW weight changes can have dramatic effects on the selection of the pavement designs that rely on them. The collection and analysis of continuous data collection is the easiest method to begin to understand the temporal variation.

The key for the weight data collection program is to measure and account for both DOW and seasonal differences in vehicle weights within each truck weight group. The only way to do this adequately is to have each WIM station providing continuous WIM data, unless analysis has shown that temporal variability is not present. For States with large numbers of continuous WIM stations, sufficient stations to populate the groups likely already exist. For smaller States facing resource limitations, the installation of many continuous WIM sites is not as feasible. The general recommendation is that each truck weight group should have at least one, and preferably more than

one, continuous WIM device collecting continuous data. This site should be maintained in a calibrated condition, and the data obtained from it should be used to determine whether significant differences exist between vehicle weights (by vehicle class) for different days of the week, months of the year, and year to year. Where resources are limited and neighboring States have similar truck size and weight laws, States can share WIM data to create weight groups where site groups can come from more than one State.

The remaining sites within a group can have either short duration counts or additional continuous counts. As with vehicle classification and volume counting, a minimum of 48 hours should be used. Weight data has been shown to vary by time of day, day of week, weekdays, and weekends. As with vehicle classification and volume counts, it is acceptable to use different data collection periods as needs and constraints allow. Because of differences in weekday and weekend vehicle weights, the data collection program should be designed to cover those differences and account for them when statistics are produced. Counts taken for a period of one week eliminate the need for DOW adjustment, allow the equipment and traffic conditions to stabilize, provide data verification capabilities, and identify weekday/weekend differences in average weights. A monitoring period of seven continuous days is recommended for all WIM sites that do not provide continuous data.

Short duration WIM measurements should be collected with permanently mounted sensors because permanent sensors can be mounted flush to the road surface, providing a more accurate weight measurement. (Permanent sensors include sites where the sensors are permanently installed but only used periodically; sites where the sensors are installed permanently but the electronics removed from the roadside when not in use, and sites where semi-permanent sensor frames are permanently installed but the actual sensors are replaced with a dummy scale when not in use.) Use of permanently mounted sensors also allows data collection periods to be lengthened at relatively little additional cost.

Portable sensors introduce accuracy issues that may compromise the validity of the data, although they are not completely ruled out. Organizations using portable WIM sensors should carefully ensure that the data collected is sufficiently accurate to meet user needs.

Step 7. Select WIM Sites

Many issues are to be considered when installing WIM sites. Current installations range from full coverage for all lanes and directions of travel to the LTPP standard of a single lane in one direction. Some of the issues to be reviewed when selecting the number of lanes of WIM to install include:

- Available funding;
- The cost of installation;
- Program objectives to be met;
- The design of current installations in the State;
- The trade-offs between obtaining more complete coverage at each site versus less coverage at each site but getting more sites covered;
- Prior experience with WIM equipment;
- The type of equipment being installed;
- The type of array installed;
- Equipment installation options;
- Specific site characteristics (such as pull off area, slope, and communications);
- Truck volumes present at the roadway being monitored;
- Use of the scale for or influence from nearby enforcement activities;

- The ability to perform maintenance on equipment at that site; and

- The ability to perform calibration of the scales.

Analyses of available WIM data have shown that significant differences in loads by direction of travel often occur. The collection of WIM data in at least one lane in each direction of travel at each site allows a clear assessment of directional differences in weights and loadings. WIM differences by travel lane are generally less significant and difficult to generalize, although previous analyses have shown that the outside lanes tend to carry heavier vehicles. More analysis of current installations is needed before a determination of the cost-effectiveness of covering several lanes at some of the WIM sites or at all sites can be made.

A WIM site covering all lanes and direction of travel provides the most complete data collection coverage. At least one continuous WIM station in each weight group should provide WIM coverage for all or a minimum of two travel lanes in each direction. This will allow future pavement design analysis to cover most possibilities. For multi-lane facilities, covering two lanes in each direction provides the most cost-effective alternative. If some lanes are not monitored by WIM sensors, each WIM site should have, at a minimum, a portable classification count by direction and travel lane to measure truck travel in the lanes not being monitored with WIM. Continuous classification in those lanes is preferable. Figure 3-12 shows examples of this.

FIGURE 3-12   BEST PRACTICE FOR WIM LANE

A. Best: WIM Covers All Lanes and Directions
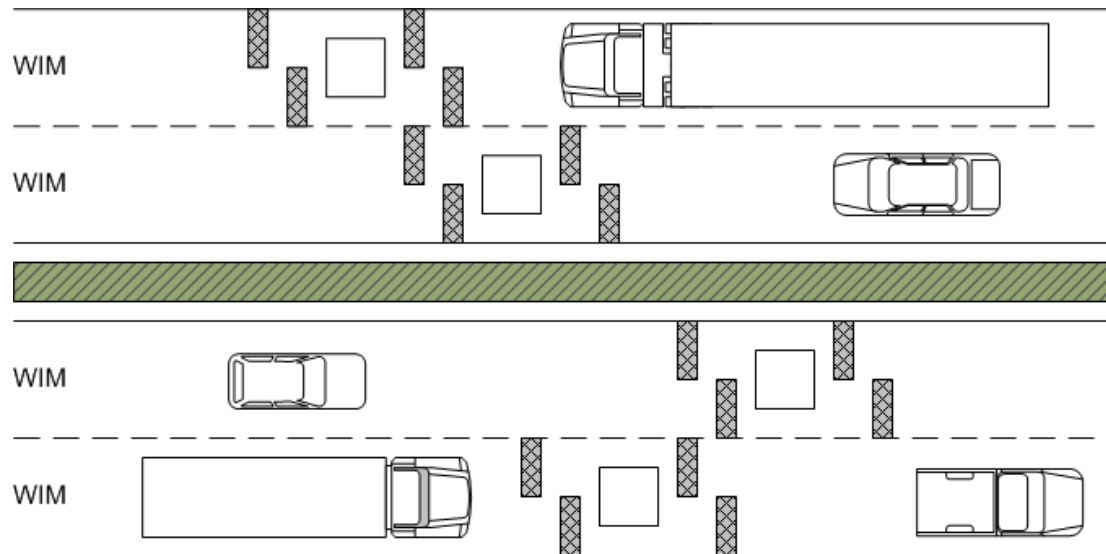
B. Better: WIM or Two Permanent Axle Sensors in All Lanes
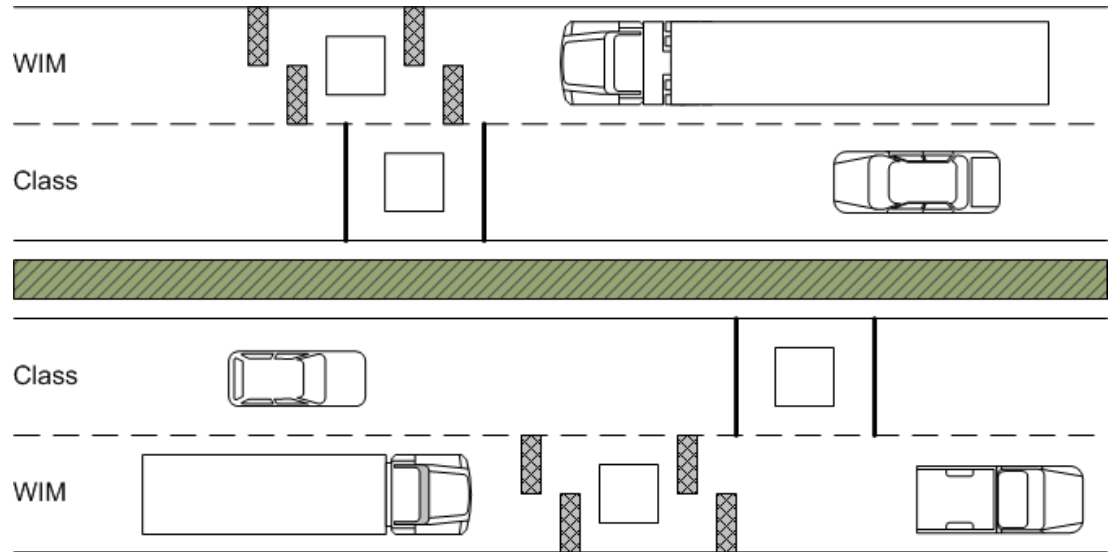
C. Good: Two Portable Axle Sensors in All Lanes
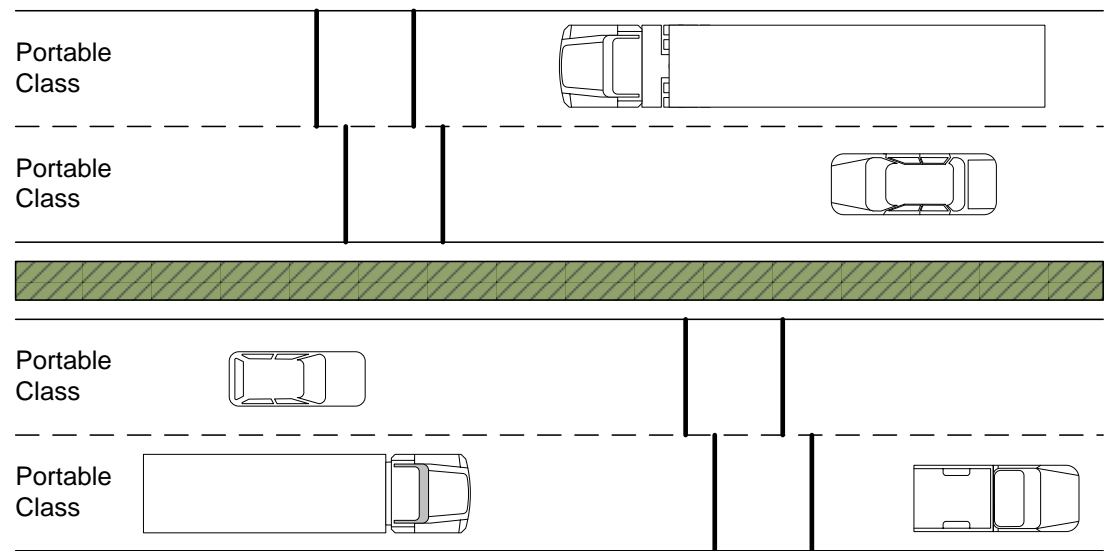
Source: Federal Highway Administration.

Site Selection

WIM systems also provide counts of vehicle volume by classification, speed, and total volume. Consequently, WIM data collection locations can also provide volume and vehicle classification count data that can take the place of counts required to meet the needs reviewed in sub-sections 3.2.1 and 3.2.2. Unfortunately, for a variety of technical reasons, WIM data cannot be collected on all roadway sections. Physical constraints on many road sections prevent the collection of accurate weight data. In addition, most States do not have the resources to collect weight data at more than a modest number of locations. Finally, most States already have a significant investment in WIM sites, either as part of their existing truck weight-monitoring program or as part of the LTPP.

Each State should begin to apply the procedures assessed with its existing WIM data collection sites. Because of the study, the addition of sites may become necessary. As existing sites require attention

because of failure of the pavement surrounding the WIM sensors or failure of the WIM equipment itself, the need for that WIM station or site should be reevaluated. Sites that are still needed should be reinstalled. If that site is no longer needed or if other higher priority locations exist, the WIM equipment should be moved to another site.

New WIM Site Selection Criteria

The selection of new WIM sites should be based on the needs of the data collection program and the site characteristics of the roadway sections that meet those needs. The needs of the data collection program include, but are not limited to, the following:

- The need to obtain more vehicle weight data on roads within a given truck weight roadway group;

- The need to collect data in geographic regions that are poorly represented in the existing WIM data collection effort;

- The need to collect data on specific facilities of high importance (e.g., interstate highways or other national highway system routes);

- The need to collect data for specific research projects or other special needs of the State; and

- The need to collect weight information on specific commodity movements of importance to the State.

However, just because a roadway section meets some or all of the above characteristics does not make it a good WIM site. With current technologies, WIM systems only accurately weigh trucks when the equipment is located in a physical environment that meets specific criteria. Therefore, States should place WIM equipment only in pavements that allow for accurate vehicle weighing. While individual equipment vendors may require slightly different pavement characteristics to achieve specified results, in general all WIM sites should have the following (An excellent reference for learning about WIM site requirements is *ASTM Standard E-1318, Highway Weigh-in-Motion (WIM) Systems with User Requirements and Test Method*. Another excellent source is *States' Successful Practices Weigh-in-Motion Handbook.*):

- Smooth, flat (in all planes) pavement;

- Pavement that is in good condition and that has enough strength to adequately support axle weight sensors;

- Vehicles traveling at constant speeds over the sensors;

- Cross slope;

- Grade;

- Weaving; and

- Access to power and communications (although these can be supplied from solar panels and through various forms of wireless communications).

In addition, there should be sufficient truck traffic at the site to justify the installation of a WIM data collection site. The actual sites can be selected randomly or judgmentally (using the previous list of criteria) from sites that meet all of the site requirements. Smooth, strong pavement is needed to reduce the effect of vehicle dynamics. Although placing multiple sensors in series (Cebon 1999) can significantly reduce the error that vehicle dynamics produce in individual weight measurements, placement of WIM sensors on smooth, flat pavements that reduce vehicle dynamics significantly improves WIM accuracy, regardless of the equipment used.

Pavement strength can affect sensor accuracy. Weight estimates produced by strip sensors (such as piezo-cables) that are embedded directly into pavements are often affected by changes in pavement strength caused by changes in environmental conditions (e.g., AC flexibility for spring thaw periods).

A decrease in pavement strength invariably decreases system accuracy. Therefore, WIM sensors should only be placed in strong pavements that are not subject to significant changes in structural response during different seasons. Similarly, WIM sensors begin to become inaccurate as soon as pavements start to rut. In most cases, installations in pavements likely to rut are a poor investment of limited data collection funds.

The requirement for constant vehicle speed (which limits the use of WIM equipment in many urban and suburban areas where routine congestion occurs) is primarily because braking and acceleration causes shifts in load from one set of axles to another. This shifting causes inaccurate comparison of WIM estimates against static loads.

The availability of power and communications allows extended operation of the WIM equipment. While this is not as crucial for sites intended for short duration WIM counts, the availability of power allows the collection of longer duration or continuous WIM measurements. This is particularly helpful for research studies intended to confirm or refute the ability of short duration counts to meet the accuracy needs of the data collection plan. It also allows the WIM site to be used as a continuous classifier or continuous counter even while weight data is not being collected.

Step 8. Integrate the WIM Sites with the Remaining Count Program

Even with all of the constraints described above, most of the existing sites can be used to meet a given need. When exploring alternative sites, the ultimate decision can often be made by examining how well these alternative sites fit within the existing State traffic monitoring program.

Sites selected for WIM data collection should be located within HPMS volume sample sections, if possible. If two alternative sites exist to meet a specific need and one is already an HPMS sample site, it should be given priority over the alternative (all other factors being equal). If neither site falls on an HPMS sample section, the selected WIM site should become an HPMS sample section the next time the HPMS sample is revised. The HPMS volume and classification data should be collected at the same time as the WIM data, using the same equipment where practical. This reduces the staffing and resources needed to collect these HPMS data and directly ties the different data items.

Total Size of the Weight Data Collection Program

The recommendations evaluated above lead to the conclusion that the size of the weight data collection program will be a function of the variability of the truck weights, accuracy, and precision desired to monitor and report on those weights.

For a small State that has only two basic truck weight road groups, the basic recommendation is to have a minimum of approximately 12 weighing locations with a minimum of four continuously operating weigh-in-motion sites. The number of locations could be further reduced if the State worked with surrounding States to collect joint vehicle weight data. A larger State with diverse trucking characteristics might have as many as 10 or 15 distinct truck weight road groups, and accordingly 60 to 90 WIM sites, with a corresponding increase in the number of continuously operating WIM locations. Most States will be between the two extremes presented, and the number of weighing locations should fall somewhere between 12 and 90 locations.

3.2.5 LANE OCCUPANCY

Many continuous traffic monitoring devices can produce traffic performance statistics, in addition to those described above, that can be used for other important analytical tasks. In some cases, these statistics should be routinely collected, stored, and reported as part of the traffic monitoring program. In other cases, the added data collection capability should be simply noted and used only when required for a special study.

For example, inductive loop detectors and other devices that mimic loop output, such as video image-based counters, can produce lane occupancy statistics that describe the percentage of time that a

vehicle occupies the detection zone. This value can be converted into a reasonable measure of vehicle density. Lane occupancy can also be used as a direct measure of congestion. Many urban freeway and arterial performance monitoring programs use lane occupancy measurements to describe the onset and duration of congested conditions. For example, the Washington State Department of Transportation uses lane occupancy values above 35 percent to indicate the formation of stop-and-go congestion.

Traffic monitoring devices that time stamp the passage of either individual vehicles or the axles of individual vehicles can be used to report the headway between vehicles and/or the time gap between vehicles. These statistics are useful for a number of specific operational analyses but are not routinely reported as an output of most traffic monitoring programs. Consequently, most headway and gap information is collected and reported as part of special studies. However, some traffic monitoring systems—such as weigh-in-motion scales—routinely collect time-stamped vehicle records that can be used to estimate vehicle gap and headways. When States collect data using the new PV format, occupancy, headway, and gap can all be a by-product.

3.3   SHORT DURATION DATA PROGRAM

3.3.1   VOLUME

Short duration traffic volume counts are traditionally the primary focus of most statewide traffic monitoring efforts. They provide the majority of the geographic (spatial) diversity needed to provide traffic volume information on the State roadway system.

The recommended short duration volume-counting program is divided into coverage count and special needs count primary subsets. The coverage count subset covers the roadway system on a periodic basis to meet both point-specific and area needs, including the HPMS reporting requirements. The special needs subset comprises additional counts necessary to meet the needs of other users. This second category of counts can be further subdivided into counts taken to meet State-specific statistical monitoring goals, to provide increased geographic coverage of the roadway system, and to meet the needs of specific project or data collection efforts. Each of these categories of counts is presented in the following paragraphs.

Short duration counts ensure that adequate geographic coverage exists for all roads under the jurisdiction of the highway authority. In simple terms, coverage counts are data collection efforts that are undertaken to ensure that at least some data exist for all roads maintained by the agency. How much data should be collected to provide adequate geographic coverage is a function of each agency's policy perspective. Some State highway agencies consider a weeklong count every seven years with data recorded for every hour of each day to be adequate. Others consider a 48-hour count every 3 years with no hourly records to be adequate. Clearly, significant utility can be gained from having at least hourly volume estimates at coverage counts, since that data can be used to obtain a much more accurate understanding of traffic volume peaks during the day. As indicated in Section 3.2.3, at a minimum the *TMG* recommends that State highway agencies initially aim to collect 25 to 30 percent of their short-duration counts with classification counting equipment. Agencies that can exceed this figure are encouraged to do so. The ability to meet or exceed this goal depends on agency perspective and is a function of the equipment available and the nature of the road system.

Short Duration Counts

The following steps apply to short classification counts:

1. Divide the road system into homogeneous traffic volume segments; determine the count locations needed to cover the system over a maximum cycle of six years.

2. Determine the count locations required to meet the HPMS and other data needs by reviewing HPMS manuals.

3. Determine the count locations and data collection needs of specific projects that will require data in the next year or two. This entails working with the offices that will request this data to determine their data needs. This coordination should occur on a continuous basis to ensure counts for special projects are collected when needed.

4. Overlay the counts on maps of the highway system including the location of functioning continuous counters.

5. Determine how counts can be combined to make best use of available counting resources.

6. Schedule the counts to use the available data collection crews and equipment efficiently.

These steps are intended to reduce count duplication and increase the efficiency of the data collection staff.

The spacing between short duration counts in a roadway is also subject to agency discretion. This method for section length should also be detailed in the State TMS plan. The primary objective is to count enough locations on a roadway so that the traffic volume estimate available for a given highway segment accurately portrays the traffic volume on that segment. Generally, roadway segments are treated as homogenous traffic sections (that is, traffic volumes are the same for the entire segment). For a limited access highway, this is true between interchanges. However, it is also true for all practical engineering purposes for a rural road where access and egress along a ten-mile segment is limited to a few driveways and low volume, local access roads. Highway agencies are encouraged to examine existing traffic volume information to determine how best to segment their roadway systems to optimize the number and spacing of short duration counts. A rule of thumb that has been used in the past to define these traffic count segments is that traffic volume in each roadway segment be within 10 percent. An alternative approach would be to define limits using a graduated scale such as the one shown in Table 3-17.

TABLE 3-17   ESTIMATING SPACINGS OF SHORT-DURATION COUNTS

Beginning Segment AADT	Adjoining Segment AADT Within
100,000 or more	+ 10%
50,000 – 99,999	+ 20%
10,000 – 49,999	+ 30%
5,000 – 9,999	+ 40%
1,000 – 4,999	+ 50%
Less than 1,000	+ 100%

Breaking the system into very large segments reduces the number of counts needed but also the reliability of the resulting traffic estimates for any given section of that large roadway segment. Use of small segments increases the reliability of a specific count but also the number of traffic counts needed.

The character of the road systems and the volumes carried has a major impact in the definition of segments. For roads where access is controlled (such as the interstate system), a simple definition of segments between interchanges is appropriate. For lower systems, clear traffic volume breaks are not always apparent and other rules of thumb (such as major intersections) should be applied. Rural and urban characteristics also require different handling. For the lowest volume roads, the 10 percent rule of thumb may be too narrow and a wider definition sought. Careful definition of roadway segments can significantly reduce the number of counts needed to cover all highways within an

agency's jurisdiction, while still providing the accurate volume data required for planning and engineering purposes.

Once roadway segments are finalized, the FHWA recommends as a rule that each roadway segment be counted at least once every six years. This ensures that reasonable traffic volume data is available for State needs, and that all roadway segments are correctly classified within the proper HPMS volume groups when State highway agencies compute statewide VDT as part of their required Federal reporting. HPMS further requires counting every three years for higher functional class roadways.

Not all count locations should be counted on a six-year basis. Some count locations should be counted more often. Other roads can be counted less frequently without loss of volume estimate accuracy. In general, roadway sections that experience high rates of growth require more frequent data collection than those that do not experience growth. Therefore, roads near growing urban centers and expanding recreational sites should be counted more frequently than roads in areas where activity levels have hardly changed for many years. Counting roads more frequently in volatile areas also allows the highway agency to respond with confidence to questions from the public about road use (a common concern in high growth areas), and ensures that up-to-date by lane and directional statistics are available for the roadway design, maintenance, and repair work that is common in high growth areas.

The short duration count data collection program itself can be structured in many ways. One simplistic approach is to randomly separate all of the roadway segments into unique sets and count one of these sets each year. However, this approach does not always lend itself to efficient use of data collection staff and equipment. Grouping counts geographically leads to more efficient data collection activity, but results in the need to account for the geographic bias in the data collected when computing annual average traffic statistics or looking at trends in traffic growth around the State.

In addition, most highway agencies collect data at some sites on a cycle shorter than six years. For example, more frequent counts (three-year cycle) are required on HPMS sections, and most States count higher system roads more frequently as well. Still, considerable flexibility is allowed in the structure of each agency's short duration count program.

Special Needs Counts

The HPMS standard sample meets the need for computation of a statistically reliable measure of statewide travel. The data collected also cover many highway agency needs. However, there remain traffic data needs that cannot be met by the short duration count program. This is where an effective short duration program supplemented by special counts can substantially fill the gap.

Non-HPMS data needs vary dramatically from State to State and from agency to agency. Some State highway agencies are responsible for almost all road mileage in their State. Other State highway agencies control, operate, and maintain only the largest, most inter-regional facilities. Some States must meet strict reporting requirements (by jurisdiction) adopted by their legislatures. Others have relatively few mandatory reporting requirements, and instead focus on collecting data that meet each particular agency's priorities. In some extreme cases, agencies are prohibited by law from expending resources outside of their areas of responsibility.

A consequence of this variety of traffic data needs is that no single traffic monitoring program design fits all cases. Therefore, the philosophy of the special needs element is to provide highway agencies wide flexibility to design this portion of their monitoring program in accordance with their own self-defined needs and priorities. The guidance in this report is intended to provide highway agencies with a framework within which they can ensure that they collect the data they need.

The special needs portion of a data collection program can be divided into two basic portions:

- Statistical samples for developing system wide summary measures; and

- Point-specific estimates intended to meet project requirements and other studies defined by the highway agency.

Statistical Samples in the Special Needs Program

Statistical samples such as the HPMS are the most efficient way to estimate population means and totals. Most statistical samples involve the collection of data at randomly selected locations to compute unbiased estimates of population means and totals. Random sampling is a very efficient mechanism for computing these totals.

A variety of texts is available on the design of samples. *Sampling Techniques* is one such standard text. The *HPMS Field Manual* provides a description of how the HPMS sample was developed and implemented. These documents are useful in helping design a sampling program to meet objective needs. The keys to successfully designing a statistical sampling plan are defining the objectives, understanding the variability of the data being sampled, having a clear understanding of what statistics should be computed, and establishing the accuracy and precision of the estimates. Any statistical samples developed should make use of the available data from the short duration element to minimize the duplication of effort, as much as possible. One possible use of statistical samples is to estimate VMT for the local functional systems, where extensive mileage makes the collection of traffic data very costly.

Point Specific Estimates in the Special Needs Program

Unfortunately, the random selection of count locations required by most statistical samples is an inefficient mechanism for meeting many site-specific traffic data needs. For example, an uncounted roadway section is not a major concern for HPMS because the sample expansion process represents all road sections in the statewide VMT estimation. However, if pavement needs to be designed for that section of roadway, a statewide average or total is not a substitute for one or many traffic counts specific to that road section.

Consequently, data needs require agencies to collect data at locations that are not part of the short duration program. However, by maximizing the use of available data, it is possible to keep the number of these special counts to a minimum and to save resources for other data collection and analysis tasks. No additional data should be collected if existing data meet the desired need.

Special counts are generally required for specific project needs. Project counts are undertaken to meet the needs of a given study (for example, a pavement/corridor study, rehabilitation design, or a specific research project). These cover a range of data collection subjects and are usually paid for by project funds. Project counts are traditionally taken on relatively short notice, and they often collect data at a greater level of detail than for the short duration or the HPMS parts of the program. Often, the need is not realized until after a project has been selected for construction, and insufficient time exists by that date to schedule the project counts within the regular counting program. However, where it is possible to include project counts within the regular count program's schedule, significant improvements in staff utilization and decreases in overall costs can be achieved.

Many different types of counts can fall within the special needs element. Counts are taken by many public and private organizations for many purposes including intersection studies, signal warrants, turning movements, safety analysis, and environmental studies. As much as possible, these activities should be coordinated within the program umbrella.

In general, roadway sections that experience high rates of growth and recreational areas require more frequent counting than those that do not experience growth. Counting roads frequently in volatile areas allows the highway agency to respond with confidence to questions from the public

about road use (a common concern in high growth areas), while also ensuring that up-to-date statistics are available for the roadway design, maintenance, and repair work that is common in high growth areas. Many agencies prefer the use of several counts a year to understand the traffic variability inherent in high growth better. Likewise, recreational roads usually experience major traffic peaking at specific times necessitating frequent data collection times.

High growth areas (if not necessarily roads with high volume growth) can usually be selected on the basis of knowledge of the highway system and available information on the construction of new travel generators, highway construction projects, requirements for highway maintenance, applications for building permits, and changes in population. Recreational areas are also well known to experienced transportation professionals.

Coordinating the Short Duration and Special Needs Counts

Cost efficiency in the traffic-monitoring program is best achieved by carefully coordinating the different aspects within the program. This includes both continuous and short duration counts. It also includes the short duration, HPMS, and special needs counts.

In theory, the highway agency would start each year with a clear understanding of all of the counts that need to be performed. The list could then be examined to determine whether one count could be used for more than one purpose. For example, a classification count at one interstate milepost might easily provide the data required for both that count and a volume count required at the next milepost, since no major interchanges exist between those mileposts. By careful analysis of traffic count segments, location, and data requirements, it is often possible to significantly reduce the total number of counts required to meet user needs.

The next step is to compare the reduced list of count locations with locations covered by continuous counters (volume, classification, weight, and ITS). Continuous counter locations can be removed from this list, and the remaining sites are the locations that require short duration counts. These locations should then be scheduled to make best use of available staffing and resources.

To make this scenario work, it is necessary to understand where data should be collected and the kinds of data that need to be collected. This can be difficult to do because some requirements, such as those for project counts, are not identified until after the count schedule has been developed. Many project count locations and project count needs can be anticipated by examining the highway agency's priority project list and from knowledge of previous requests for data. Project lists detail and prioritize road projects that need to be funded in the near future, normally including road sections with poor pavement that require repair or rehabilitation, locations with high accident rates, sections that experience heavy congestion, and roadways with other significant deficiencies. While priority lists are rarely equivalent to the final project selection list, high priority projects are commonly selected, analyzed, and otherwise examined. Making sure that up-to-date, accurate traffic data is available for the analyses helps make the traffic database useful and relevant to the data users and increases the support for maintenance and improvements to that database and entire traffic counting programs.

Adjustments to Short Duration Volume Counts

Short duration volume counts usually require a number of adjustments to convert a daily traffic volume raw count into an estimate of AADT. The specific set of adjustments needed is a function of the equipment used to collect the count and the duration of the count itself. Almost all short duration counts require adjustments to reduce the effects of temporal bias, if those short duration counts will be used to estimate AADT. In general, a 48-hour axle count is converted to AADT with the following formula:

$$AADT_{hi} = VOL_{hi} \times M_h \times D_h \times A_i \times G_h$$

Where:

$AADT_{hi}$ =   the annual average daily travel at location i of factor group h

VOL_{hi} =   the 48-hour axle volume at location i of factor group h

M_h =   the applicable seasonal (monthly) factor for factor group h

D_h =   the applicable DOW factor for factor group h (if needed)

A_i =   the applicable axle-correction factor for location i (if needed)

G_h =   the applicable growth factor for factor group h (if needed)

This formula is then modified as necessary to account for the traffic count's specific characteristics. For example, if the short duration count is taken with an inductive loop detector instead of a conventional pneumatic axle sensor, the axle correction factor (A_h) is removed from the formula. Similarly, if the count is taken for seven consecutive days, the seven daily volumes can be averaged, substituted for the term VOL_{hi}, and the DOW factor (D_h) removed from the equation. Lastly, growth factors are only needed if the count was taken in a year other than the year for which AADT is being estimated.

3.3.2   SPEED (PORTABLE, SHORT DURATION COUNTS)

Traffic monitoring devices used for vehicle classification or WIM can also collect vehicle speed data for use in speed and other safety studies. For example, dual sensor-based event recorders that record the passage of individual vehicles and/or their axles collect vehicle speed data because of the time stamps associated with each passing axle/vehicle and the recorded distance between axle sensors. This same information is collected by portable vehicle classifiers, which use vehicle speed measurements in the calculations of axle spacings and overall vehicle length. A number of portable, non-intrusive detector systems can also be used to collect vehicle speeds at locations where data collection crews cannot safely place portable axle detectors.

The key to successful portable classification and speed data collection efforts is to ensure that the data collection equipment is carefully calibrated after it has been placed (the measurement of the distance between portable sensors is of particular importance) and that the data collection electronics connected to those sensors have been set to collect the desired speed bins. (See Chapter 7, Section 7.4 for instructions on the summary data formats that should be used for speed data collection and reporting.) Crews should perform an on-site calibration process each time they place equipment on the roadway by using a laser or radar speed-monitoring device to compare equipment output with the speed data being collected or using a vehicle of known axle-distance to calibrate the axle spacing reported by the portable counter.

To ensure that short duration speed data collection is cost effective, it is important that the traffic data collection office reach out to the safety management office within the agency before developing the annual traffic data collection plan. This allows early identification of locations for which speed data is needed, thus ensuring the inclusion of those data locations within the routine short count data collection program.

3.3.3   CLASSIFICATION (AXLE AND LENGTH)

Short Duration Counts

Short duration vehicle classification counts serve as the primary mechanism for collecting information on heavy vehicle volumes. They provide the geographic distribution necessary to meet the general agency needs and the needs of its customers, as well as the site-specific knowledge needed for the more detailed technical analyses of users.

Large numbers of transportation analyses are starting to require more and better truck volume information. Truck volume information has become particularly important for pavement design, freight mobility, planning, safety, and project programming decisions.

Earlier versions of the *TMG* recommended the collection of 300 vehicle classification counts during a three-year data collection cycle. This recommendation stemmed from research performed in the early 1980s, when automated vehicle classifiers were just beginning to be adopted by highway agencies. However, 100 vehicle classification counts per year is not adequate to meet the current truck volume data needs of most State highway agencies, and many currently collect far more classification data than this.

A more comprehensive approach is needed to provide the classification data. The recommendation is based on the following objectives:

- Increasing the accuracy and availability of truck volume data;

- Improving the truck volume data for national studies;

- Improving the truck volume data used for site-specific studies; and

- Decreasing the per-count cost of collecting classification data by having more classification counts in the traffic data collection program.

Short duration counts by themselves, however, are only part of the data collection process. Research has shown that heavy vehicle volumes vary dramatically during the day, often differ significantly between weekdays and weekends, and can change as well from one season to the next season. If adjustments are not made for DOW and seasonal variation, the result is likely to be erroneous analytical conclusions. For example, safety research that uses truck crash rates computed only from weekday counts will significantly under-estimate the truck crash rate for most locations because unadjusted weekday volumes tend to over-estimate annual average daily volumes. A base of continuous classification counters is used to support the temporal factoring process.

Classification Short Duration Counts

The classification short duration count program should be designed to operate like a traditional volume coverage program to provide a minimum level of heavy vehicle traffic data on all system roads. The basic short duration program would be supplemented by special counts as needed to meet site-specific data needs. At a minimum, the *TMG* recommends that State highway agencies initially aim to collect 25 to 30 percent of their short-duration counts with classification counting equipment. Agencies that can exceed this figure are encouraged to do so. The ability to meet or exceed this goal depends on agency perspective and is a function of the equipment available and the nature of the road system. Classification data is difficult to collect in many urban settings because of safety or equipment limitations.

To develop a classification coverage program, the highway system should be divided into vehicle classification (truck) segments similar to what is currently performed for volume and described in sub-section 3.2.1. Theoretically, vehicle classification segments should carry a homogeneous volume of trucks, where trucks are defined as the aggregation of FHWA classes four to thirteen. In practice, development of these section definitions is a judgment call since the definition is usually based on the available classification data combined with specific knowledge of the system. The more classification data and the better knowledge of trucks available, the easier and better the definition will be. The availability of truck or commercial vehicle flow maps during the road segmentation process is very useful. Most vehicle classification segments are expected to span several traffic volume segments because truck traffic can remain constant despite changes in total traffic volume (that is, changes in car volumes do not necessarily result in changes in truck volume). With time, as more data and information become available, the definition of segments will improve. As with traffic volume, the classification segments will change over time as roadway and traffic characteristics change and as more classification data helps to better define the segments. Periodic reassessments will be necessary to maintain the classification segment inventory and keep it current.

Many caveats apply to the development of the classification short duration count program. Each agency will have to develop a classification inventory system to cover the roads that meet its needs.

Table 3-18 illustrates some of the considerations used in developing traffic segments and classification coverage programs based on the functional classification (and use) of roadways.

TABLE 3-18   TRAFFIC SEGMENTS AND CLASSIFICATION SHORT DURATION PROGRAM BASED ON FUNCTIONAL CLASSIFICATION AND TRUCK ACTIVITY

Functional Classification	Truck Traffic Activity	Classification Segment Lengths	Number of Classification Segments	Traffic Volume Segments
Higher FC roads, i.e., Interstates, Principal Arterials – Other Freeways and Expressways, etc.	High	Long	Few, but this number should be about equal to 25-30% of volume counts	Few – encompasses classification segments
Lower FC roads, i.e., Minor Arterial, Major and Minor Collector, Local	Combination of Low, Medium, High	Combination of long and short segments where traffic generators are found	Depends upon number of defined traffic segments; also this number should be about equal to 25-30% of volume counts	Depends upon length (extent) of road and level of truck activity; the higher the fluctuation in truck activity, the more counts should be taken at locations with +/- 10% change in traffic volumes; the traffic volume segments should encompass the classification segments

In some cases, the truck traffic may not change over large expanses of road and a small number of classification segments will cover the road. In the interstate system, for example, classification segments may extend over several interchanges and be very long. The character of the highway and the traffic it carries will play a major role in the definition of these segments and in the number of classification counts needed. Roads that service truck traffic generating activities will necessitate more classification segments, more classification counts, and more frequent revision than roads through regions that experience little trucking activity.

Lower functional systems, where truck traffic may be sporadic, may require long segments in some areas and shorter segments in others, particularly where truck traffic generators are found. Judgment will play a large role in the roadway segmentation and the classification count planning in these areas. Additional classification counting may be needed to better identify where significant changes occur and how these affect the definition of segments.

The structure of the road system is superimposed by a system of traffic volume segments that allow the traffic-counting program to cover it. Likewise, the traffic volume segments will be covered with a smaller subset of vehicle classification segments that allow the establishment of a vehicle classification program that covers the system and provides comprehensive truck data.

The vehicle classification segment inventory will allow a determination of how much classification counting is needed and how many of the volume counts should be classified. A general rule of thumb is that 25 to 30 percent of the coverage volume counts should be classification. This depends on the actual volume coverage program in operation, the character of the road system covered, and many other considerations. The general rule of thumb applies to the traffic volume program recommendation using a coverage program over a three-year cycle.

Common sense and judgment are greatly needed to determine how to integrate classification and volume counting. Different agencies will make different decisions depending on many considerations. In some cases, the availability of low cost classification equipment can almost justify the conversion of most counting to classification. The gain in information on trucks, combined with the elimination of the error introduced by axle correction, will likely justify the extra cost. Many of the newer counters perform classification, and many agencies that have acquired the new equipment classify rather than only collect volume data. The trend is to go towards collecting and storing all vehicle types in a per vehicle format. On the other hand, changes in program direction, the acquisition of newer equipment, and the implementation of program changes do not occur overnight. Many organizations depend on available counters, have long-term data collection contracts, or do not have established classification programs.

Many lower volume roads do not have the volume of classified vehicles (trucks) to justify the full conversion of volume counting to classification. These are the roads where the installation of classifiers based on road tubes is easier and where equipment limitations are not a problem. However, once a classification count is taken, additional repetitive counts may not improve the truck volume estimates. In these cases, a decision to save a little time, effort, and funding could be appropriate.

On higher road systems, repetitive classification may greatly enhance the understanding of truck volume variability and result in better truck volume estimates. However, on these roads the collection of classification data is much more problematic. In the higher volume systems, portable equipment installation may not be safe or effective, and the installation of more expensive equipment is the only solution.

Such constraints may dictate a slower conversion from the current data collection program to the recommended program that emphasizes classification counting. Still, all highway agencies need to understand the use of their roadways by trucks, and consequently counting of trucks is an important task. To help achieve that objective, another useful rule of thumb is that a minimum of one vehicle classification count should be taken on each road each year to insure a minimum of data available annually to represent each road. Where practical, these counts should be taken at existing HPMS volume sample sections to insure the quality of classification data reported to the HPMS.

Many caveats apply to this rule of thumb as well. For long roads (such as roads that extend across an entire State), far more than one count should be taken; for roads that change character (e.g., a route may be primarily a farm to market road in one place but become a major freight hauling road in another), several classification counts may be appropriate.

Roads that experience significant changes in truck traffic due to changes in industrial activity and/or junctions that lead to truck generators may need classification counts on either side of the junctions where truck activity levels change. For minor routes, a single classification count may be all that is needed. Finally, some agencies may decide to take additional vehicle classification counts whenever resources permit simply because truck volume data play a major role in defining coverage program segments and to insure quality data is available to meet user needs.

The implementation of a comprehensive classification coverage program requires direct integration into the standard volume counting program activities. The manner of scheduling, equipment, staff, and resources should be adequately considered.

It may not be necessary to perform vehicle classification counts at the same location every year. Any placement within the defined segment should provide adequate representation and any additional counts taken help to verify the annual estimate provided. Likewise, classification counts need not be taken at the same time each year because the conversion to annual estimates accounts for the temporal variability. In fact, counts taken at different times of the year provide independent estimates that will help to verify and/or improve the segment estimate. Careful scheduling of the data collection effort may also be necessary to measure important, seasonal truck movements such as those due to harvesting or other highly seasonal events. The recommended minimum length of

monitoring for vehicle classification data remains at 48 hours. The recommended cycle of monitoring for the classification program is also three years. The schedule of counts should be developed to ensure that coverage of each classification segment occurs at least once within a six-year cycle.

Whenever possible, vehicle classification counts should be taken within the HPMS volume sample sections. This results in direct estimates for each sample section, thereby allowing the expansion of the truck percent variables in the HPMS to valid system estimates of truck travel.

Other Special Needs Counts

As with traditional volume counting, the vehicle classification count program requires special counts in addition to those collected for coverage to meet needs that the short duration program does not cover. Traditionally, these counts have been primarily project related.

Project Counts

In some States, a significant number of classification counts are project related. Most commonly, these counts are taken to determine the truck traffic on a road segment that requires a traffic load estimate as an input for a pavement rehabilitation design. Collection of the data specifically for the road segment being rehabilitated ensures that the count data reflect current conditions and that the data used in the geometric and structural design procedures are accurate enough to ensure adequate performance of the new pavement over the design life of the project. Common reasons for project counts include pavement design, operational design (e.g., signal timing or testing the need for truck climbing and/or passing lanes), geometric design, and corridor studies. Each project count can have different requirements for duration, spatial frequency, and types of summary measures that must be produced.

The establishment of a classification short duration program will allow a more complete understanding of truck traffic on the highway systems and optimistically limit the need for additional counting to only special cases.

Urban Classification Count Programs

The need for classification data in urban areas is pressing. Unfortunately, these are some of the most difficult places for current data collection equipment to operate. Existing counter technologies have significant difficulty classifying vehicles in conditions where vehicles do not operate at constant speed, where vehicles follow very closely, or where stop and go traffic occurs. This is particularly true for equipment that relies on inductive loops and axle detectors.

However, this does not mean that vehicle classification counts cannot be taken in urban areas. Agencies must simply take special care in selecting the technologies they use, the sensor and array that works best, and the locations where they place the equipment to ensure that the data collected are valid. Research efforts to investigate new technologies should continue. Several new technologies (ITS and segmented sensors), particularly video and various laser-based technologies, can classify accurately in urban conditions when they are correctly placed and calibrated. In the future, the trend is moving towards Super Sites that combine two or more sensor technologies.

Studies can be undertaken to identify the classification segments where classification data needs exist. The first step is to identify current installations where classification data may already be collected by ITS installations, State continuous counters, tolls, bridges, traffic signals, etc. Retrieving that data reduces the need for the use of portable data collection equipment at many sites. Second, identify the remaining locations where the portable data collection program can collect data using current technology. Subtracting these sites from the set of all needed locations should result in a set of locations where data cannot be collected using current means. The use of manual counts or visual counts is often a last resort in cases where data cannot be collected by other means. Finally, a

determination can be made of the counting/classification program needed to provide system short duration and meet special count needs.

Classification data also offers the additional advantage of providing speed data that are often used in air quality analysis and other urban studies. Likewise, speed studies provide classification data; thereby offering an opportunity for coordination and reduced data collection.

Integration of the Short Duration Count Program with Other Programs

At first glance, the short duration program recommended for classification counts can seem large. It is true that the recommended program is an expansion over previous recommendations. The expansion is due to the maturation of vehicle classification technology and an explosion of the need for truck data. However, many States that already actively collect substantial amounts of classification data to meet their own data needs may find that the current recommendations do not significantly increase the size of the program.

The first level of integration is that classification counts should replace traditional volume counts on road sections where classification counts are taken. Therefore, for every classification count taken, one less volume count is needed. (In most cases, this still requires an increase in data collection resources because it takes more staff time as well as more physical data collection equipment to set classification counters than it does to set traditional volume counters for the same number of lanes of data collection.) Use of classification counters to provide total daily volume estimates also has the advantage of providing direct measurement of daily volume since the need for axle correction is eliminated.

The short duration count program should also be integrated as much as possible with the project count program. Existing project counting activities can eliminate the need for short duration counts. Similarly, existing short duration counts can often supply project information, if the existing short duration count meets the informational needs of the project. Metadata to be included with the short duration count is very important.

Finally, the classification count program should be integrated with other traffic surveillance systems, particularly those involving regulation of the trucking industry (such as mainline sorting scale operations upstream of weight enforcement stations), as well as surveillance systems installed as part of traffic management, safety, and traveler information systems.

Duration of Short Counts

The period of monitoring recommended for vehicle classification counts is 48 consecutive hours. Other count durations can produce reasonable results in some cases, but are not recommended for general use. Equipment that can collect data in hourly traffic bins should be used for the general program. In urban areas or for special studies, the use of shorter intervals, such as 15 minutes, may be appropriate. The use of 48-hour periods is recommended because:

- The accuracy of the annual load estimates of 48-hour counts is better than that of 24-hour counts;

- Significant improvement in quality control capabilities become possible with the comparison of one day's hourly traffic counts against the second day's counts; and

- Longevity of the sensors/road tube and equipment has improved to provide longer duration counts.

Counts for less than 24 hours are not recommended unless they are intended to provide project specific information (such as turning movement counts for signal timing plans). This is because truck travel changes significantly during the day and some sites can experience relatively large truck volumes at times when other traffic volumes are light. Counting throughout the day is important to determine accurate daily truck volumes, particularly on roads that carry substantial numbers of trucks.

Counts of less than 48 hours are usually taken as a last resort when other data collection alternatives are not available. These counts will need to be adjusted to daily totals using a daily adjustment factor to convert the shorter period to a 24-hour estimate. This adjustment factor should be obtained from more extensive classification counts on similar roads because the time-of-day distribution of truck volume is not the same as that for total volume. The daily volume will need to be converted to an annual estimate by using the appropriate DOW and monthly factors. Reasons should be detailed in the State TMS plan and approved by the local FHWA district office.

Vehicle classification counts of longer than 48 hours are useful, particularly when those counts extend over the weekend, since they provide better DOW volume information. However, in some locations it is difficult to keep portable axle sensors in place for periods that significantly exceed 48 hours. Many highway agencies have also had difficulty in developing cost-effective staff and equipment utilization plans when using 72-hour or longer count durations. Whether a highway agency can conduct longer counts is a function of short duration area size, staff utilization, and other factors. Longer duration counts from 72 hours to 7 days are encouraged.

While a strong case can be made for a number of other count durations, the benefits of 48-hour counts are supported by recent research findings. In particular, a study of truck volume variability and the effect of factoring classification counts showed that an improvement of between three and five percent in estimation of annual average volumes could be achieved by increasing the duration of the classification count from 24 to 48 hours. A study of total traffic volume counts by Cambridge Systematics found that lower volume roads tend to have much greater day-to-day volume fluctuations (in percentage terms) than higher volume roads. These roads showed the greatest improvement when traffic counts were extended from 24 to 48 hours.

3.3.4 OCCUPANCY/HEADWAY/GAP

Many traffic monitoring devices used to collect short duration traffic performance statistics can produce other data in addition to those measures described in the previous section. This data can be used for other key analytical tasks. For example, traffic monitoring devices called event recorders time stamp the passage of individual vehicles and/or their axles. This data not only describe the traffic volume and often vehicle classification, they explicitly measure the headway between vehicles and thus the vehicle gaps in the traffic stream available for vehicles to make turning movements across that traffic stream. Most headway and gap information is collected and reported as part of special studies and capacity analysis for which short duration counts are highly suited. Traffic volume and classification data is also available from most event recorders. Some portable equipment can provide estimates of lane occupancy, but this statistic is not commonly requested from short duration counts. PV format allows this to be reported from only one format.

3.3.5 MOTORCYCLES

Motorcycles are the most dangerous motor vehicles for both operators and passengers of any age. Moreover, data from the NHTSA's Fatality Analysis Reporting System (FARS) indicate disturbing trends in motorcycle safety:

- In 2006, motorcycle rider fatalities increased for the ninth consecutive year since reaching the lowest level in 1997 from 2,116 in 1997 to 4,810 in 2006 – an increase of 127 percent;

- Trends accompanying the rising motorcyclist death toll include a dramatic increase in motorcycle ownership, particularly by riders over 40 years old, along with changes in other factors such as motorcycle size; and

- The rate of increase in fatalities has outpaced the rate of increase in motorcycle registrations.

To assess motorcycle safety, it is necessary to know the number of crashes as well as the corresponding exposure to determine a fatality rate. One of the key exposures is the motorcycle miles traveled (MC data is the denominator for exposure and crash rates):

- Motorcycle exposure data is used to inform national decisions and establish motorcycle related policies and safety countermeasure programs;

- Motorcycle exposure data is an important part of current safety performance measures, which measure the number of motorcycle fatalities per vehicle registrations and per million miles traveled; and

- Motorcycle travel data, especially by roadway functional system, helps the DOT to better understand the distribution of travel and devise effective design and operational measures for both reliable and safe travel of motorists. Motorcycle travel data is a critical element used in developing effective safety countermeasures.

The Highway Performance Monitoring System (HPMS) requires the reporting of percent of motorcycle travel by functional system group in the HPMS Vehicle Summaries dataset. Historically, approximately 15 percent of the States do not report motorcycle travel, and the FHWA estimates for these missing data in the table VM-1, *Annual Vehicle Distance Traveled in Miles and Related Data by Highway Category and Vehicle Type*. However, based on the HPMS requirement for motorcycle travel and research documented in the *Counting Motorcycles* report for the AASHTO Standing Committee on Planning (February 2010), of the 24 States surveyed, 23 States are currently counting motorcycles (Class 1 vehicles), with 20 States using road tubes for short counts and 17 States using piezo cable for continuous counts. The benefits and challenges associated with the use of these and other technologies are explored in the report. This report indicates that inductive loops and piezoelectric sensors are also used in combination to collect short classification counts, particularly on roads whose traffic volumes make the use of road tubes difficult. The report also specifies that to maximize the probability that inductive loops detect the presence of Class 1 vehicles, the loops should extend nearly across the full width of the lane.

A successful example of one State's ability to detect motorcycles using inductive loops and piezo sensors comes from the State of Virginia. The Virginia DOT (VDOT) worked with their vendor to develop a four-channel loop board that meets the required performance standard and a piezo card that provides improved detection of motorcycle axles by analyzing complex waveforms and rejecting energy from adjacent lanes. VDOT attributes their ability to detect motorcycles to their installation standards for loops and piezos. Loops are installed with four turns of wire and no splices, using wire that meets International Municipal Signal Association (IMSA) Specification 51-7; and they are now installing two piezos stacked in a single saw cut. VDOT also uses a magnetic length (detected by the inductive loops) of seven feet to distinguish motorcycles from other compact vehicles. To reduce the potential of undercounting Class 1 vehicles using the combination of loops and piezos, VDOT takes an additional step of using six bins instead of a single bin for all vehicle counts that cannot be classified (Thomas O. Schinkel, *Mid-Atlantic Successes and Challenges* presented at NATMEC, August 2008). One of these bins, Bin 21, is used for vehicles whose length is less than seven feet, but for which fewer than two axles are detected. On two-lane, two-way roads, this condition usually indicates that the piezo at a classification site has begun to fail and did not detect one or both of the axles of a Class 1 vehicle. Accordingly, on these roads, Bin 21 vehicles can be assigned to Vehicle Class 1.

Traffic Data Collection and Motorcycles

A State DOT should be able to provide users with an estimate of the amount of traffic by vehicle class by road segment – including motorcycle travel. Motorcycle volume and percentage estimates should be available for the date when data were collected and as annual average estimates corrected for yearly, monthly, and DOW variation.

Complicating the process for annualizing motorcycle counts is that travel patterns for motorcycles are usually different from those for cars or trucks. Motorcycle volume patterns are primarily recreational patterns, although commuter travel may be significant in some cases. Consequently, motorcycle travel is frequently heavily dependent on the DOW (higher on weekends), season (higher in summer), and special events (e.g., rallies). Recreational motorcycle travel may also concentrate on specific

roads more than car or truck travel typically does. (That is, some specific roads are commonly used by large groups of motorcycles for "group rides" – therefore creating very large increases in motorcycle VMT on a relatively modest series of roads and days of the year.)

The *TMG* recommends that a vehicle classification-counting program include both extensive, geographically distributed, short duration counts and a smaller set of continuous counters. This same guidance works for effectively collecting motorcycle travel, but accurately estimating motorcycles does require some refinement of the traditional count program to account for motorcycle patterns, simply because many of the traditional data collection plans are structured specifically around understanding the movements of cars and trucks.

The first change required to the traditional traffic monitoring program is for States to develop a process for converting short counts to estimates of annual average daily travel that specifically factors short duration motorcycle counts (as well as specifically factor the other vehicle classes) based on the travel patterns observed for each of those classes. Without motorcycle specific adjustments, short duration classification counts yield biased annual estimates of motorcycle travel.

Continuous counters should provide an understanding of how typical motorcycle travel varies by day of the week and month of the year. Continuously operating vehicle classification counters (CVC) are the backbone of the vehicle classification program and should be maintained to a high degree of accuracy. To provide motorcycle specific adjustment factors, States should account for motorcycle travel patterns when selecting locations for permanent vehicle classification counters.

As with traditional traffic volume counting, continuous classifiers should be supplemented by classification short duration counts. A large number of short duration vehicle classification counts should be performed to monitor movements of motorcycles and other vehicle classes on individual roads. They should include data for all lanes and directions for a given location.

To capture motorcycle movements and more effectively estimate annual motorcycle VMT, some short counts should be taken during rallies and in places where motorcyclists are known to travel. For example, two-lane rural roads without much truck traffic should be counted if there is reason to expect their use for recreational motorcycle travel. Some short counts should be taken on weekends on roads that are suspected or known to be serving recreational motorcycle travel needs. Data collected on weekends and during special events and periods of seasonal travel should be annualized to represent AADT and accounted for in VMT estimates. Some of this data should be collected using effectively sited, permanent AVC systems placed on recreational routes with motorcycle travel.

This data collection effort yields the basic motorcycle traffic statistics needed on any given road, including the geographic variability and the time-of-day distribution at a variety of locations.

A sufficient number of locations should be monitored to meet HPMS requirements. Motorcycle travel is reported under the HPMS summary travel as a proportion of total travel by roadway functional class. The State should have motorcycle and other vehicle class travel data for all of the roadway functional classes. If the stations are sufficiently distributed according to road type and by traffic volume, a simple average of the observed proportions from all stations can be reported on the summary travel table (see *HPMS Field Manual*).

Traffic data collection, including motorcycle data collection, is eligible for Federal funding under a wide range of Federal-aid highway programs with all past (ISTEA, TEA-21, SAFETEA-LU) and current (MAP-21) Federal-aid highway legislations.

Historically, many traffic data collection technologies have had difficulty accurately counting motorcycles. Considerable improvement in this area has been made in the past few years. Montana utilizes bi-wheel path counting for proper motorcycle counting and is especially effective during motorcycle rallies where they may be doubled-up into one lane. Arizona uses a wider 6' by 8' loop in the lane to provide a large lane coverage that prevents motorcycles from not being detected with loops. This wider lane width of 8' requires that each bi-lane array be staggered so that interference or

"cross talk" between loops does not occur. Multiple technologies can be used successfully for this activity, although each technology has its own strengths and limitations.

Axle, visual, and presence sensors can all be used successfully for collecting motorcycle volumes as part of vehicle classification counts, although each provides a different mechanism for classifying vehicles. Within each of these three broad categories are an array of sensors with different capabilities, levels of accuracy, performance capabilities within different operating environments, and output characteristics. Each type of sensor works well under some conditions and poorly in others. For example:

- Light axle weights, low metal masses, and narrow footprint make motorcycles harder to detect;

- Motorcycles in parallel or staggered formation may confuse detectors;

- Adjusting detector sensitivity for trucks may lead to reduced detection of motorcycles; and

- Some combination trucks may be misclassified as a single-unit truck followed by a motorcycle (the rear tandem axle) when the loop incorrectly detunes in the middle of the vehicle.

Conventional full lane road tubes are relatively inexpensive and provide short, sharp signals but may have problems counting groups of motorcycles traveling together. Using more sophisticated axle sensors and data collection electronics that can monitor left and right wheel paths independently can improve the ability of axle sensor based classification equipment to count all motorcycles in a group, while also correctly counting and classifying cars and trucks. For axle sensor arrays that are placed in a staggered formation, a motorcycle will usually hit one sensor but not both; the system will likely record this as a vehicle with missing axle detection and classify it as a passenger car by default – unless the data collection electronics are specifically designed to look for motorcycles. For this reason, FHWA recommends full-lane width axle sensors (road tube, tape switches, or piezo sensors) rather than half-lane width sensors.

Side-looking radar provides length-based classification and detects motorcycles. Inductive loops can work well if properly installed and maintained, but they too can have problems with motorcycles traveling in groups, especially when riding in slightly staggered side-by-side configurations in individual lanes. Conventional loops can also be hard to tune to capture motorcycles while at the same time not having that same sensitivity setting, resulting in over counting of cars and trucks. Some studies have shown that accuracy of counting in all classes can be improved by using inductive loop signature technology and calibrating sites to be accurate. Accuracy improvements have also been shown to occur when using 6' by 8' foot loop layouts instead of the conventional 6' by 6' configuration. Quadrupole loops also known as figure-8 style loop detectors have enhanced sensitivity for detecting motorcycles, bicycles, and smaller cars.

Sensors that cover a small area such as magnetometers have problems detecting motorcycles or groups of motorcycles.

All vehicle classifiers should be calibrated and tested, and it is a good idea to involve motorcycles traveling in groups as part of those tests to ensure that motorcycles are properly counted. It is also advisable to use a test standard such as ASTM E2532-06, *Standard Test Methods for Evaluating Performance of Highway Traffic Monitoring Devices*.

If length-based classification is used, it should accommodate motorcycle identification as one of the groups. The reader should reference Federal Highway Administration Pooled Fund Program Report TPF-5[192], *Loop and Length Based Vehicle Classification* prepared for Minnesota DOT.

Axle sensors, loops, and road tubes that detect the presence of vehicles should be placed – and loop sensitivities set – in the travel way of motorcycles to assure their detection. Sensors that detect vehicles over the width of a lane are preferable to those that are partial lane.

All vehicle classes are important; no vehicle class should be shortchanged. It is the responsibility of each agency to make the best decision as to the types of automatic vehicle classifiers to purchase, install,

calibrate, and maintain so that their classification (both axle and/or length) data accurately represents traffic conditions.

3.4 CALCULATIONS AND COMPUTATIONS FOR END OF YEAR PROCESSING

This section presents basic procedures for computing statistics or estimates derived from the vehicle classification program. Statistics discussed include:

- ADTT;
- AADTT (annual average daily truck traffic);
- Axle correction factors;
- Factors for converting daily truck traffic counts into estimates of AADTT (by class);
- Factors that allow conversion of AADTT estimates (by class) into average day of week estimates for use in the draft *NCHRP 1-37A Pavement Design Guide;*
- Sum of 4-13 for 24 hours;
- % Single Unit (SU); and
- % Combination Unit (CU).

3.4.1 COMPUTATION OF AADTT

Computation of AADTT (by vehicle class) from a short duration count requires the application of one or more factors that account for differences in time-of-day, DOW, and seasonal truck traffic patterns. These adjustments are the same as those applied to traditional volume counts, except that they should be applied by individual vehicle classification when working with classification count data.

3.4.2 ESTIMATING DAILY VOLUMES FROM LESS THAN DAILY COUNTS

Classification counts should be taken for 48 consecutive hours. When it is not possible to collect at least 24 hours of data, time-of-day adjustments can expand the short counts to daily estimates. Most classification counts are taken in hourly increments. When these hourly volumes add up to less than 24 hours (usually with visual counts), it is necessary to expand them to 24 hour estimates.

This should be accomplished using adjustments from data collected by continuous vehicle classification counters. Adjustment tables should be created for specific types of roadways (using the factor groups discussed earlier in this chapter if a better system is not available) and specific hours of the day. In this manner, the factor applied to adjust a very short count to an estimate of daily traffic volume (by class) will depend not just on how many hours were counted but on which hours were counted, as well as on which class of vehicles is being adjusted. For example, the adjustment for a six-hour count taken from 8 a.m. to 2 p.m. may be very different from the adjustment that should be applied to a six-hour count taken from 2 p.m. to 8 p.m..

These adjustment tables can be created by simply computing the percentage of daily traffic that occurs during any one hour of the day for each vehicle class for each type of day of the week. These percentages can then be added together as needed to create an adjustment percentage for any series of hours of data collection.

TABLE 3-19   CALCULATION OF AVERAGE TRAVEL BY TIME OF DAY FOR COMBINATION TRUCKS AT AN EXAMPLE CONTINUOUS COUNTER SITE

Hour	Average Weekday Volumes By Hour	Percentage of Traffic
Midnight - 1 a.m.	20	1.9%
1 a.m. - 2 a.m.	30	2.8%
2 a.m. - 3 a.m.	10	0.9%
3 a.m. - 4 a.m.	10	0.9%
4 a.m. - 5 a.m.	20	1.9%
5 a.m. - 6 a.m.	40	3.7%
6 a.m. - 7 a.m.	80	7.4%
7 a.m. - 8 a.m.	100	9.3%
8 a.m. - 9 a.m.	60	5.6%
9 a.m. - 10 a.m.	80	7.4%
10 a.m. - 11 a.m.	70	6.5%
11 a.m. - Noon	80	7.4%
Noon - 1 p.m.	50	4.6%
1 p.m. - 2 p.m.	60	5.6%
2 p.m. - 3 p.m.	90	8.3%
3 p.m. - 4 p.m.	80	7.4%
4 p.m. - 5 p.m.	50	4.6%
5 p.m. - 6 p.m.	40	3.7%
6 p.m. - 7 p.m.	30	2.8%
7 p.m. - 8 p.m.	20	1.9%
8 p.m. - 9 p.m.	10	0.9%
9 p.m. - 10 p.m.	20	1.9%
10 p.m. - 11 p.m.	10	0.9%
11 p.m. - Midnight	20	1.9%
	1,080	100.0%

To compute the daily total traffic volume estimated by the short count, the simple formula below is used:

$$\text{Daily Traffic Volume} = \frac{\text{Short count volume} \times 100}{\text{Percent of travel during time period counted}}$$

Therefore, if a six-hour count was taken from six a.m. to noon on a weekday and 260 combination trucks were counted, the total daily combination truck volume would be estimated as 600 trucks (260 × 100 / 43.6 = 596 ≈ 600).

3.4.3   ESTIMATING ANNUAL AVERAGE DAILY TRAFFIC VOLUMES FROM MORE THAN 24-HOUR COUNTS

If the data that is collected cover 48 or more hours, the data should be summarized to represent a single daily count. This can be accomplished in two ways, depending on how the factoring process is performed.

- If individual DOW factors are used (e.g., a different factor for Tuesdays than for Wednesdays), then each 24 hour count can be converted into an estimate of annual average daily traffic, and the different daily values averaged into a single estimate of AADTT.

- If a general DOW adjustment (e.g., a single weekday to average DOW adjustment), the individual hourly volumes can be averaged. (Only data for complete hours should be used. Partial hours should be discarded.) These averages are then totaled to produce a single daily volume, which can then be adjusted for seasonality and day of week.

3.4.4 COMPUTATION OF AXLE CORRECTION FACTORS

Emphasis on the collection of classification data should minimize the need for axle correction. Whenever possible, axle correction factors needed to convert axle counts to vehicles should be developed from vehicle classification counts taken on the specific road. In addition, the classification count should be taken from the same general vicinity and on the same day of week (a weekday classification count is usually sufficient for a weekday volume count) as the axle count it will be used to adjust. Where a classification count has not been taken on the road in question, an average axle correction factors can be estimated from the WIM and continuous classification sites.

The computation is the same whether the data come from a single short duration count or from a continuous WIM scale. Table 3-20 illustrates the process.

In the table, vehicle volume is computed by dividing the total number of axles counted by the average number of axles per vehicle. Thus, an axle count of 4,465 axles would be equal to a vehicle volume of 1,795 (4,465 / 2.49 = 1,795).

Multiplicative axle correction factors can be derived as the inverse of the average number of axles per vehicle. In the above example, the factor would be 0.40 (the inverse of 2.49). The number of vehicles (1,795) would then be estimated by multiplying the number of axles (4,465) times the factor (0.40).

TABLE 3-20   NUMBER OF AXLES PER VEHICLE

FHWA Vehicle Class (A)	Daily Vehicle Volume (B)	Average Number of Axles Per Vehicle	Total Number of Axles
1	100	2.0	200.0
2	1,400	2.2	3,080
3	45	2.3	103.5
4	15	2.1	31.5
5	20	2.0	40.0
6	40	3.0	120.0
7	5	4.2	21.0
8	15	3.9	58.5
9	120	5.0	600.0
10	5	6.4	32.0
11	15	4.9	73.5
12	5	6.0	30.0
13	10	7.5	75.0
Total Volume	1,795	Total Number of Axles	4,465.0
		Average Number of Axles Per Vehicle	2.49

3.4.5 FACTORS FOR CONVERTING DAILY CLASSIFICATION COUNTS TO AADTT BY CLASS

The calculation of factors for converting average daily traffic (by class) to annual average conditions begins by computing average DOW, average-day-of-month, and annual average daily traffic statistics at each continuous count location. The ratios from each continuous count location are then averaged within the factor groups to produce the average factor for the group.

The first step in computing DOW adjustment factors is to compute an average day of week for each month. For example, the average Monday is computed by adding the Monday traffic volumes in the month, and then dividing by the number of Mondays in the month.

An average-day-of-month can be computed by simply averaging the seven daily values within each month. This is preferable to calculating a simple average for all days of the month, because then average monthly statistics can be compared from one year to the next without worry that in one year there were more weekend days than in another year.

Annual average daily traffic for each day of the week for each vehicle class can then be computed as the average of the 12 months. The best computational procedure is recommended in the *AASHTO Guidelines for Traffic Data Programs* and can be shown mathematically as follows:

$$AADTT_c = \frac{1}{7} \sum_{i=1}^{7} \left[\frac{1}{12} \sum_{j=1}^{12} \left(\frac{1}{n} \sum_{k=1}^{n} ADTT_{ijkc} \right) \right]$$

Where:

$ADTT_{ijkc}$ = daily truck traffic for class c, day k, of DOW i, and month j

i = day of the week

j = month of the year

k = 1 when the day is the first occurrence of that day of the week in a month, 4 when it is the fourth day of the week

n = the number of days of that day of the week during that month (usually between one and five, depending on the calendar and the number of missing days.)

Chapter 4 TRAFFIC MONITORING FOR NON-MOTORIZED TRAFFIC

4.1 INTRODUCTION

This is the first edition of the *Traffic Monitoring Guide* to include information on monitoring pedestrians, bicyclists, and other non-motorized road and trail users. Even though both of these modes preceded the automobile, the monitoring of non-motorized traffic has not been systematic or widespread in the U.S. and, even today, is not nearly as comprehensive as motorized traffic monitoring.

This chapter provides basic guidance intended to improve the state-of-the-practice in non-motorized traffic volume monitoring (other attributes like origin-destination, gender, and helmet use are not addressed in this *Guide*). In many cases, however, this guidance is limited because the systematic monitoring of pedestrians and bicyclists is still an emerging area that requires more research. Limited information is known about the best and most cost-effective ways to automatically collect non-motorized traffic data, especially because non-motorized traffic levels are typically much lower and more variable than motorized traffic levels.

One of the key differences in state-of-the-practice between non-motorized and motorized traffic monitoring is the scale of data collection. Most non-motorized data collection programs have a much smaller number of monitoring locations, and these limited location samples may not accurately represent the entire geographic area of interest. In many cases, the non-motorized monitoring locations have been chosen based on highest usage levels or strategic areas of facility improvement. Given limited data collection resources and specific data uses, these site selection criteria may be appropriate. However, one should recognize that these limited location samples might represent a biased estimate of overall usage and trends for a city or State. More research is needed to identify statistically representative site selection criteria.

A second key difference is that non-motorized traffic will typically have higher use on lower functional class roads and streets as well as shared use paths and pedestrian facilities, simply because of the more pleasant environment of lower speeds and volumes of motorized traffic. Conversely, motorized traffic monitoring focuses on higher functional class roads that provide the quickest and most direct route for motorized traffic.

A third key difference in current practice is a tendency to use very short duration counts (i.e., as short as 2 hours) for non-motorized traffic monitoring, primarily because of the perceived difficulty of automatically counting pedestrians and bicyclists (as well as the desire to collect gender and bicycle helmet use). Although this practice is not prohibited by the *Guide*, data users should recognize that these very short-duration counts can introduce significant overall error when non-motorized traffic use is low and inherently variable. If short-duration non-motorized counts are to be used, then it is essential that longer counts be taken to establish hourly patterns and a statistical basis for extrapolation of these counts. This issue will be addressed in more detail in Sections 4.4 and 4.5.

Finally, a fourth key difference is that technologies for counting pedestrians and bicyclists still are evolving and error rates associated with different technologies are not well known. All methods for counting both motorized and non-motorized traffic have error rates and provide estimates that only approximate actual use; however, the error rates for technologies used to count motorized traffic generally are better understood, as are the procedures for managing or reducing these errors.

4.2 NON-MOTORIZED TRAFFIC MONITORING TECHNOLOGY

This section describes the various technologies that are commonly used to count non-motorized (i.e., bicyclists and pedestrians) traffic volumes at fixed locations. The discussion differentiates between those technologies best suited to count bicyclists versus those best suited to count pedestrians. The

discussion also identifies those technologies that are ideal for short-duration (i.e., portable) count locations and those that are ideal for continuous (i.e., permanent) count locations. This document does not address technologies that collect other attributes of non-motorized travel, such as the use of GPS-enabled mobile devices for trip traces or the use of Bluetooth-enabled devices for origin-destination or travel time.

4.2.1 OVERVIEW AND CHALLENGES

Many of the basic technologies used to count bicyclists and pedestrians are similar to those used to count cars and trucks; however, the design/configuration of the sensors and the signal processing algorithms are often quite different. Therefore, separate equipment typically is used to monitor non-motorized traffic.

Technological challenges to non-motorized traffic monitoring are as follows:

- Pedestrians and bicyclists are less confined to fixed lanes or paths of travel than motor vehicles, and they sometimes make unpredictable movements. Pedestrians take shortcuts off the sidewalk or cross streets at unmarked crossing locations. Bicyclists sometimes ride on sidewalks or travel outside designated bikeways. They may stop in front of a sensor to talk, wait, or even to examine the sensor. These actions make it difficult to place or aim sensors and may decrease the accuracy of the sensor equipment.

- Pedestrians and bicyclists sometimes travel in closely spaced groups, and some sensors have difficulty differentiating between individuals within the group. In these cases, a group with multiple persons will be counted as one person, and the sensor will underestimate the actual counts.

- Despite these challenges, several technologies can be used to accurately count non-motorized traffic. The growing demand for automatic counters has brought about recent improvements in equipment accuracy and capabilities. Increased competition in this marketplace and collective experience with existing products will continue to drive improvements to automatic bicyclist and pedestrian counters.

4.2.2 SELECTING NON-MOTORIZED COUNTING EQUIPMENT

Selecting the most appropriate bicyclist and/or pedestrian counter can be a daunting task. Commercially available counters use a variety of technologies and features that can vary dramatically and affect how, what, where, and how long counts are collected. Cost per data point can also vary greatly between counters.

Figure 4-1 presents a simplified flowchart that can help to narrow possible choices based on the two most important aspects of data collection:

1. What are you counting? Bicyclists only, pedestrians only, pedestrians and bicyclists combined, or pedestrians and bicyclists separately?

2. How long (are you counting)? Permanent, temporary, or somewhere in-between?

Consider the following example: a city wishes to monitor a shared-use path and would like to count bicyclists and pedestrians separately on a permanent basis. Using the simplified flowchart (Figure 4-2 for this example), the first decision point is "What are you counting?" In this example, the city wants to count both modes separately (note the circled blue and green icons in Figure 4-2). The next question in the decision process is "How long (will the counters be collecting data)?" In this example, the city wants continuous data from a permanent location, so technologies toward the middle and top of the table are relevant. Several equipment technologies are possible (e.g., pressure sensor and automated video imaging), but only a few have been used in common practice. Manual observers and video imaging with manual reduction are possible, but are typically used for short-term data collection.

For a permanent site capable of counting pedestrians and bicyclists separately, two technologies will have to be paired together. Because inductance loops are more commonly used at permanent sites, the city staff selects a combined system that has an infrared pedestrian counter paired with an inductance loop detector for bicyclists. The infrared sensor by itself is not capable of differentiating between people walking or bicycling; however, when combined with the inductance loop detector, the bicyclist counts are automatically subtracted from the infrared sensor counts.

1. What Are You Counting?

2. How Long? (Permanent → Temporary/Short Term)

Technology	Bicyclists Only	Pedestrians Only	Pedestrians & Bicyclist Combined	Pedestrians & Bicyclist Separately	Cost
Inductance Loops[1]	●			◐	$$
Magnetometer[2]	○				$-$$
Pressure Sensor[2]	○	○	○	○	$$
Radar Sensor	○	○	○		$-$$
Seismic Sensor	○	○	○		$$
Video Imaging: Automated	○	○	○	○	$-$$
Infrared Sensor (Active or Passive)	○[3]	●	●	◐	$-$$
Pneumatic Tubes	●			◐	$-$$
Video Imaging: Manual	○	○	○	●	$-$$$
Manual Observers	●	●	●	●	$$-$$$

○ Indicates what is technologically possible.

● Indicates a common practice.

◐ Indicates a common practice, but must be combined with another technology to classify pedestrians and bicyclists separately.

$, $$, $$$: Indicates relative cost per data point.

[1] Typically requires a unique loop configuration separate from motor vehicle loops, especially in a traffic lane shared by bicyclists and motor vehicles.

[2] Permanent installation is typical for asphalt or concrete pavements; temporary installation is possible for unpaved, natural surface trails.

[3] Requires specific mounting configuration to avoid counting cars in main traffic lanes or counting pedestrians on the sidewalk.

FIGURE 4-2   EXAMPLE: SELECTING NON-MOTORIZED COUNT EQUIPMENT

	Technology	Bicyclists Only	Pedestrians Only	Pedestrians & Bicyclist Combined	Pedestrians & Bicyclist Separately	Cost
Permanent	Inductance Loops[1]	●			◐	$$
	Magnetometer[2]	○				$-$$
	Pressure Sensor[2]	○	○	○	◐	$$
	Radar Sensor	○	○	○		$-$$
2. How Long?	Seismic Sensor	○	○	○		$$
	Video Imaging: Automated	○	○	○	◐	$-$$
	Infrared Sensor (Active or Passive)	○[3]	●	●	◐	$-$$
	Pneumatic Tubes	●			◐	$-$$
Temporary/ Short Term	Video Imaging: Manual	○	○	○	●	$-$$$
	Manual Observers	●	●	●	●	$$-$$$

1. What Are You Counting?

2. How Long? (Permanent ↑ to Temporary/Short Term ↓)

○ Indicates what is technologically possible.

● Indicates a common practice.

◐ Indicates a common practice, but must be combined with another technology to classify pedestrians and bicyclists separately.

$, $$, $$$: Indicates relative cost per data point.

[1] Typically requires a unique loop configuration separate from motor vehicle loops, especially in a traffic lane shared by bicyclists and motor vehicles.

[2] Permanent installation is typical for asphalt or concrete pavements; temporary installation is possible for unpaved, natural surface trails.

[3] Requires specific mounting configuration to avoid counting cars in main traffic lanes or counting pedestrians on the sidewalk.

Based on budget and commercial availability, a final decision can be more easily made about technology to be deployed. Table 4-1 provides additional technology information for counting bicyclists and pedestrians, various attributes of each technology, and their strengths and weaknesses. More detailed guidance on selecting equipment for non-motorized traffic data collection is provided later in this chapter. Table 4-1 is best used after the relevant technologies have been narrowed down using Figure 4-1.

The accuracy of commercially available products can vary significantly (Turner, et al., 2007; Grembek and Schneider, 2012; Greene-Roesel et al., 2008) based on configuration, installation, and level of use, even within a specific technology (such as inductance loops for bicycles). Calibration/validation procedures (even if conducted on a limited scale) should be used to ensure that count data is within the bounds of acceptable accuracy. In fact, some local agencies have developed an equipment adjustment factor that adjusts for systematic error (e.g., undercounting) that may occur with some technologies.

TABLE 4-1   COMMERCIALLY-AVAILABLE BICYCLIST AND PEDESTRIAN COUNTING TECHNOLOGIES

Technology	Typical Applications	Strengths	Weaknesses
Inductance Loop	Permanent counts Bicyclists only	Accurate when properly installed and configured Uses traditional motor vehicle counting technology	Capable of counting bicyclists only Requires saw cuts in existing pavement or pre-formed loops in new pavement construction May have higher error with groups
Magnetometer	Permanent counts Bicyclists only	May be possible to use existing motor vehicle sensors	Commercially-available, off-the-shelf products for counting bicyclists are limited May have higher error with groups
Pressure sensor/pressure mats	Permanent counts Typically unpaved trails or paths	Some equipment may be able to distinguish bicyclists and pedestrians	Expensive/disruptive for installation under asphalt or concrete pavement
Seismic sensor	Short-term counts on unpaved trails	Equipment is hidden from view	Commercially-available, off-the-shelf products for counting are limited
Radar sensor	Short-term or permanent counts Bicyclists and pedestrians combined	Capable of counting bicyclists in dedicated bike lanes or bikeways	Commercially-available, off-the-shelf products for counting are limited
Video Imaging – Automated	Short-term or permanent counts Bicyclists and pedestrians separately	Potential accuracy in dense, high-traffic areas	Typically more expensive for exclusive installations Algorithm development still maturing
Infrared – Active	Short-term or permanent counts Bicyclists and pedestrians combined	Relatively portable Low profile, unobtrusive appearance	Cannot distinguish between bicyclists and pedestrians unless combined with another bicycle detection technology Very difficult to use for bike lanes and shared lanes May have higher error with groups

Technology	Typical Applications	Strengths	Weaknesses
Infrared – Passive	Short-term or permanent counts Bicyclists and pedestrians combined	Very portable with easy setup Low profile, unobtrusive appearance	Cannot distinguish between bicyclists and pedestrians unless combined with another bicycle detector Difficult to use for bike lanes and shared lanes, requires careful site selection and configuration May have higher error when ambient air temperature approaches body temperature range May have higher error with groups Direct sunlight on sensor may create false counts
Pneumatic Tube	Short-term counts Bicyclists only	Relatively portable, low-cost May be possible to use existing motor vehicle counting technology and equipment	Capable of counting bicyclists only Tubes may pose hazard to trail users Greater risk of vandalism
Video Imaging – Manual Reduction	Short-term counts Bicyclists and pedestrians separately	Can be lower cost when existing video cameras are already installed	Limited to short-term use Manual video reduction is labor-intensive
Manual Observer	Short-term counts Bicyclists and pedestrians separately	Very portable Can be used for automated equipment validation	Expensive and possibly inaccurate for longer duration counts

4.2.3 INDUCTANCE LOOP DETECTORS

Inductance loop detectors operate by circulating a low alternating electrical current through a formed wire coil embedded in the pavement. The alternating current creates an electromagnetic field above the formed wire coil, and a conductive object (e.g., car, truck, and bike) passing through the electromagnetic field will disrupt the field by a measurable amount. If this disruption meets predetermined criteria, then detection occurs and an object is counted by a data logger or computer controller.

Inductance loop detectors do not require the presence of ferrous (i.e., iron, steel) bicycle frames; however, large conductive objects (like a car or truck) are more likely to meet the predetermined disruption criteria than smaller conductive or non-ferrous objects (like a motorcycle or bicycle). The sensitivity of an inductance loop can be changed to better detect motorcycles or bicycles, but the increased sensitivity often results in over counting for cars and trucks. For this reason, most agencies typically use dedicated loop detectors for counting bicycles rather than trying to use existing loop detectors to count cars, trucks, and bicycles.

Loop detectors are commonly used to detect the presence of motorized vehicles at or near intersections for the purposes of traffic signal control. In some cases, these loop detectors may detect the presence of bicycles. However, the location and configuration of these intersection-based loop detectors are often not ideal (and therefore rarely used) for counting purposes, both for motor vehicles and bicycles.

The preferred counting location is at mid-block or other locations where bicycles are free-flowing and/or not likely to stop. Ideally, loop detectors for bicycle counting are placed in lane positions primarily used by bicycles. If the loop detectors are placed in lanes shared by motorized traffic and bicycles, special algorithms will be necessary to distinguish the bicycles from the motorized traffic.

Inductance loop detectors are capable of measuring the direction of bicyclist travel using at least two possible options:

1. Installing an inductance loop within each directional travel lane and assuming that all (or a certain percentage) bicyclists in that lane are traveling in the specified direction (e.g., shared use path or directional bike lane).

2. Installing two inductance loops in series, such that direction can be inferred from the timing of detection events for each loop.

The first option is the most commonly used practice to date. For the second option, some data loggers or controller equipment may not be capable of interpreting signals from a paired inductance loop sequence.

The most important variables in accurate bicycle detection via a loop detector are:

- Loop configuration: Several different wire patterns have been used for counting bicycles, including quadrupole, diagonal quadrupole (also called Type D), chevron, and elongated diamond patterns (see Figure 4-3).

- Detector circuit sensitivity: The sensitivity should be high enough to detect non-ferrous bicycle frames but not so high as to detect motor vehicles in adjacent lanes.

- Bicycle position over the loop: Pavement stencils may be used to indicate optimal (i.e., most accurate) bicycle position over the loop detector, which is typically directly over the saw cut for the wire coil.

- Bicycle size and composition: A large steel frame is more likely to disrupt the loop detector's field than a smaller non-steel frame, but the threshold amount of ferrous metal is not a known quantity and varies based on the above three and other variables. Some inductance loop detectors are able to detect bicycles with non-steel frames due to the presence of ferrous metal in the wheels or other bicycle components.

FIGURE 4-3A   EXAMPLES OF INDUCTANCE LOOP DETECTOR SHAPES FOR BICYCLIST COUNTING
QUADRUPOLE SHAPE

Quadrupole Shape

SYMBOL

WINDING DETAIL

SAWCUT DETAIL

TYPE Q LOOP DETECTOR CONFIGURATION
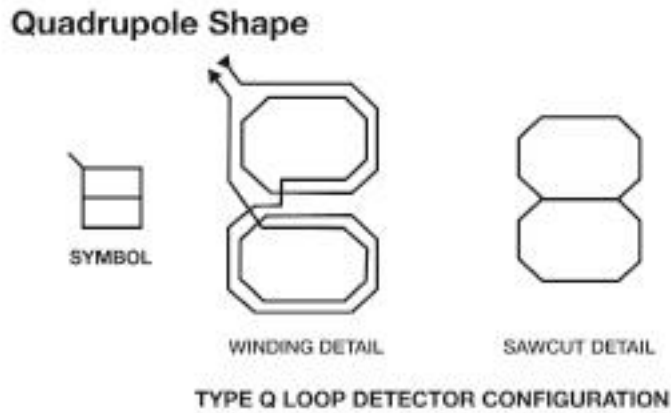
Source: Caltrans Standard Plan ES-5B, 2002.

FIGURE 4-3B   EXAMPLES OF INDUCTANCE LOOP DETECTOR SHAPES FOR BICYCLIST COUNTING
DIAGONAL QUADRUPOLE SHAPE

Diagonal Quadrupole Shape

SYMBOL

WINDING DETAIL

SAWCUT DETAIL

TYPE D LOOP DETECTOR CONFIGURATION
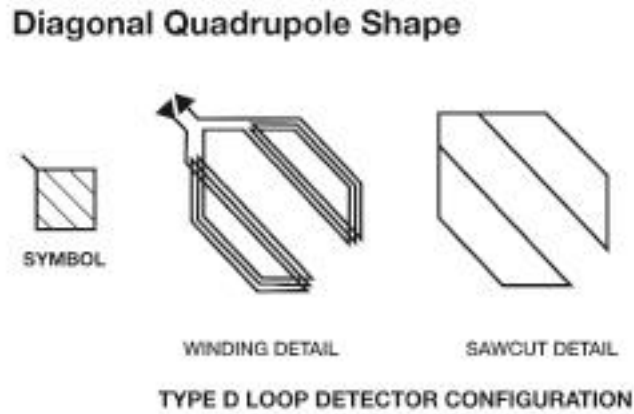
Source: Caltrans Standard Plan ES-5B, 2002.

FIGURE 4-3C **EXAMPLES OF INDUCTANCE LOOP DETECTOR SHAPES FOR BICYCLIST COUNTING**
DOUBLE CHEVRON SHAPE
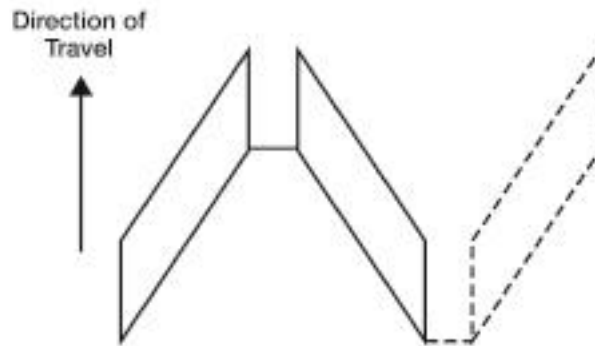
Source: Traffic Detector Handbook*, 2006.*

FIGURE 4-3D **EXAMPLES OF INDUCTANCE LOOP DETECTOR SHAPES FOR BICYCLIST COUNTING**
DOUBLE CHEVRON SHAPE: PHOTO

Source: *Shawn Turner, TTI.*

FIGURE 4-3E   EXAMPLES OF INDUCTANCE LOOP DETECTOR SHAPES FOR BICYCLIST COUNTING
ALTERNATIVE DOUBLE CHEVRON SHAPE
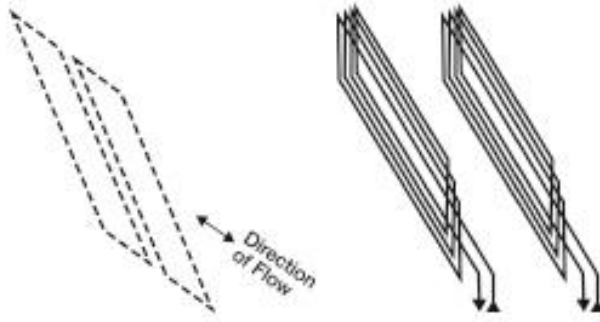
Source: Jeff Bunker, City of Boulder.

FIGURE 4-3F   EXAMPLES OF INDUCTANCE LOOP DETECTOR SHAPES FOR BICYCLIST COUNTING
ALTERNATIVE DOUBLE CHEVRON SHAPE: PHOTO

Source: Shawn Turner, TTI.

FIGURE 4-3G   EXAMPLES OF INDUCTANCE LOOP DETECTOR SHAPES FOR BICYCLIST COUNTING
ELONGATED DIAMOND SHAPE
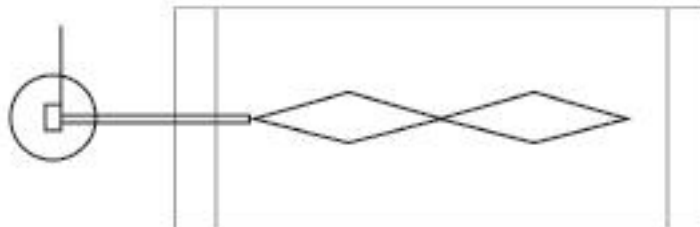
Source: Dan Dawson, Marin County NTPP Specifications Sheet, 2009.

Source: Shawn Turner, TTI.

4.2.4   INFRARED SENSORS

Two types of infrared sensors can be easily distinguished:

- Active infrared sensors use a signal transmitter on one side of the detection area and a receiver or target reflector on the other side. Active infrared sensors operate by sending a series of infrared pulses in a beam from a transmitter to a receiver. When the beam is broken for a pre-determined time, then an event or count is registered.

- Passive infrared sensors use a signal transmitter only on one side of the detection area and operate by identifying a changing heat differential in the detection area. If the heat differential and pattern meet pre-defined criteria, then a detection and/or count is registered.

Active infrared sensors have a narrower cone/zone of detection than passive infrared sensors. However, installation of active infrared sensors can be more challenging than passive infrared sensors. The transmitter and receiver parts of an active infrared sensor need to be aligned properly, and require a vertical mounting location on both sides of the detection area with a clear line of sight between. A passive infrared sensor only requires a single vertical mounting location on one side of the detection area. However, accuracy is improved when the passive infrared sensor is pointed toward a wall, building face, dense vegetation, or similar background.

Most infrared sensors perform best in areas where the travel area is constrained and/or the detection area is well defined. Because of the basic operating principle, infrared sensors sometimes cannot distinguish multiple persons in a group (i.e., side-by-side or closely spaced front-to-back). In addition, infrared sensors cannot differentiate between bicyclists and pedestrians; therefore, if separate counts are required, infrared sensors will need to be paired with another technology able to accurately count bicycles. For example, Figure 4-4 shows a permanent monitoring location that combines a passive infrared sensor with inductance loop detectors.

Most infrared sensors have a small profile and form factor (see Figure 4-5 for examples). For portable applications, infrared sensors can be enclosed in a vandal-resistant, lockable box and attached to an existing pole, fence post, or tree. For permanent applications, infrared sensors are often enclosed within wooden fence or other vertical posts.

Because passive infrared sensors look for heat differentials and their patterns, there may be higher error rates when the ambient air temperature approaches normal body temperature (97°-100°

Fahrenheit). However, no conclusive evidence of this increased error exists, and the error may vary among different brands of passive infrared counters.

Figure 4-6 shows a typical configuration for an active infrared sensor. This example shows an ideal location: 1) primarily used by pedestrians and bicyclists only; 2) the travel area is constrained with the detector pointing across the sidewalk away from the street; and 3) the detection area is well defined in a position where pedestrians and bicyclists will be traveling perpendicular to the sensor.

FIGURE 4-4   EXAMPLE OF PASSIVE INFRARED SENSOR COMBINED WITH INDUCTANCE LOOP DETECTORS
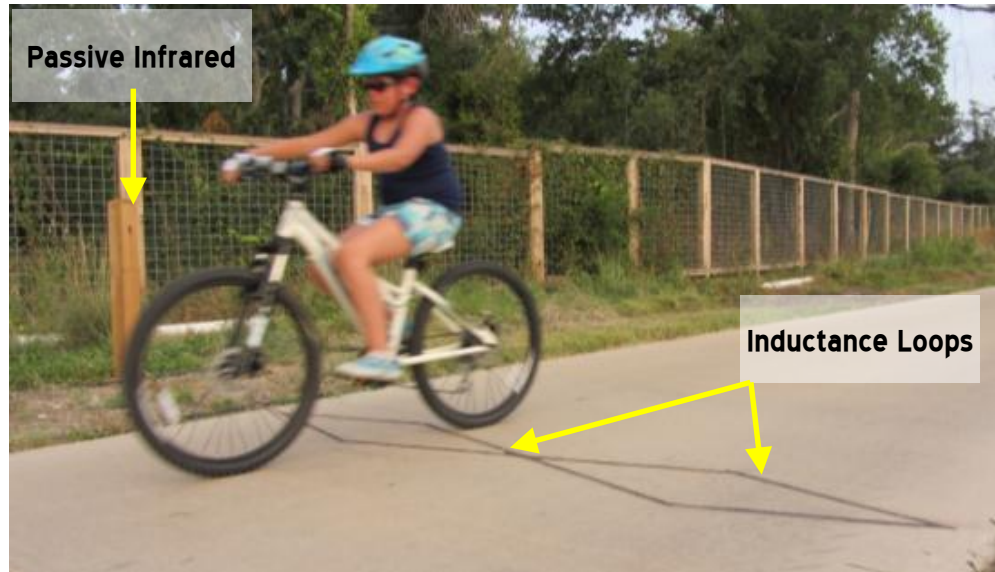
Source: Shawn Turner, TTI.

FIGURE 4-5   DIFFERENT TYPES OF INFRARED COUNTERS FOR NON-MOTORIZED TRAFFIC

Source: Shawn Turner, TTI.

Note: Equipment shown in a temporary testing and evaluation configuration

FIGURE 4-6   TYPICAL CONFIGURATION FOR ACTIVE INFRARED SENSOR
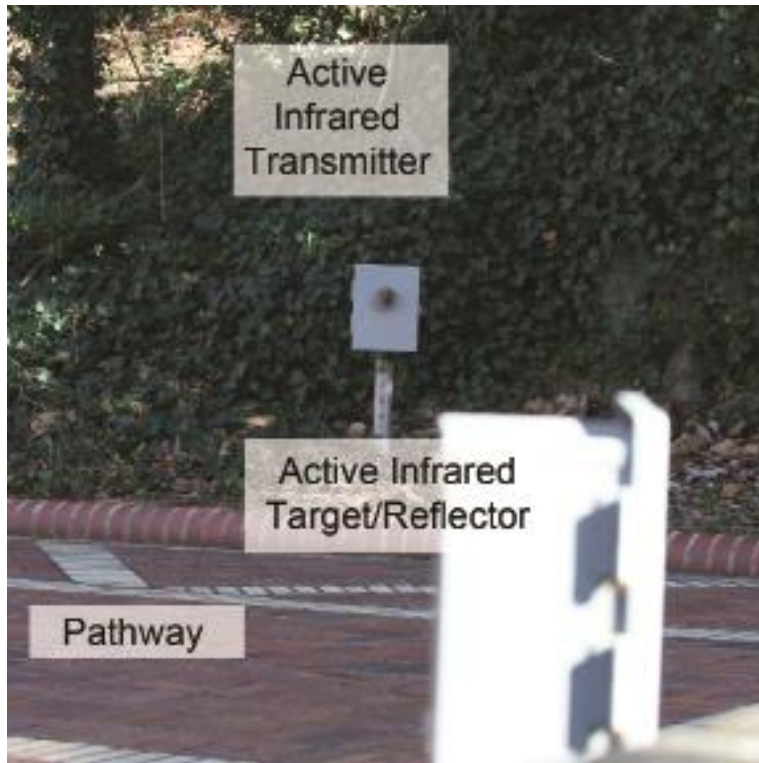
Source: Shawn Turner, TTI.

4.2.5   MAGNETOMETERS

Magnetometers operate by detecting a change in the normal magnetic field of the Earth caused by a ferrous metal object (e.g., bicycle frame or components). It may be possible to use existing motorized traffic magnetometers for counting bicyclists; however, the installation and configuration may not be optimal for accurate bicyclist counting. According to the Third Edition (October 2006) of the *Traffic Detector Handbook*, "Magnetometers are sensitive enough to detect bicycles passing across a four-foot span when the electronics unit is connected to two sensor probes buried six inches deep and spaced three feet apart." The shallow placement of magnetometers will result in more accurate bicyclist counts but could over count motor vehicles, as the detector might distinguish between changes in sections of the vehicle (e.g., engine block, axles, transmission) as multiple vehicles.

Magnetometers designed for motorized traffic (see Figure 4-7) may be capable of detecting bicycle frames made of non-ferrous materials (e.g., aluminum, carbon fiber, titanium), but they are not designed or optimized for this purpose. Few commercially available magnetometers designed for bicycle detection and counting exist.

Another drawback to the use of existing magnetometers for the detection of bicycles is increased equipment needs. For example, a thirty-foot detection area for automobiles would require five magnetometers and one electronic data logger. The same thirty-foot detection area would require ten magnetometers and four to five data loggers to detect bicycles.

Source: FHWA-HRT-08-001, http://www.fhwa.dot.gov/publications/publicroads/07nov/04.cfm.

4.2.6   PNEUMATIC TUBES

Pneumatic tubes are a low-cost, portable approach for counting bicyclists only (Figure 4-8). Pneumatic tubes operate by using an air switch to detect short burst(s) of air from a passing motorized or non-motorized vehicle. The data logger then uses pre-defined criteria (e.g., axle spacing, etc.) and/or algorithms to determine whether a valid vehicle type has passed over the tubes. The technology has been used to count cars and trucks for several decades, so most public agencies either have the equipment or are familiar with the technology. Pneumatic tubes have been combined with infrared sensors at locations where both bicyclist and pedestrian counts are desired.

As with other traditional motorized traffic monitoring technology, the optimal placement and configuration of pneumatic tubes for counting bicyclists will be different from that for cars and trucks. Ideally, the placement of pneumatic tubes for bicycles should adequately cover the bicycle travel path while not being exposed to excessive passage by motor vehicles. When counting bicycles in a bike lane or shared lane, passage and activation by motorized traffic may be unavoidable. In these cases, the data logger criteria should be capable of ignoring typical motor vehicle axle spacing. If direction of bicyclist travel is desired, a pair of pneumatic tubes can be placed (see Figure 4–8), and travel direction can be inferred from the timing of detection events at each tube.

FIGURE 4-8   EXAMPLE OF PNEUMATIC TUBE CONFIGURATION FOR COUNTING DIRECTIONAL BICYCLIST TRAFFIC

Source: Jean-Francois Rheault, Eco-Counter.

Bicyclist safety may be a concern when pneumatic tubes are installed with pavement nails or other metal fixtures, as they could possibly dislodge from the pavement and puncture a bicycle tire or create a road hazard for bicyclists. Extra care should be taken in installing pneumatic tubes, either by placing metal fixtures outside the bicycle facility or by using tape or other adhesive.

4.2.7   PRESSURE AND SEISMIC SENSORS

Pressure sensors operate by detecting changes in force (i.e., weight), much like an electronic bathroom scale. Seismic sensors (also sometimes called acoustic sensors) operate by detecting the passage of energy waves through the ground caused by feet, bicycle tires, or other non-motorized wheels. As with other monitoring technologies, pre-defined criteria are used to determine a valid detection and therefore a valid user to be counted.

Both pressure and seismic sensors require the sensor element to be placed underneath or very near the detection area. Pressure and seismic sensors are most common on unpaved trails or paths (Figure 4-9), where burial of the sensor element is typically low-cost and minimally disruptive. However, pressure sensors have been used (more commonly in Western Europe) at curbside pedestrian signal waiting areas, as a supplement to or replacement of a pedestrian crosswalk push button.

Some models of pressure and seismic sensors are capable of detecting the difference between pedestrians and bicyclists. Placement and size of the pressure sensors (also known as pressure mats) can be used to gather directional information. When installed properly, pressure and seismic sensors can serve as permanent continuous counters.

FIGURE 4-9   EXAMPLES OF PRESSURE SENSORS ON NATURAL (A) AND PAVED (B) SURFACES

(a) Pressure sensor on natural surface trail

(b) Pressure sensor on paved surface

Source: Jean-Francois Rheault, Eco-Counter.

4.2.8   VIDEO IMAGE PROCESSING

Video image processing operates by using sophisticated visual pattern recognition to identify (and sometimes track) a pedestrian or bicyclist traveling through a video camera's field-of-view (see Figure 4-10). The critical element for accurate bicyclist and pedestrian counting is the pattern recognition algorithms and software. Because of the commercial demand for detecting and counting motorized traffic, this software has been extensively refined by manufacturers and vendors. Some research and development for bicyclist and pedestrian-specific algorithms has been conducted at the university level; however, much of this university research has not been incorporated into existing commercially available products.

FIGURE 4-10   EXAMPLE OF VIDEO IMAGE PROCESSING FOR TRACKING AND COUNTING NON-MOTORIZED TRAFFIC
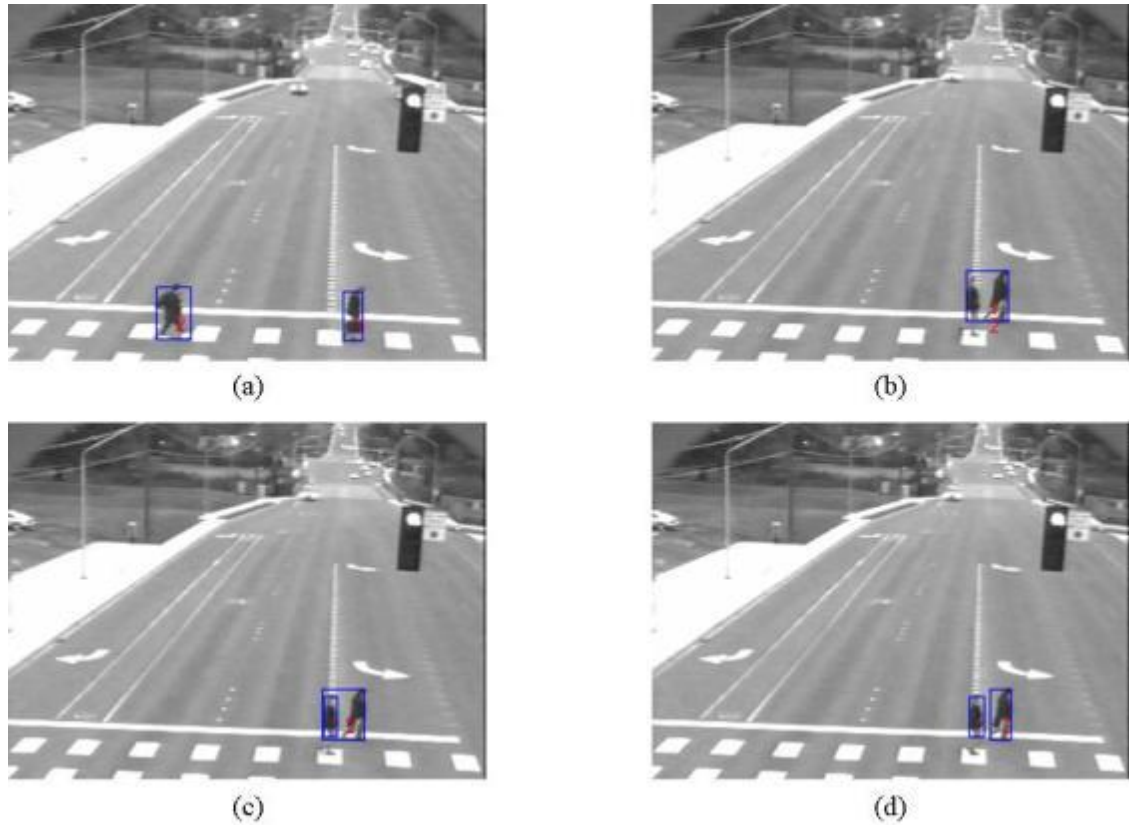
Source: Malinovskiy, Zheng, and Wang, 2009.

Video image processing has the capability to distinguish pedestrians and/or bicyclists traveling in a group or cluster. The technology also has the capability to distinguish direction of travel and potentially track the non-motorized traffic through the field-of-view. Again, these capabilities are dependent on the level of algorithm development of the commercial products. Weather and lighting may reduce the accuracy of this technology. Finally, video image processing typically has the highest equipment costs.

In some cities, pedestrian and bicyclist counts are manually reduced by viewing recorded video from intersection control or surveillance cameras. This manual approach is practical and low-cost for periodic short-term counts, but is not sustainable for continuous monitoring purposes (due to required labor and associated costs). This approach eliminates equipment installation (and corresponding traffic control), but also requires a low-cost labor force to manually review the video. Several companies offer a portable video recording unit as well as data reduction services. This recorded video may be useful to other agencies or departments that wish to study bicyclist and pedestrian behavior (e.g., in response to safety issues or concerns). Additionally, this recorded video can also be used for quality assurance purposes (i.e., for verification/validation of nearby automated counts).

4.2.9   EMERGING TECHNOLOGIES

The commercial marketplace for non-motorized traffic monitoring is still maturing, and several companies are still working to adapt their motorized traffic monitoring technology to accurately count bicyclists and pedestrians. For example, several companies are working to adapt their existing

video image processing products to accurately count bicyclists and pedestrians. However, several companies have been successfully selling their non-motorized traffic monitoring equipment for more than a decade. An increased demand for non-motorized traffic monitoring data will provide incentives to existing companies that want to develop non-motorized traffic monitoring products.

Mobile devices with GPS and/or Bluetooth capabilities also provide a means to monitor small samples of bicyclist and pedestrian traffic. Several cities are evaluating or using these technologies to gather route choice, origin-destination, and travel time data (e.g., San Francisco, Austin, and Monterey). However, these technologies alone cannot directly count the total volumes of bicyclists and pedestrians.

4.3   VARIABILITY AND TRAFFIC MONITORING CONCEPTS

Comprehensive information on non-motorized traffic variability is limited, primarily because very few public agencies have collected and analyzed continuous non-motorized traffic data to date. Future analyses will contribute a much better understanding to the traffic monitoring guidance contained here. For this section, a single continuous monitoring location (i.e., Cherry Creek Trail, Denver, Colorado) is used to illustrate variability at that site. This single example may not be indicative of non-motorized traffic variability at other U.S. locations, especially those with a mild climate year-round.

4.3.1   TIME-OF-DAY VARIATION

The time-of-day variation for mixed-mode (i.e., pedestrians and bicyclists), non-motorized traffic at a single location is shown in Figure 4-11. The time-of-day patterns for non-motorized traffic data will vary by location and trip purposes. The time-of-day patterns are somewhat different from car and truck patterns (Figure 1-2), but similarities do exist. Diurnal peaking patterns can be seen during the weekdays for non-motorized traffic; however, the non-motorized peaks are less pronounced than the car and truck peaks. The weekend profiles for non-motorized traffic have a single peak (same as rural cars), but the non-motorized peak is mid-day (as opposed to an evening peak for rural cars) and is much more pronounced (12%-13% for non-motorized as compared to 8% for rural cars). For this trail in Colorado, the time-of-day patterns for non-motorized traffic do vary by season of the year.

FIGURE 4-11   TIME-OF-DAY PATTERNS FOR A COLORADO SHARED USE PATH
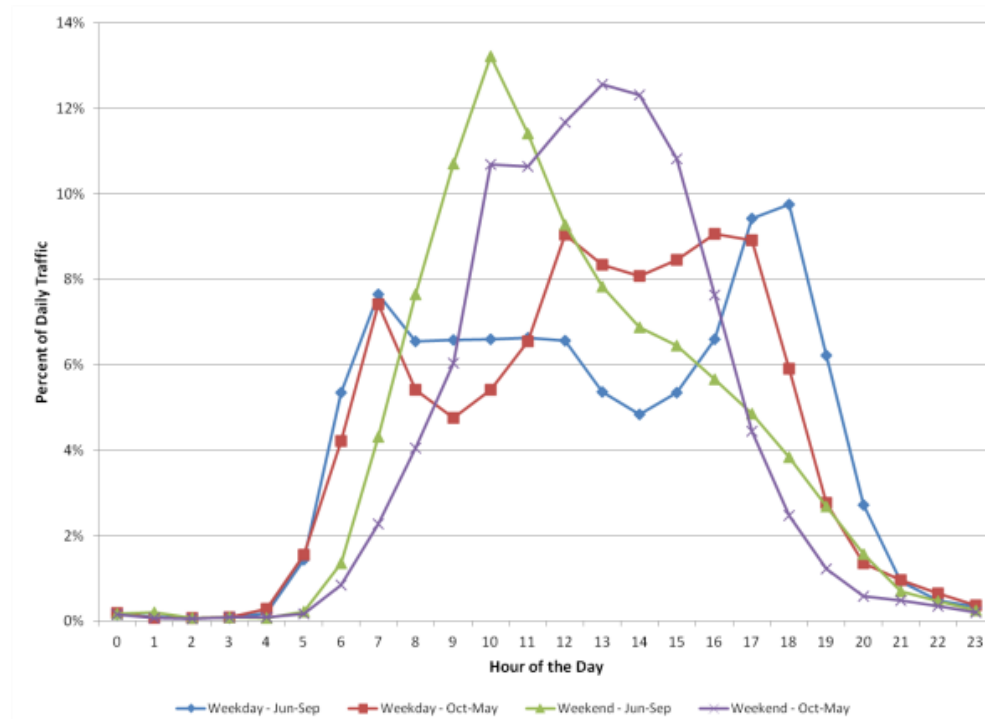
Source: Cherry Creek Trail continuous count data, Colorado Department of Transportation, 2010.

Figure 4-12 shows average hourly traffic profiles from 12-hour manual counts of bicyclists and pedestrians on 43 weekdays in Minneapolis, Minnesota. This data illustrates one of the limitations of manual counting relative to automated counting: it is expensive and difficult to obtain 24-hour counts. However, these counts illustrate patterns in time-of-day use and that peak hour counts correlate well with 12-hour counts. This data also underscores the importance of longer-duration counts so that the limitations of short duration (e.g., two hour) counts can be understood and interpreted.

Figure 4-12 also illustrates that different time-of-day traffic patterns may occur when pedestrian and bicyclist modes are reported separately. In this case, pedestrian traffic has a much stronger mid-day peak than bicyclists. If automated counter equipment can differentiate pedestrians from bicyclists, then counts should be stored separately by mode to permit analysis and reporting by mode (if desired).

FIGURE 4-12 **AVERAGE TIME-OF-DAY PATTERNS FOR 43 SHORT-DURATION MONITORING LOCATIONS IN MINNEAPOLIS, MINNESOTA**
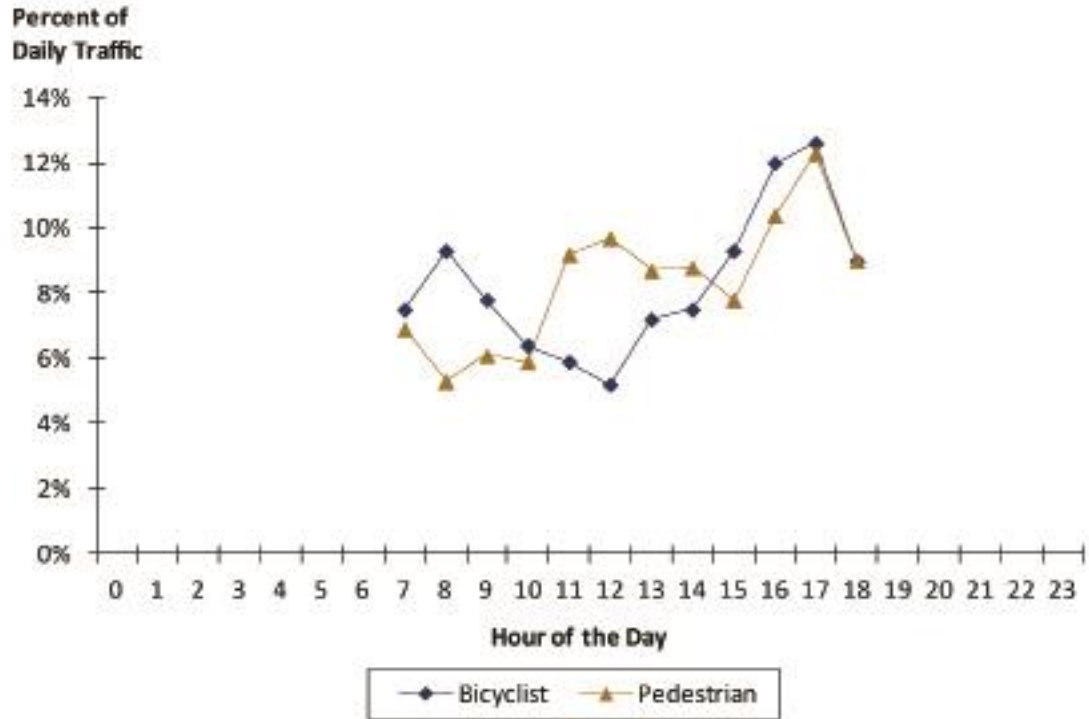
Source: *Greg Lindsey, University of Minnesota.*

4.3.2 DOW VARIATION

The DOW variation for mixed-mode non-motorized traffic at a single location is shown in Figure 4-13. The overall profile of the non-motorized traffic is similar to the recreational car or through truck as shown in Figure 1-4. However, the weekend traffic is more pronounced for the non-motorized trail traffic. The other significant difference is how the magnitude varies by season of the year. As shown in Figure 4-13, the typical DOW traffic during the summer and early fall months (June through September) are nearly twice that during the winter and spring months (October through May).

FIGURE 4-13   DOW PATTERNS FOR A COLORADO SHARED USE PATH
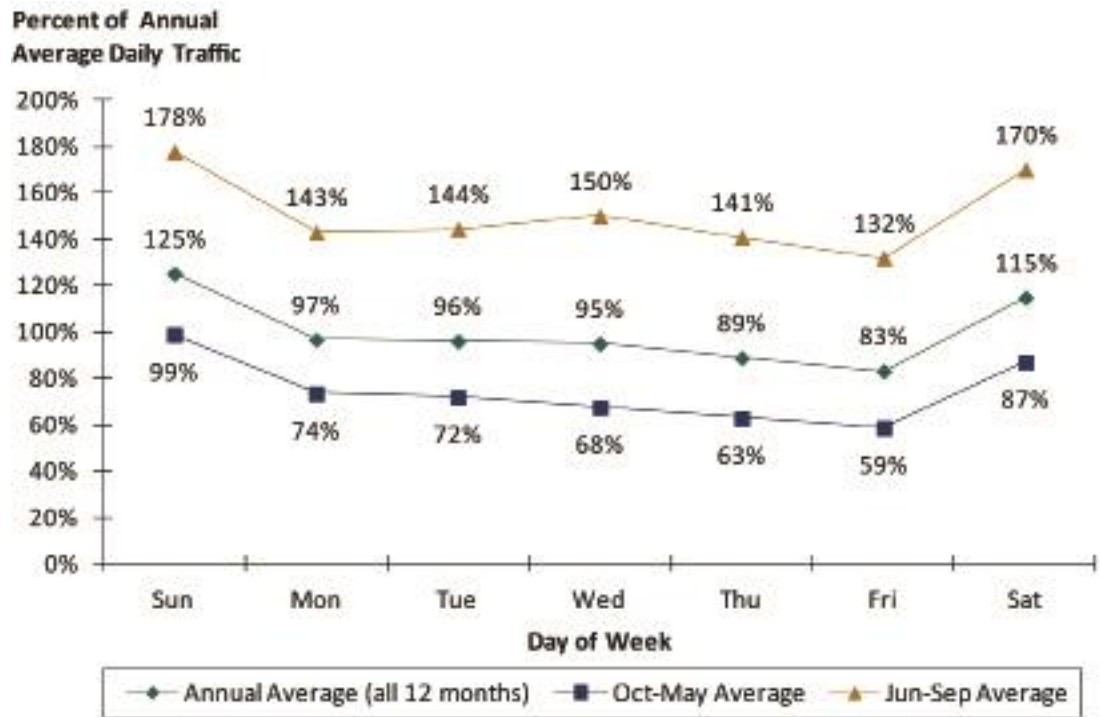
Source: Cherry Creek Trail continuous count data, Colorado Department of Transportation, 2010.

The DOW patterns shown in Figure 4-13 are averaged over a full year. The actual day-to-day variation of non-motorized traffic volumes will be substantially greater than shown in this figure. Adverse weather (e.g., heavy rain, extreme hot or cold temperatures) has a significant impact on bicycling and walking traffic levels. In fact, even forecasts of adverse weather may also have an impact on non-motorized traffic.

4.3.3   MONTHLY VARIATION

The monthly variation for mixed-mode, non-motorized traffic at a single location in Colorado is shown in Figure 4-14. The overall monthly patterns are similar to the rural car and truck patterns in Figure 1-5; however, the seasonality for non-motorized traffic is much more pronounced. For example, the peak summer non-motorized traffic during July is about 200%, or nearly twice the annual average. The winter non-motorized traffic (November through February) is about 50%, or one-half of the annual average. Figure 4-14 clearly demonstrates the seasonal effects on non-motorized traffic at this Colorado location.

FIGURE 4-14   MONTHLY PATTERNS FOR A COLORADO SHARED USE PATH
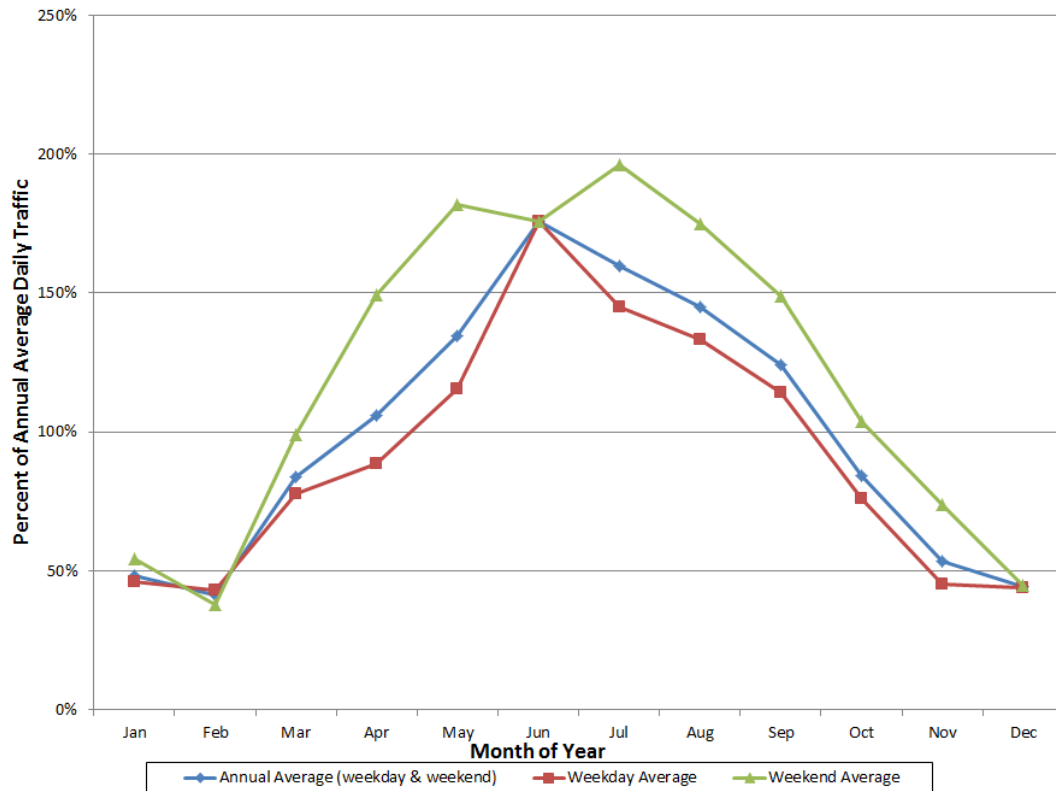
Source: Cherry Creek Trail continuous count data, Colorado Department of Transportation, 2010.

Figure 4-15 illustrates similar monthly patterns at six shared use path locations in Minneapolis, Minnesota where weather is more seasonal, with colder winters and more humid summers. The Minneapolis data, which are quite similar across the six locations, show greater seasonality than the Colorado data, with average daily traffic in summers more than double the annual average daily traffic, and winter (e.g., January) daily traffic well below 25% of annual average daily traffic. These two examples illustrate the importance of understanding the effects of weather and seasonality on non-motorized traffic.

FIGURE- 4-15   **MONTHLY PATTERNS FOR SIX SHARED USE PATH LOCATIONS IN MINNEAPOLIS, MINNESOTA**
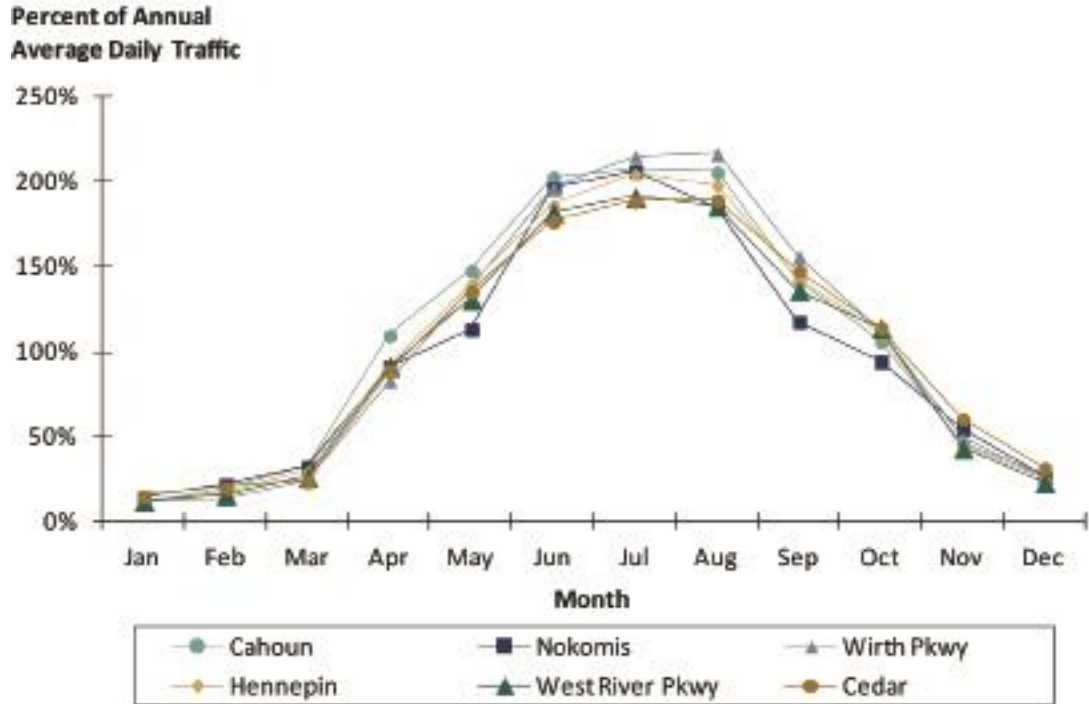
Source: *Greg Lindsey, University of Minnesota.*

4.3.4   PROGRAM AND TECHNOLOGY DESIGNS THAT ACCOUNT FOR TRAFFIC VARIABILITY

The variability described in the previous sections should be measured and accounted for in a non-motorized traffic data collection and reporting program. The data collection program should also identify changes in these traffic patterns as they occur over time. To meet these needs in a cost effective manner, statewide traffic monitoring programs generally include:

- A modest number of permanent, continuously operating, data collection sites; and

- A large number of short duration data collection efforts.

The short duration counts provide the geographic coverage to understand traffic characteristics on individual roads, streets, shared use paths, and pedestrian facilities, as well as on specific segments of those facilities. They provide site-specific data on the time of day variation, can provide data on DOW variation in non-motorized travel, but are mostly intended to provide current general traffic volume information throughout the larger monitored network. However, short duration counts cannot be directly used to provide many of the required data items desired by users. Statistics such as annual average traffic cannot be accurately measured during a short duration count. Instead, data collected during short duration counts are factored or adjusted to create these annual average estimates. The procedures to develop and apply these factors are discussed in Section 4.4.

The development of those factors requires the operation of at least a modest number of permanently operating traffic monitoring sites. Permanent data collection sites provide data on seasonal and DOW trends. Continuous count summaries also provide very precise measurements of changes in travel volumes and characteristics at a limited number of locations.

4.4   PERMANENT DATA PROGRAM

The process for collecting continuous non-motorized traffic data should follow the steps already outlined for motorized traffic in Chapter 3, as follows:

1. Review the existing continuous count program;
2. Develop an inventory of available continuous count locations and equipment;
3. Determine the traffic patterns to be monitored;
4. Establish pattern/factor groups;
5. Determine the appropriate number of continuous monitoring locations;
6. Select specific count locations; and
7. Compute monthly, DOW, and hour-of-day (if applicable) factors to use in annualizing short-duration counts.

The following sections provide additional detail for implementing these steps.

In this edition of the *Traffic Monitoring Guide*, pedestrians and bicyclists are grouped together as non-motorized traffic. There will be differences in these two types of facility users that may affect the monitoring approach. However, the known distinctions and differences between pedestrian and bicyclist traffic will be pointed out in each combined section. As ongoing research identifies the best approach for each, future editions of the *Guide* may provide additional information for separate monitoring of pedestrian traffic and bicyclist traffic.

4.4.1   STEPS 1 AND 2: REVIEW THE EXISTING CONTINUOUS COUNT PROGRAM; DEVELOP AN INVENTORY OF AVAILABLE CONTINUOUS COUNT LOCATIONS AND EQUIPMENT

The first two steps are to inventory, review, and assess what your agency currently has (in regard to permanent monitoring locations and equipment). This may be a short exercise for some agencies, as permanent continuous counts are much less common than short-duration pedestrian and bicyclist counts.

However, these first two steps should not be bypassed simply because your own agency does not have permanent count locations. Because non-motorized traffic levels are typically higher on lower-volume and lower functional class roads/streets as well as shared use paths and pedestrian facilities, city and county agencies and metropolitan planning organizations (MPOs) have often been more active than State DOTs in monitoring non-motorized traffic.

Therefore, if a State DOT traffic data collection program will monitor non-motorized traffic, they should coordinate with local and regional agencies as they inventory and review existing continuous counts. Additionally, they should inquire with departments other than the transportation or public works department. The following lists possible agencies and/or departments that may have installed permanent pedestrian and bicyclist counters:

- City or county parks and recreation department (e.g., on shared use paths);
- National or State parks (e.g., on internal or connector paths);
- Public health departments (e.g., monitoring physical activity);
- Retail or business associations (e.g., on pedestrian malls or plazas); and
- Pedestrian and/or bicyclist advocacy groups.

The process outlined in Section 3.2.1 for motorized traffic volume is equally applicable for non-motorized traffic. The review of existing continuous counts should review and assess the following:

Overall Program Design

- Existing monitoring locations and why they were chosen.

- Existing equipment and any noted performance/accuracy limitations.

- Who is using existing data, and for what decisions?

- Is the existing data sufficient? If not, what are the additional needs and their priorities?

- If there is no existing data, who would like data and for what decisions?

Traffic Patterns

If existing continuous count data is available, it should be analyzed to determine typical traffic patterns and profiles:

- How do counts vary throughout the day?

- How do counts vary by day of the week?

- How do counts vary by month or season?

- How do counts vary for inclement weather and other special events?

- How does traffic vary by street functional class and the presence of bike or pedestrian facilities?

- How do traffic patterns and profiles compare at different locations in areas with different land use and demographic characteristics?

Note that the count magnitude may not be similar, but the time-of-day, DOW, or month-of-year patterns may be similar in shape or overall profile. These patterns of variation will ultimately be used to create groups of similar locations (called factor groups) that can be used to factor (i.e., annualize) short-duration counts to an annual volume estimate.

If continuous non-motorized count data is not available, short-duration counts can be used to estimate the traffic patterns that may be typical. However, because of the higher variability of pedestrian and bicyclist count data, short-duration counts should be used with great caution. Short-duration counts cannot be used to determine monthly variability and, depending on the duration of the counts, may not be indicative of typical DOW variability. In addition, inclement weather or other special events may skew the time-of-day patterns in short-duration counts. In most cases, though, some data is better than no data in establishing typical traffic patterns.

Data Processing

In reviewing the current program and existing non-motorized data, one should also understand the basics of how data is processed by the field equipment and loaded into its final repository, whether that be a stand-alone spreadsheet, a mode-specific database, or a traffic monitoring data warehouse. The following elements should be considered:

- What formats (e.g., data structure, time intervals, metadata) are available and/or being reported from the field equipment?

- What quality assurance and quality control processes are applied to the field data?

- Are suspect or erroneous data flagged and/or removed?

- What summarization or adjustment procedures are applied to the field data?

- How does the current process/system address missing data (e.g., due to equipment hardware, software, or communications errors)?

- Are estimated or imputed values flagged or documented with metadata?

- Are the non-motorized data stored/integrated with motorized data? Alternatively, is there an entirely separate process?

- Are data summarization processes automated to the fullest extent possible? At what points are manual review and/or intervention required?

Subjective data manipulation or editing should be avoided. Instead, appropriate business rules and objective procedures can be used in combination with supporting metadata to address missing or invalid data.

Summary Statistics

The final step in reviewing the existing program is to consider summary statistics, both those that are currently computed as well as those that may be needed. Permanent count locations should be providing count data 24 hours per day, 365 days per year; however, this continuous data stream is often summarized into a few basic summary statistics, like annual average daily traffic. Because of the greater monthly variability of non-motorized traffic, other summary statistics may be more relevant:

- Seasonal average daily traffic (includes those months that contain at least 80 percent of the annual traffic) (seasonal average daily traffic (SADT) is a traffic statistic used by the National Park Service in recreational areas that have very high seasonal peaking (e.g., very high use in summer with low use in winter));

- Average daily traffic by month and day of week; and

- Peak hour volumes for peak seasons (i.e., different user types in summer and winter for shared use paths).

The review of existing and needed summary statistics should be based on those users and uses that have been identified earlier in this process. In this way, one can ensure that the variety of users has the required information to make decisions.

4.4.2   STEP 3: DETERMINE THE TRAFFIC PATTERNS TO BE MONITORED

After reviewing the existing non-motorized program (both what is being done and what is needed), Step 3 is to determine those traffic patterns that are to be monitored. Part of this determination will depend upon the functional road classes and bicyclist and pedestrian facilities of interest. For example, do State DOTs want to collect pedestrian and bicyclist count data on local streets, shared use paths, and pedestrian facilities that are considered off-system (i.e., not included on the State highway system)? In some cases, State DOT funding has been used for non-motorized projects on local streets and shared use paths through the Transportation Enhancements (TE) or Congestion Mitigation and Air Quality (CMAQ) funding categories.

Once the non-motorized network to be monitored has been defined, one should determine the most likely types of traffic patterns that are expected on this network. In most cases, the non-motorized network will include facilities that have a mix of commute, recreational, and utilitarian trips. Depending upon the relative proportions of these different trip types, distinct traffic patterns will emerge. These patterns should be used in the Step 4 to establish seasonal pattern groups.

The most common way to determine typical traffic pattern groups is through the visual analysis and charting of existing data. Continuous count data is preferred for this step, but short-duration counts (multiple full days, but not two-hour counts on a single day) may also be used with caution.

4.4.3   STEP 4: ESTABLISH SEASONAL PATTERN GROUPS

In the previous step (Step 3), existing non-motorized data was used to determine the traffic patterns that are to be monitored. In Step 4, this information is used to establish unique traffic pattern groups that will be used as the foundation for the monitoring program.

In some cases, non-motorized count data may not be available in Step 3 to determine the most likely traffic pattern groups. In these cases, previous analyses of non-motorized data from previous studies or of similar locations should be used as a starting point. Once more non-motorized data is gathered in your region, these traffic pattern groups can be refined based on your local data.

Previous (but limited) research indicates that non-motorized traffic patterns can be classified into one of these three categories (each with their own unique time-of-day and DOW patterns):

● Commuter and work/school-based trips – typically have the highest peaks in the morning and evening;

● Recreation/utilitarian – may peak only once daily, or be evenly distributed throughout the day;

● Mixed trip purposes (both commuter and recreation/utilitarian) – has varying levels of these two different trip purposes, or may include other miscellaneous trip purposes.

For example, Figures 4-16, a-b-c shows typical traffic patterns for a permanent monitoring location that has a higher percentage of commuting-based trips:

● The time-of-day patterns (16a) show strong peaks during the morning and evening, with less traffic during mid-day.

● The DOW patterns (16b) show more traffic occurring during the weekdays than the weekends, and the pattern is consistent across all months.

● The month-of-year patterns (16c) show less variation throughout the year than Figures 4-14 and 4-15, regardless of season or climate.

FIGURE 4-16A   TYPICAL TRAFFIC PATTERNS FOR LOCATIONS WITH HIGHER PERCENTAGE OF COMMUTING TRIPS; B90007 6TH AVENUE/VAUGHN STREET; 1/1/2011-12/31/2011

HOUR OF DAY
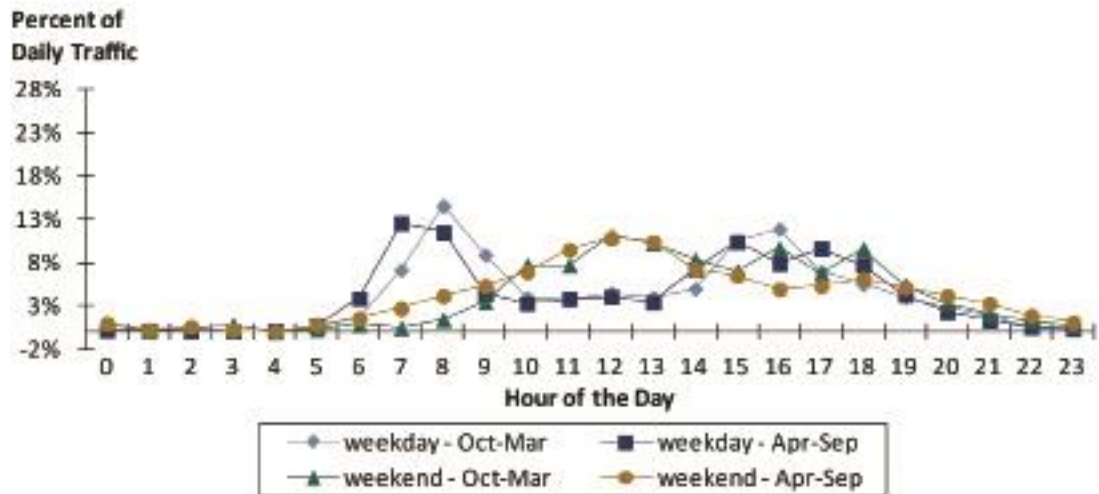
Source: Continuous Count Data, Colorado Department of Transportation, 2010-2011.

FIGURE 4-16B TYPICAL TRAFFIC PATTERNS FOR LOCATIONS WITH HIGHER PERCENTAGE OF COMMUTING TRIPS; B90007 6TH AVENUE/VAUGHN STREET; 1/1/2011-12/31/2011

DAY OF WEEK
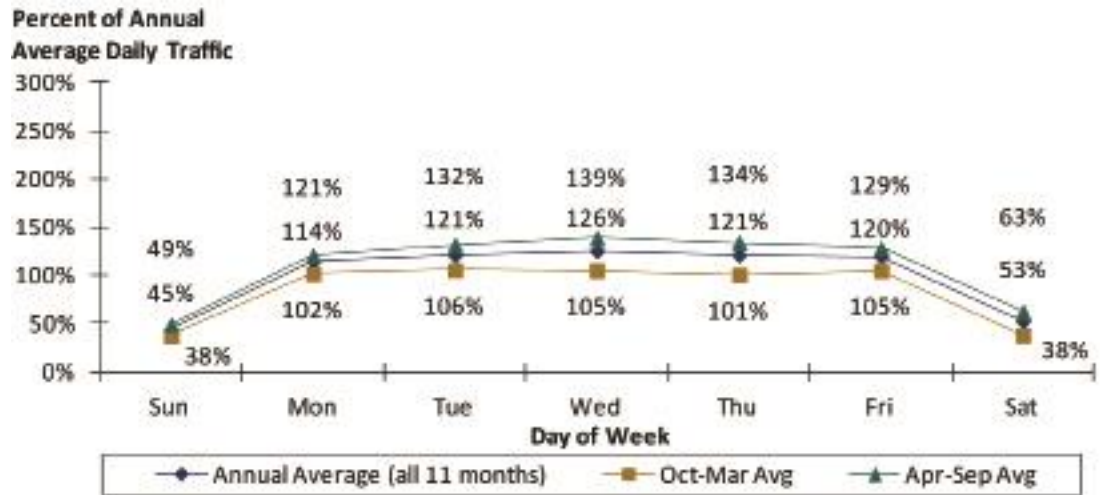
Source: *Continuous Count Data, Colorado Department of Transportation, 2010-2011.*

FIGURE 4-16C TYPICAL TRAFFIC PATTERNS FOR LOCATIONS WITH HIGHER PERCENTAGE OF COMMUTING TRIPS; B90007 6TH AVENUE/VAUGHN STREET; 1/1/2011-12/31/2011

MONTH
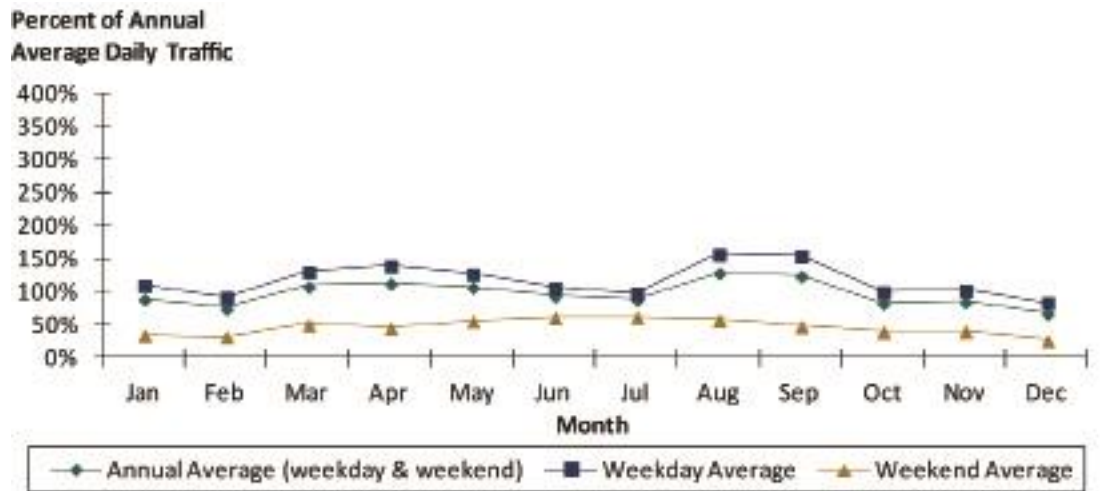
Source: *Continuous Count Data, Colorado Department of Transportation, 2010-2011.*

Figures 4-17, a-b-c show typical traffic patterns for a permanent monitoring location that has a higher percentage of recreation-based trips:

- The time-of-day patterns (17a) show a single strong peak during the middle of the day, with little or no morning and evening peaks.

- The DOW patterns (17b) show more traffic occurring during the weekends than the weekdays, and the levels vary by season.
- The month-of-year patterns (17c) show a strong peak during the most ideal months (late spring and summer) for recreational trips.

FIGURE 4-17A   TYPICAL TRAFFIC PATTERNS FOR LOCATIONS WITH HIGHER PERCENTAGE OF RECREATIONAL TRIPS; B90004 US36; 1/1/2011-12/31/2011
HOUR OF DAY
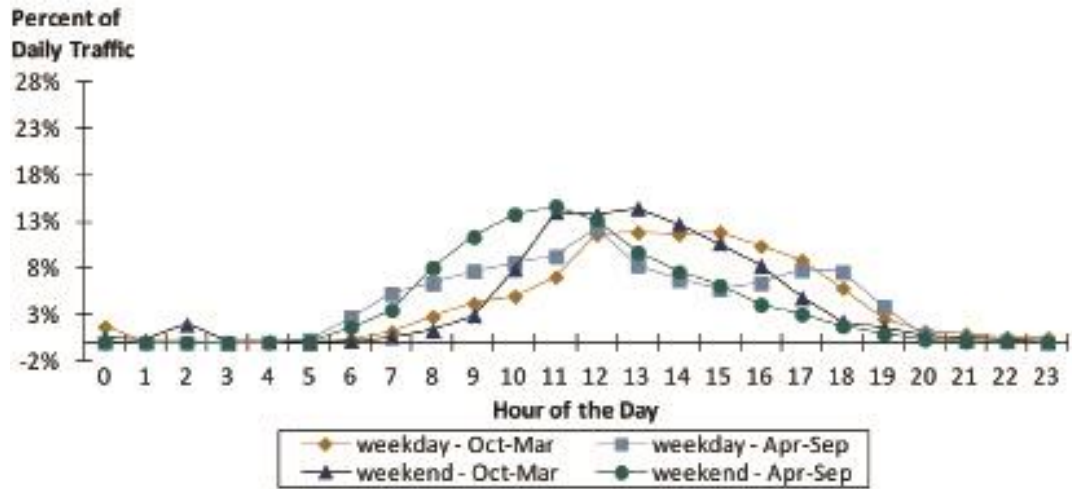
Source: Continuous Count Data, Colorado Department of Transportation, 2010-2011.

FIGURE 4-17B   TYPICAL TRAFFIC PATTERNS FOR LOCATIONS WITH HIGHER PERCENTAGE OF RECREATIONAL TRIPS; B90004 US36; 1/1/2011-12/31/2011
DAY OF WEEK
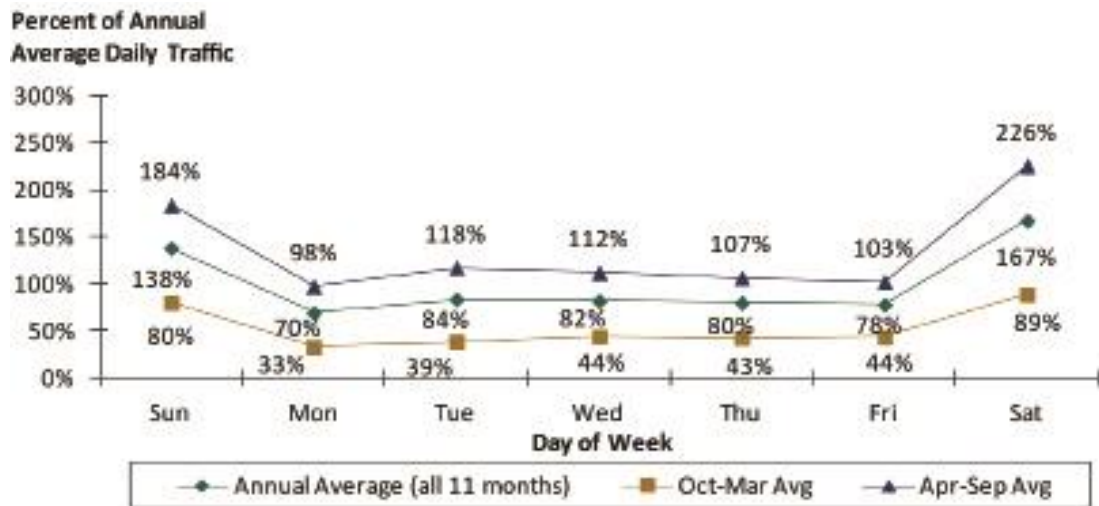
Source: Continuous Count Data, Colorado Department of Transportation, 2010-2011.

FIGURE 4-17C   TYPICAL TRAFFIC PATTERNS FOR LOCATIONS WITH HIGHER PERCENTAGE OF RECREATIONAL TRIPS; B90004 US36; 1/1/2011-12/31/2011

MONTH
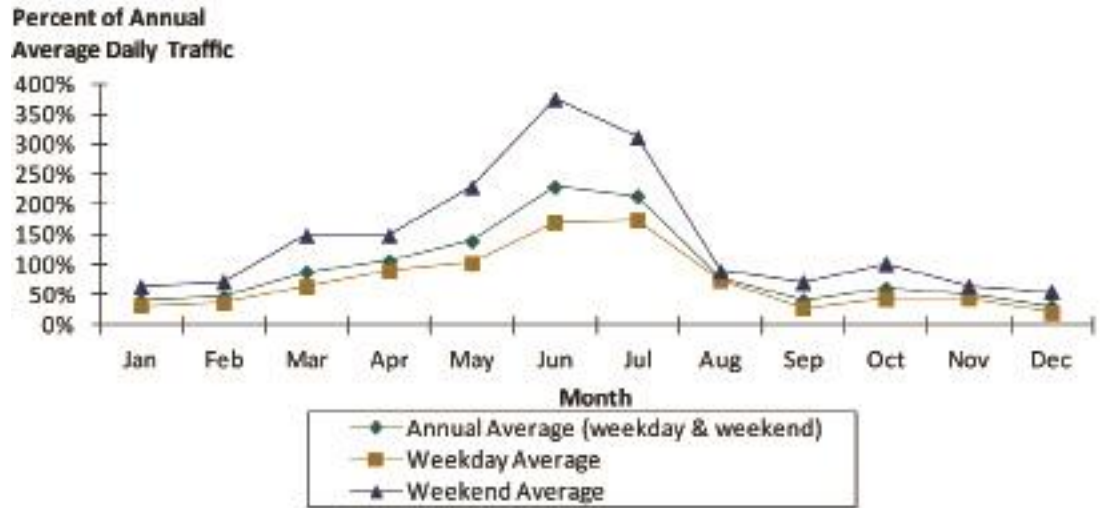
Source: Continuous Count Data, Colorado Department of Transportation, 2010-2011.

Overall climate conditions will strongly influence seasonal patterns. Day-to-day weather conditions will also influence specific daily or weekly patterns, but should not have a seasonal impact.

Facility type and adjacent land use are important variables; however, these will influence the mix of trip purpose, which is likely the strongest predictor of time-of-day and DOW traffic patterns.

4.4.4   STEP 5: DETERMINE APPROPRIATE NUMBER OF CONTINUOUS MONITORING LOCATIONS

Very little is known about spatiotemporal variation of non-motorized traffic, and what is known is very location-specific and difficult to generalize nationwide. In most cases (where no non-motorized counting currently exists), the number of count locations will be based on what is feasible given existing traffic monitoring budgets.

If equipment budgets are not constrained, then a rule of thumb is that about three to five continuous count locations should be installed for each distinct factor group (based on trip purpose and seasonality). The number of permanent count locations can be refined and/or increased as more data is collected on non-motorized traffic.

4.4.5   STEP 6: SELECT SPECIFIC COUNT LOCATIONS

Once the number of locations within factor groups has been established, the next step is to identify specific monitoring locations. Several considerations should be addressed in this step.

Differentiating pedestrian and bicyclist traffic – Will pedestrian and bicyclist traffic be separately monitored at each permanent count location? In the case of shared use paths, pedestrians and bicyclists will be traveling in the same space, and specialized equipment should be used to differentiate these different user types. In other situations, it may be preferable to monitor bicyclists separately from pedestrians. Exclusive bicycle lanes or separated bicycle paths can be instrumented with inductance loops (permanent) or pneumatic tubes (short-duration) that will not count larger/heavier motorized vehicles. Pedestrian malls, sidewalks or walkways can be instrumented with a single-purpose infrared counter if bicyclists are not typically present.

Selecting representative permanent count locations – Although it may be tempting to select the most heavily used locations for permanent monitoring, one should focus primarily on selecting those locations that are most representative of prevailing non-motorized traffic patterns (while still having moderate non-motorized traffic levels). In some cases, permanent count locations may be installed at low-use locations if higher use is expected after pedestrian or bicycle facility construction. The primary purpose of these continuous monitoring locations is to factor/annualize the other short-duration counts. Continuous counts at a high-pedestrian or high-bicyclist location may look impressive, but may not yield accurate results when factoring short-duration counts.

Selecting optimal installation locations – Once a general site location is identified, the optimal installation location should be chosen for the specific monitoring technology and equipment. In most cases, the optimal location is:

- On straight, level sections of road or trail, not on curves or on or near a steep grade;

- On smooth pavement or other compacted surface;

- Where the traveled way is clearly delineated and deviation is not common;

- For infrared sensors, not near water or in direct sunlight;

- For infrared sensors, not directly facing the roadway unless a vertical barrier exists; and

- For inductance loop detectors, not near high-power utility lines that could disrupt or distort the detection capability.

4.4.6 STEP 7: COMPUTE ADJUSTMENT FACTORS

The computation of adjustment factors should follow a similar process as motorized traffic volumes outlined in Section 3.2.1. These adjustment factors will be calculated for each unique non-motorized traffic factor group as determined in Step 4.

In practice, very few agencies have applied monthly or DOW adjustment factors to short-duration non-motorized counts. The current prevailing practice is to collect short-duration counts during those dates and times that are believed to be average, thereby reducing the perceived need for adjustment. However, this practice should evolve to a more traditional traffic monitoring approach as more permanent non-motorized count locations are installed.

4.5   SHORT DURATION DATA PROGRAM

Similar to motorized traffic monitoring, the majority of non-motorized locations will be monitored using short-duration counts. However, in some non-motorized monitoring programs the distinction between short-duration counts and special needs counts is not clearly defined. Short-duration counts are performed on specific facilities based on certain needs for that facility (e.g., before-after), but it is not known whether that specific facility is representative of other facilities and can therefore be expanded to a sub-area or regional estimate of overall non-motorized travel.

Unfortunately, clear guidance does not yet exist on this statistical representation issue and one will have to use their best judgment in determining which special needs counts also can be used to represent sub-area or regional travel estimates and trends.

4.5.1 SELECTION OF COUNT LOCATIONS

For motorized traffic, State DOTs have a short-duration data program that provides traffic data for *all* roads on their State highway system. The same goal for non-motorized traffic data may not be feasible, especially since most non-motorized travel occurs off the State highway system and on lower-volume and lower-speed city streets, shared use paths, and pedestrian facilities.

The prevailing practice for collecting short-duration non-motorized traffic data has been to focus on targeted locations where activity levels and professional interest are the highest. Although this non-random site selection may not yield a statistically representative regional estimate, it provides a more efficient use of limited data collection resources (e.g., random samples could possibly result in many locations with low or very low non-motorized use).

The following National Bicycle and Pedestrian Documentation (NBPD) Project criteria are recommended for short-duration counts:

- Pedestrian and bicycle activity areas or corridors (downtowns, near schools, parks, etc.);

- Representative locations in urban, suburban, and rural locations;

- Key corridors that can be used to gauge the impacts of future improvements;

- Locations where counts have been conducted historically;

- Locations where ongoing counts are being conducted by other agencies through a variety of means, including videotaping;

- Gaps, pinch points, and locations that are operationally difficult for bicyclists and pedestrians (potential improvement areas);

- Locations where either bicyclist and/or pedestrian collision numbers are high; and

- Select locations that meet as many of the criteria as possible.

The number of short-duration count locations will depend on the available budget and the planned uses of the count data. To date, there has been no definitive analysis of, or guidance for, determining the required number of short-duration count locations. For most regions getting started with counting non-motorized travel, the short count program is best developed by working with other key stakeholders interested in collecting and using this data. By discussing needs and budgets, this group can identify and prioritize the special needs short count locations which the available data collection budget can afford to collect. (These same discussions should also identify those key regional facilities that should be used for early deployment of permanent counters that will then be used to expand the short count data into estimates of annual and peak use.) The special needs counts will then provide the data needed to guide the development of a more statistically valid sample of short count locations. These more statistically rigorous sample designs will become possible in the future as more data is collected and as research is performed in the coming years.

Once general monitoring locations have been identified, the most suitable counter positioning should be determined. The NBPD Project recommended the following guidance for counter positioning:

- For multi-use paths and parks, locations near the major access points are best.

- For on-street bikeways, locations where few if any alternative parallel routes are best.

- For traditional downtown areas, a location near a transit stop or in the center of downtown is best.

- For shopping malls, a location near the main entrance and transit stop is best. Count at one access point.

- For employment areas, either on the main access roadway or near off-street multi-use paths is best. Count at one access point, typically a sidewalk and street.

- For residential areas, locations near higher density developments or near parks and schools are the best. Count at one access point, typically a sidewalk or street.

In many cases, these recommended counter-positioning locations will result in the highest non-motorized traffic volumes. Given limited data collection resources and specific data uses, this focus

on high-use locations may be appropriate. However, one should recognize that these high-use locations might represent a biased estimate of use levels and trends for an entire city or State.

4.5.2 SCREENLINE VERSUS INTERSECTION COUNTS

The two basic location types for non-motorized traffic monitoring are:

1. Screen line counts that are taken at a mid-segment location along a non-motorized facility (e.g., sidewalk, bike lane, cycle track, shared use path); and,

2. Intersection crossing counts that are taken where a non-motorized facility crosses another facility of interest.

Screen line counts are typically used to identify general use trends along a facility, and are analogous to most short duration motorized traffic counts. Although taken at a specific location, screen line counts are sometimes applied to the full segment length to calculate vehicle-miles of travel, pedestrian-miles of travel, and bicyclist-miles of travel.

Intersection crossing counts are typically used for safety and/or operational purposes, and are most analogous to motorized intersection turning movement counts. Example applications include using intersection counts to determine exposure rates at high collision crossings, as well as to retime or reconfigure traffic signal phasing. Intersection counts are typically more complicated than screen line counts and may require additional counters, primarily because multiple intersection approaches are being counted at once.

The uses of the non-motorized traffic data will dictate which types of counts are most appropriate.

4.5.3 DURATION OF COUNTS

There is no definitive guidance on the minimum required duration of short-duration counts. The prevailing practice has been two consecutive hours on a single day, but that practice is evolving as more public agencies use automatic counters and become aware of the inherent variability of non-motorized traffic. The following paragraphs discuss several factors that agencies should consider when determining the duration of their short-duration counts.

Manual Versus Automated Collection

The use of automatic counter equipment can dramatically extend the duration of short-duration counts. If automatic counters are used, then the minimum suggested duration is 7 days (such that all weekday and weekend days are represented). Depending on several other factors (e.g., day-to-day count variability, the total number of short-duration monitoring sites, and the number of automatic counters), the preferred duration of automatic counts could be as long as 14 days at each location.

The use of manual observers will limit the duration of short-duration counts. However, the minimum suggested duration for manual observers is 4 to 6 hours and should be scheduled to coincide with the heaviest non-motorized use (typically mid-day for weekend/recreational trips and morning/evening commute times for other trips). Manual observers' counting accuracy declines after 2 hours, so observers should be given short breaks or replaced with other observers. The preferred length for short-duration counts is 12 hours, which permits calculation of time-of-day use profiles. However, it is recognized that available resources may limit the collection of 12-hour counts.

The prevailing practice for short-duration manual counts has been 2 hours, largely because of resource and manual observer limitations. There is recognition that 2 hours of count data is better than no data; however, 2 hours of count data may lead to high error rates when annualizing counts and could lead to erroneous conclusions. If manual observers are the only possibility for short-duration counts, then agencies are encouraged to count for longer periods at fewer locations. Alternatively, the NBPD project (*National Bicycle and Pedestrian Documentation Project: Instructions*) has encouraged agencies to count multi-hour periods on several different days:

"We suggest that between 1 and 3 counts be conducted at every location on sequential days and weeks, based on the approximate levels of activity. Areas with high volumes (over 100 people per hour during mid-day periods) can usually be counted once on a weekday and weekend day, unless there is some unusual activity that day or land use nearby."

"Areas with lower activity levels and/or with unusual nearby land uses (with any irregular activity, such as a ball park) or activity (such as a special event) should be counted on sequential days or weeks at least one more and possibly two more times."

Count Magnitude and Variability

If non-motorized traffic levels are high and consistent from day-to-day, then shorter periods and/or fewer days may be considered. However, a longer-duration count period will be needed to determine how variable the non-motorized traffic is by time-of-day and DOW. Unfortunately, there is little quantitative guidance or consensus in this area, and ongoing research will improve future guidance.

Weather

Weather can be a significant factor in the level and variability of non-motorized traffic and should be considered when developing a short-duration monitoring program. Seasonal weather patterns (such as cold winters or hot/humid summers) are expected by pedestrians and bicyclists and will result in relatively consistent patterns from year to year. However, heavy precipitation or unexpectedly hot or cold weather may introduce abnormal variations on a given time of day or day of year. These variations can both generate unusually high levels of activity (e.g., a very nice day) or depress otherwise expected levels of activity (due to very bad weather.)

If automatic counter equipment is used for short-duration counts in typical weather, then the minimum suggested duration is 7 days (such that all weekday and weekend days are represented). This duration provides an average of 5 weekdays and 2 weekend days. However, if atypical heavy precipitation or inclement weather occurs during this entire 7-day period, agencies should consider extending the duration to 14 days.

When heavy precipitation or inclement weather occurs with manual observers, the counts should be extended over multiple days at the same time. Local judgment should be used to determine whether to include inclement-weather days into a multi-day average.

Because of inclement weather's influence on non-motorized traffic, weather conditions should be recorded in a non-motorized traffic monitoring program. The non-motorized data submittal format in Chapter 7 recommends three weather-related attributes:

1. Precipitation (yes/no): Did measurable precipitation fall at some time during data collection?
2. High temperature: Approximate high temperature for either the day (if a day or longer count) or the duration of the count (if the count is less than a day in duration).
3. Low temperature: Approximate low temperature for either the day (if a day or longer count) or the duration of the count (if the count is less than a day in duration).

Historical weather data can be obtained from several different sources and does not necessarily have to be collected at the exact count location.

4.5.4 MONTHS/SEASONS OF YEAR FOR DATA COLLECTION

The specific months/seasons of the year for short-duration counts should be chosen to represent average or typical use levels, which can be readily determined from permanent continuous counters (thereby underscoring the importance of these automatic continuous counters). In most climates in the U.S., the spring and fall months are considered the most representative of annual average non-motorized traffic levels (e.g., the NBPD projects recommends mid-May and mid-September).

Short-duration counts may be collected during other months/seasons of the year that are not considered average or typical; however, a factoring process will be necessary to adjust these counts to best represent an annualized estimate of non-motorized traffic.

4.5.5 FACTORING SHORT-DURATION COUNTS

As indicated in the previous section, a factoring process may be necessary to adjust short-duration counts to best represent an annualized estimate. The factoring process for motorized traffic has been described in depth in Chapter 3. It is recommended that a similar factoring process be used to annualize non-motorized traffic counts.

Depending on the count duration, type of automated equipment used, and presence of inclement weather, there may be up to five factors that could be applied:

1. Time-of-day: If less than a full day of data is collected, this factor adjusts a sub-daily count to a total daily count.

2. DOW: If data is collected on a single weekday or weekend day, this factor adjusts a single daily count to an average daily weekday count, weekend count, or day of week count.

3. Month/season-of-year: If less than a full year of data is collected, this factor adjusts an average daily count to an annual average daily count.

4. Occlusion: If certain types of automatic counter equipment are used, this factor adjusts for occlusion that occurs when pedestrian or cyclists passing the detection zone at the same time (i.e., side-by-side or passing from different directions).

5. Weather: If short-duration counts are collected during periods of inclement weather, this factor adjusts an inclement weather count to an average, typical count.

Adjustment factors are developed for distinct factor groups, which are groups of continuous counters that have similar traffic patterns. The continuous counters in the factor groups provide year-round non-motorized traffic counts and permit these short-duration counts to be annualized in a way that minimize error.

The non-motorized data submittal formats in Chapter 7 provide the capability to report these five types of adjustment factors in five separate factor groups.

Although factoring is a straightforward mathematical process, very few agencies are using factor groups for non-motorized traffic counts. There is no consensus yet on several aspects of the factoring process, such as the required type of factor adjustments, the number of factor groups for each adjustment type, and the number of continuous count locations within each factor group. It is hoped that future editions of the *Guide* will be able to provide additional guidance on this non-motorized count factoring process.

Many State DOTs do have data warehouse tools that already perform the factoring process for motorized traffic counts. Many of these tools and factoring processes could be used for non-motorized traffic factoring, given some adaptation as discussed.

4.5.6 EXAMPLE: FACTORING SHORT-DURATION COUNTS

The following is a simplified example that illustrates the process of calculating an estimate of average annual traffic based on a short-duration count. The example (Lindsey, G., Chen, J., Hankey, S., and Wang, X., 2012.) uses adjustment factors from a permanent monitoring location to annualize the short-duration counts. The example is for mixed-mode non-motorized traffic (i.e., bicyclists and pedestrians combined) along the Midtown Greenway, a shared-use path in Minneapolis, Minnesota. An active infrared counter was used at the permanent monitoring location along the Greenway, near an intersection with Hennepin Avenue.

For this example, assume that the Minneapolis Department of Public Works installed a temporary infrared sensor to count traffic for 48 hours on a Friday and Saturday in February 2012 on a different shared-use path where no monitoring previously had occurred (Monitoring Site A). Suppose further that the 24-hour mixed-mode traffic count for Friday was 175 and that the 24-hour count for Saturday was 250. What is a reasonable estimate of annual traffic (or annual average daily traffic (AADT)) at Site A? DOW and monthly ratios or adjustment factors from the Midtown Greenway-Hennepin Avenue location can be used to obtain this estimate.

Table 4-2 presents the following actual mixed-mode traffic count statistics for 2011 at the Hennepin Avenue monitoring location along the Midtown Greenway:

- Annual average daily traffic (AADT);

- Monthly average daily traffic (MADT);

- Ratio of mean day of week traffic to MADT for each month; and

- Ratio of MADT to AADT for each month.

The steps in using these factors to obtain estimates of annual traffic and AADT for Site A are:

1. Use the 2011 Friday and Saturday mean daily traffic ratios for February to calculate an average adjustment factor for the February 2012 48 hour monitoring period.

2. Estimate the MADT for February 2012.

3. Use the MADT/AADT ratio from February 2011 to estimate the 2012 AADT and 2012 annual traffic.

   From Table 4-2, the average Friday traffic in February 2011 was 1.04 times February average daily traffic, and the average Saturday traffic was 1.27 times February average daily traffic. Therefore, for the Friday-Saturday monitoring period, the average daily traffic was 1.16 times the February average daily traffic.

4. Using this ratio, the 2012 February average daily traffic can be calculated from the 2012 48-hour traffic count:

   2012 February average daily traffic = (175 + 250) / 1.16 = 183

5. From Table 4-2, the February MADT/AADT ratio is 0.18 (i.e., February average daily traffic is 18% of annual average daily traffic). This factor then is used to calculate AADT and annual traffic for 2012 for Site A:

   Site A AADT = (183 / 0.18) = 1,023

   Site A cumulative annual traffic = 1,023 × 365 = 373,422

This example could easily be extended for counts of different duration (e.g., daily or weekly or peak hour). To extrapolate two-hour, peak hour counts, hourly adjustment factors from the continuous monitoring sites would be needed. While the general process would be the same, extrapolation from peak hour counts would introduce additional uncertainty into the estimates of AADT and annual traffic.

TABLE 4-2   2011 MIXED-MODE TRAFFIC COUNT STATISTICS FOR MIDTOWN GREENWAY NEAR HENNEPIN AVENUE, MINNEAPOLIS, MINNESOTA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Annual Average Daily Traffic	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975
Monthly Average Daily Traffic (MADT)	239	354	586	1,807	2,753	3,699	4,099	3,896	2,805	1,960	886	495
Ratio of MADT to AADT	0.12	0.18	0.30	0.92	1.39	1.87	2.08	1.97	1.42	0.99	0.45	0.25
Ratio of Sunday ADT to MADT	0.89	1.33	0.89	1.55	0.88	1.29	1.18	1.34	1.06	1.20	0.75	1.11
Ratio of Monday ADT to MADT	1.01	0.66	1.10	1.10	0.98	0.95	0.98	0.87	1.22	0.96	1.00	1.08
Ratio of Tuesday ADT to MADT	1.10	0.74	0.91	0.96	1.27	0.89	0.91	0.74	0.86	1.03	1.01	1.07
Ratio of Wednesday ADT to MADT	1.15	0.96	0.93	0.76	1.11	0.96	0.94	1.07	0.99	0.87	1.03	0.97
Ratio of Thursday ADT to MADT	1.06	1.00	1.03	0.88	0.93	0.96	0.90	1.03	0.85	0.87	0.97	0.92
Ratio of Friday ADT to MADT	0.97	1.04	0.84	0.78	0.79	0.96	0.95	0.88	0.87	0.82	1.31	0.91
Ratio of Saturday ADT to MADT	0.88	1.27	1.34	1.03	1.02	1.02	1.09	1.15	1.23	1.16	0.91	0.98

Source: Greg Lindsey, University of Minnesota.

Chapter 5   TRANSPORTATION MANAGEMENT AND OPERATIONS

5.1   INTRODUCTION

Traffic monitoring within a State DOT affects many other functions and offices, and it is important for traffic monitoring staff to be aware of how their work and the data it produces affects the business of their customers and partners. Additionally, the audience for this *Guide* should be aware of how the work of their customers and partners affects their processes and work. The most important theme of this chapter is the need for coordination and cooperation among those groups responsible for traffic monitoring functions and the processes affected by them. This is especially important in light of the passage of MAP-21 and its emphasis on performance measures.

This chapter covers guidance and examples related to coordinating activities with transportation management and operations functions within State DOTs. The specific types of functions covered here include:

- Traffic management and operations (freeway, freight, arterial), including traveler information, incident management, and planning for operations (including performance measures);

- Special monitoring for evacuations/emergency/planned events;

- Commercial vehicle enforcement;

- Safety; and

- Planning (including access management, modeling and long range planning).

Most of the chapter is dedicated to coordination with the traffic management and operations functions covered in Section 5.2. Sections 5.3 through 5.6 are designed to inform traffic monitoring staff about the other functions listed above and to suggest coordination mechanisms.

5.2   TRAFFIC MANAGEMENT AND OPERATIONS

Traffic monitoring functions in many State DOTs are managed within two different workgroups, as follows.

1. Planning and Programming – this group collects, maintains, and reports historical traffic statistics for agency planning, programming, and public information. This group is the primary audience for this *Guide*. The discussion of data collected in the planning and programming group is distributed throughout the *TMG*.

2. Traffic Management and Operations – this group collects real-time traffic condition data to manage and operate the State highway network. This is often accomplished within transportation management centers (TMCs) where the flow of data and traveler information is managed.

Because these two groups are often organized into separate agency divisions or offices, they typically function independently of one another with their own separate budgets and traffic monitoring equipment and infrastructure. In some cases, these two groups may have traffic monitoring sensors placed immediately adjacent to one another, which operate and report independently.

Several State DOTs have begun developing cooperative approaches to traffic monitoring between their planning and operations groups. These DOTs are coordinating functions such as installing new equipment, sharing data from existing equipment, and sharing costs and responsibilities for installation and maintenance. In a time of severely constrained budgets, traffic monitoring resource coordination and sharing simply makes sense.

There can be significant cost savings associated with resource sharing. This section begins by outlining the typical data requirements for traffic management and operations, and compares and contrasts these requirements to typical planning-based data requirements. The section also provides several different examples to illustrate various possibilities for resource sharing. Appendix D and Case Studies 3 and 4 also describe approaches used for data sharing.

5.2.1   Typical Data Requirements for Management and Operations

The first step in coordinating traffic monitoring activities between planning and operations-based workgroups is to understand the functions within each workgroup that have similar data requirements. These similar data requirements represent immediate opportunities for coordination and can be used to build the foundation for further cooperation.

Providing detailed data requirements for all possible traffic management functions is beyond the scope of this chapter. Instead, several attributes of typical operations-based traffic monitoring systems and functions are outlined. This outline should help to better define the common areas of interest as well as potential obstacles to overcome.

Types of Operations-Based Traffic Monitoring Systems

Although the specific details and capabilities are evolving, two basic types of operations-based traffic monitoring systems are relevant to this discussion:

1. Fixed-point sensor systems that measure the attributes of all detected vehicles passing a permanent equipment location. Inductive loop detectors are the most common fixed-point sensor, but other non-intrusive sensor technologies (e.g., radar, video, magnetometer, etc.) are increasingly being used.

2. Probe-based systems that monitor a sample of specially instrumented vehicles as they routinely traverse the road network. Probe-based systems can monitor vehicle travel at fixed locations (typically called re-identification, such as toll tag or Bluetooth matching), at predetermined time intervals using wireless communications (GPS or cell phone-based probes), or a combination.

Probe-based systems can collect a variety of data attributes, but the most common attributes for traffic management functions are spot speed and/or link travel time. With re-identification systems, unique anonymous vehicle identifiers can be matched to provide origin-destination data. The probe-based system only monitors a sample of specially instrumented vehicles; relevance to planning traffic monitoring (covering the entire populations) is limited. This is likely to change in the future, as specially instrumented vehicles become much more common or even universal in the traffic stream.

Area-based systems such as radar, video and satellite can detect multiple vehicles over an area at the same time. However, they are generally not used for traffic measurement. Fixed-point sensor systems will likely be the near-term target for cooperation and coordination between planning-based and operations-based traffic monitoring. In some cases, the exact same sensor technologies are used by both workgroups. However, several differences exist in the design of each workgroup's monitoring system.

Focus on Real-Time, Most Current Conditions – Operations-based systems are designed with a clear focus on gathering and using the most current, up-to-date real-time travel data. After inclusion of the Archived Data User Service (ADUS) in the National ITS Architecture in the late 1990s, more operations-based systems are including the capability to permanently archive/save real-time data. However, historical data retention and access remains a secondary focus and is sometimes neglected in traffic management systems.

Communications Design – Operations-based systems are designed to collect and send traffic data to a centralized database in real-time, which typically range from every 20 seconds to 2 minutes. Therefore, little traffic data is stored on field devices, and sometimes a real-time communications packet will fail. The result is small gaps of missing data across most locations and times of the day.

Location of Sensors – Some operations-based sensors are placed in the immediate vicinity of freeway entrance ramps for metering entering traffic. On arterial streets, sensors are commonly placed at intersection approaches for presence detection for traffic signal control. These locations are desirable for traffic control purposes (for measuring lane occupancy or presence), but are probably less than optimal for traffic counting purposes. However, operations-based data samples at locations like these should first be evaluated for accuracy instead of being dismissed outright.

Equipment Maintenance – For a variety of reasons, some DOTs have not been able to maintain their operations-based sensors at the level desired by planning-based workgroups. The most common workaround for this has been to designate a limited subset of the operations-based sensors for priority maintenance.

Equipment Calibration – In many TMCs, spot speed data is the most commonly used data attribute for incident detection, traveler information, and overall traffic management. Traffic counts are rarely used for traffic management functions. A consequence is that sometimes these fixed-point sensors are not adequately calibrated for accurate traffic counting (i.e., spot speeds can still be accurately measured even if the sensor does not detect all vehicles).

5.2.2 EXAMPLES OF RESOURCE SHARING AND COORDINATION

Several State DOTs have tried to coordinate traffic monitoring approaches between their operation and planning workgroups. Some attempts have resulted in usable traffic data for both groups, some are ongoing, and a few have failed. The successful approaches can be categorized into four basic types, based on where the stream of collected data diverges into separate data flows to the traffic operations and planning workgroups (see Figure 5-1):

1. At the traffic sensor – Some non-intrusive traffic sensors offer on-device data storage capability, which provides the ability to bin and store data for two or more separate groups.

2. At the roadside cabinet – With traffic sensors that do not have on-device data storage capability, the data flow should be split at the roadside cabinet. With some equipment vendors, a single multi-function controller or traffic data recorder can be used to collect both real-time data for operations and binned count totals once daily for planning. With legacy equipment, a separate traffic data recorder may be needed for binning, in addition to the operations-based traffic controller.

3. After the TMC – Once the traffic data has been gathered by the TMC, it can be archived in its original from-the-field format (such as 20-second periods), or it can be post-processed and summarized into aggregate data (such as 5-, 15-, or 60-minute time periods). Chapter 7 of the *AASHTO Guidelines for Traffic Data Programs* contains detailed information on best practices to integrate operations data after it has been archived.

4. Coordinated equipment location only – This approach has been used when the traffic operations and planning workgroups cannot agree on a common traffic sensor specification. By selecting mutually agreeable equipment locations for traffic monitoring, the two groups, though using disparate technologies, can share/save on construction mobilization, power, and communications costs. In this approach, the roadside equipment cabinets may or may not be shared, depending upon each group's needs and requirements.

FIGURE 5-1   COOPERATIVE APPROACHES FOR TRAFFIC MONITORING
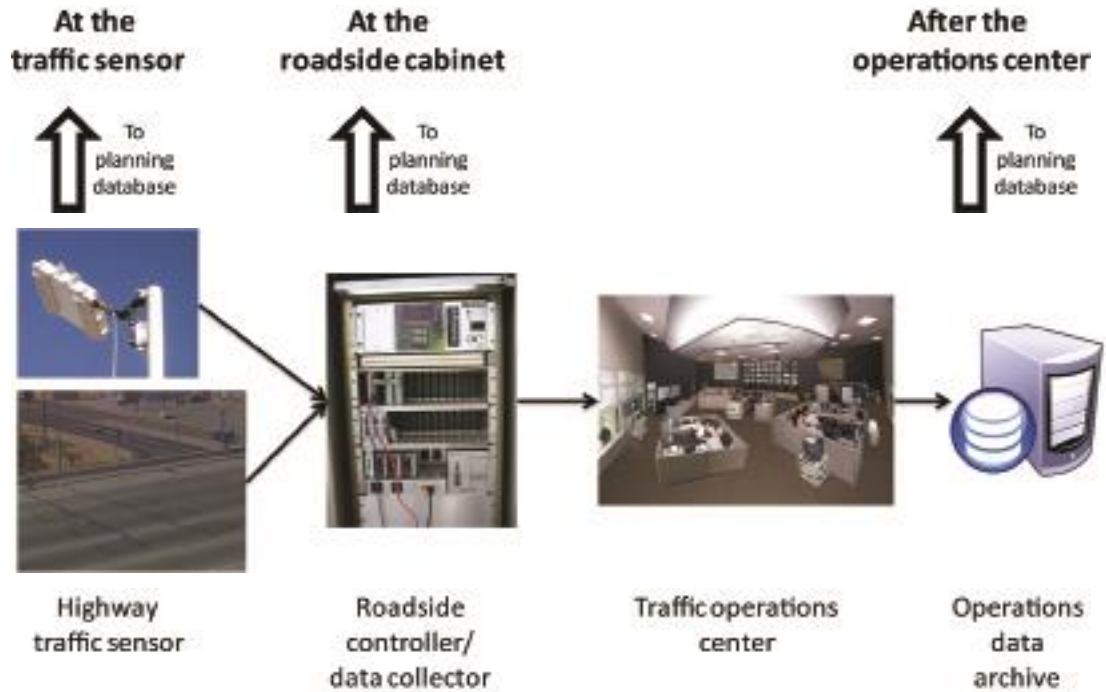
Source: *Federal Highway Administration.*

When developed in 1999, the Archived Data User Service envisioned that real-time data would be sent to a historical archive (approach #3), which would then be the single entry point for all archived data users. In practice, however, several DOTs have found it more advantageous to capture traffic data for planning purposes earlier in the data stream (approaches #1 and #2). The following examples illustrate a variety of ways in which resources can be better coordinated for traffic monitoring purposes.

Case Study 1: Illinois

Illinois DOT planners have been using operations-based data for several years and have relied on a data archive (i.e., "After the operations center" in Figure 5-1) as their primary means to obtain the data.

The Illinois Traffic System Center (TSC) monitors nearly 150 freeway miles with 2,400 detectors. Transportation planners at the Illinois DOT and the Chicago Area Transportation Study (CATS) have used the TSC's archived data for several years. The access mechanism and data formats have evolved several times since data sharing began. In 2004, a private company began collecting operations traffic data from its roadway sensors in the Chicago area as part of the FHWA's Intelligent Transportation Infrastructure Program (ITIP). A provision of the ITIP contract requires the private company to integrate the public agency traffic data (in this case, Illinois DOT) with their own data and provide the combined archived data for planning purposes.

The Illinois DOT's Office of Planning and Programming has designated 35 operations-based detector locations as continuous count stations. These 35 locations were selected based on spacing and the availability of detectors in all lanes. The Illinois DOT planners download hourly traffic data in MS Excel format on a monthly basis from the private company's web site. The hourly traffic counts are imported into IDOT's planning database, where they undergo standard data quality review checks. Valid data is then made available for summarization and reporting. Once integrated within the planners' traffic database, the archived operations data is used for HPMS reporting as well as other

AADT count reports.

Before the current system was in place, IDOT planners struggled with efficient data access and formatting issues. Early efforts at using IDOT TSC archived data for planning relied on paper copies of summarized data. In the 1980s and 1990s, CATS used the TSC archived data to produce a Travel Atlas that reported AADT values for the Northeastern Illinois Expressway System. IDOT planners have noted few problems with the current system for accessing archived operations data, and data quality has been acceptable due to responsive operations equipment maintenance procedures.

The most important lessons learned are as follows:

- Technical solutions are feasible to provide access to archived operations data, and proper data formatting allows easy import into planning databases; and

- Responsive equipment maintenance procedures build confidence in archived operations data and their use in official data reporting, such as HPMS and AADT counts.

Case Study 2: Minnesota

Minnesota DOT planners have been using operations-based data for several years and have contracted with the University of Minnesota-Duluth to develop software that automates the process (using the "After the operations center" approach shown in Figure 5-1).

MnDOT's Regional Transportation Management Center (RTMC) monitors more than 500 freeway miles and maintains about 5,000 inductive loop detectors (including both mainline and ramp-based detectors) in the Minneapolis-St. Paul area. The University of Minnesota-Duluth has developed post-processing software that reviews the quality of the data, imputes missing data, and summarizes the archived operations data to planning-level traffic statistics for the planning division.

The MnDOT RTMC has made the archived operations data publicly available since the late 1990s and provides numerous data extraction and analysis tools. Both MnDOT operations and planning staff use the archived operations data for a variety of other applications and purposes. Detector maintenance has been a priority for MnDOT because the inductive loop detectors are essential for several key traffic management functions (like ramp metering). Typically, the detectors are operating at higher than 95% availability.

The most important lessons learned are as follows:

- Responsive equipment maintenance procedures build confidence in archived operations data and their use in official data reporting, such as HPMS and AADT counts;

- Post-processing software can be developed to deal with data quality issues that may arise with archived operations data; and

- Good installation processes help to reduce maintenance and extend the life of sensors.

Case Study 3: Ohio

Ohio DOT planners have been working with their traffic operations group to obtain operations-based data from several different data archives (i.e., "After the operations center" in Figure 5-1).

The Advanced Regional Traffic Interactive Management and Information System (ARTIMIS) in Cincinnati monitors more than 50 miles of freeway using 1,100 traffic detectors of various types. Ohio DOT planners selected several ARTIMIS detector locations to serve as continuous count stations. They were able to download the archived hourly traffic count files from an ARTIMIS computer server. The archived data were imported into the planning database as raw hourly counts, which were then processed by the data quality review checks. Valid data was then retained for summarization and reporting purposes, including HPMS reports and official AADT count reports. It was noted that there were some data quality issues with the archived operations data.

In addition to ARTIMIS in Cincinnati, recently developed traffic management software is used (and provides archived operations data) in Akron-Canton, Cleveland, and Columbus. The Ohio DOT planners provided input on a preferred data format for the archived data files that closely resembles those specified in the *Traffic Monitoring Guide.* The Ohio DOT planning group also cooperated with the operations group in specifying field computers that are capable of collecting vehicle classification data.

Similar to Illinois DOT, the Ohio DOT also uses ITIP operations-based data that has been collected and archived by a private data provider. This ITIP data is being collected at selected locations in Cincinnati and Columbus.

The most important lessons learned are as follows:

- Communicating early and often with the operations group is critically important. Preferred data format can be accommodated if communicated early in the software development process.

- Cooperation is possible on other things such as equipment standards. It may be desirable to specify certain performance and data output requirements for multipurpose traffic monitoring locations.

Case Study 4: Utah

Utah DOT planners first attempted to use the archived ITS data directly from the traffic operations center (i.e., "After the operations center" in Figure 5-1), but had the common problem of periodic missing/incomplete data. After several attempts, the planning group decided to install their own data collection units at selected operations-based locations (i.e., "At the roadside cabinet" in Figure 5-1). Recently, they have also begun using ramp traffic counts from an operations data archive that was provided via FHWA's ITIP program.

Utah DOT planners are getting data from operations-maintained sensors. The planning group is using the operations-based cabinets and installing their own data collection equipment alongside the operations equipment. The equipment enables the signal from the traffic sensors to be split; the operations-based controller reports data in frequent time intervals (less than 5 minutes), whereas the planning-based equipment reports data on a daily basis.

Newer non-intrusive sensors have also been installed by the Utah DOT operations staff, and these sensors permit multiple outputs at the traffic sensor itself (i.e., "At the traffic sensor" in Figure 5-1).

UDOT planners are also now getting ramp counts at about 50 locations from an archived ITS system called PeMS, which is similar software to what California is using. The Utah PeMS was installed as part of FHWA's ITIP program. There is still some missing data in these ramp counts, but UDOT planners are able to use this data in their traffic monitoring system. Finally, the UDOT planning group does once-a-year spot checks at shared continuous locations to ensure that accurate data is being collected.

The most important lessons learned are as follows:

- Multiple approaches to resource sharing exist. If the data archive has lots of missing data, then alternative approaches are possible for getting operations-based sensor data directly.

- Periodic checks can be important to ensure ongoing data accuracy.

Case Study 5: Virginia

Virginia DOT (VDOT) has taken an innovative and unique approach to resource sharing with regard to traffic monitoring. In Virginia, the Traffic Engineering Division (TED) is responsible for traditional traffic monitoring program activities. TED worked closely with the Operations and Security Division (OSD) (which operates the traffic operations centers) with the installation of planning-based sensors in less urbanized regions of the State. A major factor in the success of the program is that both TED and OSD fall under the same organization within VDOT.

The VDOT approach has two components, depending upon the types of traffic sensors installed:

1. For existing inductive loop detectors, an existing commercial product is used to provide real-time data to traffic managers in OSD and daily data uploads to TED, with both data flows coming from the same equipment. This is analogous to "At the roadside cabinet" as shown in Figure 5-1.

2. For new installations of non-intrusive traffic sensors, separate data flows to both OSD and TED are available from the traffic sensor itself (i.e., "At the traffic sensor" in Figure 5-1).

The TED had additional funding for equipment to meet the data requirements for performance measures, and this was the mechanism used to install the newer non-intrusive sensors.

The most important lessons learned are as follows:

- Multiple approaches to resource sharing exist, and it does not always have to be the traditional traffic monitoring group that gets data from existing operations-based sensors. In the case of Virginia DOT, the operations group got data from traditional traffic monitoring sensors.

- Good working relationships can substantially improve the probability of success.

- There is value in locating the traffic monitoring and TMC offices under the same division.

5.3   SPECIAL MONITORING FOR EVACUATIONS/EMERGENCY/PLANNED EVENTS

5.3.1   FUNCTIONS PERFORMED

Sudden shifts in the movement of traffic because of evacuations (planned or not planned), emergencies, or planned events have a significant impact on the operation of the transportation system. Emergency operations centers (EOCs) are often established during times of need such as weather events (hurricanes, etc.), homeland security breaches, and other unexpected emergency events. These EOCs are often collectors and users of traffic speed and volume data to carry out their functions.

There are functions within State departments (other than the DOTs) responsible for planning for large-scale events. These functions are usually associated with tourist or economic offices. Oftentimes, State traffic operations offices are notified and included in the planning of special events that may impact traffic operations and monitoring, and in the operation of EOCs. However, traffic monitoring functions within planning offices are not always included in these activities. However, having a good baseline of the traffic can only benefit in planning transportation management plans for special events.

5.3.2   TRAFFIC MONITORING AND PLANNED SPECIAL EVENTS

The FHWA *Managing Travel for Planned Special Events Handbook: Executive Summary* strongly encourages the use of traffic monitoring on the day of the event. Traffic monitoring is one of several day-of-event activities necessary to ensure a successful event and more importantly, future events. Real time traffic monitoring allows for a "swift and coordinated response to unplanned events."

The *Executive Summary* provides a clear explanation of why traffic monitoring is an important day-of-event activity. It provides traffic and incident management support in addition to performance evaluation data. Timely deployment of contingency plans developed during the event operations planning phase depends on the accurate collection and communication of real-time traffic data between traffic management team members. Potential uses of day-of-event traffic/conditions monitoring observations and information include:

- Track changes in system operations during event;

- Identify locations with poor performance;

- Note potential causes and required mitigation;

- Deliver information to decision-makers and public;

- Present specific improvements for future events; and

- Provide input to post-event evaluation activities.

Methods for collecting traffic data on the day-of-event include: 1) CCTV systems for viewing real-time conditions; 2) in-roadway or over-roadway traffic sensors; 3) vehicle probes for surveillance and travel data; 4) traffic signal and system detectors; 5) parking management systems; and 6) manual methods. Example statistics or measures that can be obtained from traffic monitoring on the day-of-event include congestion delay, travel time, travel speed, change in travel mode, and change in transit ridership.

The FHWA *Planned Special Events: Checklists for Practitioners* includes traffic monitoring as one of its checklists.

FIGURE 5-2   STEP 4: TRAFFIC MONITORING ON DAY-OF-EVENT

	DAY-OF-EVENT ACTIVITIES CHECKLIST			
	ASSESSMENT	**IF CHECKED**	**TIPS / EXAMPLES**	**USER NOTES**
Step 4. Traffic Monitoring on Day-of-Event				
☐	Surveillance of real-time conditions on day-of-event	• Determine use(s) of surveillance information • Identify surveillance methods • Activate traffic surveillance plan	• Surveillance information may be used to: (1) measure traffic and environmental conditions in real-time, (2) make control decisions, (3) disseminate traveler information, and (4) monitor and evaluate system and plan performance • Surveillance methods include automated techniques (closed-circuit television) or manual methods (field personnel observation and reporting) • Overhead helicopter surveillance	
☐	Performance measures	• Establish applications for performance measures • Determine statistics or measures that can be obtained from traffic monitoring	• Apply performance measures to: (1) identify locations or corridors with poor performance, (2) identify potential causes and associated remedies, (3) identify specific areas that require improvements / enhancements for future events, (4) provide information to decision-makers and the public, and (5) provide input to post-event evaluation • Example transportation system performance measures include congestion delay, travel time, travel speed, change in travel mode, and change in transit ridership	
☐	Data collection	• Determine methods for collecting data used to compute performance measures • Assess need and method for archiving collected data • Activate data collection	• Data collection methods include: (1) road sensors for measuring traffic flow parameters, (2) vehicle probes for collecting data on travel times and origin-destination information, (3) CCTV systems for viewing real time video images of the roadway, (4) traffic signal and system detectors to measure congestion on streets, (5) manual methods for collecting traffic (volume/speed) and parking (demand/occupancy) data • Stakeholders can archive raw data for use in future event feasibility studies and evaluation reports • Exercise great care in collecting performance evaluation data in order to ensure data quality and consistency • Maintain counters • Monitor travel times and intersection operations	
☐	Set Traffic Control	• Implement traffic control per traffic control plans for ingress • Change traffic control to normal • Change traffic control for egress	• Set temporary signs, barricades, cones and other traffic control devices • Monitor traffic flow and amend on site as necessary • Maintain traffic control devices – knockdowns and blow over.	

Source: FHWA – HOP – 06-113, Planned Special Events: Checklists for Practitioners.

5.3.3 TRAFFIC MONITORING AND EVACUATIONS

FHWA's *iFlorida Model Deployment Final Evaluation Report* (January 2009) found that prior to iFlorida, access to real-time traffic data to support evaluation decision making was limited. On a statewide level, Florida Department of Transportation (FDOT) supported a network of 54 monitoring stations that uploaded hourly data and made that data available via the internet during a hurricane evacuation. Staff at the State Emergency Operations Center (SEOC) monitored this information and, when observed volumes significantly exceeded historical values, alerted evacuation managers at the SEOC. The Florida Highway Patrol also reported on congestion observed by its personnel in the field. Individual counties would sometimes report on traffic problems during regularly scheduled conference calls between the SEOC and all FDOT counties.

Georgia Department of Transportation (GDOT) uses the data it collects for both leisure purposes and evacuations. The GDOT Office of Transportation Data provides data to a large variety of external customers, including transportation planning professionals, educational institutions, design engineers, contractors, real estate agencies, private companies, and other government agencies. Traffic data is important in determining which routes citizens are using for their daily commutes and leisure travel. In addition, during emergency evacuations, critical traffic data is provided to the Georgia Emergency Management Agency and surrounding states. The data is used on a state and national level by the U.S. DOT and other customers for planning, modeling, allocating of funding, etc. (Georgia Department of Transportation Traffic Monitoring Program V2, 2012.)

South Carolina has also incorporated traffic monitoring data into its evacuation plans. According to the Dorchester County Government website, emergency planners have significantly improved evacuation plans. Since Hurricane Floyd, the state has established lane-reversal strategies on some major highway such as Interstate 26, expanded traffic monitoring systems, and improved coordination of multi-state evacuation plans.

5.3.4 OPPORTUNITIES FOR COORDINATION

Traffic monitoring staff should proactively reach out to emergency operators and planners of special events on a routine basis. A collaboration mechanism should be established and coordination maintained to discuss issues such as data formats available and needed for sharing. They should make the traffic and speed data available to them for their use. A good example of this is in Florida, where the permanent traffic counters can be polled in real time to monitor the flow and speed of traffic along evacuation routes. The polling is activated during emergencies such as hurricane evacuation, and the real time data (updated every 5 minutes) is made available on a map on the Internet for the public and EOC use.

Occasionally, traffic monitoring staff may also obtain additional funding or sources of additional data to supplement their programs.

5.4 COMMERCIAL VEHICLE ENFORCEMENT

5.4.1 FUNCTIONS PERFORMED

Commercial vehicle enforcement is an important function within a State DOT to ensure that overweight vehicles do not damage pavement and shorten the life of transportation facilities. The commercial vehicle operations (CVO) office may be located within operations, planning, or maintenance. However, it may fall outside the jurisdiction of the DOT altogether (e.g., Department of Public Safety). The CVO office often installs and maintains weigh in motion (WIM) equipment at designated locations (notably at weigh stations). The CVO is responsible for enforcing maximum weight limits for commercial vehicles. The CVO office is also often involved with planning for freight traffic and efficient operations within the State.

5.4.2 OPPORTUNITIES FOR COORDINATION

The traffic monitoring office should coordinate with the CVO office regularly regarding:

1. Shared use and maintenance of WIM equipment – Both groups could benefit from potential resource sharing.

2. Shared use of data – The CVO office can benefit from real time WIM data to detect overweight vehicles for purposes of enforcement. In addition, the CVO office could benefit from the traffic data generated by the traffic monitoring office for purposes of planning longer-term operations or enforcement activities. For example, traffic data should be made available to the CVO or department responsible for weight enforcement on a regular basis to assist in their targeted enforcement planning activities.

5.5 SAFETY

5.5.1 FUNCTIONS PERFORMED

National and State safety programs are dependent upon accurate, timely and complete data to support reporting, analysis of countermeasures, decision-making and resource allocation for safety improvement. The Highway Safety Improvement Program (HSIP) relies on both crash and roadway data elements to support safety analysis and planning.

The safety community at Federal and State levels could benefit from working with their partners in the planning and operations offices of the State DOTs to ensure that the needed data is collected once and used many times, so that resources can be integrated and economies of scale achieved. Recent Federal initiatives have emphasized the need for integration of roadway, crash, and traffic data even more in support of highway safety programs.

Safety functions are generally conducted within a State DOT, either within the operations office, a separate safety office, or planning offices. Example functions include production of statistical reports and performance measures related to fatalities and vehicle miles traveled (VMT) and analysis of high crash locations based on crashes and VMT.

5.5.2 OPPORTUNITIES FOR COORDINATION

Traffic monitoring staff should make a concerted effort to ensure that the safety offices are aware of the data collection and reporting capabilities in the traffic monitoring offices. They should learn how their safety partners are using VMT data and any other traffic data collected by the traffic monitoring group, and what other initiatives are ongoing in the safety offices that may be of interest to the traffic monitoring office. There may be opportunities for shared resources for locating traffic monitoring devices and for exchange of data and information collected by those devices. For example, there may be an opportunity to share resources to collect traffic data on non-state highway facilities because safety offices are required to report on crashes and VMT for all public roads.

5.6 PLANNING

5.6.1 FUNCTIONS PERFORMED

The traffic monitoring group is often located in the transportation planning group within a State DOT. However, they may not always be aware of the opportunities for collaboration with the transportation planners related to data collection and analysis. The planning division is responsible for long and short range multi-modal transportation planning, which often involves the use of micro and macro travel demand models. The models often require detailed traffic volume and speed data as input to the models. This data is then used to produce travel forecasts, or projections of future

travel, on a route or within a particular corridor. Planning staff are exploring new passive methods of data collection including private sector sources. Other planning functions that require traffic and speed data include access management, corridor planning, project prioritization, and programming of funding streams.

5.6.2 OPPORTUNITIES FOR COORDINATION

The traffic monitoring community should coordinate carefully with transportation planners to ensure they are aware of the vast data resources (including real time data) available for modeling and analysis. If the planning group is investigating newer data sources, the traffic monitoring community could benefit by integrating the new data with existing data.

For example, many offices within a State DOT are currently interested in obtaining private sector probe/GPS data for the purposes of speed and origin/destination data. These offices include operations, planning, and freight for the purposes of modeling, long-range planning, and performance reporting.

The traffic monitoring office should continue to partner with metropolitan planning organizations (MPOs) and Councils of Government (COGs) for exchange of traffic data used for modeling and analysis, particularly in urbanized areas or areas designated as non-attainment status according to the Environmental Protection Agency (EPA) standards.

5.6.3 CONCLUSION

This chapter discussed the importance of establishing regular collaboration and communication between traffic monitoring professionals and many other State DOT and local government offices. Some mechanisms for establishing and maintaining such coordination are described below.

The first step should be to identify contacts in the relevant offices. Consider contacting the office manager for the relevant department/section to express the desire to coordinate. It may be appropriate to send the representative a copy of this chapter of the *TMG*. A discussion could follow to cover the following items/questions:

- *Do you use traffic volume data in your business processes?*
- *If so, how?*
- *If not, why not?*
- *Are you aware of the data collected in the traffic monitoring unit?*

These questions could start a conversation related to how the two offices could better share information, data, and possibly resources to achieve their individual mission.

Another successful strategy may be to establish a data coordination group. The group could be comprised of representatives from all of the offices mentioned in this chapter (operations, emergency, planned/special event planning, freight, commercial vehicle enforcement, safety, and planning). The group could meet on a regular basis to discuss what data is collected and how gaps or overlaps in collection could be resolved.

The end result of initiating and establishing regular communication mechanisms between traffic monitoring and other offices will be maximization of the use of limited resources for collecting, analyzing, and reporting traffic data.

Chapter 6   HPMS Requirements for Traffic Data

6.1   INTRODUCTION

This chapter provides guidance to States in meeting the traffic reporting requirements of the Highway Performance Monitoring System (HPMS) program.   Traffic data comprise a significant portion (approximately 25%) of the data that is reported annually for HPMS purposes. Each State's traffic monitoring program is used to collect, process, and store a variety of types of traffic data. While the traditional traffic monitoring program includes the collection of volume, classification, weight, and speed data, the primary focus of the guidance in the *TMG* is on volume and classification data, both used for HPMS purposes. The traffic data reported in HPMS should mirror the State's traffic monitoring program so that information published by the State and FHWA are as similar as possible. HPMS traffic data should be developed in a cooperative process among the State's HPMS, traffic monitoring, and traffic demand modeling personnel.

This data is nationally standardized so that multiple uses of the data are possible, and the data should be of the highest quality possible or it would not be acceptable for engineering capacity design, pavement deterioration analysis, or use in analytical models such as the Highway Economic Requirements System (HERS). This data is an important part of the *Conditions and Performance Report to Congress* and development of Federal transportation legislation.

FHWA's requirements for the States regarding data for HPMS are provided in the *HPMS Field Manual (HFM)*. This manual contains detailed instructions for the States regarding reporting of data for HPMS, including traffic data. The reader should refer to the most recent version of the manual for detailed traffic data reporting requirements, as those requirements may change over time. The information provided in the *TMG* is based on the most recent *HPMS Field Manual* of 2012.

A limited amount of background information is provided here to offer an overview explanation of how the HPMS system is organized. The main difference for traffic monitoring is that HPMS is organized by road sections in order to estimate VMT and correlate with road inventory data. HPMS data cover what are known as full extent, sample panel, and partial extent. The following definitions for each of these types of data are from the *HPMS Field Manual.*

Full extent data refers to a limited set of data items that are reported for an entire road system such as the National Highway System (NHS) or all public roads. AADT is an example of traffic data that should be reported on a full extent basis and reported for ramps at grade-separated interchanges (HFS 4.4).

Sample panel data consists of data items added to the full extent data that are reported for a select portion of the total roadway system length. K-Factor and D-Factor are examples of traffic data that should be reported on a sample panel basis (HFM 4.4).

Partial extent data refers to those data items that are reported on a full extent basis for some functional systems and on a sample panel basis for other functional systems. AADT-single-unit (truck volumes) and AADT-combination (truck volumes) are examples of traffic data that should be reported on a partial extent basis (HFM 4.4).

The purpose of sampling is to provide a statistically valid representation of the public road network for the State, without imposing additional data collection burdens. Within HPMS, these samples are expanded for a statistically valid representation of the public road network for the State.

The State's HPMS coordinator is responsible for providing the location of sample sections to the traffic monitoring staff as new samples are added or removed for each HPMS data collection year. The addition of samples, which may require additional traffic data collection, is determined by using the sample management process within the HPMS system. This process allows the HPMS coordinator to work with the traffic monitoring staff to either establish permanent count stations at those

locations or take short duration coverage counts at specific locations to provide count data for use with HPMS.

For sampling purposes, HPMS uses the Table of Potential Samples, or TOPS, as the sampling frame. HPMS sample sections are selected from the TOPS. The TOPS includes all Federal-aid highways, which are highways on the National Highway System (NHS) and all other public roads not classified as local roads or rural minor collectors.

Five critical data items are used to establish the TOPS. One of these data items is AADT. The four additional items are functional system, through lanes, urban code, and facility type (used to identify ramps). TOPS sections are defined where the values for these five items remain unchanged (or are homogenous) for a section of road along the full extent of the road. Figure 6-1 illustrates the TOPS sections for a given route (Route ABC) based on the five homogenous data items. The potential TOPS sections are labeled as A, B, C, D, and E on the bottom row of the figure.

FIGURE 6-1   HPMS TOPS DEVELOPMENT PROCESS
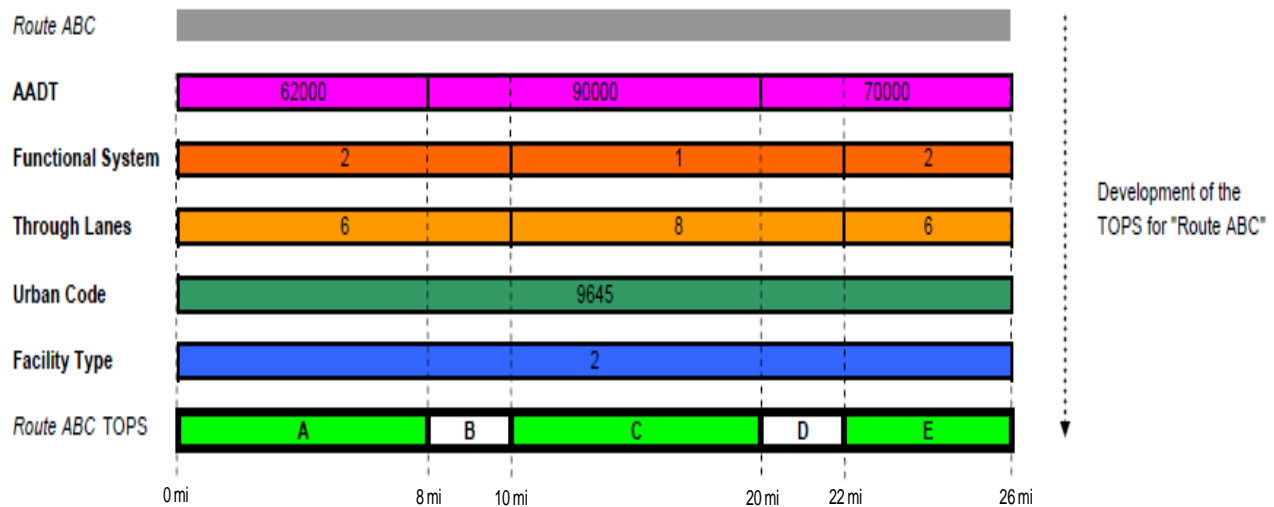
Source: HPMS Field Manual.

Out of the five data elements listed above, States are typically organized such that the AADT comes from the traffic data program, and the other four data elements come from the road inventory data program. Working across these two programs to produce the HPMS statistics is challenging. The following is an example of this challenge.

HPMS requires combining tabular traffic data attributes with geospatial linear referencing system attributes. For example, the combination of point roadway traffic count data with the location (GIS point and linear features) provides information about where exactly along a traffic segment the original point traffic data is applicable. However, State DOTs are sometimes technically and administratively challenged with integrating GIS line and point features.

The AADT statistic is created by the travel monitoring program staff. In some States, the AADT attribute is stored in the roadway inventory, and in other States, the AADT attribute is stored with the travel monitoring data. States should establish business rules to synchronize roadway inventory and traffic data to support management of these data layers.

The *HPMS Field Manual*, Chapter 6, contains additional information on TOPS.

The remainder of this chapter includes the following sections:

6.2 HPMS Requirements – This section describes traffic data reporting requirements for HPMS.

6.3 Guidelines for Collecting Traffic Data to Support HPMS – This section provides guidance about how to acquire the traffic data needed to meet the HPMS requirements.

6.4 Calculation of Data Items – This section provides guidance about how to compute the HPMS data items and includes references.

6.2 HPMS REQUIREMENTS

While traffic data is collected and reported on a full extent, sample, and partial extent basis for HPMS, State highway agencies may not need to physically conduct traffic counts at all locations. In some cases, the States may rely on local governments to collect data and supply the data to the State for use with HPMS. In other cases, procedures such as ramp balancing can be used to estimate traffic volumes on roads where portable counts cannot be performed safely. Regardless of how the data is collected, each State highway agency is responsible for the quality, completeness, and accuracy of all traffic data within their State boundaries.

Specific emphasis is placed on the collection of vehicle classification data on HPMS sample sections, since this data is used in many nationally significant analyses, including estimating annual average truck travel and in pavement deterioration models. Truck volumes are used to calculate the percent of single-unit trucks (Pct_Peak_Single) and the percent of combination (Pct_Peak_Combination) trucks, in the form of annual average daily truck traffic (AADTT) provided by the State's traffic monitoring program.

The volume data is also used to support the assessment of the nation's transportation system and helps to ensure a fair distribution of Federal funds to maintain that system.

6.2.1 HPMS DATA MODEL

The HPMS Data Model (Figure 6-2) is a geospatial model that allows updates to particular types of data, independent of other types of data. This means that traffic data can be updated without impacting pavement, inventory, route, and geometric data. The geospatial model also provides analytical capabilities to compare traffic data with other information, such as pavement data for use in pavement design, and geometric data for use in highway safety analysis.

The HPMS data model includes six catalogs and seventeen datasets. The traffic data reported in HPMS are stored in the **Sections** and **Metadata** catalogs. The Sections dataset identified as part of the Sections catalog grouping is used to store thirteen traffic data items, seven of which are provided by the States' traffic monitoring program. The additional six items may be provided by other areas of the agency, including operations and/or other sections of the States' planning division. The traffic data items reported in HPMS are identified in Table 6.1. The following data definitions indicate how these data items are defined for the HPMS program.

AADT – is the Annual Average Daily Traffic and represents all days of the reporting year for traffic on a section of road and is required for all Federal-aid highways and grade-separated interchange ramps (HFM 4.4).

AADT_Single_Unit – is the Annual Average Daily Traffic for single-unit trucks and buses and is required for all National Highway System (NHS) and Sample Panel sections (HFM 4.4). This item requires detailed vehicle classification data and includes FHWA vehicle classes 4-7 (HFM 4.4).

Pct_Peak_Single – is the number of single-unit trucks and buses traveling on a section of road during the peak hour, divided by the AADT, and is required for all Sample Panel sections (HFM 4.4). This item requires hourly directional detailed vehicle classification data and includes FHWA vehicle classes 4-7 (HFM 4.4).

AADT_Combination – is the Annual Average Daily Traffic for Combination Trucks and must be reported for the entire NHS and all Sample Panel sections (HFM 4.4). This item requires detailed vehicle classification data and includes FHWA vehicle classes 8-13 (HFM 4.4).

Pct_Peak_Combination – is the percent of peak combination trucks traveling on a section of road during the peak hour. This item requires hourly directional detailed vehicle classification data and includes FHWA vehicle classes 8-13 (HFM 4.4).

K_Factor – is the peak hour volume (i.e., 30th highest hourly volume) expressed as a percentage of total AADT. This item is needed for all Sample Panel sections (HFM 4.4). It is best developed from hourly ATR data. The different methods used for developing short-duration and continuous count K-factors are described in more detail in Chapter 3.

Dir_Factor – is the percent of peak hour volume flowing in the peak direction and is required for all Sample Panel sections (HFM 4.4).

FIGURE 6-2   HPMS DATA MODEL STRUCTURE

Shapes Catalog (GIS Shapefiles)

- Urban Area Boundaries
- State Boundaries
- County Boundaries
- Climate Zone Boundaries
- Soil Type Boundaries
- Routes
- NAAQS Area Boundaries

Summaries Catalog (Summary Data)

- Statewide Summaries
- Vehicle Summaries
- Urban Summaries
- County Summaries
- NAAQS Summaries

Sections Catalog (HPMS Section Data)

- Sections
- Sample Panel Identification

References Catalog (Reference Data)

- Line References
- Point References

Estimates Catalog (Estimates Data)

- Estimates

Metadata Catalog (Metadata)

- Metadata

Legend:
- Datasets within each catalog
- Dataset only submitted when changes have occurred to Urban Area Boundaries and the changes have been approved by FHWA
- Datasets required from the States in the annual HPMS submittal
- Datasets with Traffic Data required from the States in the annual HPMS submittal

Source: HPMS Field Manual.

TABLE 6-1   HPMS TRAFFIC DATA ITEMS

Item Number	Data Item	Data Format	Example Value
21	AADT	Numeric	100,000
22	AADT_Single_Unit	Numeric	10,000
23	Pct_Peak_Single	Decimal to nearest 0.1% (one-tenth)	2.2
24	AADT_Combination	Numeric	30,000
25	Pct_Peak_Combination	Decimal to nearest 0.1% (one-tenth)	0.3
26	K_Factor	Numeric (2-digit)	1-99 (represents 1%-99%)
27	Dir_Factor	Numeric (2-digit)	1-99 (represents 1%-99%)
28	Future_AADT		
29	Signal_Type		
30	Pct_Green_Time		
31	Number_Signals		
32	Stop_Signs		
33	At_Grade_Other		

Further guidance for items 21 through 27 can be found in *TMG* Chapter 3. HPMS traffic data items 28 through 33 are not collected by the States' traffic monitoring program.

The standard HPMS reporting requirements for traffic data include the following topics, which are addressed in the subsequent paragraphs:

- AADT Reporting on Mainlines and Ramps;
- Travel Estimates for Local Roads and Rural Minor Collectors;
- Rounding AADTs;
- Motorcycle Counts;
- Vehicle Classification Counts;
- Truck AADT;

- Estimates of Travel by Vehicle Type;

- Volume Group Assignments; and

- Traffic Metadata.

6.2.2 AADT REPORTING ON MAINLINES AND RAMPS

AADT data is reported in HPMS for both mainlines and ramps on Federal aid facilities. The FHWA HPMS Field Manual provides the following guidelines.

- Mainline counts for each NHS, interstate, principal arterial, and sample panel section should be counted at least once every three years with yearly factored values provided for the intervening years (HFM 4.4).

- Mainline counts for the non-principal arterial system and non-sample panel sections must be conducted at least once every six years with yearly factored values provided for the intervening years (HFM 4.4).

- Counts at grade-separated interchange ramp sections must be conducted at least once every six years with yearly factored values provided for the intervening years (HFM 4.4).

- All traffic data reported for HPMS should be based on a minimum of 48-hour counts for traffic volume and vehicle classification data. The 48-hour counts are particularly important for the HPMS because standard data collection periods from all States ensure similar levels of accuracy and precision for all traffic volume data in the HPMS database. Seven day counts are the preferred method when possible.

- Bi-directional AADT should be reported for two-way roads; directional AADT should be reported for one-way roads, couplets, and ramps.

- If count volumes are available on ramps and not mainlines, use estimated AADT on mainlines.

- Where continuous data is not available from traffic management systems on freeways and expressways, ramp balancing is the mechanism most commonly used to calculate volumes. Use of ramp balancing to provide AADT for mainlines is common practice by several States.

Four approaches can be used to conduct ramp counts where needed:

- Plan to include ramp counts as part of the traffic monitoring efforts for the State.

- If count volumes are available on mainlines, but not ramps, then a method for estimating ramp counts similar to the Turns5 software developed and used by Florida DOT can be utilized. Turns5 combines the intersection balancing component of TURNFLOW with the same basic setup relating to output, menu options, and format similar to Turns3. Turns3 provides estimates of intersection turning movements and produces traffic volume outputs in a format suitable for use in various traffic analysis reports. The use of the TURNFLOW program to balance intersection turning movements was chosen since the program balances inbound and outbound volumes for each approach. Since AADTs are normally developed first in the traffic forecasting process, the program balances these values to achieve equal flow as is normally common to daily traffic flows (Project Traffic Forecasting Handbook). A method similar to this intersection balancing approach can be used to estimate traffic volumes for ramps, when only mainline counts are available.

- Regional models can be used to estimate ramp volumes, assuming these ramps were validated to a set of earlier base year counts.

- Take all ramp counts done in the State with the same functional class and assign the average ramp count value to the non-counted ramps for each functional class. This last method is the least desired approach; however, it should be used as a last resort if no other method is available.

Additionally, the following approach may be used for estimating ramp counts:

- Interchange ramps provide access from limited access highways to other highways, both limited access and others. Since most limited access highways are generally classified as principal arterials or higher, those facilities should have AADT information available. With mainline AADT available, mathematical formulas can be used to estimate some ramp volumes instead of field counting every loop and ramp. As an example, for a typical diamond interchange where the limited access road (mainline) runs east-west, you can count the eastbound on ramp and westbound off ramp, for example, and use mathematical equations to estimate the remaining ramps. For diamond, trumpet, and three-legged directional type interchanges, counts would need to be taken on 2 of the 4 ramps. Cloverleaf interchanges are more complicated. Six of the eight ramps would need to be counted when only mainline AADT is known, and mathematical formulas could be used to estimate the remaining two ramps. On rural diamond interchanges, often ramp traffic can be estimated by using an origin destination approach, as the volume on a westbound off-ramp is typically equal to the eastbound on ramp volume, for example. This approach still requires that two of the four interchange ramps be counted.

The following are equations and example computations of using relevant data to compute unknowns rather than field counting for the most common interchange configurations.

FIGURE 6-3   TYPICAL DIAMOND INTERCHANGES

Typical Diamond Interchange

Single Point Urban Diamond Interchange
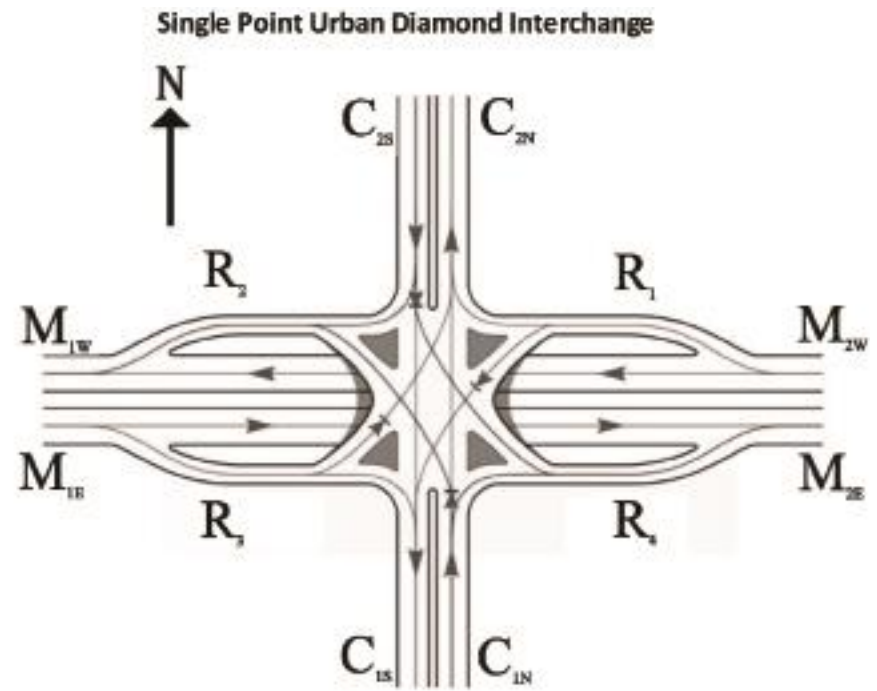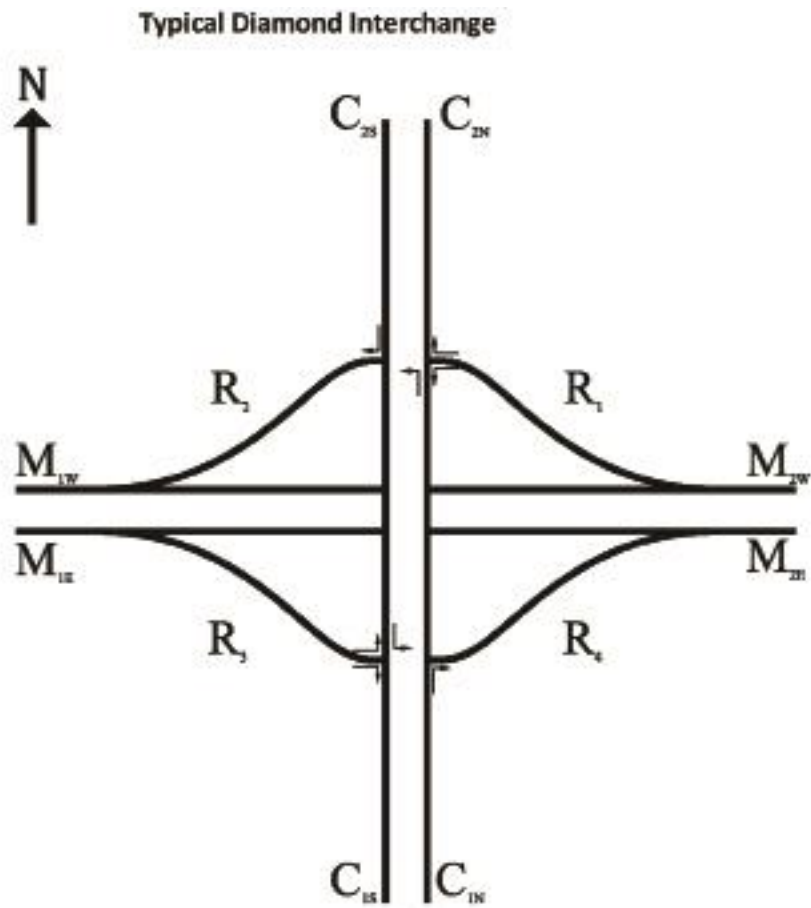
Source: Federal Highway Administration.

Mathematical Formulas

$$R_1 = \left(\frac{C_{1S}+C_{2S}}{C_{1S}}\right)[C_{1S} - C_{2S}] + \left(\frac{C_{2S}}{C_{1S}}\right)[R_2 - R_4] - R_3 \quad (1)$$

$$R_2 = (M_{1W} - M_{2W}) + R_1 \quad (2)$$

$$R_3 = \left(\frac{C_{1N}+C_{2N}}{C_{2N}}\right)[C_{2N} - C_{1N}] + \left(\frac{C_{1N}}{C_{2N}}\right)[R_2 + R_4] - R_1 \quad (3)$$

$$R_4 = (M_{2E} - M_{1E}) + R_3 \quad (4)$$

While formulas 1 and 3 require cross street data, ramps 1 and 3 can be counted and formulas 2 and 4 can be used to estimate ramps 2 and 4.

Example

A diamond interchange located on an E/W freeway has directional mainline data both upstream and downstream of the interchange. Two ramps need to be counted in order to use formulas (3) and (5). Ramps R_1 and R_4 were counted and the following data is now known:

M_{1E} = 25,000

M_{2E} = 23,200

M_{1W} = 31,000

M_{2W} = 30,000

R_1 = 1,200

R_4 = 2,350

FIGURE 6-4   DIAMOND INTERCHANGE RAMP ESTIMATION PROBLEM
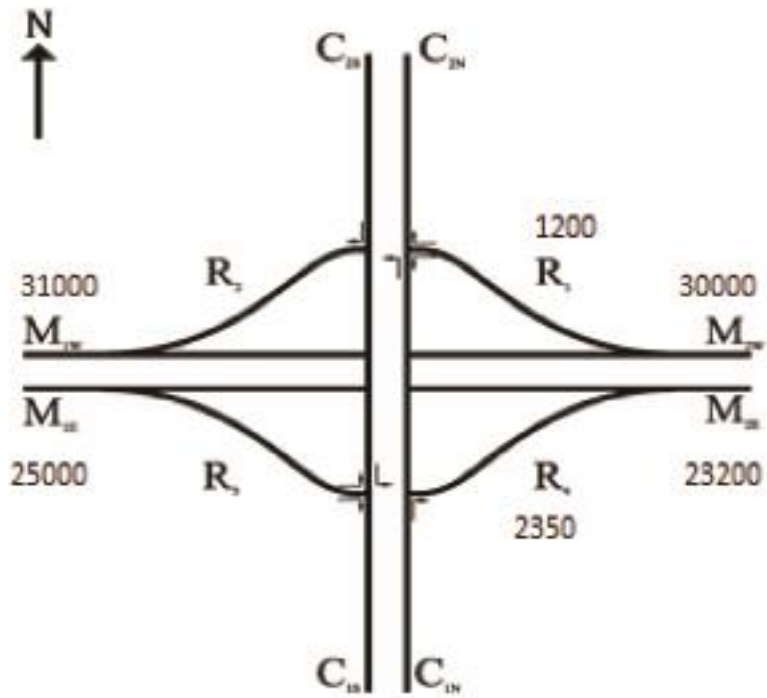
Source: Federal Highway Administration.

R_2 = $(M_{1W} - M_{2W}) + R_1$

R_2 =   (31,000 - 30,000) + 1,200

R_2 =   2,200

R_4 = $(M_{2E} - M_{1E}) + R_3$

2,350   =   (23,200 - 25,000) + R_3

2,350   =   -1,800 + R_3

R_3 =   4,150

FIGURE 6-5   TYPICAL TRUMPET AND THREE-LEGGED DIRECTIONAL INTERCHANGES

Typical Trumpet Interchange
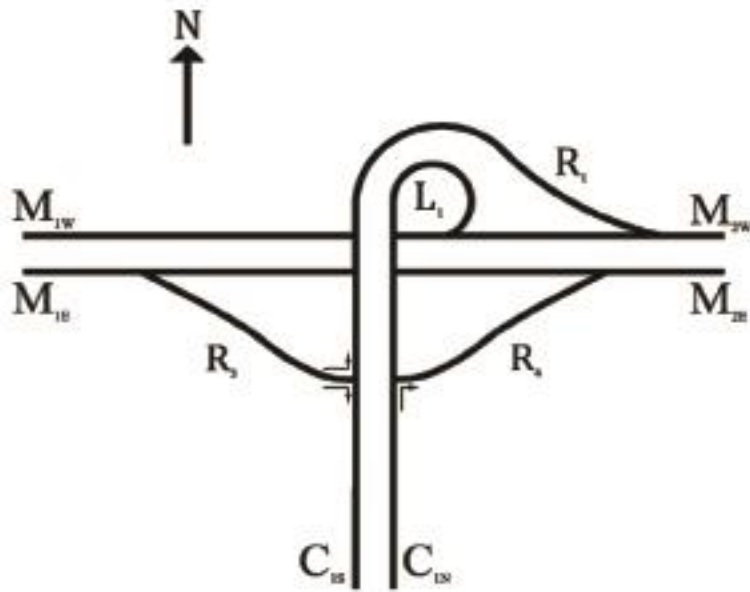
Typical Three-Legged Directional Interchange
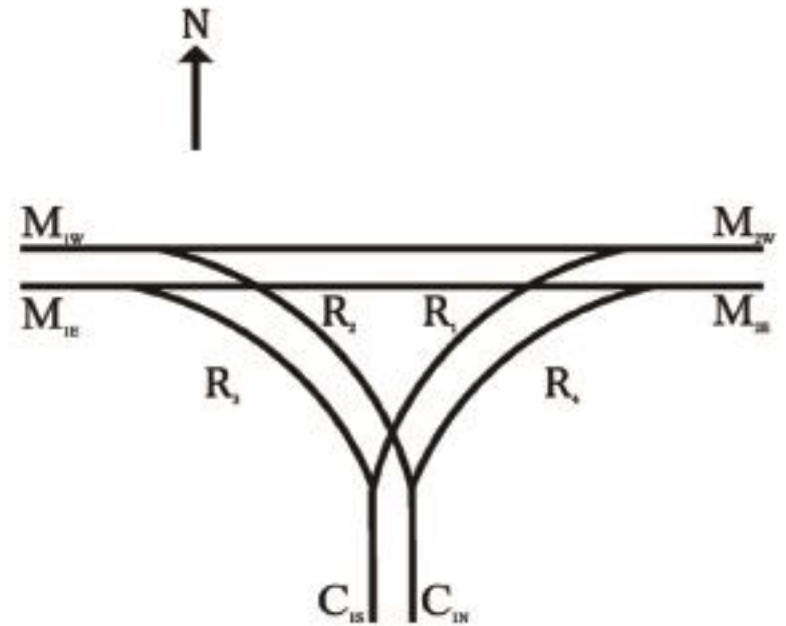
Source: Federal Highway Administration.

Mathematical Formulas

$C_{1S} = R_1 + R_3$ (5)

$R_1 = (M_{2W} - M_{1W}) + L_1$ or $R_1 = (M_{2W} - M_{1W}) + R_2$ (6)

$R_3 = (M_{1E} - M_{2E}) + R_4$ (7)

$L_1 = C_{1N} - R_4$ or $R_2 = C_{1N} - R_4$ (8)

While formulas 5 and 8 require cross street data, ramps 2 (or loop 1) and 4 can be counted and formulas 6 and 7 can be used to estimate ramps 1 and 3.

Example

A trumpet interchange located on an E/W freeway has directional mainline data both upstream and downstream of the interchange. Two ramps need to be counted in order to use formulas (9) and (10). Ramps R_1 and R_4 were counted and the following data is now known:

M_{1E}	=	21,000
M_{2E}	=	19,300
M_{1W}	=	16,500
M_{2W}	=	18,900
R_1	=	2,800
R_4	=	2,650

FIGURE 6-6   TRUMPET INTERCHANGE RAMP ESTIMATION PROBLEM
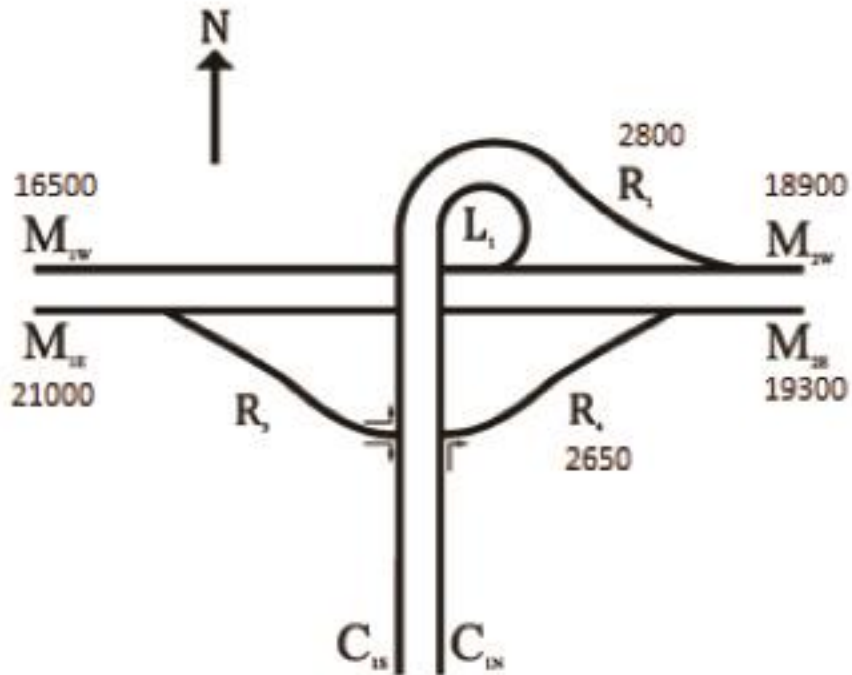
Source: Federal Highway Administration.

R_1	=	$(M_{2W} - M_{1W}) + L_1$
2,800	=	(18,900 - 16,500)+ L_1
2,800	=	2,400 + L_1
L_1	=	400
R_3	=	$(M_{1E} - M_{2E}) + R_4$
R_3	=	(21,000 - 19,300) + 2,650
R_3	=	4,350

FIGURE 6-7   TYPICAL CLOVERLEAF INTERCHANGE
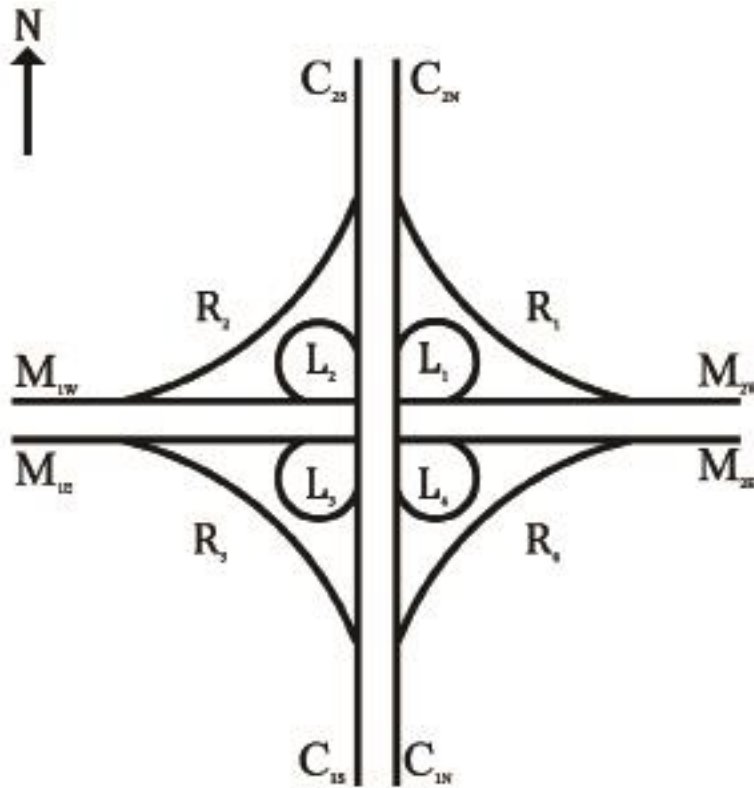
Source: Federal Highway Administration.

1.   Cloverleaf interchanges are the most complex and data intensive scenario for volume to ramp count relationships.

2.   Formulas (9) through (12) can be used directly assuming some combination of mainline, cross street, and ramp volumes are known for a given year.

3.   A weight factor does not need to be used for exit ramps when approaching the cross street because vehicles do not have an option of which direction to take once on a ramp.

Mathematical Formulas

$R_1 = (M_{2W} - M_{1W}) + (L_1 - L_2) + R_2$ (9)

$R_2 = (C_{2S} - C_{1S}) + (L_2 - L_3) + R_3$ (10)

$R_3 = (M_{1E} - M_{2E}) + (L_3 - L_4) + R_4$ (11)

$R_4 = (C_{1N} - C_{2N}) + (L_4 - L_1) + R_1$ (12)

Mainline and cross-street AADTs available with one ramp known.

- In order to calculate all ramps, two ramps from each of the following groupings need to be counted in total:

  {R_1, L_1, R_2, L_2}

  {R_3, L_3, R_4, L_4}

  For example, if R_1 is already known, then count L_1, R_2, or L_2 plus two ramps from the second group.

- Once volumes are known for four ramps, use formulas (9) through (12) to determine the remaining volumes.

If only mainline AADT data is available, count three ramps from each of the following lists:

  {R_1, L_1, R_2, L_2}

  {R_3, L_3, R_4, L_4}

With six ramps counted, use formulas (9) and (11) to determine the volumes for the remaining ramps.

Example

A cloverleaf interchange located at an intersection of two freeways has directional mainline (E/W) data both upstream and downstream of the interchange. Two ramps need to be counted in order to use formulas (9) and (11). Ramps R_1 and R_4 were counted and the following data is now known:

M_{1E}	=	54,000
M_{2E}	=	51,500
M_{1W}	=	58,500
M_{2W}	=	59,000
R_1	=	2,500
L_1	=	2,100
R_2	=	2,800
R_3	=	2,200
L_3	=	2,450
R_4	=	2,500
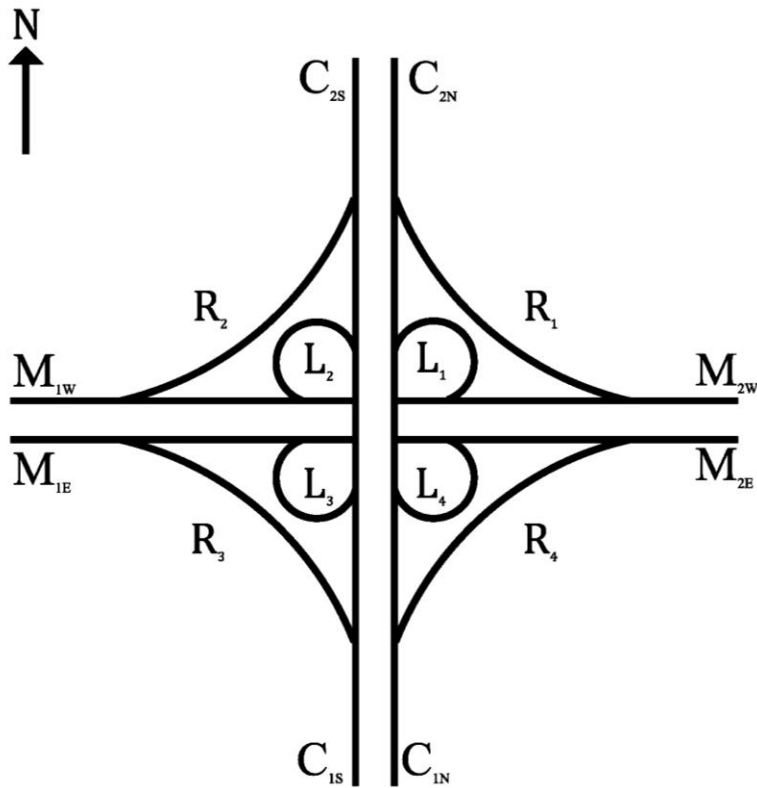
$R_1 = (M_{2W} - M_{1W}) + (L_1 - L_2) + R_2$

$2,500 = (59,000 - 58,500) + (2,100 - L_2) + 2,800$

$2,500 = 5,400 - L_2$

$L_2 = 2,900$

$R_3 = (M_{1E} - M_{2E}) + (L_3 - L_4) + R_4$

$2,200 = (54,000 - 51,500) + (2,450 - L_4) + 2,500$

$2,200 = 7,400 - L_4$

$L_4 = 5,250$

Source: Federal Highway Administration.

6.2.3   TRAVEL ESTIMATES FOR LOCAL ROADS AND RURAL MINOR COLLECTORS

Instead of reporting AADT values for local roads and rural minor collectors, VMT estimates are reported for these functional classes. These estimates should be produced by the States using a documented statistically valid procedure based on monitored traffic. The estimated VMT is summarized by States and is reported in the Statewide Summaries dataset, which is stored in the Summaries catalog of the HPMS database.

Three examples for collecting counts on local roads and rural minor collectors are illustrated by New York, Iowa, and Mississippi.

New York

New York DOT utilizes the assistance of the counties, towns, and cities in collecting local road data for HPMS purposes. The State purchases and provides the counters and supplies for two qualifying counts per counter per year for five years (e.g., ten counts total). A qualifying count is a count on the NHS. The number of counts provided is dependent on the number of miles of roadway within the county. For example, the receiving local agency may be required to perform two counts for a season and the rest are done when the local agency needs them. The State enters into a Memorandum of Agreement (MOA) with the counties in which they collect and provide all the data to the State at select locations, and in turn, the county keeps the equipment. If the county does not fulfill their obligation to the State, the equipment must be returned. After they have completed their obligation to the State, the county can retain the equipment and continue to take counts for themselves. The State does ask that the county continue to provide data, and in turn, the State will help out with repairs to the equipment.

Iowa

Iowa DOT used a different approach to support their HPMS data collection process. Maintenance staff received training, a truck, and data collection equipment to be used for purposes of collecting the HPMS data. The staff then conducts the scheduled counts during the year. Beginning in 2004 through 2010, the DOT utilized maintenance crews that cleared snow in the winter and provided continuity of employment and job diversity for equipment operators. Staff worked locally in the counties where they lived. Overall program benefits were realized through decreases in travel time and personal expenses, as well as increases in data collection quantity, quality, and metadata regarding changes in traffic patterns. Using permanent staff from local maintenance garages allowed for better ownership of the data and conveyance of personal understanding regarding changing traffic patterns, while at the same time maintaining procedural integrity through a centralized program.

Mississippi

Mississippi had some obsolete traffic counts that were not part of the routine traffic monitoring program. These counts pre-dated the implementation of the HPMS system in 1978. The traffic monitoring staff collaborated with the HPMS staff to determine where additional data collection sites were needed. These sites then became part of the routine traffic monitoring program, and updates were scheduled to be collected on the recommended six-year cycle. This includes expanding the coverage of traffic monitoring to include data collection on local roads.

Each State is encouraged to select the best approach for collecting or estimating local road data and rural minor collectors that meets their business needs.

The *TMG* does not recommend using a fixed percent of traffic growth method, or using the result of calculating statewide total VMT minus highway systems VMT to produce the estimates for local roads and rural minor collectors.

Other methods can be used to estimate counts and include the following:

- Count update based on site-specific growth;
- Count update based on route-specific growth;
- Count update based on systems growth; and
- Count update based on regional growth.

The following example explains the use of these four methods to estimate current year counts based on previous year actual counts.

In this example, a location in an urban area on a principal arterial roadway does not have a current year counted traffic volume. The AADT from the previous year was 44,500. The current year traffic can be estimated using one of the four methods or a combination of these methods.

1. Using the first method, a linear projection is performed based on historical data from the same site. If the growth rate is -3% per year, the current year traffic volume estimate would then be 43,165, which can be rounded to 43,000.

2. Using the second method, it has been determined that one or more permanent sites on similar routes exhibit a growth rate of -3.7%. The current year traffic volume estimate would then be 42,854, rounded to 43,000.

3. The third approach uses the previously determined urban system growth rate of -3.6% based on all permanent counters in urban area. The current year traffic volume estimate is therefore 42,898, which is rounded to 43,000.

4. The fourth approach is based on a regional growth rate of -3.8% from all permanent counters in the region, yielding a current year traffic volume estimate of 42,809. This value is rounded to 43,000.

In the above example, all four methods yield the same value. Use method number one first to obtain estimate counts. If site specific growth is not available, then use route-specific growth; if route-specific growth is not available, use systems growth; and finally if systems growth is not available, regional growth should be used.

6.2.4 ROUNDING AADTS

The rounding of AADTs is acceptable for HPMS purposes only following the scheme recommended by the *AASHTO Guide*. The *TMG* does not recommend this unless it is common practice for the State to round all traffic data in their traffic monitoring database and is applied to all traffic data consistently. This applies to the reporting of volume and vehicle classification data.

Rounding should be performed after all adjustments to the raw count data have been made and should NOT be performed when calculating percent single-unit and combination trucks. Low volume counts (e.g., 0.2%) should not be rounded to report zero as a volume or as a percent since this will not accurately represent the presence of the minimal volumes, and will also show no change in trends. A zero should only be reported when the actual count is zero.

The following guidance should be followed regarding rounding of AADTs:

- When sufficient data is available to develop a reasonable AADT estimation from permanent continuous counters for the current year, rounding is not recommended. Rounding is allowable for estimating AADT for HPMS purposes when there is no current year data available from permanent continuous counters, as discussed in the four previous examples.

6.2.5 MOTORCYCLE COUNTS

Accurate motorcycle counting may require unique procedures and equipment. More information is provided on this topic in Chapter 3. Some limitations exist regarding the use of technology in properly measuring motorcycle counts. More information on the type of equipment used for these counts is found in Appendix F.

6.2.6 VEHICLE CLASSIFICATION COUNTS

Vehicle classification data is needed in HPMS to determine the accurate percentage of truck traffic on the roadway during peak travel hours as well as off-peak travel hours. Both truck volume (AADT_Single_Unit and AADT_Combination) and truck percent data is reported for the various types of records in HPMS. This data is used to analyze the impact of truck traffic on pavement deterioration and are also used for reporting in summary tables in HPMS.

Since class counts are required by HPMS for many road sections, it will likely be too costly to maintain permanent traffic classifiers on all of these sections. Therefore, a combination of permanent and portable classifiers will be needed to meet the requirement. This will entail adjusting portable class counts by the permanent classifiers as further described in *TMG* Chapter 3.

6.2.7 TRUCK AADT

The AADT for trucks is required for the entire NHS and all HPMS Sample Panel Sections. Two types of truck AADT are reported in HPMS: AADT_Single_Unit (which is the single-unit truck and bus AADT for vehicle classes 4 through 7) and AADT_Combination (which is the combination truck AADT for vehicle classes 8 through 13). Appendix C provides additional information on the 13 vehicle classes.

In addition to truck AADT for single and combination trucks, two additional types of truck data is required. These are the percent of single-unit trucks (Pct_Peak_Single) and percent of combination trucks (Pct_Peak_Combination) traveling on a section of road during the peak hour.

6.2.8 ESTIMATES OF TRAVEL BY VEHICLE TYPE

Estimates of travel by vehicle type are required for HPMS and are summarized by Area Type (AT) and Functional System (FS) group. While there are seven functional systems, there are only three FS groups. The three FS groups are combined with two area types, rural and urban, for six combined AT and FS groups as shown in Table 6-2.

HPMS is designed as a random sample stratified by traffic volume groups. To the extent that vehicle class counts reflect this design, they may be averaged to estimate the distribution of VMT by vehicle type. Estimating the VMT by vehicle type to meet this requirement is not necessary.

TABLE 6-2   COMBINED AREA TYPE AND FUNCTIONAL SYSTEM GROUPS

Area Type and Functional System	Group
Rural Interstate	1
Rural Other Arterial (includes Other Freeways and Expressways, Other Principal Arterials, and Minor Arterials)	2
Rural Other (includes Major Collectors, Minor Collectors, and Locals)	3
Urban Interstate	4
Urban Other Arterial (includes Other Freeways and Expressways, Other Principal Arterials, and Minor Arterials)	5
Urban Other (includes Major Collectors, Minor Collectors, and Locals)	6

The estimates of travel by vehicle type are reported as percent values for the type(s) of vehicles in each AT-FS group, such as percent of motorcycles (Pct MC), percent of passenger cars (Pct Cars), and percent of single-unit trucks (Pct SU Trucks).

These estimated values are reported in the Vehicle Summaries dataset and are stored in the Summaries catalog of the HPMS database. This information can be derived from the vehicle classification and WIM programs.

6.2.9 Volume Group Assignments

The State's comprehensive traffic count program should be used to develop traffic volume group assignments for all road sections in a program that adequately monitors both high and low volume roads, including those off the State system. High and low volume sites are specific to each State, and engineering judgment is required to determine the values for these for each State individually. To facilitate this process, count station locations should be selected to represent expected AADT volume group breakpoints for the volume ranges of all required samples. This may require locating count stations at one per several miles in rural areas and more closely in urban areas. If there are homogeneous traffic sections (i.e., traffic counts are same for the length of the sections) as determined by prior counts or knowledge of local traffic conditions, more than one section may be represented by a single traffic count station as long as traffic does not vary more than 10%. In this scenario, local traffic monitoring offices may know of no major traffic generators or significant enough development to cause changes in the traffic volumes within HPMS sections. This situation can result in more than one HPMS section using the same traffic count station. HPMS sections exist for reasons other than fluctuations in traffic volumes, as noted in the discussion of TOPS sections. Selection of count locations should be based on previous count experience on the section or adjacent sections, recent land use development, and the existence of uncounted sections along the route.

6.2.10 Traffic Metadata

Metadata for traffic are also reported in HPMS and are used to further explain any variability in the collection and/or reporting of traffic, such as: whether the AADT is adjusted for DOW or for number of axles; if the traffic data is reported from the State traffic database only; or if the data is reported from the State traffic database and local governments.

The metadata provide additional information about the following:

- Traffic counts;
- Vehicle classification;
- Source of the travel data (State, local, etc.); and
- Ramp traffic estimation method (i.e., ramp metering, ramp balancing, etc.).

Additional information on the reporting of traffic metadata in HPMS can be found in Chapter 3 of the HPMS Field Manual.

6.3 GUIDELINES FOR COLLECTING TRAFFIC DATA TO SUPPORT HPMS

The traffic data supplied for HPMS use are derived from the State's regular traffic monitoring program with adjustments (such as aggregating data for short/long samples or using weighted-average for HPMS sections) to meet specific HPMS requirements. Collection of HPMS-specific traffic data should be fully integrated into the normal traffic monitoring program. As stated in Chapter 3, measures should be taken to ensure the quality of all data within the traffic monitoring program.

Several guidelines should be followed when collecting and processing traffic data to ensure that the highest quality traffic data is provided to HPMS. This section describes the following guidelines:

- Permanent (continuous) counts;
- Short duration counts;
- Ramp counts;
- Vehicle classification counts; and
- Equipment calibration.

6.3.1 PERMANENT (CONTINUOUS) COUNTS

States should provide at least one continuous counter on each major (as defined by HPMS) Principal Arterial System (PAS)/NHS highway route, where possible. HPMS requires at least one; however, States are encouraged to use engineering judgment. The *HPMS Field Manual* defines the NHS as a network of nationally significant highways approved by Congress in the National Highway System Designation Act of 1995. It includes the interstate system and over 117,000 miles of other roads and connectors to major intermodal terminals. Due to MAP-21 legislation, the NHS was enhanced to include many roads from the PAS. At a minimum, each continuous counter should have at least one full day of data for each day of the week for each month provided the State has an adequate automatic editing process, with documentation of the edits performed based on historic trends.

6.3.2 SHORT DURATION COUNTS

This *Guide* recommends that the short duration counts used for HPMS reporting purposes be fully integrated with the agency's coverage count program. This means using the same personnel, procedure, equipment, and counting schedule used for coverage and other traffic counts.

Highway agencies should be aware of the potential for geographic and temporal bias when scheduling counts and counteract it by devising strategies to distribute counts as much as feasible.

The HPMS sample and full extent sections are located within the traffic volume segments defined in the coverage count program. Traffic counts taken to meet the HPMS requirements are taken the same way as other short duration traffic volume counts. These are described in Chapter 3. The main difference is that the HPMS has specified nationally standardized criteria for the collection and duration of the counts. The HPMS Coordinator should request those additional counts needed for HPMS sufficiently in advance (i.e., prior to scheduling of traffic counts for the data collection year) to allow them to be included in the regular coverage count program. Whenever possible, coverage counts taken within a defined traffic count roadway section should be taken within an HPMS section. Since HPMS sections within the TOPS may change over time, this may require counts to be added or eliminated as needed for the traffic count roadway section.

One third of the HPMS full extent (NHS/PAS) and sample sections should be included in each current year coverage sample to ensure that, at a minimum, each of these HPMS full extent/sample sections are counted once every three years.

While short duration traffic counts can be taken for anywhere from just a few hours to more than a week, this *Guide* recommends a 48-hour monitoring period for traffic volume and vehicle classification. The 48-hour counts are particularly important for the HPMS because common data collection periods from all States ensure similar levels of accuracy and precision for all volume data in the HPMS database.

Where axle correction factors are needed to adjust raw counts, they should be derived from facility-specific vehicle classification data obtained on the same route or on a similar route with similar traffic in the same area. No other factors (such as equipment error factors) should be applied; only daily, seasonal, and axle correction factors should be used.

6.3.3 RAMP COUNTS

A minimum of one count every six years is required for ramps. At a minimum, 48-hour ramp counts should be adjusted with axle correction factors as needed.

The same procedures used to develop AADTs on all HPMS sections should be used to develop ramp AADTs. States are encouraged to use adjustment factors developed based on either entrance or exit travel patterns or on the functional class of the ramp and to use this procedure consistently statewide. Good judgment and experience should be applied regarding factor use. Additional information on developing adjustment factors is found in Chapter 3. Ramp counts should be available from freeway monitoring programs that continuously monitor travel on ramps and mainline facilities.

Ramp balancing programs implemented by States on ramp locations and on high volume roadways could also be used to provide AADTs. If a State has a traffic modeling office, ramp traffic estimates may be computed as part of the modeling process.

6.3.4 VEHICLE CLASSIFICATION COUNTS

Vehicle classification counts reported in HPMS should follow the guidelines outlined in Chapter 3. Hourly vehicle classification data by direction should be used for all the truck related data items, including Pct_Peak_Single (trucks) and Pct_Peak_Combination (trucks).

6.3.5 EQUIPMENT CALIBRATION

The State should ensure that data collection equipment is calibrated and tested in the field and that the results are validated for accuracy prior to use for HPMS reporting. More information on equipment calibration procedures is found in Appendix F.

6.4 CALCULATION OF DATA ITEMS

The traffic data items reported for HPMS are derived from the traffic data collection activities, which are part of the State's traffic monitoring program. These data items include:

- AADT;
- AADT_Single_Unit;
- Pct_Peak_Single;
- AADT_Combination;
- Pct_Peak_Combination;
- K_Factor;
- Dir_Factor; and
- Future AADT.

The calculation methods for these data items are described in the following paragraphs.

6.4.1 AADT

Annual Average Daily Traffic calculations are defined in Chapter 3. The following Quality Control (QC) checks on AADT data will be performed manually by FHWA staff or will be checked by the HPMS submittal software and may indicate an error with the AADT data:

- Adjacent GIS links with more than 50% change in AADT;
- AADT is missing;
- AADT – GIS flow check on AADT to and from major cities; and
- AADT changes by Functional Class from year to year checked against the Travel Monitoring Analysis System (TMAS) Growth Factors report.

6.4.2 AADT_SINGLE_UNIT

Annual Average Daily Traffic for Single Unit Trucks – This value represents all single-unit truck and bus activity based on vehicle classification count data from both the State's and other agency's traffic monitoring programs over all days of the week and all seasons of the year. Single-unit trucks are defined as vehicle classes five through seven, and buses are defined as vehicle class four. AADT_Single_Unit is reported as the volume for all single-unit activity over all days of the week and

seasons of the year in terms of the annual average daily traffic. The following QC checks will be performed by the HPMS submittal software and may indicate an error with the AADT_Single_Unit data:

- AADT_Single_Unit > 50% of AADT;

- AADT_Single_Unit + AADT_Combination > AADT; and

- GIS check will be performed on AADT_Single_Unit by area.

6.4.3   PCT_PEAK_SINGLE

Percent of single-unit trucks and buses during the peak hour – The percent of single-unit trucks and buses is the single-unit truck and bus volume during the peak hour shown as the percentage of section AADT, to the nearest tenth of a percent (0.1%). For example, if the section AADT is 3,000 and the volume of single-unit trucks and buses in the peak hour is 65, then the Pct_Peak_Single data item is shown as 0.2%. This percent should not be rounded to the nearest whole percent or to zero percent if minimal trucks and buses exist. The following QC check will be performed by the HPMS submittal software and may indicate an error with the Pct_Peak_Single data:

If (Pct_Peak_Single/100) × AADT > AADT_Single_Unit, there is an error.

6.4.4   AADT_COMBINATION

Annual Average Daily Traffic for Combination Trucks – This value represents all combination truck activity based on vehicle classification count data from both the State's and other agencies' traffic monitoring programs over all days of the week and all seasons of the year. Combination trucks are defined as vehicle classes eight through thirteen. AADT_Combination is reported as the volume for combination-unit truck activity over all days of the week and seasons of the year in terms of the annual average daily traffic. The following QC checks will be performed by the HPMS submittal software and may indicate an error with the AADT_Combination data:

- AADT_Combination > 50% of AADT; and

- GIS check will be performed on AADT_Combination by area.

6.4.5   PCT_PEAK_COMBINATION

Pct_Peak_Combination – Percent of peak combination trucks during the peak hour. The percent of peak combination trucks is the combination truck traffic volume during the peak hour shown as the percentage of section AADT, to the nearest tenth of a percent (0.1%). For example, if the section AADT is 5,000 and the volume of combination trucks in the peak hour is 165, then the Pct_Peak_Combination trucks is shown as 0.3%. This percent should not be rounded to the nearest whole percent or to zero percent if minimal trucks exist. The following QC check will be performed by the HPMS submittal software and may indicate an error with the Pct_Peak_Combination data:

If (Pct_Peak_Combination/100) > AADT_Combination, there is an error.

6.4.6   K_FACTOR

K_Factor – K_Factor is the design hour volume expressed as a percent of AADT. The K_Factor conveys the design hour volume or the 30th highest hourly volume, as a percent of total AADT. The value for K_Factor is reported to the nearest percent. For example, if the traffic volume during the design hour or 30th highest hourly volume is 10% of the AADT for a section of road, then the K_Factor is reported as 10 for that section. The following QC checks will be performed by the HPMS submittal software and may indicate an error with the K_Factor data:

- K_factors are missing;

- GIS check will be performed on distribution of K_factors by area; and

- GIS check will be performed on adjacent samples with related K_factors.

6.4.7 DIR_FACTOR

Dir_Factor (Directional Factor) – Dir-Factor is the percent of design hour volume flowing in the peak direction. The Dir_Factor is reported as the percentage of design hour volume (30th highest hour) flowing in the peak direction. For example, a Dir_Factor of sixty indicates that sixty percent of the design hour volume is flowing in the peak direction. A value of one hundred is used for one-way facilities when reporting this value in HPMS. The following QC checks will be performed by the HPMS submittal software and may indicate an error with the Dir_Factor data:

- Dir_Factor is 100% for only one-way roads;

- Dir_Factors are missing;

- Dir_Factors are over 80% for two-way roadways (Facility Type = 2);

- GIS check will be performed to check distribution of Dir_Factors by area;

- GIS check will be performed to check distribution of Dir_Factors by urban area; and

- GIS check will be performed on adjacent samples with related Dir_Factors.

6.4.8 FUTURE AADT

Future AADT may not be an item reported as part of a State's traffic monitoring program although reported as a data item in HPMS. The estimates for Future AADT are usually developed from statewide modeling programs and on input provided by MPOs as appropriate. If data from statewide modeling programs is not available, population growth or gasoline tax growth can be used to estimate traffic growth. The Future AADT is a 20-year forecast AADT, which may cover a period of 18 to 25 years from the date of the HPMS data year submittal. The following QC checks will be performed by the HPMS submittal software and may indicate an error with the Future AADT data:

- Future AADT is missing;

- Future AADT < AADT; and

- Future AADT > 300% of AADT.

This chapter discussed the HPMS requirements for traffic data. The traffic data derived from the State's traffic monitoring program should be the primary source for the traffic data reported in HPMS, supplemented with additional traffic data from local governments or MPOs as needed. All data validations for HPMS, including traffic data, are done within the HPMS submittal software and are discussed briefly in the HPMS Field Manual. A different set of data validations are performed on traffic data submitted for the Travel Monitoring Analysis System (TMAS). The next chapter discusses the traffic data format requirements for TMAS.

Chapter 7 TRAFFIC MONITORING FORMATS

7.1 INTRODUCTION

This chapter provides coding instructions and detailed record formats for the traffic data reported to FHWA as part of each State's traffic monitoring program. The CSV format is acceptable for all formats described in this chapter. By-direction data should use the same format for all data submitted to FHWA. This chapter explains the record formats and reporting requirements for both motorized and non-motorized data. The types of motorized data include station, volume, speed, classification, weight, and per vehicle data.

These formats and instructions have been developed to provide input to national databases maintained by FHWA, including the Travel Monitoring Analysis System (TMAS). Each record format described in this chapter has a specific length. In order to submit a record format that is smaller or larger than the specified length, it is necessary to submit a CSV file with a pipe character "|" between each field in the record. This rule applies to all record formats described in this chapter. In addition, there are no decimals or commas used in any fields, other than when applicable in notes descriptions.

The data records for motorized data are divided into six types: station description data, traffic volume data, speed data, vehicle classification data, weight data, and the per vehicle data format (referred to as PVF). Each type of data has its own individualized record format. Specific coding instructions and record layouts are discussed separately for each type of data in the following sections.

Fields in the record formats include instructions to "blank fill" or "zero fill" those fields. This means that either leading blanks or zeros, starting at the left of the field are to be used when the value in the field does not consume all of the columns for the field. For example, if a field is five columns wide, and the data value is 250, then a blank-filled representation for this field is _ _ 250, and a zero-filled representation for this field is 00250.

In addition, each of the data fields on the record formats are labeled as critical, optional, or critical/optional. A designation of critical means that a record cannot be processed by the TMAS software without these fields being supplied. An optional designation indicates that the data is not required for the record to be processed by TMAS. The critical/optional designation indicates that in certain cases, this field may be critical for the record to be processed by TMAS, based on input of other data fields on the record, or, it may be optional. The designations for each field are included with their field definitions. Also, certain data items are common to all six types of records. For example, all records contain a six-character station identification field. This allows States to use a common identification system for all traffic monitoring stations. Also, it is important to note that data reporting requirements described in the *TMG* are in English units, not metric units.

7.1.1 FILE NAMING RECOMMENDATIONS FOR MOTORIZED RECORDS

An example file naming convention for motorized records is the following:

ssabcxyzmmyyyy.TYP

Where:

ss = State FIPS code

abcxyz = traffic counting station ID (may be omitted if file contains more than one site's data)

mm = month of data

yyyy = year of data

TYP = type of data using the following three-character names:

> STA = station data
>
> VOL = volume data
>
> SPD = speed data
>
> CLA = axle classification data
>
> LEN = length classification data
>
> WGT = weight data
>
> PVF = per vehicle data

FHWA also recommends the use of consistent file naming conventions as this helps identify files, helps States perform quality assurance testing of the data they are utilizing, and provides an easy mechanism for identifying the content of files when transferring data to users. However, the use of the example file naming convention by the States is not required.

Record formats are also included in this chapter for non-motorized data. The two record formats described are non-motorized count station description and non-motorized count record.

Each of these records also includes fields, which are designated as critical or optional. A designation of critical means that a record should contain this field for the record to be processed. A designation of optional means that the record can be processed if this field is left blank on the record.

The remainder of this chapter is organized into the following sections:

- 7.2 Station Description Data Format;
- 7.3 Traffic Volume Data Format;
- 7.4 Speed Data Format;
- 7.5 Vehicle Classification Data Format;
- 7.6 Weight Data Format;
- 7.7 Detailed Per Vehicle Data Format (PVF) (optional);
- 7.8 Data Submittal Frequency;
- 7.9 Non-Motorized Count Station Description Data Format; and
- 7.10 Non-Motorized Count Data Format.

7.2   STATION DESCRIPTION DATA FORMAT

The Station Description record format is needed for reporting all data. If a Station Description record is omitted, any succeeding records for other record formats will not be processed by the TMAS software. The Station Description file contains one record per traffic monitoring station, per direction, per lane (unless lanes are combined by the data collection device), per year. In addition, updated station records can be submitted at any time during the year if an equipment change occurs at a site, which would result in a different type of data being submitted at that location. All fields on each record are character fields.

The TMAS software retains all approved station records as of December 31 of each year. FHWA recommends that a yearly review of all station record fields be conducted to insure the records are current and reflect what is in the field. It is expected that TMAS version 3.0 will have the capability to read all 2001 and 2012 *TMG* formats.

An example file naming convention for the Station Description Record is:

ssabcxyzmmyyyy.STA

Table 7-1 summarizes the Station Description record format.

TABLE 7-1   STATION DESCRIPTION RECORD

Field	Columns	Width	Description	Type
1	1	1	Record Type	C
2	2-3	2	FIPS State Code	C
3	4-9	6	Station ID	C
4	10	1	Direction of Travel Code	C
5	11	1	Lane of Travel	C
6	12-15	4	Year of Data	C
7	16-17	2	Functional Classification Code	C
8	18	1	Number of Lanes in Direction Indicated	C
9	19	1	Sample Type for TMAS	C
10	20	1	Number of Lanes Monitored for Traffic Volume	C
11	21	1	Method of Traffic Volume Counting	C
12	22	1	Number of Lanes Monitored for Vehicle Class	C
13	23	1	Method of Vehicle Classification	C/O
14	24	1	Algorithm for Vehicle Classification	C/O
15	25-26	2	Vehicle Classification Groupings	C/O
16	27	1	Number of Lanes Monitored for Truck Weight	C
17	28	1	Method of Truck Weighing	C/O
18	29	1	Calibration of Weighing System	C/O
19	30	1	Method of Data Retrieval	C
20	31	1	Type of Sensor	C
21	32	1	Second Type of Sensor	O
22	33	1	Primary Purpose	C
23	34-93	60	LRS Identification	C

Field	Columns	Width	Description	Type
24	94-101	8	LRS Location Point	C
25	102-109	8	Latitude	C
26	110-118	9	Longitude	C
27	119-122	4	LTPP Site Identification	O
28	123-128	6	Previous Station ID	O
29	129-132	4	Year Station Established	C
30	133-136	4	Year Station Discontinued	O
31	137-139	3	FIPS County Code	C
32	140	1	HPMS Sample Type	C
33	141-152	12	HPMS Sample Identifier	C/O
34	153	1	National Highway System	C
35	154-155	2	Posted Route Signing	C
36	156-163	8	Posted Signed Route Number	C
37	164-213	50	Station Location	O

Note: *C=Critical, C/O=Critical/Optional, O=Optional*

Fields designated as Critical *are required for entry of this record into the TMAS software.*

Fields designated as Optional *on the record formats in this chapter are not required for that record format only. Follow the coding instructions as indicated for each optional field.*

Fields designated as Critical/Optional *could be either critical or optional based on values used for other related fields.*

The fields for the Station Description record are:

1. Record Type (Column 1) – *Critical*

   S = station description record (Code the letter "S" in the first column.)

2. FIPS State Codes (Columns 2-3) – *Critical*

TABLE **7-2**   **FIPS** **S**TATE **C**ODES

State	Code	State	Code	State	Code
Alabama	1	Maine	23	Pennsylvania	42
Alaska	2	Maryland	24	Rhode Island	44
Arizona	4	Massachusetts	25	South Carolina	45
Arkansas	5	Michigan	26	South Dakota	46
California	6	Minnesota	27	Tennessee	47
Colorado	8	Mississippi	28	Texas	48
Connecticut	9	Missouri	29	Utah	49
Delaware	10	Montana	30	Vermont	50
D.C.	11	Nebraska	31	Virginia	51
Florida	12	Nevada	32	Washington	53
Georgia	13	New Hampshire	33	West Virginia	54
Hawaii	15	New Jersey	34	Wisconsin	55
Idaho	16	New Mexico	35	Wyoming	56
Illinois	17	New York	36	Puerto Rico	72
Indiana	18	North Carolina	37	American Samoa	60
Iowa	19	North Dakota	38	Guam	66
Kansas	20	Oregon	41	Northern Mariana Islands	69
Kentucky	21	Ohio	39	Virgin Islands of the U.S.	78
Louisiana	22	Oklahoma	40		

Canadian Provinces may use TMAS with the following codes (based on the LTPP):

State	Code	State	Code	State	Code
Alberta	81	Nova Scotia	86	Yukon	91
British Columbia	82	Ontario	87	Northwest Territory	92
Manitoba	83	Prince Edward Island	88	Labrador	93
New Brunswick	84	Quebec	89	Nunavut	94
Newfoundland	85	Saskatchewan	90		

3.   Station Identification (Columns 4-9) – *Critical*

This field should contain an alphanumeric designation for the station where the survey data is collected. Station identification field entries must be identical in all records for a given station. Differences in characters, including spaces, blanks, hyphens, etc., prevent proper match.

Right justify the Station ID if it is less than 6 characters. This field should be right-justified with unused columns zero-filled. This field can only be longer than 6 characters if the CSV pipe format is used for all fields on the record.

4.   Direction of Travel Code (Column 10) – *Critical*

Combined directions are only permitted for volume stations only. There should be a separate record for each direction identified in Table 7-3. Whether or not lanes are combined in each direction depends on field #5, Lane of Travel.

TABLE 7-3   DIRECTION OF TRAVEL CODES

Code	Direction
1	North
2	Northeast
3	East
4	Southeast
5	South
6	Southwest
7	West
8	Northwest
9	North-South or Northeast-Southwest combined (volume stations only)
0	East-West or Southeast-Northwest combined (volume stations only)

5.   Lane of Travel (Column 11) – *Critical*

Either each lane is considered a separate station or all lanes in each direction are combined.

TABLE 7-4   LANE OF TRAVEL CODES

Code	Lane
0	Data with lanes combined
1	Outside (rightmost) lane
2-9	Other lanes

Note: *The Station ID, Direction of Travel, and Lane of Travel make up the Station Code. There should be one Station Description record per Station Code. Stations can be either by lane or with lanes combined by direction, but not both.*

All data for volume, class, and speed should be reported with the same resolution of being by lane/direction or lanes combined/direction to be consistent in the station record for all data types submitted. All data in either weight or PVF must be submitted by individual lane and by individual direction.

FIGURE 7-1   DIRECTION AND LANE CODE EXAMPLE
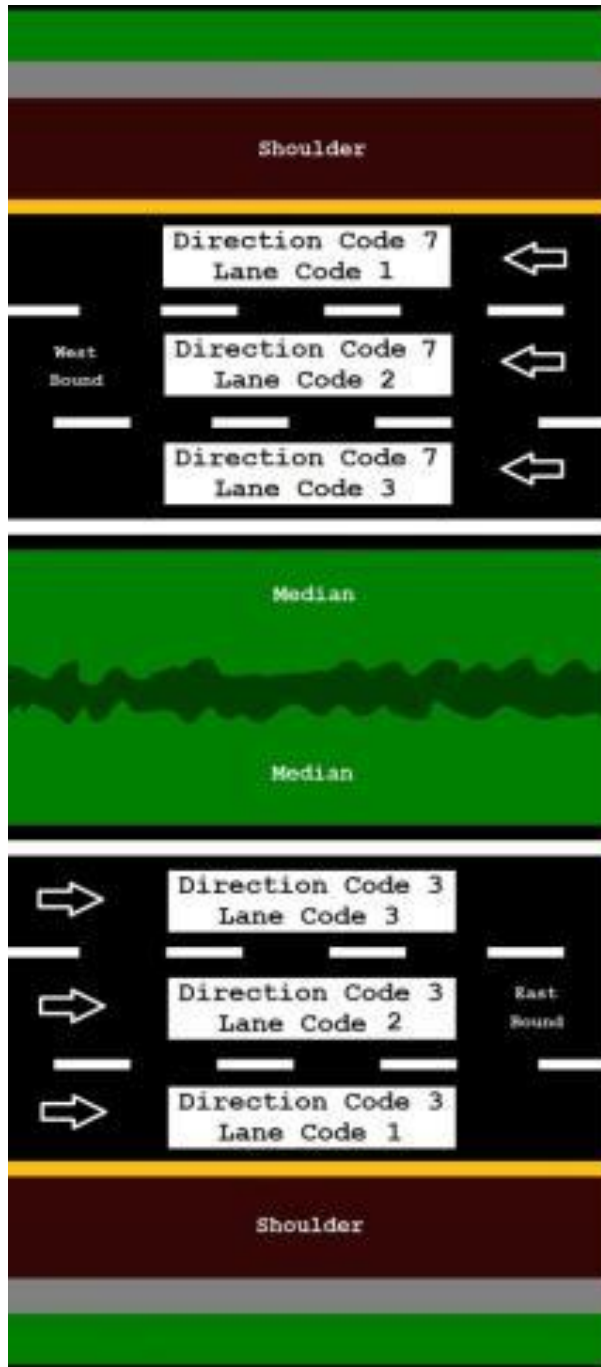
Source: Federal Highway Administration.

6. Year of Data (Columns 12-15) – *Critical*

    Code the four digits of the year in which the data were collected.

7. Functional Classification Code (Columns 16-17) – *Critical*

    Column 16 contains one of the Functional Classification Codes listed in Table 7-5. Column 17 contains either an "R" for rural or "U" for urban. For example, a code of 2R indicates a Rural Principal Arterial – Other Freeways and Expressways.

TABLE 7-5   FUNCTIONAL CLASSIFICATION CODES

Code	Functional Classification
1	Interstate
2	Principal Arterial – Other Freeways and Expressways
3	Principal Arterial – Other
4	Minor Arterial
5	Major Collector
6	Minor Collector
7	Local

8. Number of Lanes in Direction Indicated (Column 18) – *Critical*

    Code the number of lanes in one direction at the site regardless of the number of lanes being monitored. Use 9 if there are more than eight lanes.

9. Sample Type for TMAS (Column 19) – *Critical*

    Y = Station used for TMAS

    N = Station not used for TMAS

    Data submitted to TMAS may be from research or other needs that do not follow the trends in a given State and may not be for long-term purposes.

10. Number of Lanes Monitored for Traffic Volume (Column 20) – *Critical*

    Code the number of lanes in one direction that are monitored at this site. Use 9 if there are more than eight lanes.

11. Method of Traffic Volume Counting (Column 21) – *Critical*

    1 = Human observation (manual)

    2 = Portable traffic recording device

    3 = Permanent continuous count station (CCS) formerly ATR

12. Number of Lanes Monitored for Vehicle Classification and/or speed (Column 22) – *Critical*

    Code the number of lanes in one direction that are monitored for vehicle classification and/or speed at this site. Use 9 if there are more than eight lanes in a given direction.

13. Method of Vehicle Classification and/or speed (Column 23) – *Critical/Optional*

    Blank-fill this field when unused.

    1 = Human observation (manual) vehicle classification

    2 = Portable vehicle classification device

    3 = Permanent vehicle classification device

    4 = Speed only site

14. Algorithm for Vehicle Classification (Column 24) – *Critical/Optional*

    Blank-fill this field when unused.

    Code the type of input and processing used to classify vehicles:

A = Human observation on site (manual)

B = Human observation of vehicle image (e.g., video)

C = Automated interpretation of vehicle image or signature (e.g., video, microwave, sonic, radar)

D = Vehicle length classification

E = Axle spacing with ASTM Standard E1572

F = Axle spacing with FHWA 13 Vehicle Types

G = Axle spacing with FHWA 13 Vehicle Types (modified)

H = Other axle spacing algorithm

K = Axle spacing and weight algorithm

L = Axle spacing and vehicle length algorithm

M = Axle spacing, weight, and vehicle length algorithm

N = Axle spacing and other input(s) not specified above

R = LTPP classification algorithm (The details of this scheme can be obtained in the report Verification, Refinement, and Applicability of LTPP Classification Scheme.)

S = State specific algorithm

V = Vendor default algorithm

Z = Other means not specified above

15. Vehicle Classification Groupings (Columns 25-26) – *Critical/Optional*

The value in this field indicates the total number of classes in the vehicle classification system being used as well as how vehicles are grouped together in those classes in relation to the 13 FHWA categories. The recommended default value is 13, which indicates that the standard FHWA 13 vehicle category classification system (see Appendix C) is being used. Other vehicle classification systems may be based on the HPMS or specific States' classification schema documented in the State's Traffic Monitoring System (TMS) documentation. The value that is placed in columns 25 and 26 will determine the number of count fields needed on the Vehicle Classification Record (see Section 7.5). The following list indicates the acceptable values that can be entered into Columns 25 and 26 and their meaning. In the following table, the numbers in parentheses refer to the 13 FHWA classes, and describe how the FHWA classes relate to the classes being reported. Blank-fill this field when unused.

TABLE 7-6   VALUES TO BE ENTERED TO DEFINE VEHICLE CLASSIFICATION GROUPINGS

Value Entered Into Columns 25-26	Number of Groups	How Vehicles are Classified
02	Two groups	(classes 1-3) vehicles (classes 4-7; 8-10; 11-13) vehicles
03	Three groups	(classes 1-3) vehicles single-unit (classes 4-7) combination (classes 8-13) vehicles
04	Four groups	(classes 1-3) vehicles single-unit vehicles (classes 4-7) single-trailer vehicles (classes 8-10) multiple -trailer vehicles (classes 11-13)
05	Five groups	motorcycles (class 1) two-axle, four-tire vehicles (classes 2-3) buses and single-unit vehicles (classes 4-7) single-trailer combination vehicles (classes 8-10) multiple-trailer combination vehicles (classes 11-13)
06	Six groups	motorcycles (class 1) two-axle, four-tire vehicles (classes 2-3) buses (class 4) single-unit vehicles (classes 5-7) single-trailer combination vehicles (classes 8-10) multiple-trailer combination vehicles (classes 11-13)
13		FHWA's standard 13 class system
Other Positive Integers		number of classes (unsupported by TMAS software)

16. Number of Lanes Monitored for Truck Weight (Column 27) – *Critical*

    Code the number of lanes in one direction that are monitored for truck weight at this site. Use 9 if there are more than eight lanes.

17. Method of Truck Weighing (Column 28) – *Critical/Optional*

    Blank-fill this field when unused.

    1 = Portable static scale

    2 = Chassis-mounted, towed static scale

    3 = Platform or pit static scale

    4 = Portable weigh-in-motion system

5 = Permanent weigh-in-motion system

18. Calibration of Weighing System (Column 29) – *Critical/Optional*

    Code the method used to calibrate the weighing system, e.g., comparing weigh-in-motion and weights from static scales. At a minimum, yearly calibration is recommended, and maybe more often depending upon the site, sensors, equipment, and array used. Blank-fill this field when unused.

    A = ASTM Standard E1318

    B = Subset of ASTM Standard E1318

    C = Combination of test trucks and trucks from the traffic stream (but not ASTM E1318)

    D = Other sample of trucks from the traffic stream

    M = Statistical average of the steering axle of class nines

    R = LTPP Calibration Method

    S = Static calibration

    T = Test trucks only

    U = Uncalibrated

    Z = Other method

19. Method of Data Retrieval (Column 30) – *Critical*

    Blank-fill this field when unused.

    1 = Not automated (manual)

    2 = Automated (telemetry)

20. Type of Sensor (Column 31) – *Critical*

    Code the type of sensor used for traffic detection.

    A = Automatic vehicle identification (AVI)

    B = Bending plate

    C = Capacitance strip

    D = Capacitance mat/pad

    E = Load cells (hydraulic or mechanical)

    F = Fiber optic

    G = Strain gauge on bridge beam

    H = Human observation (manual)

    I = Infrared

    K = Laser/Lidar

    L = Inductive loop

    M = Magnetometer

    P = Piezoelectric

    Q = Quartz piezoelectric

    R = Road tube

S = Sonic/acoustic

T = Tape switch

U = Ultrasonic

V = Video image

W = Microwave (radar)

X = Radio wave (radar)

Z = Other

21. Second Type of Sensor (Column 32) – *Optional*

    If there are two types of sensors at the station, code the second using the same codes as Type of Sensor. Otherwise, code N for none. Blank-fill this field when unused.

22. Primary Purpose (Column 33) – *Critical*

    This field indicates the *primary purpose* for installing the station and hence which organization is responsible for it and supplies the data.

    E = Enforcement purposes (e.g., speed or weight enforcement)

    I = Operations purposes in support of ITS initiatives

    L = Load data for pavement design or pavement management purposes

    O = Operations purposes *but not ITS*

    P = Planning or traffic statistics including HPMS reporting purposes

    R = Research purposes (e.g., LTPP)

23. LRS Identification (Columns 34-93) (60 characters) – *Critical*

    The LRS Identification reported in this item for the station must be the same as the LRS identification reported in the HPMS for the section of roadway where the station is located. The LRS identification is a 60-character, right justified value. The LRS ID can be alphanumeric, but must not contain blanks; leading zeros must be coded. More information concerning the LRS may be found in Chapter III of the *HPMS Field Manual*, Linear Referencing System Requirements.

24. LRS Location Point (Columns 94-101) (8 digits) – *Critical*

    This is the LRS location point for the station. It is similar information to the LRS Beginning Point and LRS Ending Point in the HPMS. The milepoint for the station must be within the range of the LRS beginning point and LRS ending point for the roadway section upon which the station is located. It is coded in miles, to the nearest thousandth of a mile, with an implied decimal in the middle: XXXX.XXX.

25. Latitude (Columns 102-109) – *Critical*

    This is the latitude of the station location with the north hemisphere assumed and decimal place understood as XX.XXX XXX. If the value is 39.166 400 (Kansas), then the field is coded as '39166400', with an implied decimal point after the second digit.

26. Longitude (Columns 110-118) – *Critical*

    This is the longitude of the station location with the west hemisphere assumed and decimal place understood as XXX.XXX XXX. If the value is 088.354 800 (Kansas), then the field is coded as '088354800', with an implied decimal point after the third digit.

27. LTPP Site Identification (Columns 119-122) – *Optional*

    If the site is used in the LTPP sample, give the LTPP site ID.

Blank-fill this field when unused.

28. Previous Station ID (Columns 123-128) – *Optional*

   If the station replaces another station, give the station ID that was used previously. Blank-fill this field when unused.

29. Year Station Established (Columns 129-132) – *Critical*

   Code the four digits of the appropriate year if known.

30. Year Station Discontinued (Columns 133-136) – *Optional*

   Code the four digits of the appropriate year if known. Blank-fill this field when unused.

31. FIPS County Code (Columns 137-139) – *Critical*

   Use the three-digit FIPS county code (see Federal Information Processing Standards Publication 6, *Counties of the States of the United States*).

32. HPMS Sample Type (Column 140) – *Critical*

   N = No, not on an HPMS standard sample section

   Y = Yes, on an HPMS standard sample section

33. HPMS Sample Identifier (Columns 141-152) – *Critical/Optional*

   If the station is on an HPMS standard sample section, code the HPMS Sample Identifier per the HPMS Field Manual (Field 7 in the HPMS Sample Panel Identification dataset). Blank-fill this field when unused.

34. National Highway System (Column 153) – *Critical*

   N = No, not on National Highway System

   Y = Yes, on National Highway System

35. Posted Route Signing (Column 154-155) – *Critical*

   This is the same as Route Signing in *HPMS Field Manual, 2012* (Data Item 18 in HPMS Sections dataset).

TABLE 7-7   POSTED ROUTE SIGNING CODES

Code	Description
1	Not signed
2	Interstate
3	U.S.
4	State
5	Off-Interstate Business Marker
6	County
7	Township
8	Municipal
9	Parkway Marker or Forest Route Marker
10	None of the above

36. Posted Signed Route Number (Columns 156-163) – *Critical*

Code the route number of the principal route on which the station is located. This is the same as Signed Route Number in *HPMS Field Manual, 2012* (Data Item 17 in HPMS Sections dataset).

If the station is located on a city street, zero-fill this field.

37. Station Location (Columns 164-213) – *Optional*

This is an English text entry field. For stations located on a numbered route, enter the name of the nearest major intersecting route, State border, or landmark on State road maps and the distance and direction of the station from that landmark to the station (e.g., "12 miles south of the Kentucky border"). If the station is located on a city street, enter the city and street name. Abbreviate if necessary. Left justify this field.

Blank-fill this field when unused.

TABLE 7-8   STATION DESCRIPTION RECORD EXAMPLES

VOLUME SITE (4 LANE SITE WITH ALL LANES AND DIRECTIONS COMBINED) STATION FILE

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18	19	20	21	22	23	24	25-26	27	28	29	30	31	32	33
Content Example:	S	17	01810A	9	0	2012	2R	2	Y	2	3	0	Blank	Blank	Blank	0	Blank	Blank	2	L	Blank	P

continued

Column Number:	34-93	94-101	102-109	110-118	119-122	123-128
Content Example:	000000000000000000000000000000000000000000000867K65T4RE348	00785600	39166400	088354800	Blank	Blank

continued

Column Number:	129-132	133-136	137-139	140	141-152	153	154-155	156-163	164-213
Content Example:	2001	Blank	049	Y	000012345000	Y	03	00000404	.6 miles past old Mill Road

CLASSIFICATION (8 LANE SITE WITH ONLY LANES COMBINED) SITE STATION FILE

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18	19	20	21	22	23	24	25-26	27	28	29	30	31	32	33
Content Example:	S	17	01811B	1	0	2012	1R	4	Y	4	3	2	3	F	13	0	Blank	Blank	2	L	L	P
Content Example:	S	17	01811B	5	0	2012	1R	4	Y	4	3	2	3	F	13	0	Blank	Blank	2	L	L	P

continued

Column Number:	34-93	94-101	102-109	110-118	119-122	123-128
Content Example:	0000000000000000000000000000000000000000000000880IR5T4RE348	00785600	39166400	088354800	Blank	Blank
Content Example:	0000000000000000000000000000000000000000000000880IR5T4RE348	00785600	39166400	088354800	Blank	Blank

Column Number:	129-132	133-136	137-139	140	141-152	153	154-155	156-163	164-213
Content Example:	1945	Blank	049	N	Blank	Y	20	00000708	.5 miles past Steven City near County Line Road
Content Example:	1945	Blank	049	N	Blank	Y	20	00000708	.5 miles past Steven City near County Line Road

WEIGHT SITE (2 LANE SITE) STATION FILE

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18	19	20	21	22	23	24	25-26	27	28	29	30	31	32	33
Content Example:	S	17	01812C	1	1	2012	1R	1	Y	4	3	1	3	F	13	1	5	A	2	Q	L	L
Content Example:	S	17	01812C	5	1	2012	1R	1	Y	4	3	1	3	F	13	1	5	A	2	Q	L	L

Column Number:	34-93	94-101	102-109	110-118	119-122	123-128	129-132
Content Example:	0000000000000000000000000000000000000000000000890IR5T4RE348	00785600	39166400	088354800	Blank	Blank	1965
Content Example:	0000000000000000000000000000000000000000000000890IR5T4RE348	00785600	39166400	088354800	Blank	Blank	1965

Column Number:	133-136	137-139	140	141-152	153	154-155	156-163	164-213
Content Example:	Blank	049	Y	008905673459	Y	20	00000708	.5 miles past Steven City near County Line Road
Content Example:	Blank	049	Y	008905673459	Y	20	00000708	.5 miles past Steven City near County Line Road

7.3   TRAFFIC VOLUME DATA FORMAT

The Hourly Traffic Volume Record format is a fixed length, fixed field record. One record is used for each calendar day for which traffic monitoring data is being submitted. Each record contains a field for traffic volume occurring during each of the 24 hours of that day. Blank fill the columns used for any hours during which no data is being reported. Table 7-9 summarizes the Hourly Traffic Volume record.

All numeric fields should be right-justified and blank fill the columns for which no data is being reported.

An example file naming convention for the Volume record is:

ssabcxyzmmyyyy.VOL

As a reminder, pipe characters "|" can be used between each field in the record if the record length needs to be shorter or longer than the record length of 153 columns, as identified in Table 7-9.

TABLE 7-9   HOURLY TRAFFIC VOLUME RECORD

Field	Columns	Width	Description	Type
1	1	1	Record Type	C
2	2-3	2	FIPS State Code	C
3	4-5	2	Functional Classification	C
4	6-11	6	Station Identification	C
5	12	1	Direction of Travel	C
6	13	1	Lane of Travel	C
7	14-17	4	Year of Data	C
8	18-19	2	Month of Data	C
9	20-21	2	Day of Data	C
10	22	1	Day of Week	C
11	23-27	5	Traffic Volume Counted, after 00:00 – to 01:00	O
12	28-32	5	Traffic Volume Counted, after 01:00 – to 02:00	O
13	33-37	5	Traffic Volume Counted, after 02:00 – to 03:00	O
14	38-42	5	Traffic Volume Counted, after 03:00 – to 04:00	O
15	43-47	5	Traffic Volume Counted, after 04:00 – to 05:00	O
16	48-52	5	Traffic Volume Counted, after 05:00 - to 06:00	O
17	53-57	5	Traffic Volume Counted, after 06:00 – to 07:00	O

Field	Columns	Width	Description	Type
18	58-62	5	Traffic Volume Counted, after 07:00 – to 08:00	O
19	63-67	5	Traffic Volume Counted, after 08:00 – to 09:00	O
20	68-72	5	Traffic Volume Counted, after 09:00 – to 10:00	O
21	73-77	5	Traffic Volume Counted, after 10:00 – to 11:00	O
22	78-82	5	Traffic Volume Counted, after 11:00 – to 12:00	O
23	83-87	5	Traffic Volume Counted, after 12:00 - to 13:00	O
24	88-92	5	Traffic Volume Counted, after 13:00 – to 14:00	O
25	93-97	5	Traffic Volume Counted, after 14:00 – to 15:00	O
26	98-102	5	Traffic Volume Counted, after 15:00 – to 16:00	O
27	103-107	5	Traffic Volume Counted, after 16:00 – to 17:00	O
28	108-112	5	Traffic Volume Counted, after 17:00 – to 18:00	O
29	113-117	5	Traffic Volume Counted, after 18:00 - to 19:00	O
30	118-122	5	Traffic Volume Counted, after 19:00 – to 20:00	O
31	123-127	5	Traffic Volume Counted, after 20:00 – to 21:00	O
32	128-132	5	Traffic Volume Counted, after 21:00 – to 22:00	O
33	133-137	5	Traffic Volume Counted, after 22:00 – to 23:00	O
34	138-142	5	Traffic Volume Counted, after 23:00 – to 24:00	O
35	143	1	Restrictions	C

Note: C=Critical, C/O=Critical/Optional, O=Optional

Fields designated as Critical are required for entry into the TMAS software.

Fields designated as Optional are not required for this record to be processed in TMAS.

The Hourly Traffic Volume record is defined as follows (note that the data items used in both the Hourly Traffic Volume Record and the Station Description Record are not redefined below, but simply referenced to the earlier definitions in Section 7.2):

1. Record Type (Column 1) – *Critical*

    3 = Traffic volume record (Code the value "3" in the first column.)

2. FIPS State Code (Columns 2-3) – See section 7.2, Field #2. – *Critical*

3. Functional Classification Code (Columns 4-5) – See section 7.2, Field #7. – *Critical*

4. Station Identification (Columns 6-11) – See section 7.2, Field #3. – *Critical*

    This should be right-justified with unused columns zero-filled. – *Critical*

5. Direction of Travel Code (Column 12) - See section 7.2, Field #4. – *Critical*

6. Lane of Travel (Column 13) – See section 7.2, Field #5. – *Critical*

   The code for data being submitted with all lanes combined is zero (0).

7. Year of Data (Columns 14-17) – See section 7.2, Field #6. – *Critical*

8. Month of Data (Columns 18-19) – *Critical*

   01 = January

   02 = February

   03 = March

   04 = April

   05 = May

   06 = June

   07 = July

   08 = August

   09 = September

   10 = October

   11 = November

   12 = December

9. Day of Data (Columns 20-21) – *Critical*

   Code the day of the month of data, 01-31. Must correspond to the month of data.

10. Day of Week (Column 22) – Critical

    1 = Sunday

    2 = Monday

    3 = Tuesday

    4 = Wednesday

    5 = Thursday

    6 = Friday

    7 = Saturday

11 through 34. Traffic Volume Counted Fields (Columns 23-27, …, 138-142) - *Optional*

   Enter the traffic volume counted during the hour covered in the columns indicated in Table 7-10.

   If the data is missing, blank fill the appropriate columns.

TABLE 7-10   HOUR COVERED FIELDS

Field	Hour Covered
11	after 00:00 to 01:00
12	after 01:00 to 02:00
13	after 02:00 to 03:00
14	after 03:00 to 04:00
15	after 04:00 to 05:00
16	after 05:00 to 06:00
17	after 06:00 to 07:00
18	after 07:00 to 08:00
19	after 08:00 to 09:00
20	after 09:00 to 10:00
21	after 10:00 to 11:00
22	after 11:00 to 12:00
23	after 12:00 to 13:00
24	after 13:00 to 14:00
25	after 14:00 to 15:00
26	after 15:00 to 16:00
27	after 16:00 to 17:00
28	after 17:00 to 18:00
29	after 18:00 to 19:00
30	after 19:00 to 20:00
31	after 20:00 to 21:00
32	after 21:00 to 22:00
33	after 22:00 to 23:00
34	after 23:00 to 24:00

35. Restrictions (Column 143) - *Critical*

   0 = no restrictions

   1 = construction or other activity affected traffic flow, traffic pattern not impacted

   2 = traffic counting device problem (e.g., malfunction or overflow)

   3 = weather affected traffic flow, traffic pattern not impacted

   4 = construction or other activity affected traffic flow, traffic pattern impacted

   5 = weather affected traffic flow, traffic pattern impacted

Table 7-11 Hourly Traffic Volume Record Examples

VOLUME SITE (4 LANES WITH ALL LANES AND DIRECTIONS COMBINED) VOLUME FILE

Column Number:	1	2-3	4-5	6-11	12	13	14-17	18-19	20-21	22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	58-62	63-67	68-72	73-77
Content Example:	3	17	2R	01710A	9	0	2012	04	25	4	00046	00022	00014	00013	00029	00030	00075	00136	00179	00218	00264

continued

Column Number:	78-82	83-87	88-92	93-97	108-112	113-117	118-122	123-127	128-132	133-137	138-142	143
Content Example:	00293	00322	00401	00439	00366	00261	00202	00143	00098	00054	00022	0

VOLUME SITE (4 LANES WITH ONLY LANES COMBINED) VOLUME FILE

Column Number:	1	2-3	4-5	6-11	12	13	14-17	18-19	20-21	22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	58-62	63-67	68-72
Content Example:	3	17	2R	018130	3	0	2012	04	25	4	00005	00004	00004	00002	00001	00001	00005	00003	00012	00016
Content Example:	3	17	2R	018130	7	0	2012	04	25	4	00008	00001	00003	00003	00004	00000	00000	00001	00004	00009

continued

Column Number:	73-77	78-82	83-87	88-92	93-97	98-102	103-17	108-112	113-117	118-122	123-127	128-132	133-137	138-142	143
Content Example:	00019	00019	00019	00026	00019	00020	00015	00019	00014	00011	00009	00013	00004	00002	0
Content Example:	00019	00015	00014	00022	00026	00015	00019	00011	00005	00016	00003	00010	00006	00004	0

7-22

7.4   SPEED DATA FORMAT

The speed data file format is a variable length record used to report the number of vehicles traveling in specified 5 mph speed bins during specified time periods. Each record can contain 1 hour of data, 15 minutes of data, or 5 minutes of data. The submitting State chooses the time interval for which data is being reported and indicates that time interval as a field in the record.

To submit data to FHWA, the speed data format must have a minimum of 15 bins up to a maximum of 25 bins and should supply data in 5 mph speed bins defined as being required by FHWA. Any speed data records that do not meet these data specifications   are purged by the TMAS software. All records should follow the record formats defined in the *TMG*. In addition to the minimum and maximum number of bins, a State may choose to report data in additional speed bins (see next paragraph). When submitting data only using the minimum number of speed bins (15), the first speed bin includes all vehicles traveling 20 mph or slower. The second speed bin is then defined as all vehicles traveling faster than 20 mph but less than or equal to 25 mph. The last of the fifteen speed bins is defined as all vehicles traveling faster than 85 mph.

If they desire, States may submit one or two additional speed bins for slow traveling vehicles. They may create one additional slow speed bin (for vehicles traveling 15 mph or slower), or two slow speed bins (one for vehicles traveling 10 mph or slower, and the other for vehicles traveling greater than 10 mph up to 15 mph.) Similarly, a State may create additional high speed bins. Up to eight additional bins may be added to provide more detail on high speed travel. The number of additional high speed bins being reported should be indicated on the speed record. Finally, when additional high speed bins are reported, the length of the speed record changes.

An example file naming convention for the Vehicle Speed Record is:

ssabcxyzmmyyyy.SPD

Table 7-12 summarizes the Vehicle Speed record format.

TABLE 7-12   VEHICLE SPEED RECORD

Field	Columns	Width	Description	Type
1	1	1	Record Type	C
2	2-3	2	FIPS State Code	C
3	4-9	6	Station ID	C
4	10	1	Direction of Travel Code	C
5	11	1	Lane of Travel	C
6	12-15	4	Year of Data	C
7	16-17	2	Month of Data	C
8	18-19	2	Day of Data	C
9	20-21	2	Hour of Data	C
10	22	1	Speed Data Time Interval	O

Field	Columns	Width	Description	Type
11	23	1	Definition of First Speed Bin	O
12	24-25	2	Total Number of Speed Bins Reported	O
13	26-30	5	Total Interval Volume	O
14	31-35	5	Bin 1 Count	C
15	36-40	5	Bin 2 Count	C
16	41-45	5	Bin 3 Count	C
17	46-50	5	Bin 4 Count	C
18	51-55	5	Bin 5 Count	C
19	56-60	5	Bin 6 Count	C
20	61-65	5	Bin 7 Count	C
21	66-70	5	Bin 8 Count	C
22	71-75	5	Bin 9 Count	C
23	76-80	5	Bin 10 Count	C
24	81-85	5	Bin 11 Count	C
25	86-90	5	Bin 12 Count	C
26	91-95	5	Bin 13 Count	C
27	96-100	5	Bin 14 Count	C
28	101-105	5	Bin 15 Count	C
29	106-110	5	Bin 16 Count	C/O
30	111-115	5	Bin 17 Count	C/O
31	116-120	5	Bin 18 Count	C/O
32	121-125	5	Bin 19 Count	C/O
33	126-130	5	Bin 20 Count	C/O
34	131-135	5	Bin 21 Count	C/O
35	136-140	5	Bin 22 Count	C/O
36	141-145	5	Bin 23 Count	C/O
37	146-150	5	Bin 24 Count	C/O
38	151-155	5	Bin 25 Count	C/O

Note: *C=Critical, C/O=Critical/Optional, O=Optional*

Fields designated as Critical are required to upload speed data.

Fields designated as Optional are not required for this record format. Code these fields according the instructions for each optional field.

The fields for the Vehicle Speed record are defined as follows:

1. Record Type (Column 1) – *Critical*

   T = Vehicle Speed record

2. FIPS State Code (Columns 2-3) – *Critical*

   See section 7.2, Field #2.

3. Station Identification (Columns 4-9) – *Critical*

   See section 7.2, Field #3.

   This field should be right-justified with unused columns zero-filled.

4. Direction of Travel Code (Column 10) – *Critical*

   See section 7.2, Field #4.

5. Lane of Travel (Column 11) – *Critical*

   See section 7.2, Field #5.

   Note: The Station ID, Direction of Travel, and Lane of Travel make up the Station Code. No combined lanes allowed. There should be one Station Description record per Station Code.

6. Year of Data (Columns 12-15) – *Critical*

   See section 7.2, Field #6.

7. Month of Data (Columns 16 17) – *Critical*

   See section 7.3, Field #8.

8. Day of Data (Columns 18-19) – *Critical*

   See section 7.3, Field #9.

9. Hour of Data (Columns 20-21) – *Critical*

   Code the beginning of the hour in which the count was taken:

   > 00 = after 00:00 to 01:00
   >
   > 01 = after 01:00 to 02:00
   >
   > …
   >
   > …
   >
   > …
   >
   > 22 = after 22:00 to 23:00
   >
   > 23 = after 23:00 to 24:00

10. Speed Data Time Interval (Column 22) – *Optional*

    A 60 minute time interval is assumed if this column is left blank. This field can be used to designate either 5 minute or 15 minute binned speed data.

    For 15 minute binned intervals of speed data use the following:

    > Code 1 for the interval 0.0-14.999
    >
    > Code 2 for the interval 15.0-29.999
    >
    > Code 3 for the interval 30.0-44.999
    >
    > Code 4 for the interval 45.0-59.999

For 5 minute binned intervals of speed data use the following:

Code A for the interval 0.0-4.999

Code B for the interval 5.0-9.999

Code C for the interval 10.0-14.999

Code D for the interval 15.0-19.999

Code E for the interval 20.0-24.999

Code F for the interval 25.0-29.999

Code G for the interval 30.0-34.999

Code H for the interval 35.0-39.999

Code I for the interval 40.0-44.999

Code J for the interval 45.0-49.999

Code K for the interval 50.0-54.999

Code L for the interval 55.0-59.999

11. Definition of First Speed Bin (Column 23) – *Optional*

If this field is left blank, the first speed bin is assumed to be defined as being all vehicles traveling equal to or slower than 20 mph.

If the State wishes to submit data that provides more detail of vehicles traveling at slower speeds, it may supply data in one or two additional slow speed bins. If the value "1" is coded in Column 21 the first speed bin is defined as "all vehicles traveling at equal to or slower than 15 mph." If the value "2" is coded in Column 21, the first speed bin submitted will contain "all vehicles traveling at equal to or slower than 10 mph" while the second bin will be defined as "all vehicles traveling faster than 10 mph and at equal to or slower than 15 mph."

12. Total Number of Speed Bins Reported (Columns 24-25) – *Optional*

If this field is left blank the record should contain data in 15 speed bins; the first bin is defined as all vehicles traveling 20 mph or slower, and the last bin is defined as all vehicles traveling faster than 85 mph. The length of the record for 15 speed bins is 105 columns wide.

If the State is supplying data in additional speed bins, this value is used to determine the correct record length.

TABLE 7-13   TOTAL NUMBER OF SPEED BINS
RECORD LENGTH

Total Number of Speed Bins (Defined in Columns 24-25)	Record Length (number of columns)
15	105
16	110
17	115
18	120
19	125
20	130
21	135
22	140

23	145
24	150
25	155

When used in conjunction with Field 11 (Column 23) it is possible to determine the definition of all speed bins being submitted.

13. Total Interval Volume (Columns 26-30) – *Optional*

This numeric field is the total traffic volume for the interval being reported on this record. The total volume is needed because vehicle speed may not have been detected for all vehicles, in which case the sum of the speed counts would not equal the total volume. If the total volume is not collected, leave this field blank.

The following speed count fields are numeric fields with the traffic volume by vehicle speed for each interval being reported. Traffic volumes in each speed bin for each reporting interval should be entered as zero-filled or blank-filled right justified integers in the appropriate columns.

14. Bin 1 Count (Columns 31-35) – *Critical*

Bin 1 includes the number of vehicles in the slowest speed range being submitted. Right justify the integer volume number in the data entry field. The default condition for this speed bin is "all vehicles traveling equal to or slower than 20 mph." If a different definition is used Field 11 (Column 23) should be used to define this speed bin. If there are no vehicles observed in this speed range during the time period being reported, enter "0", not " " (blank), to indicate that there are no vehicles in this speed range, and enter "0" similarly for each speed bin below.

15. Bin 2 Count (Columns 36-40) – *Critical*

Bin 2 includes the number of vehicles in the second slowest speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

16. Bin 3 Count (Columns 41-45) – *Critical*

Bin 3 includes the number of vehicles in the third speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

17. Bin 4 Count (Columns 46-50) – *Critical*

Bin 4 includes the number of vehicles in the fourth speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

18. Bin 5 Count (Columns 51-55) – *Critical*

Bin 5 includes the number of vehicles in the fifth speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

19. Bin 6 Count (Columns 56-60) – *Critical*

Bin 6 includes the number of vehicles in the sixth speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

20. Bin 7 Count (Columns 61-65) – *Critical*

Bin 7 includes the number of vehicles in the seventh speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

21. Bin 8 Count (Columns 66-70) – *Critical*

Bin 8 includes the number of vehicles in the eighth speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

22. Bin 9 Count (Columns 71-75) – *Critical*

Bin 9 includes the number of vehicles in the ninth speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

23. Bin 10 Count (Columns 76-80) – *Critical*

Bin 10 includes the number of vehicles in the tenth speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

24. Bin 11 Count (Columns 81-85) – *Critical*

Bin 11 includes the number of vehicles in the eleventh speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

25. Bin 12 Count (Columns 86-90) – *Critical*

Bin 12 includes the number of vehicles in the 12th speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

26. Bin 13 Count (Columns 91-95) – *Critical*

Bin 13 includes the number of vehicles in the 13th speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

27. Bin 14 Count (Columns 96-100) – *Critical*

Bin 14 includes the number of vehicles in the fourteenth speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

28. Bin 15 Count (Columns 101-105) – *Critical*

Bin 15 includes the number of vehicles in the fifteenth speed range being submitted. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

29. Bin 16 Count (Columns 106-110) – *Critical/Optional*

Bin 16 includes the number of vehicles in the sixteenth speed range being submitted. It is used only when a State submits data in additional speed bins beyond the 15 required by FHWA. If this bin is used, Field #12 (Columns 24-25) should contain a value equal to or greater than 16. Right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0".

30. Bin 17 Count (Columns 111-115) – *Critical/Optional*

Bin 17 includes the number of vehicles in the seventeenth speed range being submitted. It is used only when a State submits data in additional speed bins beyond the 15 required by FHWA. If this bin is used, Field #12 (Columns 24-25) should contain a value equal to or greater than 17. When reporting data in this speed bin right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

31. Bin 18 Count (Columns 116-120) – *Critical/Optional*

Bin 18 includes the number of vehicles in the eighteenth speed range being submitted. It is used only when a State submits data in additional speed bins beyond the 15 required by FHWA. If this bin is used, Field #12 (Columns 24-25) should contain a value equal to or greater than 18. When reporting data in this speed bin right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

32. Bin 19 Count (Columns 121-125) – *Critical/Optional*

    Bin 19 includes the number of vehicles in the nineteenth speed range being submitted. It is used only when a State submits data in additional speed bins beyond the 15 required by FHWA. If this bin is used, Field #12 (Columns 24-25) should contain a value equal to or greater than 19. When reporting data in this speed bin right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

33. Bin 20 Count (Columns 126-130) – *Critical/Optional*

    Bin 20 includes the number of vehicles in the twentieth speed range being submitted. It is used only when a State submits data in additional speed bins beyond the 15 required by FHWA. If this bin is used, Field #12 (Columns 24-25) should contain a value equal to or greater than 20. When reporting data in this speed bin right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

34. Bin 21 Count (Columns 131-135) – *Critical/Optional*

    Bin 21 includes the number of vehicles in the twenty-first speed range being submitted. It is used only when a State submits data in additional speed bins beyond the 15 required by FHWA. If this bin is used, Field #12 (Columns 24-25) should contain a value equal to or greater than 21. When reporting data in this speed bin right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

35. Bin 22 Count (Columns 136-140) – *Critical/Optional*

    Bin 22 includes the number of vehicles in the twenty-second speed range being submitted. It is used only when a State submits data in additional speed bins beyond the 15 required by FHWA. If this bin is used, Field #12 (Columns 24-25) should contain a value equal to or greater than 22. When reporting data in this speed bin right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

36. Bin 23 Count (Columns 141-145) – *Critical/Optional*

    Bin 23 includes the number of vehicles in the twenty-third speed range being submitted. It is used only when a State submits data in additional speed bins beyond the 15 required by FHWA. If this bin is used, Field #12 (Columns 24-25) should contain a value equal to or greater than 23. When reporting data in this speed bin right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

37. Bin 24 Count (Columns 146-150) – *Critical/Optional*

    Bin 24 includes the number of vehicles in the twenty-fourth speed range being submitted. It is used only when a State submits data in additional speed bins beyond the 15 required by FHWA. If this bin is used, Field #12 (Columns 24-25) should contain a value equal to or greater than 24. When reporting data in this speed bin right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

38. Bin 25 Count (Columns 151-155) – *Critical/Optional*

Bin 25 includes the number of vehicles in the twenty-fifth speed range being submitted. It is used only when a State submits data in additional speed bins beyond the 15 required by FHWA. If this bin is used, Field #12 (Columns 24-25) should contain a value equal to or greater than 25. When reporting data in this speed bin right justify the integer volume number in the data entry field. If there are no vehicles observed in this speed range during the time period being reported, enter "0."

TABLE 7-14   3 SPEED BIN TABLE EXAMPLES

SPEED SITE (15 BIN, 2 LANES WITH LANES OR DIRECTIONS NOT COMBINED AT 5 MINUTE INTERVAL FOR 1 HOUR) SPEED FILE

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18-19	20-21	22	23	24-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65
Content Example:	T	17	018114	1	1	2012	06	20	00	A	Blank	15	00375	00000	00000	00000	00000	00000	00000	00007
Content Example:	T	17	018114	1	1	2012	06	20	00	B	Blank	15	00305	00000	00000	00000	00000	00000	00004	00005
	T	17	018114	1	1	2012	06	20	00	C	Blank	15	00266	00000	00000	00000	00000	00000	00000	00003
	T	17	018114	1	1	2012	06	20	00	D	Blank	15	00268	00000	00000	00000	00000	00000	00000	00002
	T	17	018114	1	1	2012	06	20	00	E	Blank	15	00248	00000	00000	00000	00000	00000	00001	00001
	T	17	018114	1	1	2012	06	20	00	F	Blank	15	00231	00000	00000	00000	00000	00000	00000	00002
	T	17	018114	1	1	2012	06	20	00	G	Blank	15	00197	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	1	1	2012	06	20	00	H	Blank	15	00183	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	1	1	2012	06	20	00	I	Blank	15	00173	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	1	1	2012	06	20	00	J	Blank	15	00159	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	1	1	2012	06	20	00	K	Blank	15	00154	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	1	1	2012	06	20	00	L	Blank	15	00145	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	5	1	2012	06	20	00	A	Blank	15	00427	00000	00000	00000	00000	00000	00000	00008
	T	17	018114	5	1	2012	06	20	00	B	Blank	15	00307	00000	00000	00000	00000	00000	00000	00006
	T	17	018114	5	1	2012	06	20	00	C	Blank	15	00268	00000	00000	00000	00000	00000	00000	00002
	T	17	018114	5	1	2012	06	20	00	D	Blank	15	00294	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	5	1	2012	06	20	00	E	Blank	15	00277	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	5	1	2012	06	20	00	F	Blank	15	00288	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	5	1	2012	06	20	00	G	Blank	15	00272	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	5	1	2012	06	20	00	H	Blank	15	00242	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	5	1	2012	06	20	00	I	Blank	15	00212	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	5	1	2012	06	20	00	J	Blank	15	00198	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	5	1	2012	06	20	00	K	Blank	15	00185	00000	00000	00000	00000	00000	00000	00000
	T	17	018114	5	1	2012	06	20	00	L	Blank	15	00155	00000	00000	00000	00000	00000	00000	00000

Column Number:	66–70	71–75	76–80	81–85	86–90	91–95	96–100	101–105	106–110	111–115	116–120	121–125	126–130	131–135	136–140
Content Example:	00012	00048	00165	00086	00031	00021	00005	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content Example:	00008	00025	00143	00079	00025	00013	00003	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00003	00032	00131	00058	00026	00011	00001	00001	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00004	00037	00128	00043	00039	00012	00003	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00003	00039	00119	00039	00028	00015	00004	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00002	00025	00108	00042	00032	00015	00005	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00001	00018	00099	00035	00028	00011	00005	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00000	00013	00098	00032	00027	00009	00004	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00000	00008	00095	00031	00028	00008	00003	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00000	00007	00092	00028	00025	00005	00002	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00000	00011	00088	00025	00026	00003	00001	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00000	00012	00084	00021	00024	00004	00000	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00013	00049	00015	60008	70003	20002	20000	60000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00009	00026	00014	10008	20002	70001	10000	50000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00003	00031	00012	80006	10002	50001	30000	40001	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00001	00035	00013	40006	50003	60001	50000	70001	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00007	00031	00012	10005	80003	10002	10000	80000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00002	00026	00011	50005	50003	20002	20000	70001	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00004	00027	00012	20005	60003	50002	30000	50000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00003	00021	00011	40004	90003	30001	80000	40000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00000	00015	00010	40004	80002	40001	90000	20000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00000	00012	00009	80004	70002	50001	30000	30000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00000	00008	00008	70005	10002	40001	20000	30000	Blank	Blank	Blank	Blank	Blank	Blank	Blank
	00000	00005	00007	60004	40002	10000	90000	00000	Blank	Blank	Blank	Blank	Blank	Blank	Blank

continued

Column Number:	141–145	146–150	151–155
Content Example:	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank
	Blank	Blank	Blank

SPEED SITE (21 BIN, 4 LANES WITH LANES OR DIRECTIONS NOT COMBINED AT 60 MINUTE INTERVAL FOR 1 HOUR, TOTAL VOLUME NOT RECORDED) SPEED FILE

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18-19	20-21	22	23	24-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65
Content Example:	T	17	018114	1	1	2012	06	20	00	Blank	1	21	Blank	00000	00000	00000	00000	00000	00000	00000
Content Example:	T	17	018114	1	2	2012	06	20	00	Blank	1	21	Blank	00000	00000	00000	00000	00000	00000	00000
Content Example:	T	17	018114	5	2	2012	06	20	00	Blank	1	21	Blank	00000	00000	00000	00000	00000	00000	00000
Content Example:	T	17	018114	5	1	2012	06	20	00	Blank	1	21	Blank	00000	00000	00000	00000	00000	00000	00000

continued

Column Number:	66-70	71-75	76-80	81-85	86-90	91-95	96-100	101-105	106-110	111-115	116-120	121-125	126-130	131-135	136-140
Content Example:	00000	00005	00034	00054	00021	00015	00002	00001	00000	00000	00000	00000	00000	00000	Blank
Content Example:	00000	00007	00030	00046	00024	00013	00003	00002	00000	00000	00000	00000	00000	00000	Blank
Content Example:	00000	00010	00028	00056	00031	00021	00005	00004	00003	00000	00000	00000	00000	00000	Blank
Content Example:	00000	00008	00026	00036	00029	00018	00003	00003	00002	00001	00000	00000	00000	00000	Blank

continued

Column Number:	141-145	146-150	151-155
Content Example:	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank

SPEED SITE (25 BIN, 2 LANES WITH LANES OR DIRECTIONS NOT COMBINED AT 60 MINUTE INTERVAL FOR 1 HOUR) SPEED FILE

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18-19	20-21	22	23	24-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65
Content Example:	T	17	018114	3	1	2012	06	20	00	Blank	2	25	000683	00000	00000	00000	00000	00000	00000	00000
Content Example:	T	17	018114	7	1	2012	06	20	00	Blank	2	25	000681	00000	00000	00000	00000	00000	00000	00000

continued

Column Number:	66-70	71-75	76-80	81-85	86-90	91-95	96-100	101-105	106-110	111-115	116-120	121-125	126-130	131-135	136-140
Content Example:	00000	00000	00005	00014	00026	00056	00086	00109	00121	00095	00082	00042	00021	00015	00011
Content Example:	00000	00000	00004	00012	00028	00064	00085	00098	00127	00094	00081	00041	00018	00013	00013

continued

Column Number:	141-145	146-150	151-155
Content Example:	00000	00000	00000
Content Example:	00003	00000	00000

7.5 VEHICLE CLASSIFICATION DATA FORMAT

The Vehicle Classification file is a variable length record. It contains one record for each time period (e.g. by 5 min., 15 min., hour of the day) which data is being submitted. That record includes the traffic volume by vehicle class data for that hour. The length of the record (number of columns in each record) is determined by the value in Field 15 (columns 25-26) of the Station Description Record. This means that if two different kinds of data collection equipment are used at a site and those different pieces of equipment collect classification data in different formats (e.g., one uses length classes and the other uses the 13-FHWA categories), then an updated State Description Record should be submitted prior to submitting data using the second classification system or the records being submitted will not be read correctly. All lanes in one direction should have the same data being collected. FHWA uses the latest version of the State Description Record that is submitted. If this record type already exists in TMAS, and no change in the equipment functionality (e.g., the type of vehicle class data being collected) has occurred since that earlier record was submitted, it is not necessary to submit an additional Station Description Record for the data to be processed in TMAS.

An example file naming convention for the Vehicle Classification record is:

ssabcxyzmmyyyy.CLA

A single file can contain data from multiple stations and/or locations.

Table 7-15 summarizes the Vehicle Classification record format.

TABLE 7-15   VEHICLE CLASSIFICATION RECORD

Field	Columns	Width	Description	Type
1	1	1	Record Type	C
2	2-3	2	FIPS State Code	C
3	4-9	6	Station ID	C
4	10	1	Direction of Travel Code	C
5	11	1	Lane of Travel	C
6	12-15	4	Year of Data	C
7	16-17	2	Month of Data	C
8	18-19	2	Day of Data	C
9	20-21	2	Hour of Data	C
10	22	1	Classification Data Time Interval	O
11	23-27	5	Total Interval Volume	C
12	28	1	Restrictions	C
13	29-33	5	Class 1 Count	C
14	34-38	5	Class 2 Count	C
15	39-43	5	Class 3 Count	C/O
16	44-48	5	Class 4 Count	C/O
17	49-53	5	Class 5 Count	C/O
18	54-58	5	Class 6 Count	C/O
19	59-63	5	Class 7 Count	C/O

Field	Columns	Width	Description	Type
20	64-68	5	Class 8 Count	C/O
21	69-73	5	Class 9 Count	C/O
22	74-78	5	Class 10 Count	C/O
23	79-83	5	Class 11 Count	C/O
24	84-88	5	Class 12 Count	C/O
25	89-93	5	Class 13 Count	C/O

Note: *C=Critical, C/O=Critical/Optional, O=Optional*

Fields designated as Critical *are required for entry into the TMAS software used for submitting data to FHWA.*

Fields designated as Optional *are not required for this record format, code according to the instructions for each Optional field.*

The fields for the Vehicle Classification record are:

1. Record Type (Column 1) – *Critical*

   C = Vehicle classification record (Code the letter "C" in the first column)

2. FIPS State Code (Columns 2-3) – *Critical*

   See section 7.2, Field #2.

3. Station Identification (Columns 4-9) – *Critical*

   See section 7.2, Field #3.

   This field should be right-justified with unused columns zero-filled.

4. Direction of Travel Code (Column 10) – *Critical*

   See section 7.2, Field #4.

5. Lane of Travel (Column 11) – *Critical*

   See section 7.2, Field #5.

   Note: The Station ID, Direction of Travel, and Lane of Travel make up the Station Code. *There should be one Station Description record per Station Code.*

6. Year of Data (Columns 12-15) – *Critical*

   See section 7.2, Field #6.

7. Month of Data (Columns 16-17) – *Critical*

   See section 7.3, Field #8.

8. Day of Data (Columns 18-19) – *Critical*

   See section 7.3, Field #9.

9. Hour of Data (Columns 20-21) – *Critical*

   Code the beginning of the hour in which the count was taken:

   00 = after 00:00 to 01:00

   01 = after 01:00 to 02:00

   …

   …

…

    22 = after 22:00 to 23:00

    23 = after 23:00 to 24:00

10. Classification Data Time Interval – (Column 22) – *Optional*

A 60 minute time interval is assumed if this column is left blank. This field can be used to designate either 5 minute or 15 minute binned classification data.

For 15 minute binned intervals of classification data use the following:

    Code 1 for the interval 0.0 – 14.999

    Code 2 for the interval 15.0 – 29.999

    Code 3 for the interval 30.0 – 44.999

    Code 4 for the interval 45.0 – 59.999

For 5 minute binned intervals of classification data use the following:

    Code A for the interval 0.0 – 4.999

    Code B for the interval 5.0 – 9.999

    Code C for the interval 10.0 – 14.999

    Code D for the interval 15.0 – 19.999

    Code E for the interval 20.0 – 24.999

    Code F for the interval 25.0 – 29.999

    Code G for the interval 30.0 – 34.999

    Code H for the interval 35.0 – 39.999

    Code I for the interval 40.0 – 44.999

    Code J for the interval 45.0 – 49.999

    Code K for the interval 50.0 – 54.999

    Code L for the interval 55.0 – 59.999

11. Total Interval Volume (Columns 23-27) – *Critical*

This numeric field is the total traffic volume for the hour. The total volume is needed because the data collection process might not be able to classify some vehicles, in which case the sum of the vehicle class counts will not equal the total hourly volume.

Fields 12 to 24:

The following class count fields are numeric fields with the traffic volume by vehicle class for each hour of data. Field #15 in the Station Description Record, "Vehicle Classification Groupings," determines the number of classes expected from this station. This value also determines how many columns are expected in the remainder of each record submitted in a given file. Truncate the vehicle classification record after the last classification field has been used. (That is, if only five vehicle classes are being reported, the record should only be 52 columns wide.)

The default classification system is the FHWA 13 class system (see Appendix C). Where a classification (grouping) system other than FHWA's 13-category system is used, the total number of columns for which data is entered will change from that described below. When no vehicles of a class being monitored are counted during a given hour, zero fill and right-justify the data in the columns associated with that class of vehicles.

Before submittal to FHWA, these counts should be checked for reasonableness and quality controlled. When 13 vehicle types are reported, the Vehicle Classification record would not be larger than 92 columns, with Classes 1-13 (fields 12-24) all considered to be *Critical*. A relationship exists between Table 7-6 and the Vehicle Classes used. These need to be synchronized for proper processing in the TMAS software. TMAS allows users to set a limit for each class count as part of its automated quality assurance checks.

12. Restrictions (Column 28) – *Critical*

    0 = no restrictions

    1 = construction or other activity affected traffic flow, traffic pattern not impacted

    2 = traffic counting device problem (e.g., malfunction or overflow)

    3 = weather affected traffic flow, traffic pattern not impacted

    4 = construction or other activity affected traffic flow, traffic pattern impacted

    5 = weather affected traffic flow, traffic pattern impacted

13. Class 1 Count (Columns 29-33) – *Critical*

    Class 1 is for Motorcycles when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the first class of vehicles being reported.

14. Class 2 Count (Columns 34-38) – *Critical*

    Class 2 is for Passenger Cars when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the second class of vehicles being reported.

15. Class 3 Count (Columns 39-43) – *Critical/Optional*

    Class 3 is for Light Duty (2-axle, four-tire) Pick-up Trucks when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the third class of vehicles being reported.

16. Class 4 Count (Columns 44-48) – *Critical/Optional*

    Class 4 is for Buses when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the fourth class of vehicles being reported.

17. Class 5 Count (Columns 49-53) – *Critical/Optional*

    Class 5 is for Two-Axle, Six-Tire, Single-Unit Trucks when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the fifth class of vehicles being reported.

18. Class 6 Count (Columns 54-58) – *Critical/Optional*

    Class 6 is for Three-Axle, Single-Unit Trucks when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the sixth class of vehicles being reported.

19. Class 7 Count (Columns 59-63) – *Critical/Optional*

    Class 7 is for Four-or-More Axle, Single-Unit Trucks when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the seventh class of vehicles being reported.

20. Class 8 Count (Columns 64-68) – *Critical/Optional*

    Class 8 is for Four-or-Less Axle, Single-Trailer Trucks when using the 13 FHWA classification

groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the eighth class of vehicles being reported.

21. Class 9 Count (Columns 69-73) – *Critical/Optional*

Class 9 is for Five-Axle, Single-Trailer Trucks when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the ninth class of vehicles being reported.

22. Class 10 Count (Columns 74-78) – *Critical/Optional*

Class 10 is for Six-or-More Axle, Single-Trailer Trucks when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the tenth class of vehicles being reported.

23. Class 11 Count (Columns 79-83) – *Critical/Optional*

Class 11 is for Five-or-Less Axle, Multi-Trailer Trucks when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the eleventh class of vehicles being reported.

24. Class 12 Count (Columns 84-88) – *Critical/Optional*

Class 12 is for Six-Axle, Multi-Trailer Trucks when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the 12th class of vehicles being reported.

25. Class 13 Count (Columns 89-93) – *Critical/Optional*

Class 13 is for Seven-or-More Axle, Multi-Trailer Trucks when using the 13 FHWA classification groups. If the FHWA 13-category system is not being used, this field will contain the traffic volume for the 13th class of vehicles being reported.

The vehicle classification record should be ended here if 13 classes are being reported. If volumes for additional classes of vehicles are being reported, add five additional columns for each additional vehicle class being reported. (These additional vehicle classes can include the vehicle categories of "Unclassified", "Unclassifiable" vehicles that are reported by some types of equipment, or some state specific type of vehicle.)

TABLE 7-16 **VEHICLE CLASSIFICATION RECORD EXAMPLE**

LENGTH CLASSIFICATION (3 LENGTH CLASS BINS, 4 LANES WITH LANES AND DIRECTIONS NOT COMBINED AT 60 MINUTE INTERVAL FOR 2 HOURS) SITE CLASSIFICATION FILE

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18-19	20-21	22	23-27	28	29-33	34-38	39-43	44-48	49-53	54-58	59-63
Content Example:	C	17	01811B	1	1	2012	04	25	00	Blank	00099	0	00051	00048	00010	Blank	Blank	Blank	Blank
	C	17	01811B	1	2	2012	04	25	00	Blank	00020	0	00005	00014	00001	Blank	Blank	Blank	Blank
	C	17	01811B	5	2	2012	04	25	00	Blank	00011	0	00002	00008	00001	Blank	Blank	Blank	Blank
	C	17	01811B	5	1	2012	04	25	00	Blank	00066	0	00023	00037	00006	Blank	Blank	Blank	Blank
	C	17	01811B	1	1	2012	04	25	01	Blank	00072	0	00042	00021	00009	Blank	Blank	Blank	Blank
	C	17	01811B	1	2	2012	04	25	01	Blank	00017	0	00005	00011	00001	Blank	Blank	Blank	Blank
	C	17	01811B	5	2	2012	04	25	01	Blank	00011	0	00002	00007	00002	Blank	Blank	Blank	Blank
	C	17	01811B	5	1	2012	04	25	01	Blank	00057	0	00021	00029	00007	Blank	Blank	Blank	Blank

continued

Column Number:	64-68	69-73	74-78	79-83	84-88	89-93
Content Example:	Blank	Blank	Blank	Blank	Blank	Blank
	Blank	Blank	Blank	Blank	Blank	Blank
	Blank	Blank	Blank	Blank	Blank	Blank
	Blank	Blank	Blank	Blank	Blank	Blank
	Blank	Blank	Blank	Blank	Blank	Blank
	Blank	Blank	Blank	Blank	Blank	Blank
	Blank	Blank	Blank	Blank	Blank	Blank
	Blank	Blank	Blank	Blank	Blank	Blank

AXLE CLASSIFICATION (13 AXLE CLASS BINS, 2 LANES WITH LANES OR DIRECTIONS NOT COMBINED AT 15 MINUTE INTERVAL FOR 1 HOUR) SITE CLASSIFICATION FILE

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18-19	20-21	22	23-27	28	29-33	34-38	39-43	44-48	49-53	54-58	59-63
Content Example:	C	17	018140	3	1	2012	12	01	00	1	00054	0	00000	00037	00006	00000	00001	00000	00000
	C	17	018140	7	1	2012	12	01	00	1	00055	0	00001	00038	00009	00000	00000	00000	00000
	C	17	018140	3	1	2012	12	01	00	2	00051	0	00000	00039	00008	00000	00001	00001	00000
	C	17	018140	7	1	2012	12	01	00	2	00058	0	00000	00037	00010	00000	00000	00000	00000
	C	17	018140	3	1	2012	12	01	00	3	00060	0	00001	00037	00006	00000	00000	00001	00000
	C	17	018140	7	1	2012	12	01	00	3	00067	0	00000	00036	00005	00000	00001	00000	00000
	C	17	018140	3	1	2012	12	01	00	4	00064	0	00001	00034	00009	00001	00001	00000	00000
	C	17	018140	7	1	2012	12	01	00	4	00063	0	00000	00038	00008	00000	00000	00000	00000

continued

Column Number:	64-68	69-73	74-78	79-83	84-88	89-93
Content Example:	00002	00007	00000	00000	00000	00001
	00003	00005	00000	00000	00000	00000
	00001	00008	00000	00000	00000	00001
	00002	00009	00000	00000	00000	00000
	00004	00012	00001	00000	00000	00000
	00000	00015	00002	00000	00000	00000
	00002	00016	00000	00001	00000	00000
	00003	00013	00000	00000	00000	00001

7.6 WEIGHT DATA FORMAT

The Weight Data Format is the mechanism currently used to submit weight data to FHWA. FHWA prefers that States submit weight data using the Per Vehicle Formats (PVF) described in Section 7.7. In particular, weight data should be submitted using the "W" or "Z" variants of the PVF record format (Sections 7.7.4 and 7.7.5, respectively).

If States still wish to use the current Weight Data Format, a description of that file format is as follows. Each file submitted in this format contains one record for each vehicle. Each record describes that vehicle's axle weights and axle spacings.

As a reminder, all weight data is to use English units.

An example of the file naming convention for the Weight Data record is:

ssabcxyzmmyyyy.WGT

Table 7-17 summarizes the Weight record format.

TABLE 7-17   WEIGHT RECORD

Field	Columns	Width	Description	Type
1	1	1	Record Type	C
2	2-3	2	FIPS State Code	C
3	4-9	6	Station ID	C
4	10	1	Direction of Travel Code	C
5	11	1	Lane of Travel	C
6	12-15	4	Year of Data	C
7	16-17	2	Month of Data	C
8	18-19	2	Day of Data	C
9	20-21	2	Hour of Data	C
10	22-23	2	Vehicle Class	C
11	24-26	3	Open	O
12	27-32	6	Total Weight of Vehicle	C
13	33-34	2	Number of Axles	C
14	35-39	5	Axle Weight 1	C
15	40-43	4	Axles 1-2 Spacing	C
16	44-48	5	Axle Weight 2	C
17	49-52	4	Axles 2-3 Spacing	C/O
18	53-57	5	Axle Weight 3	C/O
19	58-61	4	Axles 3-4 Spacing	C/O

Field	Columns	Width	Description	Type
20	62-66	5	Axle Weight 4	C/O
21	67-70	4	Axles 4-5 Spacing	C/O
22	71-75	5	Axle Weight 5	C/O
23	76-79	4	Axles 5-6 Spacing	C/O
24	80-84	5	Axle Weight 6	C/O
25	85-88	4	Axles 6-7 Spacing	C/O
26	89-93	5	Axle Weight 7	C/O
27	94-97	4	Axles 7-8 Spacing	C/O
28	98-102	5	Axle Weight 8	C/O
29	103-106	4	Axles 8-9 Spacing	C/O
30	107-111	5	Axle Weight 9	C/O
31	112-115	4	Axles 9-10 Spacing	C/O
32	116-120	5	Axle Weight 10	C/O
33	121-124	4	Axles 10-11 Spacing	C/O
34	125-129	5	Axle Weight 11	C/O
35	130-133	4	Axles 11-12 Spacing	C/O
36	134-138	5	Axle Weight 12	C/O
37	139-142	4	Axles 12-13 Spacing	C/O
38	143-147	5	Axle Weight 13	C/O

Note 1:   C=Critical, C/O=Critical/Optional, O=Optional

Fields designated as Critical *are required for entry into the TMAS software.*

Fields designated as Optional *are not required for this record format. Code these fields according the instructions for each optional field.*

Fields designated as C/O could be either critical or optional based on other field values in the weight record.

Note 2:   The number of axles determines the number of axle weight and spacing fields.

Note 3:   For those vehicles with fourteen or more axles, add the appropriate number of additional fields.

Note 4:   Additional axle spacing and axle weight fields may be added in the same manner if needed up to a maximum of 25 axles per record.

The fields for the weight record are:

1. Record Type (Column 1) – *Critical*

    W = Truck weight record (Code the letter "W" in the first column.)

2. FIPS State Code (Columns 2-3) – *Critical*

    See section 7.2, Field #2.

3. Station Identification (Columns 4-9) – *Critical*

   See section 7.2, Field #3.

This field should be right-justified with unused columns zero-filled.

4. Direction of Travel Code (Column 10) – *Critical*

   See section 7.2, Field #4.

5. Lane of Travel (Column 11) – *Critical*

   See section 7.2, Field #5.

Note: The Station ID, Direction of Travel, and Lane of Travel make up the Station Code. *There should be one Station Description record per Station Code.*

6. Year of Data (Columns 12-15) – *Critical*

   See section 7.2, Field #6.

7. Month of Data (Columns 16-17) – *Critical*

   See section 7.3, Field #8.

8. Day of Data (Columns 18-19) – *Critical*

   See section 7.3, Field #9.

9. Hour of Data (Columns 20-21) – *Critical*

   Code the beginning of the hour in which the count was taken:

   00 = after 0:00 to 01:00

   01 = after 01:00 to 02:00

   …

   …

   …

   22 = after 22:00 to 23:00

   23 = after 23:00 to 24:00

10. Vehicle Class (Columns 22-23) – *Critical*

    Enter the class of the vehicle from FHWA Vehicle Classes 1 to 13. (Note: vehicles from classes 1 - 3 are ordinarily omitted from weight data submittals.)

    A dummy vehicle class of 'm' indicates that weight data for this hour are missing. A dummy vehicle class of 'd' indicates that weight data for this hour are not missing, and thus if there are no weight records for the hour, then there were no trucks during that hour. Without these indications, no weight records for an hour might be interpreted to mean that the WIM system was not working.

11. Open (Columns 24-26) – *Optional*

    This field is for special studies or State use such as for vehicle speed (miles per hour) or pavement temperature (degrees Fahrenheit).

12. Total Weight of Vehicle (Columns 27-32) - *Critical*

    Enter the gross vehicle weight to the nearest pound. For example, 110,200 lbs. would be reported in the field as 110200. There are no decimals or commas used in the field. This should equal the sum of all the axle weights except for rounding.

13. Number of Axles (Columns 33-34) – *Critical*

Enter the total number of axles in use by the vehicle (including any trailers).

The number of axles determines how many axle weight and spacing fields will be expected on each record. As a reminder, the axle weight and spacing fields should be reported in English units. The rest of the record alternates between axle weights and axle spacings, starting from the front of the vehicle. Axle weights are to the nearest pound. Axle spacings are to the nearest tenth of a foot. All values should be right-justified with leading blanks as needed.

Quality control (QC) checks should be performed on the axle weights and spacings.

14. Axle Weight 1 (Columns 35-39) - *Critical*

15. Axles 1-2 Spacing (Columns 40-43) - *Critical*

16. Axle Weight 2 (Columns 44-48) - *Critical*

17. Axles 2-3 Spacing (Columns 49-52) – *Critical/Optional*

18. Axle Weight 3 (Columns 53-57) – *Critical/Optional*

19. Axles 3-4 Spacing (Columns 58-61) - *Critical/Optional*

20. Axle Weight 4 (Columns 62-66) - *Critical/Optional*

21. Axles 4-5 Spacing (Columns 67-70) - *Critical/Optional*

22. Axle Weight 5 (Columns 71-75) - *Critical/Optional*

23. Axles 5-6 Spacing (Columns 76-79) - *Critical/Optional*

24. Axle Weight 6 (Columns 80-84) - *Critical/Optional*

25. Axles 6-7 Spacing (Columns 85-88) - *Critical/Optional*

26. Axle Weight 7 (Columns 89-93) - *Critical/Optional*

27. Axles 7-8 Spacing (Columns 94-97) - *Critical/Optional*

28. Axle Weight 8 (Columns 98-102) - *Critical/Optional*

29. Axles 8-9 Spacing (Columns 103-106) - *Critical/Optional*

30. Axle Weight 9 (Columns 107-111) - *Critical/Optional*

31. Axles 9-10 Spacing (Columns 112-115) - *Critical/Optional*

32. Axle Weight 10 (Columns 116-120) - *Critical/Optional*

33. Axles 10-11 Spacing (Columns 121-124) - Critical/Optional

34. Axle Weight 11 (Columns 125-129) - *Critical/Optional*

35. Axles 11-12 Spacing (Columns 130-133) - *Critical/Optional*

36. Axle Weight 12 (Columns 134-138) - *Critical/Optional*

37. Axles 12-13 Spacing (Columns 139-142) - *Critical/Optional*

38. Axle Weight 13 (Columns 143-147) - *Critical/Optional*

TABLE 7-18   WEIGHT RECORD EXAMPLE

WEIGHT SITE WEIGHT FILE

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18-19	20-21	22-23	24-26	27-32	33-34	35-39	40-43	44-48	49-52	53-57	58-61
Content Example:	W	17	018115	3	1	2012	11	07	16	09	Blank	057886	05	11210	0151	12300	0045	13730	0214
Content Example:	W	17	018115	3	1	2012	11	07	16	04	Blank	018351	02	08522	0252	09829	Blank	Blank	Blank
Content Example:	W	17	018115	3	1	2012	11	07	16	06	Blank	047289	03	09818	0131	91025	0046	18346	Blank

continued

Column Number:	62-66	67-70	71-75	76-79	**80-84**	**85-88**	**89-93**	**94-97**	**98-102**	**103-106**	**107-111**	**112-115**	**116-120**	**121-124**	**125-129**
Content Example:	09815	0048	10831	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank

continued

Column Number:	**130-133**	**134-138**	**139-142**	**143-147**
Content Example:	Blank	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank	Blank

In the Weight Record examples listed above, the Vehicle Class field (columns 22-23) indicates either class 09 (semi-trailer), class 04 (bus), or class 06 (dump-truck; 3-axle single unit) as illustrated below.

09 – semi-truck

04-bus

06-dump-truck

Class 9	
5-Axle tractor semitrailer	
Class 4	
Buses	
Class 6	
Three axle, single unit	

7.7   DETAILED PER VEHICLE DATA FORMAT (PVF)

As an *optional* way to submit traffic monitoring data to FHWA, State highway agencies may submit volume, speed, vehicle classification, and vehicle weight data as individual vehicle records rather than using the more traditional formats described earlier in this chapter. The FHWA's Travel Monitoring Analysis System (TMAS) will be configured to accept individual vehicle records in the formats described below.

Individual vehicle records require more disk space than aggregated records, but they also allow much more detailed analysis of traffic patterns. States are encouraged to submit data in these formats whenever possible. While these types of records are not necessary for all data collection efforts, having a sample of such records available for use permits the investigation of a number of key traffic flow and vehicle characteristics (e.g., vehicle gap analysis, speed by class, and changes in axle spacing

distributions) that are not possible when only aggregate traffic records are stored.

The submission of one PVF data file (1 record) will:

- Meet all of the FHWA reporting needs for the traffic monitoring system (TMS);
- Allow for more detailed quality control (QC) checks to be performed; and
- Provide better quality data for use in national statistics.

The following table provides a quick reference for the units of measurement to be reported for weight, length, speed, and temperature.

TABLE 7-19   UNITS OF MEASUREMENT

Measure	Unit	Resolution Reported
Weight	Pounds	Pound
Vehicle Length	Feet	Tenths of feet
Speed	Mph	Tenths of mph
Temperature	Degrees fahrenheit	Degrees
Time	Seconds	Hundredth of second
Inter-Axle Spacing	Feet	Tenths of feet

Individual vehicle records can be collected by a variety of different traffic monitoring devices and technologies. However, the type of data collected for each passing vehicle differs when these alternative technologies are used. Consequently, FHWA has developed five different variations of the Per Vehicle Format. Each of these variations corresponds to a specific type of data collection device. All of the formats use a fixed column record structure, and the first 28 columns of data are the same for all five record formats. The 28th column contains a variable that describes the type of data contained in that record. After the first 28 columns, the remainder of each vehicle record differs based on the type and amount of data collected by that device for that vehicle.

The five different versions of the Per Vehicle Format are as follows:

1. Traffic volume only format;
2. Speed, length classification data formats;
3. Axle classification data format (i.e., axle spacing and classification data);
4. Weight data format for reporting axle weights; and
5. Vehicle classification and weight data format for reporting weight by wheel (path) load.

Each of these record formats is described in detail below. In all cases, each format uses one record for each vehicle observation. All units are given in English units (pounds for weight, feet for distance, miles per hour for speed, and degrees Fahrenheit for temperature). All unused entries are to be blank filled.

The first 28 columns contain the same information for all individual vehicle records. These 28 columns are all that is used by the Traffic Volume Only Format.

An example of the file naming convention for the Per Vehicle Format record is:

ssabcxyzmmyyyy.PVF

7.7.1 TRAFFIC VOLUME ONLY FORMAT ("V" VARIANT)

The following definitions describe the data to be included in the first 28 columns of all per vehicle records submitted to FHWA, regardless of which one of the five record types is being submitted.

TABLE 7-20   INDIVIDUAL VEHICLE RECORD COLLECTED BY VOLUME DEVICE (V VARIANT)

Field	Columns	Width	Description	Type
1	1	1	Record Type	C
2	2-3	2	FIPS State Code	C
3	4-9	6	Station ID	C
4	10	1	Direction of Travel Code	C
5	11	1	Lane of Travel	C
6	12-15	4	Year of Data	C
7	16-17	2	Month of Data	C
8	18-19	2	Day of Data	C
9	20-27	8	Time of Data	C
10	28	1	V	C
11	29-32	4	Vehicle Signature/Other Use	O

Note: C=Critical, C/O=Critical/Optional, O=Optional

Fields designated as Critical are required to upload data through the TMAS system.

Fields designated as Optional are not required for this record format. Code these fields according to the instructions for each optional field.

Fields designated as Critical/Optional are based on other fields provided in the station record.

1. Record Type (Column 1) – *Critical*

   I = Individual Vehicle Record

2. FIPS State Code (Columns 2-3) – *Critical*

   See section 7.2, Field #2.

3. Station Identification (Columns 4-9) – *Critical*

   See section 7.2, Field #3.

   This field should be right-justified with unused columns zero-filled.

4. Direction of Travel Code (Column 10) – *Critical*

   See section 7.2, Field #4.

5. Lane of Travel (Column 11) – *Critical*

   See section 7.2, Field #5.

Note: The Station ID, Direction of Travel, and Lane of Travel make up the Station Code. *There should be one Station Description record per Station Code.*

6. Year of Data (Columns 12-15) – *Critical*

   See section 7.2, Field #6.

7. Month of Data (Columns 16-17)

   Critical – See section 7.3, Field #8.

8. Day of Data (Columns 18-19) – *Critical*

   See Chapter 7.3, Field #9.

9. Time of Data (Columns 20-27) – hhmmssff with an implied decimal – *Critical*

   hh = Hour in which record was taken

   Code the beginning of the hour (digits 20-21) in which the record was taken:

   > 00 = after 00:00 to 01:00
   >
   > 01 = after 01:00 to 02:00
   >
   > ...
   >
   > ...
   >
   > ...
   >
   > 22 = after 22:00 to 23:00
   >
   > 23 = after 23:00 to 24:00

   mm = Minute in which record was taken

   Code the beginning of the minute (digits 22-23) in which the record was taken:

   > 00 = 0 minute to less than 1 minute
   >
   > 01 = 1 minute to less than 2 minutes
   >
   > ...
   >
   > ...
   >
   > ...
   >
   > 58 = 58 minutes to less than 59 minutes
   >
   > 59 = 59 minutes to less than 60 minutes

   ss = Second in which record was taken

   Code the beginning of the second (digits 24-25) in which the record was taken:

   > 00 = 0 second to less than 1 second
   >
   > 01 = 1 second to less than 2 seconds
   >
   > ...
   >
   > ...
   >
   > ...
   >
   > 58 = 58 seconds to less than 59 seconds
   >
   > 59 = 59 seconds to less than 60 seconds

   ff = Fraction of a second to the nearest hundredth of a second in which the record was taken

   Code the fraction of a second to the nearest hundredth second (digits 26-27) in which the record was taken:

00 = 00 hundredth seconds to less than 01 hundredth seconds

01 = 01 hundredth seconds to less than 02 hundredth seconds

…

…

…

98 = 98 hundredth seconds to less than 99 hundredth seconds

99 = 99 hundredth seconds to less than 100 hundredth seconds

10. Type of Base Counting Device (Column 28) – *Critical*

This alphanumeric field details the type of counting device recording the individual record formats, and the type of data contained in this record. The value in this field affects the length of the record being read (the number of columns software reading the record should expect to exist), as well as the definition of the data contained in subsequent columns. Code the correct value for type of traffic counting device.

V = volume only type of device (the expected number of columns is 32)

T = speed type of device (the expected number of columns is 44)

C = classification type of device (the expected number of columns varies with the number of axles on each vehicle)

W = weight type of device by axle weights (the expected number of columns varies with the number of axles on each vehicle)

Z = weight type of device by left and right wheel path weights (the expected number of columns varies with the number of axles on each vehicle)

Note: This assumes that "T" records have filled data columns, allowing speed records to supply vehicle length data, meaning those columns should be blank filled if not used.

11. Vehicle Signature or Other Use Field (Columns 29-32) – *Optional*

Enter the vehicle unique loop or magnetic signature using the right-most digits first. This field can also be used for other purposes such as vehicle overhang, vehicle width, or other uses. Blank fill all unused columns. For any distance measurement (English) the decimal is implied to be between the 31st and 32nd digits (XXX.X)

TABLE 7-21   VOLUME SITE (SOUTH BOUND LANE 1, NOTE – RECORD LENGTH ENDS WITH 4 BLANKS) PER VEHICLE FORMAT

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18-19	20-27	28	29-32
Content Example:	I	17	018116	5	1	2012	11	07	13284687	V	Blank
	I	17	018116	5	1	2012	11	07	13345054	V	Blank
	I	17	018116	5	1	2012	11	07	13383189	V	Blank

7.7.2 SPEED, LENGTH CLASSIFICATION, AND VOLUME DATA FORMAT ("T" VARIANT) (ALSO COLUMNS 33-44 FOR ALL FORMATS CONTAINING VEHICLE CLASSIFICATION DATA – INCLUDING FORMATS C, W, AND Z)

To submit individual vehicle records that also contain vehicle speed data for each of those vehicles, use the above data format for the first 28 columns, place the letter "T" in column 28, and optionally add vehicle signature data in columns 29-32, then add data to columns 33 to 44 as described below. Blank fill all columns for which data is not available.

TABLE 7-22   INDIVIDUAL VEHICLE RECORD COLLECTED BY SPEED AND LENGTH CLASS MEASURING DEVICE (T VARIANT)

Field	Columns	Width	Description	Type
1	1	1	Record Type	C
2	2-3	2	FIPS State Code	C
3	4-9	6	Station ID	C
4	10	1	Direction of Travel Code	C
5	11	1	Lane of Travel	C
6	12-15	4	Year of Data	C
7	16-17	2	Month of Data	C
8	18-19	2	Day of Data	C
9	20-27	8	Time of Data	C
10	28	1	T	C
11	29-32	4	Vehicle Signature/Other Use	O
12	33-36	4	Vehicle Speed	C/O
13	37-38	2	Vehicle Classification	C/O
14	39-40	2	Number of Axles	C/O
15	41-44	4	Total Vehicle Length (bumper to bumper)	C/O

Note: C=Critical, C/O=Critical/Optional, O=Optional

Fields designated as Critical are required to upload data through the TMAS system.

Fields designated as Optional are not required for this record format. Code these fields according to the instructions for each optional field.

Fields designated as Critical/Optional are based on other fields provided in the station record.

12. Vehicle Speed (Columns 33-36) – *Critical/Optional*

Enter the speed of the vehicle to the nearest tenth of a mph. The decimal is implied between digits 35 and 36. Blank fill if unused.

Example – for a 104.1 mph vehicle, it would be coded as 1041.

13. Vehicle Classification (Columns 37-38) – *Critical/Optional* according to the following: Critical for C, W and Z devices, Optional for T devices

    Enter the classification of the vehicle from FHWA classes 1 to 13. Blank fill if unused.

14. Number of Axles (Columns 39-40) – *Critical/Optional* according to the following: Critical for C, W and Z devices, Optional for T devices

    Enter the total number of detected axles in use by the vehicle (including any trailers). Blank fill if unused.

    Note – for the number of axles on the recorded vehicle, the data items related to those axles (in record formats C, W, and Z) shall be classified as critical. Otherwise, the remainder of the fields through column 44 should be blank filled. The record should end after column 44 if no axle spacing data is available (record formats C, W, and Z).

15. Total Vehicle Length (bumper to bumper) (Columns 41-44) – *Critical/Optional*

    Enter the total length of the vehicle from bumper to bumper to the nearest tenth of a foot. The decimal is implied between digits 43 to 44. If no total vehicle length is available blank fill this field.

    If the data being submitted do not contain axle spacing information, the data record should be 44 characters in length.

TABLE 7-23   SPEED SITE (NORTH BOUND LANE 2) PER VEHICLE FORMAT

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18-19	20-27	28	29-32	33-36	37-38	39-40	41-44
Content Example:	I	17	018117	1	2	2012	11	07	09245838	T	Blank	0624	03	02	0163
	I	17	018117	1	2	2012	11	07	09331278	T	Blank	0613	09	05	0691
	I	17	018117	1	2	2012	11	07	09421436	T	Blank	0648	02	02	0097

7.7.3   VEHICLE AXLE CLASSIFICATION ONLY DATA FORMAT ("C" VARIANT)

This section only applies to those individual records designated with a "C" in Field 10, column 28.

The "C" variant of the per vehicle record format is used to describe the vehicle characteristics (number and spacing of axles) of traffic observed by axle sensing vehicle classification devices. It is a variable length record, where the length (number of columns) of the record is controlled by the number of axles being reported for each vehicle. The number of axles associated with each vehicle is given in columns 39 and 40 as described above. This value is used by the TMAS software reading the record to determine how many columns remain to be read in each record. Do NOT zero fill additional columns beyond those required to report the observed axles for each vehicle.

The maximum record size allowed for "C" formatted records is 140 columns. A record this long is needed only if a single vehicle has 25 axles. The number of columns included in each record can be computed with the following formula.

Last column = ((*number of axles* - 1) × 4) + 44

Where:

number of axles is the value found in columns 39 and 40 of that record.

TABLE 7-24   INDIVIDUAL VEHICLE RECORD COLLECTED BY CLASSIFICATION DEVICE (C VARIANT)

Field	Columns	Width	Description	Type
1	1	1	Record Type	C
2	2-3	2	FIPS State Code	C
3	4-9	6	Station ID	C
4	10	1	Direction of Travel Code	C
5	11	1	Lane of Travel	C
6	12-15	4	Year of Data	C
7	16-17	2	Month of Data	C
8	18-19	2	Day of Data	C
9	20-27	8	Time of Data	C
10	28	1	C	C
11	29-32	4	Vehicle Signature/Other Use	O
12	33-36	4	Vehicle Speed	C
13	37-38	2	Vehicle Classification	C
14	39-40	2	Number of Axles	C
15	41-44	4	Total Vehicle Length (bumper to bumper)	O
16	45-48	4	Axles 1-2 Spacing	C
17	49-52	4	Axles 2-3 Spacing	C/O
18	53-56	4	Axles 3-4 Spacing	C/O
19	57-60	4	Axles 4-5 Spacing	C/O
20	61-64	4	Axles 5-6 Spacing	C/O
21	65-68	4	Axles 6-7 Spacing	C/O
22	69-72	4	Axles 7-8 Spacing	C/O
23	73-76	4	Axles 8-9 Spacing	C/O
24	77-80	4	Axles 9-10 Spacing	C/O
25	81-84	4	Axles 10-11 Spacing	C/O
26	85-88	4	Axles 11-12 Spacing	C/O
27+	Use additional spacing in 4-digit increments up to 25 axles			C/O

Note: C=Critical, C/O=Critical/Optional, O=Optional

Fields designated as Critical are required to upload data through the TMAS system.

Fields designated as Optional are not required for this record format. Code these fields according to the instructions for each optional field.

Fields designated as Critical/Optional are based on other fields provided in the station record.

The definitions of the data to be contained in columns 1 – 44 for the "C" format are described above. The data to be included in columns 45 and later are defined as follows:

16. Axle 1 to 2 Spacing (Columns 45-48) – Critical for C, W, and Z record variants

    Enter the total spacing between axles 1 and 2 as a <u>right-justified</u> value, in units of feet. All axle spacings are reported in tenths of a foot with an implied decimal between digits 3 and 4. For example, an axle spacing of 9.6 feet would be entered as "0096."

17. Axle 2 to 3 Spacing (Columns 49-52) – *Critical/Optional*

    Enter the total spacing between axles 2 and 3 as a <u>right-justified</u>, value, in units of feet.

18. Axle 3 to 4 Spacing (Columns 53-56) – *Critical/Optional*

    Enter the total spacing between axles 3 and 4 as a <u>right-justified</u>, value, in units of feet.

19. Axle 4 to 5 Spacing (Columns 57-60) – Critical/Optional

    Enter the total spacing between axles 4 and 5 as a <u>right-justified</u>, value, in units of feet.

20. Axle 5 to 6 Spacing (Columns 61-64) – *Critical/Optional*

    Enter the total spacing between axles 5 and 6 as a <u>right-justified</u>, value, in units of feet.

21. Axle 6 to 7 Spacing (Columns 65-68) – *Critical/Optional*

    Enter the total spacing between axles 6 and 7 as a <u>right-justified</u>, value, in units of feet.

22. Axle 7 to 8 Spacing (Columns 69-72) – *Critical/Optional*

    Enter the total spacing between axles 7 and 8 as a <u>right-justified</u>, value, in units of feet.

23. 23. Axle 8 to 9 Spacing (Columns 73-76) – *Critical/Optional*

    Enter the total spacing between axles 8 and 9 as a <u>right-justified</u>, value, in units of feet.

24. 24. Axle 9 to 10 Spacing (Columns 77-80) – *Critical/Optional*

    Enter the total spacing between axles 9 and 10 as a <u>right-justified</u>, value, in units of feet.

25. Axle 10 to 11 Spacing (Columns 81-84) – *Critical/Optional*

    Enter the total spacing between axles 10 and 11 as a <u>right-justified</u>, value, in units of feet.

26. Axle 11 to 12 Spacing (Columns 85-88) – *Critical/Optional*

    Enter the total spacing between axles 11 and 12 as a <u>right-justified</u>, value, in units of feet.

    Each additional axle space measurement is allocated four columns. The maximum allowed number of axles is 25, which results in a maximum record length of 140 columns.

TABLE 7-25   CLASSIFICATION SITE (EAST BOUND LANE 4) PER VEHICLE FORMAT

Column Number:	1	2-3	4-9	10	11	12-15	16-17	18-19	20-27	28	29-32	33-36	37-38	39-40	41-44	45-48	49-52	53-56	57-60
Content Example:	I	17	018118	3	4	2012	11	07	18583348	C	Blank	0582	08	04	0584	0135	0251	0048	Blank
Content Example:	I	17	018118	3	4	2012	11	07	18595775	C	Blank	0627	02	02	0102	0076	Blank	Blank	Blank
Content Example:	I	17	018118	3	4	2012	11	07	19001358	C	Blank	0606	13	08	0845	0152	0043	0154	0045

continued

Column Number:	61-64	65-68	69-72	73-76	77-80	81-84	85-88
Content Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content Example:	0128	0147	0046	Blank	Blank	Blank	Blank

7.7.4 Vehicle Classification and Axle Weights ("W" Variant)

This section only applies to those individual records designated with a W in Field 10, Column 28.

This variation of the individual record format (the "W" record format) is used to describe the number, spacing, and weight of axles for traffic observed by weigh-in-motion scales. The "W variant" is a variable length record, where the length (number of columns) of the record is controlled by the number of axles being reported for each vehicle. The number of axles associated with each vehicle is given in columns 39 and 40 as described above. This value is used by the TMAS software reading the record to determine how many columns should be read in each record. Do NOT zero fill additional columns beyond those required to report the observed axles for each vehicle.

The maximum record size permitted for "W" formatted records is 268 columns. A record this long is needed only if a single vehicle has 25 axles. The number of columns included in each record can be computed with the following formula.

A dummy vehicle class of 'm' indicates that weight data for this hour are missing. A dummy vehicle class of 'd' indicates that weight data for this hour are not missing, and thus if there are no weight records for the hour, then there were no trucks during that hour. Without these indications, no weight records for an hour might be interpreted to mean that the WIM system was not working.

Last column = ((number of axles - 1) × 9) + 52

Where:

number of axles is the value found in columns 39 and 40 of that record. Based on this 'last column' calculation, some optional fields could become critical if it is determined that more than 2 axles are on the given vehicle being reported in the record.

TABLE 7-26   INDIVIDUAL VEHICLE RECORD COLLECTED BY WEIGHT (AXLE) DEVICE (W VARIANT)

Field	Columns	Width	Description	Type
1	1	1	Record Type	C
2	2-3	2	FIPS State Code	C
3	4-9	6	Station ID	C
4	10	1	Direction of Travel Code	C
5	11	1	Lane of Travel	C
6	12-15	4	Year of Data	C
7	16-17	2	Month of Data	C
8	18-19	2	Day of Data	C
9	20-27	8	Time of Data	C
10	28	1	W	C
11	29-32	4	Vehicle Signature/Other Use	O
12	33-36	4	Vehicle Speed	C
13	37-38	2	Vehicle Classification	C
14	39-40	2	Number of Axles	C
15	41-44	4	Total Vehicle Length (bumper to bumper)	O
16	45-47	3	Pavement Temperature	O
17	48-52	5	Axle Weight 1	C

Field	Columns	Width	Description	Type
18	53-56	4	Axles 1-2 Spacing	C
19	57-61	5	Axle Weight 2	C
20	62-65	4	Axles 2-3 Spacing	C/O
21	66-70	5	Axle Weight 3	C/O
22	71-74	4	Axles 3-4 Spacing	C/O
23	75-79	5	Axle Weight 4	C/O
24	80-83	4	Axles 4-5 Spacing	C/O
25	84-88	5	Axle Weight 5	C/O
26	89-92	4	Axles 5-6 Spacing	C/O
27	93-97	5	Axle Weight 6	C/O
28	98-101	4	Axles 6-7 Spacing	C/O
29	102-106	5	Axle Weight 7	C/O
30	107-110	4	Axles 7-8 Spacing	C/O
31	111-115	5	Axle Weight 8	C/O
32	116-119	4	Axles 8-9 Spacing	C/O
33	120-124	5	Axle Weight 9	C/O
34	125-128	4	Axles 9-10 Spacing	C/O
35	129-133	5	Axle Weight 10	C/O
36	134-137	4	Axles 10-11 Spacing	C/O
37	138-142	5	Axle Weight 11	C/O
38	143-146	4	Axles 11-12 Spacing	C/O
39	147-151	5	Axle Weight 12	C/O
40+	Use additional spacing in 4-digit increments up to 25 axles			C/O
41+	Use additional weights in 5-digit increments up to 25 axles			C/O

Note: *C=Critical, C/O=Critical/Optional, O=Optional*

Fields designated as Critical are required to upload data through the TMAS system.

Fields designated as Optional are not required for this record format. Code these fields according to the instructions for each optional field.

Fields designated as Critical/Optional are based on other fields provided in the station record.

The data to be provided in columns 1 – 44 are described earlier in sections 7.7.1 and 7.7.2 of this chapter. The data to be included in columns 45 and later are defined as follows:

16. Pavement Temperature (Columns 45-47) – *Optional*

Enter the pavement temperature rounded to the nearest integer Fahrenheit value. A negative sign may be placed in column 45 if appropriate. If the pavement temperature is unknown blank fill these digits.

17. Axle Weight 1 (Columns 48-52) – *Critical*

   Enter the total axle 1 weight as a right-justified, decimal value, in units of pounds. For example, the axle weight measured as 9,120 pounds could be entered as " _ 9120" or as "09120" (where "_" represents a blank space.)

18. Axle 1 to 2 Spacing (Columns 53-56) – *Critical*

   Enter the total spacing between axles 1 and 2 as a right-justified value, in units of tenths of feet. All axle spacings are reported in tenths of feet with an implied decimal between digits 3 and 4. For example, an axle spacing of 11.35 feet would be entered as "0114" or "_114" and an axle spacing of 9.6 feet would be entered as "0096" or "__96" (where "_" represents a blank space).

19. Axle Weight 2 (Columns 57-61) – *Critical*

   Enter the total axle 2 weight as a right-justified value, in units pounds .

20. Axle 2 to 3 Spacing (Columns 62-65) – *Critical/Optional*

   Enter the total spacing between axles 2 and 3 as a right-justified value, in units of tenths of feet.

21. Axle Weight 3 (Columns 66-70) – *Critical/Optional*

   Enter the total axle 3 weight as a right-justified, decimal value, in units of pounds .

22. Axle 3 to 4 Spacing (Columns 71-74) – *Critical/Optional*

   Enter the total spacing between axles 3 and 4 as a right-justified value, in units of tenths of feet.

23. Axle Weight 4 (Columns 75-79) – *Critical/Optional*

   Enter the total axle 4 weight as a right-justified, value, in units of pounds .

24. Axle 4 to 5 Spacing (Columns 80-83) – *Critical/Optional*

   Enter the total spacing between axles 4 and 5 as a right-justified value, in units of tenths of feet.

25. Axle Weight 5 (Columns 84-88) – *Critical/Optional*

   Enter the total axle 5 weight as a right-justified value, in units of pounds .

26. Axle 5 to 6 Spacing (Columns 89-92) – *Critical/Optional*

   Enter the total spacing between axles 5 and 6 as a right-justified value, in units of tenths of feet.

27. Axle Weight 6 (Columns 93-97) – *Critical/Optional*

   Enter the total axle 6 weight as a right-justified value, in units of pounds .

28. Axle 6 to 7 Spacing (Columns 98-101) – *Critical/Optional*

   Enter the total spacing between axles 6 and 7 as a right-justified value, in units of tenths of feet.

29. Axle Weight 7 (Columns 102-106) – *Critical/Optional*

   Enter the total axle 7 weight as a right-justified value, in units of pounds .

30. Axle 7 to 8 Spacing (Columns 107-110) – *Critical/Optional*

   Enter the total spacing between axles 7 and 8 as a right-justified value, in units of tenths of feet.

31. Axle Weight 8 (Columns 111-115) – *Critical/Optional*

   Enter the total axle 8 weight as a right-justified value, in units of pounds.

32. Axle 8 to 9 Spacing (Columns 116-119) – *Critical/Optional*

   Enter the total spacing between axles 8 and 9 as a right-justified value, in units of tenths of feet.

33. Axle Weight 9 (Columns 120-124) – *Critical/Optional*

   Enter the total axle 9 weight as a right-justified value, in units of pounds.

34. Axle 9 to 10 Spacing (Columns 125-128) – *Critical/Optional*

    Enter the total spacing between axles 9 and 10 as a <u>right-justified</u> value, in units of tenths of feet.

35. Axle Weight 10 (Columns 129-133) – *Critical/Optional*

    Enter the total axle 10 weight as a <u>right-justified</u> value, in units of pounds.

36. Axle 10 to 11 Spacing (Columns 134-137) – *Critical/Optional*

    Enter the total spacing between axles 10 and 11 as a right-justified value, in units of tenths of feet.

37. Axle Weight 11 (Columns 138-142) - Critical/Optional

    Enter the total axle 11 weight as a right-justified value, in units of pounds.

38. Axle 11 to 12 Spacing (Columns 143-146) – Critical/Optional

    Enter the total spacing between axles 11 and 12 as a right-justified value, in units of tenths of feet.

39. Axle Weight 12 (Columns 147-151) – Critical/Optional

    Enter the total axle 12 weight as a right-justified value, in units of pounds.

For each additional axle beyond the 12th axle, an additional nine columns should be entered. The first four of these columns are the axle spacing to the next axle, followed by the five columns for the weight of that next axle. The maximum number of axles permitted is 25, which uses a record length of 268 columns.

TABLE 7-27   WEIGHT SITE (WEST BOUND LANE 3) PER VEHICLE FORMAT

Column Number:	1	2–3	4–9	10	11	12–15	16–17	18–19	20–27	28	29–32	33–36	37–38	39–40	41–44	45–47	48–52	53–56	57–61	62–65
Content Example:	I	17	018119	7	3	2012	11	07	05123472	W	Blank	0551	03	02	0174	065	03215	0142	05445	Blank
Content Example:	I	17	018119	7	3	2012	11	07	05123821	W	Blank	0572	05	02	0211	064	05620	0187	06523	Blank
Content Example:	I	17	018119	7	3	2012	11	07	95124378	W	Blank	0560	09	05	0753	064	12518	0152	15790	0043

continued

Column Number:	66–70	71–74	75–79	80–83	84–88	89–92	93–97	98–101	102–106	107–110	111–115	116–119	120–124	125–128	129–133
Content Example:	Blank	blank	Blank	Blank	blank	Blank	Blank	Blank	Blank	blank	Blank	Blank	Blank	Blank	Blank
Content Example:	Blank	blank	Blank	Blank	blank	Blank	Blank	Blank	Blank	blank	Blank	Blank	Blank	Blank	Blank
Content Example:	16250	0285	16535	0085	15885	Blank	Blank	Blank	Blank	blank	Blank	Blank	Blank	Blank	Blank

continued

Column Number:	134–137	138–142	143–146	147–151
Content Example:	Blank	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank	Blank

Use additional spacing in 4-digit increments up to 25 axles

Use additional weights in 3-digit increments up to 25 axles

7.7.5 VEHICLE CLASSIFICATION AND WHEEL WEIGHTS ("Z" VARIANT)

This section only applies to those individual records designated with a Z in Field 10, column 28.

The "Z" variant of the individual record format is used to describe the number, spacing, and weight of axles for traffic observed by weigh-in-motion scales that measure both left and right axle weights. It differs from the "W" record by the fact that it allows the user to report the left- and right-side wheel path weights independently for each axle. This data is available when independent weight sensors are placed in the two wheel paths, such as is typically the case for bending plate, load cell load scale, and some by wheel path piezo systems. Like the "C" and "W" record variants, the "Z variant" is a variable length record, where the length (number of columns) of the record is controlled by the number of axles being reported for each vehicle. The number of axles associated with each vehicle is given in columns 39 and 40 as described in Section 7.7.2. This value is used by the TMAS software reading the record to determine how many columns remain to be read in each record. Do NOT zero fill additional columns beyond those required to report the observed number of axles for each vehicle.

The maximum record size permitted for "Z" formatted records is 393 columns. A record this long is needed only if a single vehicle has 25 axles. The number of columns included in each record can be computed with the following formula.

Last column = (*number of axles* × 14) + 43

Where:

number of axles is the value found in columns 39 and 40 of that record.

TABLE 7-28 **INDIVIDUAL VEHICLE RECORD COLLECTED BY WEIGHT (LEFT AND RIGHT) DEVICE (Z VARIANT)**

Field	Columns	Width	Description	Type
1	1	1	Record Type	C
2	2-3	2	FIPS State Code	C
3	4-9	6	Station ID	C
4	10	1	Direction of Travel Code	C
5	11	1	Lane of Travel	C
6	12-15	4	Year of Data	C
7	16-17	2	Month of Data	C
8	18-19	2	Day of Data	C
9	20-27	8	Time of Data	C
10	28	1	Z	C
11	29-32	4	Vehicle Signature/Other Use	O
12	33-36	4	Vehicle Speed	C
13	37-38	2	Vehicle Classification	C
14	39-40	2	Number of Axles	C
15	41-44	4	Total Vehicle Length (bumper to bumper)	O
16	45-47	3	Pavement Temperature	O
17	48-52	5	Weight 1 Left Wheel Path	C
18	53-57	5	Weight 1 Right Wheel Path	C
19	58-61	4	Axles 1-2 Spacing	C
20	62-66	5	Weight 2 Left Wheel Path	C
21	67-71	5	Weight 2 Right Wheel Path	C
22	72-75	4	Axles 2-3 Spacing	C/O
23	76-80	5	Weight 3 Left Wheel Path	C/O
24	81-85	5	Weight 3 Right Wheel Path	C/O
25	86-89	4	Axles 3-4 Spacing	C/O
26	90-94	5	Weight 4 Left Wheel Path	C/O
27	95-99	5	Weight 4 Right Wheel Path	C/O
28	100-103	4	Axles 4-5 Spacing	C/O
29	104-108	5	Weight 5 Left Wheel Path	C/O
30	109-113	5	Weight 5 Right Wheel Path	C/O
31	114-117	4	Axles 5-6 Spacing	C/O
32	118-122	5	Weight 6 Left Wheel Path	C/O
33	123-127	5	Weight 6 Right Wheel Path	C/O
34	128-131	4	Axles 6-7 Spacing	C/O
35	132-136	5	Weight 7 Left Wheel Path	C/O
36	137-141	5	Weight 7 Right Wheel Path	C/O
37	142-145	4	Axles 7-8 Spacing	C/O
38	146-150	5	Weight 8 Left Wheel Path	C/O
39	151-155	5	Weight 8 Right Wheel Path	C/O

Field	Columns	Width	Description	Type
40	156-159	4	Axles 8-9 Spacing	C/O
41	160-164	5	Weight 9 Left Wheel Path	C/O
42	165-169	5	Weight 9 Right Wheel Path	C/O
43	170-173	4	Axles 9-10 Spacing	C/O
44	174-178	5	Weight 10 Left Wheel Path	C/O
45	179-183	5	Weight 10 Right Wheel Path	C/O
46	184-187	4	Axles 10-11 Spacing	C/O
47	188-192	5	Weight 11 Left Wheel Path	C/O
48	193-197	5	Weight 11 Right Wheel Path	C/O
49	198-201	4	Axles 11-12 Spacing	C/O
50	202-206	5	Weight 12 Left Wheel Path	C/O
51	207-211	5	Weight 12 Right Wheel Path	C/O
52+	Use 4 columns for each axle up to 25 axles (include 10 columns of weight prior to the next axle distance)			C/O
53+	Use 5 additional columns for each additional axle for the left wheel path weight, up to 25 axles			C/O
54+	Use 5 additional columns for each additional axle for the right wheel path weight, up to 25 axles			C/O

Note: *C=Critical, C/O=Critical/Optional, O=Optional*

Fields designated as Critical *are required to upload data through the TMAS software.*

Fields designated as Optional *are not required for this record format. Code these fields according to the instructions for each optional field.*

Fields designated as Critical/Optional *are based on other fields provided in the station record.*

The definitions of the data to be contained in columns 1 – 44 for the "Z" format are described in Sections 7.7.1 and 7.7.2 earlier in this chapter. The data to be included in columns 45 and later are defined as follows:

16. Pavement Temperature (Columns 45-47) – *Optional*

Enter the pavement temperature rounded to the nearest integer Fahrenheit value. A negative sign may be placed in Column 45 if required. If the pavement temperature is unknown blank fill these digits.

17. Weight 1 Left Wheel Path (Columns 48-52) -– *Critical*

Enter the left axle 1 weight as a right-justified value, in units of pounds. For example, the axle weight measured as 9,120 pounds could be entered as "09120" or "_9120"

18. Weight 1 Right Wheel Path (Columns 53-57)) – *Critical*

    Enter the right axle 1 weight as a <u>right-justified</u> value, in units of pounds.

19. Axle 1 to 2 Spacing (Columns 58-61) -– *Critical*

    Enter the total spacing between axles 1 and 2 as a <u>right-justified</u> value, in units of tenths of feet. All axle spacings are reported in tenths of a foot with an implied decimal between digits 3 and 4. For example, an axle spacing of 11.35 feet would be entered as "0114."

20. Weight 2 Left Wheel Path (Columns 62-66) -– *Critical*

    Enter the left axle 2 weight as a <u>right-justified</u> value, in units of pounds.

21. Weight 2 Right Wheel Path (Columns 67-71) -– *Critical*

    Enter the right axle 2 weight as a <u>right-justified</u> value, in units of pounds.

22. Axle 2 to 3 Spacing (Columns 72-75) – *Critical/Optional*

    Enter the total spacing between axles 2 and 3 as a <u>right-justified</u> value, in units of tenths of feet.

23. Weight 3 Left Wheel Path (Columns 76-80) - *Critical/Optional*

    Enter the left axle 3 weight as a <u>right-justified</u> value, in units of pounds.

24. Weight 3 Right Wheel Path (Columns 81-85) -– *Critical/Optional*

    Enter the right axle 3 weight as a <u>right-justified</u>, decimal value, in units of pounds.

25. Axle 3 to 4 Spacing (Columns 86-89) – *Critical/Optional*

    Enter the total spacing between axles 3 and 4 as a <u>right-justified</u> value, in units of tenths of feet.

26. Weight 4 Left Wheel Path (Columns 90-94) - *Critical/Optional*

    Enter the left axle 4 weight as a <u>right-justified</u> value, in units of pounds.

27. Weight 4 Right Wheel Path (Columns 95-99) - – *Critical/Optional*

    Enter the right axle 4 weight as a <u>right-justified</u> value, in units of pounds.

28. Axle 4 to 5 Spacing (Columns 100-103) – *Critical/Optional*

    Enter the total spacing between axles 4 and 5 as a <u>right-justified</u> value, in units of tenths of feet.

29. Weight 5 Left Wheel Path (Columns 104-108) -) – *Critical/Optional*

    Enter the left axle 5 weight as a <u>right-justified</u> value, in units of pounds.

30. Weight 5 Right Wheel Path (Columns 109-113) -– *Critical/Optional*

    Enter the right axle 5 weight as a <u>right-justified</u> value, in units of pounds.

31. Axle 5 to 6 Spacing (Columns 114-117) – *Critical/Optional*

    Enter the total spacing between axles 5 and 6 as a <u>right-justified</u> value, in units of tenths of feet.

32. Weight 6 Left Wheel Path (Columns 118-122) - – *Critical/Optional*

    Enter the left axle 6 weight as a <u>right-justified</u> value, in units of pounds.

33. Weight 6 Right Wheel Path (Columns 123-127) -   Critical/Optional

    Enter the right axle 6 weight as a <u>right-justified</u> value, in units of pounds.

34. Axle 6 to 7 Spacing (Columns 128-131) – *Critical/Optional*

    Enter the total spacing between axles 6 and 7 as a <u>right-justified</u> value, in units of tenths of feet.

35. Weight 7 Left Wheel Path (Columns 132-136) -– *Critical/Optional*

    Enter the left axle 7 weight as a <u>right-justified</u> value, in units of pounds.

36. Weight 7 Right Wheel Path (Columns 137-141) -– *Critical/Optional*

   Enter the right axle 7 weight as a right-justified value, in units of pounds.

37. Axle 7 to 8 Spacing (Columns 142-145) – *Critical/Optional*

   Enter the total spacing between axles 7 and 8 as a right-justified value, in units of tenths of feet.

38. Weight 8 Left Wheel Path (Columns 146-150) -) – *Critical/Optional*

   Enter the left axle 8 weight as a right-justified value, in units of pounds.

39. Weight 8 Right Wheel Path (Columns 151-155) -) – *Critical/Optional*

   Enter the right axle 8 weight as a right-justified value, in units of pounds.

40. Axle 8 to 9 Spacing (Columns 156-159) – *Critical/Optional*

   Enter the total spacing between axles 8 and 9 as a right-justified value, in units of tenths of feet.

41. Weight 9 Left Wheel Path (Columns 160-164) -) – *Critical/Optional*

   Enter the left axle 9 weight as a right-justified value, in units of pounds.

42. Weight 9 Right Wheel Path (Columns 165-169) -– *Critical/Optional*

   Enter the right axle 9 weight as a right-justified value, in units of pounds.

43. Axle 9 to 10 Spacing (Columns 170-173) – *Critical/Optional*

   Enter the total spacing between axles 9 and 10 as a right-justified value, in units of tenths of feet.

44. Weight 10 Left Wheel Path (Columns 174-178) -) – *Critical/Optional*

   Enter the left axle 10 weight as a right-justified value, in units of pounds.

45. Weight 10 Right Wheel Path (Columns 179-183) -– *Critical/Optional*

   Enter the right axle 10 weight as a right-justified value, in units of pounds.

46. Axle 10 to 11 Spacing (Columns 184-187) – *Critical/Optional*

   Enter the total spacing between axle 10 and 11 as a right-justified value, in units of tenths of feet.

47. Weight 11 Left Wheel Path (Columns 188-192) -– *Critical/Optional*

   Enter the left axle 11 weight as a right-justified value, in units of pounds.

48. Weight 11 Right Wheel Path (Columns 193-197) -) – *Critical/Optional*

   Enter the right axle 11 weight as a right-justified value, in units of pounds.

49. Axle 11 to 12 Spacing (Columns 198-201) – *Critical/Optional*

   Enter the total spacing between axle 11 and 12 as a right-justified value, in units of tenths of feet.

50. Weight 12 Left Wheel Path (Columns 202-206) -) – *Critical/Optional*

   Enter the total axle 12 weight as a right-justified value, in units of pounds.

51. Weight 12 Right Wheel Path (Columns 207-211) -) – *Critical/Optional*

   Enter the total axle 12 weight as a right-justified value, in units of pounds.

   For each additional axle beyond the 12th axle, an additional ten columns should be entered. The first four of these columns contain the axle spacing to the next axle, followed by five columns for the weight measured in the left wheel path for that axle, followed by five more columns for the weight measured in the right wheel path. The maximum number of axles permitted is 25, which creates a record length of 393 columns.

TABLE 7-29   LEFT AND RIGHT WEIGHT SITE (WEST BOUND LANE 1) PER VEHICLE FORMAT

Column Number:	2-3	4-9	10	11	12-15	16-17	18-19	20-27	28	29-32	33-36	37-38	39-40	41-44	45-47	48-52	53-57	58-61	62-66
Content Example:	17	018119	7	1	2012	11	07	07103474	Z	Blank	0561	01	02	0074	071	Blank	00590	0051	Blank
Content Example:	17	018119	7	1	2012	11	07	07103838	Z	Blank	0605	02	02	0174	071	01225	01315	0078	01700
Content Example:	17	018119	7	1	2012	11	07	07105881	Z	Blank	0593	07	04	0174	070	07335	06742	0128	03478

continued

Column Number:	67-71	72-75	76-80	81-85	86-89	90-94	95-99	100-103	104-108	109-113	114-117	118-122	123-127	128-131	132-136
Content Example:	00400	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content Example:	01580	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content Example:	03765	0038	05200	04797	0045	04935	04809	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank

continued

Column Number:	137-141	142-145	146-150	151-155	156-159	160-164	165-169	170-173	174-178	179-183	184-187	188-192	193-197
Content Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank

continued

Column Number:	198–201	202–206	207–211
Content Example:	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank
Content Example:	Blank	Blank	Blank

Use 4 columns for each axle up to 25 axles (include 6 columns of weight prior to the next axle distance)

Use 5 additional columns for each additional axle for the left wheel path weight, up to 25 axles

Use 5 additional columns for each additional axle for the right wheel path weight, up to 25 axles

7.8   DATA SUBMITTAL FREQUENCY

Table 7-30 provides the recommended data submittal frequency to FHWA.

TABLE 7-30   DATA SUBMITTAL FREQUENCY

Data Type	Submittal Frequency
Volume Data	Monthly, by 25 days after close of the month for which the data was collected
Station Description Record	Annually, or when a change occurs
Classification Data	Monthly, by 25 days after close of the month for which the data was collected
Weight Data	Minimum quarterly by the 25th of the month after the end of the quarter or, with recommended monthly submissions 25 days after the close of the month for which the data was collected
Speed Data	Monthly, by 25 days after close of the month for which the data was collected
Per Vehicle Format (PVF) (Optional)	Data type submissions follow the above timelines
Non-Motorized Data	Minimum quarterly by the 25th of the month after the end of the quarter

All data files should be submitted to FHWA through TMAS via the User Profile and Access Control System (UPACS). States should contact their State FHWA Division Offices for further instructions regarding UPACS.

All data should be in the record formats described in this chapter and quality controlled to ensure it truly represents travel on the given location/time period. If the files are large, it is preferable that a compression program such as PKZIP be used to condense them. For further information, contact the Travel Monitoring and Surveys Division at (202) 366-0175 or access information from the Office of Highway Policy and Information web site.

7.9   NON-MOTORIZED COUNT STATION DESCRIPTION DATA FORMAT

This publication of the *TMG* includes a new chapter (Chapter 4) on the collection of non-motorized data. Collecting and reporting on non-motorized travel is growing in importance, due to the significant efforts being made to encourage the use of more active modes of transportation (walking/biking) in order to gain a variety of health, financial, and environmental benefits. It is therefore, important to be able to track changes in the amount of walking and biking that result from changes in public attitudes and land uses, the implementation of new policies, and the construction of new facilities.

Two record formats are defined for submitting non-motorized data:

- Count Station Description Record; and

- Non-Motorized Count Record.

The Count Station Description Record parameters are described in this section, and Section 7.10 describes the requirements for the Non-Motorized Count Record.

The Non-Motorized Count Station Description Record is needed for reporting all non-motorized data to FHWA. If a Non-Motorized Station Description record is omitted, any succeeding records containing non-motorized data will not be processed by the TMAS software. The Non-Motorized Count Station Description file contains one record per traffic monitoring station for each land by direction per year. In addition, updated station records can be submitted at any time during the year if an equipment change occurs at a site, which would result in a different type of data being submitted at that location. All fields on each record are considered to be character fields.

The TMAS software retains all approved station records as of December 31st of each year. FHWA recommends that a yearly review of all station record fields be conducted to insure the records are current and reflect what is in the field.

An example file naming convention for the Non-Motorized Station Description Record is:

ssabcxyzmmyyyy.SNM

The non-motorized record formats should be submitted to FHWA on a quarterly basis. A future version of TMAS (3.0 or prior) will include pedestrian and bicycle data formats, processing and reporting.

TABLE 7-31   NON-MOTORIZED COUNT STATION DESCRIPTION RECORD

Field	Columns	Width	Description	Type
1	1	1	Non-motorized station/location record identifier (L)	C
2	2-3	2	State FIPS Code	C
3	4-6	3	County FIPS Code	C
4	7-12	6	Station ID	C
5	13	1	(Functional) classification of road (expanded)	C
6	14	1	Direction of route	C
7	15	1	Location of count relative to roadway orientation	C
8	16	1	Direction of travel	C
9	17	1	Crosswalk, sidewalk, or exclusive facility	C
10	18	1	Intersection	O
11	19	1	Type of count (bike/pedestrian/both)	C
12	20-21	2	Method of counting	C
13	22-23	2	Type of Sensor	O
14	24-27	4	Year of data	C
15	28	1	Factor Group 1	O
16	29	1	Factor Group 2	O
17	30	1	Factor Group 3	O
18	31	1	Factor Group 4	O
19	32	1	Factor Group 5	O
20	33	1	Primary Count Purpose	O
21	34-35	2	Posted Speed Limit	O
22	36-39	4	Year station established	C
23	40-43	4	Year station discontinued	O
24	44	1	National highway system	O

Field	Columns	Width	Description	Type
25	45-52	8	Latitude	C
26	53-61	9	Longitude	C
27	62-63	2	Posted Route Signing	O
28	64-71	8	Posted Signed Route Number	O
29	72-131	60	LRS Identification	O
30	132-139	8	LRS Location Point	O
31	140-189	50	Station location	O
32	190-239	50	Other Notes	O

Note: C = Critical, O = Optional

Fields designated as Critical *are required for this record format.*

Fields designated as Optional *are not required for this record format. Code these fields according to the instructions for each optional field.*

Non-motorized station/location record identifier (Column 1) – *Critical*

Code the letter "L"

State FIPS Code (Columns 2-3) – *Critical*

TABLE 7-32   FIPS STATE CODES

State	Code	State	Code	State	Code
Alabama	1	**Maine**	23	**Pennsylvania**	42
Alaska	2	**Maryland**	24	**Rhode Island**	44
Arizona	4	**Massachusetts**	25	**South Carolina**	45
Arkansas	5	**Michigan**	26	**South Dakota**	46
California	6	**Minnesota**	27	**Tennessee**	47
Colorado	8	**Mississippi**	28	**Texas**	48
Connecticut	9	**Missouri**	29	**Utah**	49
Delaware	10	**Montana**	30	**Vermont**	50
D.C.	11	**Nebraska**	31	**Virginia**	51
Florida	12	**Nevada**	32	**Washington**	53
Georgia	13	**New Hampshire**	33	**West Virginia**	54
Hawaii	15	**New Jersey**	34	**Wisconsin**	55
Idaho	16	**New Mexico**	35	**Wyoming**	56
Illinois	17	**New York**	36	**Puerto Rico**	72
Indiana	18	**North Carolina**	37	**American Samoa**	60
Iowa	19	**North Dakota**	38	**Guam**	66
Kansas	20	**Oregon**	41	**Northern Mariana Islands**	69
Kentucky	21	**Ohio**	39	**Virgin Islands of the U.S.**	78
Louisiana	22	**Oklahoma**	40		

Canadian Provinces may use TMAS with the following codes (based on the LTPP):

State	Code	State	Code	State	Code
Alberta	81	**Nova Scotia**	86	**Yukon**	91
British Columbia	82	**Ontario**	87	**Northwest Territory**	92
Manitoba	83	**Prince Edward Island**	88	**Labrador**	93
New Brunswick	84	**Quebec**	89	**Nunavut**	94
Newfoundland	85	**Saskatchewan**	90		

County FIPS Code (Columns 4-6) – *Critical*

Use the three-digit FIPS county code (see Federal Information Processing Standards Publication 6, *Counties of the States of the United State*s).

Station ID (Columns 7-12) - Critical

This field should contain an alphanumeric designation for the station where the survey data is collected. Station identification field entries should be identical in all records for a given station. Differences in characters, including spaces, blanks, hyphens, etc., prevent proper match.

This field should be right-justified with unused columns zero-filled. Do not use embedded blanks.

Functional Classification of Road (expanded) (Column 13) – Critical

This starts with the current U.S. DOT functional classification system, but also adds categories for trail or share use path, and general activity count (i.e., for pedestrian counts in an open area like the Mall in Washington, D.C.). It is used in association with a second variable that indicates for roads whether the count was made on the main roadway, on a sidewalk, or on a special lane intended for use exclusively by non-motorized vehicles (e.g., bike lane.)

TABLE 7-33   CLASSIFICATION CODES

Code	Classification
1	Interstate
2	Principal Arterial – Other Freeways and Expressways
3	Principal Arterial – Other
4	Minor Arterial
5	Major Collector
6	Minor Collector
7	Local
8	Trail or Shared Use Path
9	General Activity Count

6. Direction of Route (Column 14) – *Critical*

This is the direction of travel of the main roadway. Note that a north/south roadway can be coded as <u>either</u> a "N" or as a "S" but the selection of the direction affects how the "Location of Count Relative to Roadway Orientation" variable (the next variable) is coded in order to effectively define the location and direction of the non-motorized count.

TABLE 7-34 **DIRECTION OF TRAVEL CODES**

Code	Direction
0	East-West or Southeast-Northwest combined (volume stations only)
1	North
2	Northeast
3	East
4	Southeast
5	South
6	Southwest
7	West
8	Northwest
9	North-South or Northeast-Southwest combined (volume stations only)

7. Location of Count Relative to Roadway Orientation (Column 15) – *Critical*

   1 = the count is taken on the side of the road for the listed direction of travel;

   2 = the count is taken on the opposite side of the road from the listed direction (i.e., the side with on-coming traffic, given the listed direction of travel);

   3 = both sides of the road combined (appropriate for example, if counting a trail or other shared use path); and

   4 = traffic moving perpendicular to the roadway (that is, crossing the street).

   Example: If you code the Direction of Route as "North" and are in fact driving in that northbound direction, a "1" for this variable would indicate that you are counting on the right (eastern) side of the road; a "2" would indicate you are counting non-motorized traffic on the left (western) side of the road; a "3" would indicate that you are counting all non-motorized traffic, regardless of which side of the road, and would be appropriate for use on a trail or other shared use path. For that same facility, if Direction of Route were coded as "South" then a count performed on the eastern side of the road would be coded as a "2", since it would be on the opposite side of the road for vehicle traveling southbound.

8. Direction of Travel (Column 16) – *Critical*

   1 = travel monitored only occurring in the Direction of Route;

   2 = travel monitored only occurring opposite to the Direction of Route;

   3 = travel in both (all) directions; and

   4 = travel at an intersection that includes all movements (e.g., the sum of movements on all four crosswalks, or all movements occurring during a pedestrian scramble (or "Barnes Dance") phase. *Note: The "Intersection" variable should also be coded as a 1 or 2 if this variable is coded as a 4. For a "General Activity Count" that includes all movements in all directions, code direction of travel as a "3" "all directions."*)

   Note: To actually understand where a count is being taken (what side of the road, and which directions of travel are being counted) it is necessary to look at all three variables, Direction of Route, Location of Count Relative to Roadway Orientation, and Direction of Travel. It may also be necessary to look at the Crosswalk variable immediately below.

9. Crosswalk, Sidewalk, Exclusive Facility, or Total Intersection Count (Column 17) – *Critical*

   Indicates if the count was taken outside of the primary right-of-way:

   1 = in roadway/trail right of way (potentially shared with motorized vehicles)

2 = exclusively in a crosswalk

3 = on a sidewalk

4 = on an exclusive (for non-motorized traffic) right-of-way, parallel to the primary facility (including exclusive bike lanes, whether those lanes are separated from motorized vehicles by paint stripes or by some specific physical barrier but not including sidewalks, crosswalks, or trails or other shared use paths that are not for licensed, motorized vehicles)

5 = on a grade separate facility designed to allow non-motorized traffic to pass over top of a roadway (e.g., a pedestrian bridge)

6 = on a grade separate facility designed to allow non-motorized traffic to cross underneath a roadway (e.g., a pedestrian undercrossing)

For an "Area Count" leave this field blank.

Note 1: if "perpendicular to traffic" is selected in "Location of Count Relative to Roadway Orientation" variable and the "Crosswalk" variable is coded as "in roadway right of way" then the count includes ALL people crossing a roadway. If "exclusively in a crosswalk" is indicated, then only those in the crosswalk (or directly next to the crosswalk) are being counted. This coding differentiation is designed to indicate if all pedestrians crossing a street within a given block (including jaywalkers) are being counted, or whether only pedestrians actually using a marked crosswalk are being counted.

Note 2: if the count is being taken on a trail or other shared use path that is not intended for conventional passenger cars or licensed commercial vehicles, code the trail count as a "0", even if the trail may be routinely used by motorcycles, snowmobiles or other motorized vehicles designed for off-road uses.

10. Intersection (Column 18) – *Optional*

   1 = count is taken at an intersection (but not an intersection with a roundabout),

   2 = count taken at an intersection with a roundabout

   otherwise (blank) NOT at an intersection

11. Type of Count (Column 19) – *Critical*

   1 = pedestrians (only) are being counted

   2 = bicycles (only) are being counted

   3 = equestrians (only) are being counted

   4 = both pedestrians and bicycles are included in this count

   5 = all passing non-motorized traffic are included in this count

   6 = motorized vehicles are being counted (intended for counts of snowmobiles, all terrain vehicles, and other off-road vehicles using a trail or other shared use path)

   7 = all motorized and non-motorized traffic using the facility (intended for trails and share use paths that experience a combination of pedestrian, bicycle, equestrian, and off-road vehicle traffic)

   8 = other animals (specify in Field #32 (Other Notes) what kind of animals)

12. Method of Counting (Columns 20-21) – *Critical*

   1 = Human observation (manual)

   2 = Portable traffic recording device

   3 = Permanent, continuous count station (CCS)

13. Type of Sensor (Columns 22-23) – *Optional*

Code for the type of sensor used for detection.

9 = Multiple counts are made at this location, different counts may use different sensors (see the individual count records for the sensors used for specific counts)

H = Human observation (manual)

I = Infrared (passive)

2 = Active Infrared (requires a target on other side of facility being monitored)

K = Laser/lidar

L = Inductive loop

M = Magnetometer

P = Piezoelectric

Q = Quartz piezoelectric

R = Air tube

S = Sonic/acoustic

T = Tape switch

3 = other pressure sensor/mat

U = Ultrasonic

V = Video image (with automated or semi-automated conversion of images to counts)

1 = Video image with manual reduction of images to counts performed at a later time

W = Microwave (radar)

X = Radio wave (radar)

Z = Other

14. Year of Data (Columns 24-27) – *Critical*

Code the four digits of the year in which the data were collected.

FACTOR GROUPS: A total of five single digit fields are provided so that States can list the identifiers used to factor the count provided. The values in these records are not the factors themselves, but simply identifiers of the factor groups used. The factors are used to convert short duration counts to estimates of daily travel or annual travel. In the case of permanent, continuous count locations these identifiers describe which factor group that count location belongs to, so that these adjustment factors can be computed. States and other submitting agencies can use the text field in the "other information" category at the end of this record to further describe the factor groups to which the site is assigned. At this time, the use of these factor groups is both optional and flexible. A submitting agency may assign each factor identifier to purposes as the agency sees fit.

15. Factor Group 1 (Column 28) – *Optional*

The first of five allowable (but optional) variables that allow identification of a factor group that is used to adjust short duration counts at this location to estimates of annual average condition. (For example, this first factor group could be used to identify this site's time-of-day pattern, but it does not have to be used for that purpose.)

16. Factor Group 2 (Column 29) – *Optional*

The second of five allowable (but optional) variables that allow identification of a factor group

that is used to adjust short duration counts at this location to estimates of annual average condition. For example, this second factor group could be used to identify DOW patterns (Is this a commuter route or a recreational route?), but it does not have to be used for that purpose.

17. Factor Group 3 (Column 30) – *Optional*

    The third of five allowable (but optional) variables that allow identification of a factor group that is used to adjust short duration counts at this location to estimates of annual average condition. (For example, this third factor group could be used to identify monthly or seasonal patterns, but it does not have to be used for that purpose.)

18. Factor Group 4 (Column 31) – *Optional*

    The fourth of five allowable (but optional) variables that allow identification of a factor group that is used to adjust short duration counts at this location to estimates of annual average condition. (For example, this factor group could be used to identify equipment adjustment patterns needed because of the specific type of equipment being used, but it does not have to be used for that purpose.)

19. Factor Group 5 (Column 32) – *Optional*

    The fifth of five allowable (but optional) variables that allow identification of a factor group that is used to adjust short duration counts at this location to estimates of annual average condition. (For example, this factor group could be used for adjustments due to the type of weather being experienced during the count, but does not have to be used for that purpose.)

20. Primary Count Purpose – (Column 33) – *Optional*

    This field indicates the primary purpose for installing the station and hence which organization is responsible for it and supplies the data.

    O = Operations and facility management purposes

    P = Planning or statistic reporting purposes

    R = Research purposes

    S = Count taken as part of a Safe Route to School data collection effort

    L = Facility design purposes

    E = Enforcement purposes

21. Posted Speed Limit (Columns 34-35) – *Optional*

    If count is taken on a facility with posted speed limit indicate that limit in miles per hour. Otherwise leave blank.

22. Year Station Established (Columns 36-39) – *Optional*

    Code the four digits of the appropriate year if known

23. Year Station Discontinued (Columns 40-43) – *Optional*

    Code the four digits of the appropriate year if known

24. National Highway System (Column 44) – *Optional*

    N = No, not on National Highway System

    Y = Yes, on National Highway System

25. Latitude (Columns 45-52) – *Critical*

    This is the latitude of the station location with the north hemisphere assumed and an implied decimal place understood as XX.XXX XXX.

26. Longitude (Columns 53-61) – *Critical*

This is the longitude of the station location with the west hemisphere assumed and an implied decimal place understood as XXX.XXX XXX.

27. Posted Route Signing – (Columns 62-63) – *Optional*

This is the same as Route Signing in the 2012 *HPMS Field Manual* (Data Item 18 in HPMS Sections dataset). These codes are shown below.

TABLE 7-35   POSTED ROUTE SIGNING CODES

Code	Description
1	Not signed
2	Interstate
3	U.S.
4	State
5	Off-Interstate Business Marker
6	County
7	Township
8	Municipal
9	Parkway Marker or Forest Route Marker
10	None of the above

28. Posted Signed Route Number (Columns 64-71) – *Optional*

If the station is located on a city street and is not on a U.S. Bike Route, zero-fill this field.

29. Linear Referencing System (LRS) Identification (Columns 72-131) – *Optional*

The LRS Identification reported in this item for the station must be the same as the LRS identification reported in the HPMS for the section of roadway where the station is located. The LRS identification is a 60-character, right justified value. The LRS ID can be alphanumeric, but must not contain blanks; leading zeros must be coded. More information concerning the LRS may be found in Chapter III of the HPMS Field Manual (Sept. 2010), Linear Referencing System Requirements.

30. Linear Referencing System (LRS) Location Point (Columns 132-139) - *Optional*

This is the LRS location point for the station. It is similar information to the LRS Beginning Point and LRS Ending Point in the HPMS. The milepoint for the station must be within the range of the LRS beginning point and LRS ending point for the roadway section upon which the station is located. It is coded in miles, to the nearest thousandth of a mile, with an implied decimal in the middle: XXXX.XXX.

31. Station Location (Columns 140-189) – *Optional*

This is an English text entry field. For stations located on a numbered route, enter the name of the nearest major intersecting route, State border, or landmark on State road maps and the distance and direction of the station from that landmark to the station (e.g., "12 miles south of the Kentucky border"). If the station is located on a city street, enter the city and street name. Abbreviate if necessary. Left justify.

32. Other Notes (Columns 190-239) - *Optional*

This is an English text field that can be used to provide notes to others users of data from this location. For example, it can be used to describe the specific use of factor groups 1 through 5. Also, if Field #11 (Type of Count) is coded as 8 (other animals), indicate the type(s) of animals in this field (Other Notes).

TABLE 7-36   NON-MOTORIZED COUNT STATION DESCRIPTION RECORD EXAMPLE

Column Number:	1	2–3	4–6	7–12	13	14	15	16	17	18	19	20–21	22–23	24–27	28	29	30	31	32	33	34–35	36–39
Content Example:	L	08	045	GLWD06	2	3	1	1	4	Blank	2	01	–H	2011	Blank	Blank	Blank	Blank	Blank	R	65	2010

continued

Column Number:	40–43	44	45–52	53–61	64–71	72–131	132–139	140–189	62–63
Content Example:	Blank	Y	39550600N	107324200	– – – – US-6	0000….00LRSID123456		2 miles east of US 6 and SH82	03

continued

Column Number:	190–239
Content Example:	This station is for collection of bicycle counts using human observation

7.10 NON-MOTORIZED COUNT DATA FORMAT

The Non-Motorized Count Record format is a variable length, fixed field record. One record is used for each calendar day for which traffic monitoring data is being submitted. Considerable flexibility is built into this record. It allows non-motorized data to be reported at a variety of time intervals. The time interval being counted can be 5, 10, 15, 20, 30, 60, or 120 minutes, with the interval being reported as a field on each record. Table 7-37 describes all the fields used in this record.

As with previous data formats, all numeric fields should be right-justified and blank fill the columns for which no data is being reported. All fields should be blank filled if not used.

> An example file naming convention for the Volume record is:
>
> ssabcxyzmmyyyy.VNM

TABLE 7-37   NON-MOTORIZED COUNT RECORD

Field	Columns	Width	Description	Type
1	1	1	Non-motorized count record identifier (N)	C
2	2-3	2	State FIPS Code	C
3	4-6	3	County FIPS Code	C
4	7-12	6	Station ID	C
5	13-20	8	Latitude	O
6	21-29	9	Longitude	O
7	30	1	Direction of route	C
8	31	1	Location of count relative to roadway orientation	C
9	32	1	Direction of travel	C
10	33	1	Crosswalk, sidewalk, or exclusive facility	C
11	34	1	Intersection	O
12	35	1	Type of count (e.g., bike/pedestrian/both)	C
13	36-37	2	Type of sensor	C
14	38	1	Precipitation (yes/no)	O
15	39-41	3	High temperature	O
16	42-44	3	Low temperature	O
17	45-48	4	Year of count	C
18	49-50	2	Month of count	C
19	51-52	2	Day of count	C
20	53-56	4	Count start time for this record (military time, HHMM)	C
21	57-59	3	Count interval being reported (in minutes) Allowable entries: 05, 10, 15, 20, 30, 60, or 120)	C
22	60-64	5	Count for interval 1	C
23	65-69	5	Count for interval 2	C/O
24	70-74	5	Count for interval 3	C/O
25	75-79	5	Count for interval 4	C/O
26	80-84	5	Count for interval 5	C/O
27	85-89	5	Count for interval 6	C/O
28	90-94	5	Count for interval 7	C/O
29	95-99	5	Count for interval 8	C/O
30	100-104	5	Count for interval 9	C/O
31	105-109	5	Count for interval 10	C/O

Field	Columns	Width	Description	Type
32	110-114	5	Count for interval 11	C/O
33	115-119	5	Count for interval 12	C/O
34	120-124	5	Count for interval 13	C/O
35	125-129	5	Count for interval 14	C/O
36	130-134	5	Count for interval 15	C/O
37	135-139	5	Count for interval 16	C/O
38	140-144	5	Count for interval 17	C/O
39	145-149	5	Count for interval 18	C/O
40	150-154	5	Count for interval 19	C/O
41	155-159	5	Count for interval 20	C/O
42	160-164	5	Count for interval 21	C/O
43	165-169	5	Count for interval 22	C/O
44	170-174	5	Count for interval 23	C/O
45	175-179	5	Count for interval 24 – End of hourly count record	C/O
46-309	180-2500		Count intervals 25 – 288 are used only if the reported day contains this many reporting time periods. Only report those periods for which data were collected. Up to 288 reporting periods are needed if 5-minute intervals are used. Up to 144 periods are needed for 10-minute intervals. Up to 96 periods are needed for 15-minute intervals Up to 72 periods are needed for 20-minute intervals Up to 48 periods are needed for 30-minute intervals Up to 24 periods are needed for 60-minute intervals	O

Note: C = Critical, O = Optional and C/O = Critical or Optional

1. Non-motorized count record identifier (Column 1) – *Critical*

    Code the letter "N"

2. State FIPS Code (Columns 2-3) – *Critical*

    See Section 7.9, Field #2 of Non-Motorized Count Station Description Record.

3. County FIPS Code (Columns 4-6) – *Critical*

    Use the three-digit FIPS county code (see Federal Information Processing Standards Publication 6, "Counties of the States of the United States").

4. Station ID (Columns 7-12) – *Critical*

    This field should contain an alphanumeric designation for the station where the survey data is collected. Station identification field entries should be identical in all records for a given station. Differences in characters, including spaces, blanks, hyphens, etc., prevent proper match.

    This field should be right-justified with unused columns zero-filled. Do not use embedded blanks.

5. Latitude (Columns 13-20) – *Optional*

    This is the latitude of the station location with the north hemisphere assumed and an implied decimal place understood as XX.XXX XXX.

6. Longitude (Columns 21-29) – *Optional*

    This is the longitude of the station location with the west hemisphere assumed and an implied decimal place understood as XXX.XXX XXX.

7. Direction of route (Column 30) – *Critical*

    This is the direction of travel of the main roadway. Note that a north/south roadway can be

coded as either a "N" or as a "S" but the selection of the direction affects how the "Location of Count Relative to Roadway Orientation" variable (the next variable) is coded in order to effectively define the location and direction of the non-motorized count.

TABLE 7-38   DIRECTION OF TRAVEL CODES

Code	Direction
1	North
2	Northeast
3	East
4	Southeast
5	South
6	Southwest
7	West
8	Northwest
9	North-South or Northeast-Southwest combined (volume stations only)
0	East-West or Southeast-Northwest combined (volume stations only)

8. Location of count relative to roadway orientation (Column 31) – *Critical*

    1 = the count is taken on the side of the road for the listed direction of travel

    2 = the count is taken on the opposite side of the road from the listed direction (i.e., the side with on-coming traffic, given the listed direction of travel)

    3 = both sides of the road combined (appropriate for example, if you were counting a trail)

    4 = traffic moving perpendicular to the roadway (that is, crossing the street)

    Example: if you code the Direction of Route as "North" and are in fact driving in that northbound direction, a 1 for this variable would indicate that you are counting on the right (eastern) side of the road. A "2" would indicate you are counting non-motorized traffic on the left (western) side of the road. A "3" would indicate you are counting all non-motorized traffic, regardless of which side of the road, and would be appropriate for use on a trail or other shared use path. For that same facility if Direction of Route were coded as "South" then a count performed on the eastern side of the road would be coded as a "2" as it would be on the opposite side of the road for vehicle traveling southbound.

9. Direction of Travel (Column 32) – *Critical*

    1 = travel monitored only occurring in the Direction of Route

    2 = travel monitored only occurring opposite to the Direction of Route

    3 = travel in both (all) directions

    4 = travel at an intersection that includes all movements (e.g., the sum of movements on all four crosswalks, or all movements occurring during a pedestrian scramble (or "Barnes Dance") phase. *Note: The "Intersection" variable should also be coded as a 1 or 2 if this variable is coded as a 4. For a "General Activity Count" that is not taken on a linear facility, and that includes all movements in all directions, code the Direction of Travel variable as a "3" all directions.*

    Note: To actually understand where a count is being taken (what side of the road, and which directions of travel are being counted) it is necessary to look at all three variables, Direction of Route, Location of Count Relative to Roadway Orientation, and Direction of Travel. It may also be necessary to look at the Crosswalk variable immediately below.

10. Crosswalk, sidewalk, or exclusive facility (Column 33) – *Critical*

Indicates if the count was taken outside of the primary right-of-way:

1 = in roadway/trail right of way (potentially shared with motorized vehicles)

2 = exclusively in a crosswalk

3 = on a sidewalk

4 = on an exclusive (for non-motorized traffic) right-of-way, parallel to the primary facility (including exclusive bike lanes, whether those lanes are separated from motorized vehicles by paint stripes or by some specific physical barrier. But not including sidewalks, crosswalks, or trails or other shared use paths that are not for licensed, motorized vehicles)

5 = on a grade separate facility designed to allow non-motorized traffic to pass over top of a roadway (e.g., a pedestrian bridge)

6 = on a grade separate facility designed to allow non-motorized traffic to cross underneath a roadway (e.g., a pedestrian undercrossing)

For an "Area Count" leave this field blank

Note 1: if "perpendicular to traffic" is selected in "Location of Count Relative to Roadway Orientation" variable and the "Crosswalk" variable is coded as "in roadway right of way" then the count includes ALL people crossing a roadway. If "exclusively in a crosswalk" is indicated, then only those in the crosswalk (or directly next to the crosswalk) are being counted. This coding differentiation is designed to indicate if all pedestrians crossing a street within a given block (including jaywalkers) are being counted, or whether only pedestrians actually using a marked crosswalk are being counted.

Note 2: if the count is being taken on a trail or shared use path that is not intended for conventional passenger cars or licensed commercial vehicles, code the trail count as a "0", even if the trail may be routinely used by motorcycles, snowmobiles or other motorized vehicles designed for off-road uses.

11. Intersection (Column 34) – *Optional*

1 = count is taken at an intersection (but not an intersection with a roundabout)

2 = count taken at an intersection with a roundabout

otherwise (blank) NOT at an intersection

12. Type of Count (Column 35) – *Critical*

1 = pedestrians (only) are being counted

2 = bicycles (only) are being counted

3 = equestrians (only) are being counted

4 = both pedestrians and bicycles are included in this count

5 = all passing non-motorized traffic are included in this count

6 = motorized vehicles are being counted (intended for counts of snowmobiles, all terrain vehicles, and other off-road vehicles using a trail or other shared use path)

7 = all motorized and non-motorized traffic using the facility (intended for trails and share use paths that experience a combination of pedestrian, bicycle, equestrian, and off-road vehicle traffic)

8 = other animals (specify what kind of animals in Field #32 of the Non-Motorized Count Station Description Record)

13. Type of Sensor (Columns 36-37) – *Optional*

    Code for the type of sensor used for detection:

    H = Human observation (manual)

    I = Infrared (passive)

    2 = Active Infrared (requires a target on other side of facility being monitored)

    K = Laser/lidar

    L = Inductive loop

    M = Magnetometer

    P = Piezoelectric

    Q = Quartz piezoelectric

    R = Air tube

    S = Sonic/acoustic

    T = Tape switch

    3 = other pressure sensor/mat

    U = Ultrasonic

    V = Video image (with automated or semi-automated conversion of images to counts)

    1 = Video image with manual reduction of images to counts performed at a later time

    W = Microwave (radar)

    X = Radio wave (radar)

    Z = Other

14. Precipitation (Column 38) (yes/no) – *Optional*

    1 = measurable precipitation fell at some time during this record's data collection at this location

    2 = measurable precipitation did not fall at some time during this record's data collection at this location

15. High Temperature (Columns 39-41) – *Optional*

    Approximate high temperature for either the day (if a day or longer count), or the high temperature during the duration of the count, if the count is less than a day in duration. Expressed in Fahrenheit

16. Low Temperature (Columns 42-44) – *Optional*

    Approximate low temperature for either the day (if a day or longer count), or the low temperature during the duration of the count, if the count is less than a day in duration. Expressed in Fahrenheit

17. Year of count (Columns 45-48) – *Critical*

    Code the four digits of the year in which this data was collected.

18. Month of count (Columns 49-50) – *Critical*

    Code the two digits for the month in which this data was collected

19. Day of Count (Columns 51-52) – *Critical*

    Code the two digits for the day on which this data was collected

20. Count Start Time for this record (Columns 53-56) – *Critical*

Expressed in military time. The count start time must be on a five minute interval. For hourly records it is expected to be on the hour (e.g., 0900), and if a 15-minute count interval, it is expected to be on one of the 15-minute intervals (e.g., 0900, 0915, 0930, or 0945)

Note that this value will change from record to record.

21. Count Interval being reported (Columns 57-59) – *Critical*

Must be 05, 10, 15, 20, 30, 60, or 120.

NOTE: The remaining data items are the actual count data being submitted. They can represent 5, 10, 15, 20, 30, 60, or 120 minute time intervals, depending on how the record is coded. (See Item #21 - The first count interval is for the time period starting at "Start Time for this Record" (Item #20)).

NOTE 2: Data from different days should be submitted on different records. This allows each record to be read independently. One entire day of data can be submitted on one record, regardless of the count interval being reported. If 24 consecutive hours of data is collected on two separate days (e.g., 9 a.m. on June 1 – 8:59 a.m. on June 2) then two records are required to submit the data. If a 48 hour count, reported at 15-minute intervals, is taken starting at 9 a.m. on June 1 and ending at 8:59:59 a.m. on June 3rd, three records are needed. The first record provides data from 9:00 a.m. on June 1 through 11:59:59 p.m. on June 1. This count data is supplied in the count interval variable fields "Count Interval 1" through "Count Interval 60." The "Start Time for this Record" variable should be recorded as "0900." The second record provides all 24-hours of data for June 2nd. It requires the use of count interval variable fields "Count Interval 1" through "Count Interval 96." The variable "Start Time for this Record" should be "0000." The last record for reporting this 2 day count should also have a "Start Time for this Record" of "0000." It will use only variables Count Interval 1 through Count Interval 36.

22. Count for interval 1 (Columns 60-64) – *Critical*

This contains the number of pedestrians, bicycles or other units counted in the first time interval being reported. The beginning of the time period reported is given by the variable "Start Time for this Record." Right justify the integer being reported. Blank fill leading columns as needed. If no traffic was counted during this time period, place a zero (0) in column 64. Blank fill columns 60 through 63.

23. Count for interval 2 (Columns 65-69) – *Optional*

This contains the number of pedestrians, bicycles or other units counted in the second time interval being reported. Right justify the integer being reported. Blank fill leading columns as needed. If no traffic was counted during this time period, place a zero (0) in column 69. Blank fill columns 65 through 68 as necessary.

24. Count for interval 3 (Columns 70-74) – *Optional*

This contains the number of pedestrians, bicycles or other units counted in the third time interval being reported. Right justify the integer being reported. Blank fill leading columns as needed. If no traffic was counted during this time period, place a zero (0) in column 74. Blank fill columns 70-73 as necessary.

25 - 309. Count intervals 4-288 (Columns 75-79; 80-84; 85-89; … 2496-2500) – *Optional*

These variables are used as needed for fields 25 - 309. Five columns are required for each time period reported for that day. All time periods from start to end of the count on that day should be reported. Right justify each reported count in the 5 columns allocated for that time interval. Blank fill any required leading columns. If no traffic was counted during a given time period, place a zero (0) in the right most column for that count interval. Blank fill the prior columns for that time period.

Note: It is assumed that the software reading each record can determine the end of each record and the start of the next record (which indicates either a new day of counting or a new station location.) The software should then parse the data based on the information included in the record (time interval being reported, and start time of the count).

TABLE 7-39   NON-MOTORIZED COUNT RECORD EXAMPLE

Column Number:	2-3	4-6	7-12	13-20	21-29	30	31	32	33	34	35	36-37	38	39-41	42-44	45-48	49-50	51-52	53-56	57-59
Content Example:	08	045	GLWD06	39550060	107324200	3	1	1	4	–	2	H	2	– 60[a]	– 45[a]	2011	06	15	0800	060

[a] This is 60° (high temp) or 45° (low temp) Fahrenheit, not 'minus 60° or 45°. The '-' indicates a blank prior to the number 60 (or 45).

continued

Column Number:	60-64	65-69	70-74	75-79	80-84	85-89	2496-2500
Content Example:	– – – 45	– – – 30	– – – 25	– – – –0	– – – –0	– – – – 0	…

Appendix A.   GLOSSARY OF TERMS

Annual Average Daily Traffic (AADT) – The Annual Average Daily Traffic (AADT) identifies the average volume of traffic for a one day (24 hour period) during a data reporting year.

Annual Average Daily Truck Traffic (AADTT) – The Annual Average Daily Truck Traffic identifies the volume of truck traffic for a one day (24 hour period) during a data reporting year.

Annual Vehicle Distance Traveled (AVDT) – The annual vehicle distance traveled identifies the distance traveled by vehicles over a 1 year (365 day) period. The AVDT can be grouped according to functional classification of roads and/or vehicle classification strata.

ATR Site – The location of an automated traffic recorder (permanent station) used for collecting traffic volume data, now use the term CCS.

Axle Factor – Axle correction factors can be applied at either the point or system level. That is, axle correction factors can be developed either from specific vehicle classification counts at specific locations, or from a combination of vehicle classification counts averaged together to represent an entire system of roads.

Axle Weight – The weight placed on the road by all wheels of one axle (Oregon DOT).

Blank-Fill – When the value in a field does not consume all of the columns for the field, leading blanks are to be used starting at the left of the field. For example, if a field is five columns wide, and the data value is 250, then a blank-filled representation for this field is _ _ 250.

Continuous Count Station (CCS) – Volume counts derived from permanent counters (ATRs), for a period of 24-hours each day over 365 days for the data reporting year.

Coverage Count – Special temporary count taken on a 24-48 hour basis for a specific segment of road, usually associated with HPMS sections.

Daily Vehicle Miles Traveled (DVMT) - indicates how many vehicles have traveled over the distance of a route, for a data reporting year, when reported as an average day for a given year. (DVMT = AADT X section length)

Extent – Spatial coverage for which the data are to be reported: functional system, NHS, sample, paved etc.

Federal-Aid Highways – All NHS routes and other roads functionally classified as Interstate, Other Freeways and Expressways, Other Principal Arterials, Minor Arterials, Major Collectors, and Urban Minor Collectors.

FHWA – Federal Highway Administration.

Full Extent – A population comprised of all sections of a functional system of public roads, which serves as a statistical universe for HPMS sampling and census data collection.

Full Extent Data – Data that are collected in a census of a whole population, which for HPMS means data collected on all sections of a functional system of public roads.

Functional Systems – Functional systems result from the grouping of highways by the character of service they provide. The functional systems designated by the States in accordance with 23 CFR 470 are used in the HPMS.

Metadata – Describes how data are collected or converted for reporting; explains variations in data that do not warrant the establishment of a collection requirement (e.g., type of equipment used, sampling frequency etc.).

Monthly Average Daily Traffic (MADT) – For a CCS site that operates 365 days per year without failure, the MADT can be computed by adding the daily volumes during any given month and dividing by the number of days in the month.

National Highway System (NHS) – The National Highway System is a network of nationally significant highways approved by Congress in the National Highway System Designation Act of 1995 and redefined by MAP-21. It includes the Interstate System, other roads, and connectors to major intermodal terminals.

Sample Panel (HPMS) – A collection of designated roadway sections within a system of public roads that is stable over time and is used to estimate attributes for the entire system.

Seasonality Factor – Seasonal (or Monthly) factors are used to correct for seasonal bias in short duration counts.

Short Duration Count – Count taken on a 24-48 hour basis for roadway segment-specific locations. These counts may be used in special studies.

Table of Potential Samples (TOPS) – A collection of roadway sections spanning the public road network that provides the sampling frame for selection of the HPMS Sample Panel.

Travel Monitoring Analysis System (TMAS) – the FHWA-provided online software used by States, MPOs and cities to submit data for Federal purposes.

User Profile and Access Control System (UPACS) – Federal Highway Administration's access control for information systems. The UPACS has two major functions: it provides users with a menu of systems that they have access to and provides authorized personnel a mechanism for granting such access. The UPACS provides access control for FHWA's applications through system-generated user IDs and user-supplied passwords and PINs, in combination with individual access profiles created for users by system owners.

Vehicle – Assembly of one or more units coupled for travel on a highway; vehicles include one powered unit and may include one or more unpowered full-trailer, or semi-trailer units.

Vehicle Axle – The axis oriented transversely to the nominal direction of vehicle motion, and extending the full width of the vehicle, that the wheel(s) at both ends rotate.

Vehicle Axle Spacing – For each vehicle axle, the horizontal distance between the center of that axle and that of the preceding axle; the axle spacing for the vehicle's front axles is assumed to be zero.

Vehicle Class – The FHWA vehicle typology separates vehicles into categories, or classes, depending on whether they carry passengers or commodities. There are 13 vehicle classes identified by FHWA, as listed in Appendix C.

Vehicle Counts – The activity of measuring and recording traffic characteristics such as vehicle volume, classification, speed, weight, or a combination of these characteristics.

Vehicle Length – Overall length of a vehicle measured from the front bumper to the rear bumper.

Vehicle Miles Traveled (VMT) – Vehicle miles traveled indicates how many vehicles have traveled over the distance of a route, for a data reporting year, when reported as Annual VMT (VMT = DVMT x 365).

Vehicle Speed – Measure of how fast a vehicle is traveling in kilometers/hour or miles/hour.

Weigh In Motion (WIM) – A measure of the vertical forces applied by axles to sensors in the roadway. This is used to measure the weight carried by trucks to determine the appropriate depth for pavement sections.

Zero-Fill – When the value in a field does not consume all of the columns for the field, leading zeros are to be used starting at the left of the field. For example, if a field is five columns wide, and the data value is 250, then a zero-filled representation for this field is 00250.

Appendix B.   ACRONYMS

3S2	3-axle tractor with a 2-axle semi-trailer
AADT	Annual Average Daily Traffic
AADTT	Annual Average Daily Truck Traffic
AASHTO	American Association of State Highway and Transportation Officials
AAWDT	Annual Average Weekday Traffic
ADMS	Archived Data Management System
ADT	Average Daily Traffic
ADUS	Archived Data User Service
APTS	Advanced Public Transportation Systems
ARTS	Advanced Rural Transportation Systems
ASTM	American Society for Testing and Materials
ATIS	Advanced Traveler Information System
ATS	Average Tandem Spacing
ATMS	Advanced Traffic Management System
ATR	Automated Traffic Recorder
AVC	Automatic Vehicle Classification
AVDT	Annual Vehicle Distance Traveled
BMS	Bridge Management System
CAAA	Clean Air Act Amendments (1990)
CCS	Continuous Count Station
CFR	Code of Federal Regulations
CMS	Congestion Management System
CVC	Continuous Vehicle Classifier
CVO	Commercial Vehicle Operations
DOT	Department of Transportation
DOW	Day of Week
DVDT	Daily Vehicle Distance Traveled
EAL	Equivalent Axle Loading
EPA	Environmental Protection Agency
ESAL	Equivalent Single Axle Loading
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
GIS	Geographic Information System

GPS	Global Positioning System
HOD	Hour of Day
HPMS	Highway Performance Monitoring System
IRI	International Roughness Index
ISTEA	Intermodal Surface Transportation Efficiency Act (1991)
ITS	Intelligent Transportation System
KIPS	Kilopounds (thousands of pounds)
LRS	Linear Referencing System
LTBP	Long Term Bridge Performance
LTPP	Long Term Pavement Performance
LTTP	Long-Term Transportation Plan
MADT	Monthly Average Daily Traffic
MADTT	Monthly Average Daily Truck Traffic
MAF	Monthly Adjustment Factor
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
MAWDT	Monthly Average Weekday Daily Traffic
MAWDTT	Monthly Average Weekday Daily Truck Traffic
MAWET	Monthly Average Weekend Daily Traffic
MOY	Month of Year
MPO	Metropolitan Planning Organization
NEPA	National Environmental Policy Act
NHPN	National Highway Planning Network
NHS	National Highway System
NIT	National Institute of Technology
NPS	National Park Service
OFE	Other Freeways and Expressways
OPA	Other Principal Arterial
PAS	Principal Arterial System
PHF	Peak Hour Factor
PMS	Pavement Management System
PSR	Present Serviceability Rating
PTR	Portable Traffic Recorder
RF	Radio Frequency
SADT	Seasonal Average Daily Traffic
SAWA	Steering Axle Weight Average
SHRP	Strategic Highway Research Program

TEA21	Transportation Equity Act for the 21st Century
TMAS	Travel Monitoring Analysis System
TMG	Traffic Monitoring Guide
TVT	Travel Volume Trends
TWS	Truck Weight Study
UPACS	User Profile and Access Control System
VDT	Vehicle Distance Traveled
VMT	Vehicle Miles Traveled
VTRIS	Vehicle Travel Information System
WIM	Weigh-in-Motion

Appendix C. VEHICLE TYPES

Motorcycles – All two or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handlebars rather than steering wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles.

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.

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. Because automatic vehicle classifiers have difficulty distinguishing class 3 from class 2, these two classes may be combined into class 2.

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 a truck and should be appropriately classified.

In reporting information on trucks, the following criteria should be used:

- Truck tractor units traveling without a trailer will be considered single-unit trucks;

- A truck tractor unit pulling other such units in a saddle mount configuration will be considered one single-unit truck and will be defined only by the axles on the pulling unit;

- Vehicles are defined by the number of axles in contact with the road. Therefore, floating axles are counted only when in the down position; and

- The term "trailer" includes both semi- and full trailers.

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.

Three-Axle Single-Unit Trucks – All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., with three axles.

Four or More Axle Single-Unit Trucks – All trucks on a single frame with four or more axles.

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.

Five-Axle Single-Trailer Trucks – All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.

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.
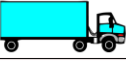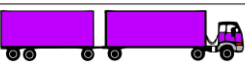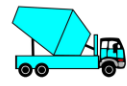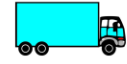
Five or Fewer Axle Multi-Trailer Trucks – All vehicles with five or fewer axles consisting of three or more units, one of which is a tractor or straight truck power unit.

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.

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.

Figure C-1 lists the 13 vehicle category classifications used by FHWA.

FIGURE C-1 FHWA 13 VEHICLE CATEGORY CLASSIFICATION

Class			Class		
Class 1 Motorcycles			**Class 7** Four or more axle, single unit		
Class 2 Passenger cars					
			Class 8 Four or less axle, single trailer		
Class 3 Four tire, single unit					
			Class 9 5-Axle tractor semitrailer		
Class 4 Buses			**Class 10** Six or more axle, single trailer		
			Class 11 Five or less axle, multi trailer		
Class 5 Two axle, six tire, single unit			**Class 12** Six axle, multi-trailer		
			Class 13 Seven or more axle, multi-trailer		
Class 6 Three axle, single unit					

Source: Federal Highway Administration

Certain truck configurations utilize axles that can be lifted when the vehicle is empty or lightly loaded. The position of these axles — sometimes called lift axles, drop axles, or tag axles — affects the classification category into which the vehicle falls. To maintain consistency between visual and axle-based counts, the *TMG* recommends that only axles that are in the dropped position be considered when classifying the vehicle. While this promotes consistency, it may induce difficulty when interpreting summary classification statistics at certain locations. For example, a site may exhibit directional differences in vehicle classification even though the same trucks may be travelling one direction loaded (with axles down) and the other direction empty (with axles lifted).

Appendix D. COMPENDIUM OF DESIGNING STATEWIDE TRAFFIC MONITORING

D.1 CASE STUDY #1: DESIGNING A STATEWIDE TRAFFIC MONITORING PROGRAM - TEXAS DEPARTMENT OF TRANSPORTATION (TxDOT)

D.1.1 INTRODUCTION

This case study examines the processes and technology used in Texas for designing a statewide traffic monitoring program. The State of Texas is the second largest U.S. State by area and population. With 254 counties, Texas has just over 311,000 centerline miles of roadways: 25.7% are State roadways (including highways and frontage roads), 47.3% are county roads, and the remaining 27% are city streets, including those functionally classified as local.

In accordance with 23 CFR 500, Subpart B, the Texas Department of Transportation (TxDOT) operates a traffic monitoring system for highways and public transportation facilities. The traffic monitoring system is based on the concepts described in the *AASHTO Guidelines for Traffic Data Programs* and the FHWA *Traffic Monitoring Guide* (*TMG*).

Background

TxDOT was established in 1917 as the Texas Highway Department and charged with "getting the farmer out of the mud". Within 20 years, it became obvious that information about the number of vehicles using the new roadways was crucial, so beginning in 1936, the Department embarked on an effort to capture this information in what is known today as a traffic monitoring system and traffic data collection program. The first district traffic count maps were published with information from traffic surveys conducted from August 1936 to August 1937, supplemented by short-term counts taken from December 1936 to May 1939 (actual months varied by district).

Program Overview

TxDOT's Transportation Planning and Programming Division is designated as the Department's single source for all traffic data. The Division collects traffic counts via various methods on all on-system roadways statewide. Count on many local and rural minor collector roads are also collected annually via the short-term count program.

TxDOT's Traffic Monitoring System consists of continuous counter operations as well as short-term traffic monitoring, including pneumatic tube counts and manual classification counts. TxDOT has installed and maintains about 350 permanent, continuous traffic data collection sites that include collection of volume, classification, speed, and weight data.

Traffic data is used both internally and externally by countless end users and is routinely provided to TxDOT's Commission, the Legislature, the governor, and the public. Data is used for a wide variety of purposes, including engineering design, engineering economy, environmental analysis, finance, legislation, maintenance, operations, planning, safety, and statistics.

D.1.2 TRAFFIC MONITORING PROGRAM PROCESSES

Continuous Counter Operations

TxDOT's continuous counter operations include the installation, upgrade, repair, and maintenance of in-road traffic data collection hardware at about 350 permanent traffic data collection sites statewide. The sites include automatic traffic recorder (ATR), speed, automatic vehicle classification

(AVC), long-term pavement performance (LTPP), and weigh-in-motion (WIM) data collection sites. TxDOT purchases and installs WIM systems in support of TxDOT's WIM Strategic Plan.

Actual installation of roadway infrastructure is dependent on local district construction schedules. Efforts are coordinated with TxDOT's 25 districts and four regions to meet Federal, State, and local needs, and the system continues to expand at the rate of approximately two new sites per month on average. Where good signal strength is available, TxDOT installs wireless modems rather than using landline communications.

Traffic data is collected remotely via telemetry from permanent traffic data collection sites statewide. The collected and analyzed data is used for producing traffic maps, forecasting future traffic volumes, estimating the frequency of application of wheel, axle, and gross vehicle weight loads on Texas highways, and developing pavement and bridge designs.

Short-Term Traffic Monitoring – Pneumatic Tube Data Collection

TxDOT administers and monitors the work of a contractor who collects on-system traffic data and off-system saturation count data in urban areas, including county roads and city streets throughout Texas. Approximately 75,000 to 85,000 counts are conducted annually. Saturation counts account for approximately one-third of the overall counts, and TxDOT coordinates internally and with metropolitan planning organizations (MPOs) to accommodate State and local needs. Collected data is used to assist in forecasting future traffic volumes.

Pneumatic tube data is also collected by in-house personnel on an ad-hoc basis to meet the volume and classification data needs of special projects, corridor analyses, and travel demand modeling development.

The *TMG* recommends a three-year cycle with 48-hour counts to be effective without unreasonably affecting reliability and addresses the possibility of a five-year cycle by noting that the potential error from a compounded average growth rate can exceed the daily volume variability. In the mid-1990s, the variability of even a three-year cycle was of concern, so TxDOT requested and received approval from FHWA to alter the traffic data collection methodology to collect all on-system data annually with 24-hour counts and to collect off-system data on a five-year rotating cycle. As Texas is a large state, the financial impact is substantial but the modified methodology is more cost effective, and having actual ground truth data from on-system roadways on an annual basis has been valuable. For example, the vehicles miles traveled (VMT) trends are being tracked more accurately.

For many years, TxDOT conducted the pneumatic tube counts with both in-house equipment and in-house personnel. Beginning in the late 1980s, TxDOT contracted out the data collection, but the contractor still used TxDOT equipment. With the award of the latest contract in January 2011, the contractor is responsible for obtaining, maintaining, repairing, and calibrating the data collection equipment. The primary reason TxDOT made the decision to make this contractual change was due to in-house staffing issues.

Short-Term Traffic Monitoring – Manual Classification Data Collection

TxDOT administers and monitors the work of a contractor who collects vehicle classification information relative to the numbers and percentages in the traffic stream based on the FHWA 13 vehicle category classification system. The detailed information of the number of vehicles of different sizes and operating characteristics is critical when planning, designing, constructing, and maintaining the State highway system.

For many years, TxDOT conducted the manual classification data collection with in-house personnel. Beginning in the mid-1990s, with the success of the pneumatic tube services contracts and the continued staffing issues, TxDOT contracted out the manual classification data collection.

Equipment – Collection

TxDOT currently uses both the Diamond Traffic Products Unicorn Limited and the International Roadway Dynamics (IRD) Model ITC as portable road tube classifier/counter equipment for collecting axle and classification data. As noted later, the Trimble Nomad is used to collect GPS data, and the Trimble TerraSync software is used to process the Trimble data files. TxDOT's manual classification contractor uses MioVision Technologies for video data collection.

For continuous counter operations, TxDOT currently uses IRD Model ITC rack mount equipment to collect volume and classification data with loops and Measurement Specialties Brass Linguini (BL) Sensors. For WIM, TxDOT uses both the IRD/PAT Model 190 and IRD iSync equipment with bending plate and Kistler sensors.

D.1.3 INFORMATION TECHNOLOGY TOOLS – ANALYSIS, QUERY, REPORTING

Analysis

TxDOT processes and analyzes statewide and metropolitan area traffic data to meet the needs of the Highway Performance Monitoring System (HPMS), MPOs, and other States. The traffic data certified on an annual calendar basis includes continuous vehicle counts (ATR), 24 hour pneumatic tube axle counts (Accumulative Count Recorders (ACR)), automatic vehicle classification (AVC), speed, and weigh-in-motion (WIM) counts.

Quality control measures ensure that accurate traffic data is available for the publication of traffic maps and reports, the certification of vehicle miles traveled (VMT), the forecasting of future traffic volumes, geometric design, pavement design, urban transportation assignments, and special studies. Special counts are analyzed and used for calculating traffic data estimates and projections and for developing engineering change recommendations.

TxDOT currently uses the Statewide Traffic Analysis and Reporting System (STARS) and is in the process of pursuing enhancements for the traffic data analysis systems. Maps are developed and maintained using ESRI ArcGIS.

Query/Reporting

TxDOT's annual district traffic, urban saturation, and statewide flowband maps for traffic and trucks are available in PDF format via TxDOT's website.

Annually TxDOT also produces an automatic traffic recorder (ATR) report and vehicle classification report that are graphically represented in report format within a MS Excel spreadsheet.

D.1.4 CONTINUOUS COUNTER OPERATIONAL IMPROVEMENTS AND ACCOMPLISHMENTS

TxDOT currently maintains and monitors about 350 permanent traffic counters statewide.

- TxDOT replaced landline modems with internet protocol (IP) modems at more than 95% of the permanent sites. The initial cost to purchase wireless modems was substantial compared with landline modems, but with reduced monthly charges, wireless modems paid for themselves within only 6 months of operation. An added benefit also came in the form of greater reliability with fewer connection problems, which reduced trouble calls and therefore travel costs. TxDOT also now has the capability to reset the modem remotely instead of having to send a technician.

- Efforts are centrally coordinated with the 25 districts and four regions statewide to install road bores, ground boxes, and concrete foundations for new and existing permanent sites. Where available, they piggyback on existing routine maintenance contracts work to have contractors install inductive loop detectors and make saw cuts for sensor slots. Several TxDOT districts are working to develop contracts to install/repair permanent sites. Once completed, the contracts will be available to other districts for implementation.

- The available technology for traffic counter equipment and in-road sensors has improved over time, and TxDOT is in the process of improving the data accuracy at WIM sites by upgrading piezoelectric sensors to quartz sensors.

- Data collection in urban areas is problematic due to congestion and slower speeds, which are outside the acceptable operating conditions of some of the current technology equipment. In addition, in some districts, installation of embedded sensors is not permitted. In some locations, TxDOT installed non-intrusive equipment to collect volume and classification (two bins) data. Several attempts have been made to use Intelligent Transportation Systems (ITS) data from traffic management centers, but the data has been found to have inconsistencies that make the data unusable for planning purposes.

- TxDOT discovered that changing the configuration of the detection array in the roadway for classification to a loop-piezo-loop configuration greatly reduced sensor failure. This change not only positively affected the bottom line, as sensors have high replacement costs, but it also decreased the disruption of traffic flow when repairs are made.

- As needed, district personnel are contacted to reset permanent traffic counters in their area. If needed, electronic components and batteries for replacement are sent to the district personnel, and the central office provides technical support by phone. In addition, detailed instructions on how to reset and configure the electronics are stored in all controller cabinets.

- TxDOT staff monitors and provides feedback from monthly WIM and ATR reports to verify data accuracy. This activity is independent of the traffic data analysis.

D.1.5 SHORT-TERM OPERATIONAL IMPROVEMENTS AND ACCOMPLISHMENTS – PNEUMATIC TUBE

With in-house personnel, TxDOT developed a new software program in three phases to improve the pneumatic tube short-term count program.

Phase 1 – Develop an off-the-shelf system to collect data that incorporates bar coding for the station information and a standard tube counter that produces a standard printer (PRN) file. The developed system uses the Trimble Nomad, through a template that captures bar coding, GPS, and contractor / TxDOT inspector information.

Phase 2 – Create a site-scheduling program in ArcGIS. This scheduling feature allows a TxDOT technician to view the sites through a map-based system. After all the stations in a district have been scheduled, the schedules can be displayed individually or by district, and the schedules are subsequently converted into PDF files and provided to the contractor. Each file contains bar coding information for each site and a map for each station location.

Phase 3 – Create an acceptable count program that imports the bar coding and PRN files from the contractor and TxDOT inspectors into a database. This data is screened using 29 pre-defined data error checks. For example, stations are reviewed to verify that the actual GPS collection points are within 500 feet of the original map location. After the data is screened, two reports are generated. The first report includes the accepted counts by schedule number, and the second report included detailed information of the rejected counts. Both reports are sent to the contractor for invoicing.

Efficiency/Cost Savings

- Using bar coding has eliminated data entry errors. Errors regarding station identification and locations set in the wrong place are easily identified.

- The TxDOT inspector reports are generated through a template in the Trimble Nomad. Since these reports are now paperless, information does not get lost or misplaced. In addition, the information to verify inspector activities, as well as verify issues that might affect contractor payment, is readily available.

- In addition to the reports, pictures can be taken by the contractor and be associated with the site when a count is not acquired. This can provide verification information for the situation, such as when a bridge or roadway is closed.

- By creating this system in-house, the time needed to implement updates or make corrections for encountered problems is typically short.

- With the improvements noted, TxDOT changed the contract to no longer pay the contractor for missing or partial data, such as when a machine fails, when a tube is cut, the count was taken in the wrong location, bar coding information or PRN files are missing, etc.

- When time is money, the new program saved time scheduling the data collection, reviewing the data for payment, and streamlining the process for the creation and writing of reports by TxDOT inspectors.

- The contractor is now required to provide, maintain, repair, and calibrate all data collection equipment. These activities were previously performed by TxDOT personnel.

D.1.6 SHORT-TERM OPERATIONAL IMPROVEMENTS AND ACCOMPLISHMENTS – MANUAL CLASSIFICATION

Historically, for the Manual Classification Data Collection Program, individuals would work in crews with each taking a block of time of the 24-hour count period, and the individuals would be stationed on site collecting the data in real time. With the most recent contract award in August 2010, the contractor proposed and TxDOT Administration approved the use of video technology to record the 24-hour count period. Then, the video is counted manually by the contractor at a later time. Gaining approval for such a paradigm shift regarding operations was an accomplishment that resulted in several advantages to TxDOT:

- When issues are identified, having access to the videos permits a recount for verification; and

- Even though the contractor has an investment in video capture equipment, since the overall travel costs are reduced, the contractor was able to pass the cost savings onto TxDOT with a lower per count cost than with the previous contract.

D.1.7 LESSONS LEARNED

- Positive change rarely happens quickly, so be persistent. For example, the in-house ArcGIS system for scheduling and processing the pneumatic tube counts took almost a year to develop from conception to approval and then another three years until implementation; and occasionally TxDOT still deals with issues as unique situations arise.

- Acquire, train, and recognize qualified staff. Having people that know and understand traffic data is the "priceless" factor when attempting core business process changes and system upgrades.

- Develop, maintain, and update, as necessary, detailed documentation of historical information, business processes, definitions, assumptions, programming source code, manuals, and other relevant information.

- In spite of the challenges and obstacles faced, it is vitally important to have a vision while maintaining the flexibility to be adaptable. Always be mindful and take advantage of opportunities; you may not get a second chance.

D.2 CASE STUDY #2: DESIGNING A STATEWIDE TRAFFIC MONITORING PROGRAM - IDAHO TRANSPORTATION DEPARTMENT (ITD)

D.2.1 INTRODUCTION

This case study examines how the statewide traffic monitoring program at the Idaho Transportation Department (ITD) supports business needs and how the program is used to comply with Federal traffic data reporting requirements. Idaho was selected to represent the group of small state DOTs, in terms of centerline miles, as an example of best practices in the development and use of a traffic monitoring program.

Background

The Division of Highways, Roadway Data Section (RDS) is responsible for managing the traffic program, including the collection, analyses, reporting, and retention of statewide traffic data and the management of the traffic related databases.

The Roadway Data Section accomplishes this goal by managing traffic-related databases, as well as locating, designing and installing traffic counting sites statewide, and utilizing automatic traffic recorders (ATRs) and short-term count devices. Ultimately, the RDS analyzes and presents the data to a broad variety of clients – ranging from the Federal Highway Administration (FHWA) to public consumers.

Program Overview

Idaho began its automated traffic monitoring program in the early 1950s with the installation of the first ATR in the state. Currently, the RDS maintains approximately 225 permanent data collection sites. The majority of these sites collect a variety of classification, volume, and count data, while 26 sites specifically collect Weigh In Motion (WIM) data. Additionally, each year ITD lays down over 2,200 portable counts at more than 600 stations. The Roadway Data Section maintains all of the ATR and portable count equipment, collects the data, and processes it into a readable format. This information is available to internal and external customers.

ITD utilizes the *TMG* as a blueprint for its traffic monitoring program. From that foundation, the department has integrated other guidelines and established a network of traffic devices and processes. These processes determine everything from the frequency of collection to the methods of reporting, and they have been developed over the years to reflect the needs of ITD and its customers. Ultimately, The Roadway Data Section collects and processes this data in order to meet ITD internal and external needs, such as State and Federal reporting.

A multitude of reports are eventually made available to clients of the Idaho Transportation Department. Many reports are posted to the ITD website, while other detailed information is formatted and submitted electronically to meet FHWA requirements.

Clients of this data can include municipal planning organizations (MPOs), local highway districts, FHWA, law enforcement, and others. ITD strives to create an atmosphere of participation when it comes to working with other agencies. In fact, the department works with other States and highway districts frequently to provide comprehensive and consistent information sharing.

For example, Ada County Highway District (ACHD), which maintains the roadway system for the largest urbanized area in the state, routinely provides speed and/or volume data. At the same time, ITD provides ACHD with copies of the ITD portable count schedule. This allows for coordination between the two agencies, and reduces redundant data collection.

D.2.2 Traffic Monitoring Program Processes

This section discusses the business processes, equipment, and information technology (IT) tools that are used with the ITD traffic monitoring program to support data collection, analysis, and query and reporting functions.

Statewide traffic data collection within Idaho follows a well-established, pre-determined order of business. It begins with equipment maintenance before each collection season, followed by scheduling and collection. The process continues with data processing and analysis, and results in reporting. Some activities occur throughout the year, such as continuous count collection and ATR installation and maintenance. All of these factors go into planning each year's business needs.

Since its inception, the *TMG* has been used by ITD as an outline for comprehensive traffic monitoring. In addition, other sources (from other FHWA programs to vendor processes) complement the *TMG* and enhance Idaho's processes for monitoring and validating statewide traffic data. Ultimately, more than just the *TMG* provide a means for assuring and controlling the quality of data being reported by Idaho.

Equipment – Collection

ITD collects traffic volume data at sites statewide. There are approximately 225 permanent traffic counting sites in Idaho using ATRs. Weigh-in-motion (WIM) data is collected at 26 permanent WIM stations statewide.

ITD uses four primary equipment vendors for collecting statewide traffic data:

- Diamond Traffic Products of Oregon makes volume, speed, and classification equipment;
- Wavetronix, LLC of Utah also makes volume, speed, and classification equipment;
- Electronic Control Measurement (ECM) of Paris, France provides many of the WIM systems; and
- IRD of Canada manufactures several WIM systems used by ITD.

Most commonly, ATR sites collect speed and length data by bins. Straight volume collection occurs next in frequency; and individual vehicle data is collected third in order of frequency. The selection of data types for each permanent ATR site is based on various criteria, including roadway geometry, vehicle volumes, and the availability of power and phone at the time of installation.

New sites are added each year, and the locations are largely determined by special request and funding from the districts.

Information Technology Tools – Collection

The RDS uses several tools to perform collection activities. For short-term counts, the mainframe is used to start the information technology step of collection. On the mainframe, schedules are built for each field person and are printed out for them to take into the field. Then an internally developed DOS application (IDASITE) is used to generate a file that contains pertinent information about the location and geometry of each scheduled count. This file is sent out with the field personnel.

In the meanwhile, Geographical Information Systems (GIS) are used to create maps of where the collection should occur. The maps specify where the station and HPMS sample collection should occur, and are saved as PDF files. They provide the field personnel with a practical reference to use in the field. The field personnel then use the IDASITE software to load up the IDASITE files they received. Specific information about the location and the data collection filename are then tied to that original IDASITE file, and it is sent back into the office along with the data file for processing. Office personnel then tie all of this data together and load it into the recently implemented TRAffic DAta System (TRADAS).

Meanwhile, a series of modems are used to retrieve ATR data on a nightly basis. This continuous data is placed in TRADAS, thus making TRADAS the central storage system for traffic data collected by field personnel and by the ATRs.

Information Technology Tools – Analysis

ITD uses traffic data for many analysis scenarios, and also uses a multitude of platforms and applications. In the mainframe environment, SAS is primarily used for analyzing data and preparing data for reporting. Meanwhile, ITD utilizes in-house software applications, SAS for Windows, MS Excel, and other tools to analyze data in a MS Windows environment.

For example, the vehicle miles traveled (VMT) is calculated using mainframe SAS, and then exported to the Windows environment where Microsoft Excel is used for final analysis. With the implementation of the new TRADAS system, and the general move away from the mainframe platform, more and more analysis will be done in the future using Structured Query Language (SQL).

Information Technology Tools – Query/Reporting

Many tools are currently available to report traffic information. On the mainframe, several SAS jobs provide reports, including volume and classification reports. Furthermore, analysts are able to query the data in order to perform quality assurance steps. In the future, however, the data will be migrated to a Microsoft Windows client environment.

The newly implemented ITD Traffic Asset Management System (TAMS) intends to link count data to location in order to merge the two types of data – pavement and traffic. This allows for greater power in comprehensively reporting the state of the roads. TRADAS will be the source of count data, while TAMS becomes the source of count locations, thus moving from the mainframe environment; TAMS will generate reports to internal ITD users. The department's website will continue to provide data to outside users.

There are a wide variety of reports available to external customers as well, particularly for WIM and ATR data. These reports include monthly, annual, and specialty reports that can be accessed and downloaded from the ITD website. The reports are illustrated in Figures D-1 through D-3.

Figure D-1 is a map of District 1 in north Idaho. This map identifies the locations of ATR sites (pentagonal shape), Weigh-In-Motion sites (rectangular shape), and sites that are inactive (circle shape). By selecting a site with the cursor, as illustrated in Figure D-2, a picture appears, with information about the location of the specific permanent ATR site (#46). The location information displayed includes the route-milepoint, distance from intersecting route(s), and segment code ID.

Also included in Figure D-4 is an example of a Flow Map that ITD publishes on its website. This series of maps shows Average Annual Daily Traffic (AADT) at points on the rural state highway system, as well as the entire interstate system. These maps provide an overview of traffic flow throughout the interstate and rural state highway system in Idaho. District-specific maps are also available. Furthermore, commercial maps show the flow of commercial traffic through the State. Figure D-4 shows a partial view of District 1, between Coeur d'Alene and the Canadian border.
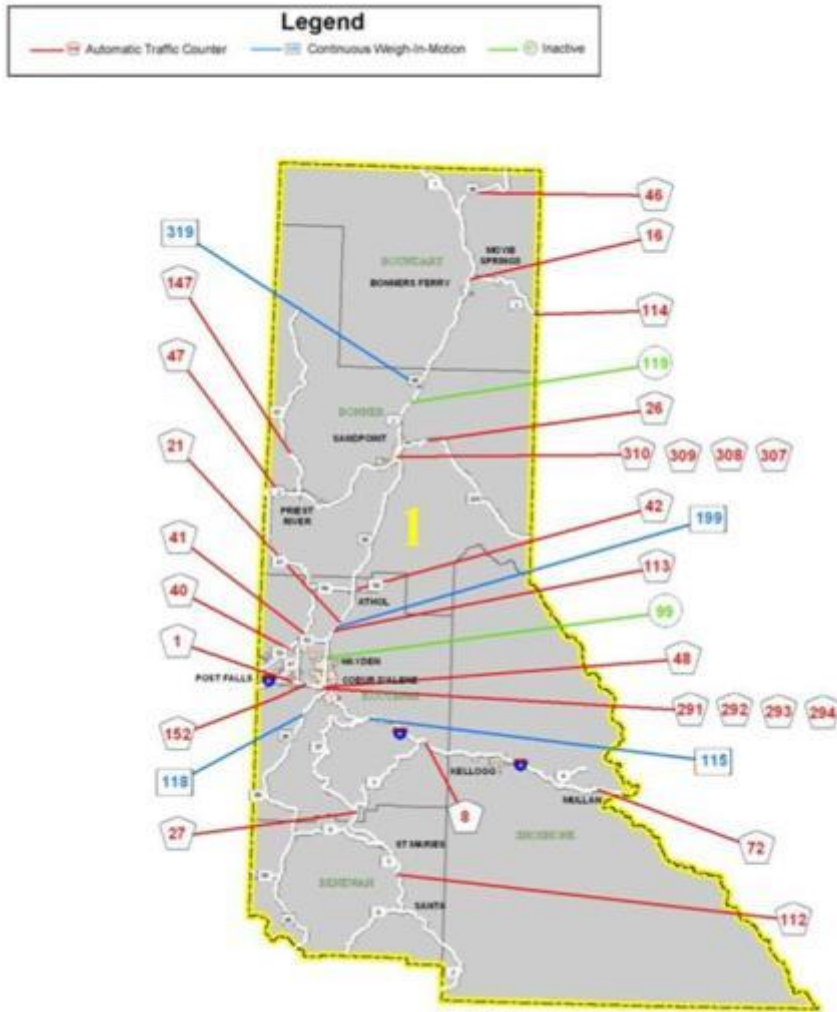
Source: Idaho Transportation Department.

FIGURE D-2   PERMANENT SITE LOCATION
ATR #46

Source: Idaho Transportation Department.

By clicking on the permanent site #46, a tabular report appears as illustrated in Figure D-3. This report includes average daily traffic for each month and an annual average daily traffic count over a multi-year period. This data is also available in comma delimited, tab delimited, and space delimited formats as noted at the bottom of the report.

F<small>IGURE</small> D-3   ATR T<small>ABULAR</small> R<small>EPORT</small>
S<small>ITE</small> #46

Counter #46 - Copeland
Automatic traffic recorder

| Average Daily Traffic | Published reports | Combine Sites | Your Cart |

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual 24-hr Avg.
1990	495	508	675	842	920	1204	1595	1720	1130	849	650	471	925
1991	463	572	705	876	1000	1221	1755	2214	1398	985	752	660	1054
1992	613	681	730	1055	1127	1314	2026	2559	1373	991	774	585	1158
1993	561	596	669	870	1016	1208	1823	1826	1258	984	714	617	1015
1994	616	607	752	873	950	1110	1613	1496	1181	918	705	584	953
1995	603	639	747	935	1000	1098	1531	1550	1220	962	784	618	974
1996	583	639	740	930	981	1112	1529	1576	1147	906	665	526	945
1997	578	634	683	886	1010	1167	1498	1528	1126	934	749	639	953
1998	588	693	819	956	1029	1119	1411	1400	1122	782	704	600	935
1999	627		851	963	1016	1131	1524	1540	1217	974	802	681	
2000	667	751	870	946	1025	1126	1503	1511	1179	960	779	675	999
2001	679	712	819	876	1039	1132	1487	1517	1049	835	766	598	959
2002	630	707	775	946	892	1061	1430	1472	1187	944	813	694	963
2003	681	735	775	876	922	1052	1387	1367	1063	925	755	667	934
2004	637	740	825	913	946	1099	1418	1350	1221	1054	818	684	975
2005	651	753	843	912	1036	1128	1432	1424	1084	912	843	700	977
2006	688	773	875	986	1119	1194	1531	1555	1225	1006	836	726	1043
2007	716	752	851	984	1107	1398	1674	1792	1318	1154	1027	766	1128
2008	707	772	911	938	1123	1141	1508	1613	1192	986	848	632	1031
2009	687	718	783	863	1063	1122	1537	1573	1200	989	848	714	1008
2010	709	793	916	1014	1117	1160	1739	1720	1282	1027	853	723	1088

This Data is also available in the following forms: Comma Delimited , Tab Delimited and Space Delimited.
Right-Click and 'Save Target As' to download a copy.
For a graph of June average daily traffic from year to year -- click here.

Source: Idaho Transportation Department.

FIGURE D-4   PARTIAL DISTRICT 1 FLOW MAP
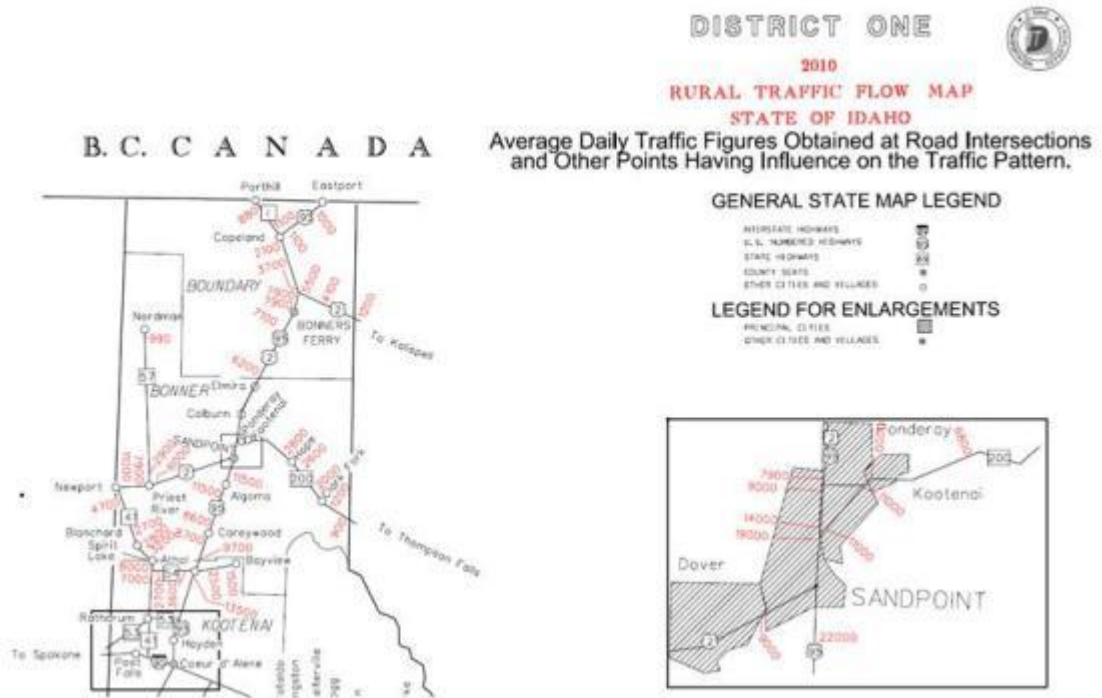
Source: Idaho Transportation Department.

D.2.3   SIGNIFICANT ACCOMPLISHMENTS

Because traffic monitoring is such a specialized industry, the software needed can often be specialized as well. ITD has developed a multitude of specialized tools to schedule, collect, analyze, and report data. Some software has been around for many years (such as IDASITE and a host of SAS programs), while other systems have come online much more recently (such as ITD's customized version of TRADAS).

Even as technology changes and the software itself changes to meet the changing requirements, the process itself remains sound. For example, as ITD moves away from the mainframe environment, the IDASITE software will be moved as well. However, because the business requirements are being met efficiently, only some minor software changes will be made in order to reflect the new environment. The manner in which the software is used will not change. The business of maintaining, collecting, analyzing, and reporting will continue to follow established business practices.

With the implementation and further development of the newly installed TRADAS, customized reports are expected to become more easily produced ad hoc and opportunities will arise to provide more information in a web environment.

D.2.4   LESSONS LEARNED

Over the years, personnel, technology, and processes have changed. ITD has learned a few lessons along the way. These lessons include challenges associated with implementing a traffic monitoring program, and recommendations for how to address the challenges. ITD's experiences offer practical guidance to similar sized State DOTs in enhancing their traffic monitoring programs.

There are two main areas where ITD has learned important lessons in maintaining an effective traffic data collection and reporting business model. The first involves strong cooperation and coordination of work, and the second involves a strong business process around testing.

Coordination and Cooperation

The State of Idaho is largely unpopulated and primarily rural in nature. With only six urbanized areas and a handful of small urban areas, the majority of roads are rural in character and location. This makes gathering traffic data more time-consuming and difficult, because the portable counters take time to set up and maintain for the required 48 hour counts; not to mention that it could take a field person hours to get to the location. Add into these limitations the seasonal issues that occur. Forty eight hour short term counts can only occur for eight months out of the year in the southwest portion of the State (the desert region), with significantly shorter periods in the more mountainous regions in the northern "panhandle" and the east.

With limited personnel and time, the Roadway Data Section has spent a great deal of time trying to develop the best methods for scheduling portable counts and sharing information. By doing so, ITD can gather data more efficiently and provide a more comprehensive look at traffic in the State of Idaho. The Roadway Data Section continues to examine new technologies, never shrinking away from the ever-growing data requirements of the State and Federal government.

ITD has learned that by working cooperatively with others in the transportation industry, knowledge can be more comprehensively obtained and shared. Because ITD works with other groups, such as Ada County Highway District (ACHD), the Washington Department of Transportation, and others, data collection redundancy is reduced greatly through increased schedule coordination.

In previous years, the HPMS Coordinator simply provided a list of sections to the traffic monitoring group, broken down into three collection years. The person responsible for scheduling followed that list for each year. In scheduling portable counts, the Roadway Data Section has worked with Idaho's HPMS Coordinator and established a more integrated method of scheduling.

Finally, the personnel in the field and the personnel in the office maintain close contact. Those who go out into the field routinely call into the office should questions arise, and the Roadway Data Section treats any calls from those out in the field as high priority. This close contact allows for a quicker resolution of any issues or concerns. It also makes the entire process from scheduling to collection to analysis cohesive.

The common thread is communication inside and outside of ITD. Because of information sharing, ITD maintains a consistent traffic monitoring system.

Testing

The Roadway Data Section spends a great deal of time and effort in maintenance-level and implementation-level testing. Maintenance ATR testing is exactly what is implied – maintenance checks are routinely run on counters to verify their accuracy. The field personnel perform manual counts, while the corresponding ATR collects volume data. The manual and continuous data are analyzed in the office to verify no systemic issues exist.

Field personnel perform manual checks against classifier sets. This acts as a refresher on setting classification counters and also verifies that the classifier hardware works prior to the traffic collection season starting. These ongoing maintenance tests occur regularly and are an integral part of how ITD does business.

Implementation testing tends to be more limited, because it revolves around the implementation of new software systems or types of hardware. The organization spends a great deal of time reducing the risk of failure by testing for as many potential issues as possible. By spending time testing, ITD assures a lower chance of systemic issues affecting the business processes from collection to reporting.

Future Enhancements

The Roadway Data Section has several short-term and long-term enhancement goals. They revolve around integration and development of the newly implemented systems and technologies.

Short-term enhancements will include integrating TRADAS data with the pavement management system implemented in the winter of 2010. At the same time, ITD's Location Referencing System will also be implemented in the pavement management system, making the data streamlined, cohesive, and complete.

The long-term enhancements include developing new reporting systems and tools. Standardized reports outside of those within the TRADAS software will be developed for more customized analysis. Ad hoc reporting tools will need to be implemented to handle specialized requests for information. Both of these are currently being researched, and business processes developed.

Besides these specific long- and short-term goals, the ITD recognizes that more changes will be occurring over the next few years. With reporting requirements changing on a more frequent basis, and technology rapidly advancing and changing the very environment in which data is stored and analyzed, the Roadway Data Section has been working towards developing a system that can handle unforeseen developments. This flexibility leaves the door open for more enhancements and refinement of existing systems in the future.

D.3 CASE STUDY #3: STATE DATA SHARING – COLORADO DOT (CDOT)

D.3.1 INTRODUCTION

This case study discusses the state data sharing activities of short term traffic count data between the Colorado Department of Transportation (CDOT) and local agencies in Colorado. This program has incorporated volume counts from vehicles as well as pedestrian and bicycle counts. This traffic data are submitted to CDOT and then incorporated into CDOT's traffic database and shared through a web traffic data application.

Background

The Traffic Analysis Unit (TAU) is responsible for the development and maintenance of the traffic monitoring program at CDOT. During the fall of every calendar year, TAU staff begins the process of contacting various local agencies for the submittal of their traffic data to CDOT. These local agencies include cities, counties, and metropolitan planning organizations (MPOs). Data must be submitted to CDOT by December 1 of every year in order for CDOT staff to have sufficient time to convert and submit the raw traffic data. Once traffic data is sent to CDOT, TAU staff converts the data into a TRADAS-readable format and submits and processes the data through TRADAS for incorporation into the traffic database. TRADAS then incorporates monthly, seasonal, and axle factors calculated from automatic traffic recorders (ATRs) into the raw count to calculate an AADT for that segment of road. Once annual traffic processing phases are completed, a statistically calculated or unofficial AADT is produced by TRADAS. These numbers are then rounded to produce a published or official AADT.

D.3.2 DATA SHARING ENVIRONMENT

The official AADT produced by CDOT is then able to be shared to local agencies through a web traffic data application called AVID. AVID allows traffic data to be seen spatially, incorporated from various data sources, analyzed once data is loaded into the traffic database, and shared within CDOT and external agencies. Traffic data given by local agencies to CDOT must also submit a latitude/longitude for each count in order for the data to be shown spatially in AVID. For the raw traffic counts that local

agencies submit, they are given in return a statistically calculated AADT. This traffic data can be downloaded by local partners from the AVID website without waiting on a response from TAU staff.

D.3.3 USE AND BENEFITS OF SHARING DATA

The use of sharing data through local agencies has been a tremendous asset to CDOT. During the annual Highway Performance Monitoring System (HPMS) submittal, there have been several HPMS sections that were flagged by CDOT staff due to significant changes in the AADT. With the counts collected both by CDOT and local agencies on these sections, TAU staff was able to defend the significant changes in AADT by showing two counts that were collected in the same section of road by two different agencies in the same year. Traffic counts by local agencies on CDOT highways have also been used in the development of the annual traffic file that CDOT produces for CDOT owned and operated highways. CDOT had collected a count in the City of Longmont on a CDOT-owned highway that was nearly double that of a count that was collected by Longmont traffic engineering staff. When looking at nearby traffic sections and historical AADTs, it was determined that the count collect by the City of Longmont was more accurate than the CDOT collected count.

There has also been considerable cost savings by CDOT from the submittal of traffic data from local agencies. Since 2008, CDOT has received 3,946 short-term counts from local agencies. With the average cost of a short-term count by CDOT's contractor being $100, the cost savings from the data sharing program have been approximately $400,000.

D.3.4 LESSONS LEARNED

There were several lessons that were learned in the development of the data sharing program at CDOT.

- Standard data format submittal. When the data sharing program was first introduced, CDOT had requested local agencies to submit their traffic data using a CDOT-developed standard data submittal spreadsheet. The reason for this initial spreadsheet development was to allow a one-step process from the submittal of local agency traffic data into CDOT's traffic database. This spreadsheet proved to be very time consuming and challenging for many local agencies because their raw traffic counts are converted into many different formats, including Adobe PDF, MS Excel and text files. Due to these challenges by local agencies, CDOT has allowed local agencies to submit their raw data in any format, with CDOT staff converting the data into an appropriate format for loading into TRADAS.

- Data types/intervals. In order for TRADAS to calculate an AADT properly from a short-term traffic count, data must be a bi-directional volume count with a time interval of at least 24 hours. There were several cases where local agencies were submitting different types of counts such as turning movement and travel time counts that could not be incorporated into the TRADAS database. In addition, several of the counts that were submitted were shorter intervals from the 24-hour minimum requirement.

- Local Agency QA/QC steps. While CDOT has many steps in determining whether a CDOT collected count should be accepted or rejected, local agencies must have QA/QC steps in place to determine whether their raw traffic count is acceptable or not before submittal to CDOT.

D.3.5 FUTURE ENHANCEMENTS

- Data from other jurisdictions in Colorado. While CDOT has received traffic data from 15 local agencies within the State, there is significant growth potential in the data sharing program. There are 271 incorporated municipalities in the State and 64 counties in the State; with the total share of local agencies involved in the data sharing program in 2011 at around 4%. CDOT will continue to build partnerships through its Statewide Traffic Data Committee to show the benefits of the data sharing program and to continue to encourage local agencies to submit their traffic data to CDOT.

- Incorporating local data in AADT calculation. As traffic data is submitted by local agencies on traffic sections also collected by CDOT, business processes and rules must be developed to allow the incorporation of local agency data into the calculation of an AADT for a particular section of road.

D.4 CASE STUDY #4 (PART 1): LOCAL AGENCY DATA SHARING DELAWARE VALLEY REGIONAL PLANNING COMMISSION (DVRPC)

D.4.1 INTRODUCTION

This case study illustrates how the sharing of traffic data is accomplished from the perspective of a local agency, represented by the Delaware Valley Regional Planning Commission (DVRPC). The types of traffic data shared include Annual Average Daily Traffic (AADT) volume and classification counts for vehicles, as well as pedestrian and bicycle counts.

Background

The Delaware Valley Regional Planning Commission (DVRPC) is the Federally designated Metropolitan Planning Organization (MPO) that serves the greater Philadelphia region. The region includes nine counties, five of which are located in Pennsylvania and four counties that are located in New Jersey. DVRPC's responsibilities include planning for the immediate and long-term transportation needs in the region. The MPO relies on partnerships and sharing of data and information with the Pennsylvania Department of Transportation (PennDOT), New Jersey Department of Transportation; county and local governments; and regional transportation providers in order to develop the Long-Range Transportation Plan and the Transportation Improvement Program (TIP). One of the most important types of data shared between agencies is traffic data, which is used for assessing environmental impact to the region, addressing congestion, and managing projects to preserve and maintain the existing transportation infrastructure.

DVRPC has also taken a leadership role in Transportation Operations (TO) by providing a forum in which a comprehensive Transportation Operations Master Plan has been developed for the region. While implementing the Master Plan is the responsibility of individual agencies, the plan identifies the services and projects that support ITS and operations in the region.

Data sharing is also exemplified by the Regional Integrated Multi-Modal Information Sharing (RIMIS) project. This is an information exchange network oriented to traffic and transit operations centers, state police, county 911/emergency management agencies, and local emergency responders. Its primary objective is to provide situational information about incidents, maintenance and construction activity, and special events that impact the transportation system. In addition to event information, RIMIS is a common platform to distribute CCTV images, and eventually VMS messages and traffic speeds.

The next section explores the technology and tools that are used for sharing traffic data in the Delaware Valley region.

D.4.2 DATA SHARING ENVIRONMENT

The primary tool used for sharing traffic data is referred to as Traffic Count Viewers. These viewers are available on the DVRPC website. The traffic viewers are connected to the traffic count database, so that when counts are entered or updated in the database, they appear on the website and are accessible to the public. Figures D-5 through D-7 illustrate the basic functionality of the Traffic Count Viewers, which incorporates components including Google maps and tabular reports.

Figure D-5 shows the map of the region prior to the overlay of traffic count locations.

FIGURE D-5   DVRPC MAP OF REGION

Source: Delaware Valley Regional Planning Commission.

Figure D-6 illustrates the map of the region with the overlay of traffic count locations, indicated by the dots on the map. These dots represent counts taken between 1995 and the current time. A slide bar feature on the left side of the map allows the user to zoom in/out within the map window. Selection options are located to the right of the map. These options include the following:

- Data Filter – allows the user to select a:

  - Range for the count year;

  - Range for AADT counts from/to;

  - Road name;

  - Municipality; and

  - Type of data to display, i.e. volume, classification, etc.

- Zoom to a municipality – allows the user to zoom to a specific municipality within the region (there are 357 municipalities in the DVRPC region).

- How to Use – provides instructions for the use of the tool bar above the map.

- Contact and Disclaimer – contact information at DVRPC and disclaimer regarding use of the data. This is also important, as information beyond that available on the viewers can be obtained by contacting the Office of Travel Monitoring. Such information includes speed data, intersection turning movement counts, vehicle classification detail reports and counts at the 15 minute increment level of detail.

FIGURE D-6   DVRPC REGION TRAFFIC COUNT LOCATIONS
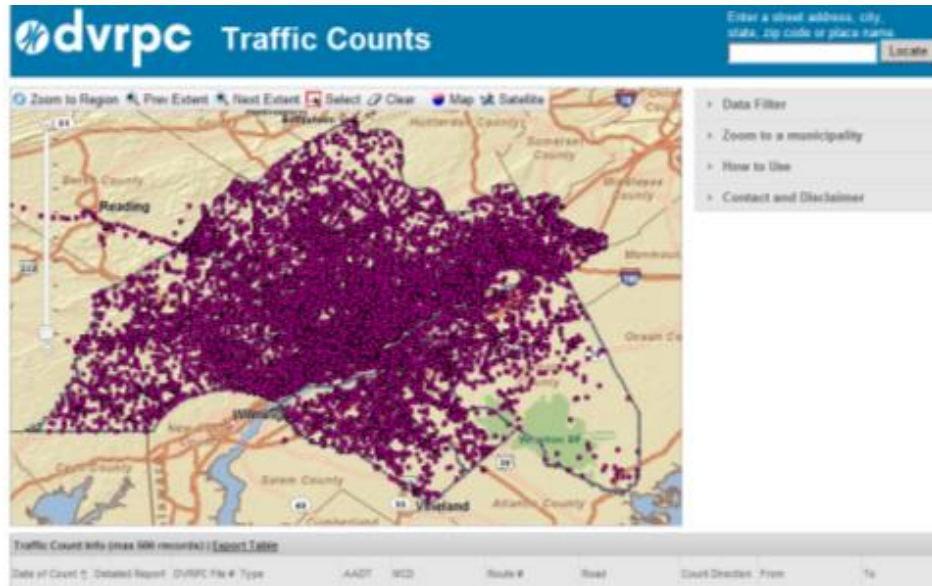
Source: Delaware Valley Regional Planning Commission.

Figure D-7 illustrates the type of report that is generated when the 'select' option is used for two traffic count locations on Wissahickon Avenue between Hortter Street and Westview Street. This figure also shows the report that is generated with information including the date of the count(s), the Annual Average Daily Traffic (AADT) at the location, the road where the counts were taken, direction counted, and "from" and "to" limits (intersecting roads) of the counted road segment.

FIGURE D-7   DVRPC TRAFFIC COUNTS REPORT

Source: Delaware Valley Regional Planning Commission.

Choosing the "Detailed Report" for a specific count generates a report for that count that contains further location information, the hourly count detail, factors used to calculate the AADT and the a.m. and p.m. peak hour information. In the Figure D-7 example, choosing the count taken 12/17/2002 generates the report shown in Figure D-8.

FIGURE D-8   DVRPC TRAFFIC COUNT DETAIL REPORT

DVRPC - Travel Monitoring

TAKEN BY   DATE: 12/17/2002   PROJECT 23-200   STATION ID:
ROAD: WISSAHICKON AVE SB   ROAD ID: 4003/0060/1515
FROM: HORTTER ST   TO: WESTVIEW ST
STATE: PA   COUNTY: PHILADELPHIA   MCD: 4210160000 - PHILADELPHIA
COUNT DIR: SOUTH   TRAFFIC DIR: BOTH   SPEED LIMIT: 25   FC: 17   TYPE: VOLUME
DVRPC FILE #: 33176   COUNTER #:   9835   WEATHER: F   DATA SOURCE: INTERNAL
COMMENTS:

Hour Beginning	Mon 12/16/02	Tue 12/17/02	Wed 12/18/02
12 AM		47	42
1 AM		12	20
2 AM		10	11
3 AM		5	14
4 AM		17	21
5 AM		73	57
6 AM		329	284
7 AM		914	892
8 AM		894	962
9 AM		512	550
10 AM		324	334
11 AM		304	315
12 PM	267	324	
1 PM	343	314	
2 PM	325	378	
3 PM	410	442	
4 PM	424	456	
5 PM	459	463	
6 PM	428	446	
7 PM	241	250	
8 PM	187	186	
9 PM	162	184	
10 PM	105	138	
11 PM	77	94	
TOTAL		7,116	

SEASONAL FACTOR:	0.997	AADT:	7,010	AM Peak %	12.8	Hour Beginning:	7:00 AM
AXLE CORR. FACTOR:	0.988			PM Peak %	6.5	Hour Beginning:	5:00 PM

Source: Delaware Valley Regional Planning Commission.

Pedestrian and bicycle counts are also provided on the Traffic Count Viewers. Figures D-9 through D-12 illustrate how the pedestrian and bicycle count data is displayed on the map and how reports can be generated for this type of data. When the viewer is first opened, a window appears providing a disclaimer, instructions on use, and contact information for pedestrian and bicycle counts.

FIGURE D-9   PEDESTRIAN AND BICYCLE COUNTS DISCLAIMER, HOW TO USE AND CONTACT INFORMATION
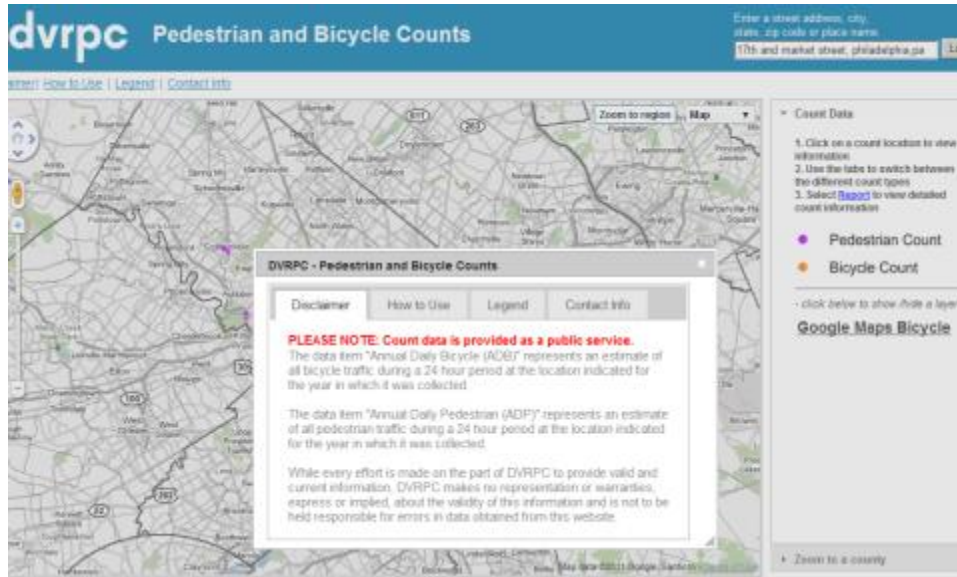
Source: Delaware Valley Regional Planning Commission.

Behind this information box, a map is displayed with dots to represent locations of pedestrian and bicycle counts. A link on the right side of the map adds the Google bicycle facilities in the region to the map.

FIGURE D-10   PEDESTRIAN AND BICYCLE COUNT LOCATIONS
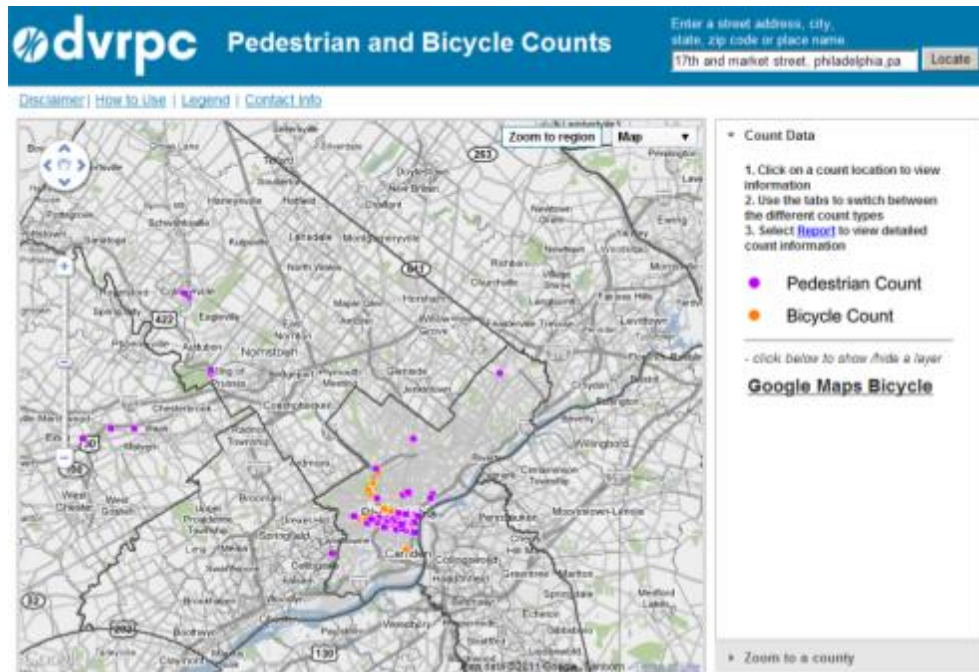
Source: Delaware Valley Regional Planning Commission.

A location on the Walnut Street Bridge between Center City, Philadelphia and University City was selected for purposes of illustration in Figure D-11.

FIGURE D-11   BICYCLE COUNTS
WALNUT STREET BRIDGE; FROM SCHUYLKILL AVENUE TO 23RD STREET
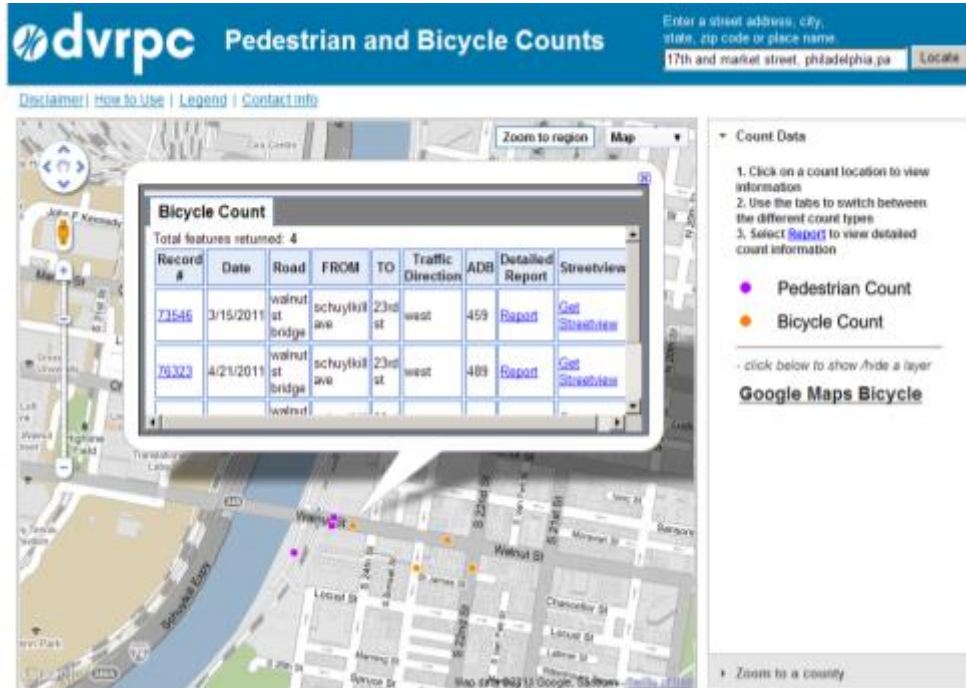
Source: Delaware Valley Regional Planning Commission.

The above figure illustrates the bicycle counts taken on the Walnut Street Bridge (from Schuylkill Avenue to 23rd Street). Similar to the case with the traffic viewer, the table provides a summary of the date of count (usually the first full day of data in a weeklong count), facility, limits of the counted segment, direction of the count and the average of the daily counts within the particular record. An additional function provides a link to Google Streetview so the user can see a street view of the count location.

A detailed report can also be generated for this location, as illustrated in Figure D-12. This report includes further detail of the location, hourly counts during the week that the count was taken, and an average of counts from complete days.

FIGURE **D-12** **B**ICYCLE **C**OUNTS **R**EPORT

DVRPC - Bicycle Count

TAKEN BY JH DATE: 9/23/2010 PROJECT 11-43-040 STATION ID:

ROAD: WALNUT ST BRIDGE ROAD ID: 0003/0091/2834

FROM: SCHUYLKILL AVE TO: 23RD ST FC: 14

STATE: PA COUNTY: PHILADELPHI MCD: 4210160001 - CENTER CITY PHILADELPHIA TYPE: BICYCLE

DVRPC FILE #: 71562 COUNTER #: 1008 WEATHER: DATA SOURCE: INTERNAL

COMMENTS:

Hour Beginning	Wed 09/22/10	Thu 09/23/10	Fri 09/24/10	Sat 09/25/10	Sun 09/26/10	Mon 09/27/10	Tue 09/28/10	Wed 09/29/10
12 AM		11	13	10	8	2	6	18
1 AM		4	9	18	11	7	4	8
2 AM		3	4	7	12	1	7	6
3 AM		2	2	4	2	0	2	2
4 AM		2	4	6	2	0	1	2
5 AM		10	6	4	1	6	9	11
6 AM		24	20	12	6	12	28	20
7 AM		36	50	10	8	25	48	55
8 AM		106	89	18	10	41	72	109
9 AM		83	79	23	9	22	60	80
10 AM		69	55	33	22	39	49	72
11 AM		48	45	40	15	25	46	44
12 PM		40	51	39	12	15	32	27
1 PM		48	27	34	12	21	18	
2 PM	19	29	40	33	28	20	28	
3 PM	25	30	38	42	25	17	30	
4 PM	35	38	35	24	31	37	37	
5 PM	64	65	33	38	25	17	54	
6 PM	36	46	28	39	22	17	47	
7 PM	34	31	35	30	11	20	29	
8 PM	22	24	27	15	15	13	33	
9 PM	31	26	26	15	12	11	15	
10 PM	17	19	31	23	10	12	19	
11 PM	10	15	17	15	2	6	12	
TOTAL	293	809	764	532	311	386	686	454

BIKE SEASONAL FACTOR: 0.949 FACTOR: 1 ADP: 551

Source: *Delaware Valley Regional Planning Commission.*

The next section discusses the role of the data-sharing partners in the exchange of traffic data and information.

D.4.3 ROLE OF DATA-SHARING PARTNERS

DVRPC is not the only entity collecting traffic count data. Consultants regularly collect traffic count information in the preparation of development proposals, etc. The availability of count information from highway operations staff via many forms of technology (loosely grouped as ITS) is growing and will play an increasingly prominent role in the data field. Even private sector entities such as Traffic.com (NAVTEC) are gathering count as well as speed data. All of these varied entities benefit when this data is brought together in a central location accessible to all data users. In DVRPC's database, all traffic counts - no matter the source - are given equal value. On the traffic count detail report, the field "Taken By" identifies the source of the count.

In order to be effective as a source of data, all data must be put through a series of quality control checks. For counts taken by DVRPC staff (approximately 3,000 per year), the field sheet lists the

previous two counts at a location. The new count must fall within a certain percentage of historical data or the count is flagged. When this situation arises, barring a reasonable explanation for the variation, the count is scheduled to be retaken. When a location has not been previously counted, nearby counts provide guidance. For counts submitted by traffic counting partners, the same procedure is performed. But when a count falls outside an expected range and no reasonable explanation for the variance is forthcoming, the count is rejected for inclusion in the database.

D.4.4 LESSONS LEARNED

The primary purpose of using the Traffic Count Viewers is to increase the efficiency of the data collection process. This helps to eliminate duplicate data collection efforts and to support the concept of "collect data once, use it many times".

There are many advantages to this partnership for all providers and users of traffic data, from both the local agency and the state perspective. Several of these are listed below:

- Provides quick and easy access to traffic data for agencies, the consultant community, and the public.

- Reduces duplicate data collection efforts, thereby saving time and money for participating agencies and the consultant community.

- Provides a richer source of traffic data that includes data collection from State, regional, and local government; and private sector efforts. The comprehensive nature of the traffic data creates a better basis for planning decisions.

- Increases the efficiency of the data process by maintaining a central repository of data, lessening the need to consult multiple sources to obtain traffic count data.

D.4.5 FUTURE ENHANCEMENTS

- Expand the traffic count database to include additional types of counts (i.e. intersection turning movement counts, manual classification counts, speed counts) to increase the usefulness of the data to all users.

- Continue outreach to traffic counting entities to encourage them to submit their data so that the database can truly be a regional resource.

D.5 CASE STUDY #4 (PART 2): STATE DATA SHARING – PENNSYLVANIA DOT (PENNDOT)

D.5.1 INTRODUCTION

This case study illustrates how the sharing of traffic data is accomplished from the perspective of a state Department of Transportation, represented by the Pennsylvania DOT (PennDOT). The types of traffic data shared include Annual Average Daily Traffic (AADT) volume and classification counts for vehicles and other types of traffic data shared by PennDOT.

Background

The Bureau of Planning and Research (BPR) is one of 25 bureaus and offices under the Pennsylvania Department of Transportation (PennDOT). BPR's Transportation Planning Division, Traffic Monitoring Section, is responsible for the development and maintenance of the State's portable and permanent traffic counting programs. The Bureau partners with Metropolitan Planning Organizations (MPO), Rural Planning Organizations (RPO), PennDOT Engineering Districts, and vendors. Data that is provided to BPR by those agencies and companies are used for Federal Highway Administration (FHWA) reporting, congestion management, air quality, pavement design, and development of traffic

factors. Over the years, several applications and tools have been developed to assist with timely submittal of traffic data, easy viewing of traffic data for both the public and counting partners, and quick and accurate reporting.

D.5.2 DATA SHARING ENVIRONMENT

Internet Traffic Monitoring System (iTMS)

The main way traffic data is shared is through the Internet Traffic Monitoring System (iTMS). Figures D-13 through D-16 show the functionality of iTMS. Users can search for traffic data by ten different categories that are listed below:

- County;
- Municipality;
- Zip Code;
- State Route;
- State Route and Segment;
- Place Name;
- Street Name;
- Road Intersection;
- Street Address; and
- TMS Site Number.

Figure D-13 shows the initial map when querying a county.

FIGURE D-13   ADAMS COUNTY MAP
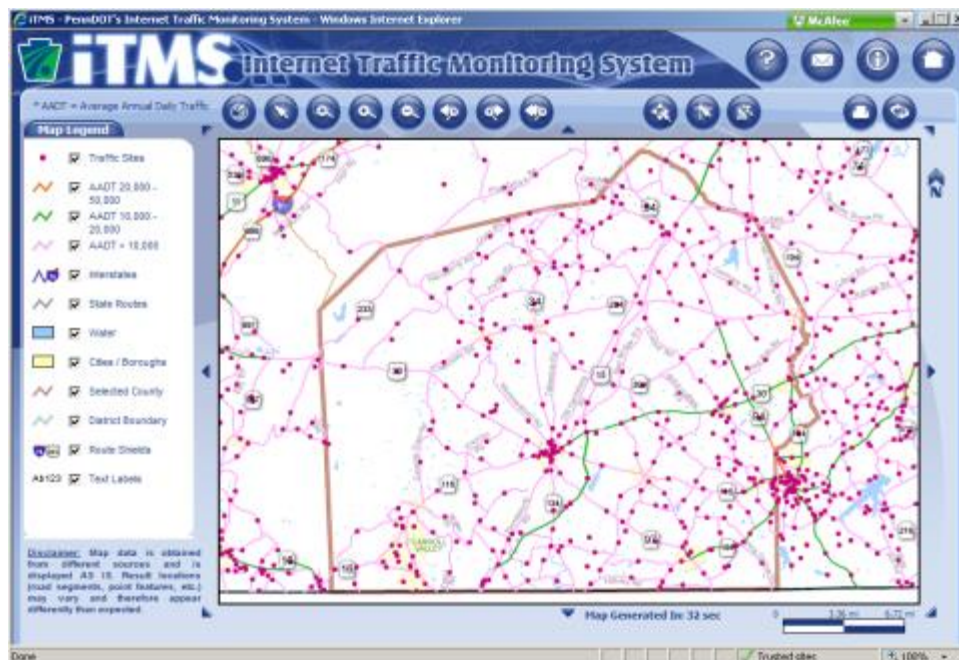
Source: Pennsylvania Department of Transportation.

Figure D-14 illustrates the county map after the user zooms into a specific area. The purple dots represent the area where the traffic counts were collected. All data displayed on the iTMS website is current traffic data. An interactive legend displays on the left of the page, as well as a toolbar across the top of the map. Users can filter what information they would like to display by turning on/off the map icons.

FIGURE D-14   **SPECIFIC TRAFFIC COUNT LOCATION**
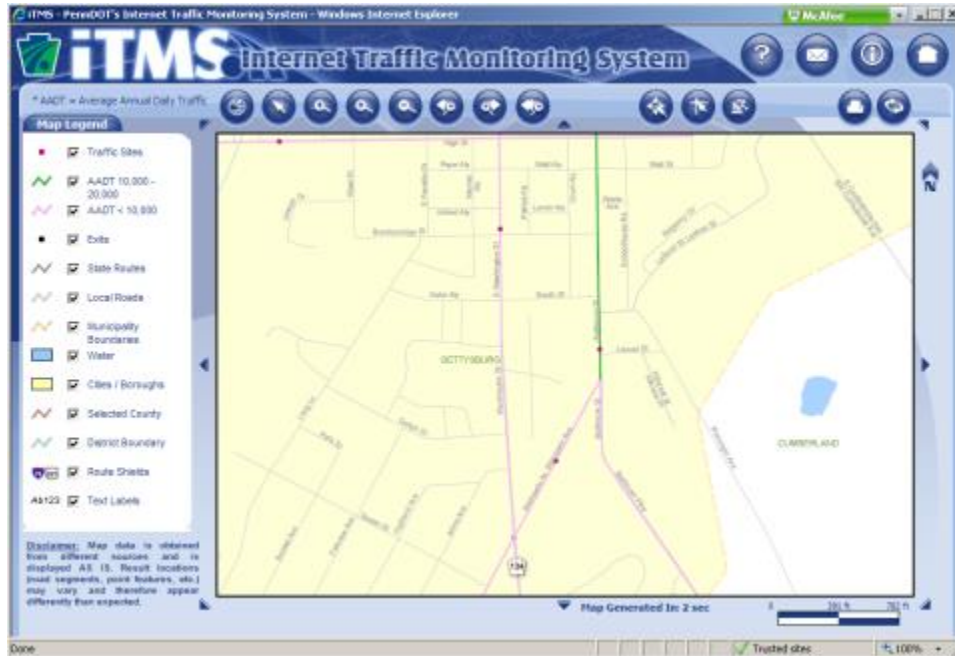
Source: Pennsylvania Department of Transportation.

Figure D-15 displays what type of information the user can expect when selecting the specific site location. The AADT, count frequency, count year, and latitude/longitude are also shown among other information. The user also has the ability to print the information or to go to PennDOT's Videolog application.

FIGURE D-15   SITE SPECIFIC INFORMATION
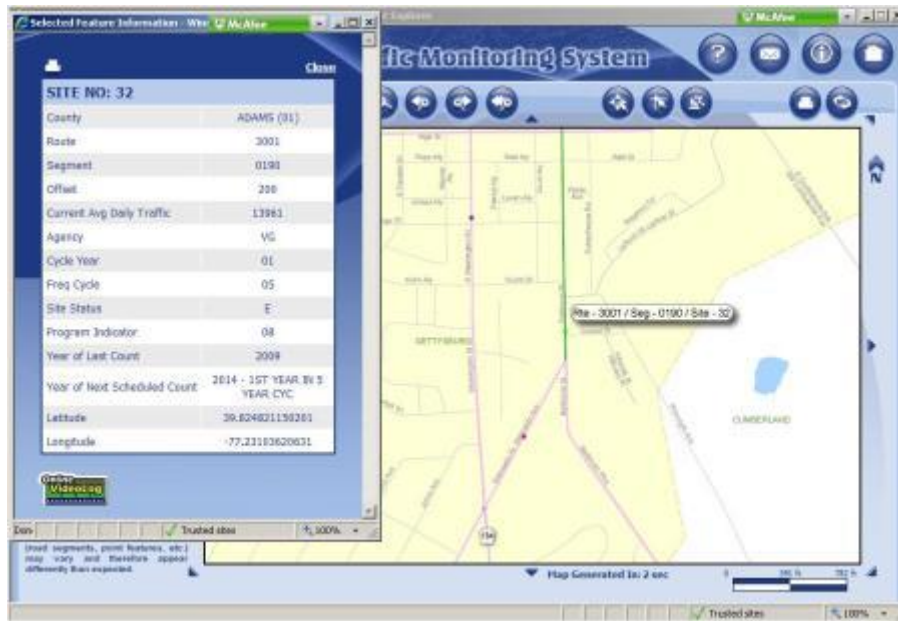
Source: Pennsylvania Department of Transportation.

Figure D-16 displays other information for the site's limit. Some of the information displayed is the specific traffic data including AADT or the ADTT (Average Daily Truck Traffic).

FIGURE D-16   LIMIT SPECIFIC INFORMATION
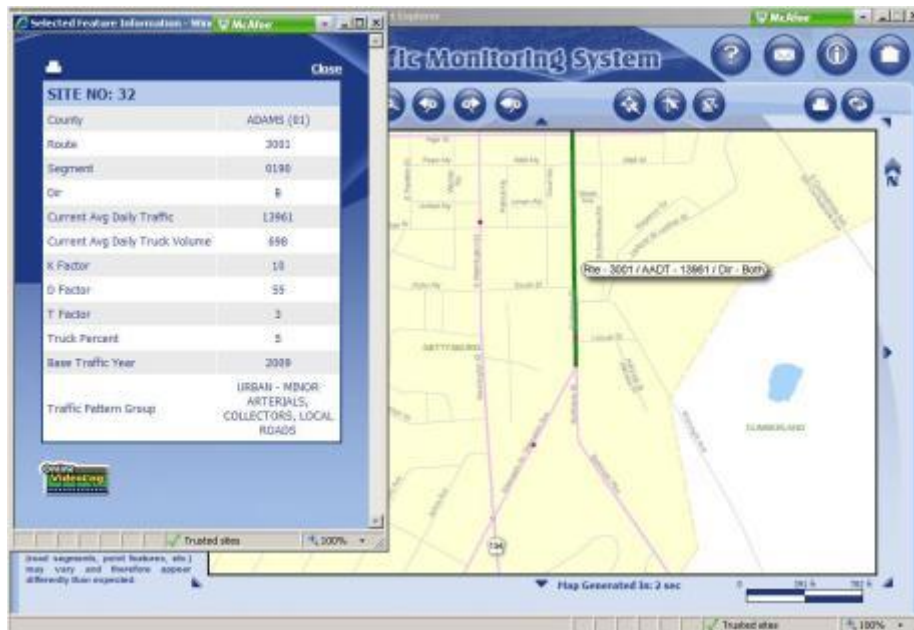
Source: Pennsylvania Department of Transportation.

Traffic Volume Maps and Permanent Site Location Maps:

The traffic data is shared with the public through the Bureau's traffic volume maps. Statewide and county traffic volume maps (Figure D-17) are generated each year and are accessible for the public to

view through PennDOT's website. (www.dot.state.pa.us) The Statewide traffic volume map displays AADT's for all interstates, U.S. and PA routes across the State. The county maps display the AADT's for all State-owned roads in the specific county.

FIGURE D-17   COUNTY TRAFFIC VOLUME MAP
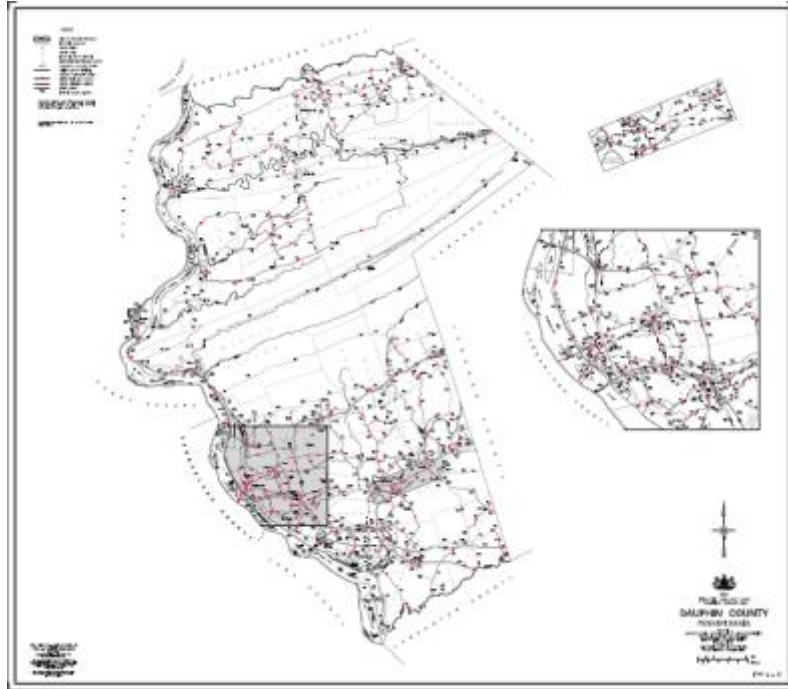
Source: Pennsylvania Department of Transportation.

Permanent traffic sites maps, which show locations and specific information for each of the department's permanent traffic sites are updated each year and can be found on the Department's website. Maps are available by district or county. The maps are used by in house field staff and are also provided to PennDOT Engineering Districts as a reference when planning construction projects. Since the Districts were provided the maps, the Bureau has been able to have permanent sites reinstalled during construction projects. In the past, the sites were destroyed during construction and never replaced.

Internet Traffic Data Upload System (iTDUS)

A second form of data sharing is the internet Traffic Data Upload System (iTDUS). iTDUS is a website that allows our traffic counting partners to submit their data quickly and more accurately. The previous traffic data upload system application was a desktop application. Each year the Bureau mailed out each partner's counts on a floppy disk, which the partners then loaded to the software. Collected raw traffic count data would then be submitted to the Bureau either on floppy disks or via email. Traffic analysts would then have to manually verify the raw data formatting before submission into PennDOT's mainframe system, Roadway Management System (RMS).

iTDUS has automated error checks for formatting before the data files are entered into the database. The user is notified immediately if the file does not meet the submittal format. Traffic Counting Partners are now able to submit a site in less than one minute and the analyst can review the site right after submittal where previously it would take up to a week to get the same file checked and ready for the mainframe.

Automatic Traffic Information Collection Suite (ATICS)

Another form of data sharing is the Automatic Traffic Information Collection Suite (ATICS). ATICS is a web portal that allows the Bureau to generate Station Cards (SCard), Volume Cards (Card3), Class Cards (CCard) and Weight Cards (WCard) for monthly permanent data submittals in minutes compared to hours in the previous application. ATICS also has an ad hoc reporting feature. Currently the web portal has 16 reports using the data from the State's permanent sites. Most of the reports are used for requests such as AADT, AADTT, Volume Detail, and Class Detail among others. Some are used for factors that are stored in RMS and displayed in the Bureau's traffic data book (PUB 601). The last two reports are used with the Bureau's quality assurance program of the State's permanent sites. Manual and tube counts are entered into ATICS; these reports compare the permanent data to the portable data. This program helps the Bureau know how the sites are performing.

D.5.3 ROLE OF DATA SHARING PARTNERS

As stated before, the Bureau receives data from MPOs, RPOs, PennDOT Engineering Districts, BPR field staff, and vendors. All of the traffic counts are collected with guidelines that each vendor, agency, and State employee follows.

The MPOs and RPOs are under agreement with the Department through the Unified Planning Work Program (UPWP). The UPWP specifies the number of counts and due dates the agencies are required to collect and the MPOs and RPOs are paid accordingly. Each year the Planning Partners are given a traffic count packet and are required to submit the data through iTDUS by a specified date.

The Department has a Statewide Traffic Counting Contract that is used as a supplement for collecting traffic count data. After all of the Planning Partners, PennDOT Engineering Districts, and Bureau Field Staff are assigned counts, the remainder of the counts are assigned to the vendor. There is no set amount of counts for each vendor every year. The vendor is paid for only accepted data. If a traffic count is rejected, the vendor is notified. The vendor has the option of resetting the count.

The partners play a significant role in data collection. Without the partners there would not be the quantity of accurate data to be able to display on the websites and report to FHWA.

D.5.4 SIGNIFICANT ACCOMPLISHMENTS

The Bureau has created two websites that has not just helped the Bureau, but, also the agencies that use those websites.

The internet Traffic Data Upload System (iTDUS) enables the partners to submit data quickly and more accurately. It has allowed for quicker upload of the raw data and quicker download for the analysts to get the counts into the mainframe system. With the built in error checks in iTDUS, the system has removed the hours of manual checking the analysts previously did with the desktop version. The website has built-in reports for agencies and analysts to see what data has been submitted. This feature was not available in the previous version. The capability of the report feature means less time for the traffic analysts to verify that all the data was provided to the Bureau.

The Automatic Traffic Information Collection Suite (ATICS) web portal allows the traffic analysts to provide permanent data more quickly. The Bureau generates monthly permanent data submittals in minutes, compared to hours in the previous application. The reports now provide more data to a wider range of business areas. The quality assurance section allows the Bureau to see how the permanent sites are working. The configuration of each site is shown on one page within the portal. Previously the traffic analyst would have to update information through two applications on multiple pages. Along with the monthly submittals; the reports, station configurations, and quality assurance links have saved the Bureau hours in manual work. This allows the traffic analysts more time to review the permanent data in addition to other areas of their jobs.

D.5.5 LESSONS LEARNED

Improving the applications and methods of data submission and availability has increased productivity and efficiency. The data sharing between the Department and partners helps provide data to multiple bureaus and thousands of customers for various purposes.

Since the implementation of iTMS, the number of traffic data requests has been cut by nearly 50%.

The creation of iTDUS has cut the lifecycle of the traffic count submission by more than 90%. This allows a quicker turnaround of the data to the user.

Permanent Traffic Site Maps have opened the lines of communications between the Bureau and the engineering districts, and made the districts more aware not only of the location of the sites but also the importance of the permanent traffic counting sites.

ATICS provides quicker generation of monthly files for FHWA submission and also internal report generation, which assists with developing factors and processing larger data requests. Larger data requests used to take days to extract. With the various reports now available, those requests can be done in a fraction of the time. The quality assurance section allows the Bureau to see potential issues with permanent site data and to address those issues before they become a significant problem.

D.6 CASE STUDY #5: ALABAMA

The State of Alabama has a unique approach for incorporating data collected by local governments, which is then used to provide some of the data for the HPMS submittal, and occasionally, the lower functionally classified roads. Alabama DOT (ALDOT) collects all of the traffic data except on the county roads. Local governments are used to collect the county road data. ALDOT provides instructions and regulations to the local governments for collecting the 48-hour counts by lane and by direction. The data is then sent to ALDOT where it is validated using established quality control procedures.

In addition to the partnership with local governments, which enhances ALDOT's traffic data collection program, ALDOT has also developed an automated method to calculate AADT values using short duration counts. This method is described in the following paragraphs:

The continuous data is collected daily and processed through the Traffic Monitoring System (TMS) to produce the day of month counts, which are submitted to FHWA in a TMS Plan (note this is not the same as the Data Business Plan discussed in Chapter 2). At the end of the year, the continuous counts are grouped from recorders in the area where the short duration counts were made. A weighted average is then generated by the TMS system and this average is used to factor the short duration counts to produce the AADT values. For example, if a short duration count is made on June 1, the data is entered into the Traffic Data Processing System (TDPS) as raw data. At the end of the year, the TDPS program uses the continuous counts from the count stations around the same area where the counts were made, and for that same period (June 1), to calculate a weighted average from those counts. The TDPS then calculates a factor that is applied to the short duration counts to produce the AADT value.

The automated method now used to develop the AADT from short duration counts replaces a previous method in which a 48-hour count was used to calculate a day of month count, which was then factored to derive an AADT value, and this process was all done manually. The automated method now allows ALDOT to go directly from short duration counts to AADT values, thereby, eliminating manual steps, reducing errors in manual calculations, and saving time for the entire process.

D.7 CASE STUDY #6: CONNECTICUT

The State of Connecticut provides a different example of how factoring is done by computing a monthly rolling average based on the previous 12 month period. The following steps are used to develop the AADT from raw count data:

- Initially, raw count data is collected from a continuous site for 24 hours, 7 days a week, for 365 days/year. This data is collected in both directions. If the CONTINUOUS site indicates that data was only collected in one direction, the data for the site for that day is not used.

- The data is then validated using established quality control procedures.

- A series of C++ programs (which are part of a traffic management system) are used to develop monthly factors, based on the previous 12 months of data. A weighted average of raw counts taken from the CONTINUOUS sites is calculated and is then used to develop monthly factors. At least six months of data taken in both directions must be available to develop the factors that are applied to the raw data. If six months of data is not available, ConnDOT does not use that information in developing the expansion factors. ConnDOT uses an average based on previous year's data.

- The factors are developed based on six factor groups, and any counts taken on special holidays, or in construction zones are not used in developing the factors.

Once the factors are developed, they are applied to the weight-averaged data to calculate the AADT.

Appendix E. COMPENDIUM OF DATA QUALITY CONTROL CRITERIA

E.1 CASE STUDY #1: INNOVATIONS IN DATA QUALITY QA/QC SYSTEMS FOR TRAFFIC DATA

E.1.1 INTRODUCTION

This case study describes innovations in the application of QA/QC systems at the Virginia Department of Transportation (VDOT) as part of the best practices of planning for, and building in, high quality in traffic monitoring, data collection, and the analysis of raw data. By utilizing private contractors for field installation and maintenance, selecting equipment with advanced classification and binning options, and specially tailored in-house software, VDOT was able to develop an end-to-end solution for processing large volumes of high quality site data efficiently. The automated software tools allow staff to efficiently review data, and quickly assess site performance, including diagnostic assessment of sensor performance as exhibited through classification patterns over time. This information is used to quality grade data and provides preliminary diagnostic information for service call dispatch of private sector contractors.

Virginia has developed a custom classification algorithm (Binning ClassTree), with the support of the equipment vendor, which uses loop logic and makes decisions based on empirical sensor factoring knowledge to accept the data from sites into 22 defined types, which is a superset of the commonly used FHWA 13 vehicle category classification system.

An additional benefit of the process is the ability to continue to extract high quality useable data as sensors age, degrade or fail in the field, greatly extending the useable life of the site. When combined with a rigorous approach to site installation practices, VDOT has been able to deploy, operate and maintain over 600 traffic monitoring sites, with over 95% of sites generating useable data for multiple applications, using a combination of traditional sensors (loops and piezos), and non-intrusive radar sensors. The quality control procedures described in this appendix facilitate the assessment of the permanent telemetry sites using traditional in-pavement sensors.

E.1.2 VDOT QUALITY ANALYSIS SOFTWARE

Back Office Quality Checks

Virginia has a very extensive traffic monitoring program. In order to process the large volume of data collected each year, VDOT has invested in a processing system to automate the flow of data and the necessary quality checks that are applied to the data. This effort has resulted in the development of a catalog of rules (currently over 95 rules - available on request) used in the Traffic Monitoring System Raw Data Error Review Process. As a part of the review analysis, quality ratings are assigned to the raw total volume data, the classification data, and the speed data. Per vehicle weight records of WIM data are processed separately, but classification, speed, and volume data that is collected concurrently from the same sites is included in the quality analysis software processing. The quality ratings determine the use of the raw data in reporting and processing activities that lead to the creation of AADT and VMT estimates and other special studies such as speed analysis.

Raw Data Pre Load Activity

Each permanent telemetry site is polled nightly by a process that contacts each site and downloads and processes the available previous day's data. VDOT TMS analysts review the results each morning and then manually contact any sites that did not automatically download. If problems are identified, a service call maybe initiated, with contractually specified service response times.

Raw Data Loading Process

Data files that were automatically downloaded are loaded into management software as part of the Quality Analysis procedure. Manually collected files, which include portable coverage counts and other data file formats can be manually loaded using one of the several acceptable formats. The preferred and fastest method uses a manufacturer's proprietary binary format via a vendor DLL that is imbedded in the VDOT software. The other formats are typically ASCII text or PRN file readers and allow acceptance of all equipment generated data files in use in Virginia at this time. VDOT also has the ability to manually generate a special study data file as a text document that can then be system processed. This is occasionally done for data received from other sources, such as cities or consultants that are not normally part of the VDOT system.

Raw Data Review Process

Once data is loaded into the system it can be processed by the automatic review software. This review process runs as a series of comparisons. Based on the results of the comparisons, a tentative quality rating is assigned for the volume data and for the classification data, and where appropriate, messages are created for review by the analyst. The analyst uses the same software to review the messages and to determine the validity. Spreadsheets can be produced from the analysts console for outside review.

The analyst uses the information provided by the software and where appropriate can apply other information such as known site conditions (construction for example) to determine if the tentative ratings as determined by the software should be retained or if different quality ratings would be more appropriate. Due to the rigorous installation and maintenance practices followed, the default level is set at 5 as acceptable for all uses. The analyst may accept the system recommendations or may input a different rating based on other knowledge and experience with the site. Ratings are subject to review by contract administrators and in some cases by the service contractor to facilitate maintenance activity.

Raw Data Review Messages

A key element of the raw data quality review software is the creation of messages that provide advice to the analyst in data review. At this time there are 96 individual messages corresponding to rules in the software that are displayed when conditions are met. The messages are established at levels of guidance for the analyst with displayed icons for quick recognition.

TABLE E-1   MESSAGE URGENCY LEVELS

Level one icon is a question mark in a circle, an advisory of a questionable nature.	
Level two icon is the letter I in a circle, an informational advisory.	
Level three icon is an exclamation mark in a triangle, which is a warning level message.	
Level four is an X in a circle, which is an error level message.	

Source: Virginia Department of Transportation.

Below is a screen image of the VDOT Quality Analysis Software.

FIGURE E-1   VDOT QUALITY ANALYSIS SOFTWARE
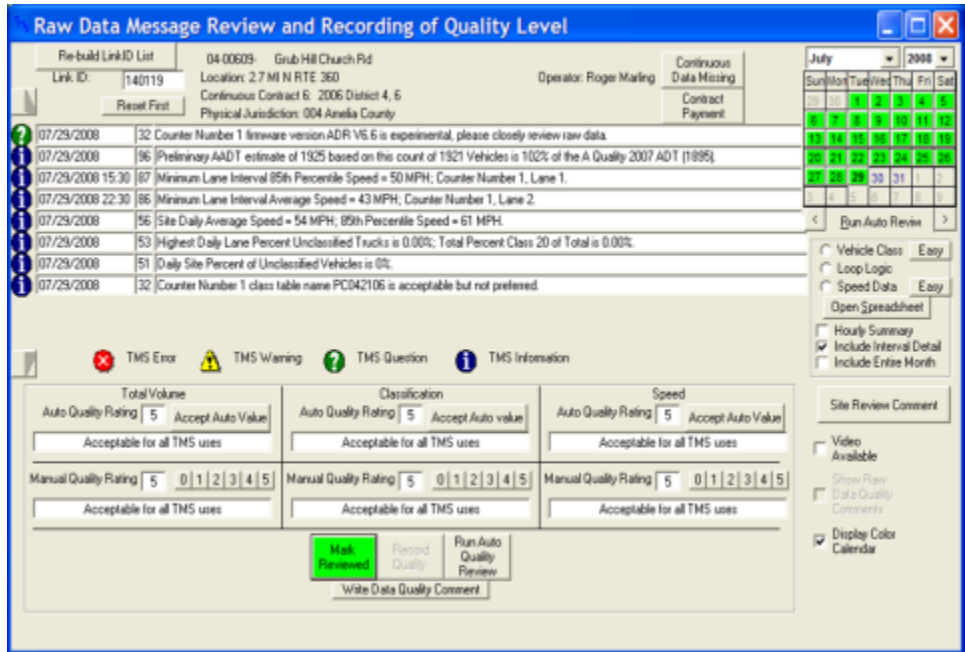
Source: Virginia Department of Transportation.

The following image is a VDOT display screen in spreadsheet analysis mode. As you look at the image, you will quickly note the upper interval of data has information boxes displayed in "Green is Good" mode, while the three lower intervals (which are subsequent days) are displaying the "Orange is Bad Mode" intended to catch the analyst's eye that something has changed or is out of tolerance.

At the top is header information that identifies the site, followed by a banner bar for a day of data in columns from left to right. Column A is the date, and continuing as Counter Number, Lane, Direction, Daily Total, and then the volume per vehicle class starting with Class 2. Notice the classes do not directly progress as 2, 3, 4, etc., but are grouped by analysis of relationship within the 21 bin scheme, described more fully below. That is, that a Class 2 is followed by classes 16 and 18 and calculated percentages and class 16+1 and the percentage of class 16 plus 18. These are defined by the rules as empirically determined by the department.

Below the banner bar are blocks of explanatory color codes. Text of explanation inside the block instructs what rule has been activated. In this example there was a dramatic change from "Max Class 20 as % of Lane Truck Volume = 0.0%", and "Class 20 as % of Total Volume = 0.00%" (i.e., good) to the following unacceptable call out.

FIGURE E-2 VEHICLE CLASS AND PERCENT OF LANE VOLUME

LinkID:	40185	SR-00040 McKenney Hwy; .50 E RT 654 (RAINEY CREEK ROAD).											
	Dinwiddie County												
	Richmond District		Functional Class: (State = 3; Federal = 6) Rural Minor Arterial										
	Speed Limit: 55												

Daily Summary   Sunday

Color Legend:		Max Class 20 as % of Lane Truck Volume =	7.5%	Color Legend:		Max Class 20 as % of Lane Truck Volume =	7.5%
Daily Total		Class 20 as % of Total Volume =	0.71%	Daily Total		Class 20 as % of Total Volume =	0.71%
Value from Raw Data Table		Class 20 Values Acceptable		Value from Raw Data Table		Class 20 Values Acceptable	
Value from Loop Logic Table				Value from Loop Logic Table			
Raw Data and Loop Logic Derivation				Raw Data and Loop Logic Derivation			
Sum of Values from Loop Logic Table				Sum of Values from Loop Logic Table			
Percent				Percent			
Percent Combined Sum				Percent Combined Sum			

Daily Summary   Friday

Date	CounterN	Lane	Direction	DailyTotal	Class2	Class16	Pct 16	Class18	Pct 18	Class16+18	Pct 16+18	Class3	Class17	Pct 17	Class19	Pct 19	Class17+19	Pct 17+19	Trucks	Class20	Pct 20	Class2...
4/20/12	1	1	2	535	320	0	0%	271	85%	271	85%	100	0	0%	55	55%	55	55%	99	66	67%	
4/20/12	1	2	4	599	324	13	4%	218	67%	231	71%	158	1	1%	57	36%	58	37%	104	38	37%	
Daily Link Total				1134	644	13	2%	489	76%	502	78%	258	1	0%	112	43%	113	44%	203	104	51%	

Color Legend:		Max Class 20 as % of Lane Truck Volume =	66.7%	Color Legend:		Max Class 20 as % of Lane Truck Volume =	66.7%
Daily Total		Class 20 as % of Total Volume =	9.17%	Daily Total		Class 20 as % of Total Volume =	9.17%
Value from Raw Data Table		Data downgraded, not valid for factor creation purposes.		Value from Raw Data Table		Data downgraded, not valid for factor creation purposes.	
Value from Loop Logic Table		Rule D		Value from Loop Logic Table		Rule D	
Raw Data and Loop Logic Derivation				Raw Data and Loop Logic Derivation			
Sum of Values from Loop Logic Table				Sum of Values from Loop Logic Table			
Percent				Percent			
Percent Combined Sum				Percent Combined Sum			

Source: *Virginia Department of Transportation.*

Note: *This display image has been edited to fit the page in this document.*

E.1.3   THE 21 BIN CLASSIFICATION TABLE AND HOW IT WORKS

Manufacturers typically supply a default classification table based on an interpretation of the 13 FHWA class definitions and sensor characteristics. The 13 categories defined for vehicle types have some limitations for what to do with vehicles that either do not fit into the definitions, or due to missed sensor activations that can occur on the road, may be determined to be in error or incomplete. The cause of an error in sensing may be as simple as a vehicle changing lanes in the area of the sensors or may be a result of a defective sensor, vehicle characteristics, or rough pavement. The irregular sensor pattern, which may represent a valid vehicle, must be assigned to a class.

One approach is to combine all the error vehicles into Class 2 that are normally the numerically largest class as it contains all standard passenger cars. Another is to provide additional bins in the default scheme, for example a set up for 15 bins of vehicle types with type 14 being unused, and type 15 being the bucket into which all errors are tossed. VDOT takes advantage of the deployed equipment's capability to provide more definitions and use additional criteria in the determination of vehicle class type. After empirical study of the pre vehicle raw data, VDOT determined that a specialized classification table could be used to apply logic based on the magnetic length of vehicles to the determination of what to do with irregular patterns that would otherwise be thrown into an unclassified category. This diagnostic classification algorithm adds six additional diagnostic data bins to the default 15-class scheme. At permanent sites, it is an excellent indicator of piezo health. The gradual degradation of piezo health and performance as the roadway ages and the surface wears is captured and can be traced over the life of a site, and allows for extended operation of the site before maintenance is required. Typically, missed axles tend to occur on lighter vehicles first, and are particularly noticeable on small front wheel drive cars where the second axle may be missed by the electronics as a low output signal is often produced. It was determined that loop logic could be incorporated to identify a real vehicle that had an appropriate length as measured by the loops, and be placed in to a normal classification bin with confidence, as described in the following figures.

FIGURE E-3   PIEZO HEALTH AND PERFORMANCE (VEHICLES)

Sensor Output	Piezo Condition	Axles Detected	Class 21 BIN	Class 13 BIN	Why
Piezo / Loop	Good	2	2	2	Matches a class 2 definition
Piezo / Loop	Error	1	16	2	Matches a class 16 definition
Piezo / Loop	Very Poor	0	18	2	Matches a class 18 definition
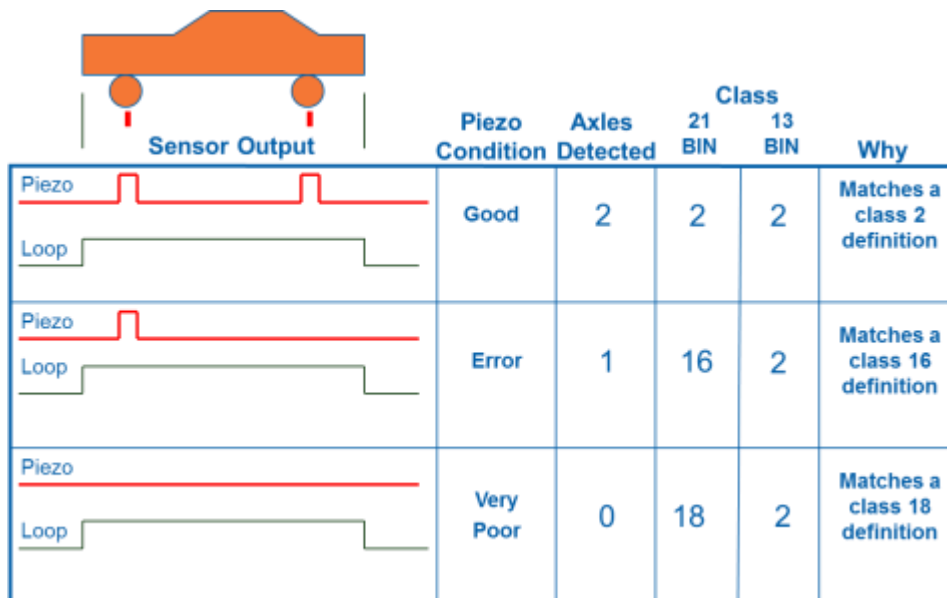
Source: Virginia Department of Transportation.

FIGURE E-4   PIEZO HEALTH AND PERFORMANCE (TRUCKS)

Sensor Output	Piezo Condition	Axles Detected	Class 21 Bin	Class 15 Bin	Why
Piezo (axle) / Loop presence	Good	5	9	9	Matches a class 9 definition
Piezo / Loop	Error	4	15	15	Does not match a class definition
Piezo / Loop	Error	1	20	15	Matches a class 20 definition
Piezo / Loop	Error	0	20	15	Matches a class 20 definition
Piezo / Loop	Oscillating	10	15	15	Does not match a class definition
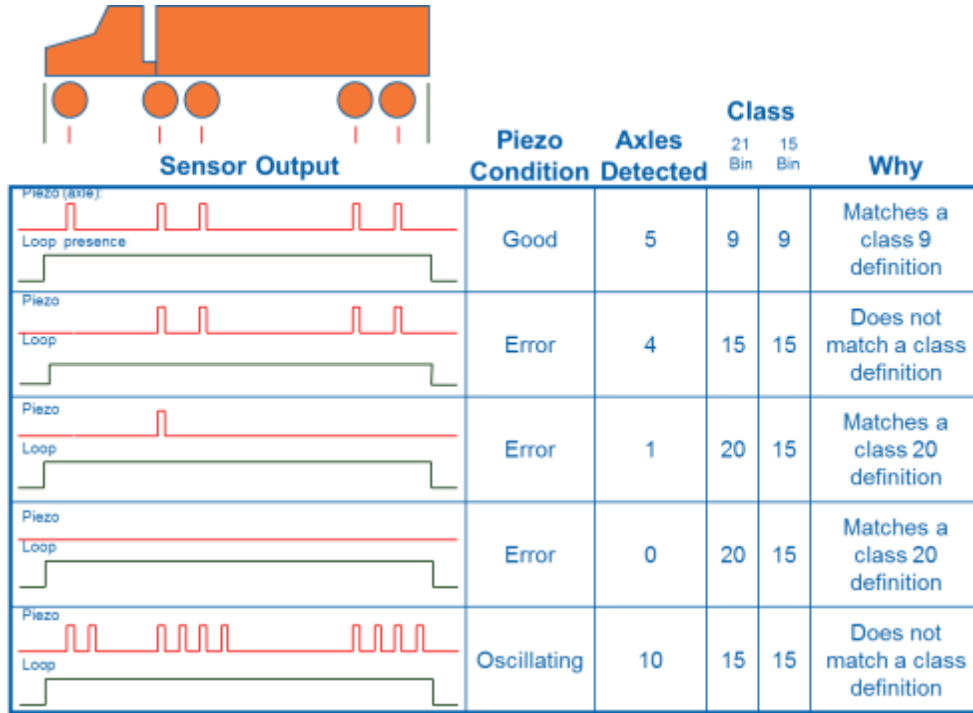
Source: Virginia Department of Transportation.

TABLE E-2   ADR ADVANCED LOOP LOGIC

ADR Advanced Loop Logic-21 Bin Table Explanation																				
Vehicle Bins Displayed on TOPS and ADR Screen	1	2	3	4	5	6	7	8	9	10	11	12	13	N/A	15	16	17	18	19	20	21
Vehicle Class After TMS Translation	1	2	3	4	5	6	7	8	9	10	11	12	13	N/A	15	2	3	2	3	15	15
Piezo Axle Performance	Normal Valid Vehicle Classification Axle Rules Apply No Loop Logic Rules Apply All Vehicles Have 2 or More Axles Unchanged															1 Axle Vehicle Detected, Loop Logic, Rules Apply	1 Axle Vehicle Detected, Loop Logic Rules Apply	0 Axle Vehicle Detected, Loop Logic Rules Apply	0 Axle Vehicle Detected, Loop Logic Rules Apply	0-1 Axle Vehicle Detected Loop Logic Rules Apply	
Vehicle Magnetic Length Rules	Normal Valid Vehicle Classification Axle Spacing Rules Apply No Loop Logic Rules Apply Unchanged															7' to 16'	16' to 19'	7' to 16'	16' to 19'	19' to 100'	All Others, Including Vehicles Less than 7' Vehicle Length, Lane Changers, Etc.

Source: Virginia Department of Transportation

Table E-2 defines the relationship between the 21 bin classification scheme of Virginia and the FHWA 13 Per Vehicle Raw field data defining when a vehicle is assigned to one of the 21 bins that are subsequently post processed by analysis to a correlating FHWA 13 class. At this time, please notice the bin 18, which is a vehicle with zero detected axles and an overall detected length of 7 to 16 feet. Based on empirical study, this is a real vehicle, and based on the detected length is most likely a class 2, passenger car.

Speed and Volume Graphs, a full day, hour by hour

Figure E-5 illustrates a graphic tool available to VDOT analysts responsible for checking the data. This particular visualization confirms that there is a serious problem at the site and that it was not just for an hour or for a single recording interval.

FIGURE E-5   WEST BOUND 21 BIN GRAPHS (FROM COLLECTED RAW DATA)
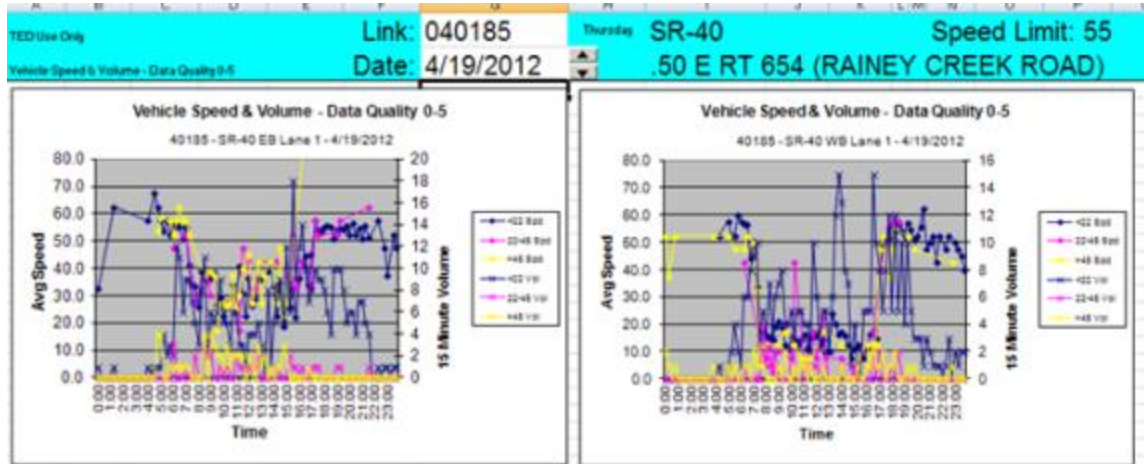
Source: Virginia Department of Transportation.

Previously it was pointed out that Bin 18 contains vehicles detected as valid, with a length of 7 to 16 feet but with no detected axles. Notice that on this day there were approximately 275 vehicles in Bin 18.

FIGURE E-6   VEHICLE VOLUMES AND BIN CLASSIFICATION DATA
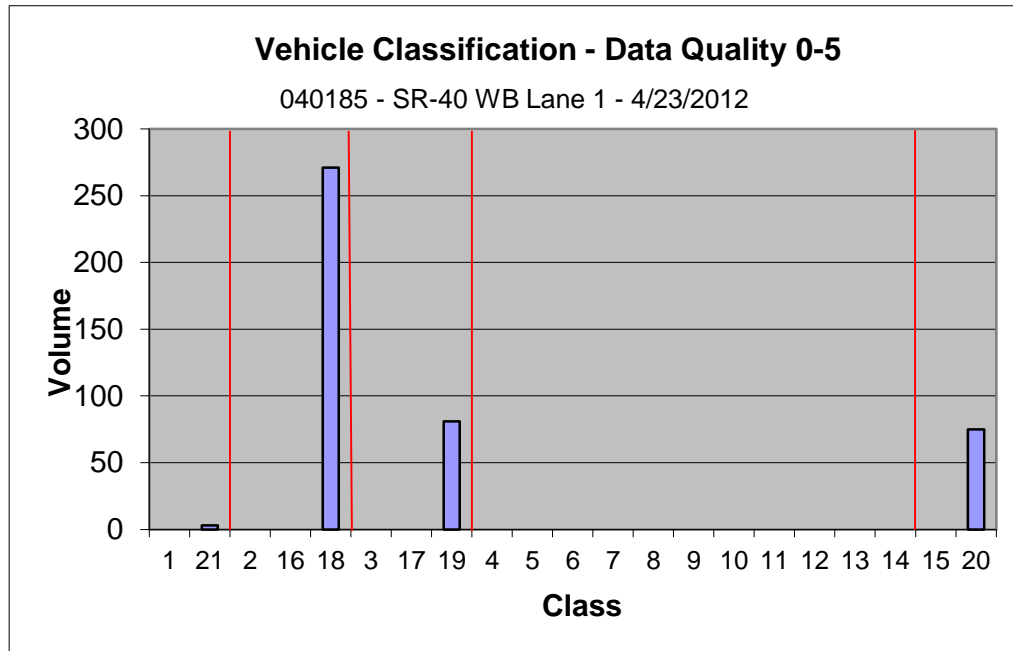
Source: Virginia Department of Transportation.

E.1.4 INITIATION AND RESOLUTION OF SERVICE CALLS

Example: In processing routine data files, a VDOT traffic data analyst initiates a service call because the VDOT quality analysis software "alarmed" at processing classification data from a site that was previously working. A typical service call is shown below, and the primary information is circled. Note the 21-Bin classification data provides additional diagnostic information for the technician.

FIGURE E-7   VDOT TRAFFIC SERVICE CALL APRIL 2012

> From: Contract Admin. (VDOT)   Sent: Tuesday, April 24, 2012 3:27 PM
> To: callalert@dtsits.com
> Subject: Service Calls for 04/24
>
> The following SC has been sent to **Contract 1006ES**: SC#20120308
>
> Rte 40 B – ID# 04018501
>
> Lanes 1 & 2 high % Class 16+18; 17+19, 20 & 15's – See Data 04/18 – 23 & graphs
>
> *Vehicle Monitor Log showing both loop and piezo error codes – See VML.
>
> *Tech toggled sensitivity; did not resolve issue
>
> *Per David Sample's (VDOT) PMI on 02/14/12 – Loops overlaid, lots of road cracks. P1 has grout cracked cable end. P2 adding axles; poly tubing exposed; P2 HR and grout cracked numerous places. P1 & P2 bad readings; but output ok. P2 set to 3 and DB to 035 – axle count good. P1 axle count ok.
>
> * See previous SC# 20110078 – (8 March 2011)
>
> * And see previous SC#'s 20111006 (29 December 2011)
>
> * SC not reviewed by Contract Administrator
>
> **TED / Traffic Monitoring**

Source: Virginia Department of Transportation.

As an additional diagnostic aid, the following is a partial print-out of the VML (Vehicle Monitoring Log) as referenced above in the service call. The VDOT analyst originating the service call created this log by telemetry contact from his office to the remote site using the equipment manufacturer's supplied software to monitor the site in operation. The question marks indicate that the equipment could not calculate the length of the vehicle, and there are error (status) codes present. FFFF is a correctly detected vehicle, while FFAD indicates a vehicle that missed the piezo sensors.

FIGURE E-8 VML PRINT-OUT

```
***Opened On 04-24-2012 @ 12:01:33, Site: 087, Classes: (All)
HH:MM:SS ARR STAT VEHNO CL SPD LPL WBL AX WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8 WB9 WB10
WB11 WB12 WB13
12:01:40-ADRVehs, Viewed: 0, Skipped: 0, Classes: (All), ViewPVRs: 1,2
FB 10 0000  CONTROL:  PSTART
00 01 CB93 LOOP  ON
01 01 D4F3 LOOP  ON
00 81 DF3C LOOP  OFF
12:01:54  2+ FFAD     1 21  16 ??? ---  0 --- --- --- ---- ---- ---- ----
FE 02 EA5D  MINUTE 02
00 02 126C LOOP  ON
01 82 24BD LOOP  OFF
12:01:54  1+ FFFF     1 20   5 932 ---  0 --- --- --- ---- ---- ---- ----
12:02:04  1+ FFAD     2 21  28 ??? ---  0 --- --- --- ---- ---- ---- ----
00 82 38D7 LOOP  OFF
00 02 CB34 LOOP  ON
01 02 D016 LOOP  ON
00 82 D813 LOOP  OFF
12:02:54  2+ FFFF     2 19   9 182 ---  0 --- --- --- ---- ---- ---- ----
12:02:58  2+ FFFF     3 18  13 135 ---  0 --- --- --- ---- ---- ---- ----
FE 03 EA5E  MINUTE 03
12:02:53  1+ FFFF     3 20   9 362 ---  0 --- --- --- ---- ---- ---- ----
00 03 2A58 LOOP  ON
01 83 3771 LOOP  OFF
12:03:10  1+ FFAD     4 21  28 ??? ---  0 --- --- --- ---- ---- ---- ----
00 83 4793 LOOP  OFF
12:03:57-ADRVehs, Viewed: 7, Skipped: 0, Classes: (All), ViewPVRs:
***Exit VehMon On 04-24-2012 @ 12:03:59
```

Source: Virginia Department of Transportation.

In response to the emailed service call and its supportive information, the private contractor routed a technician to investigate the site. Excerpts from the service report containing his readings and observations is shown on the following pages along with photographs that he took while at the site.

VIRGINIA DEPARTMENT OF TRANSPORTATION

TRAFFIC ENGINEERING DIVISION - TRAFFIC MONITORING SECTION

SERVICE CALL

SERIAL NO#: 20120308
STATION ID #: 04018501
CONTRACT ID: 040185
DISTRICT: 4   REGION : Central
TYPE SITE: AVC   STOPWATCH/REALTIME?

SC Timeframe: Standard-10 day

SITE INFORMATION : _____

ROUTE / DIRECTION: 40 B (2 LANES) LOCATION: 0.5 MI E RTE 654 (RAINEY CREEK RD.)
TELEPHONE: (804) 478-42XX COMMID: IP ADDRESS: IPSUBNETID:
VDOT DATA ANALYST CONTACT INFO. Robert Mallow 804-786-28XX
VDOT CONTRACT ADMINISTRATOR CONTACT INFO: Tech 1 804-371-27XX
REAL TIME/STOPWATCH CONTACT: ITS name 804-796-40XX

VDOT REPORTED PROBLEM:_____

DATE SUBMITTED: 4/24/2012 SUBMITTED BY: ROBERT MALLOW 804-786-28XX REVIEWED BY:
ADR not properly classifying

VDOT COMMENTS:

Lanes 1 & 2 high % Class 16+18, 17+19, 20 & 15's – See Data 04/18 – 23 & graphs

*Vehicle Monitor Log showing both loop and piezo error codes – See VML

*Tech toggled sensitivity; did not resolve issue

*Per David Sample's PMI on 02/14/12 – Loops overlaid, lots of road cracks. P1 has grout cracked cable end. P2 adding axles; poly tubing exposed; P2 HR and grout cracked numerous places. P1 & P2 bad readings; but output ok. P2 set to 3 and DB to 035 – axle count good. P1 axle count ok.

*See previous SC#'s 20111006 & 20110078 – Sent for same

*SC not reviewed by Contract Administrator

CONTRACTOR SHALL PERFORM NORMAL S/C ACTIONS PER THEIR STANDARDS.

CONTRACTOR SC RESPONSE: _____

DATE CORRECTED: 04-26-12   Arrival Time: 14:00   Departure Time: 15:00

Posted Speed: 55 mph   Observed Speed: 57 mph

TECHNICIAN CORRECTIVE ACTION(S)/COMMENTS:

See Below   Contractor Representative

Service Call Response Area (Be sure to notate additional information to above sections & any requests in VDOT comments section)

When I arrived, found site has been milled/paved.
The shoulder appears to have been widened by approx.. a foot.
Found poly tube with cut piezo on shoulder.
Collected static readings of all sensors.
All eensors are faulty and no usable data is obtainable.
Collected digital pictures of roadway and sensors see link below.
ftp://Sites_Ready_For_VDOT_Inspection/SC_Supporting_Info/SC_20120308_Data
See table below for sensor readings.

Sensor	Insulation Resistance	Resistance	Inductance
L1	0 Ω	∞ Ω	4.83H
L2	0 Ω	∞ Ω	5.97H
L3	0 Ω	∞ Ω	8.83H
L4	0 Ω	∞ Ω	3.85H

Sensor	Capacitance	Resistance		DC Offset Voltage
P1	2.96nF	100k Ω	2M Ω	60mV
P2	1.56nF	1M Ω	1M Ω	110mV

Technician:

Important: Confirm Station ID matches with Service Call

Service Call Response Area (Be sure to notate additional information to above sections & any requests in VDOT comments section)

Source: Virginia Department of Transportation.

FIGURE E-10   OVERALL VIEW OF ROADWAY FACING EAST

Source: Virginia Department of Transportation.

Roadway has been completely milled, and the westbound lane has been widened and initial base asphalt has been placed. The entire road is expected to receive additional surface asphalt and then will be re-marked.

FIGURE E-11   OVERALL SENSORS FACING EAST

Source: Virginia Department of Transportation.

DTS Technician found that milling did not reach the sensors and they were not exposed. Destruction of the sensors requiring replacement is due to the widening process that ripped out the lead wiring that was under the shoulder apron.

FIGURE E-12   PIEZOS 1 AND 2 LOOKING SOUTH

Source: Virginia Department of Transportation.

Piezos (old style) are visible but not exposed, and do not appear to be damaged in the roadway. Electronic test measurements indicate no connection to the cabinet.

FIGURE E-13   PIEZOS 1 AND 2 LOOKING SOUTH

Source: Virginia Department of Transportation.

FIGURE E-14   LOOKING SOUTH AT LOOPS 4 AND 1, AND LOOPS 3 AND 2

Source: Virginia Department of Transportation.

Loops do not appear to be exposed or damaged by the milling in the roadway. Test measurements taken at the cabinet indicated the connecting wires are shorted. The technician also reported that he/she found long pieces of connecting wire and tubing in the grass at the side of the road.

E.1.5   LESSONS LEARNED IMPLEMENTING QA/QC FOR TRAFFIC MONITORING

- Recognize that quality cannot be inspected into the data; rather all aspects of the program should be reviewed to ensure the quality is built into the process (see Case Study #2 for a detailed description of how VDOT and its private sector contractors have approached this). By focusing on high quality processes and materials, VDOT and its contractors have been able to greatly increase site reliability and performance, reducing total life cycle cost of operation and improving data availability. This focus has led to significant improvements in methods and equipment design, firmware, and configuration.

- Automated processes allow for administrative efficiency, and to allow a consistent approach to data quality assessment. Quality rules are fully defined and coded into the automated review process. It should be noted that by focusing on a high quality field installation process, one is able to minimize the volume of data flagged for suspect data quality, even when the rules are quite tight.

- The data is checked every day as part of the Traffic Monitoring System Raw Data Review Process software that uses automated data checks to flag potential issues, with rules for interpolating data and handling gaps. A calendar check of noted exceptions and events is used along with human review of flagged exceptions and Automated Alerts for the system. This allows rapid identification and correction of potential problems, avoiding significant data loss.

- The development and implementation of the 21 bin classification table was and is a most significant tool in the quest for data quality and reliability. In addition to providing useful diagnostic information to guide service call activity, it allows the continued use of sites with marginal sensor performance, to collect useful traffic data, greatly extending the useful operational life of sites, thus reducing overall program costs.

- By focusing on an automated end-to-end solution that generates high quality data, VDOT has been able to provide timely support for operations by providing reliable, accurate traffic data in real-time for multiple applications. The reliability, availability, and utility of this data feed has built support for the traffic monitoring function during a time of fiscal restraint. The QC/QA processes provide assurance that the data being provided are of consistent high quality, even prior to the daily QC/QA checks.

- A focus on continuous improvement within VDOT and by its private contractors has facilitated many changes to the program over the years, which, when taken as a whole, have allowed the expanded deployment of additional traffic monitoring sites (currently over 600 sites) in support of both core traffic monitoring needs and operations. Performance based contracting is an essential element in insuring VDOT is able to reliably generate the traffic data needed to support its internal decision processes and provide timely accurate data to external parties.

E.2 CASE STUDY #2: QA/QC SYSTEMS FOR TRAFFIC DATA

E.2.1 INTRODUCTION

This case study discusses the quality control systems used for traffic data in the State of Vermont. Vermont has 3,900 road centerline miles on Federal aid routes and 10,200 road centerline miles on local roads. The Vermont Agency of Transportation (VTrans) Traffic Research Unit uses a combination of permanent in-house staff and summer temporary employees to collect traffic count data on Federal aid routes and on local roads.

E.2.2 CONTINUOUS TRAFFIC COUNTS

VTrans is currently operating 60 continuous volume counters, 21 WIM, and 2 continuous vehicle classification counters.

E.2.3 SHORT-TERM TRAFFIC COUNTS

The coverage count program includes 2,200 short-term ATR counts on Federal aid routes and 2,400 short-term ATR counts on local roads. The counts are done on either a three or a six-year cycle, depending on the route. Each year VTrans collects around 500 week long ATR counts on Federal aid routes, including interstate ramps and other grade separated ramps, and 400 weeklong ATR counts on local roads. Counts performed on the Federal aid routes are typically vehicle classification and speed while the local road counts are volume only.

VTrans conducts 12-hour manual turning movement counts at 1,300 intersections over a four-year period. Either counts are done on a two or four-year cycle, with about 450 counts annually. VTrans is in the process of implementing a bicycle and pedestrian manual count program. VTrans collected trip generation data over the past several years and has submitted 675 counts to ITE to be considered for the ITE Trip Generation Manual. VTrans intends to continue to collect trip generation data on an every other year basis, alternating with the bicycle/pedestrian count program.

E.2.4 TRAFFIC MONITORING SYSTEM

VTrans currently uses an Oracle based consultant designed traffic monitoring system to manage traffic count data but is planning to implement a new system within the next two years. Various off-the-shelf products are under consideration, as well as possibly another consultant designed system.

E.2.5 QA/QC PROCEDURES

The VTrans Traffic Research Unit does not have a formal QA/QC program but does have quality checks built into the data collection and data review procedures as described briefly herein.

Field Procedures – Continuous Traffic Counter (CTC)

VTrans field technicians check the CTC sites on a monthly basis while downloading data at the site. The field technician checks batteries and hardware as well as verifies that the counters are recording correctly.

Office Procedures – Continuous Traffic Counter (CTC)

Monthly traffic is reviewed for daily directional distribution. If the percent of traffic in the lower volume direction is less than 48% the data is reviewed more closely for a potential problem.

Using an Excel based routine that pulls data from the Traffic Monitoring System, graphs are produced on a monthly basis that show a particular day of the week, for each occurrence of that day of the week over the month. For example, Sundays are reviewed and differences between Sundays may indicate where the counter has stopped working on any one lane, or where there has been a period of resonation shown by surges in the volume.

Monthly reports are generated that compare the current year's average daily volumes with last year's average daily volumes. Differences of more than 10% are reviewed more closely.

Field Procedures – WIM

On a monthly basis, the WIM Technician visually inspects each WIM site and runs diagnostic reports. VTrans relies largely on auto calibration to maintain calibration at the WIM sites but on occasion has used a test vehicle or portable scales to recalibrate the systems.

Office Procedures – WIM

WIM counts are converted to volume counts and compared alongside the other CTC counts (see above).

Field Procedures – Short-Term ATR

As each count is set out, the Field Technician checks to see that the recorder is collecting data and that the data is accurate. When the count is picked-up, the field technician downloads and reviews the data on a laptop computer and resets the count as needed.

Office Procedures – Short-Term ATR

Each ATR count is reviewed individually. The minimum duration is 48-hours of weekday data. The estimated AADT is compared to historical volumes to ensure that it is not unreasonable. The following table shows specific quality checks performed on vehicle classification counts.

TABLE **E-3**   **Q**UALITY **C**HECKS FOR **V**EHICLE **C**LASSIFICATION **C**OUNTS

Checks	Criteria requiring additional review
Class 14s	>5% for the count as a whole
Directional ADT	DAY SPLIT > 53% for the count as a whole
Cycles	> 2%
Cars	<70%
Pickups	>22%
Buses	> 1%
8s vs. 9s	8s > 9s, N/A for local streets, weekdays only
Multi trailers	CL 11-13 > 1%
Med vs. Heavy	med < heavy (med - heavy < 0)
Sat % ADTT	> 75% of weekday ADTT
Sun % ADTT	> 75% of weekday ADTT
Peak hr trucks	> weekday ADTT
Misclassification	Class 3s can be misclassified as 5s – look for high class 5s; High cycles can indicate problems with classes 2-5

Source: Vermont Agency of Transportation

Vehicle classification data is also reviewed for daily directional distribution by vehicle classification. Differences of greater than 10% indicate a potential problem requiring additional review.

VTrans records speed as well as vehicle classification for most ATR counts, however the speed data files are not loaded into the database but are stored separately in their raw format and are used only occasionally. If the vehicle classification data for a count is rejected, the speed data for the same count is also rejected.

Regarding site location, the field technicians are able to load GPS coordinates directly into the traffic recorder and the coordinates appear in the header of each count file. The coordinates are checked using a GIS application to verify that the count was set in the correct location.

Field Procedures – Manual Turning Movement Counts

The turning movement count program is very well supervised with a Field Technician, as well as a senior temporary employee, circulating among the count staff answering questions, helping to find the correct intersection, verifying that safety measures are in place, filling out field sheets correctly,

and providing breaks over the day. A one-day training program is provided at the start of the season.

Office Procedures – Manual Turning Movement Counts

The turning movement counts are reviewed by the Field Technicians at the end of the count season. Information provided on the field sheets is used to enter the street names, orient the count, etc.

E.2.6 LESSONS LEARNED

Using GPS to locate the ATR sites has been very beneficial. The Field Supervision for the turning movement count program has also been very worthwhile, with very few counts rejected over the season and very few safety related problems.

The VTrans Traffic Research Unit does not have a well documented QA/QC procedure. This is due in large part to having a very experienced staff with quality checking routines in place and little need to refer to documentation. However, as staff members move on it will be more difficult to train new employees in QA/QC without written guidelines. This was made apparent when it was discovered well into the season that a new employee was setting up ATR counts incorrectly and the vehicle classification was inaccurate.

E.3 CASE STUDY #3: PENNDOT – QA/QC SYSTEMS FOR TRAFFIC DATA

E.3.1 INTRODUCTION

This case study discusses the quality assurance and quality control processes for both short term traffic count data and permanent traffic count data at the Pennsylvania Department of Transportation (PennDOT). PennDOT is responsible for collecting, analyzing, and reporting traffic data on approximately 40,000 miles of road. This data collection includes short term and permanent traffic volume, classification, and weight data. Speed data is collected only at permanent traffic sites. PennDOT has 89 permanent traffic counting sites and over 42,000 short term count locations, including ramp locations.

E.3.2 QA/QC SPECIFIC PROCEDURES

The short term traffic count data go through a series of quality assurance edit checks. The raw count data are first submitted through PennDOT's Internet Traffic Data Upload System (iTDUS). This web based application subjects the counts to basic checks (site number, file type, header file format, 24 hours, duplicate data, and same data for both directions) before configuring the count in a format acceptable for the mainframe computer system, the Roadway Management System (RMS). Once the counts have passed the iTDUS checks, a text file is created from the iTDUS application and loaded weekly to the RMS. The short term traffic count data is run through a series of automated error checks.

The raw traffic count data first goes through the 15 error checks contained in Table E-4. If the count fails one or more of the edits, it will appear on the 650 Traf Raw Count Load Error Report.

TABLE E-4   TABLE 650: TRAF RAW COUNT LOAD ERROR REPORT ERROR CHECKS

```
Upload File Empty

Invalid Record Type

Header Sequence Error

Invalid Jurisdiction Code

Segment Not Found On Database
```

```
Key Does Not Exist On LFA DB

Offset Exceeds Segment Length

Invalid Count Type

Limit ID Not Found

Opposite Side Key Not Found

Duplicate Class Count Exists

Duplicate Volume Count Exists

Parallel Count Types Not Equal

Incomplete Count < 24 Hours

Invalid Count Date
```

If the raw traffic count data passes the 650 edit checks, it moves on to the next set of edits as illustrated in Table E-5. If the count fails one or more of the 28 edit checks, it will appear on the 660 Traf Raw Count Error Extract Report.

TABLE E-5   TABLE 660: TRAF RAW COUNT ERROR EXTRACT REPORT ERROR CHECKS

```
Record not found on database

Traffic Offset greater than segment length

Parallel Road:  Traffic opposite key = 0

Non-Parallel Road:  Traffic opposite key > 0

Parallel road, Raw traffic opposite record not found

Errors encountered when processing opposite side data

Raw traffic volume count date greater than run date

Day of the week is Saturday or Sunday

Manual: Count not in 6am – 6pm range

Less than 6 consecutive hours of count data

Invalid hour range less than 24 hours

Zero volume for peak hours

6 or more non-consecutive hours with zero volume

Same volume has occurred 4 consecutive hours

Manual: Count of zero volume for 1 hour period

Midnight hour volume greater than noon hour volume

Machine: 2 axle truck count greater than car count

Distribution is greater than 60/40 for all count

Current traffic record not found

Current traffic count date greater than raw traffic count date

Machine: lane count invalid
```

```
Count dates not equal

Could not find child segment

Type of count not same for primary/opposite side

Parallel counts on same side of road

Peak hour comparison greater than percentage range

Cannot process data not numeric

Opposite side traffic factor julian date is greater than zero
```

If the count passes the 28 edit checks in Table E-5, the count moves on to the final set of automated edit checks illustrated in Table E-6. If the count fails one or more of the edits in Table E-6, it will appear on the 661 Traf Extrapolation Report.

TABLE E-6   TABLE 661: TRAF EXTRAPOLATION REPORT ERROR CHECKS
AADT AND TRUCK PERCENT VARIANCE EDITS

```
0 – 2,000 AADT= 50% Variance

2,001 – 10,000 AADT = 20% Variance

10,001 – 25,000 AADT = 10% Variance

25,001 – 999,999 AADT = 10% Variance

Machine: Motorcycle count greater than 9.9%

Machine: Bus count is greater than 10%

Machine: 6 axle-single trl count greater than 9.9%

Machine: 5 axle-multi trl count greater than 9.9%

Machine: 6 axle-multi trl count greater than 9.9%

Machine: 7 axle-multi trl count greater than 9.9%

Machine: Car class greater than 99,000 vehicles for one side

Count date is less than 01/01/2008
```

If the count passes all checks, the data will be loaded automatically into the database.

Counts appearing on an error report are reviewed by a traffic analyst who will determine if the count is acceptable by reviewing historical data in RMS, traffic volume maps that allow them to see the flow of traffic in the area, viewing PennDOT's Video Log, and even calling Planning Partner contacts in the area of the count. Data considered to be acceptable will be manually processed into the system. Counts that are rejected are requested to be retaken and run through the whole process again once new data is submitted.

E.3.3 PERMANENT TRAFFIC COUNT Q/A PROCESS

PennDOT has 89 (42 ATR, 34 CAVC, and 13 WIM) permanent traffic counting sites. The ATR and CAVC sites are subject to the Quality Assurance Program. This program entails field staff performing a 4 hour manual classification count at each CAVC and ATR site. The manual count data is then compared to the permanent traffic counter data for the same 4 hour timeframe. All of the data is entered into PennDOT's Quality Assurance application that is part of the Automatic Traffic Information Collection

Suite (ATICS). The application compares the data by lane, direction, and classification. The Quality Assurance application generates reports that show the comparisons of the data.

E.3.4 QA/QC PROCEDURES

The short term traffic data collection program quality assurance/control program has been in place since 1985. Prior to 2008, the department grouped vehicles into 11 vehicle classes. This presented a problem for users trying to retrieve data for a specific classification because most of the requested classes were grouped together. There were adjustments made to the vehicle classes in 2008 when PennDOT went from 11 vehicle classes to 13 vehicle classes to comply with motorcycle data collection and the FHWA Scheme F format. The new vehicle expansion in RMS shows a more accurate vehicle breakdown that provides users better quality data. During the expansion, error checks were added to incorporate the new classes. This change took over a year to implement.

The permanent traffic data collection program quality assurance/control program was automated for ATR and CAVC data within the ATICS portal. Prior to the use of automation, the data was collected and stored in spreadsheets.

E.3.5 LESSONS LEARNED

When dealing with changes to the RMS mainframe system, patience is needed. The mainframe requires changes to be made using Common Business-Oriented Language (COBOL) programming language. Due to the multiple areas within PennDOT that utilize RMS, changes must be carefully done so that other mainframe applications are not affected. Any changes, whether major or minor, take time and have to be subjected to extensive testing.

When the opportunity presents itself, it is advisable to automate workflow processes. Automated processes save time. When automating a process, plan extra time for unexpected issues to arise. Even with the best planning, issues come about when converting a manual process (whether large or small) into an automated one.

E.3.6 FUTURE ENHANCEMENTS

The current processes have been working well. Without being able to update the mainframe system (RMS), the short term traffic count program edit checks will remain the same. If the short term count duration is eventually extended to 48 hour counts, the edit checks within RMS would have to be reconfigured for the longer timeframe and the iTDUS application would have to be enhanced to handle 48 hours of data.

The permanent traffic count program QA reviews will be put on a cyclical basis. In 2011, all permanent ATR and CAVC sites were reviewed that provided a baseline. In previous years, only a handful of sites were reviewed each year. Starting with 2012, the sites will be put on a rotating basis to have a more consistent QA process of PennDOT's permanent traffic counting devices.

E.4 CASE STUDY #4: QA/QC SYSTEMS FOR TRAFFIC DATA – WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT)

E.4.1 INTRODUCTION

This case study will discuss the quality assurance and quality control processes for both short term traffic count data and permanent traffic count data for the Statewide Travel and Collision Data Office (STCDO) of Washington State DOT. STCDO conducts an extensive traffic data collection, analysis and reporting program to gather information on usage of the approximately 7,060 miles of roadway composing the State highway system. The purpose of this program is to develop transportation data

that will enable the department to construct, operate, and maintain the most efficient and cost-effective transportation system possible.

STCDO is responsible for collecting, processing, analyzing, and reporting historical/archived traffic data for the State highway system and does not contract out for any services. The five major sections in STCDO that perform this work are Electronics, Short Duration Traffic Count Field Operations, Automated Data Collection, Short Duration Traffic Count Processing, and Travel Analysis. Each of these sections perform quality assurance (QA) and quality controls (QC) using their own procedures from site evaluation prior to collection of the traffic data to scrutinize the collected data for accuracy and consistency prior to dissemination to customers. The following paragraphs provide an overview of the procedures, experiences, and lessons learned over the history of WSDOT's traffic data program. The data collected is made available to WSDOT's customers through a Traffic Datamart, which includes traffic volume, classification, speed, and weight information.

E.4.2 QA/QC PROCEDURES

The following paragraphs describe specific quality control procedures that are used to evaluate WSDOT's traffic data and to correct errors as they are identified.

Machine Malfunctions: Machine malfunctions are a common cause of invalid traffic count data. TRIPS edits detect some machine malfunctions. Most machine malfunctions are detectable by the field person and documented on the Recording Counter Field Sheet. Sources of malfunction include road tubes (or other roadway sensors), system electronics, power supplies, and data transfer links.

Equipment Limitations and Improper Set-up: Factors such as traffic congestion, parking, counter/road tube placement, and total number of lanes being counted can influence data validity.

Typical Traffic Statistics: Peak hour percentages, truck percentages, and individual daily volume as a percentage of average daily volume generally fall within certain parameters considered to be "normal" for a short-duration count. Each count is reviewed in order to determine if the statistics from the count fall within these parameters. If not, the data is investigated more closely in order to determine ITS validity.

Atypical Traffic: Holidays, sporting events, parades, and traffic incidents can result in atypical traffic conditions. If a count is conducted entirely during abnormal conditions, such as the week of a major holiday, the count data will likely be inconsistent with data collected historically for that count location. If the atypical traffic conditions are more limited in duration, as can happen with a traffic accident, the data collected during the period of atypical traffic will often be inconsistent with the data collected during the same period of other days of the count.

Data Context: Data context is both the history of traffic at the same location and traffic characteristics at other points along the same roadway. Comparing a count to historical count data or counts that have been taken in the same vicinity at the same time can identify questionable data for further review. This type of editing can also help identify equipment malfunctions. Particularly careful scrutiny in relation to data context should be given to any count that is in question.

Count Duration: A count should be a minimum of 48-hours in each direction. Counts that are less than 48-hours are difficult to validate because there is insufficient data available for comparisons. Therefore, traffic counts that have statistics calculated from less than 48-hours of data in each direction are labeled accordingly.

The following is performed prior to accepting and updating summarized volume counts:

- Confirm that the header information on the count summary matches the header information on the field sheet.

- Review field sheets for notes made by the field person that pertain to the performance of the counter. If equipment malfunctions, traffic congestion, parking on sensors, difficulties setting up equipment properly, or short-term abnormal traffic conditions (such as those caused by a

collision) are noted, and the impacted time periods should be identified. This is done based on field sheet notes, a comparison of data between days and directions, and a review of data context. Data that is more than nominally impacted by such issues should be considered unacceptable and count statistics manually recalculated based on valid data (if the invalid data was used in the summarization process). However, if less than 24 hours of valid directional data is available, then the count is left as-is and an appropriate index note is added.

- If 24 hours of potentially acceptable data remains for each direction, continue with Step 3. If only 24 hours of potentially acceptable data remains for a single direction, only a more limited review of the count in relation to data context and fluctuations in volume is possible.

- Compare daily totals on the directional summaries and scan interval data for gaps and erratic volumes. Daily totals should be within 10% of the average week day (AWD) directional volume. If the daily totals vary: 1) Review the hourly data more closely to verify that the counter was operating properly; 2) Look for other counts taken nearby during the same time period to see if the variability occurs on the same day; and 3) If the variability cannot be substantiated in this manner, but two out of three days is consistent with each other, use only those two days in calculating count statistics. If none of the days are consistent, the data should be appropriately labeled and professional judgment used prior to accepting it.

- Compare the directional AWD volumes. AWD volumes by direction are generally within 10% of each other. If the volumes are not within 10% of each other, follow the procedure outlined in step 3 above.

- Compare daily totals on the summary and scan interval data for gaps and erratic volumes. Daily totals should be within 10% of the AWD volume. If they are not, follow the procedure outlined in step 3 above.

- Review the peak hour percentages and time.

- Peak Time – The peak hour generally occurs in the afternoon between the hours of 3 p.m. and 6 p.m. A morning peak hour is also acceptable between the hours of 6 a.m. and 9 a.m., as well as a lunch time peak hour between 11 a.m. and 1 p.m. If the peak hour occurs outside of this time period: 1) Verify that the peak hour occurs during a similar time period on other days; 2) Look for other counts taken nearby during the same period to see if the peak hour occurs during a similar time period; and 3) Review historical counts to see if the peak hour occurs during a similar period. If a peak hour time cannot be substantiated, the peak hour period should be noted.

- K-Factor – The peak hour percentage (K) is most commonly less than 12% and greater than 7%. If the K does not fit these criteria: 1) Verify that the peak hour volume is similar on other days; 2) Look for other counts taken nearby during the same time period to see if the peak hour is similar; and 3) Review historical counts to see if the peak hour is similar. If a peak hour percentage cannot be substantiated, it should be appropriately labeled and peak hour percentages recalculated based on the next highest volume hour between noon on Monday and noon on Friday. If the newly calculated K-Factor is not less than 12% and greater than 7%, repeat the verification process.

- D-Factor – The peak hour directional percentage (D) is usually less than 65% (always 50% or more). If the D does not fit these criteria: 1) Verify that the directional split is similar on other days; 2) Look for other counts taken nearby during the same time period to see if the peak hour directional percentage is similar; and 3) Review historical counts to see if the peak hour directional percentage is similar. If a high peak hour directional percentage cannot be substantiated, it should be appropriately labeled, and peak hour percentages recalculated based on the next highest volume hour between noon on Monday and noon on Friday. Once peak hour percentages are recalculated, the review process must be repeated for the K and D-Factors.

The following seven steps are performed prior to accepting and updating summarized classification counts. Professional judgment should be used prior to accepting the data, and the data should be appropriately labeled if questionable:

Step 1. Class unknown for each direction should be less than 10% of the directional AWD volume. If the class unknown is not less than 10%, then look at the distribution of class unknown. If the distribution is even, then write on the left of the field sheet that both directions of data must be deleted from the class count file. If the distribution is one direction only, then write that the one direction of data must be deleted from the class count file. If the distribution is limited to a certain number of hours, rework the count so that those hours are not used in any calculations and then write that those hours of data should be deleted from the class count file.

Step 2. Summary single unit trucks should be less than 10% of the AWD volume. Single units are most commonly distributed as follows: bus low, medium high, heavy medium to high, and 4+ low. If the distribution and percentage of single unit trucks does not meet these criteria, then look at the distribution of singles. If the distribution is even or one direction only, follow the procedure outlined in step 7. If the distribution is limited to a certain number of hours, rework the count so that those hours are not used in any calculations and then write that those hours of data should be deleted from the class count file.

Step 3. Summary double unit trucks should be less than 10% of the AWD volume. Double units are most commonly distributed with 4- low, 5 high, and 6+ medium. If the distribution and percentage of double unit trucks does not meet these criteria, then look at the distribution of doubles. If the distribution is even or one direction only, follow the procedure outlined in step 7. If the distribution is limited to a certain number of hours, rework the count so that those hours are not used in any calculations and then write that those hours of data should be deleted from the class count file.

Step 4. Summary triple unit trucks should be less than 6% of the AWD volume. Triple units are most commonly distributed with 5- low, 6 medium, and 7+ high. If the distribution and percentage of triple unit trucks does not meet these criteria, then look at the distribution of triples. If the distribution is even or one direction only, follow the procedure outlined in step 7. If the distribution is limited to a certain number of hours, rework the count so that those hours are not used in any calculations and then write that those hours of data should be deleted from the class count file.

Step 5. Summary total truck percentages will vary depending on the count location. Rural counts will normally be higher than urban counts. Counts taken in Eastern Washington will commonly be higher than those in Western Washington. Professional judgment should be used prior to accepting the data and the data should be appropriately labeled if questionable.

Step 6. Review directional data using the steps outlined for data.

Step 7. If truck data does not meet the criteria above: 1) Review the hourly data more closely to verify that the counter was classifying properly; 2) Look for other counts taken nearby during the same time period, as well as historical data collected at the same location, to see if the classification data is similar; and 3) If the variability cannot be substantiated in this manner, but two out of three days are consistent with each other, use only those two days. If none of the days are consistent, the data should be appropriately labeled, not used, and noted as requiring deletion from the class count file.

Implementation

WSDOT has not implemented any significant changes to their QA/QC procedures in the last several years. They have been using the same procedures for the last 15 years. The processing software was re-written to be compatible with Windows 7.

E.4.3 ESTIMATING MISSING OR EDIT-REJECTED DATA

Data for short-duration traffic counting is never estimated. For example, if a traffic count contains 47-hours of usable count data, the missing hour will not be estimated. However, in order to arrive at 24

or 48 hours of valid data for use in calculating statistics for a count, missing or invalid weekday data may be replaced in the calculations with valid data from the same time period of a different weekday. This can only be done if the valid data is not thereby included twice in the calculations.

Recounts

If an HPMS or ATR count did not have 48 hours of valid data in each direction from which to calculate an average weekday traffic figure, a recount note is written at the top of the field sheet and a copy is given to the Travel Data Field Operations Supervisor. This individual should also be notified of any equipment malfunctions not documented by the field person on the Recording Counter Field Sheet, regardless of the purpose of the count.

E.4.4 Lessons Learned

- Routinely review QA/QC process to ensure that the process is correctly followed.

- Communicate with other States on what works and doesn't work for them to prevent errors.

E.4.5 Future Enhancements

The database infrastructure and reporting software currently in use is old and outdated. As funding becomes available, updated database infrastructure and reporting software will be purchased.

E.5 Case Study #5: New York State DOT (NYSDOT) QA/QC Systems for Traffic Data

E.5.1 Introduction

This case study examines the QA/QC systems used by the New York State Department of Transportation (NYSDOT) for traffic data analysis and presents current practices and lessons learned that can benefit other State DOT's traffic monitoring programs. NYSDOT is responsible for managing a State and local highway system of more than 113,000 highway miles and more than 17,400 bridges. This extensive network supports annual travel of over 130 billion vehicle miles. Also included in the New York State transportation network is an extensive 3,500-mile rail network over which 68 million tons of equipment, raw materials, manufactured goods, and produce are shipped each year. Over 485 public and private aviation facilities are part of the transportation network that more than 80 million people travel each year. Included are over 130 public transit operators that serve more than 80 million passengers each day. Lastly, this extensive network also includes 12 major public and private ports. The responsibility for collecting, processing, and disseminating the traffic data at NYSDOT resides with the Highway Data Services Bureau. Managing the collection of traffic data for such an extensive network is challenging, however, NYSDOT uses a variety of counters and classifiers with over 170+ continuous count stations used to collect the volume data and 24 sites for collecting weigh-in-motion (WIM) data. The following information, documented in the report *Change in Traffic on NYS Bridges, Thruway and Roads (January 2010)*, provides an overview of the use of continuous count stations statewide.

E.5.2 NYSDOT Continuous Count Stations

The New York State continuous count stations vary in volume size (ranging from low to high volume), differing geographic location and areas of population density, and facility type (functional classification of the roadway). The individual continuous count sites are also subject to occasional equipment failure, removal, and addition of new sites. The continuous count sites are grouped by Highway Performance Monitoring System (HPMS) volume group and urban type (urban, small urban and rural) categories. The vehicle miles traveled (VMT) is estimated through HPMS and as such, it relies on expanded samples and multi-year short count volume measurement adjusted to the current

year. Equally important is how bridges and tunnels are considered. Often these represent constriction points within the network and may or may not be a fair representation of overall travel if no other toll or free alternatives exist. Figure E-15 provides an illustration of the New York State Thruway network and the continuous count sites.

FIGURE E-15   NEW YORK STATE THRUWAY AND CONTINUOUS COUNT SITES
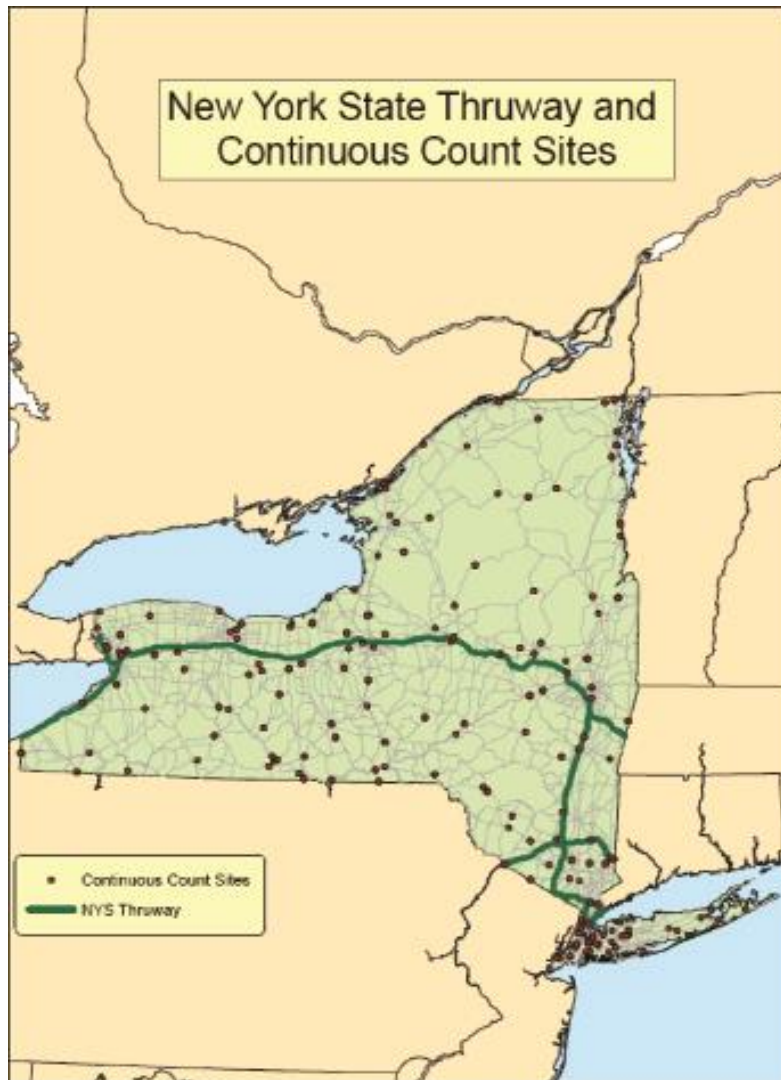
Source: New York State Department of Transportation.

E.5.3   WEIGH-IN-MOTION (WIM) STATIONS

Weight data are also collected at several WIM sites throughout the State. NYSDOT uses the following guidance in establishing their WIM sites. Each site should exhibit the following characteristics:

- Free flowing traffic (it is preferred that trucks travel 30 mph or more);
- No daily traffic jams;
- No nearby intersections;
- Straight and level terrain at the site, including pavement that is in good condition;
- At least 100 Class 9s identified in each lane daily;

- The process to collect and validate this data is documented in the next section; and

- QA/QC procedures used at NYSDOT.

The QA/QC procedures presented in this section provide a high-level overview of these processes, with more detailed information documented in Appendix F of the *TMG*. Quality control of traffic data at NYSDOT begins with field staff inspections of traffic data collection sites on an annual basis. All physical components of the data collection equipment are checked thoroughly and recorded on a site specific spreadsheet by the field staff to ensure that all components are in proper working order. How in-depth the checks are depends upon the level and type of data being collected at the site. The following paragraphs present an overview of the quality checks used at NYSDOT.

E.5.4 Volume, Classification, Speed Data

In the case of volume data only, a process of assuring that the loops are activating and each vehicle is counted as one vehicle will typically suffice. Sites that collect speed data are checked for accuracy by a radar gun. Sites that collect classification data are checked to make sure that there are no missing, or extra axles on the vehicles. On a normal site inspection, data validation may range from watching just ten vehicles to watching a few hundred vehicles. At a minimum, the test will last until all lanes have been validated.

E.5.5 Weight Data

Validation of weight data at NYSDOT typically follows these steps (FHWA, Andrew Haynes, 2010):

- Data collected at counter.

- Data polled to office PC.

- WIM data is polled on Sunday, Monday, Thursday, and Friday.

- Data verified for completeness:

  - Is there file corruption?

  - Are all days retrieved?

  - Are all days complete?

  - Are all lanes present?

- Initial daily and hourly validity checks performed:

  - Is the clock correct to +/- 5 minutes?

- Monthly data checks performed.

- Data edited.

- Data stored in final database.

- There are also a series of office checks and remote checks that are performed for the WIM data collection sites. Additional information on the specific types of validations performed may be found in *TMG* Appendix F.

- Experiences implementing QA/QC procedures at the DOT.

- This section provides information about the experiences and significant accomplishments and challenges in implementing QA/QC procedures for traffic data at NYSDOT.

- Some of the challenges and some system limitations associated with collecting WIM data include the following:

  - No vehicle types are collected, only classes;

- There is no way available to check lane discipline of the vehicles; vehicles riding the edge of a lane are likely to be classified correctly and weighed incorrectly;

- Additional checks such as left/right wheel weights are not available; and

- No error is given for vehicles changing speed over sensors.

E.5.6 LESSONS LEARNED

Several of the lessons learned in implementing the QA/QC procedures for traffic data at NYSDOT are listed below. These lessons are presented to offer guidance to other State traffic monitoring program managers who are responsible for the collection and quality control of their State's traffic data:

- Each site has its own limitations – an acceptable error at one site is not necessarily acceptable at another site;

- Knowledge of the site layouts and typical traffic is required to decipher the automated check warnings;

- Monitor for data completeness;

- Monitor data from the bottom up: Volume > Class > WIM; and

- General WIM checks can be a good indicator of overall site health, but, they do not give the entire picture.

E.5.7 FUTURE ENHANCEMENTS

The most prominent enhancement to NYSDOT QA/QC procedures is the addition of TRADAS. The traffic monitoring group intends to use TRADAS to QC continuous data of all types using automated checks with parameters tailored to individual sites. This will provide the staff with additional time for a more in-depth analysis of problematic sites that require closer scrutiny of problems.

Current practices also put a lot of emphasis on monthly processing, which means that some errors are not identified until they have been occurring for many weeks. The implementation of TRADAS should allow NYSDOT to analyze more up to date data, and therefore catch problems sooner.

WIM data is currently monitored at a very high level and the WIM data that is disseminated is nearly always raw data. With less time spent converting data, NYSDOT has more time for a thorough review of data on a weekly basis. This will allow technicians to more closely monitor calibrations and provide better data to the customers.

Appendix F. COMPENDIUM OF EQUIPMENT CALIBRATION PROCEDURES, CURRENT PRACTICES, AND NEW PROCEDURES

F.1 CASE STUDY #1: WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT), STATEWIDE TRAVEL AND COLLISION DATA OFFICE (STCDO)

F.1.1 INTRODUCTION

This case study discusses some of the equipment calibration procedures, current practices, and new procedures used by the Statewide Travel and Collision Data Office (STCDO) at the Washington State Department of Transportation (WSDOT). WSDOT conducts an extensive traffic data collection program to gather information on usage of the approximately 7,060 miles of roadway composing the State highway system. The purpose of this program is to develop transportation data that will enable the department to construct, operate, and maintain the most efficient and cost-effective transportation system possible given resource constraints.

STCDO is responsible for collecting, processing, analyzing, and reporting historical/archived traffic data for the State highway system and does not contract out for any services. The five major sections in STCDO that perform this work are Electronics, Short Duration Traffic Count Field Operations, Automated Data Collection, Short Duration Traffic Count Processing, and Travel Analysis. Each of these sections perform quality assurance (QA) and quality controls (QC) using their own procedures from site evaluation prior to collection of the traffic data to scrutinize the collected data for accuracy and consistency prior to dissemination to the customers. The following paragraphs provide an overview of the procedures, experiences, and lessons learned over the history of WSDOT's traffic data program. The data collected is made available to WSDOT's customers through a Traffic Datamart that includes traffic volume, classification, speed, and weight information.

F.1.2 CURRENT PRACTICES

The following paragraphs describe the procedures used for equipment validation, field and office testing, and the reporting method used for WIM sites.

Equipment Calibration Methods/Field Testing

Permanent Count Equipment – WSDOT Statewide Travel and Collision Data Office (STCDO) field technicians check weigh-in-motion (WIM) and classification counters for accuracy of axle counts, vehicle speeds and lengths, weights for WIM computers, and basic total counts of vehicles. Loop and sensor sensitivity is checked for each site. Observations are recorded for each detector source. If the loop or axle sensor is found to be over or under counting, adjustments can be made that raise or lower the sensitivity. Loop size and spacing are based on actual measurements taken at each site that are then entered into the counter. Vehicle speeds are checked against a calibrated radar gun. Vehicle classification accuracy is visually checked against the data displayed in the permanent traffic recorder for the FHWA 13 vehicle category classification system if based on axles or on a length-based classification system developed based on a research project completed in the 1990s. Any counter that does not pass system checks is removed from service, repaired and then bench-tested before placing back into service. When performing WIM calibration, a class 9 truck is used that has been taken to a certified set of static scales and the weight of each axle is determined. All axle weights are recorded and vehicle axle spacing and overall length is measured. The truck then passes over the WIM sensors 10 plus rounds and calibration adjustments are completed to bring the WIM site accuracy to accurate levels. Weight tolerances are within 5% to 7% of static weight, vehicle lengths to one foot, and axle spacings within 5 inches. Calibrations are based on steering axle weight of a class 9

truck. Weight checks are also tested at different vehicle speeds to achieve quality weights for varying traffic conditions.

Pneumatic or Short Count Counters – Any new equipment is first tested on a highway using real traffic flow where the traffic volume is high enough to collect an adequate sample of at least 200 vehicles per hour and classification of at least 20 trucks per hour. The vehicle counts and classification results from the new counter are compared to a manual count performed by a short count technician. If the counter passes the manual test comparison, the equipment is put into regular service.

Each time a portable counter is set, the counter should be checked for proper operations and accuracy. Checks are accomplished by visual comparison and hand tally of vehicles for 5 minutes or 50 vehicles for volume or class. Results of both comparisons are recorded on the traffic counter field sheet. If the traffic counter is not functioning properly, air tubes are checked and replaced or the traffic counter is replaced. Equipment malfunctions are recorded on the traffic counter field sheet. The supervisor is notified of traffic counter malfunctions and it is turned over to the Electronic Section for further testing and/or repair.

Office Testing

Data collection counters for permanent and temporary count sites can be checked for operation with testing equipment available in the electronics shop. A loop/piezo simulation device was designed and built by the electronics shop. Any newly purchased equipment or permanent counter brought back to the shop for repairs can be tested for loop and piezo activations.

Short count tube counters can also be tested in the office. Traffic counters can be connected to an air pulse simulator that runs through a sequence of classification schemes.

Office Remote Checking (automated validation procedures)

All STCDO permanent count data sites are accessible from an office telemetry connection. Office personnel can look for possible data problems in all active lanes. Any sensor miss errors or unusual vehicle classification can be checked for possible calibration from the office or noted and sent to the electronics crew for further remote calibration or a possible field site visit. STCDO has found that copper landlines for data collection can be expensive and have erratic service. STCDO has been replacing typical phone lines with wireless IP devices, microwave, and fiber connections. Most all wireless IP connections have a monthly service bill of $5 to $7 per month, saving $25 to $45 per month for a single site.

Reporting Methods

A sheet 16 calibration report is completed for WIM calibration. This report is sent to LTPP for verification of calibration. All other QC reports for calibration and data accuracy are retained in-house.

Challenges with Current Practices

Winter weather can inhibit regular site preventative measures (PM) in many areas of Washington State. The regular construction and repair season can leave little time for site preventative measures. Many permanent count sites do not get a regular PM check until a site visit is needed for some type of troubleshooting and repair.

Use of a known weight truck for WIM calibration can be costly. Budget reductions have limited the use of this resource.

Challenges for short count are areas where tubes can no longer be set to collect the data due to traffic volumes or roadway geometrics. In this case, an alternative method is required to obtain the data.

F.1.3 LESSONS LEARNED

- Accurate and reliable shop test equipment provides the best tool to prevent time spent troubleshooting in difficult field environments.

- A good product vendor is priceless. All of the data counting equipment currently in use has its own unique characteristics, so buy a product that will offer good support.

- Communicate with other agencies that are using the same equipment that you intend to use and see what their experience has been.

- Vendor information for weigh-in-motion systems is lacking. STCDO WIM specialist has made changes to software programming and installation techniques.

- Contracting out services requires careful planning and close supervision.

F.1.4 FUTURE ENHANCEMENTS

- Require or encourage vendors to make products NTCIP compliant.

- Upgrade equipment as budget allows.

F.2 CASE STUDY #2: NEW YORK STATE DOT

F.2.1 INTRODUCTION

This case study examines the traffic data collection equipment calibration and validation procedures used by the New York State Department of Transportation (NYSDOT), and presents current practices and lessons learned, which can benefit other State DOT traffic monitoring programs. NYSDOT is responsible for managing a State and local highway system of more than 113,000 highway miles and more than 17,400 bridges. The responsibility for collecting traffic data on this extensive system relies on a comprehensive network of data collection equipment for volume, classification, and weight data. Procedures are in place to ensure that the processing and reporting of this data results in delivering the highest quality traffic data possible.

This case study focuses on the equipment used to collect traffic data for the highway system. The responsibility for collecting, processing, and disseminating the traffic data at NYSDOT resides with the Highway Data Services Bureau. Managing the collection of traffic data for such an extensive network is challenging, however, NYSDOT uses a variety of counters and classifiers with over 170+ continuous count stations used to collect the volume data and a network of 24 sites for collecting Weigh-In-Motion (WIM) data.

F.2.2 NYS CONTINUOUS COUNT STATIONS

The New York State continuous count stations vary in volume size (ranging from low to high volume), differing geographic location and areas of population density, and facility type (functional classification of the roadway). The individual continuous count sites are also subject to occasional equipment failure, removal, and addition of new sites. The methods used to field check and maintain the data collection sites are the subject of this case study. As a frame of reference, Figure F-1 provides an illustration of the New York State Thruway network and the continuous count sites.

FIGURE F-1   NEW YORK STATE THRUWAY AND CONTINUOUS COUNT SITES
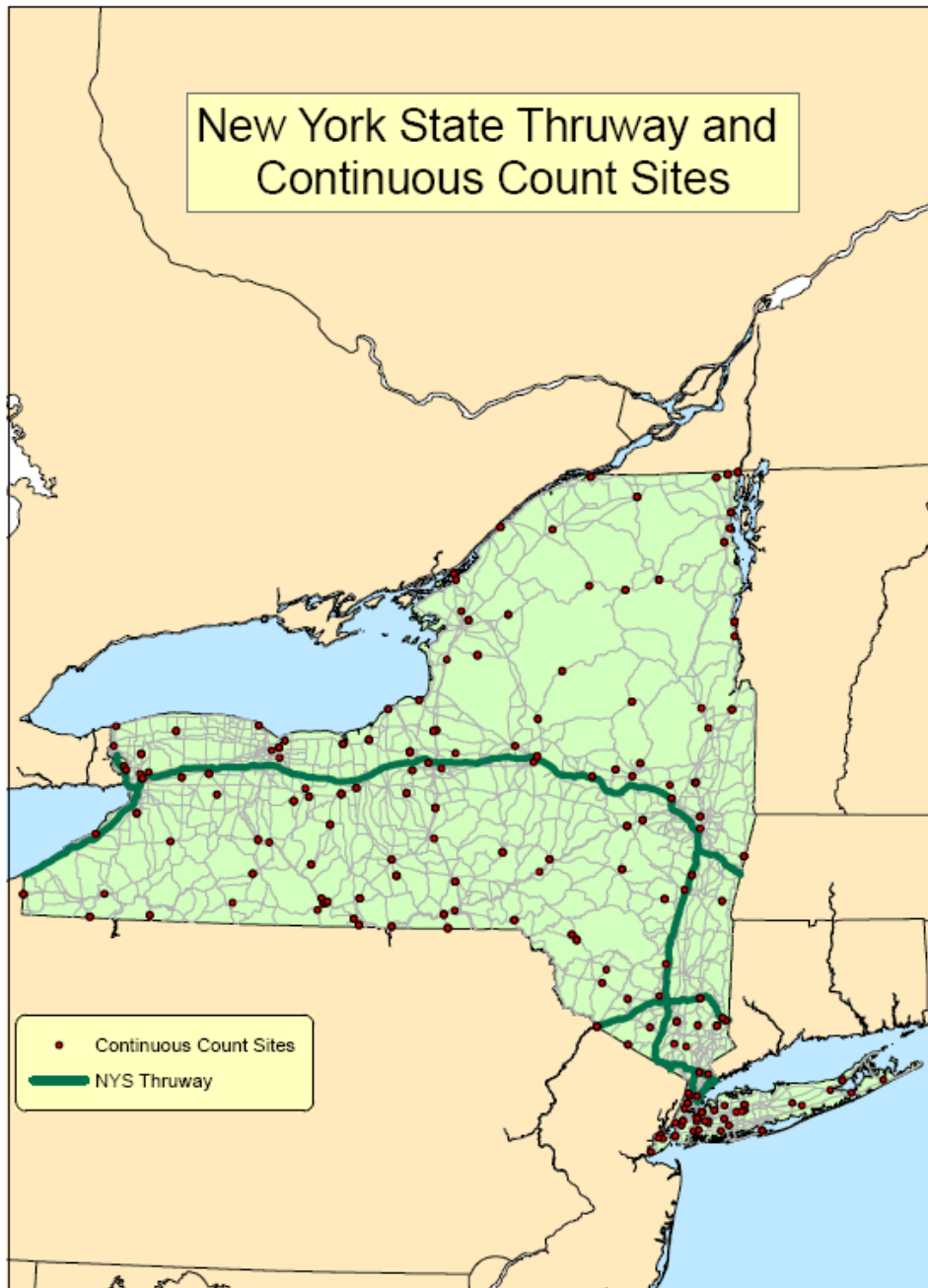
Source: New York State Department of Transportation.

F.2.3   WEIGH-IN-MOTION (WIM) STATIONS

In addition to the continuous count stations used to collect volume data, a series of WIM sites located throughout the state are used to collect weight data. Information about establishing the sites and calibrating the equipment used is discussed in more detail in the next section. At a minimum, NYSDOT uses the following guidance in establishing their WIM sites. Each site should exhibit the following characteristics:

- Free flowing traffic (it is preferred that trucks travel 30 mph or more);

- No daily traffic jams;

- No nearby intersections;

- Straight and level terrain at the site, including pavement that is in good condition; and

- At least 100 Class 9s identified in each lane daily.

F.2.4 CURRENT PRACTICES

This section presents current practices pertaining to equipment validation and testing.

Field Testing

In order to maintain quality data collection, the NYSDOT traffic monitoring field staff inspects each traffic data collection site annually. During these inspections, the physical condition of the site is recorded on a site-specific spreadsheet by field staff. This includes the counters, communications devices, cabinets, solar panels, pavement conditions, pull boxes, sensors, and cabinet wiring. Once all components of the site are deemed to be in good condition the communication is checked to be sure remote access and data retrieval is possible. Then the counter is checked to make sure that data is collecting correctly. This typically involves watching sensor activations in real time, and also watching vehicle records in real time. How in-depth the check is depends upon the level of data a site is collecting. For volume only data, typically assuring that the loops are activating and each vehicle is counted as one vehicle is sufficient.

Sites that collect speed data are checked for accuracy by a radar gun. Sites that collect classification data are checked to make sure there are no missing or extra axles on the vehicles. On a normal site inspection, data validation may range from watching as few as ten vehicles to watching a few hundred vehicles. At the very least, the test will last until all lanes have been validated. The data is also validated in this manner any time a technician is on site. In some cases, a polling technician may log into a site without a field technician on site. In these cases, less information is available; for example there is no way to tell that a recorded class 8 was really a class 9 that missed a tandem axle.

Equipment Calibration

NYSDOT uses a TC/C-540 counter with a WIM board to collect WIM data. As such, the sites are auto-calibrated by adjusting the Front Axle Weight of Class F9s to be between 9-12 KIPS. Depending upon the volume of trucks at the site, the calibration may be set to use the average front axle weight from a sample of anywhere from 10-30 trucks. WIM sites calibrations are monitored through a variety of charts and checks. The checks listed above provide minimal detail, and usually lead to resetting the auto-calibration factors to one.

A FAW/GVW (Front Axle Weight/Gross Vehicle Weight) chart was developed that shows the Class 9s for a site by direction, and is also available in a PDF format to be used as a flip book to see where calibration has drifted and what data needs to be removed. Figure F-2 illustrates an example of the FAW/GVW chart.

CC_ID: 0199   MONTH: 1/28/2008

CC ID	DIR	MONTH	AVG	STD
0199	North	1/28/2008	10676	1897
0199	South	1/28/2008	9768	3011

CC_ID: 0199   MONTH: 1/29/2008

CC ID	DIR	MONTH	AVG	STD
0199	North	1/29/2008	10763	1833
0199	South	1/29/2008	10359	2089
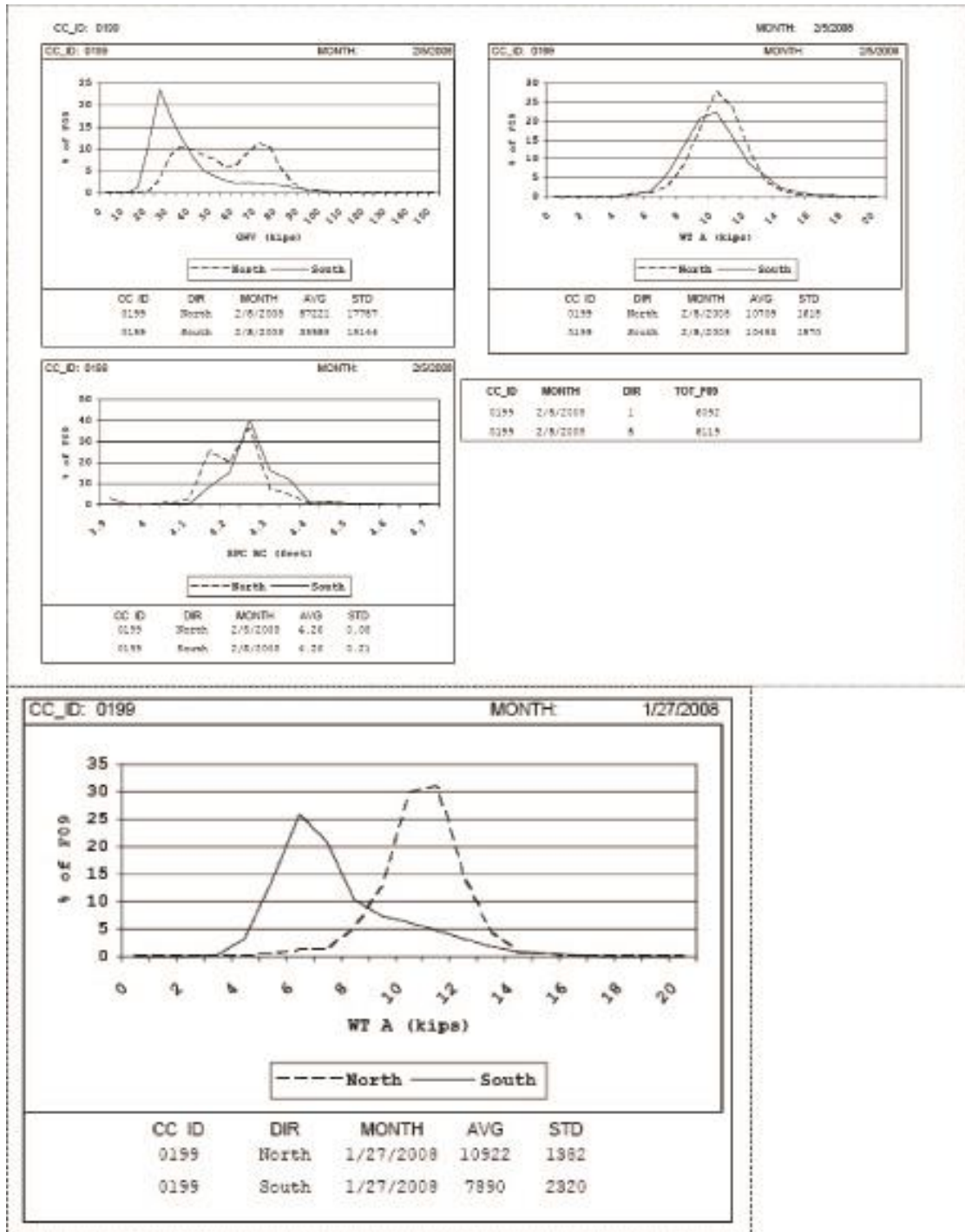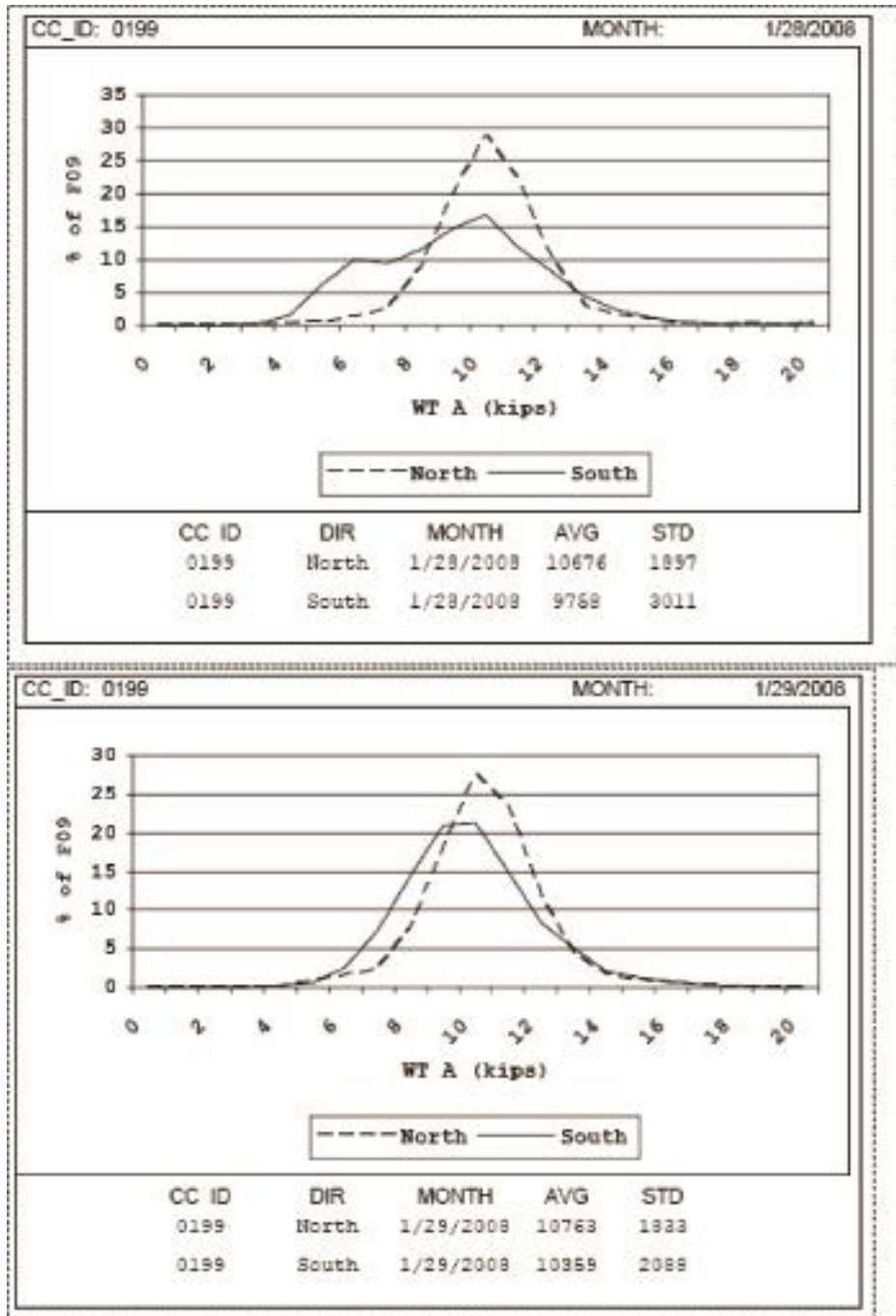
Sources: New York State Department of Transportation.

The field crews also spot check WIM calibration by running a class-9 lowboy carrying a loaded dump truck over the sensors. Prior to testing, the lowboy is weighed and axle spacings and overall length are measured and recorded. Then the truck performs ten passes over each WIM enabled lane. The results are recorded on the "WIM Field worksheet.tif" (see Figure F-3) and then entered into the "WIMCalibration.xls" file (see Figure F-4) to monitor the performance. If the performance is outside of acceptable range, the maintenance contractor is notified.

FIGURE F-3   WIM FIELD WORKSHEET

Source: New York State Department of Transportation.

Source: New York State Department of Transportation.

Office Testing

In the absence of having someone watch the traffic, the office is limited to checking that sensors are activating in sequence by lane and that speeds seem to be reasonable for the site. When available, the speeds can be validated by watching the drive axle spacing on Class 9s, if they are within the range of 4.2 to 4.4 feet. Under these circumstances, the site would be considered acceptable. Traffic can also be remotely monitored to make sure that there is an acceptable amount of sensor misses at the site. The amount of information available also varies based on the equipment used. NYSDOT uses a variety of counters and classifiers to collect their volume and classification data.

Office Remote Checking (Automated Validation Procedures)

Several remote checks are performed using automated procedures. NYSDOT Traffic Monitoring polling technicians review data from continuous sites at many levels. The data starts on a counter and ends up in an Oracle database with many steps along the way.

The first step is downloading the data. This is done using the Autopoll function of a few different programs. From most sites, the data is downloaded once a week. The most basic high level checks include the following:

- Are the communications working?

- Is the counter collecting data?

- Are both the date/time correct?

- Has the counter been collecting data continuously since the previous polling?

- Is there any file corruption, and if so did it come from the transfer or the counter memory?

- Are all lanes accounted for?

Once these questions have been answered, the data collected is stored in a holding database. This database runs a number of automated quality checks on the data; some checks apply to volume, class, or WIM data. Higher levels of data have more checks that apply.

Volume data checks include the following:

- Consecutive zero hours – Looks for periods where a given lane has more consecutive zero hours than a user set threshold. NYSDOT uses 3 hours.

- Midnight/Noon comparison – Compares the volume of the midnight hour to that of the noon hour. A flag is produced if midnight is greater.

- Directional Split Daily/Hourly – Compares the directional volumes and produces a flag if the percentage of traffic in one direction is greater than a threshold. NYSDOT uses 75% for the hourly threshold and 65% for the daily.

- Unchanging hours – Looks for periods where the volume in a given lane does not change, a flag is produced if more than 3 consecutive hours have the same value.

- Peak hour zeroes – Looks for zero hours in any lane during peak hours of 6 a.m.-9 a.m. and 3 p.m.-7 p.m..

Classification data checks include the following:

- Class 1s – Provides a flag if a site has more class 1s than a user set threshold. NYSDOT uses 1%. This causes many extra flags, but also allows for earlier detection of problems.

- Class 2s – Provides a flag if a site has more class 2s in a given lane than a user set threshold. NYSDOT uses 95%.

- Percent Unclassified – Provides a flag if a lane has more unclassified vehicles than a user set threshold for an interval. NYSDOT uses 10%, and typically collects an hourly interval.

- Class 4-13 – Provides a flag if the sum of class 4-13s is higher than a threshold for a lane by interval. NYSDOT uses 25%.

- Class 3-13 – Provides a flag if the sum of class 3-13s is less than a threshold for a lane by interval. NYSDOT uses 2%.

- Class 8 vs. Class 9 – Provides a flag if there are more class 8s than class 9s for a lane by interval.

- Class 9 vs. Class 11-13 – Provides a flag if the sum of class 11-13s is more than class 9s for a lane by interval.

WIM data checks include the following:

- Class 9 Front Axle Weight out of range – This flag shows the percentage of vehicles with FAWs outside a user defined range. NYSDOT uses 9-12 KIPS and typically expects 15-30% out of range depending on the location.

- Class 9 Axle 2-3 spacing – The flag shows the percentage of class 9s with the axle 2-3 spacing outside of a user-defined range. NYSDOT uses 4.1-4.4 feet. This flag also does not display if less than 5% of class 9's are out of range.

- The flags are displayed in a text document sorted by site and date. Each flag shows the lane, direction, and interval that it applies to, as well as specific information like how many class 1s are observed, or what is the total volume for the interval. Using the combination of flags displayed, a background of the site's history, typical traffic, and weather reports, a polling technician then goes through the flags and determines if any action needs to be taken.

F.2.5 REPORTING METHODS

Once data has been collected into the holding database for an entire month, it is extracted into the NYSDOT format as defined by NYSDOT EB 11-030 Traffic Monitoring Standards for Contractual Agreements. This format allows the data to be processed through NYSDOT's Traffic Count Editor (TCE) program. This program displays volume, classification, and speed data in various charts and tables. It can allow a processor to find errors in the data that were not apparent from the initial automated checks. TCE also allows the technician to remove data that is identified as 'no good'. The files are then edited and saved for import into the final Oracle database. On import, the data is checked to ensure it is not duplicate data.

After completion of checks for duplicate data, the data is now ready for reporting. The standard FHWA Volume and Classification records are created and submitted to FHWA and an Hourly Volume report and Monthly Class and Speed summaries are created and posted to the NYSDOT Traffic Data Viewer available at https://www.dot.ny.gov/tdv. Raw data files for volume data are created and posted on the NYSDOT website:

https://www.dot.ny.gov/divisions/engineering/technical-services/highway-data-services/hdsb. The standard reports display data directionally. An example of this type of report is shown in Figure F-5. Figure F-6 includes screen images of volume, speed, and classification reports.

FIGURE F-5   NYSDOT STANDARD REPORT EXAMPLE

Source: New York State Department of Transportation.

Source: New York State Department of Transportation.

Source: New York State Department of Transportation.

In addition to the standard reports, all data is available at the interval level by lane. NYSDOT provides this data in report and comma separated variable (CSV) formats on request. The next section discusses the challenges associated with using the current practices.

F.2.6   CHALLENGES WITH CURRENT PRACTICES

Communication with sites was a challenge for NYSDOT. Without communication, it takes longer to obtain data, identify errors, and correct problems. Over the last two years, NYSDOT has converted approximately 75% of continuous sites to IP connections over cellular networks. This allows for faster downloading and more reliable connections compared to landline and dial-up cellular service.

Another challenge is the conversion of data from counter to holding database then editing files and processing them to the final database. This process can be lengthy and without sufficient staff can take months to cleanse and publish the data. NYSDOT is currently going into production with TRADAS; this should allow data to be downloaded from the counters and placed directly into the final database. This process will not eliminate any of the QC checks and will add some that are not currently used by NYSDOT. Once this is fully implemented data publishing will be timelier.

F.2.7   LESSONS LEARNED

One advantage NYSDOT has when validating traffic counts is the Traffic Count Editor (TCE) software application. This software displays all short term and continuous traffic counts in side-by-side graphical and tabular displays. The user can choose the aggregation level of the charts and the type of charts. This visual display makes apparent errors that would not be found by automated means. The software was originally designed for short term counts, thus necessitating continuous counts to be loaded one month at a time to maintain performance. TCE is owned by NYSDOT and can be provided to other States, and modified by the developer at a modest cost to suit their individual needs.

NYSDOT also tests counters against existing permanent sites. Currently the favored test site used is a six-lane expressway with an AADT of more than 160,000. This site allows NYSDOT to see the

performance of new devices in heavy volume, at both high and low speeds, and in free flow and congested conditions.

NYSDOT requires their traffic count contractors to test annually all portable traffic counters intended for use on contracts, prior to the count season, to ensure that the contractor's count deviation does not exceed 2%. The following instructions illustrate the required procedure for testing.

- Step 1 – Make sure that all counters display the same clock time when deployed and when picked up. Record the counter and module serial numbers.

- Step 2 – Set, at a minimum, 10 counters along the same section of road simultaneously. Obtain volume, speed, and classification data for the same traffic in the same direction at hourly intervals for a minimum of 24 hours. If available, a NYSDOT approved traffic simulating device capable of calibrating traffic counters may be substituted for this step. If such a device is utilized, obtain volume, speed, and classification data for the same simulated traffic in the same direction at five minute intervals for a minimum of 2 hours.

- Step 3 – If applicable, retrieve the counters and download and process the counts.

- Step 4 – Examine the output from the counters to find the counters with intervals that exceed the average value by +/- 2%.

- Step 5 – Compare the average value for each interval with the individual interval counts. Determine values that stand out and eliminate the respective machine from the comparison. Re-compute the average values. Repeat this process until remaining count data falls within +/- 2% of the acceptable average.

- Step 6 – Troubleshoot suspect equipment, repair if necessary, and retest.

- Step 7 – Compile the results from the testing process in spreadsheet format listing the validated traffic counters by model and serial number and their comparative count values. Provide one copy of the results to the Regional Contract Manager and one copy to the Main Office Traffic Monitoring Supervisor.

F.2.8 FUTURE ENHANCEMENTS

There are a number of areas that NYSDOT Traffic Monitoring has identified for improvement. One of these issues includes the time lag between collecting and publishing data, which will be resolved upon the implementation of TRADAS.

Reporting of data will be improved by reducing the number of steps between collection and publication. Currently, continuous count data is converted multiple times and edited manually before being published. Upon full implementation of TRADAS, continuous counts will be converted one time or perhaps not at all, and some data edits will be tied to automated validity parameters.

The implementation of TRADAS will also allow the NYSDOT Traffic Monitoring staff to pursue quality checks that are not currently being used, such as:

- Month to month and year over year volume and classification comparisons for continuous data.

- Short counts will be checked for location through the use of GPS points that are now required to be submitted along with traffic data.

- Short count classification data can be more readily compared to prior counts at the same location.

- WIM data will be analyzed both more frequently and more thoroughly. Current practice typically analyzes WIM data directionally, rather than by lane.

- More non-intrusive devices are also being approved for use in New York. This will allow segments that are difficult to count with traditional methods to be counted.

Traffic Monitoring is also pursuing collaboration with various other sections within NYSDOT and other agencies to collect more data. These sections include ITS for each metro area in New York, traffic safety and mobility, and even traffic signals groups. Various data types are becoming available to traffic monitoring, and will be integrated into NYSDOT systems as they become available.

F.3 CASE STUDY #3: ALASKA DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES (ADOT&PF)

F.3.1 INTRODUCTION

The State of Alaska DOT&PF has the responsibility for analyzing and reporting traffic data on the approximately 16,000 centerline miles of public roads in the state. The primary responsibility for traffic data collection is held by the State DOT, although about 5% of traffic count data comes from local governments. The data collection staff in each DOT region (Northern, Central, and Southeast) is responsible for the short term and continuous vehicle volume, classification, speed, and intersection turning movement count programs. The continuous count program in Alaska consists of about 100 stations distributed throughout the State, of which half are vehicle classification sites. Approximately 2,000 short-term counts are conducted annually.

Traffic volume reports are published by each region annually and are located on the department website, and include continuous data, classification data, and VMT tables. The department does not currently have a bicycle and pedestrian data collection program, although some bicycle and pedestrian data is being collected at a project specific level. The weight data collection program is handled in the headquarters office that also compiles the completed ADT and AADT data and submits it to FHWA for the monthly travel volume trends report and annual HPMS report.

F.3.2 CURRENT PRACTICES

Continuous Count Program

In the process of installing new permanent traffic recorders or maintaining an existing site, traffic sensors, primarily inductive loops and piezoelectric axle sensors, are tested with the appropriate instruments before installation to ensure functionality. A member of the traffic monitoring program staff is on site to oversee the installation and offer any assistance that may be required during the construction process. Once installed, the site undergoes a formal acceptance testing procedure to ensure the proper calibration of the traffic counter and performance of the newly installed sensors. The test consists of 10 passes of three differently classified vehicles (Class 5, 6, and 9 or 10 with a 50% legal load). Before the test begins, measurements of the axle spacing for the test vehicles are recorded. In order to pass the acceptance testing, each lane should correctly assign the class designation for 9 out of 10 successive passes and compute axle spacing to within six inches of the actual measurements. As is the case with site construction, a traffic monitoring employee will supervise the test. If necessary, modifications to the set up of the equipment, such as loop sensitivity and axle spacing, are made to ensure that the sensors and traffic counter are accurately reflecting observed traffic patterns.

Field Testing

To ensure the accuracy of the permanent stations, each site undergoes an accuracy test annually. Traditionally manual two hours counts are conducted at permanent locations, recording either volume or classification depending on the site configuration. If available, video recorders are used to monitor two hour segments of traffic that are analyzed for vehicle volume or classification. The video has the added benefit of being able to be repeatedly played back if there are issues that need to be

rectified due to discrepancies between the data sets. Along with the accuracy tests, manual site inspections are performed at this time.

The manual site inspections are conducted twice annually. These primarily consist of testing traffic sensors with the appropriate test equipment, checking traffic counting equipment, testing batteries, communications equipment, and assessing the condition of the installation overall.

Portable traffic counting equipment not only needs to be checked for accuracy before the season of short term traffic counts begins, but also needs to be configured once it's deployed in the field. Configuring ADRs allows ADOT&PF to specify the type of modem and its communications, details of sensors, data and time, format media, assign file storage, check measurements, etc. Calibrating at each count station is important according to the road, sensor, and site condition. Not only do checks ensure that the counter is calibrated correctly, but they also make sure that the sensors are working properly at each traffic count station.

Office Remote Checking

Before the beginning of each season, all of the portable traffic counters are tested using an ATRT-1700 tester to assure the accuracy of collected data and identify potential problems so they can be repaired before being deployed. The ATRT-1700 is an automated tester of counters and classifiers that is designed to simulate any type of highway vehicle passing over a user-defined array of highway traffic sensors. The traffic count tester blows a set number of air pulses, similar to those generated by vehicles driving over pneumatic road tubes, so that they can test the accuracy of the air switches, which includes volume and class data. The tester can replicate vehicle classes and speeds by matching the timing of the simulated pulses. Different input sensors can also be tested, such as piezoelectric axle sensors, pneumatic road tubes, and inductive loops. Battery life is also tested in the office before the count season begins.

QA/QC Procedures

Quality assurance and quality control procedures are manually conducted in order to eliminate the possibility of reporting bad data. The current traffic data system does not have the capability to run automatic QA/QC checks. Stations are set up to download nightly. The data is visually checked weekly to ensure conformity to the normal traffic patterns and any irregularities can be noted and explained if they arise. Before submittal, data is checked again manually and compared to both the previous five years of data in each direction and the current year's patterns.

F.3.3 CHALLENGES WITH CURRENT PROCEDURES

The main challenge encountered is with the permanent stations, and the wear and lifetime of piezoelectric axle sensors. The sensors tend to have a 3-year lifespan, and with the short duration and compacted construction season in Alaska, repairing these locations is difficult to schedule as well as costly to maintain.

Equipment malfunction is also a challenge, especially when in remote areas. Often, simple repairs are not possible, and it is hard to troubleshoot and diagnose issues without sending them back to the manufacturer. Some of the issues include display, communication and download, and battery issues. This is both costly and consumes a lot of time out of a compact and busy season.

F.4 CASE STUDY #4: PRIVATE SECTOR CONTRACTING FOR QUALITY INSTALLATIONS AND DATA-SITE SELECT, INSTALL, CALIBRATE AND MAINTAIN

F.4.1 INTRODUCTION

This case study provides an overview of the benefits of state of the art "best practice" site selection, installation, and maintenance techniques as utilized in Virginia for continuous count, speed, classification, and WIM data. The direct benefits of these high quality installations include very high data quality and extended site life before failure. An additional benefit of these installations and the associated electronics has been the availability of "live" or "real time" traffic data in formats used by traffic operations centers throughout the state of Virginia as shared data. This is an example of achieving more while keeping expenditures within budget and fostering support for a comprehensive traffic monitoring program. Strict quality control measures on site selection and installation ensure that accurate traffic data is reliably available for all applications. QC/QA procedures supplement this focus on quality by efficiently identifying out of tolerance conditions quickly. This allows corrective action to be taken before there is meaningful data loss and the informed use of data with known characteristics. The collected data is used for the publication of reports, the certification of vehicle miles traveled, the forecasting of future traffic volumes, highway design, pavement life studies, and traffic operations.

While other States pay contractors to repair sensor systems when they break, providing no incentive for the contractor to exceed requirements or to improve the system installation or methods, Virginia pays its contractor for quality data, with the result that premature breakage or failure costs the contractor money in non-payment for lost data. There is the built in incentive to the contractor to perform all work to the highest standards of performance accuracy and reliability. Reliable and durable site construction facilitates the expanded deployment and support of traffic monitoring infrastructure in a world of financial budget constraints, allowing more to be done with a given level of budget.

This case study has been prepared by Digital Traffic Systems, Inc. (DTS), which has been under contract to VDOT since 2001 for the technical services described herein.

F.4.2 PLANNING FOR HIGH QUALITY

With cooperation and support from venders and Virginia DOT, procedures have been developed for data collection performance and reliability, which, barring complete pavement failure, assures high quality data is available from over 97% of all sites at a high level of confidence. The emphasis is on the following points:

- Attention to detail in site selection, to provide good conditions for collecting traffic data;
- Care in the specification, selection, and purchase of components and supplies;
- Precision and attention to detail during the installation and calibration process; and
- Ongoing cooperation with data customers and suppliers of equipment and software to facilitate continuous improvement for reliability and performance.

F.4.3 DOCUMENT THE NEEDS AND GOALS

The type of traffic data you require will have a direct bearing on the number, type, and location of the sensors that will be used. The first step is to identify the users of the traffic data and to identify their needs. Standard objectives include: volume counts, speed, classification, and weight data. Today it is reasonable to include the ITS and Traffic Operations needs in a data sharing arrangement to achieve the most cost-effective and responsive program.

## F.4.4 CONSTRUCTION PLANNING/DOCUMENTATION OF PLANS

When discussing permanent traffic data collection sites, traditional inroad sensors such as loops, piezos, or quartz sensors are usually referred to. Keep in mind that some non-intrusive sensors are also capable of collecting vehicle volume counts, speed by lane, and length classification on a statistical or "real-time" basis and will provide very good data if carefully installed. Even before deciding on the sensor type or configuration that is best for your application, it is important that a commitment to planning for quality be made. It is usually very difficult and expensive to return to a poorly designed and/or poorly installed site in an effort to correct problems post-installation.

As the first step in the quest for reliable quality traffic data, develop standardized site designs by application:

- Develop a set of drawings and written descriptions to be used as standards for all sites.

- The basic standard layout of your typical traffic monitoring site should show the desired standard relationship of sensors, pull boxes, conduits, poles for power or cabinet mounting, guard rails, cabinet door opening direction, disconnect boxes, grounding, and surge protection.

- Standardize the electronics cabinet, size, shape, and material construction.

- Document the wiring layout and a schematic diagram of all connections into, inside, and from the cabinet to any external sensors or power supply connections.

- Include full details of your requirements for surge protection, earth grounding, and communications connections. In short, if you want it done right, you must document it.

- Address construction details that facilitate ongoing upkeep or maintenance of sites to foster reliable operation and long site life expectancy.

FIGURE F-7   TRAFFIC DATA COLLECTION SITE PLANS
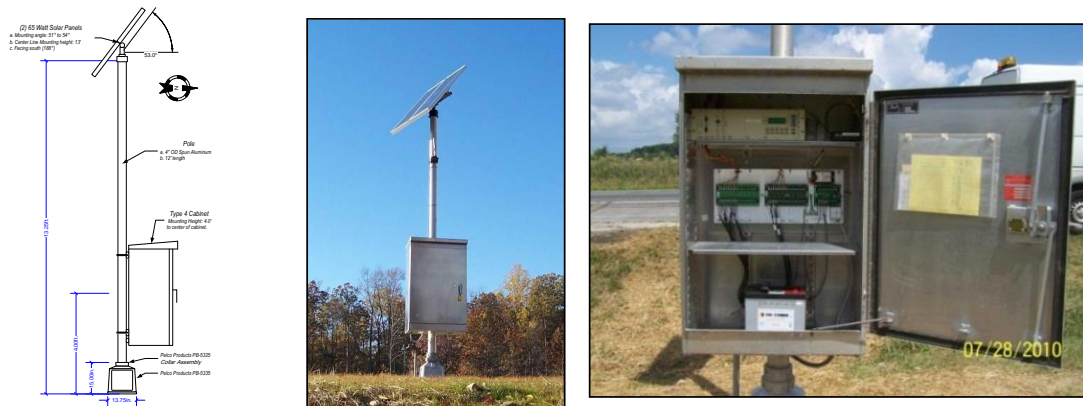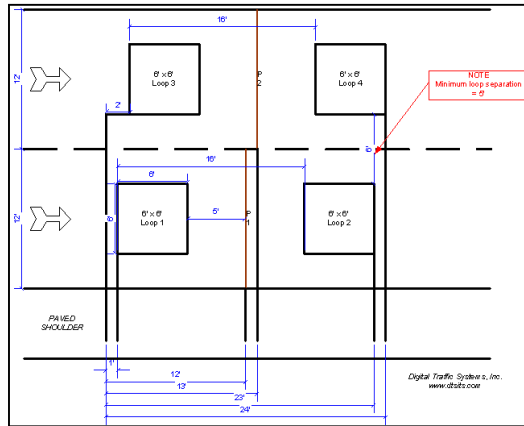
Source: Virginia Department of Transportation.

F.4.5 SELECT MATERIALS

All components and materials should be subjected to a pre-qualification testing regimen before wide spread installation and use. Ideally, all materials should be pre-approved and listed on the agency pre-approved materials listing or in contract specifications. For example, the specification and use of the highest quality most durable loop wire, IMSA 51-5 or 51-7 Traffic Signal Cable that are sheathed in a tubular protective sleeve provides significant benefits. Although nominally more expensive from an installation, material, and labor cost perspective, the installed loop lasts much longer, extending the effective life of the site, without costly in-road repairs. Use a high quality loop seal grout that is limited in shrinkage and remains slightly flexible for years for similar reasons. Loop seal grouts that shrink too much will pull away from the sides of the saw slot and will allow water entry in the small cracks thus formed. Water entry into even microscopic cracks is the single most common cause of failure of installed loops (and piezos) and the surrounding pavement. Hydraulic pressure exerted by passing vehicles or winter freezing will accelerate failure.

To promote long site life and reliable operation, special installation procedures have been developed for deep loop and deep piezo installation that lasts much longer, even in harsh climates, and is resistant to the freeze thaw cycles of winter. The deep installation will usually survive surface milling and pavement resurfacing overlay and will maintain full operation without repair or replacement for many years, allowing more sites to be installed and maintained for a given budget.

F.4.6 ELECTRONICS

The actual working performance of the electronics should be specified, tested, and certified before acceptance or final field installation. Ensure the team of manufacturer, supplier, and installer are working together to design, test, and provide a total system package that will work together to provide data in the field for years. Once it is installed and paid for, it is difficult to correct fundamental design flaws or incompatibilities between system components. Performance based contracts help avoid situations where the manufacturer can say the problem is the installers and vice versa, by holding a single party accountable. The certification of components should include the power supply, (solar or AC), regulators, batteries, cabinet, pole, pole mounting, base foundation design, pull box configuration, earth grounding, cable bonding, and surge protection. All of the various sensor interfaces and communication links should be identified, tested, and certified. Assure that supplier and installer demonstrates a complete and fully functional total system before acceptance. Quality data and long life begin with equipment and material selection and installation.

F.4.7 CERTIFICATION OF CONTRACTOR

It is extremely important to only use experienced traffic sensor installation contractors, with demonstrated experience in the specific requirements of your project or program. Require prequalification or demonstrated project experience to ensure your contractor has the correct skill set or experience to install a traffic data monitoring system to operate at high quality and reliably for years. Loops, piezos, and Quartz sensors are not something that can just be thrown into the pavement and expected to work reliably and properly for years to come. Only certified, bonded, licensed, and experienced contractors should be allowed to participate. Prepare a pre-approved qualified contractor list for your installation work. Inspect the sites where they have previously done work and consult with their customers to determine the level of satisfaction achieved and the reliability of the previous installations. Document the results and where permissible, use qualification-based procurement processes or performance-based contracts to ensure reliable delivery of traffic data.

F.4.8 TRAINING OF CREWS

The importance of installation crew training as a critical item in the overall quest for quality and reliability in traffic data site installations and their maintenance cannot be overstated. Due to the cost of continuously providing specialized training, staff retention is important, and conducive to consistent outcomes. An important key to success in achieving consistent high quality is formalizing the training process for each individual in the installation and maintenance operations. Each field installation or maintenance task is identified and documented with photographic and video procedural training aides and materials. Each employee has a "Training Qualification Record" that documents on a task by task basis the formal training received and the field evaluations of task mastery as demonstrated to the employee's job mentors. Advancement is predicated on acquiring and mastering knowledge skills and abilities (SKA) of the job.

F.4.9 SITE SELECTION BEST PRACTICES

Site Selection Concepts

The task of consistently collecting excellent classification data should be subject to the same considerations that apply to the ASTM Type I WIM data collection site selection criteria. Anything less is a potential tradeoff of quality and reliable traffic data. If the basic location of the site is flawed, then the data collected from the site will always be less than perfect, as subject to the inherent site location flaws. Apply similar criteria to the selection of non-intrusive sensor sites with different decision points. Diligent attention to detail and documentation with digital photographs assures a careful process that can be reviewed before installation, and if necessary, a move to a different location can be made. Below is an overview listing of the criteria applied when surveying a suggested traffic monitoring site location.

- Basic site selection criteria;
- Examine traffic patterns;
- Avoid curves;
- Avoid intersections;
- Avoid traffic signals;
- Avoid areas of congestion;
- Avoid stop and go traffic;
- Avoid merging traffic, ramps, and exits;
- Avoid busy driveways;

- Avoid areas of changing lanes;

- Avoid areas of speed changes (>15 mph recommended); and

- Make note of MOT safety concerns at the site.

Site Communications Criteria

Communications to the site, either by fiber-optic cable, wireless internet modem or the "plain old telephone" system is a critical part of the data collection system. Assure that your site selection survey comprehensively identifies your solution and establishes that it will work reliably. Wireless communications offer many inherent benefits with respect to system reliability, bandwidth, and remote operations.

Maintenance of Traffic Planning

While performing your site selection survey, prepare preliminary plans for maintenance of traffic during construction activities. A detailed plan should be fully developed as part of the preconstruction planning. A sample preparation and planning check list, and a developed plan are supplied as attachments for reference. Your local requirements may differ in some specifics; check with your agency.

Technician Parking

As part of the site survey, take note of the requirement for technicians to return to the site at various times in the future for calibration or testing activities. Where can they safely park without adversely affecting the passing traffic and the data collected and evaluated while on site?

Site Planning

As part of the initial site location survey a preliminary proposed location for each of the following items should be identified and staked or marked with paint in a clear manner. It is a good idea to photographically record the location markings of all items. Also, use your camera to record the proposed layout of sensors, area road conditions, and show upstream and downstream approaches as well as the road profile at the sensors. Include pictures of the proposed cabinet location.

- Where on the road will the sensors be located? What is proposed?

- Loops, size, type, location.

- Two per Lane (always a matched pair).

- Loop Size, 6' × 6' Turns of wire, always 4.

- Piezos, length of sensor, length of lead-in.

- There are several options of length and in lane placement. Virginia uses a full lane width (long) sensor. Other organizations use a half lane sensor. Allow no splices.

- Kistler Quartz, good for WIM.

- Similar to the piezo question of length and placement, there are several options to be considered.

Other Important Considerations

- Where will the electronics cabinet be located? Is the point of detection by the sensors clearly visible from this spot? The best cabinet location is behind a guard rail, outside the clear zone, accessible for maintenance, unobtrusive, and vandal resistant.

- Site power, AC or solar? Solar needs a clear view of the sun every day for at least eight hours.

- Mark a location for each junction box and underground conduit run.

- Mark or stake each pole and base foundation location.

- Where and how will communications arrive at the site?

- Are there any special grounding requirements such as a trench or array of rods?

F.4.10   SITE AND SENSOR INSTALLATION BEST PRACTICES

Virginia and their contractor work together to enforce rigid quality control over the site installations. Considerable effort is aimed at achieving high consistency with the mutual goal being to assure uniform maximum quality at each site and consistent reliable operation. Standardization and consistency are key factors in the effort to achieve reliable quality data. By utilizing precision installation techniques such as the now proven deep sensor installation, long life can be achieved, even to the point of surviving a surface milling of the road, and subsequent repaving. The focus on the consistent delivery of high quality data is driven by the performance-based contract terms, and supports the expanded use of traffic monitoring infrastructure for a broad range of data collection and operational needs.

For vehicle classification, Virginia specifies a loop-piezo-loop configuration of the detection sensor array in each lane of the roadway. This sensor array configuration provides excellent data and in the event of a sensor failure allows fall back data to continue to be collected in a highly usable form through the advanced filtering described in Appendix E Case Study #1. This provides better long-term data while often deferring the need for immediate site repairs. Numerous process improvements have been implemented over the years, all with the goal of enhancing the reliability and life expectancy of the site, or improving the quality and availability of traffic data for multiple applications. Examples of innovations include:

Deep Loop Sensor Installation

By installing the loops and lead-in 4" deep, the loop is able to survive most milling operations. The use of a high quality cable locator and site as-built drawings facilitates rapid replacement of axle sensors lost during the milling operation. This reduces the cost and effort required to repair the site. This innovation has proved so effective, that virtually the only time loops are installed is during new site installation activity.

Deep Piezo Sensor Installation

This innovation involves installing the piezo more deeply in the slot than manufacturer recommendations provide, in combination with a second piezo sensor. The increased installation cost is more than offset by greatly increased sensor life, and the ability to properly classify truck traffic, even when an individual piezo fails. Detailed installation procedures are used and all staff provided with training to ensure the process is followed precisely, to achieve a reliable long lasting outcome.

Junction Boxes and Collars

Although often overlooked, a standard junction box or in ground pull box is an important component in almost every traffic data monitoring installation. The sensor connecting wires and often the power and communications links pass through the junction box. It is important to the reliability of the installation that the junction box be securely placed, with good drainage, ready access, and be strong enough to resist any incidental traffic, pedestrians, or mowers that might pass over or near it. If the box lid and collar are not strong and secure, they can be pushed down into the earth, or collapse, crushing the wires contained within.

Cabinets, Poles, Solar Panels

Attention to detail in this area can result in significant improvements in site operation and reliability. Standard cabinets are often referred to as a "NEMA TS1-Type IV" design and were designed and developed for roadside equipment. They are a finished 0.125" thick aluminum cabinet with standard 3 point locking doors and weatherproofing and provide more than adequate room for batteries, regulators, electronics, communications devices, grounding, surge protection, and field connections; one or two adjustable shelves are specified as desired. The cabinets can be pole mounted, pedestal mounted, or base mounted as desired.

Standard traffic industry readily available aluminum pedestrian poles are compliant with the needs for breakaway design when used on the side of the road. This is a four inch inside diameter aluminum pole with one-quarter inch wall thickness. This is normally installed using a frangible cast aluminum base available from several manufacturers. For solar panel or antenna mounting the poles are routinely available in 20-foot lengths and the frangible base is typically 18 inches in height. A standard is to mount the type IV cabinet at a cabinet center height of 48 inches on a 14-foot pole. This provides approximately 16 feet to the center of a solar panel mounting at the top of the pole that is beyond the reach of casual vandals. The use of the readily available aluminum pole and the frangible base is predicated on the installation of an in-ground foundation.

Solar panels should be securely mounted and rated for the expected design wind speeds. This has saved a lot of rework and repairs after hurricanes and tornados, which is critically important if traffic monitoring assets are used to support emergency planning. Solar panel applications are an area where it is better to install oversize rather than undersize. The installations should provide reliable operation in remote areas and in harsh overcast or winter weather. The added cost of a larger solar panel is less than the one time cost of having a technician drive out to a site where the batteries have gone dead.

Grounding

The National Electric Code (250.56) requires an earth ground connection to be less than 25 ohms. Some equipment manufacturers recommend 10 ohms or less. It is important to recognize the protective value of a common point central earth ground in traffic monitoring applications. The electronics is at risk and is often placed in potential harm's way. Examples are the installation of a typical traffic monitoring site that has loops and piezos in the road, or a traffic camera mounted 50 or 60 feet in air on a pole. These sensors are effectively antennas and energy from thunderstorms (lightning) is induced into the sensors and the connecting wires in the same manner as radio signals are received by a radio. The induced signals can be thousands of volts and will have enough energy to blow sensitive electronic components up without proper grounding and surge protection. Test and record every ground connection from the cabinet central point to earth using a calibrated test instrument as designed for the task.

F.4.11 Surge protection

FIGURE F-8   LOOP FIELD CONNECTIONS DESTROYED BY LIGHTNING INDUCED SURGE
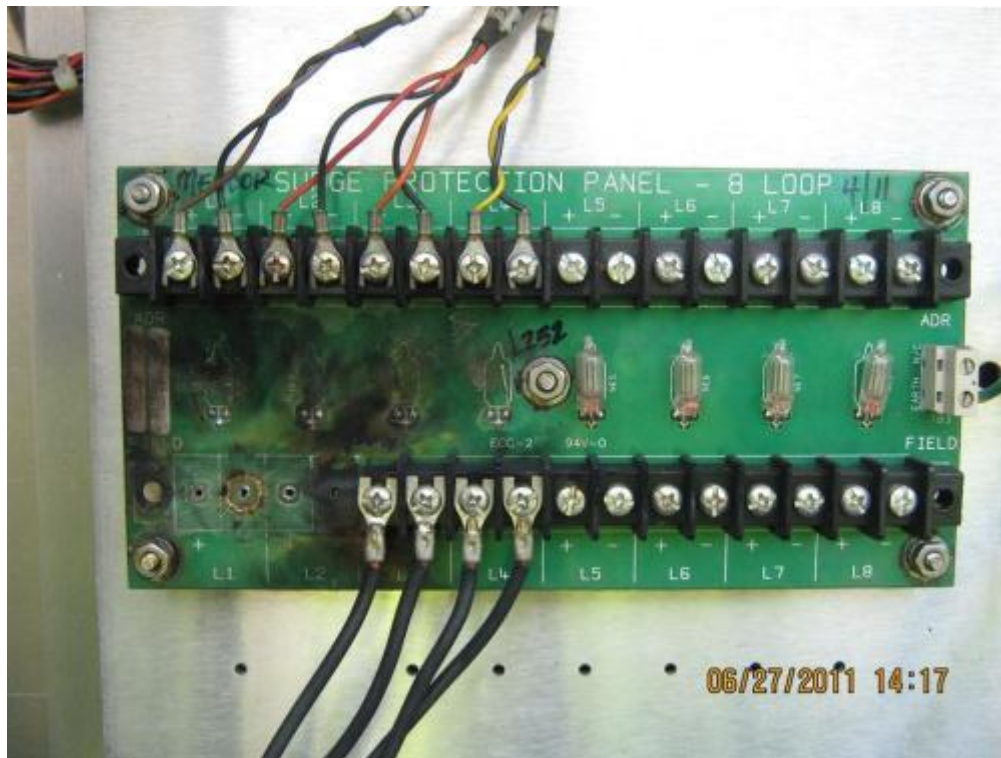
Source: Virginia Department of Transportation

The picture shows a panel of loop field connections in a cabinet after a nearby lightning strike that actually damaged the road. Direct and near direct strikes are unusual. This near strike illustrates the power unleashed. The entire system from power supply to sensors is recommended to be designed and professionally evaluated for surge protection. A standard reference for the design, evaluation, and test regimen is the NEMA TS2 environmental specification for electrical transients. The NEMA TS2 standard sets the environmental requirements for traffic control equipment.

Communications

Reliable communication is imperative to the remote traffic monitoring system, especially when data is also used to support real-time operations, such as for incident management, severe weather events, or ITS and traffic operations. While many systems still depend on POTS as their communication backbone, appropriately sized solar panels can easily support wireless data infrastructure. Wireless modems are now available with IP addresses and direct internet access that are very cost effective, provide faster communications, and are significantly more reliable. It is worth noting that when disaster strikes, the wireless internet connection may not be lost at all, and if it is lost, it will be one of the very first services to be restored, because it does not rely on lines, cables, or wooden poles for connectivity.

F.4.12 Setup and Calibration of Electronics Equipment

Please note that these instructions are generalized from Virginia Standard Operational Procedures and equipment, but can be further customized for other devices or local agency preference.

Site Setup Instructions

Most stations in Virginia record volume, classification, length, and speed at the same time. The equipment in use records multiple semi-independent traffic monitoring studies simultaneously.

Classification: Classification is determined using two loops and one piezo in a lane.

Volume: Volume count data can be obtained at any and all sites with at least one loop in each lane.

Speed Studies: Speed and length data requires two loops in each lane.

The Electronics are Set for Speed by Length by Channel. 21 speed bins (beginning at 5 mph and ending at greater than 100 mph), 3 length bins (<22 feet, >22 to <45 feet, and greater than 45 feet), Channels (depends on number of lanes at site).

Electronics Standard Setup Steps: Follow the steps and software as provided by the equipment manufacturer. Clear all old settings back to the factory default settings. Allocate file storage and essentials for the agency determined application. Load the (agency) classification scheme.

Set Site-Specific Settings: Set various filters and settings for use. ARM the unit for recording.

Observing Traffic on Site: It is vitally important to observe traffic on site and to evaluate the correct operation of the sensors and electronics.

Check for Accurate Speed, Classification, Counts, Number of Axles, Axle Spacing, Loop Length, and Weights (when applicable). Indicate a YES, NO, or N/A on the inspection form.

Count Accuracy Check: To verify the accuracy of counts during the inspection, the technician will monitor each individual lane separately with the vehicle monitor utility while connected to the electronics. The technician chooses the lane to monitor. Start the vehicle monitoring (typically at a break in traffic). Visually count the number of vehicles in the lane while the monitor also records each vehicle. Stop the vehicle monitor utility. Count the number of records in the utility and compare to the visual count. Repeat these steps for each and every lane.

Classification Accuracy Check: To verify the accuracy of classification during the inspection, the technician will again monitor each individual lane separately with the vehicle monitor utility while connected to the electronics. The technician chooses the lane to monitor. Start the vehicle monitoring (typically at a break in traffic). Depending on the type of traffic at the site, the technician will initially verify more distinct class vehicles at the site. For example, Class 9 vehicles stand out in traffic and can be easily verified while using the vehicle monitor. If a high volume of traffic exists at the site, then a visual count and number comparison may need to be done in the same manner as outlined in the "Count" section described earlier.

Electronics Speed Check and Calibration: The accuracy of speeds can be established by direct measurement and comparison. One indicator is the reported wheelbase of the tandem axle on the tractor of Class 9 vehicles. The axle spacing between these two axles should be between 4.0 feet to 4.3 feet. A technician on site can be immediately aware of discrepancies by observing the spacing reported in vehicle monitoring mode. Adjusting the speed calibration of a specific lane requires two people. One person will man the radar gun, taking measurements of vehicles, while a second person will be at the cabinet connected to the Electronics. The calibration should be done one lane at a time.

Debounce: Debounce is a filter that should only be used when site specific installation issues result in a piezo or piezos generating extra axles because of something wrong with the piezo(s) installation or road structure (e.g. slab vibration).

Sensor Tests During Installation: The following tests should be performed by the field installation crews to verify that they have a good working sensor installation while working at a site. At the time of installation, the crews perform initial sensor tests with the presence of an on-site Quality Assurance inspector. After installation is complete, a trained technician revisits the site and performs a complete site final inspection and calibration of all functions.

- Checking the loops;

- Insulation test;

- Continuity test (low voltage continuity);

- Inductance test;

- Checking the piezos;

- Resistance checks;

- Voltage check; and

- Capacitance check.

Note: Any loop or piezo sensor found with less than standard readings at time of installation should be immediately replaced, or subject to extended warranty provisions.

F.4.13 DAILY AUTOMATED DATA PROCESSING AND QUALITY ASSESSMENT

Working with the equipment supplier, Virginia has developed a custom classification algorithm (ClassTree) that uses loop logic and makes decisions based on empirical sensor factoring knowledge to accept the data from sites into 22 defined types that is a superset of the FHWA classification system. Post processing then assigns (re-assigns) the "Loop-Logic" classes in the appropriate externally reported class. An example of this action is that a vehicle detected as being 6 to 20 feet long (bumper to bumper) but having only one axle is first assigned to a special bin for strange unicycles and then in post processing, the vehicles from the strange unicycle bin are added to the Class 2 (cars) bin. If this logic and procedure was not in place, the vehicles would be unclassified as type 15s. This logic method and procedure notifies the agency that there is a problem at the site with a piezo not detecting some axles, and yet provides good, usable, accurate data.

Proposed equipment feature sets should always be reviewed and tested in detail to determine whether vendor specific features can enhance the overall quality and capability of the traffic monitoring program. VDOT was able to leverage the availability of a separate data feed for operations data to provide additional data services to internal users, increasing support for the traffic monitoring program.

F.4.14 ON CALL SERVICE AND PREVENTIVE MAINTENANCE PROCEDURES

Technicians install upgraded firmware and perform speed count and classification calibration checks as a normal part of servicing the sites. A technician typically visits each site at least once during each 12-month period either for a service call or a certification visit. During any site visit, a prescribed preventive maintenance procedure is performed that includes brush removal and cabinet cleaning as well as power supply and electronics operational checks. The procedure is quite extensive, involving as many as 216 individual steps, checks, and upgrade operations. As part of the procedure, the onsite technician confirms operation by manual count and classification comparison to machine data, and goes on line with the central office for communication checks. This preventive maintenance process provides greater assurance that site will perform reliably year round and allow early identification of potential issues, facilitating less costly repairs.

F.4.15 OPPORTUNITIES FOR CONTINUOUS IMPROVEMENT AND FUTURE ENHANCEMENTS

Cloud-Based Data Collection

Virginia is currently operating several data collection systems, entailing some duplication of effort. As older legacy systems of dial up modems and permanent classification sites are replaced, the cloud-based server system (as is currently used for the non–intrusive and IP based systems) provides enhanced reliability and availability of data while reducing maintenance costs and duplicated efforts.

The use of new and enhanced technology provides opportunities for saving fuel and precious budget resources in many areas of traffic monitoring. The internet and wireless IP modems are examples of faster and better availability of data at lower costs. Data servers in the "cloud" make more data available to more people than could be imagined 10 years ago. They offer the ability to put important information in front of operations decision makers 24/7 without human involvement or delay.

F.4.16 FAILURE ANALYSIS

All site construction and service call information is maintained on line and facilitates remote access to full documentation of all sites and all procedures on line. This serves as a database history of sites and lessons learned.

F.5 CASE STUDY #5: NCHRP AND AASHTO RECOMMENDATIONS

F.5.1 INTRODUCTION

This case study summarizes the technical guidance available from existing NCHRP and AASHTO reports on the types of traffic data collection equipment available and the associated calibration and validation procedures used with specific types of equipment. Three recent documents are of specific interest to the traffic data collection community.

The first report, NCHRP Report 509, *Equipment for Collecting Traffic Load Data* was produced as a result of NCHRP Project 1-39 *Traffic Data Collection, Analysis, and Forecasting for Mechanistic Pavement Design*. NCHRP Report 509 was written to help States understand the equipment options available for collecting the detailed truck volume, classification, and axle weight data needed to effectively use the new AASHTO *Mechanical-Empirical Pavement Design Guide* (MEPDG.)

A second NCHRP project, NCHRP 3-68 *Guide to Effective Freeway Performance Measurement*, developed a comprehensive look at the collection, processing, and reporting of the traffic data needed to monitor and report on the operational performance of freeways and expressways. This report includes a chapter on the equipment options available for monitoring traffic flow on high volume, congested urban roadways. The project findings are available in an NCHRP report that is only available on the Internet, NCHRP Web-Only Document 97, *Guide to Effective Freeway Performance Measurement: Final Report and Guidebook*.

The final report of special significance to users of the *Traffic Monitoring Guide* is the second edition of the AASHTO report, *Guidelines for Traffic Data Programs*. This report is an excellent companion guide to the FHWA *Traffic Monitoring Guide*. It provides a more comprehensive overview of general traffic data collection needs, equipment, and procedures than the two NCHRP reports, which focus on the specific needs of key uses of traffic data. The AASHTO report contains a large, significant chapter on traffic data collection equipment options.

A summary of key information about equipment selection, calibration, and use that is contained in these three reports is provided below.

NCHRP 509

This report provides detailed descriptions of the technologies used for collecting the vehicle classification (truck volume) and axle weight data needed by States that wish to use the new AASHTO mechanistic-empirical pavement design guide. The report includes:

- Detailed technology descriptions;
- A step-by-step guide that helps States select among available data collection equipment;
- Guidance for ensuring that the selected equipment operates as intended and thus collects accurate data; and

- Discussions of the tasks needed to maintain the performance of well-functioning data collection equipment.

Included in the technology descriptions are discussions of the types of data that can be collected with each technology (e.g., length based versus axle based vehicle classifications), the environmental limitations inherent in the use of specific technologies (e.g., the performance of many piezo-electric sensors can be affected by cold temperatures), and how operational, geometric, environmental, and other conditions at individual sites should be considered when selecting among available technologies (e.g., the presence of rough pavement indicates that a specific location is a poor choice for a WIM scale, or the fact that blizzard conditions occur reasonably frequently, and thus video technology may not be the best sensor for that location).

The guide provides step-by-step instructions that walk users through the process needed to select traffic data collection equipment appropriate for their needs and conditions. It also provides documentation of best practices needed to operate an efficient, productive data collection program, and helps walk an agency's staff through those best practices.

The best practice steps include:

- Identifying the user requirements;

- Determining site location and system requirements;

- Determining design life and accuracy requirements;

- Budgeting the necessary resources;

- Developing, using, and maintaining a quality assurance program;

- Purchasing equipment with a warranty;

- Managing the equipment installation;

- Calibrating the equipment and taking the steps needed to maintain that calibration; and

- Conducting preventative and corrective maintenance.

One very heavily stressed point in NCHRP Report 509 is the need for equipment calibration. The report points out that many States historically collected large amounts of vehicle classification and weight data while paying little or no attention to their equipment's calibration. The result was the expenditure of fairly large amounts of money on "data" that had little value because it did not accurately reflect the characteristics of the traffic stream. WIM equipment in particular, has been shown to need careful calibration and periodic refinement of that calibration, as changes in roadway surface condition have large effects on scale and sensor performance. To ensure that the resources spent on WIM data collection result in accurate data, NCHRP 509 provides specific steps for calibrating equipment, and periodically validating the continued accuracy of each site's performance.

NCHRP Web Document 97

NCHRP Web-Only Document 97, *Guide to Effective Freeway Performance Measurement: Final Report and Guidebook* is the primary outcome of the NCHRP Project 3-68; Guide to Effective Freeway Performance Measurement. This very large report includes a chapter (Chapter 7 of the main report) on the collection, processing, and reporting of the data needed to monitor the operational performance of freeways and expressways. Several sections of this chapter relate to the collection of volume and speed data.

While this report does not include discussions of vehicle classification or weight data, it does provide an excellent summary of the difficulties of collecting accurate traffic data in heavily traveled, congested urban environments, and the strengths and weaknesses of the technologies that are commonly used in those roles. It also presents a brief introduction to the issues associated with purchasing and using vehicle speed data collected and re-sold by the private sector.

This chapter of the report also provides guidance on selecting and purchasing the data collection equipment needed for monitoring and reporting on the performance of these key urban roadways. The steps recommended include understanding and trading off the expected performance of available technologies in the areas of:

- Types of measures that are actually collected by a device under the expected environmental and traffic conditions;

- Accuracy of the data being collected in those conditions (and the importance of that accuracy during the worst of those conditions);

- Capital cost of the devices;

- Installation and deployment costs of the devices;

- Ongoing operations and maintenance costs; and

- Communications costs of those devices.

These same considerations are appropriate for the selection of equipment used for any traffic monitoring purpose.

AASHTO Traffic Data Guidelines

Published in 2009, the Second Edition of AASHTO's *Guidelines for Traffic Data Programs (Guidelines)* contains an entire chapter (Chapter 3) on traffic data collection equipment. The chapter includes a comprehensive discussion of a wide variety of both intrusive and non-intrusive data collection technologies. Following the extensive discussion of alternative data collection devices, the report provides guidance on:

- Selecting the best equipment for an agency's needs;

- Installing and maintaining equipment; and

- Collecting data on congestion roadways.

When selecting equipment, the *Guidelines* recommend that agencies consider the following equipment attributes:

- Traffic characteristics that the equipment collects and stores;

- Accuracy that those characteristics are collected and any limitations on where and when the device can be used without compromising that accuracy;

- Expected longevity of the system along with any warranties that support that expected life cycle;

- Installation requirement of the system (in time, cost, and staffing);

- Operational requirements of the system, including power and communication needs;

- Cost of the system;

- Amount of vendor support provided; and

- Compatibility of the data and the data retrieval software with the agencies existing and planned databases and data management systems.

The AASHTO *Guidelines* correctly and effectively point out that no matter how carefully equipment is selected, if it is installed poorly or inadequately maintained, the "data collected" are often inaccurate and of little or no value. The *Guidelines* therefore provide best practices for installing and maintaining traffic monitoring equipment. While this section of the report is not a substitute for high quality installation instructions and training from an equipment vendor, the section does provide an excellent source of key quality assurance checks and inspection actions that should be performed when performing equipment installation. It also provides an excellent checklist against which the

quality and completeness of a vendor's instructions and training can be reviewed.

The third section of this *Guidelines* chapter describes the options agencies have for collecting data on heavily congested roadways where many sensor technologies do not perform accurately. These include: purchasing expensive, but highly capable equipment when the value of the data being collected is greater than the cost of that equipment (e.g., in some toll revenue control applications), placing equipment only where it collects data accurately (i.e., outside of the most heavily congested locations) while sacrificing the ability to observe the most heavy congestion, or developing procedures to identify when congestion is causing the collected data to become unreliable, and adopting procedures that attempt to adjust the collected data to reflect the errors caused by the equipment limitations during those time periods of heavy congestion.

Finally, this chapter describes the traffic control and management system's requirement for the collection of traffic performance information in order to function as intended. The roadway performance information collected has the potential to meet a large portion of the traffic monitoring needs for the roads those management systems control. Thus, independently collecting data on these same roadways means that duplication of data collection resources is occurring. Consequently, there is considerable benefit to be gained if the general traffic monitoring needs of the agency can be coordinated with the traffic monitoring needs of the traffic management system.

Appendix G. NORTH CAROLINA DEPARTMENT OF TRANSPORTATION CLUSTERING METHODOLOGY FOR NC TRAFFIC DATA INPUTS FOR MEPDG

G.1 INTRODUCTION

The recommended process for implementation of the Mechanistic-Empirical Pavement Design Guide (MEPDG) involves the development of data inputs that reflect the conditions experienced at the design locations. This requires some element of both site specific and regional inputs to support an effective design process. Data inputs include climate, soil, materials, and traffic categories. Agencies in the development of these inputs must decide what level of detail will be needed to produce a reliable pavement. North Carolina traffic inputs were developed based on a research study conducted by North Carolina State University for the North Carolina Department of Transportation. The study included the evaluation of data from 44 Weigh In Motion (WIM) stations located across North Carolina. The process used to develop the traffic data inputs from this resource involved:

- Quality control of vehicle class and truck weight data;

- Sensitivity analysis of design models to traffic inputs;

- Clustering analysis of the WIM based traffic inputs; and

- Selection criteria for using clustered based traffic data.

A brief explanation of the factors considered in developing traffic inputs, sensitivity of design models to North Carolina inputs, the clustering methodology used, and the results they produced is provided. A description of the method developed to select grouped data for input into the design process is provided also. Key decisions made during the process required to develop these traffic inputs are discussed.

This paper is a brief synopsis of information provided in the final report of the research study related to generating clustered data sets. It is not intended to convey the complete findings of that study. All of the tables and figures are taken directly from the final report.

The results of the analyses and factors developed may be fairly unique to North Carolina. The process used to develop the analysis, the methods used to cluster the data, and the considerations given and solutions selected to address the issues encountered during the research can be transferred to similar studies. The development of clustered data sets for the MEPDG can be complex and agencies involved in this type of development will have to make many choices. The experience in North Carolina may provide some insight into how best to make those choices.

G.2 FACTORS AFFECTING CLUSTERING REQUIREMENTS

A number of factors are critical to development of the analysis of the traffic data collected at WIM stations effectively. Factors that affected the development process were:

- Design Level – The NCDOT has selected Level 2 traffic inputs as the basis for most pavement designs. This is due to the impracticality of collecting site specific traffic for all inputs (Level 1) because of time and cost constraints. Level 1 traffic inputs will be used when a WIM site falls on or near a project. Level 3 inputs may be used on a limited basis and are supported also.

- WIM Data Types – The type of data collected at WIM stations by the NCDOT is continuous vehicle classification counts and truck weight measurements. These data resources provide the basis for Hourly Distribution Factors (HDF), Monthly Adjustment Factors (MAF), Vehicle Class Distributions (VCD), and Axle Load Distribution Factors (ALF). These statistics were generated for each station

(Level 1) and clustering was performed to generate grouped factors for Level 2 inputs. Other statistics generated from this data but not clustered were average axle types by vehicle class and average axle spacing by axle type. The other traffic inputs to the MEPDG are either site specific (AADTT and growth) or national defaults are used (tire pressure, lane wander, etc.).

- Model Sensitivity – A sensitivity analysis identified which models are sensitive to each of the WIM based traffic inputs. When any of the models were found to be sensitive to a process, a clustering analysis was performed to generate grouped inputs. When all models were found not to be sensitive to an input, a statewide average was generated as the default values for that input.

These factors directly impacted the requirements for clustering a data type and influenced the process. Other factors affecting the clustering analysis of individual data inputs are provided below.

G.3 SENSITIVITY OF MODELS TO NORTH CAROLINA TRAFFIC DATA

The MEPDG process requires significantly higher levels of data inputs than legacy pavement design processes. A key component to understanding how best to use the process is an understanding of how traffic inputs, and in particular, North Carolina inputs, impact the output of the design models. This provides the basis for simplifying the process, where practical, and ensures the appropriate level of detail is input to generate reliable pavement designs.

The sensitivity analysis was performed using representative LTPP sites located in North Carolina as the structural and material data is available for input. The range of values for HDF, MAF, VCD, and ALF found in the data at the 44 WIM sites was used. Only one input was changed at a time and all models in the design process were run when evaluating sensitivity. When a model output changed enough to exceed a threshold specified by the pavement designers, that model was identified as sensitive to the input being evaluated. The results of the sensitivity analysis are provided in Table G-1.

The researchers found that the longitudinal cracking model for flexible pavements did not produce outputs consistent with what is observed in the performance of North Carolina pavements. Although this model was found to be sensitive to some traffic inputs, the unreliability of the outputs resulted in the exclusion of this model's sensitivity from consideration in the clustering process.

TABLE G-1   SENSITIVITY OF MEPDG TO NORTH CAROLINA BASED TRAFFIC INPUTS

	Flexible Pavement				Rigid Pavement (JPCP)		
	Total Rut Depth (in)	Fatigue Cracking (%)	Longitudinal Cracking[a] (ft/mile)	IRI (in/mile)	Faulting (in)	Slabs Cracked (%)	IRI (in/mile)
HDF	no	no	no	no	no	no	no
MAF	no	no	yes	no	no	no	no
VCD	yes	yes	yes	yes	no	no	yes
ALF	yes	yes	yes	yes	no	no	no

Source: North Carolina Department of Transportation

[a]   *The longitudinal cracking model produced unreliable outputs and the sensitivity of this model to traffic inputs was not used.*

There are naturally occurring clusters in the HDF and MAF data sets. The lack of sensitivity of the models to these inputs (excluding the longitudinal cracking results), based on North Carolina data, eliminates the need for clustering data for these inputs. Statewide average values were generated using the average of the 44 WIM data sets for these inputs to simplify the design process.

The VCD data is a key input into the design process as models for both flexible and rigid pavements show sensitivity to this input. The flexible pavement models are sensitive to the ALF input but rigid pavements models are not sensitive. Based on these results, clustering analysis was performed on the VCD and ALF data to generate grouped data sets for Level 2 inputs.

G.4 HOURLY DISTRIBUTION FACTOR INPUT

The MEPDG models were found to not be sensitive to the range of HDF calculated for the 44 WIM stations in North Carolina. This allows the use of a single set of HDF for input into the pavement design process based on the average of the individual HDF. Figure G-1 provides a plot of the average HDF that is used in the design process.

FIGURE G-1   NORTH CAROLINA HOURLY DISTRIBUTION FACTORS
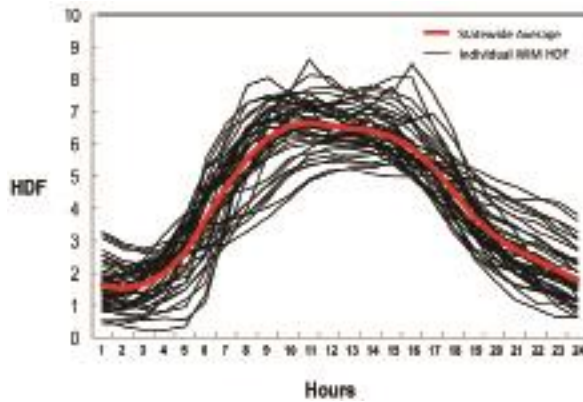
Source: North Carolina Department of Transportation.

G.5   MONTHLY ADJUSTMENT FACTOR INPUT

Similarly, the MEPDG models were not sensitive to the range of MAF experienced at North Carolina's 44 WIM stations. WIM Stations 533 and 560 were identified as outliers based on a principal component analysis and were excluded from further analysis. A statewide average based on the remaining 42 individual MAF was generated to provide a single set of MAF as input into the pavement design process. Figure G-2 provides a plot of the average MAF that is used in the design process with the outliers that were excluded identified.

FIGURE G-2   NORTH CAROLINA MONTHLY ADJUSTMENT FACTORS
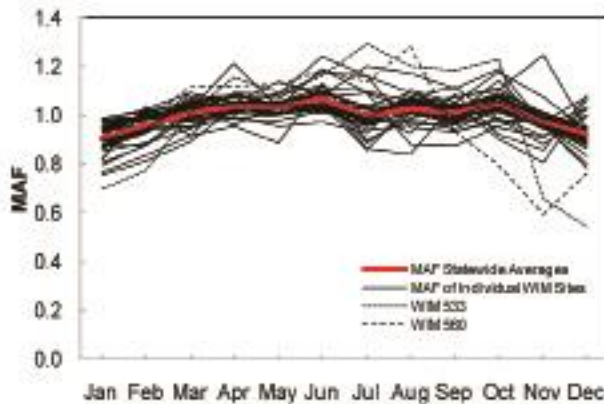
Source: North Carolina Department of Transportation.

G.6   VEHICLE CLASS DISTRIBUTION INPUT

Due to the sensitivity of most of the models to VCD inputs, a clustering analysis was performed on this data. The VCD is the distribution of the AADTT into the 10 FHWA truck classes. Therefore, the method used should support evaluating the patterns observed between the ten classes of trucks in this input. The clustering methodology used was:

- Statistic – VCD Distribution of the 10 FHWA Truck Classes;

- Technique – Agglomerative Hierarchal Clustering; and

- Measure – Sum of Least Squares of the Differences in VCD Values.

This technique starts with each WIM site as an individual cluster and calculates the difference in VCD between each pair of clusters. The difference is calculated between each of the 10 VCD percentages, each of these values is squared, and the total is summed. The clusters having the lowest value of this measure are the most similar and are grouped together. The VCD for the new cluster is the average of the component VCD making up that cluster. This process is repeated until all 44 WIM sites are clustered into a single group. The stopping level was determined by applying a metric proposed by Mojena. As iterations of the clustering process are performed, there is a loss in the uniqueness of the patterns. The new clusters created are more generalized and greater amounts of variability are introduced into the clusters. The Mojena metric identifies the most suitable number of clusters based on the level of variability in the data set. Three clusters were identified for the VCD input and are shown in Figure G-3.

FIGURE G-3   NORTH CAROLINA VCD CLUSTERS
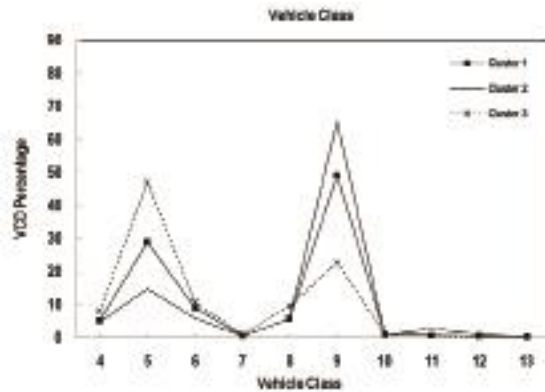
Source: North Carolina Department of Transportation.

As VCD is a distribution of total trucks at a location, it corresponds that as one class of vehicle increases, the other classes decrease. In the patterns represented by the clusters, Cluster 2 has a significantly higher proportion of Multi Unit (MU) trucks, found in Class 8 to 13, than Single Unit (SU) trucks, found in Class 4 to 7. Conversely, Cluster 3 has significantly higher proportion of SU trucks than MU trucks. Cluster 1 falls between the two other clusters with slightly higher MU trucks than SU trucks. The type of routes associated with these clusters is consistent with the patterns. Cluster 2 includes interstate and higher order U.S. routes that serve long distance trips, provide a higher level of mobility, and serve major markets. There are a higher proportion of MU trucks in this cluster due to the longer trip lengths this type of vehicle travels, the large markets served, and the regional connections they provide. Cluster 2 includes mostly State and local routes with lower mobility and limited connectivity that serve primarily the shorter business day trips associated with the SU trucks. Cluster 1 is a mix of route types including interstate routes in urban areas where there is a higher level of business day travel by SU trucks than rural interstate locations. It includes U.S. and other routes where mobility is higher than local routes but they have a lower level of long haul trips because of the smaller markets served and lower levels of connectivity they provide.

G.7 VEHICLE CLASS SEASONAL FACTOR GROUPS

A basic input into the MEPDG process is Annual Average Daily Truck Traffic (AADTT) for a project. The NCDOT collects vehicle classification counts for each project as the basis for identifying base year conditions. The counts collected classify traffic into the FHWA 13 Class scheme. This provides not only a measure of total trucks for AADTT, but the distribution of trucks between the 10 truck classes required for the VCD estimate. Based on the higher sensitivity of the models to the VCD input, and the availability of data for each project, it was decided to estimate project specific VCD based on the

short term class counts instead of using the generalized values from the VCD cluster analysis.

A key element in using short term class counts for generating AADTT and VCD estimates is seasonally factoring the count data to annualized values. A clustering analysis for the purpose of factoring short term class counts was performed. The observed pattern in the daily distributions of truck volumes through the year was performed for the 44 WIM stations available. The NCDOT processes and reports class data by aggregated vehicle class groups. Single Unit trucks (Class 4 to 7) have similar business day travel patterns and Multi Unit trucks (Class 8 to 13) have similar long haul travel patterns. This method of developing and applying seasonal factors using aggregated vehicle classes is supported by research and is a recommended practice in the *Traffic Monitoring Guide*. Key steps taken prior to clustering the data were:

1. Data Screening – The class volume data collected at the WIM stations was evaluated for daily truck distributions by day of week by month. The daily truck distributions (VCD) for each day of week within the same month were compared to identify the recurring or typical pattern for that day. Any day that exhibited a pattern different from the recurring pattern was flagged as an atypical pattern. This produced 7 day of week patterns for each month for a total of 84 sets per WIM station.

2. WIM Station Factors – The NCDOT collects short term counts on typical travel days. The factors used in this process reflect this practice. AADTT and Monthly ADTT (MADTT) were calculated for SU and MU truck class groups for each station using the method recommended in the *Traffic Monitoring Guide*. This includes using both typical and atypical days in these averages. Average day of week daily truck volumes for typical days were calculated for SU and MU trucks. Seasonal factors were calculated using the ratio of the AADTT to the average typical day of week volumes for SU and MU factors for each day of week for each month. The statistics generated for each station were:

- AADTT (1), Annual VCD (1), Monthly VCD (12);
- AADTT SU (1), MADTT SU (12), Day of Week Factor SU (84); and
- AADTT MU (1), MADTT MU (12), Day of Week Factor MU (84).

This data is suitable for factoring short term counts collected on typical days when at or near a WIM station location and was used as the basis for the clustering process for generalized class seasonal factors.

The clustering methodology used for seasonal factor development accounts for the truck volume seasonality experienced in North Carolina. A two stage procedure is used in development of seasonal factors:

Phase 1 – Analysis of Monthly VCD Seasonal Patterns

- Step 1: Evaluate Principal Components for Outliers;
- Step 2: Perform Monthly Clustering Analysis; and
- Step 3: Identify Common Groupings.

Phase 2 – Analysis of SU/MU Seasonal Patterns

- Step 1: Evaluate MADTT/AADTT Plots by SU/MU;
- Step 2: Evaluate Principal Components for Outliers; and
- Step 3: Audit Confidence Intervals of Seasonal Factors.

Since a primary output of the factoring process is VCD, this attribute, and how it varies through the year, is used as the first stage in the development of seasonal factor clusters. The second stage involves the analysis of each aggregated truck class (SU/MU) for their underlying patterns within the VCD patterns. This generates groupings specific to what is being factored.

Step 1: A principal component analysis was performed to identify which components of the VCD are most important, or account for most of the variability in the data. In the case of VCD, the components are the 10 truck classes comprising the distribution. This portion of the analysis determined that Class 4, 5, 6, 8, 9, and 11 were the classes that account for most of the variability in the data during the year. Individual classes determined to be principal components for a particular month will vary by month. The results of this analysis are provided in Table G-2.

TABLE G-2   PRINCIPAL COMPONENTS OF NORTH CAROLINA MONTHLY VCD

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January		■	■		■	■		■		
February		■	■		■			■		
March	■	■	■			■		■		
April	■	■	■			■		■		
May	■	■	■			■		■		
June	■	■			■	■		■		
July	■	■			■	■		■		
August	■	■	■			■		■		
September		■	■		■	■		■		
October		■	■		■	■		■		
November	■	■	■		■			■		
December	■		■		■	■		■		

Source: North Carolina Department of Transportation.

The PCA results were used to identify outliers to the principal components and 2 WIM stations were excluded due to their significantly different characteristics. The remaining 42 WIM stations were used in the clustering analysis.

Step 2: A monthly clustering analysis process was employed using the results of the PCA. This involved use of the following methodology:

- Statistic – Principal Monthly VCD Components by month;

- Technique – Agglomerative Hierarchal Clustering; and

- Measure – Sum of Least Squares of the Differences in Monthly VCD Values.

A cluster analysis was performed for each month to identify groupings for that month. In each case, 3 groupings were identified for each month.

Step 3: The groupings were compared from month to month to determine if the same sites were being clustered across the year. Three groupings were identified where the same sites were grouped together in at least 11 of the 12 months. These groupings represent WIM stations with the same pattern in changes in VCD across the year.

Phase 2 – Analysis of SU/MU Seasonal Patterns

Step 1: The seasonal pattern of each of the aggregated truck classes should be evaluated for consistency within the groupings identified in Phase 1. The ratio of MADTT to AADTT is calculated for SU and MU truck groups as the basis for identifying their seasonal pattern. Plots of this statistic for all WIM stations within a factor group were generated for SU and a separate set of plots for MU to make this comparison. WIM stations found to have an inconsistent plot as compared to the common pattern were excluded from the group. This resulted in the exclusion of some WIM sites and the extraction of a fourth grouping of sites located on the I-95 corridor. The unique seasonal pattern on the I-95 corridor resulted in a separate fourth seasonal factor group for both SU and MU classes.

Step 2: A separate principal component analysis of the ratio of MADTT to AADTT for SU and MU was performed. This process identified individual WIM stations that are not consistent with the pattern in principal components among a group. These were eliminated from the grouping when they occurred.

Step 3: Seasonal factors for each group are evaluated for the confidence interval obtained in them. These are calculated for each month of seasonal factors. Any WIM station whose seasonal factors exceed the 95% confidence level in multiple months were eliminated from the grouping. This occurred once in one of the SU factor groups.

The results of this two phase process are a set of seasonal factor groups for SU and MU class groups. The results are represented in the plot of the average monthly MADTT/AADTT ratio for each factor group in Figures G-4 and G-5.

In general, selection of a factor group/station for application of seasonal factors to a portable vehicle classification (PVC) count has been correlated to the route the count is located on and the class distribution identified in the count. The route location is used to determine if the I-95 group factors are to be used or the count is located on the same corridor as a WIM station and the seasonal factors from that individual WIM station should be used. If the route location is found not to be the determining characteristic, then the class distribution found in the count is used as the basis for selecting a seasonal factor group. The correlation between the distribution of total trucks between SU and MU types counted during a 48 hour short term count period and the seasonal factor group assignment is determined using the criteria provided in Table G-3.

FIGURE G-4 **MADTT/AADTT FOR NORTH CAROLINA SINGLE UNIT TRUCK SF GROUPS**
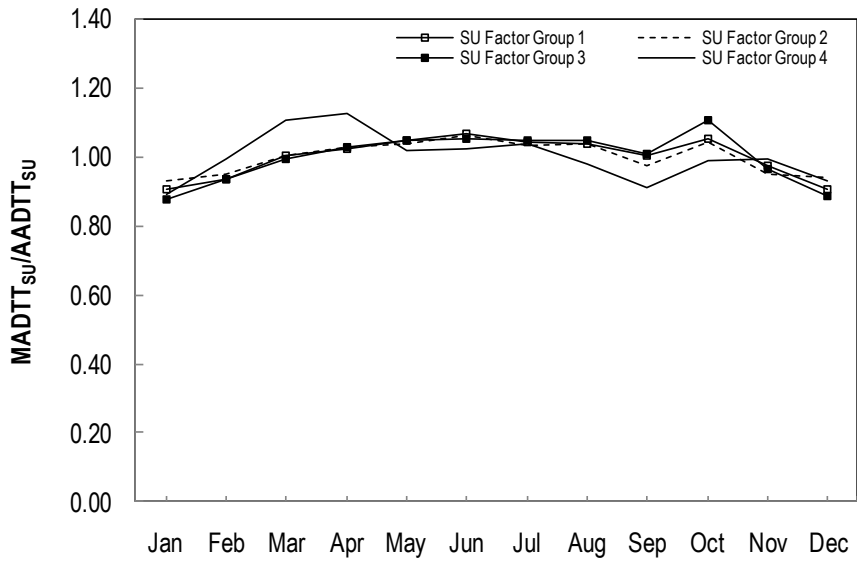
Source: *North Carolina Department of Transportation.*

FIGURE G-5 **MADTT/AADTT FOR NORTH CAROLINA MULTI UNIT TRUCK SF GROUPS**
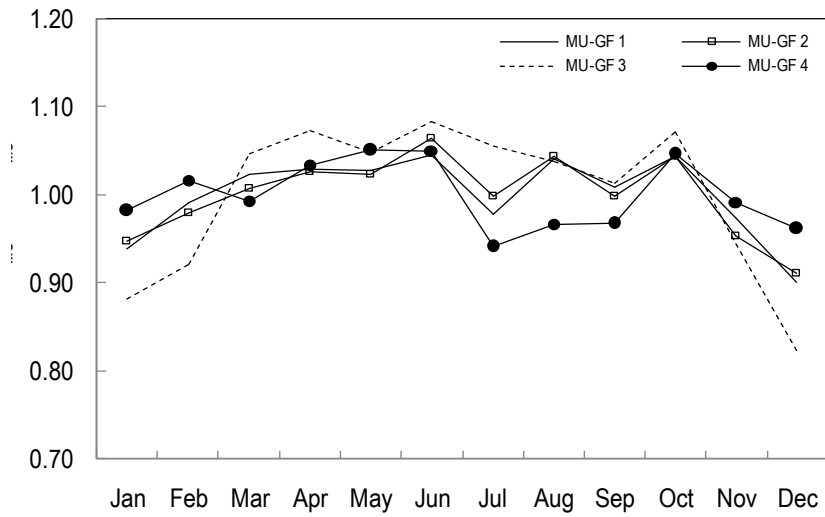
Source: North Carolina Department of Transportation.

TABLE G-3   ASSIGNMENT CRITERIA OF PVC TO NORTH CAROLINA SEASONAL FACTOR GROUPS

SU Trucks/Total Trucks		
Min (=)	Max (<)	SU Group
0.09	0.34	
0.34	0.50	
0.50	0.71	
MU Trucks/Total Trucks		
Min (=)	Max (<)	MU Group
0.67	0.92	1
0.50	0.67	2
0.29	0.50	3

Source: North Carolina Department of Transportation.

The criteria provided in Table G-3 does not cover the extreme ends of the spectrum of distributions; the WIM monitoring practice in North Carolina has been to monitor those routes that have a moderate to significant volumes of trucks. The extreme end of the range represents primarily low volume locations or facilities serving specialized land uses. It is assumed that these types of facilities will exhibit similar seasonal patterns as the adjacent seasonal group. This assumption is applied by the following rules:

If SU/Total < 0.09 assign SU Group 1

If SU/Total ≥ 0.71 assign SU Group 3

If MU/Total < 0.29 assign MU Group 3

If MU/Total ≥ 0.92 assign MU Group 1

The NCDOT plans to install monitoring stations at the extreme ends of these distributions to develop a more complete understanding of truck travel and a comprehensive method for seasonal factoring of truck data.

G.8 AXLE LOAD DISTRIBUTION FACTOR INPUT

The sensitivity analysis showed that the flexible pavement models were sensitive to the Axle Load Distribution Factor (ALF) input. An analysis of the per vehicle truck weight data collected at WIM stations was required to develop Level 2 inputs. This involved performing of the following tasks:

1.   Convert axle spacing and axle weight measurements into axle load data;

2.   Generate ALF for each WIM station (Level 1 inputs);

3.   Identify the ALF factors that most impact the pavement design process;

4.   Perform a principal component analysis to eliminate outliers/aggregate load bins;

5.   Perform a clustering analysis to identify groups of similar ALF patterns; and

6.   Evaluate the characteristics of the groups to define a method for selecting ALF.

The ALF data is an input that influences the flexible pavement design process. The research team had two issues to consider that impacted the development process:

- Quality Control of Axle Spacing/Weight Measurements – The QC method used was a rule based evaluation of individual measurements or a combination of measurements to eliminate illogical values. There are additional QC methods available that can be used to identify misclassified trucks based on axle weights. The NCDOT classifies vehicles based on the number of axles and their spacing. This is not an axle weight based algorithm. This algorithm is used in all devices that collect vehicle classification data, including portable classifiers and WIM stations. The basis for AADTT and VCD inputs for pavement design are counts collected with portable classifiers. The basis for the classifications in the ALF should be identical to those used for other classification based inputs. Although these are errors in the ALF classifications, they are measurements of valid loadings on the pavement. As long as the classification algorithms are identical for all inputs, the appropriate loadings will be generated by the models, even if applied through a different class of truck. Therefore, quality control of the axle weight data did not include validation of vehicle classification based on axle weights or validation of axle weights based on vehicle classification.

- Damage Based Clustering – The research team advised that the ALF clusters would be more reliable if based on the relative level of pavement damage caused by each ALF input. This required identifying not only which axle types caused the most damage, but the weight ranges (load bins) for those axle types that accounted for the majority of the loads being applied. Once these critical inputs were identified, the clustering process was based on them to avoid influencing the results on non-essential or nominal ALF factors. The technique was developed in Step 3 of the ALF development process.

These decisions had a significant impact on the ALF development process. Without considering these issues and addressing them appropriately, the ALF factors generated would be less reliable and could require more expensive pavement designs to adjust for this limitation.

Step 1 – Convert WIM Data into Axle Load Data

This process required the identification of axle types from the axle spacing data and combining of axle weights when an axle type included two or more axles. Although the original MEPDG software includes a module to generate this data, the class algorithm used by the NCDOT is moderately different than the default values used in the module. The truck spacing/weight data was processed using the ASTM E 1572-93 methodology for identification of axle types from axle spacing data. However, the spacing thresholds were adjusted to reflect North Carolina's classification algorithm. The spacing ranges applied are provided in Table G-4.

TABLE G-4   NORTH CAROLINA AXLE SPACINGS DEFINING AXLE TYPES FOR ASTM E 1572-93

Axle Count	Axle Spacing (inches)				
	24-39	**40-96**	**97-150**	**118-192**	**193+**
1	Single	Single	Single	Single	Single
2	Single-2	Tandem-2	2 Singles	2 Singles	2 Singles
3		Tandem-3	Tridem	Tridem	2 or 3 confg.
4		Tandem-4	Tridem-4[a]	Quad-4	Quad to 288
5		Tandem-5	Tridem-5[a]	Quad-5	Quad to 384
6			Tridem-6[a]	Quad-6	Quad to 480

Source: North Carolina Department of Transportation.

[a]   *Quad axle types takes precedence over these configurations for spans ≥ 118 inches.*

Once an axle type is defined, the weight for that axle type is generated. Axle types with a single axle are assigned the weight of that axle. Axle types with 2 or more axles are assigned the sum of the individual axle weights. The process converts each weight record to an axle load record including vehicle classification and the individual axle types and their associated weights for all axle types identified for that truck. This process was applied to each WIM station separately to allow generation of station specific ALF.

Step 2 – Generate ALF for each WIM Station

The converted axle load data was used as input into this process. Each record in the axle load data was disaggregated by each individual axle type and then categorized by the weight range it falls in. The ALF are based on frequency distributions of axle types for each vehicle class stratified by weight ranges. The factors are the ratio of the number of an axle type occurring within an individual weight range to the total number of that axle type occurring in all weight ranges. Not all axle types occur in all truck classes (e.g. Class 5 has single axles only). This is dependent on the variety of axle configurations that occur within a vehicle class. A set of ALF was generated for each of the 44 WIM stations available.

Step 3 – Identify Critical ALF

The use of a multidimensional clustering technique was selected as it supports evaluation of multiple sets of data elements. The advantage of this technique is that the multiple sets of ALF used in generating loadings on a pavement are incorporated in the cluster analysis. The limitation of this technique is the complexity of working with so many data sets and the potential for influencing the results based on data that has high variability but contributes little to the design process. To reduce the potential for this, a method was developed to identify those ALF inputs critical to the design process.

The method used involved quantifying the distribution of damage occurring during the design life of a pavement between the axle types used in the ALF. The researchers developed the Damage Factor metric that is the ratio of the fatigue damage caused by a particular axle type within a particular weight range (called a load bin) to the fatigue damage caused by an 18-kip Equivalent Single Axle

Load. The Fatigue Cracking model was used to develop these factors as 90% of pavements in North Carolina are flexible pavements and this is the primary mode of failure experienced in North Carolina for this pavement type. The damage factors were developed for each WIM station and are unique to the conditions experienced at each station. The output generated from factoring the axle types/loads to ESALs provides the basis for making comparisons and developing an understanding of the critical ALF. The result of this process is provided in Figure G-6 which shows the contribution each axle type makes to total damage at each of the 44 WIM stations.

FIGURE G-6   PERCENT DAMAGE BY AXLE TYPE AT NORTH CAROLINA WIM STATIONS
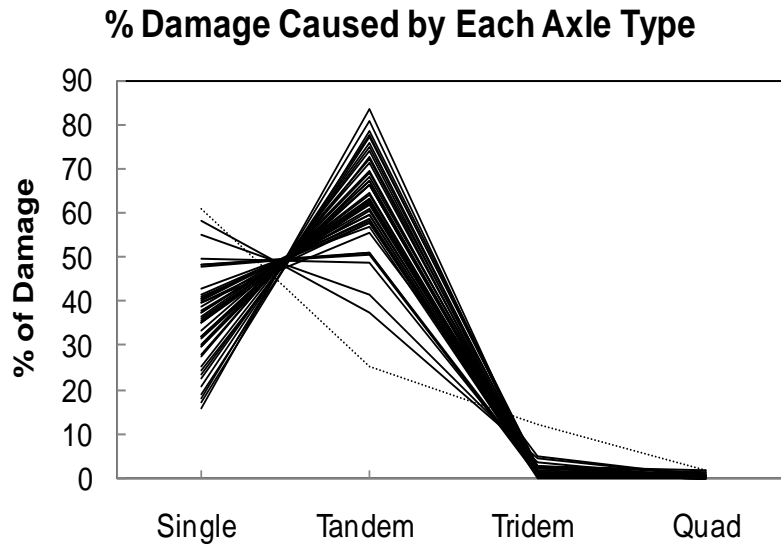
Source: North Carolina Department of Transportation.

It was determined that 98% of total damage is caused by Single and Tandem axle types. This characteristic allowed the exclusion of Tridem and Quad axle types from the clustering analysis. Additionally, the individual load bins for the Single and Tandem axle types were evaluated for two characteristics:

● Did the load bin include more than 1% of all loadings for that axle type?

● Did the load bin contribute more than 1% of all damage for that axle type?

If either of these conditions were met, the load bin was considered significant and retained for the cluster analysis. If neither of these conditions were met, the load bin was excluded. Table G-5 specifies the load bins retained based on this evaluation.

TABLE G-5   LOAD BINS RETAINED FOR ALF CLUSTER ANALYSIS

Single	Tandem	Tridem	Quad
3 KIPS-21 KIPS	6 KIPS-50 KIPS	None	None

Source: North Carolina Department of Transportation.

Step 4 – Analyze Principal Component

The analysis involved the evaluation of the ALF to determine principal components. This information was used as the basis for identifying WIM stations with ALF that were significantly different and were excluded as outliers. Two stations were identified as outliers and the remaining 42 WIM stations were used in the clustering analysis.

A second principal component analysis was performed to identify aggregations of load bins, within each axle type, that could be used in the clustering process to minimize the affect of variability in individual load bins. The results of this analysis are presented in Table G-6.

TABLE G-6   RESULTS OF THE PRINCIPAL COMPONENT ANALYSIS FOR SINGLE-TANDEM ALF

Principal Component	Aggregated Load Bin	Variance	Cumulative Variance
1	Heavy Tandem (22-50 KIPS)	74.82	0.65
2	Light Tandem (6-20 KIPS)	24.10	0.86
3	Single (11-20 KIPS)	8.83	0.94
4	Single (6-10 KIPS)	5.59	0.99
5	Single (3 KIPS)	1.42	1.00
6	Single (4 KIPS)	0.15	1.00
7	Single (5 KIPS)	0.03	1.00

Source: *North Carolina Department of Transportation.*

Step 5 – Evaluate Cluster Analysis of ALF

A two dimensional clustering technique was used to evaluate the 44 WIM station ALF to identify stations with similar loading patterns. The analysis was based on the Single and Tandem axle types for the 7 aggregated load bins found to be significant.

- Statistic – ALF for Single and Tandem Axle Types for 7 Aggregated Load Bins;
- Technique – Two Dimensional Hierarchal Clustering; and
- Measure – Sum of Least Squares of the Difference in ALF by axle type/load bin.

This technique requires the calculation of the difference between the ALF for each of the 7 aggregated load bins for a WIM site and the average value of all WIM sites for each load bin. This is done for all WIM stations in a cluster being considered. Each of those differences is squared and then summed to provide a single variability metric for the proposed cluster. This is done for all potential clusters in the step being evaluated and the cluster with the lowest value; representing the least amount of variability is the cluster identified for grouping for that step. This process is repeated until all WIM sites are grouped into a single cluster. Similar to the previous clustering analyses, the metric introduced by Mojena is the method used in identifying the appropriate number of clusters for the analysis.

The clustering analysis identified 4 clusters of WIM stations with similar ALF patterns. Figure G-7 provides the average Single and Tandem ALF (plotted as single line) using the aggregated load bins for each of the 4 clusters for comparison. The average VCD for each of the clusters is provided in Figure G-8. This plot helps us to understand the patterns observed in Figure G-7. Observations based on these two figures include:

- The VCD for Cluster 1 exhibits a much higher proportion of SU trucks compared to MU trucks; this correlates with the higher frequency of the single axle load bins and a lower frequency in the tandem, especially the heavy tandem bin as compared to the other three clusters;

- The VCD for Clusters 2, 3, and 4 all have higher proportion of MU trucks than SU trucks; these proportions increase as you progress from Cluster 2 to 4; this correlates to the higher frequency in the tandem load bins; and

- The VCD for Cluster 4 has the highest proportion of MU trucks; this correlates with the highest proportion of heavier single and heavy tandem load bins.

FIGURE G-7   **AVERAGE AGGREGATED SINGLE-TANDEM ALF FOR TWO-DIMENSIONAL CLUSTERS**
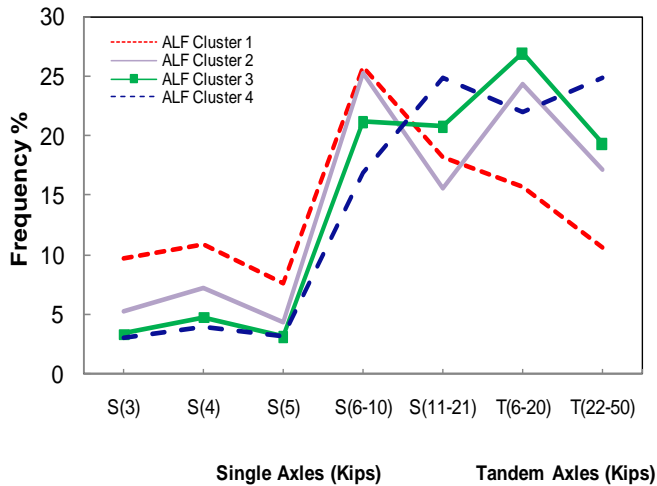
FIGURE G-8   **AVERAGE VEHICLE CLASS DISTRIBUTION FOR TWO-DIMENSIONAL ALF CLUSTERS**
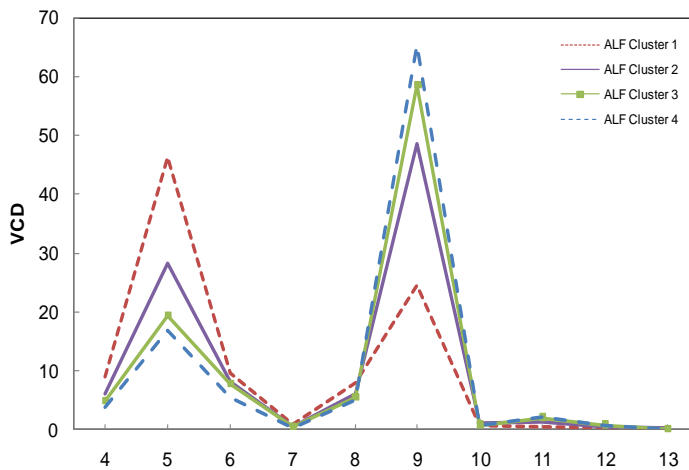
Source: North Carolina Department of Transportation.

It appears that as the proportion of MU trucks increases, the frequency in the heavier load bins increases also. This indicates that the type of facilities that serve long haul MU trucks well will experience the heaviest loading. Although this conclusion can be somewhat intuitive, it is validated by the results of the cluster analysis.

A plot of the average ALF for Single and Tandem axle types are provided in Figure G-9. These are the values used for input into the pavement design process. The average ALF for Tridem and Quad axle types were generated using the same WIM sites in each cluster to provide these inputs also.

FIGURE G-9   AVERAGE SINGLE AND TANDEM ALF FOR NORTH CAROLINA
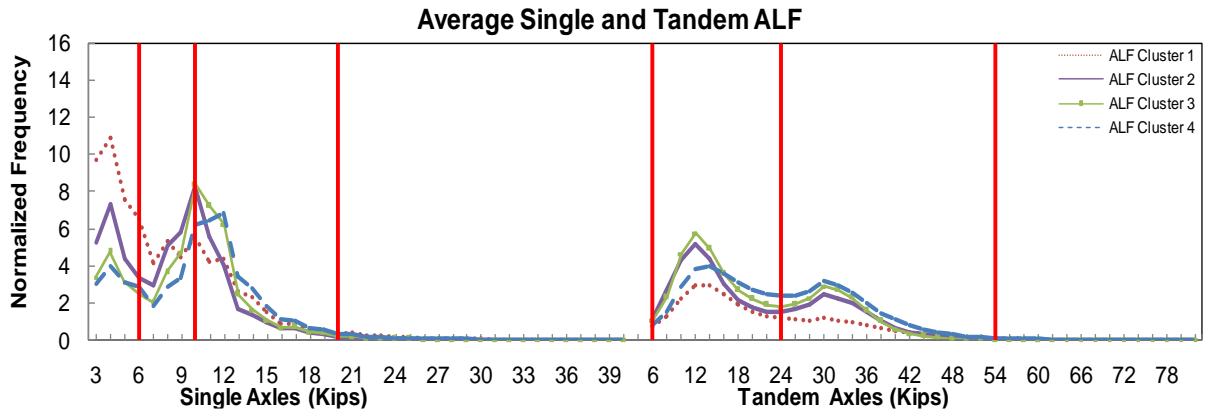
Source: North Carolina Department of Transportation.

Step 6 – Develop Method for ALF Group Selection

The results of the analysis explained in the previous steps provide the axle loading inputs needed for the pavement design process. To use these resources effectively, the designer will need to select the ALF most suitable to the traffic anticipated to travel over the pavement being designed. The research team performed an evaluation of the characteristics of the WIM stations that comprise each cluster to identify attributes that may explain why they have similar loading patterns. The same attributes for the pavement design location could then be used as the basis for selecting the appropriate ALF. Some of the attributes evaluated included:

Quantitative – AADT, AADTT, VCD, SU%, MU%, Class 5%, Class 9%

Qualitative – Route Type, Route Category, Facility Type, Functional Classification, Geographic Region, Area Type

There are some definitive quantitative measures that will determine specific ALF selections. These are based on the Class 5 and 9 percentages of total trucks calculated from the short term counts collected for a project. However, these statistics have overlap between two to three ALF groups in some ranges. In these cases, the designer will need to use a qualitative attribute, the route category, to select between the overlapping ALF. The route category types are Primary Arterial, Secondary Arterial, Collector, and Local routes. This is very similar to the Functional Classification attribute but is selected in the context of how a route will serve truck trips instead of total traffic. The designer must exercise some judgment when selecting the appropriate route category for a project. The ALF selection process is provided in Table G-7.

TABLE G-7   SELECTION CRITERIA FOR NORTH CAROLINA ALF

Parameter	Route Category	ALF
Project Route Location = WIM Route Location	N/A	WIM ALF
30 ≤ Class 5% < 54 and 4 ≤ Class 9% < 44	N/A	ALF Group 1
3 ≤ Class 5% < 18 and 68 ≤ Class 9% < 85	N/A	ALF Group 4
24 ≤ Class 5% < 37 and 44 ≤ Class 9% < 68	Primary Arterial	ALF Group 4
	Collector	ALF Group 2
10 <= Class 5% < 24 and 44 <= Class 9% < 68	Primary Arterial	ALF Group 4
	Secondary Arterial	ALF Group 3
	Collector	ALF Group 2

Source: North Carolina Department of Transportation.

If the data for Route Location, Class 5%, Class 9%, and Route Category for a project are not covered by the parameters specified in Table G-7, the designer should select the nearest match as the basis for selecting ALF. This could indicate a potential gap in the ALF data and the need to install a WIM monitoring station to provide the missing data.

G.9 SUMMARY

The study analyzed WIM data sets to generate appropriate traffic inputs for the MEPDG process. The methods used to generate North Carolina data are transferable to similar analyses. The elements considered critical to development of reliable traffic inputs for MEPDG include:

- Class Algorithms – Data collected using different technologies for traffic inputs should use the same class algorithm. This eliminates inconsistencies in the data that may result in a less reliable design process.

- Quality Control of Data – All data collection processes will capture anomalous data sets. Agencies should have a well designed quality control process to trap anomalous data and identify when data should be excluded.

- Principal Component Analysis – It is critical to perform these type of analyses to determine what elements in a data set are critical and when individual data are not consistent with the data being analyzed and should be excluded. This step is critical to understanding how the data should be clustered.

- Clustering Methodology – The method selected should account for the statistics being generated and the component elements found to be critical. This process should be simplified when practical without adversely affecting the results. This should make it easier to develop an understanding of the types of patterns captured in the groups and why those patterns occur.

- Selection Criteria – The results of the clustering analysis can't be used without developing a method for selecting the appropriate clustered data set to be used as an input. Objective measures are preferred as this simplifies the selection process. Multiple criteria may be required to definitively select the appropriate input.

There are many decisions made during the analysis process. These should be made based on the intended use of the data and the characteristics of the data being evaluated. If the analyst exercises care, and solicits input from traffic and pavement design experts, a reliable set of traffic inputs for the MEPDG can be developed.

G.10 REFERENCES

American Society for Testing and Materials. *Standard Practice for Classifying Highway Vehicles from Known Axle Count and Spacing*, ASTM E1572-93, 1994.

Stone J.R., Kim Y.R., List G. F., Rasdorf W., Jadoun F., Sayyady F., Ramachandran A., *Development of Traffic Data Input Resources for the Mechanistic Empirical Pavement Design Process, NCDOT Report 2008-11*, 2011.

Traffic Monitoring Guide, FHWA, U.S. Department of Transportation, May 2001.

Contact Information

Kent L. Taylor
State Traffic Survey Engineer
Traffic Survey Group
Transportation Planning Branch – NCDOT

Office Telephone: (919) 771-2520
Cell Telephone: (919) 218-4049
Fax: (919) 773-2935

E-mail: kltaylor@ncdot.gov

Mailing Address:

Traffic Survey Group
1547 Mail Service Center
Raleigh, NC 27699-1547

Delivery Address:

750 N. Greenfield Parkway
Garner, NC 27529

Link to Final Report for NCDOT 2008-11
http://www.ncdot.org/doh/preconstruct/tpb/research/download/2008-11FinalReport.pdf

Appendix H. TRAFFIC DATA FOR PAVEMENT DESIGN

H.1 BACKGROUND

The goal of pavement design is to obtain a set of specific pavement construction parameters, such as types of construction material and construction methods; thickness of various courses, including base, structural layer; and a surface course to achieve pre-determined performance criteria. Traffic, climate, soil, and other geological data are typically used as inputs for pavement design. Traffic data shall cover the entire life expectancy, which is between the opening year and the last year of life expectancy (Figure H-1). The last year of life expectancy of pavement is often referred to as the design year.

FIGURE H-1   TEMPORAL DATA SEQUENCE
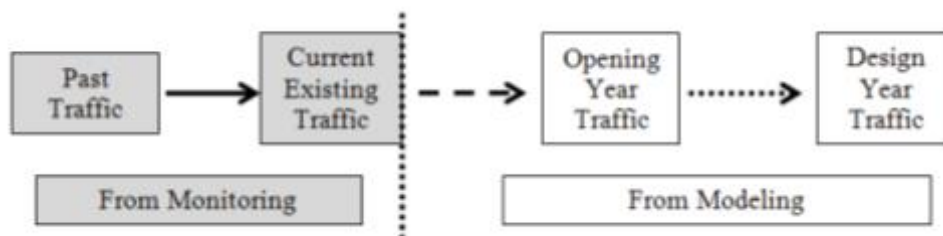
Source: Federal Highway Administration.

Traditionally, traffic impact on pavement design is through the concept of equivalent single-axle loads (ESAL). ESAL is the equivalent number of 18,000 lbf (pound force) single-axle loads that would produce the same amount of damage over the pavement design life. Traffic modeling and design traffic professionals project cumulative ESAL data from all vehicles for the entire pavement life expectancy.

NCHRP Project 1-37A's *Mechanistic-Empirical Pavement Design Guide* enables a dynamic approach where pavement performance can be modeled with very specific traffic related parameters. The new process requires significant traffic data from demand forecasting professionals, which in turn necessitates significant field monitoring data.

H.2 VEHICLE RELATED TERMINOLOGIES

The FHWA's 13 vehicle category classification system relies on vehicle axle spacing to differentiate various vehicles. Vehicle data classified under this system are referred to as vehicle class information or data.

Vehicle axle configuration refers to the different axle configurations that a vehicle may have. Under each vehicle axle configuration, the weight on the axle/axles is called axle loading. Axle load reflects both the weight of a vehicle itself and the cargo it carries.

H.3 TRAFFIC DATA ASSOCIATED WITH ESAL

To design pavement for a travel lane, AASHTO's *Guide for Design of Pavement of Structures* offers the formula for traffic data as listed below.

TABLE H-1   **TRAFFIC DATA SUMMARY**

1	D_L (lane splitting factor): traffic distribution among different lanes with the same travel direction by vehicle types
2	D_D (directional factor): directional traffic split of a two way roads
3	AADT by vehicle types
4	AADT by axle weight by vehicle types

Source: Federal Highway Administration.

$w_{18} = D_D \times D_L \times W_{18}$

Where:

w_{18} is the ESAL for the design lane. W_{18} represents the ultimate traffic data needed for pavement design.

D_D is the traffic directional factor for a two way roadway.

D_L is a lane traffic splitting factor for a roadway having more than one lane in each direction.

W_{18} is cumulative two way ESAL projected for a roadway segment.

H.3.1 W_{18} – CUMULATIVE TWO WAY EASL

The W_{18} is the cumulative dual directional ESAL covering the entire life expectancy. To compute W_{18}, data on number of axles for various axle configurations under various axle loads is needed. While the number of axles for various axle configurations under various axle loads can be obtained from traffic projection professionals, axle load equivalence factors are to be obtained from AASHTO's Guide Appendix D.

H.3.2   ONE OF MANY POTENTIAL W_{18} COMPUTATION PROCEDURES

1. Obtain Column A, B, and C information from AASHTO's *Guide for Design of Pavement Structures* Appendix D.
2. Fill out Column D with forecasted cumulative traffic measured in number of axles by axle load from traffic forecasting professionals.
3. Column E = Column C × Column D.
4. Summarize Column E to obtain the W_{18}.

TABLE H-2   ESAL COMPUTATION ILLUSTRATION

A	B	C	D	E
	AASHTO Guide Table		Traffic Forecasting	D × C
Axle Type	Axle Loads (KIPS)	Axle Load Equivalence Factor	Cumulative Number of Axle	ESALs
Single Axle	2.00	0.00	768,021	153.6
	4.00	0.00	120,123,356	240,246.7
	6.00	0.01	3,227,896,123	35,506,857.4
	8.00	0.04	623,456,799	22,444,444.8
	10.00	0.09	321,456,799	28,931,111.9
	12.00	0.19	2,100,003	396,900.6
	14.00	0.35	186,000,159	65,844,056.3
	16.00	0.61	0	0.0
	18.00	1.00	0	0.0
	20.00	1.56	0	0.0
	22.00	2.35	0	0.0
	24.00	3.43	0	0.0
	26.00	4.88	0	0.0
	…		0	0.0
	50.00	97.00	0	0.0
Tandem Axle	2.00	0.00	0	0.0
	4.00	0.00	0	0.0
	6.00	0.00	0	0.0
	8.00	0.00	12,345,789	37,037.4
	10.00	0.01	8,964,566	71,716.5
	12.00	0.02	368,945	5,903.1
	14.00	0.03	14,789	428.9
	16.00	0.05	78,965,145	3,948,257.3
	18.00	0.08	32,514,589	2,633,681.7
	…		0	0.0
	32.00	0.84	45,678,912	38,507,322.8
	34.00	1.08	256,000	276,480.0
	36.00	1.38	12,589,631	17,373,690.8
	38.00	1.73	0	0.0

A	B	C	D	E
	AASHTO Guide Table		Traffic Forecasting	D × C
Axle Type	Axle Loads (KIPS)	Axle Load Equivalence Factor	Cumulative Number of Axle	ESALs
	40.00	2.15	4,781,265	10,279,719.8
	42.00	2.64	3,612,987	9,538,285.7
	…		0	0.0
	68.00	22.40	0	0.0
	70.00	25.60	0	0.0
	…		0	0.0
	86.00	66.00	14,569,124	961,562,184.0
	88.00	73.40	1,256,789	92,248,312.6
	90.00	81.50	345,789	28,181,803.5
Cumulative ESAL				1,289,846,791.7

Source: Federal Highway Administration.

H.4 TRAFFIC DATA ASSOCIATED WITH MECHANISTIC AND EMPIRICAL PAVEMENT DESIGN

NCHRP Project 1-37A's *Mechanistic-Empirical Pavement Design Guide* requires the extensive input of traffic data. The following are traffic data items required for the process:

1. Opening Year Two-Way Annual Average Daily Truck Traffic

    Two-way annual average daily truck traffic (AADTT) (trucks are referred to as FHWA's class 4 to 13 vehicles) is needed for opening year condition. This data is used as the base for future growth projection. It is a projected traffic value done by a traffic forecasting professional.

2. Percent of Truck Traffic in Design Direction

    This value is the percentage of truck traffic in the design direction. Unless a roadway has an unbalanced travel for trucks, it should always be 50%.

3. Percent of Truck Traffic in Design Lane %

    This is the percentage of truck traffic for the design lane. The design lane is typically the outside lane with a multilane highway (more than one lane in each travel direction). Trucks tend to operate away from the far inside lane, which is adjacent to the median or the center lane divide on a multilane roadway.

4. Truck Monthly Adjustment Factor (TMAF)

    The Truck Monthly Adjustment Factor reflects truck travel patterns throughout the year. There are 10 truck types (FHWA vehicle class 4-13) that result 10 potential different temporal patterns over a 12 month period. Mathematically the monthly adjustment factor for a given vehicle class and a given month is obtained by dividing the average monthly average daily truck traffic (MADTT) for the month by the summation of all the 12 month MADTTs and then multiplied by 12. There are a total of 120 TMAFs [10 vehicle classes × 12 months = 120 individual TMAF].

The TMAF formula for vehicle class i and month k is $TMAF_{ik}=[MADTT_{ik}/(\sum(MADTT)_i)] \times 12$.

TABLE H-3   ILLUSTRATION OF MAF COMPUTATION FROM MADTT

MADTT	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	588	2,800	1,216	502	250	527	485	51	142	124
February	598	2,851	896	498	263	654	493	38	152	108
March	602	2,864	1,211	561	296	625	520	25	164	165
April	630	3,001	1,321	598	299	692	586	62	159	154
May	674	3,213	1,452	625	421	568	564	45	156	142
June	717	3,415	1,621	740	465	587	652	65	187	165
July	756	3,602	1,690	789	489	623	657	82	221	120
August	810	3,859	1,699	785	620	621	678	32	235	95
September	832	3,962	1,780	741	661	451	725	67	268	67
October	755	3,455	1,795	645	561	482	712	12	189	64
November	685	2,699	1,400	560	421	389	608	18	167	96
December	598	2,760	1,324	495	412	462	527	19	152	116
Total	8,245	38,481	17,405	7,539	5,158	6,681	7,207	516	2,192	1,416

T$MAF_{ij}=MADTT_{ij}/[\sum(MADTT)_j] \times 12$ MAF_{ij}; MAF_{ij} is the monthly adjustment factor for month i and vehicle class j truck

MADTT	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	0.86	0.87	0.84	0.80	0.58	0.95	0.81	1.19	0.78	1.05
February	0.87	0.89	0.62	0.79	0.61	1.17	0.82	0.88	0.83	0.92
March	0.88	0.89	0.83	0.89	0.69	1.12	0.87	0.58	0.90	1.40
April	0.92	0.94	0.91	0.95	0.70	1.24	0.98	1.44	0.87	1.31
May	0.98	1.00	1.00	0.99	0.98	1.02	0.94	1.05	0.85	1.20
June	1.04	1.06	1.12	1.18	1.08	1.05	1.09	1.51	1.02	1.40
July	1.10	1.12	1.17	1.26	1.14	1.12	1.09	1.91	1.21	1.02
August	1.18	1.20	1.17	1.25	1.44	1.12	1.13	0.74	1.29	0.81
September	1.21	1.24	1.23	1.18	1.54	0.81	1.21	1.56	1.47	0.57
October	1.10	1.08	1.24	1.03	1.31	0.87	1.19	0.28	1.03	0.54
November	1.00	0.84	0.97	0.89	0.98	0.70	1.01	0.42	0.91	0.81
December	0.87	0.86	0.91	0.79	0.96	0.83	0.88	0.44	0.83	0.98
Total	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00

Source: Federal Highway Administration.

5. Vehicle Class Distribution

Vehicle class distribution (VCD) refers to AADTT distribution among the 10 vehicle types (FHWA's 4 to 13 vehicle class). The percentage data are computed directly from vehicle classification data. There are 12 of such VCDs.

TABLE H-4   VEHICLE CLASS DISTRIBUTION COMPUTATION ILLUSTRATION

	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13	Total
AADTT	235	654	961	1,620	1,240	654	598	103	1,245	4,621	11,931
%	2.0	5.5	8.1	13.6	10.4	5.5	5.0	0.9	10.4	38.7	100.0

Source: Federal Highway Administration.

$VCD_j=AADTT_j/\sum(AADTT)_j;$ VCD_j is the truck distribution factor for vehicle class j truck

6. Truck Hourly Distribution Factor (THDF)

Truck hourly distribution factor refers to the percentage of hourly AADTT among a 24 hour period starting at midnight. There are 24 THDFs.

TABLE H-5   TRUCK HOURLY DISTRIBUTION FACTOR COMPUTATION ILLUSTRATION

Start Time	End Time	Hourly Distribution	
		Hourly-AADTT	%
00:00	01:00	8	0.6
01:00	02:00	9	0.7
02:00	03:00	12	0.9
03:00	04:00	16	1.3
04:00	05:00	25	2.0
05:00	06:00	36	2.8
06:00	07:00	45	3.5
07:00	08:00	68	5.3
08:00	09:00	78	6.1
09:00	10:00	76	5.9
10:00	11:00	78	6.1
11:00	12:00	82	6.4

Start Time	End Time	Hourly Distribution	
		Hourly-AADTT	%
12:00	13:00	98	7.7
13:00	14:00	98	7.7
14:00	15:00	86	6.7
15:00	16:00	88	6.9
16:00	17:00	74	5.8
17:00	18:00	78	6.1
18:00	19:00	64	5.0
19:00	20:00	52	4.1
20:00	21:00	54	4.2
21:00	22:00	26	2.0
22:00	23:00	18	1.4
23:00	24:00	10	0.8
Total		1,279	100.0

Source: Federal Highway Administration.

THDF%$_h$=AADTT$_h$/(AADTT); THDF%$_h$ is the truck distribution hourly factor for the hth hour of the day

7.   Axle Load Factor

FHWA vehicles in class 4 to 13 can have a variety of axle configurations, including single axle, tandem axle, tridem axle, and quad axle. For a given vehicle class and axle configuration, axle weight varies depending on vehicle load. Axle Load Factor (ALF) is to capture that information in terms of distributions of vehicles based on axle weight under a given vehicle class and axle configuration for a given month. This is one of the most demanding data sets. Mathematically, the ALF is the percentage of a given axle load among all axle loads under a given vehicle axle configuration.

7a.   Single Axle Configuration Axle Load Factor

There are 39 axle weight groups for single axle configuration vehicles. The axle weight group ranges from 3,000 lbs. to 41,000 lbs. with increments of 1,000 lbs. The computation of the axle load factor data is based on MADT for a particular vehicle class and axle weight group.

TABLE H-6   ILLUSTRATION OF SINGLE AXLE LOAD FACTORS FOR JANUARY, FEBRUARY AND DECEMBER

Month		January	January	January	January	January	January	January	January	January	January	February	February	December
Vehicle Class		4	5	6	7	8	9	10	11	12	13	4	5	13
Axle Weight (lbs)	3,000	1.8	10.05	2.47	2.14	11.65	1.74	3.64	3.55	6.68	8.88	1.8	10.03	8.88
	4,000	0.96	13.21	1.78	0.55	5.37	1.37	1.24	2.91	2.29	2.67	0.96	13.21	2.67
	5,000	2.91	16.42	3.45	2.42	7.84	2.84	2.36	5.19	4.87	3.81	2.91	16.41	3.81
	6,000	3.99	10.61	3.95	2.7	6.99	3.53	3.38	5.27	5.86	5.23	3.99	10.61	5.23
	7,000	6.8	9.22	6.7	3.21	7.99	4.93	5.18	6.32	5.97	6.03	6.8	9.24	6.03
	8,000	11.47	8.27	8.45	5.81	9.63	8.43	8.35	6.98	8.86	8.1	11.47	8.27	8.1
	9,000	11.3	7.12	11.85	5.26	9.93	13.67	13.85	8.08	9.58	8.35	11.31	7.12	8.35
	10,000	10.97	5.85	13.57	7.39	8.51	17.68	17.35	9.68	9.94	10.69	10.97	5.85	10.69
	11,000	9.88	4.53	12.13	6.85	6.47	16.71	16.21	8.55	8.59	10.69	9.88	4.54	10.69
	12,000	8.54	3.46	9.48	7.42	5.19	11.57	10.27	7.29	7.11	11.11	8.54	3.46	11.11
	13,000	7.33	2.56	6.83	8.99	3.99	6.09	6.52	7.16	5.87	7.32	7.32	2.56	7.32
	14,000	5.55	1.92	5.05	8.15	3.38	3.52	3.94	5.65	6.61	3.78	5.55	1.92	3.78
	15,000	4.23	1.54	3.74	7.77	2.73	1.91	2.33	4.77	4.55	3.1	4.23	1.54	3.1
	16,000	3.11	1.19	2.66	6.84	2.19	1.55	1.57	4.35	3.63	2.58	3.11	1.19	2.58
	17,000	2.54	0.9	1.92	5.67	1.83	1.1	1.07	3.56	2.56	1.52	2.54	0.9	1.52
	18,000	1.98	0.68	1.43	4.63	1.53	0.88	0.71	3.02	2	1.32	1.98	0.68	1.32
	19,000	1.53	0.52	1.07	3.5	1.16	0.73	0.53	2.06	1.54	1	1.53	0.52	1
	20,000	1.19	0.4	0.82	2.64	0.97	0.53	0.32	1.63	0.98	0.83	1.19	0.4	0.83
	21,000	1.16	0.31	0.64	1.9	0.61	0.38	0.29	1.27	0.71	0.64	1.16	0.31	0.64

Month		January	January	January	January	January	January	January	January	January	January	February	February	December
Vehicle Class		**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**4**	**5**	**13**
	22,000	0.66	0.31	0.49	1.31	0.55	0.25	0.19	0.76	0.51	0.38	0.66	0.31	0.38
	23,000	0.56	0.18	0.38	0.97	0.36	0.17	0.15	0.59	0.29	0.52	0.56	0.18	0.52
	24,000	0.37	0.14	0.26	0.67	0.26	0.13	0.17	0.41	0.27	0.22	0.37	0.14	0.22
	25,000	0.31	0.15	0.24	0.43	0.19	0.08	0.09	0.25	0.19	0.13	0.31	0.15	0.13
	26,000	0.18	0.12	0.13	1.18	0.16	0.06	0.05	0.14	0.15	0.26	0.18	0.12	0.26
	27,000	0.18	0.08	0.13	0.26	0.11	0.04	0.03	0.21	0.12	0.28	0.18	0.08	0.28
	28,000	0.14	0.05	0.08	0.17	0.08	0.03	0.02	0.07	0.08	0.12	0.14	0.05	0.12
	29,000	0.08	0.05	0.08	0.17	0.05	0.02	0.03	0.09	0.09	0.13	0.08	0.05	0.13
	30,000	0.05	0.02	0.05	0.08	0.04	0.01	0.02	0.06	0.02	0.05	0.05	0.02	0.05
	31,000	0.04	0.02	0.03	0.72	0.04	0.01	0.03	0.03	0.03	0.05	0.04	0.02	0.05
	32,000	0.04	0.02	0.03	0.06	0.12	0.01	0.01	0.04	0.01	0.08	0.04	0.02	0.08
	33,000	0.04	0.02	0.03	0.03	0.01	0.01	0.02	0.01	0.01	0.06	0.04	0.02	0.06
	34,000	0.03	0.02	0.02	0.03	0.02	0.01	0.01	0	0.01	0.02	0.03	0.02	0.02
	35,000	0.02	0.02	0.01	0.02	0.02	0	0.01	0	0	0.01	0.02	0.02	0.01
	36,000	0.02	0.02	0.01	0.02	0.01	0.01	0	0	0	0.01	0.02	0.02	0.01
	37,000	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0.01	0.01	0.01	0.01	0.01
	38,000	0.01	0.01	0.01	0.01	0	0	0	0.02	0.01	0.01	0.01	0.01	0.01
	39,000	0.01	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0.01	0	0.01
	40,000	0.01	0	0.01	0.01	0	0	0.04	0.02	0	0	0.01	0	0
	41,000	0	0	0	0	0	0	0	0	0	0	0	0	0

Month	January	January	January	January	January	January	January	January	January	January	February	February	December
Vehicle Class	4	5	6	7	8	9	10	11	12	13	4	5	13
% of Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: *Federal Highway Administration.*

H.4.2 7B. TANDEM, 7C. TRIDEM, AND 7D. QUAD AXLE VEHICLES

For tandem axle vehicles, the axle weight group starts at 6,000 lbs. and ends at 82,000, lbs. with increments of 2,000 lbs. For both tridem and quad axle vehicles, the axle weight group start at 12,000 lbs. and ends at 102,000 lbs. with increments of 3,000 lbs.

8. Number of Axle Types per Truck Class

The number of axles per vehicle class for a given axle configuration is an annual average number of axles per vehicle category (per vehicle class and vehicle axle configuration).

TABLE H-7   AVERAGE NUMBER OF AXLES

	Single Axle	Tandem	Tridem	Quad
Class 4	1.62	0.39	0	
Class 5	2	0	0	
Class 6	1.02	0.99	0	
Class 7	1	0.26	0.83	
Class 8	2.38	0.67	0	
Class 9	1.13	1.93	0	
Class 10	1.19	1.09	0.89	
Class 11	4.29	0.26	0.06	
Class 12	3.52	1.14	0.06	
Class 13	2.15	2.13	0.35	

Source: Federal Highway Administration.

9. Axle Spacing

Axle spacing data are only applicable to tandem, tridem, and quad vehicles in the sense for pavement design concepts discussed here. It is the distance between two consecutive tandem, tridem, and quad axles.

10. Average Axle Width

The distance between the two outside edges of an axle is defined as axle width.

11. Wheelbase

The distance between the steering and the first device axle of a tractor or a heavy single unit. This definition is only applicable to the pavement design concept discussed here.

TABLE H-8   TRAFFIC DATA SUMMARY

Date Item #	Date Item Name	# of Data Points	Frequency	Foundation Data	Data Dimension
1	Annual Average Daily Truck Traffic	1	Annually	AADTT	By sum of all trucks
2	% of Truck Traffic in Design Direction	1	Annually	AADTT	By sum of all trucks and travel direction
3	% of Truck Traffic in Design Lane	1	Annually	AADTT	By sum of all trucks, travel direction, and travel lane
4	Truck Monthly Adjustment Factor	120	Monthly	MADTT	MADTT by truck class for each month in a year
5	Truck Classification	12	Annually	AADTT	AADTT by truck class
6	Truck Hourly Distribution	24	Annually	AADTT	AADTT by sum of all trucks by hour of the day
7	Axle Load Factor – Single Axle	4680	Monthly	MADTT	MADTT by truck class, axle configuration, and axle weight group
	Axle Load Factor – Tandem	4680	Monthly	MADTT	MADTT by truck class, axle configuration, and axle weight group
	Axle Load Factor – Tridem	3720	Monthly	MADTT	MADTT by truck class, axle configuration, and axle weight group
	Axle Load factor – Quad	3720	Monthly	MADTT	MADTT by truck class, axle configuration, and axle weight group
8	Number of Axles	40	Annually	AADTT	AADTT by truck class and axle configuration
9	Axle Spacing-tandem, tridem, and quad	3	Annually	AADTT	AADTT by axle configuration
10	Wheelbase	3	Annually	AADTT	AADTT by wheelbase

Source: Federal Highway Administration.

H.5 SUMMARY

Traffic data is one of the most critical elements in pavement design. Even though all traffic data used in pavement design reflects future traffic conditions, traffic monitoring programs and traffic monitoring data provide the needed ground truth in the projection processes including, but not limited to, establishing historical trend and model calibration and validation.

Appendix I. FREQUENTLY ASKED QUESTIONS (FAQS)

Q.1 – When I compute a weekday factor, should I include Mondays in the weekday? Should I include Fridays?

There is no definite answer. The decision must be made by each organization. Traffic patterns vary from site to site. In most urban cases, Monday traffic volumes are fairly similar to Tuesdays, Wednesday, and Thursdays. Fridays, however, tend to have lower morning volumes and slightly higher afternoon volumes than the other weekdays. In rural recreational areas, Mondays, like Fridays, can have substantially different volumes than the other weekdays. In other rural areas, Monday volumes tend to be similar to Tuesday through Thursday volumes. The procedures recommended in the *TMG* produce adequate estimates of AADT regardless of whether these days are included or excluded.

Q.2 – Should I compute factors for days that run from midnight-to-midnight or from noon-to-noon?

The answer to this question depends on the data that analysts will be factoring. If counts are routinely taken from noon-to-noon, then computation of the factors using noon-to-noon days is appropriate. If the days from short duration counts are always based on midnight start times (that is, the earliest hours of the data collection period are essentially discarded), then the days used in the factor computation should be based on calendar days. Analysis has shown that the use of either alternative has little impact on the AADT estimates.

Q.3 – Should I use data from this year, last year, or a combination of several years to compute factors for short counts taken this year?

The best factoring results are obtained if the factors being applied are for the same year as the short duration counts being factored. That is, a short count taken in 2000 should be factored with continuous count data from 2000. This is done because significant events affecting the ratio of a short duration count to annual travel this year (e.g., a big snow storm) are accounted for in this year's continuous count data. They were not present in last year's continuous count data.

The drawback to using current year data for the factors is that computation must wait until the end of the year. States often wish to use AADT estimates from short counts taken during the current year before the end of the current year. One alternative is to create and use a temporary factor until the calendar year is complete. This factor is computed with the data from the previous 12 months. The temporary factor would be used until the final factors are computed. This final value would then be maintained as the annual estimate.

Another alternate is to use more than one year of data to compute seasonal factors. However, this technique does not account for annual conditions that affect traffic when it is applied to short duration counts that are from a different year.

Perhaps the simplest solution is to use the available AADT figure until a new one based on the current year factors is computed. Factors based on current year data are recommended.

Q. 4 – How do I assign short counts taken in rural areas that are affected by urban traffic? Are they urban counts or rural counts?

There is no simple solution to this problem. These locations tend to have unique day-of-week patterns that reflect typical urban patterns on the weekdays, but rural patterns on weekends. Similarly, seasonal variation tends to be partway between the flat pattern found in most urban settings and the more varied peak patterns often found in rural areas. This occurs with commuter

routes where the urban pattern extends outside the urban boundary. In most cases analyst judgment is the answer.

One alternative is to take longer short duration counts. A week-long count will provide the data needed to account for the day-of-week variation without factors. The factor application then only has to adjust for the seasonal component. Another solution may be to install a continuous counter for that route. Another may be to apply the appropriate factors outside the group boundaries as a special case.

Q.5 – How many continuous counts should be in a factor group?

There is no single answer to this question. Statistics and the desire to have factors that yield annual AADT estimates with +10 percent accuracy with 95 percent confidence tend to require a factor group size of five to eight counters. A minimum of two counters is required to compute a standard deviation of the average factors that become the group factors. The standard deviation is used to estimate the reliability of the group factors. Recreational or special groups often have only a single continuous counter. Many States prefer to have additional counters to compensate for downtime and missing data problems.

Q. 6 – Can continuous counters be used to accurately track vehicle distance traveled (VDT)?

Continuous counters track traffic at a point. Depending on the site, this can be expanded to a section or route. It is rarely practical to track area wide travel with continuous counters. Few agencies have the large number of continuous counters required to provide statistical reliability to the area wide travel estimates. In most cases, agencies use a limited number of continuous count locations to provide traffic trends at a limited number of sites. Individual road volumes are dramatically affected by local changes in land use and economic activity. The use of a small number of continuous count locations can result in highly biased VDT calculations. The FHWA uses the continuous count data reported monthly to the travel volume trends (TVT) system combined with the annual HPMS VDT estimates to track changes in monthly travel. A similar approach could be applied statewide for States with sufficient number of continuous counters.

Q.7 – How do I define a road segment for traffic counting?

A road segment for traffic counting is a section of road with homogeneous volume (i.e., the traffic volume does not change throughout the segment). Many State traffic programs divide their systems into traffic segments and physically count each segment to provide complete system coverage. Traffic volume is constantly changing and a perfect segment definition is not possible. For access-controlled systems, a definition between interchanges is the simplest. For non-controlled systems, the *TMG* recommends keeping a single segment until volume changes of plus or minus 10 percent are identified, at which point a new segment should be created.

Q.8 – How many vehicle classifications should I collect data for?

There is no simple answer to this question. In most cases, when using portable vehicle classification equipment, FHWA's 13 vehicle category classification system (Appendix C) have become the standard. However, it is certainly appropriate to further sub-divide these classifications to provide data on specific vehicles of interest. For example, Oregon DOT collects data on the use of triple trailer vehicles. This classification is a sub-set of class 13 (multi-trailer vehicles). Thus for their own purposes, these vehicles are a specific class of trucks. When Oregon reports data to the FHWA, the triple trailer class vehicles are simply combined with the other multi-trailer vehicles measured, and the total is reported as the volume in FHWA class 13. Permanent axle classifiers and WIM scales should also collect the FHWA 13 vehicle classes.

On many roadways, it is not possible to place axle sensors so that they accurately collect the 13 FHWA vehicle categories. However, it is possible to use two inductance loops or magnetic units to

differentiate vehicles by total length. Four vehicle classes are recommended when collecting data in this fashion. These classes should reflect cars (and pick-up trucks), single-unit trucks, single-trailer combination trucks, and multi-trailer trucks. In some States, the multi-trailer truck category may be unnecessary, and these trucks can be incorporated into the combination category because there are few multi-trailer trucks. As the truck fleets and truck size and weight laws change, States not collecting data on these vehicles may have to revise their data collection process to collect the data. While use of the simplified vehicle classes does not meet the desired level of reporting for many purposes, collecting data in the simplified categories is far better than collecting no vehicle classification data at all, and it allows monitoring the presence of trucks in urban traffic.

Q.9 – How many permanent, continuously operating vehicle classifiers should my State install and maintain?

A reasonable answer to this question cannot be given without first understanding how the State proposes to factor short duration vehicle classification counts. If a traditional factoring approach is selected (i.e., something similar to the continuous count program operated by almost all States), then as many continuous classifiers as continuous counters should be operated. If the State chooses a classification count factoring approach that measures and applies road-specific factors, the number of counters required will increase significantly.

Q.10 – How many portable classification counts should my State undertake?

There are many factors to consider in the answer. As a rule of thumb, 25 to 30 percent of volume counts should be classified. In general, each State should undertake a vehicle classification count at least once every counting cycle that can be applied to each road segment under its control. This does not mean that each road segment should be counted. Instead, super segments consisting of combined roadway volume segments should be counted. Each super segment should be relatively homogeneous for truck traffic along its length. Each super segment should be counted at the same interval used by the State for collecting volume counts. Annual truck travel estimates can be derived from the counts. The annualized truck percentages can then be converted to estimates of truck travel for the entire super segment.

Q.11 – How can my State collect classification data in urban areas?

Traditional vehicle classifiers have difficulties operating accurately in urban areas because vehicle acceleration/deceleration makes speed and length calculations inaccurate, and because closely following vehicles result in misclassification of cars as trucks. On freeways, careful placement and calibration of either video or loop based classification equipment can produce accurate truck volume counts. To date, no inexpensive classifier is available that works accurately under stop-and-go arterial conditions.

For higher systems, permanent classifiers using loops or video may be the only alternative. On lower systems, there are locations where axle or magnetic (length) portable classifiers will work. In many cases, visual counts may be the last resort.

Q.12 – How do I define a vehicle classification road segment?

In simple terms, a traffic road segment is a section of roadway that has similar (or homogeneous) volume or classification characteristics. The difficulty comes from the fact that a homogeneous segment for traffic volume may not be a homogeneous segment for other purposes such as classification or pavement design purposes. For example, the road may change from asphalt concrete to Portland cement concrete even though the volumes being carried on that road do not change appreciably. When developing a count program for vehicle classification, it may be necessary to create classification roadway segments where truck volumes do not change significantly. A single classification count taken within a properly defined super segment provides the classification data for all segments within that super segment. The use of these super segments reduces the number of

physical classification counts needed to provide adequate roadway coverage for truck volume information.

Q.13 – What vehicle lengths should I use for vehicle classification?

Analysis of available data indicated that no single set of vehicle lengths worked best for all States, as vehicle characteristics vary from State to State. As of November 2012, the vehicle length classification system that worked the best on combined data from all States is shown in Table I-1.

TABLE I-1   LENGTH BASED CLASSIFICATION BOUNDARIES

Primary Description of Vehicles Included in the Class	Lower Length Bound >	Upper Length Bound < or =
Passenger vehicles (PV)	0 m (0 ft)	3.96 m (13 ft)
Single unit vehicles (SU)	3.96 m (13 ft)	10.67 m (35 ft)
Combination vehicles (CU)	10.67 m (35 ft)	18.59 m (61 ft)
Multi-trailer vehicles (MU)	18.59 m (61 ft)	36.58 m (120 ft)

Source: Federal Highway Administration.

These criteria did an acceptable job of classifying vehicles into the four general categories. Considerable error was found in how well the length bins (and the corresponding classification results) performed when estimating aggregations of the FHWA 13 vehicle category classification system. A classifier can accurately measure vehicle length (for example as 34 feet for a given small vehicle combination), place that count in the correct length bin (in this example, the bin from 13 to 35 feet), but incorrectly classify that vehicle (in this case calling a small combination vehicle a single unit).

Table I-2 shows the errors associated with using vehicle lengths to estimate the four vehicle categories shown in Table I-1 when using the vehicle length boundaries shown in that table.

TABLE I-2   MISCLASSIFICATION ERRORS CAUSED BY USING ONLY TOTAL VEHICLES LENGTH AS THE CLASSIFICATION CRITERIA

Classification Based on Configuration and Number of Axles	Classification Based on Total Vehicle Length				
		PV	SU	CU	MU
	SU	17.7%	81.9%	0.4%	0%
	CU	0%	1.8%	84.2%	14.0%
	MU	0%	0.1%	20.8%	79.1%

Source: Federal Highway Administration.

Many States will be able to improve on these results by fine-tuning the length spacing boundaries to account for the characteristics of their trucking fleets. However, no amount of fine-tuning will lead to a perfect length classification system (where perfection is defined as the ability to use overall vehicle length to classify vehicles based on the number of units they include or the number of axles they use). This is because total vehicle length is not a consistent indicator of vehicle class as defined by these attributes. Consequently, highway agencies should be aware of the size and type of misclassification error that exists, and set their length boundaries to minimize error.

States should not abandon the axle based vehicle classification system. Data for all pavement designs are still based on FHWA's 13 category vehicle classification system, which is an axle system.

Q.14 – Should WIM data be collected only on smooth and flat pavements?

WIM data is needed to address pavement design and other uses involving all types of pavement. Data collection mechanisms that provide quality data are needed under all conditions. Indeed, the dynamic forces that vehicles apply to the pavement may increase as the quality of the pavement decreases. Research and equipment activities under the auspices of the traffic monitoring program should continue under a variety of roadway conditions. However, under current equipment constraints, the collection of WIM data based on calibrated equipment and comparable to static weight data may only be possible on smooth and flat pavement. The *TMG* emphasizes the collection of quality WIM data at permanent installations in flat and smooth pavement to insure the quality and veracity of the resulting WIM data. The limited WIM data at these sites is then expanded based on specific road groups and detailed classification data to apply WIM estimates to the complete roadway system. Extended information on these issues is available from ASTM or the LTPP program.

Q.15 – What type of information does the traffic volume trends (TVT) reports have?

TVT reports vehicle miles traveled (VMT) on all U.S. public roads on a monthly basis. VMT change rates are also reported. The geography is done by individual State.

Q.16 – When is the monthly TVT report published?

The TVT report is published within 60 days after the close of the given month. A copy of the report can be obtained at: http://www.fhwa.dot.gov/ohim/tvtw/tvtpage.cfm.

Q.17 – Can you notify me when a new TVT report is posted on your website?

To subscribe the TVT, please visit the following website, select the eSubscribe button and then follow the instruction provided.

http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm.

Q.18 – Where did the FHWA get the traffic data used in TVT?

The TVT report is based on traffic data from the Highway Performance Monitoring System and on data submitted to the FHWA by State highway agencies throughout the entire U.S. The State highway agencies collect the data through continuous counters on public roadways.

Q.19 – When should State highway agencies submit their continuous count data to FHWA?

Monthly continuous count data should be submitted to the FHWA within 20 days after the closing of the month. For example, the January 2013 data should be submitted to FHWA no later than February 20, 2013.

Q.20 – How does the FHWA compute VMT for a missing State in the TVT report?

In the event that a State does not have a traffic counter on a given functional classification of

roadway, the TVT procedure is to estimate the missing value(s) from other functional classes from the same State. If the State does not have any valid values, the average value from the surrounding States for the same roadway functional class is used. If no surrounding State data is available, National average(s) are used.

Q.21 – What is TMAS and how do I get access to it?

The Travel Monitoring Analysis System (TMAS) provides online data-submitting capabilities to State traffic offices to submit data to FHWA. Access to TMAS is obtained through the FHWA Division office in the individual State. This link provides contact information to all the Division offices: http://www.fhwa.dot.gov/field.html#fieldsites.

Q.22 – How many permanent and portable traffic counting sites should a given State have?

A State should have 5 to 8 permanent sites for each grouping of functional classified roadway.

Q.23 – How is TVT done each month?

The Traffic Volume Trends (TVT) report is published monthly by the Federal Highway Administration (FHWA). The report estimates the vehicle miles traveled (VMT) by State and several functional classes of roads. The estimates are based on two sources of data:

- The Highway Performance Monitoring System (HPMS); and

- Monthly traffic counts from continuous counters.

The HPMS compiles data from the States annually concerning the condition and performance of all roads in the United States. HPMS includes the annual average daily traffic (AADT) by road segment. When these AADTs are multiplied by the length of each road segment and summed for all road segments and days of the year, they yield the annual VMT.

The States submit to FHWA traffic counts from their continuous counters each month. These continuous counters are permanent traffic counting devices such as inductive loops in the roadway. There are about 4,000 continuous counts that are reported to FHWA each month.

Continuous count data is submitted and processed using the Travel Monitoring Analysis System (TMAS). The FHWA runs quality control checks on all data received. Only data passing the checks are used for the TVT report.

Monthly average daily traffic (MADT) is computed from the continuous counts. Each MADT is compared with the MADT for the same month the previous year to yield a change rate. The change rates are averaged by functional class of road. If a State does not provide traffic data in time, their change rates are estimated from the surrounding States.

TVT estimates monthly VMT by combining the change rates for each month with the most recent annual VMT from HPMS. The TVT report is available to the public within 60 days after the close of the month. Data that covers a minimum of 30 States and 70% of the VMT is required for publication. The next month's TVT report will include an update that covers more data.

The December TVT provides the first estimate of annual VMT for performance measures such as crash rates. When the annual HPMS data is available, they will supersede the total VMT from TVT.

Q.24 – What is a K-Factor?

The K-factor is the proportion of AADT occurring in the analysis hour. It is the ratio of analysis hour to annual average daily traffic. For example, the peak proportionality K-factor is the ration of peak hour to annual average daily traffic. By applying the peak hour proportionality K-factor to an AADT, design hour volume can be estimated. Other K-factors include the K30, which is the 30th highest peak hour divided by the annual average daily traffic (K100 is the 100th).

Q.25 – How should K-factor data be developed for HPMS reporting purposes?

The most accurate way to do this is to have a continuous count station on every HPMS sample section. This is very unlikely because of the amount of money and staff needed to maintain and operate that type of system. However, every sample section should have K-factor data coded, and an estimate should be provided for sections without a direct measurement; zero coding is not an option for this data item.

Q.26 – How are States developing estimates of K-factors on sample sections without continuous count stations?

States are using a variety of methods to develop K-factor estimates. In general, we encourage the States to use the same procedures for HPMS sample sections that are used to estimate K-factors for project level engineering and design decisions.

Q.27 – What are some of the common estimating methods used by the States?

There are a number of estimating methods in use, including use of:

- K-factors computed for a continuous count site for samples having similar road type and traffic characteristics;

- The highest hourly volume from 48 hour short counts for the sample section as a percent of the AADT;

- The peak hour volume from short term counts for the sample section as a percent of AADT. States may use either one direction or combined directions to determine the peak hour;

- Available project level information for the sample section, or for a nearby section with similar physical and traffic characteristics. Information from turning movement, volume, and/or classification counts may be used to estimate a peak hour volume as a percent of AADT; and

- Default values that adequately represent typical or average values by functional class and State sub-region or urbanized area. The use of average statewide values by functional class should only be used as an interim procedure until site-specific traffic monitoring data is available.

Q.28 – What other methods are being investigated by the States?

There are a number of estimating methods being used by States that are not common practice and that may require further investigation for applicability to other States. These include use of:

- Default values, such as functional class versus AADT, determined from a regression analysis of computed K-factors at continuous count stations. This may be useful for rural States and for low traffic volume locations.

- An average K-factor developed from continuous count data on a specific route or functional class for an individual urbanized area or a group of urbanized areas (grouped only for analyzing traffic data). Travel characteristics of the HPMS sample location and the continuous counts averaged should be similar in terms of number of lanes, percent trucks, and peak direction. This may be more accurate than short term counts because the daily variability is eliminated.

- Average highest hour volume from short term counts as a percent of the AADT at locations grouped by number of lanes actually monitored and by one or both directions (i.e., eight lanes monitored in two directions are grouped to develop an average K-factor for that group). All travel lanes may not be monitored in multi-lane high volume locations with traffic surveillance strategies in place. This may be appropriate for urban, high volume, or multi-lane locations.

Q.29 – Does FHWA endorse any particular estimation method?

No. States should use K-factors from site-specific traffic monitoring data to the greatest extent possible. Any estimating procedures should make best use of the available information and sound

traffic engineering judgment. In addition, they should be validated through the execution of a periodic test program that assesses the quality of the relationship between the estimate and factors computed from measured values. FHWA does not support the use of statewide values by functional class.

Q.30 – How should percent truck data be reported for HPMS sample sections where there is not site-specific data available?

Every sample section should include associated truck percentage data; zero should only be associated with a site if there is no truck traffic on the section or if the percentage of trucks is less than one-half of one percent (result of rounding to nearest whole percent). Zero should not be associated with the site if the percent of trucks is unknown; an estimate of the value should be used instead. Associating truck percentage data with sites where only sections that have actual measured value results in too many sample sections with zero trucks; since the HPMS uses a single expansion factor for all variables, this practice distorts the information resulting from the expanded sample. In other words, having too many zero truck percentages will result in a lack of valuable information.

Where States are collecting data that results in rounded percentage of truck values of zero, a note in the submittal comment file is appropriate. This may be the case on high volume routes, especially in urban areas, where the volume of trucks may be significant but their percent of total AADT is insignificant.

The preferred way to eliminate this problem over time is to upgrade equipment used for short count purposes to counters that also provide vehicle classification information. Used where needed for short counts on HPMS sample sections, they will permit reporting measured values.

When it is necessary to use an estimate, the State should determine the best way to estimate percentages of trucks based on the information available. The most credible method is to assign known site-specific values to other samples that are located on the same route. Other methods include assigning known site-specific values to other samples that are located on similar facilities with similar traffic characteristics that are located in the same geographical area and are in the same volume group; or, assigning known site-specific values to other samples that are in the same functional class and are located in the same area type (rural, small urban, urbanized) with similar travel characteristics. Average statewide values calculated by functional class should not be used.

Supplemental methods and sources may be particularly useful in urban areas; some of these include turning movement studies, origin and destination studies, license plate surveys, design estimates and projections, and MPO/municipal data obtained for other purposes. Short-term visual observation of truck travel on a sample section can also be of help in developing an estimate. The HPMS analyst should enlist the assistance of the State traffic engineering or traffic operations unit in developing percentage of trucks estimates.

The percentage of average daily trucks should be reported as an annualized value. This is consistent with the new *TMG* that has as a goal of traffic monitoring programs the ability to adjust short-term truck data to represent truck AADT. Until States are able to estimate truck AADT values, percent truck data that best represents average conditions should be reported.

The percentage of peak trucks should be reported as the proportion of trucks in the traffic stream during the hour or period of peak total traffic flow on the sample section.

These questions do not have one specific answer and will require input from the States and FHWA for a general response to each question.

Q.31 – What is the recommended method for collecting motorcycle data?

FHWA does not endorse one method over another. The States are encouraged to develop and test equipment and methods to meet the local conditions. Motorcycle detection and accuracy varies depending on the technology used and local environmental conditions existed. Some technologies

are suited to better count motorcycles while classification can be much harder to perform. Tracking individual motorcycles may be possible while tracking grouped or multiple motorcycles closely grouped and spread in the lanes may be much harder to count and classify properly.

Q.32 – What is the recommended depth for piezo traffic sensors to get the maximum benefit of data collection, while protecting the equipment?

Given that equipment is different, there is no universal depth to be recommended. Installer should consult vendor specification and seek State DOTs for specific information.

Q.33 – The 3-day continuous count data (Tuesday, Wednesday, Thursday) have been collected for the capacity analysis. Highway capacity software and Synchro are being used for the analysis. Do peak hour volumes need to be multiplied by seasonal and axle adjustment factors (in the same manner as daily volumes when converted to AADT)?

Seasonal factors are used to convert average daily traffic (ADT) to annual average daily traffic (AADT). Axle adjustment is used to convert axle counts to volume. For capacity analysis, you may not have to apply any correction.

Appendix J. TMAS 2.0 QUALITY CONTROL CHECKS

<u>**STATION DATA**</u>
```
    Duplicates within the batch
    Duplicates against the National Database
    Fatal errors
          no S or 1 in the 1st digit of the record
          record length less than 167 characters
          no station ID in the record (columns 4-9)
    Critical errors occur if:
          blank or invalid direction or lane
          blank or invalid functional classification
          blank or invalid state code
          improper vehicle classification designated (column 24-25)
          (all critical errors are correctable in TMAS)
    Caution flags include:
          missing Latitude/Longitude
          missing Year Established
          missing route number
          missing number of lanes for volume, classification or weight
          missing HPMS Sample, NHS or type of sensor
          (all caution errors are correctable in TMAS)
    Warning flags occur if:
          any two records that have all digits being exact duplicates will have one record removed
```

VOLUME DATA (TMG 3-CARD) - MONTHLY
```
    Duplicates within the batch
    Fatal errors occur if:
          no 3 in the 1st digit of the record
          record length less than 141 characters
          no station ID in the record (columns 6-11)
          no corresponding station in National Database
    Critical errors occur if:
          record includes 7 or more consecutive zero hours
          every DOW (day of week) not present for the given site/month/year
          record includes any zero hour volume with one or more boundary with over 50 vehicles
          24 hours of data not in a given record
          any hourly volume exceeds the max per hour per lane value
          directional splits check show unbalanced directional volumes greater than 10%
                variance from 50%
          Monthly Average Daily Traffic (MADT) from same month previous year not within 20%
          State marks data as restricted in column 141
    Warning flags occur if:
          any two records that have all digits being exact duplicates will have one record removed
```

CLASSIFICATION DATA (TMG C-CARD) - MONTHLY
```
    Duplicates within the batch
    Fatal error occurs if:
          no C in the 1st digit of the record
          record length less than number of characters based on station data field 15
          no station ID in the record (columns 4-9)
          no corresponding station in National Database
    Critical errors occur if:
          volume checks done on all classification data – see volume section above
          all classification data utilizes the station file algorithm for vehicle classification (23)
                and classification system for vehicle classification (24-25) for determining the
                length of the given record.
    Caution flags occur if:
          maximum percentage by classification by day check (done by direction)
          historical check for 6 weeks of prior approved data based on the same DOW for each class of
                vehicle by day
          any historical quality control check where insufficient historical data is available
    Warning flags
          any two records that have all digits being exact duplicates will have one record removed
```

WEIGHT DATA (TMG W-CARD) - MONTHLY
```
    Duplicates within the batch
    Fatal error occurs if:
```

```
        no W in the 1st digit of the record
        record length less than 39 characters
        no station ID in the record (columns 4-9)
        any record with more than 25 axles will not be kept in TMAS 2.0
Critical error occurs if:
        none
Caution flags
        total weight (25-28) not equal to the sum of all axle weights
        every axle weight not within acceptable range (1 kip to 50 kip)
        any inter-axle spacing not within acceptable range (1' to 50')
        sum of axle spacings by vehicle classification not within acceptable range
        number of axles by vehicle class exceeded
        historical check for 8 weeks of data using the steering axle weight average (SAWA) by
                day by lane check based on the same DOW for class 9 vehicles
        historical check for 8 weeks of data using the average tandem axle spacing (ATS) average by
                day by lane based on the same DOW for classes 8-13 vehicles
        any historical quality control check where insufficient historical data is available
Warning flags
        any record with between 13 and 25 will not be processed in TMAS 2.0 but will be placed in a
                special database.
        any two records that have all digits being exact duplicates will have one record removed
```

Appendix K.   LENGTH BASED CLASS MEMO

INFORMATION:

The HPMS calls for the annual reporting of various types of vehicle classification data. This reporting ranges from the percent of single-unit and combination trucks on HPMS sample sections to highway functional class level summary reporting of 13 vehicle classes. Because collecting such data on multi-lane, or high volume facilities is difficult, some States have proposed collecting vehicle classification data using a limited number of vehicle length categories. To date, we have not seen information that objectively compares the data collected through length based methods with that collected through the more traditional methods based on the 13 categories described in the Travel Data by Vehicle Type section of Chapter III of the HPMS field Manual. Without the review and approval of such information by my office, vehicle length based classification data are not to be reported to the HPMS.

The States proposing to report vehicle length based classification data to the HPMS must provide the following information.

- A description of the length categories to be used and how they relate to the 13 categories. For example, if four length categories are used, the description should explain how each of the 13 categories relates to a particular length category;

- A description of the method used to test how well each of the length categories captures the vehicles classes identified in point 1 and the results of those tests;

- If a State intends to disaggregate length based data into the 13 categories the imputation method must also be described; and

- Documentation on the situations in which length classification will be used. For example, a State might propose to such techniques only on high volume urban streets or a State may want to use length based classification for collecting information on percent trucks for reporting on HPMS sample sections, but will use other methods to report the Travel Data by Vehicle Type.

Appendix L. ADDITIONAL STATE TRAFFIC MONITORING PROGRAM EXAMPLES

L.1 ALASKA DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

The example below summarizes the ADOT&PF process for traffic data collection in the regions. This information is excerpted from the Traffic Data Systems Concept of Operations report for ADOT&PF (June, 2011).

The traffic data collection process is the responsibility of the regions, with the Headquarters Program Development Division being responsible for maintaining the database of the traffic data for analysis and reporting in the Highway Analysis System (HAS).

There are two types of volume counts that are taken in the regions: the continuous counts and the coverage counts. These are identified as "collect traffic data" in Figure L-1.

FIGURE L-1   ADOT&PF REGIONAL TRAFFIC DATA COLLECTION
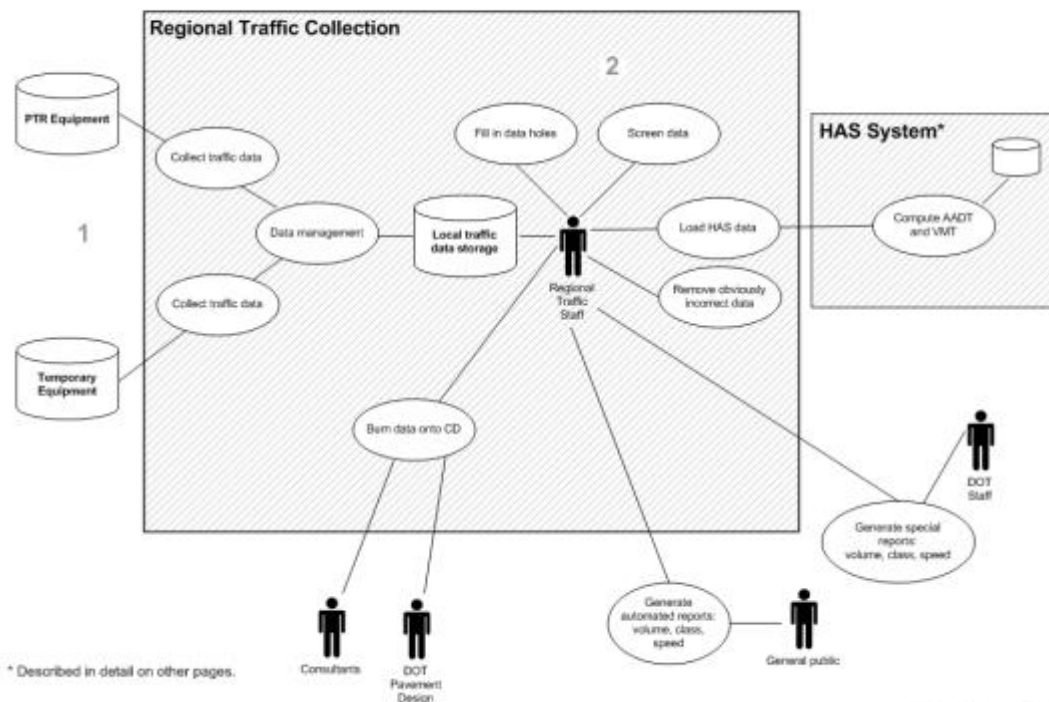
Source: Alaska Department of Transportation.

L.2 GEORGIA DEPARTMENT OF TRANSPORTATION (GDOT)

In 2006, the Georgia Department of Transportation (GDOT) conducted a Traffic Count Strategy Plan to maximize the value and return-on investment of scarce transportation revenues, and to ensure that customers' needs for traffic data were being met. The following elements were included:

- Existing Traffic Data Program Methodology and Business Processes:

- Overview of Existing Traffic Data Systems;

- Equipment Set Up and Maintenance;

- Quality Assurance;

- Description of Existing Georgia DOT Office of Transportation Data Reporting and Data Sharing Process;

- Description of Additional Programs; and

- Summary of Business Processes.

- Federal Literature Review:

  - Federal Requirements Related to Traffic Data Collection; and

  - Summary of Other Key Federal Literature Related to Traffic Data Collection.

- Select Summary of Processes Implemented in Other Departments of Transportation.

- Stakeholder Workshops and Interviews.

- Business Process Strategy.

- Federal Highway Administration (FHWA) Needs:

  - Traffic Monitoring Guide (*TMG*);

  - Highway Performance Monitoring System (HPMS) Field Manual; and

  - AASHTO's Guidelines for Traffic Data Programs.

- GDOT Business and Customer Needs:

  - Short-Term Actions for OTD;

  - Mid-Term Strategies; and

  - Long-Term Strategies.

- Traffic Program Issues:

  - Documentation;

  - Retrieval of Data/Reports;

  - System Design;

  - Specials Program Improvement; and

  - Balancing Resources.

- Recommendations:

  - Documentation;

  - Retrieval of Data/Reports;

  - System Design;

  - Specials Program Improvement; and

  - Balancing Resources.

- Strategy Plan.

This project enabled GDOT to move forward with the recommended improvements including procuring a traffic data software solution.

L.3 COLORADO DEPARTMENT OF TRANSPORTATION (CDOT)

The Colorado Department of Transportation (CDOT), Division of Transportation Development (DTD) and Traffic Analysis Unit (TAU), has been very proactive in improving the CDOT traffic data program. In 2008, CDOT embarked on a business planning process review project. Phase 1 of the Traffic Analysis Business Process and Integrated Software Recommendations project resulted in the development of a comprehensive set of business process diagrams and maps documenting the existing and recommended business process overview. The report included specific evaluations of the capability of their traffic software project to streamline and improve CDOT's collection and analysis processes. The recommended processes resulted in an estimated reduction of 318 different business processes. Recommendations of the Phase 1 report also included specific areas of improvement for CDOT associated with resources, processes, and tools. Phase 2 included follow-up on the recommendations from Phase 1; update of business process diagrams and creation of new process diagrams; improvement of the process of local traffic data sharing; development of a digital portal and requirements report; and recommendations for further enhancement of the CDOT traffic data program.

The following figure documents the high-level processes. There are numerous other detailed diagrams and process steps.

FIGURE L-2 **COLORADO DOT HIGH-LEVEL BUSINESS PROCESSES**
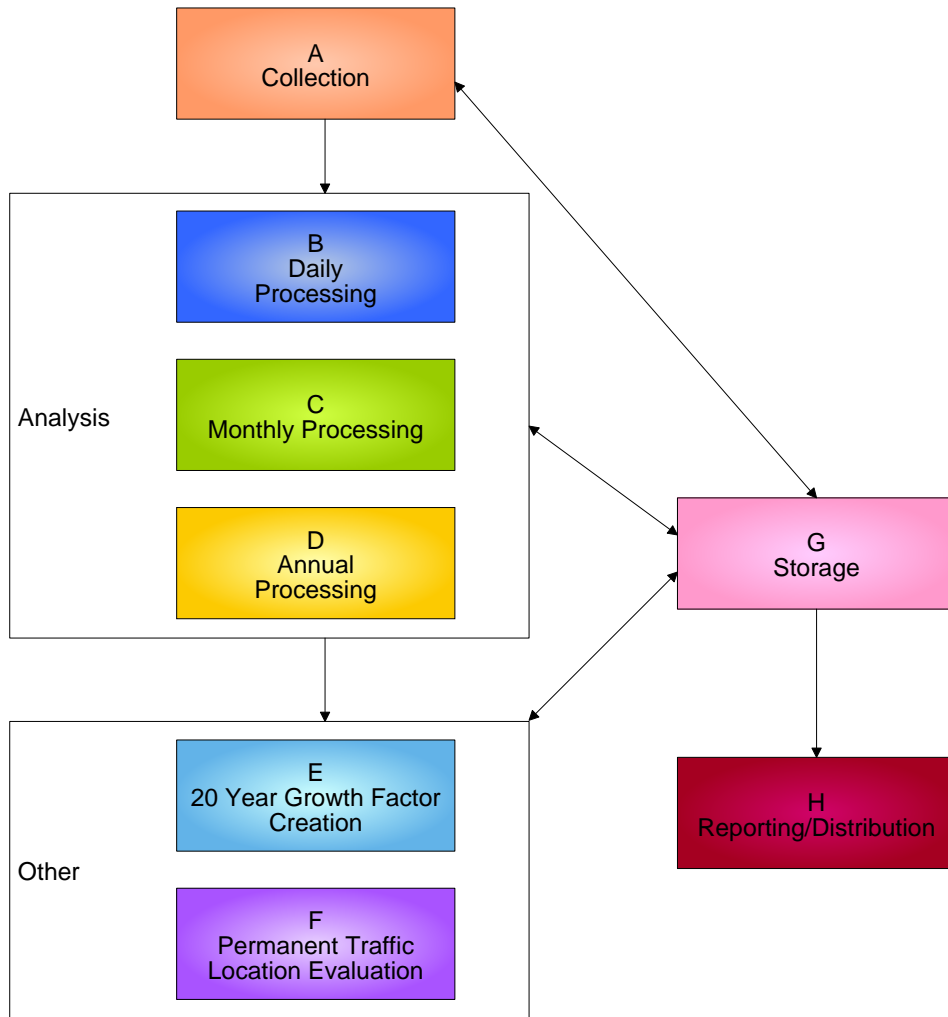
Source: Colorado Department of Transportation.

Appendix M. REFERENCES

AASHTO Guidelines for Traffic Data Programs. Washington: AASHTO. 2009.

AASHTO *Guide for Design of Pavement of Structures*.

American Society of Testing and Materials (ASTM). *Standards*. http://www.astm.org/index.shtml.

Assessing the Value of the ADOT&PF Data Programs White Paper, September 2009.

ASTM Loop Detector Handbook.

Butler, 1993.

Caltrans Standard Plan ES-5B. 2002.

Cherry Creek Trail 2010 Continuous Count Data, Colorado Department of Transportation.

Cochran, William G. 1977. *Sampling Techniques*, Third Edition. Wiley: New York.

Counting Motorcycles, AASHTO Standing Committee on Planning. February 2010.

CycleTracks for iPhone and Android. Accessed March 12, 2012. http://www.sfcta.org/cycletracks.

Federal Highway Administration HPMS Community of Practice website: http://knowledge.fhwa.dot.gov/cops/hcx.nsf/home?openform&Group=Highway%20Performance%20Monitoring%20System%20(HPMS).

Federal Highway Administration Travel Monitoring Community of Practice website. http://knowledge.fhwa.dot.gov/cops/hcx.nsf/home?openform&Group=Travel%20Monitoring.

Federal Highway Administration. 2006. *Traffic Detector Handbook*, Third Edition, Vol. 1, Chapter 1. FHWA-HRT-06-108. http://www.fhwa.dot.gov/publications/research/operations/ITS/06108.

FHWA-PL-97-018, *Field Test of Monitoring of Urban Vehicle Operations Using Non-Intrusive Technologies*, May 1997, by Minnesota DOT and SRF Consulting.

Georgia Department of Transportation Traffic Monitoring Program V2, 2012.

Greene-Roesel et al., 2008.

Grembek and Schneider, 2012.

Hallenbeck and Kim, 1993.

Hallenbeck and Weinblatt, *NCHRP Report 509, Equipment for Collecting Traffic Load Data*, Transportation Research Board, 2004.

Hallenbeck, et al., *Vehicle Volume Distributions by Classification*, 1997.

HPMS Field Manual. September, 2010. http://www.fhwa.dot.gov/policy/ohpi/hpms/fieldmanual.

https://www.dot.ny.gov/about-nysdot/history/past-present.

Hu, P., Wright, T., and Esteve, T., *Traffic Count Estimates for Short-Term Traffic Monitoring Sites: A Simulation Study*. Transportation Research Record, Number 1625, pp. 26 - 34. National Research Council, Washington, D.C., 1998.

J. Bunker, City of Boulder.

J. F. Rheault, Eco-Counter.

Kotzenmacher, Minge, and Hao, *Evaluation of Portable Non-Intrusive Traffic Detection System*, Minnesota Department of Transportation, MN-RC-2205-37, September 2005.

Lindsey, G., Chen, J., Hankey, S., and Wang, X. 2012. *Adjustment Factors for Estimating Miles Traveled by Non-motorized Traffic*. Unpublished manuscript prepared for submission to the Transportation Research Board 2013 Annual Meeting. Humphrey School of Public Affairs, University of Minneapolis, MN.

Long Term Pavement Performance Program. http://www.fhwa.dot.gov/pavement/ltpp/.

LTPP Customer Support Service Center at ltppinfo@dot.gov.

Malinovskiy, Y., Zheng, J., and Wang, Y.,. *Model-Free Video Detection and Tracking of Pedestrians and Bicyclists*. Computer-Aided Civil and Infrastructure Engineering, Volume 24, 2009.

Marin County NTPP Specifications Sheet, 2009.

MEPDG Traffic Loading Defaults Derived from LTPP Pooled Fund Study, 2012.

National Bicycle and Pedestrian Documentation Project: Instructions. Accessed March 22, 2012. http://bikepeddocumentation.org/downloads/.

National Bike and Pedestrian Documentation Project. http://bikepeddocumentation.org/.

National Condition and Performance Report.

NCHRP Project 1-37A, *Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures: Phase II*.

NCHRP Project 1-37A, *Mechanistic-Empirical Pavement Design Guide*.

Official FHWA Office of Highway Policy Information, Highway Performance Monitoring System website: http://www.fhwa.dot.gov/policyinformation/hpms/faqs.cfm.

Oregon DOT, www.oregon.gov/ODOT/MCT/docs/weight_limits.pdf.

Request access to Travel Monitoring Analysis System (TMAS). http://www.fhwa.dot.gov/field.html#fieldsites.

State practices to report local travel, http://www.fhwa.dot.gov/ohim/statepractices.cfm.

Target Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies. NCHRP Report 666.

Target Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies, Volume II. NCHRP Report 666.

Thomas O. Schinkel, *Mid-Atlantic Successes and Challenges* presented at NATMEC, August 2008.

Travel Volume Trends (TVT) Report. http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm

Turner, et al., 2007.

Vehicle Detector Clearinghouse. http://www.nmsu.edu/~traffic/ (site contains outdated materials).

Vehicle Travel Information System (VTRIS). https://fhwaapps.fhwa.dot.gov/VTRIS/default.aspx.

Vehicle Volume Distributions by Classification, Hallenbeck, Rice, Cornell-Martinez, and Smith, June, 1997 for the Long Term Pavement Performance Project. FHWA-PL-97-025

Welcome to CycleTracks Austin. Accessed March 12, 2012. http://cycletracksaustin.com/.

Wright, et al., *Traffic Count Estimates for Short-Term Traffic Monitoring Sites: A Simulation Study*.

Wright, T., Hu, P., Young, J., and Lu, A., *Variability in Traffic Monitoring Data, Final Summary Report*, Oak Ridge National Laboratory, U.S. Department of Energy, August 1997.

Wyman, John, Gary Braley Gary, and Robert Stevens, *Field Evaluation of FHWA Vehicle Classification*

Categories, Maine Department of Transportation, Final Report for contract DTFH-71-80-54-ME-03 for the U.S. Department of Transportation, Federal Highway Administration, Office of Planning, January 1985.

Appendix N. INDEX