Federal Highway Administration Traffic Monitoring Guide

Traffic Monitoring Guide

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Version 1.2 – April 2026, Revised Formats

Update

U.S. Department of Transportation
Federal Highway Administration

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Acronyms

Acronym	Definition
3S2	3-axle tractor with a 2-axle semi-trailer
AADT	Annual Average Daily Traffic
AADBT	Annual Average Daily Bicycle Traffic
AADNT	Annual Average Daily Nonmotorized Traffic
AADPT	Annual Average Daily Pedestrian 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	Automated Vehicle Classifier
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

Acronyms

ESAL	Equivalent Single Axle Loading
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
GIS	Geographic Information System
GPS	Global Positioning System
GVW	Gross Vehicle Weight
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)
MAWKDT	Monthly Average Weekday Daily Traffic
MAWKDTT	Monthly Average Weekday Daily Truck Traffic
MAWKNDT	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

TRAFFIC MONITORING GUIDE 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 about the policies, standards, procedures, reporting, and equipment utilized in a traffic monitoring program. The *TMG* presents recommendations that help improve and advance current programs with a view toward the future of traffic monitoring and with consideration for transportation regulations resulting from the Fixing America's Surface Transportation (FAST) Act and its predecessors.

The needs for traffic monitoring data at both the Federal, State, and local levels require that agencies have a well-designed traffic monitoring program. Traffic data are needed to assess current and past system performance and to predict future performance. Improved traffic data, including data on ramps, are needed for reporting in the Highway Performance Monitoring System (HPMS), and there are now opportunities to use traffic data acquired from Intelligent Transportation Systems (ITS) to support coordination of planning and operations functions at the various agency levels.

Continued improvements in traffic data collection technology have allowed States to improve their data collection processes and to streamline quality assurance and quality control (QA/QC) procedures. New technology also enables States to collect data on micromobility traffic, including bicycle and pedestrian traffic. The use of micromobility traffic data supports analyses regarding the impacts to the transportation network (on volumes and safety) resulting from the use of bicycles and other micromobility devices as alternative travel methods. The new technologies and procedures for traffic monitoring presented in the *TMG* are supplemented with practical examples from State experiences to improve traffic monitoring programs.

The *TMG* is written to assist both experienced traffic data collection personnel and those who are less experienced or new to traffic data collection. Reference material that will benefit traffic data collection programs is found in the Appendices.

This edition of the *TMG* also includes data formats for reporting traffic data, including the Individual Vehicle Record (IVR) format for reporting volume, vehicle speed, vehicle classification, and vehicle weight data. Data formats are also provided for reporting micromobility data for those agencies 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. This approach has resulted in a practical guidance document that FHWA anticipates will be helpful 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 encompasses volume, classification, speed, and weight data. Traffic monitoring data from the States continues to be required to meet the reporting requirements of the Federal Highway Administration (FHWA) under 23 CFR 420.105(b), which requires States to provide data that support FHWA's reporting responsibilities to Congress and to the public. Traffic data reported under this Federal regulation are submitted as part of the annual HPMS report from each State.

ES.3 USERS

Traffic datasets are typically used to support highway agency activities that include planning, 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 organizational constraints. These differences cause agencies to select different equipment for data collection, use different data collection plans, and emphasize different data reporting outputs. The *TMG* provides support to highway agencies in regard to successful approaches for data collection, analysis, and reporting based on noteworthy practice examples. These noteworthy practice examples are highlighted in the appendices.

ES.4 MANUAL ORGANIZATION

The *TMG* begins with an overview of traffic monitoring programs (Chapter 1). The *TMG* also covers vehicle detection theory and provides an overview of different traffic monitoring technologies (Chapter 2) and provides comprehensive guidance on the methodologies used for motorized and micromobility traffic monitoring practices (Chapter 3). Defined record formats used for submitting traffic data for both motorized and micromobility data, along with a table explaining the deadlines for submitting traffic data to the FHWA Office of Highway Policy Information, can be found in Chapter 4. Federal data reporting requirements and the importance of HPMS reporting requirements for traffic data are explained in Chapter 5. The final chapter (Chapter 6) contains new information on acquiring third-party traffic data, new technology, and data analysis (3rd Party Data Sources).

A glossary of terms, list of acronyms, and Appendices are included. The Appendices provide establishing data QA/QC criteria, setting up and calibrating data collection equipment, guidance on the use of traffic data for pavement design purposes, guidance on length-based classification, and traffic data quality control (QC) checks performed by the Travel Monitoring Analysis System (TMAS) software. The *TMG* also includes References.

There are several new sections within the 2022 TMG edition. These new sections with major changes are highlighted below and include:

- Expansion of non-motorized traffic monitoring to include all micromobility devices (Ch. 1 and 2)
- Consolidation and update of traffic monitoring technologies (Ch. 2)
- Similarities between motorized vehicle and micromobility data collection and processing (Ch. 3)
- Significantly revised data formats for FHWA submissions (Ch. 4)
- New emphasis on 3rd party roles in traffic programs (Ch. 6)

The 2022 *TMG* has been organized into six different chapters including the following:

- Chapter 1 Traffic Monitoring Theory, Technology and Concepts
- Chapter 2 Traffic Data Collection and Technology
- Chapter 3 Traffic Monitoring Methodology
- Chapter 4 Traffic Monitoring Formats
- Chapter 5 Federal Data Reporting Requirements and Tools: TMAS, HPMS
- Chapter 6 Third Party Traffic Data

Appendices in the *TMG* provide additional guidance to the user. The appendices are introduced briefly in section ES.5.

ES.5 SUPPORTING INFORMATION – APPENDICES OVERVIEW

- Appendix A – Vehicle Types (This appendix contains descriptions of 13 FHWA vehicle classes.)
- Appendix B – TMAS Quality Control Checks (This appendix provides quality checks for micromobility, volume, speed, class, weight, and IVR.)
- Appendix C – Compendium of Data Quality Control Criteria (This appendix contains compilation of data quality control (QC) criteria and QC checks used by Vermont and New York DOTs.)
- Appendix D – Equipment Calibration (This appendix contains compilation of successful traffic monitoring equipment calibration used by different highway agencies.)
- Appendix E – NCDOT Clustering Method for MEPDG Equipment Calibration (This appendix contains results of the research study that applied the clustering methodology to develop Traffic Data Inputs for Mechanistic-Empirical Pavement Design Guide (MEPDG).)
- Appendix F – Traffic Data for Pavement Design (This appendix describes the procedures for computing traffic inputs for traditional (AASHTO 93) and new MEPDG methods.)
- Appendix G – Length-Based Class Memo (This appendix describes the requirements for reporting of length-based vehicle classification data to the HPMS.)
- Appendix H – Bicycle and Pedestrian Site Selection Process/Publication - Florida Department of Transportation (FDOT's) Nonmotorized Site Selection Methodology (This appendix includes excerpts from the FDOT's 2018 Statewide Non-Motorized Traffic Monitoring Program Recommendations Report.)
- Appendix I – Motorcycle Data Collection Methods (This appendix provides detailed guidance for motorcycle data collection prepared by Montana DOT.)

- Appendix J – Traffic Pattern Examples (This appendix provides examples of temporal traffic patterns for motorized and micromobility travel including hourly, day of week, and monthly patterns for different road facility types.)
- Appendix K – Typical Interchange AADT Estimation (This appendix provides equations and computational examples to obtain AADT from limited mainline counts for the most common interchange and ramp configurations.)
- Appendix L – AASHTO AADT Calculation (This appendix provides equations to obtain AADTs using the AASHTO method.)
- Appendix M – Double Threshold WIM Array (This appendix provides the FHWA-preferred WIM array to use.)

Chapter 1. TRAFFIC MONITORING PROGRAM INTRODUCTION

1.1 INTRODUCTION

Traffic monitoring is performed to collect data that characterize the use and performance of a roadway, trail, or path traveled by motorized vehicles, micro powered devices such as electrical bicycles, and nonmotorized devices such as bicycles and pedestrians. This chapter addresses the high-level design of a traffic monitoring program and provides guidance on how data planning is used to support the program design and development at State highway agencies and Metropolitan Planning Organizations (MPOs). It explains the importance of having such a program from three perspectives: statewide, regional/sub-area, and roadway facility/corridor-specific traffic monitoring.

This chapter is organized into the following four sections:

1.2 Traffic Monitoring Program Purpose (WHY)

1.3 Traffic Data Types Introduction (WHAT)

1.4 Traffic Data Program Users (WHO)

1.5 Traffic Data Program Design Consideration (HOW)

The *TMG* has existed since before the passage of Intermodal Surface Transportation Efficiency Act (ISTEA). It has provided guidance to traffic monitoring programs across the Nation. The primary audience for this guide is State highway agencies, MPOs, and other professionals who are interested in traffic monitoring activities, equipment, and data. The *TMG* is updated on a routine basis to reflect legislation and regulation changes, technology development, and new program and initiative needs.

Traffic data monitoring programs can include both motorized and nonmotorized. Agencies may have two separate data collection programs, such as one for motorized and one for micromobility (that encompasses pedestrian traffic) travel monitoring. Differences between these programs are described below. Both programs are typically organized by continuous and short-term counting programs. Within the monitoring programs, there are two primary data collection sub-programs that include a volume and classification data collection program. In addition, motorized traffic monitoring programs also include a weight data collection program.

Motorized and Micromobility Program Differentiators

One of the key differences in the state of practice between motorized and micromobility traffic monitoring is the scale of data collection. Most micromobility 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 micromobility 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 micromobility 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. In addition, pedestrian and non-motorized vehicles are not permitted to use/operate on limited access facilities such as interstate highways. 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 is that technologies for counting micromobility traffic for pedestrians, hover boards, e-bikes, bicyclists, etc. are not always scheduled to collect data for the same period such as 24 hours, 48 hours, or 2 weeks of consecutively collected (15 minute or hourly) data.

Finally, a fourth key difference is that technologies for counting micromobility traffic are still evolving, and error rates associated with different technologies are not well known. All methods for counting both motorized and micromobility 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.

1.1.1 Legal Background

The Intermodal Surface Transportation Efficiency Act (ISTEA) put forth the need to establish a systematic statewide Traffic Monitoring System (TMS) and directed FHWA to promulgate regulations for State highway agencies to establish a functional TMS where traffic data items such as volume, classification, and weight data can be collected, processed, and reported.

Subsequently, both the Transportation Equity Act for the 21st Century (TEA-21) and the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) contained Federal funding for the State TMS. When SAFETEA-LU expired in July 2012, there was a substantial number of traffic monitoring stations established by State highway agencies, which is evidenced by both the quality and quantity of data submitted to the FHWA through both the Highway Performance Monitoring System (HPMS) and the Traffic Monitoring Analysis System (TMAS).

When Moving Ahead for Progress in the 21st Century Act (MAP-21) replaced SAFETEA-LU in 2012, the Federal requirement that each State should have an operational traffic monitoring system to be in place was deemed met.

Since that time, the mission of TMS has expanded under the authority of both MAP-21 and the Fixing America's Surface Transportation (FAST) Act to include for performance management, safety, and many other Federal-aid highway programs as detailed in the Federal statutes listed below.

Current Legal Authority and Responsibility

23 U.S.C. 134: Metropolitan Planning Organizations (MPOs), in cooperation with states and transit operators, develop long-range, performance-driven transportation plans and Transportation Improvement Programs (TIPs).

23 U.S.C. 135: Statewide Transportation Improvement Program (STIP) To support performance-based planning and the development of long-range statewide transportation plans, States must collect and analyze data to establish performance targets and track progress toward national goals such as safety, infrastructure condition, and system reliability.

23 U.S.C. 150: National Goals and Performance Management Measures (prescribes the legal requirements of systematic traffic monitoring data)

23 U.S.C. 503: Research and Technology Development and Deployment (mandates the FHWA to conduct the biennial Condition & Performance (C&P) Report to Congress and the need for State-supplied traffic data).

23 CFR 420.105(b): State DOTs are required to provide comprehensive transportation data to the FHWA to facilitate legislative reporting, system performance evaluation, federal funding analysis, and the accurate calculation of state funding apportionments.

23 CFR part 450: Planning Assistance and Standards (specifies the legal requirement to rely on data obtained from the traffic monitoring system)

23 CFR part 490: National Performance Management Measures (prescribes more specific legal requirements of systematic traffic monitoring data)

- Subpart B: Measures for Highway Safety
- Subpart E: Measures to Assess Performance of the NHS
- Subpart F: Measures to Assess Freight Movement on the Interstate
- Subpart G: Measures to Assess CMAQ Program Traffic Congestion

Additional Authority for Air Quality Non-Attainment Areas

40 CFR part 93, subpart A Transportation Conformity Requirements (defines traffic data dimensions)

40 CFR part 93, subpart A General Conformity Requirements (defines traffic data dimensions)

1.1.2 *TMG* ORGANIZATION

The chapters and appendices in the *TMG* include the following:

Chapter 1 – Traffic Monitoring Program Introduction: Federal Authority, Data Users and Data Sources, Business Planning and Design – This chapter provides a *TMG* introduction with an overview of the guide's organization and an overview of traffic monitoring program, including: traffic monitoring program purpose, traffic data customers and common traffic data requirements, and an introduction of essential elements of traffic monitoring program.

Chapter 2 – Traffic Data Collection Technology and Equipment - This chapter provides an overview of different vehicle detection technologies to collect motorized and micromobility traffic data. It also contains practical guidance on selecting traffic monitoring location, sensor layout, and equipment installation and calibration.

Chapter 3 – Methodologies for Traffic Data Collection and Processing - This chapter describes methodologies for collecting traffic data from moving vehicles and pedestrians, including guidance for continuous and short-term data collection plans. It provides guidance on how to collect traffic data to support various FHWA, State, and local-level programs. This chapter addresses limitations related to traffic monitoring program design, duration of data collection, and natural traffic variations and their potential effect on computed traffic data statistics. This chapter also contains methodology and practical examples of parameter computations based on collected traffic data.

This comprehensive chapter also provides guidance on the following:

- Methods used to determine the number of data collection sites.
- How to develop factor groups and assign sites to the group.
- How to derive Daily, Monthly, Weekly and Annual Average Daily Traffic estimates.
- Methodologies and steps to establish Continuous Count and Short-Term Count programs to collect volume, speed, vehicle classification, and weight data.
- How to estimate motorcycle Vehicle Miles Traveled (VMT).

This chapter provides guidance and examples on coordinating activities for transportation management and operations functions within State DOTs, including the following:

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

Chapter 4 – Traffic Monitoring Data Formats - This chapter describes data and file formats for traffic data collection to satisfy FHWA traffic data reporting requirements. This chapter also defines the data record formats and data submittal frequency for reporting volume, speed, vehicle classification, and weight data for motorized vehicles and also describes the data formats for reporting Micromobility data. It describes Individual Vehicle Record (IVR) formats, as an alternative method for submitting traffic data to FHWA. The traffic data formats described in this chapter are an addition to the traffic data submitted annually to FHWA as part of the HPMS submittal.

Chapter 5 – This chapter describes HPMS requirements for traffic data reporting. The traffic data items reported in HPMS are identified, and the use of these data is also explained in this chapter. This chapter also provides detailed information about the FHWA TMAS software submittal system, including a discussion about why TMAS is important and how data partners (State DOTs, MPOs, Counties, Cities, etc.) provide data to meet the Federal data needs. Traffic data represent a significant portion (25%) of the HPMS data reported to FHWA annually. Many of these datasets are provided from a state's traffic monitoring program.

Chapter 6 – This chapter provides an overview of innovative ways of collecting traffic data using emerging new technologies from connected and autonomous vehicles and from the Internet-of-Things (IoT) environment, including discussion about acquiring third-party traffic data.

There are a few differences between the 2016 *TMG* and the 2022 *TMG*. First, information has been combined and condensed to reduce the total number of chapters from 7 to 6. Second, the 2022 *TMG* now provides the new term, micromobility. The term micromobility is an all-inclusive updated and modern definition of a nonmotorized program and incorporates pedestrians, human-powered bicycles scooters, hoverboards, e-bikes, and other micro-powered traffic. Chapter 3 provides a separate subsection dedicated to the micromobility program methods for traffic data collection and processing. Third, pipe-delimited file formats are now an acceptable way to submit data (see Chapter 4). Additionally, a new informational Chapter 6 has been added providing information on how to acquire and work with third-party traffic and traffic monitoring data, and data analysis.

1.2 TRAFFIC MONITORING PROGRAM PURPOSE

Traffic data provide the foundation for transportation decision making including both program and project development. For example, Congress relies on historical, current, and projected traffic data when developing various surface transportation statutes, regulations, and funding authorizations. Other Federal programs established by surface transportation legislation such as the Highway Safety Improvement Program, the National Highway Performance Program, the National Highway Freight Program, the Congestion Mitigation and Air Quality Program, and others rely on traffic data for their implementation. Each of these programs demand accountability and transparency and traffic data that meets or exceeds known quality thresholds and fulfills such demands.

On statewide and regional scales where State highway agencies and MPOs are primarily responsible, key traffic data elements such as volume, class, and weight data provide critical pieces of needed information. The ability to understand the future needs of the transportation system is quantified with traffic data during the planning process and is critical to developing transportation planning products such as the Transportation Improvement Program (TIP) and Statewide Transportation Improvement Program (STIP).

Transportation air quality conformity determination relies on quality traffic data, as do other environmental impact evaluations such as highway noise analysis.

For capacity improvement projects, traffic data offer the ultimate justification for a project’s scope and design concept. Traffic data also offer information and data for safety projects. Traffic data enable safety trend analysis and the development of specific mitigation strategies and are used in post-crash analyses.

The importance of traffic data to road and bridge design, construction, operations, and maintenance processes are obvious, as a significant percentage of all public roadways are under repair, maintenance, and upgraded at any given time throughout the year. Traffic data help make all work zones and maintenance activities less impactful and safer for the traveling public. And, traffic data enable reliable decisions in granting access points and median openings to both businesses and citizens, ensuring an efficient highway system.

Traffic data are among the most critical data and information pieces in the transportation decision-making process. The traffic monitoring program is to ensure that the collection and processing of needed traffic data is efficient, effective, and consistent.

1.3 TRAFFIC DATA TYPES INTRODUCTION

There are several data program types that can be organized into sub-programs within a traffic monitoring program. These include volume, classification, weight, travel time (speed), and origin-destination data programs.

The different traffic monitoring data types are designed to meet specific program needs. While volume data provide an aggregate sense of demand, vehicle classification data offer insight on how different vehicle types contribute to the overall demand as well as to congestion, safety, air quality, and so on. Weight data provide necessary information for pavement and bridge design and maintenance decisions and are also used in various safety and security programs. Travel time and travel speed data offer information for travel reliability, enabling better trip planning and performance management. Origin-Destination data provide needed information on demand analysis and corridor usage, through traffic and cost allocation analysis.

There are two basic programs to obtain volume, class, weight, and speed data: a continuous count data program and short-term data program.

The following sections contain more detailed descriptions of each traffic data type and traffic data collection subprograms.

1.3.1 Volume Data

Volume data refers to the total number of vehicles or micromobility passing through a point on a roadway, bikeway, or walkway in a predefined time interval.

All highway agencies should have access to data collected from continuous counters. Agencies should work with each other to ensure that enough data are collected and shared to allow calculation of accurate adjustment factors needed to convert short-term traffic counts into estimates of annual average daily traffic (AADT). Chapter 3 provides 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 allow an agency to understand temporal (time-of-day (TOD), day of week (DOW), month-of-year (MOY) and multi-year – year-to-year (YtY)) changes in traffic volume, speed, class, and weight. This analysis provides the mechanism needed to convert short-term counts into accurate annualized estimates. Adjustments to short-term count data are also required to remove the temporal bias for an annualized purpose such as AADT, Single Unit Truck (SU) AADT, and Combination Unit (CU) Truck AADT.

1.3.2 Speed Data Collection

Speed data represent a vehicle traversing through a segment of roadway. When the length of the roadway segment is sufficiently short, the speed is also called a spot speed. Regardless of the segment length, speed data are assumed to be "space mean speed," meaning speed is equal to segment length divided by the time a vehicle takes to traverse through the segment.

1.3.3 Vehicle Classification Data

Vehicle classification data refers to the counts of vehicles by specific vehicle type. The standard vehicle classification categories are the 13-vehicle types adopted by the FHWA and are used for geometric design, pavement and bridge design, safety analysis, performance measurement, and environmental impact analysis and other programs. Vehicle classification data have the same unit as volume data (i.e., the number of vehicles passing through a point or short roadway segment in a predefined time period). Some States also collect length-based classification data. Chapter 3 provides details on the 13-vehicle types.

1.3.4 Weight Data

Weight data refers to vehicle wheel path (if collected by wheel path), axle and gross vehicle weight. The collection of vehicle weight data is typically only applicable to trucks and not the light-duty passenger vehicles (classes 1-3). The rationale for this is that both the axle weight and gross vehicle weight of regular passenger vehicles have virtually no design impact on a roadway's pavement or the loading of a bridge. For the purposes of traffic monitoring, weight data are typically collected by the Weigh-In-Motion (WIM) systems installed in a roadway.

1.3.5 Travel Time

Travel time characterizes the time it takes for a vehicle to travel from point A to point B along a roadway. While stationary sensors, such as those used in both the continuous count program and the short-term count program, can measure travel time, their applicability is limited due to coverage limits. Current probe-based devices located inside moving vehicles enable travel time collection for many highway segments in the system without the need to install any specialized hardware by a highway agency.

Vehicle Occupancy

Vehicle Occupancy refers to the number of persons inside a vehicle. Traditionally, vehicle occupancy data are collected through roadside observations, personal or household surveys. While these traditional methods work well, they are costly. More recently, roadside cameras are being used to collect such information. Also, advanced statistical methods have proven that vehicle occupancy data can be derived from crash records supplemented by other data sources.

Lane Occupancy Data

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.

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 lane occupancy.

Roadway Occupancy is well defined in the *FHWA Traffic Data Pocket Guide* (FWHA 2018) under the traffic data computation method section.

Headway and Gap Data

Headway is the time between the front of one vehicle and the front of the next vehicle, and gap is the distance between the back bumper of one vehicle and the start of the next vehicle. 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 several 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.

1.3.6 Origin and Destination

Origin and destination (OD) data refers to location data related to where a vehicle enters a road and where it exits a road. For example, a truck entered Interstate 95 at Exit # 23 and got off the interstate at Exit # 127. Exit #23 and Exit #127 are the origin and destinations. Historically, OD data are most likely obtained from surveys. Probe-based technologies have made OD data collection easier and less labor intensive. Also, new research associated with existing loop detector technology led to inductive loop signature capability for vehicle re-identification and can make OD data collection a regular component of traffic monitoring.

1.4 TRAFFIC DATA PROGRAM USERS

1.4.1 Federal Data Submittal Needs

State highway agencies are requested to submit motorized traffic monitoring program data, including volume, speed, class, and weight data from their continuous counting stations monthly to the FHWA TMAS [OMB CONTROL NUMBER: 2125-0587]. In addition, traffic volumes for all roadways are required to be submitted annually to the FHWA through the HPMS reporting process [OMB CONTROL NUMBER: 2125-0028].

1.4.1.1 Introduction of HPMS Traffic and Travel Data Elements

HPMS reporting requires State highway agencies to provide traffic and travel data elements by individual predefined HPMS segments once a year. The following elements are a sample of traffic and travel data and derived statistical parameters included in the HPMS submission:

- AADT
- D factor (directional distribution for the design hour)
- K factor (design hour)
- AADTT (Annual Average Daily Truck Traffic)
- Future AADT (20- or 25-year future AADT)
- % Peak SU and % Peak CU (number of SU or CU vehicles in the peak hour divided by AADT)
- SU and CU AADT (Single Unit and Combination Unit Annual Average Daily Traffic)

Refer to Chapter 5 for a more detailed discussion of traffic data contained in HPMS.

1.4.1.2 Introduction to the Traffic Monitoring and Analysis System

State agency traffic data programs are required to submit traffic data monthly. To facilitate this requirement, FHWA provides access to the TMAS. This software supports traffic data uploads to the FHWA National Traffic Database. For a complete list of all TMAS quality control methods, contact FHWA. The system also provides data download, quality control/quality checking, and reporting features. TMAS continues to evolve and now contains micromobility traffic monitoring data.

Refer to Chapter 5 for a more detailed discussion of TMAS.

1.4.2 Traffic Data Needs

The benefits that accrue from having comprehensive and high-quality traffic data should be balanced against the costs necessary to implement and sustain an effective and efficient traffic monitoring program.

Therefore, in planning and designing a traffic and travel monitoring program, it is critical to consider your customer user needs and the benefits that result from the timely delivery of quality traffic data for decision support.

Users of traffic data, including micromobility data, generally fall into the following categories:

- Federal and FHWA – Uses traffic data to support national transportation policy development and in preparing national reports such as traffic volume trends or HPMS programs discussed in Chapter 5 and the periodic *Status of the Nation's Highways. Bridges and Transit: National Conditions & Performance Reports to Congress*. Traffic data reported to FHWA are also used to apportion funding to States from the U.S. Highway Trust Fund.
- State DOT operating units – Use traffic data in support of DOT functions such as planning, operations, safety, bridges, design, construction, maintenance, environmental, enforcement, air quality, freight offices, and other programs.
- Other Agencies – cities, towns, counties, tribal lands, and MPOs – Use traffic data to support internal needs.
- Public – Including ad hoc public requests, academic researchers, private sector organizations such as insurance companies, special interest groups, etc.

1.4.3 Data Usage Summary

Traffic data usage continues to expand and grow in terms of the types and numbers of users. Table 1-1 illustrates the range of uses for the most common types of traffic and travel data, including traffic counts, vehicle classification, vehicle weights, and vehicle speed.

Table 1-1. Examples of Highway Traffic and Travel Data Uses

Highway Activity	Traffic Volume	Vehicle Classification	Vehicle Weight	Vehicle Speed
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	Changing weight limits on highways	Speed limits

Highway Activity	Traffic Volume	Vehicle Classification	Vehicle Weight	Vehicle Speed
Maintenance	Selecting the timing of maintenance by lane volume for lane closure policies Prioritizing activities Determine bridge responsibility (State vs. local) Determine highway striping responsibility (State vs. local)	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 Assignment/change of Federal Functional Classification Prioritizing projects	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	Annual Average daily traffic Vehicle Miles Traveled	Travel by vehicle type	Average weight by vehicle class	85th percentile
Private Sector	Location of service areas Development planning Business loans	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	N/A

1.5 PROGRAM DESIGN CONSIDERATIONS

Statewide traffic monitoring programs are designed to collect four types of data: volume, speed, classification, and weight. The information obtained from statewide traffic monitoring programs is also the primary information resource for almost all general queries about road use in the State. These data provide a critical framework for effective decision making.

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 and between States. Requests for statewide data can range from how vehicle miles of travel are changing to computing carbon emissions to whether specific roads carry enough volume to warrant new construction activity. A comprehensive statewide counting program allows an agency to confidently and effectively answer a wide range of key policy and business questions. 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. Highway 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.

While several traffic volume statistics are used in traffic analyses, primary interest for the design of statewide traffic monitoring programs are 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.

1.5.1 Statewide Traffic Monitoring Program Types (Regional, Roadway, Project Specific) Overview

1.5.1.1 Regional and Sub-Area Traffic monitoring Design

A traffic monitoring program can be implemented at regional or sub-area levels to address additional information needs 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 such as traffic movements that cross jurisdictional borders (e.g., they may provide data that are used to allocate State resources between jurisdictions within the region). Regional traffic monitoring data such as congestion and travel time reliability are used to answer key scoping questions for upcoming regional projects.

Similarly, detailed regional traffic counts can be vital to maintaining or improving the economic vitality of communities that depend on recreational movements. Data collection in geographic areas with recreational traffic movements may use different methods or times that would otherwise be collected for general State traffic monitoring purposes.

1.5.1.2 Roadway Facility Specific Traffic Monitoring Design

Facility-specific monitoring plans are the most detailed level 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, turning movements, lane distribution factors and vehicle weight by class or by axle.

Facility-specific traffic monitoring programs are designed to provide the site-specific traffic statistics needed for roadway project development and planning studies. Special counts are added to the overall traffic count database throughout the calendar year to capture special traffic data as needed. 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.

1.5.2 Components of a Traffic Data Program

The *TMG* is designed to provide guidance to States, MPOs, and local agencies in establishing and maintaining a traffic monitoring program. Other sources of information include the *AASHTO Guidelines for Traffic Programs (*AASHTO 2009*), the WIM Pocket Guide (*FHWA 2018*)*, *ASTM* and both the *FHWA Traffic Detector Handbook (*FHWA 2006*) and HPMS Field Manual (*FHWA 2016*)*. HPMS Field manual is incorporated by reference into 23 CFR part 490 by 23 CFR 490.111(b)(1).

The following sections describe the purpose and framework for establishing a traffic monitoring program. These programs are designed to collect traffic data within a defined geographic area for a State, region, or at the roadway-specific level. The types of data collected primarily consist of volume, speed, classification, and weight data for motor vehicles. Many traffic programs are adding micromobility counting to their existing motorized count programs.

Figure 1-1 shows the recommended framework for a traffic monitoring program that consists of two basic components:

- Continuous count program
- Short-term count program, including periodic coverage counts and special needs counts

CONTINUOUS COUNT PROGRAM – A continuous count program refers to the processes and procedures used to collect traffic data from permanently installed counters operating on a continuous basis throughout the entire 24 hours in a day, year-round. Data from the continuous program provide temporal information such as patterns of time of day, day of week, week of month, and month of year. A continuous count program helps to understand temporal time-of-day (TOD), day-of-week (DOW), and month-of-year (MOY) changes in traffic volume.

SHORT-TERM COUNT PROGRAM – The short-term count program refers to the processes and procedures to collect traffic data from installed sensors for a continuous period of less than one-year. The duration of the short-term counts can be as short as 24 hours or, more preferably, a week or longer period. The short-term count program is also referred to as the "coverage count program or portable counts program."

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

Continuous count stations (CCSs) form the basis for the overall traffic monitoring program. 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. In some States, this is referred to as the permanent count program. In the *TMG*, this program is referred to as the continuous count program.

Continuous count programs have many objectives that can vary from State to State. For example, continuous count station data can be used to

- develop adjustment factors.
- track traffic volume trends on important roadway segments.
- 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 determined by these objectives. As a result, it is of the utmost importance 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.

Continuous Vehicle Classification Data Program

The continuous vehicle classification (CVC) data collection program is related to, but distinct from and often is a subset to, the traditional Continuous Count Program.

> FHWA supports highway agencies programs that are designed to collect classification data (which also supply total volume information) in place of simple volume counts whenever possible.

Traditional Continuous Count Programs require motorcycle factoring, transit vehicles, and other types of traffic volume data. Class factoring traffic data programs should include a minimum of the 6 vehicle types in the HPMS Vehicle Summary table.

1.5.2.2 Short-Term Count Program (Volume, Speed, Classification, and Weight)

Transportation agencies perform short-term counts for a variety of purposes including meeting Federal reporting needs such as HPMS, supplying information for individual projects (pavement design, planning studies, etc.), and providing broad knowledge of roadway use. Portable short-term counts also ensure geographic diversity and coverage. When properly designed and executed, the short-term counting program allows network-wide traffic data coverage at a low cost. The short-term 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; providing city/county/MPO and public customers axle correction factors (ACF) and other factors; and establishing a data governance committee that crosses agency jurisdictions including national, State, county, city, and MPO boundaries.

Short-Term Count Volume Stations

Short-term count stations collect data using portable traffic counting equipment and sensors. Short-term data collected by such stations should be adjusted to represent an AADT) number. For a detailed definition of short-term counting station or related terms, please see the glossary of terms. These short-term volume stations often require ACF and temporal factors to properly annualize them.

Short-Term Vehicle Classification Stations

Short term 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. These traffic collection locations do not need ACF.

1.5.2.3 Coverage Counts Program (Full Roadway Network Traffic Data Coverage Program)

The two types of short-term counts include coverage counts and special counts. The coverage count program 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 6-year cycle. The coverage plan includes counting the HPMS sample and full-extent sections on a shorter (maximum) 3-year cycle to meet the national HPMS requirement.

1.5.2.4 Special Counts Program (Roadway- or Supporting Program-Specific Traffic Data)

The coverage program is supplemented with a special needs program subset 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.
- Lane closure policies, corridor studies, inclement weather, and construction management.

1.5.2.5 Micromobility Permanent Data Program

One of the key differences between micromobility and motorized traffic monitoring is the scale of data collection. Most micromobility traffic monitoring 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 micromobility 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, county, or State. Additional research is needed to identify statistically representative site selection criteria.

A second key difference is that micromobility 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-term counts (i.e., as short as 2 hours) for micromobility traffic monitoring, primarily because of the perceived difficulty of automatically counting pedestrians and bicyclists (as well as the desire to collect age and bicycle helmet use data).

> Although this practice is not prohibited by the *TMG*, data users should recognize that these very short-term counts can introduce significant overall error when micromobility traffic use is low and inherently variable.

If short-term micromobility counts are needed, then it is essential that longer counts be taken to establish hourly patterns and a statistical basis for extrapolation of these counts. This issue is addressed in more detail in Chapter 3.

Finally, a fourth key difference is that the monitoring technologies for counting micromobility still are evolving, and error rates associated with different technologies are becoming available. All methods for counting both motorized and micromobility 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.

National Cooperative Highway Research Project (NCHRP) *Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection* (NASEM 2014) provides additional information.

1.5.2.6 Micromobility Short Term Count Program

The majority of micromobility locations will be monitored using short-term counts and special needs counts although in micromobility programs, the distinction between short-term counts and special needs counts may not be as clearly defined in some programs. Short-term counts are often performed on specific facilities based on certain needs for that facility (e.g., before-after use). One limitation of this data lies in the uncertainty over whether the data collected at that a specific facility are representative of other similar facilities and can therefore be expanded to a sub-area or regional estimates of overall micromobility travel.

1.6 PROGRAM EVALUATION

> DOT traffic monitoring programs should be comprehensively evaluated every 5 years, at a minimum, to ensure compliance with users' needs and Federal regulations, account for changes in road usage, and address equipment or personnel needs.

This comprehensive evaluation should include auditing all aspects of the program including equipment inventories, site selection procedures, data collection practices, validation, quality control, analyzing data, staffing levels, data dissemination practices, and data user base review and documentation updates. The state DOT should provide its FHWA Division Office with the results from the comprehensive evaluation. 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 5 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 thorough program evaluation identifies potential savings of time, resources, and budget and recommends business practice improvements that eliminate unnecessary or inefficient monitoring processes or data management practices. Examples to consider include (but are not limited to) the following:

- Sharing data with partner agencies and eliminating duplication of data collection efforts.
- Elimination of travel monitoring sites by consolidating data sources that are overlapping within an agency.
- Implementing automated software technologies to eliminate or improve 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.
- 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 (i.e., peer benchmarking) 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 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 and travel monitoring program and how it fits into the agency planning, project, program, and policy development processes 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 Table 1-1)
3. Benefits of the Traffic Monitoring Program – Document the benefits of a traffic and travel monitoring program to the agency and to all the internal and external stakeholders. This can include fiscal decision-making abilities and resource benefits.
4. Documentation of Federal, State, and Local Requirements and Guidelines for the traffic and travel monitoring program – Document requirements and guidelines that must/should be followed in establishing traffic monitoring programs.
5. Documentation of Existing Monitoring Processes and Data – 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 should (minimally) include the following elements:

   - Annual Calibration protocols and procedures utilized for all data types.
   - Standardized specifications for factoring process (including ACF).
   - Data distribution and delivery methods.
   - Frequency and duration of portable counts.
   - Reporting requirements and methods.
   - Number of counts and samples taken
   - Location of permanent and portable sites and the logic used with how they are selected.
   - Inventory and age of equipment (including cabinet batteries).
   - Database management and storage procedures include data archiving, retrieval, network connectivity/access/security and storage.
   - Data retention methods and what formats are employed.
   - 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):

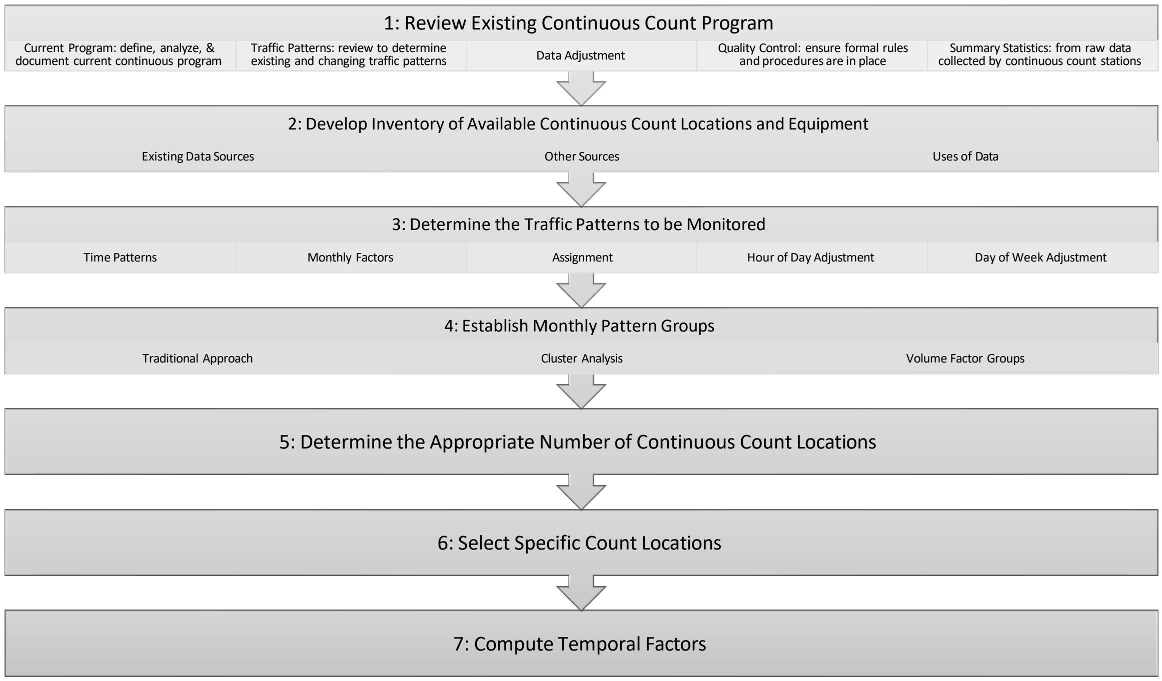
- Accuracy – The measure or degree of agreement between a data value or set of values and a source assumed to be correct.
- Completeness – The degree to which data fields and respective values are present in the attributes database (e.g., volume and speed are database fields that have values such as a volume (AADT) of 1,500 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 the quantity of data available in comparison to the quantity of data that should be available.
- 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 are being used.
- Duration
- Frequency
- Formats of data (storing, reporting, exporting, integrating, and converting)

7. Identification of Gaps and Overlaps – 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 and travel data with a local agency or duplicated count locations. The key to 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 and travel monitoring programs.

8. Review Program Components – During the program evaluation (recommended at least every 5 years), States should review all steps documented to determine if they are meeting the requirements. Figure 1-1 outlines steps for establishing elements of traffic data programs that will be particularly useful in the assessment—Steps for Establishing a Continuous Data Program, and Steps for Creating and Maintaining a Continuous Data Program.

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 and travel monitoring staff may wish to conduct a benefits analysis and risk assessment. This assessment would involve identifying the benefits from traffic monitoring program data and products, as well as the risks of not providing the traffic data at the desired level of quality.
   This business process review should be updated every 5 years 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 and travel monitoring programs.

   Data business planning is an important component of any State DOT traffic and travel 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 documenting what duties each data program staff perform. Several States have well-documented programs and can be used as references (see Appendices C and D).



Source: Federal Highway Administration.

Figure 1-1. Steps for Establishing a Data Program

1.7 COORDINATING COUNT PROGRAMS AND SHARING DATA

Coordinating count programs and sharing data are beneficial to all public agencies. Sharing data collection resources often reduces costs of purchasing and installing equipment. Access to additional counts provides another opportunity for data usage in quality assurance activities that save money, increase quality, and make reporting of data easier, allowing all data to be integrated into one platform. 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 cannot only overcome data sharing challenges, but benefit significantly through data sharing noteworthy 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 weight-in-motion sites supply weights, spacings, 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 and travel monitoring data and benefits derived, while reducing the overall cost of data collection.

Key sources for urban traffic data are the traffic surveillance systems used for traffic management and control. The ITS program offers highway agencies the ability to receive and utilize continuous traffic monitoring data at high-volume locations. Access to these data requires proactive efforts by the agencies involved (both the producer of the data and the user of the data), 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 respective agencies, benefits of ITS data can be lost because operations groups spend their limited resources on operational improvements rather than on the archiving and analysis software needed to maintain useful traffic and travel statistics. When configured properly, the traffic monitoring assets can also supplement ITS assets and provide critical information for operations.

1.8 DOCUMENTATION AND METADATA

Another critical factor of a well-designed traffic monitoring program is thorough and complete documentation. States should 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. Developing program documentation is recommended for traffic data programs. For example, HPMS annual report process documentation is required. HPMS annual reporting also requires reporting of metadata pertaining particularly to traffic data (see 23 CFR 420.105(b)).

> Documentation is recommended for any processes or methods used in data collection and analysis that may affect the outcome of the traffic data reported.

Metadata should include documentation describing specific data items and datasets. For example, traffic metadata should describe whether AADT values have been seasonally adjusted, whether AADT values are drawn directly (raw unadjusted data) from vehicle count data, or whether AADT is adjusted by annual growth/change.

Data program documentation should be a shared responsibility between the Traffic Monitoring Staff and IT divisions and the data-collecting business units within the organization. These units should bear the responsibility to document the business needs and benefits of 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.

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 is useful 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.

Chapter 2. Traffic Data Collection Technology and Equipment

2.1 MONITORING TECHNOLOGY AND EQUIPMENT

The following sections include commonly used technologies for vehicle and micromobility detection. Additional information is available in the FHWA's *Traffic Detector Handbook* (FHWA 2006) and in Chapter 3 of the *AASHTO* report *Guidelines for Traffic Data Programs (AASHTO 2009)*. The most up-to-date information on specific equipment is available from the manufacturer. The FHWA *WIM Pocket Guide* (FHWA 2018) and FHWA's *Travel Monitoring and Traffic Volume* website also contains a wealth of information.

2.1.1 Types of Traffic Data Collected

Table 2-1 lists typical types of traffic data collected by traffic monitoring devices for motorized and micromobility data collection programs. See Chapter 4 for a detailed listing of data types that could be provided by traffic monitoring devices.

Table 2-1. Basic Data Types Reported by Traffic Monitoring Devices

Motorized Vehicles	Micromobility
Individual vehicle records	Pedestrian volumes
Vehicle volumes	Micromobility device volumes
Vehicle classification	Micromobility device classification
Vehicle length	
Vehicle speed	
Axle spacing	
Axle weights (GVW)	
Gap	
Headway	
Lane occupancy	

2.1.2 Detection Methods

There are two general methods for detecting passing vehicles and micromobility users: automatic and manual.

Automatic methods – refer to the collection of vehicular and pedestrian data using automatic equipment. The equipment is designed to continuously record the presence, distribution, and variation of traffic flow. The data are recorded and reported for each individual detected observation or summarized (binned) by discrete time periods (e.g., by 5 min., 15 min., hour of the day, daily counts). Automatic methods include permanently installed or portable (typically, for less than 7 days) equipment. Automated methods are further classified as intrusive (i.e., the traffic detection sensor is placed on or under the road surface) or non-intrusive (i.e., there is no sensor on or under the road).

Manual methods – refer to those methods that involve a human observer determining and recording the numbers of vehicles and micromobility users. The total counts are reported by time interval, or the observed objects are sorted by a human observer and reported by vehicle classification, vehicle occupancy, turning movement counts, etc. While these methods have limited application due to their limited use and high cost, they serve an important function for verifying automated vehicle detection equipment performance and accuracy.

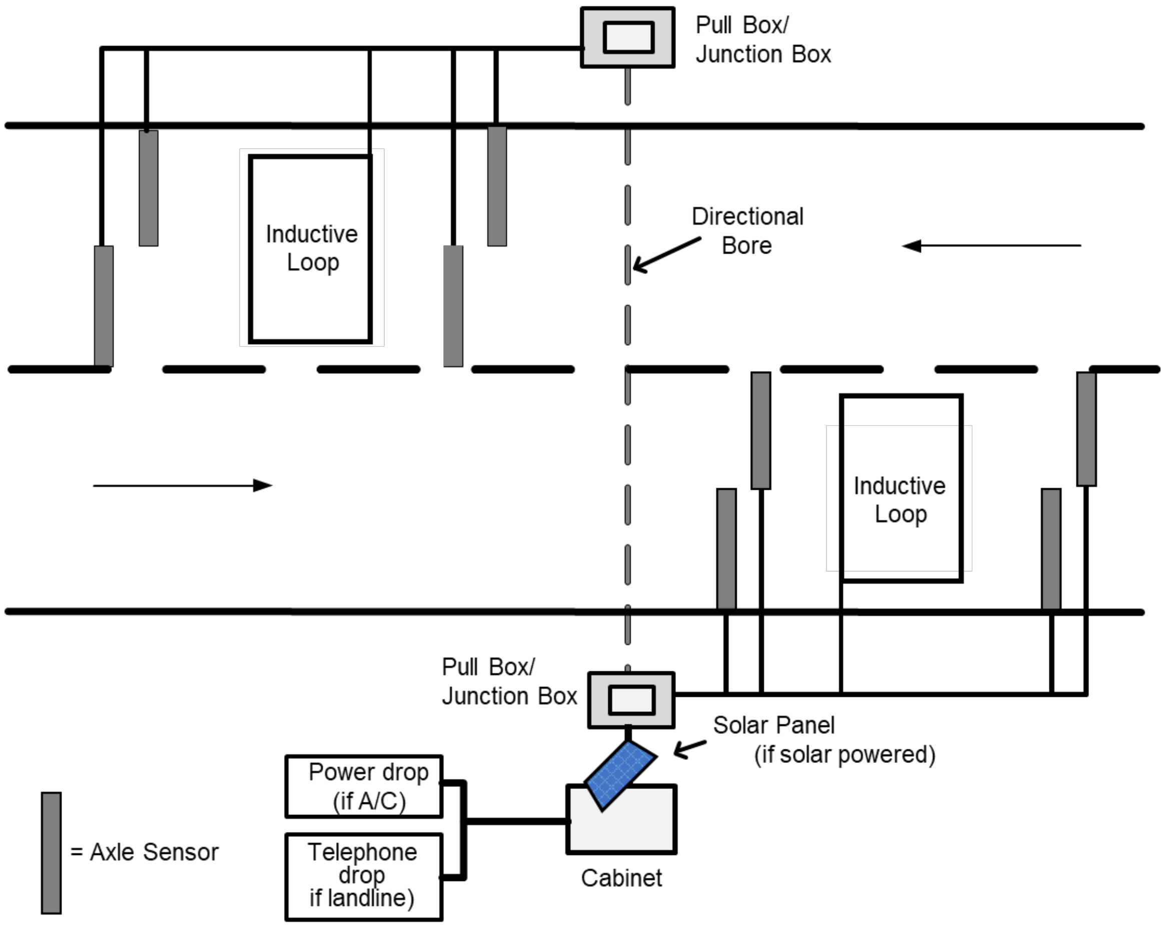
2.1.3 Equipment Types

The common names for traffic monitoring equipment are traffic counters and vehicle detectors. The equipment for specialized traffic data collection has additional names, including Continuous Vehicle Classifiers (CVC), Weigh-In-Motion (WIM) systems, and micromobility detectors. These devices can be portable and referred to as Portable Traffic Recorder (PTR) or permanently installed at Continuous Count Stations (CCSs). The *TMG* Glossary contains the detailed definitions for the above-mentioned equipment types.

2.1.4 Equipment Components

Although vehicle detectors sometimes differ in function and application, based on whether permanent or portable, these systems have common major components. These systems consist of (1) sensor(s) installed in, under, alongside, or above the roadway; (2) an electronic data collection device (controller), typically stored in a roadside cabinet that processes the signals from the sensor; (3) a power source supporting data collection device; (4) telecommunication equipment; and (5) additional support infrastructure such as wires, pull boxes, conduits, etc. A complete traffic monitoring site layout is shown in Figure 2-1. The equipment shown is a typical configuration used to collect vehicle count, vehicle classification, vehicle length, axle spacing, axle and gross vehicle weight, and vehicle speed.

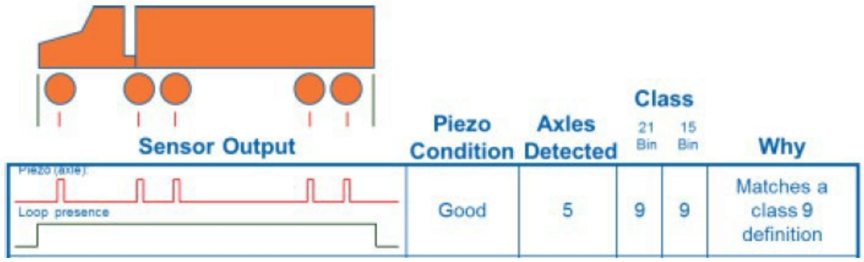
FHWA recommends using 8 feet wide by 6 feet long (along the wheel path) loops and full lane width pneumatic road tubes or axle sensors for lanes wider than 10 feet.



Source: Federal Highway Administration.

Figure 2-1. Example of Traffic Monitoring Equipment and Site Layout

The technology used to sense the passing traffic stream determines what each data collection device physically counts. The signals collected from the sensors are converted and processed by the controller (typically using a proprietary method specific to that equipment's vendor) into vehicular and traffic flow information. This information is stored in the data storage unit of the traffic controller device for later download. Figure 2-2 shows an example of the signals collected by the axle sensors and the inductive loop being interpreted into vehicle classification data.



Source: Virginia Department of Transportation

Figure 2-2. Example of Sensor Output Conversion to Vehicle Classification Data

2.1.5 Sensor Types Overview

The theory and operation of vehicle sensors is discussed in detail in the sensor technology chapter of the *Traffic Detector Handbook* (FHWA 2006). The following types of vehicle presence technologies are used for detecting moving vehicles and/or Micromobility users:

- Inductive Loop Detector – detects vehicle or micromobility device passage and presence. This sensor uses a low voltage alternating electrical current through a formed wire coil embedded in the pavement. The wire coil loop sometimes is placed in the aggregate base below the pavement. The current creates lines of flux field above the formed wire coil, which is disturbed by a passing conductive object of detecting sufficient conductive material (e.g., car, truck, and bike). If this disruption meets predetermined threshold criteria, detection occurs, and the object is counted by a data logger or computer. Advanced signal processing (such as recording and interpretation of loop signatures) is used to derive certain vehicle class characteristics. The sensor consists of four parts, namely 3 to 4 turns (depending on the loop size) 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 (Induction or Search Coil Magnetometer) – detects the presence of a ferrous metal object through the perturbation (known as a magnetic anomaly) it causes in the Earth's magnetic field. It is placed under or in the roadway to detect the passage of a vehicle over the sensor. 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*.
- Microwave Sensor – transmits electromagnetic energy from an antenna toward vehicles traveling the roadway. When a vehicle passes through the antenna beam, a portion of the transmitted energy is reflected towards the antenna. The energy then enters a receiver where the detection is made and traffic flow data, such as volume count, speed, and vehicle length, are calculated. Microwave sensors that utilize the Doppler principle analyze the frequency of the received signal. The frequency 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 Sensor – detects energy from two sources: 1) energy emitted from vehicles, road surfaces, and other objects in the 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 on an infrared-sensitive material mounted at the focal plane of the optics. The infrared sensitive element 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 or in a side-looking configuration to view approaching or departing traffic. 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 – measures 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 Sensor – transmits 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 Sensor – transmit energy in the near infrared spectrum. Models are available that scan infrared beams over multiple 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 System – typically consists 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.
- Pneumatic Tube – uses an air switch connected to the end of the rubber road tubes to detect short burst(s) of air from a vehicle that rolls over the tube. The data logger then uses pre-defined criteria (e.g., axle spacing, speed) to determine whether a valid vehicle type has passed over the tubes. This detector is widely used for portable traffic monitoring. When two tubes are placed parallel on the roadway, the signal results provide information sufficient to classify vehicles using detected axle spacing under free flow traffic conditions.
- Piezoelectric Sensor – detects a vehicle axle's passage using a change in the sensor's voltage that is directly proportional to the pressure applied by the vehicle wheel on the sensor. Piezoelectric sensors are used independently to detect and classify vehicles or in conjunction with loop inductors to increase classification accuracy by providing overall (loop) length. Piezoelectric sensors, in combination with passive infrared technologies, are capable of detecting bicycles in mixed pedestrian and bicycle traffic. Piezo sensors are also used for WIM sensing.
- Fiberoptic Sensor – detects changes of a tightened optical fiber when a vehicle passes over the sensor embedded in the road surface. This sensor is capable of vehicle detection, classification, and weighing.
- Bending Plate for WIM – utilizes strain gauges bonded to the underside of the plate to collect loading data. As vehicle axles pass over the bending plate, the system measures the strain on the plate at highway speeds and calculates the load required to induce that level of strain.
- Load Cell for WIM – utilizes two scales to detect an axle and to weigh both the right and left side of the axle at highway speeds per axle passage. The load cell sensor utilizes transducer(s), which creates an electrical signal whose amplitude is directly proportional to the force being measured. The system records the weights measured by each scale and sums them to obtain the axle weight.
- Strain Gauge Strip Sensor for WIM – uses strain gauge load cell technology. As a vehicle passes over the WIM sensor, the system measures the vertical strain placed on the sensor by the weight of the wheel. The resultant change in the electronic properties of the strain gauge load cells is translated into the dynamic load that is used by the software to estimate wheel, axle, and vehicle weight.
- Bridge WIM (B-WIM) – uses strain transducers mounted to the underside of culverts, bridge decks, or bridge structural members. These deformations of bridge structural members detected by the strain sensors are analyzed to measure the axle loads of passing traffic.
- Seismic sensors – operates by detecting the passage of energy waves through the ground caused by feet, bicycle tires, or wheels on micromobility devices. These sensors are most common on unpaved trails or paths.
- Pressure plate – detects vehicles, micromobility devices, or pedestrians by detecting changes in force (i.e., weight), much like an electronic bathroom scale. These sensors are most common on unpaved trails or paths.

2.1.6 Sensor Technology Combinations

Many State highway agencies have adopted a policy to "collect data once and use it multiple times." This approach leads to traffic monitoring site designs that combine multiple sensor technologies to achieve more comprehensive traffic data collection satisfying needs of multiple customers/data users.

Various types of sensors are used in combination, for traffic management, law enforcement, and other applications. Examples of sensor technology combinations include ultrasonic-infrared-microwave combinations, inductive loops enhanced with magnetic signature detector card, WIM sensor and inductive loop combinations, and WIM sensors combined with license plate and DOT registration number video readers. A combination of inductive loops with axle sensors or magnetic signature detector card improves quality of vehicle classification.

An example of sensor technology combinations that have been widely used over the years is a combination of inductive loops and axle sensors. That sensor combination provides opportunities to collect the following data at the same site:

- Individual vehicle records
- Vehicle volumes
- Vehicle classification (axle based)
- Vehicle length
- Vehicle speed
- Axle spacing
- Axle weights
- Gap
- Headway
- Lane occupancy

When the loop and axle sensor combination is coupled with the roadside camera, they can collect even more information about each passing vehicle, including body type (associated with carrying specifics commodities), license plate, and U.S. DOT vehicle registration number (for commercial trucks).

A combination of WIM and video monitoring equipment allows collection of the extended dataset, providing additional information of interest about heavy vehicles, including license plate, U.S. DOT registration information, body type, cargo trailer configuration, axle arrangement details (such as lifted axles).

Other examples of technological combinations, common for detecting and classifying micromobility, include the following combinations:

1. Video and infrared sensors
2. Video and pneumatic road tubes
3. Infrared sensors and inductance loop
4. Infrared sensors and piezo axle sensors

2.1.7 Strengths And Weaknesses Of Commercially Available Sensor Technologies

This section describes the kinds of technologies that are available to support traffic monitoring programs, including the general strengths and weaknesses of each of those technologies. An additional source of information on the selection of traffic monitoring equipment is Chapter 3 of the report *AASHTO Guidelines for Traffic Data Programs* (AASHTO 2009).

Table 2-2 describes the strengths and weaknesses of the types of technology used for motorized vehicle 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 2-3 describes the strengths and weaknesses of the sensors used for weighing and classifying vehicles in motion.

Table 2-4 describes the strengths and weaknesses of the sensors used for micromobility detection. In addition to sensor capabilities consideration, it is important to consider that even for the selected technology, data accuracy varies significantly based on sensor configuration, site location, pavement condition, installation, calibration, and maintenance practices.

Table 2-2. Strengths and Weaknesses of Commercially Available Sensor Technologies for Motorized Vehicle Detection and Counting

Technology	Strengths	Weaknesses
Inductive Loop	• Flexible design to satisfy large variety of applications • Mature, well-understood technology, long lasting at 20+ years • Large experience base • Provides basic traffic parameters (e.g., volume, presence, occupancy, speed, headway, and gap) • Insensitive to inclement weather 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	• 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 decreases when design requires detection of a large variety of vehicle classes (unless loop signature technology is deployed) • Does not detect axles in commonly used configurations
Piezo Sensors	• High accuracy in vehicle classification • Insensitive to inclement weather such as rain, fog, and snow • Common standard for obtaining axle count and classification • 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 • Polymer piezo is sensitive to temperature • Does not detect vehicle overall length • Does not work well in slow or stopped traffic
Pneumatic Tube	• Common standard for obtaining axle count and classification in portable applications • Mature, well-understood technology • Low cost and no damage to the pavement	• Installation sometimes requires lane closure • Does not detect vehicle overall length • Does not work well in very high volume or very slow (5 mph) or stopped traffic
Magnetic (Two-axis Fluxgate Magnetometer, Induction or Search Coil Magnetometer)	• Less susceptible than loops to the stresses of traffic • Insensitive to inclement weather such as snow, rain, and fog • Some models transmit data over wireless radio frequency (RF) link • 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	• Installation requires pavement cutting or boring under roadway • 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 or classify stopped vehicles or axles unless special sensor layouts and signal processing software are used

Technology	Strengths	Weaknesses
Microwave	• Typically, insensitive to inclement weather at the relatively short ranges encountered in traffic management applications • Direct measurement of speed • Multiple lane operation available • Detects slow-moving vehicles • Accommodates changes in lane assignment at a location • Non-intrusive installation	• Sometimes miss occasional vehicles traveling side-by-side (occlusion) • Calibration and sensor position are crucial to proper operation • Cannot detect stopped vehicles or individual 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 • Installed on one side or both sides of the roadway depending on the system used	• Operation is 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 has 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 over-height vehicle detection	• Environmental conditions such as temperature change and extreme air turbulence often affect performance; temperature compensation is built into some models • Large pulse repetition periods degrade occupancy measurement on freeways with vehicles traveling at moderate to high speeds • Cannot detect stopped vehicles or individual axles
Acoustic	• Passive detection • Insensitive to precipitation • Multiple lane operation available in some models	• Cold temperatures affect vehicle count accuracy • Specific models are not recommended with slow-moving vehicles in stop-and-go traffic • Cannot detect stopped vehicles or individual axles

Technology	Strengths	Weaknesses
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 • Non-intrusive installation	• Installation and maintenance, including periodic lens cleaning, require lane closure when camera is mounted over roadway (lane closure is not 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 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 • Complicated or expensive data processing required

Source: Adapted from Traffic Detector Handbook, 2006.

Table 2-3. Strengths and Weaknesses of WIM Technologies for Moving Motorized Vehicle Detection, Counting, Weighing, and Classifying

Sensor Type	Strengths	Weaknesses
Load Cell	Higher accuracy Provides count, classification, speed, weight, axle spacing, individual vehicle records data Long service life	Use in concrete only High cost: total life-cycle cost is more efficient over long data collection periods High maintenance Installation requires more time, training, and resources
Bending Plate	Higher accuracy Provides count, classification, speed, weight, axle spacing, individual vehicle records data Long service life	Use in concrete only High to Moderate cost; total life-cycle cost is more efficient over long data collection periods Must be regularly maintained to prevent getting loose and causing safety hazard
Quartz Piezo	High accuracy, low maintenance Provides count, classification, speed, weight, axle spacing, individual vehicle records data	Moderate cost
Strain Gauge Strip Sensor	High accuracy, low maintenance Provides count, classification, speed, weight, axle spacing, individual vehicle records data	Limited long-term performance record Implemented with limited number of controllers
Permanent Polymer Piezo (including co-ax)	Low cost, low maintenance Provides count, classification, speed, weight, axle spacing, individual vehicle records data	Temperature sensitive Needs seasonal calibration
Portable Polymer Piezo	Low initial cost, easy to set up, portable Provides count, classification, speed, weight, axle spacing, individual vehicle records data	Low accuracy Temperature sensitivity, needs local calibration
Bridge WIM (Strain Gauge)	Quick to set up, provides portable count, classification, weight, axle spacing, individual vehicle records data	Depending on local bridge structural response, needs local calibration Safety risk & special equipment for tall bridges Accuracy depends on accurate bridge response modeling

Source: Adapted from FHWA Weigh-In-Motion Pocket Guide, 2018.

Table 2-4. Strengths, Weaknesses, and Applications of Micromobility Detection Technologies

Technology	Typical Applications	Strengths	Weaknesses
Inductance Loop	Permanent counts Bicyclists and some micromobility device users (e-bikes)	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 Often have higher error with groups
Pressure Plate Sensor/Pressure Mats	Permanent counts Typically on unpaved trails or paths Bicyclists, micromobility device users, and pedestrians combined	Some equipment able to distinguish bicyclists and pedestrians	Expensive/disruptive for installation under asphalt or concrete pavement
Seismic Sensor	Short-term counts on unpaved trails Bicyclists, micromobility device users, and pedestrians combined	Equipment is hidden from view	Commercially available, off-the-shelf products for counting are limited
Radar Sensor	Short-term or permanent counts Bicyclists, micromobility device users, 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 (Lidar) – Automated	Short-term or permanent counts Bicyclists, micromobility device users, 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 of micromobility device users 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 Often have higher error with groups
Infrared – Passive	Short-term or permanent counts micromobility device users 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 Have higher error when ambient air temperature approaches body temperature range Often have higher error with groups Direct sunlight on sensor may create false counts

Technology	Typical Applications	Strengths	Weaknesses
Pneumatic Tube	Short-term counts of 2-axle micromobility device users	Relatively portable, low-cost Possible to use existing motor vehicle counting technology and equipment	Capable of counting bicyclists only Tubes pose hazard to trail users Greater risk of vandalism Special care needed when installing and configuring for counting bikes in bike or shared lanes
Video Imaging – Manual Reduction	Short-term counts of micromobility devices and pedestrians separately	Cost is lower when existing video cameras are already installed	Limited to short-term use Manual video reduction is labor-intensive Weather and lighting reduce the accuracy Video image processing has the highest equipment costs
Manual Observer	Short-term counts of micromobility devices and pedestrians separately	Very portable Also used for automated equipment validation	Expensive and possibly inaccurate for longer duration counts

2.2 SELECTING MOTORIZED TRAFFIC MONITORING TECHNOLOGIES

2.2.1 VEHICLE DETECTION EQUIPMENT CAPABILITIES BY TRAFFIC DATA TYPES

A good way to categorize traffic monitoring devices is based on the type of data they collect. Table 2-5 provides a comparison of sensor capabilities for motorized vehicle detection by key traffic attributes. The following sub-sections describe technologies for collecting the different types of traffic data.

Table 2-5. Motorized Vehicle Detection Sensor Comparison

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

Sensor Technology	Vehicle Count	Vehicle Presence	Speed	Vehicle Classification[i]	Weight	Multiple Lane, Multiple Detection Zone Data	Sensor Purchase Cost
Video Detection System	X	X	X	X		X	Moderate
Laser	X	X				X	Moderate
Contact switches closures (e.g., pneumatic tubes)	X	X	X	X			Very low, only for short-term counts
Fiber optic	X	X	X	X	X	X	Moderate
Load Cell	X	X	X	X	X	X	Very high
Bending Plate	X	X	X	X	X	X	High
Quartz piezo	X	X	X	X	X	X	Moderate to high
Strain Gauge Strip Sensor	X	X	X	X	X	X	Moderate to high
Polymer Piezo	X	X	X	X	X	X	Low
Bridge WIM	X	X	X	X	X	X	Moderate

[a] *Measured using 2 sensors a known distance apart or estimated from 1 sensor, the effective detection zone, and vehicle length*

[b] *With specialized electronics unit containing embedded firmware that classifies vehicles.*

[c] *With special sensor layouts and signal processing software.*

[d] *With microwave 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] *Axle counts converted to vehicle counts through factoring.*

[h] *Includes underground sensor and local detector or receiver electronics. Electronics options are available to receive multiple sensors and multiple lane data.*

[i] *There are different types of classification schemes (axle-based, length-based and visual schema)*

Source: Federal Highway Administration.

Individual Vehicle Records

An Individual Vehicle Record (IVR) contains information about each discrete passing vehicle, such as vehicle type (i.e., vehicle classification), number of axles, axle spacing, and vehicle length. In addition, some IVRs include information about vehicle speed, gross vehicle weight, axle and wheel loads, and magnetic loop signatures. This information is obtained by the equipment using both vehicle presence and axle detection technologies. The most commonly used sensor combinations are inductive loops and axle sensors (e.g., piezo electric, bending plates, load cells, and strip strain gauge sensors). In some cases, a pair of axle sensors used on their own is sufficient but the accuracy of IVR data collection degrades in congested traffic conditions, when the distance between vehicles converges on the distance between the axles of a large vehicles. The use of video cameras, in addition to inductive loops and axle sensors, allows for the collection of additional IVR information, such as vehicle license plate, and vehicle DOT registration numbers.

FHWA recommends collecting data in individual vehicle record (IVR) format whenever possible. For more details on the IVR format, see chapter 4. Considerations for data storage requirements must be made when purchasing equipment or evaluating older equipment because IVR data reporting requires large storage space.

Vehicle Volume

Some vehicle detection technologies count each passing object, where in most cases an object is a vehicle, whether it is a car or multi-unit truck. Others do not detect a vehicle but instead count the axles of those vehicles or actual sensor actuations. 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 to provide an estimate of vehicle volume. Table 2-6 summarizes which of the currently available traffic monitoring technologies directly count vehicle volumes, and which count axles requiring conversion of those data to vehicle volume estimates.

Table 2-6. Common Technologies Used for Counting Vehicles Versus Axles

Presence-Sensing Technologies	Axle-Sensing Technologies
Inductive loops	Infrared
Magnetic	Laser (most)
Video detection system	Polymer piezo
Acoustic	Quartz piezo
Ultrasonic	Strain gauge strip sensor
Microwave	Fiber optic
Laser radar	Capacitance mats
Passive infrared	Bending plates
	Load cells
	Inductive loop signatures
	Contact switch closures (e.g., pneumatic tubes)

This table shows the most common application of the technology. In some cases, specific implementations of the technologies are used in different ways. For example, advanced processing of magnetic signatures of the loop sensors is used to count axles very accurately and even classify vehicles. However, most loop installations are not capable of detecting axles.

Table 2-7 describes which vehicle counting technologies are capable of classifying vehicles.

Table 2-7. 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
Polymer piezo	Magnetic (magnetometer)
Quartz piezo	Video detection system
Strain gauge strip sensor	Microwave
Fiber optic	
Capacitance mats	
Bending plates	
Load cells	
Contact switch closures (e.g., pneumatic tubes)	
Specialized loop signature systems	
Any of the above combined with inductive loops	

Speed

Most modern traffic monitoring technologies produce a measure of speed as part of their routine traffic monitoring function. 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. Traffic monitoring technologies that provide either axle-based vehicle classification or weigh in motion are also capable of providing vehicle speed data.

How the speed data are 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 is computed and reported. However, more modern electronics often 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 ($d_{12} / (T_2 - T_1)$).

Speed data are collected by axle detectors using the same timing principle as described for inductive loops, based on the known distance between the axle sensors and the amount of time between the activation of the first axle sensor and the activation of the second axle sensor by a particular axle. Axle spacing is computed by multiplying the calculated speed by the time between hits for a particular axle on the first and second axle sensors. Therefore, since both speed and axle spacing measurements are related, if the detector is measuring axle spacings accurately, it is also measuring speed accurately. If a true axle spacing is known (e.g., obtained by manual measurement), the known true axle spacing value can be compared with the value estimated by the detector. The error in the axle spacing could be used to flag the error in speed measurement as well.

Figure 2-3 demonstrates how changes in speed and axle spacing can be used to identify the need for equipment calibration. Dashed horizontal lines show low and upper boundaries for a typical average tractor-tandem axle spacing for class 9 vehicles (i.e., spacing between 2nd and 3rd axles). Data points outside these boundaries signal that axle spacing measurements are out of calibration. The example shows that both the average monthly tractor-tandem axle spacing and the average monthly speed in are low in year 2015 and the first part of 2016, as compared to later months.

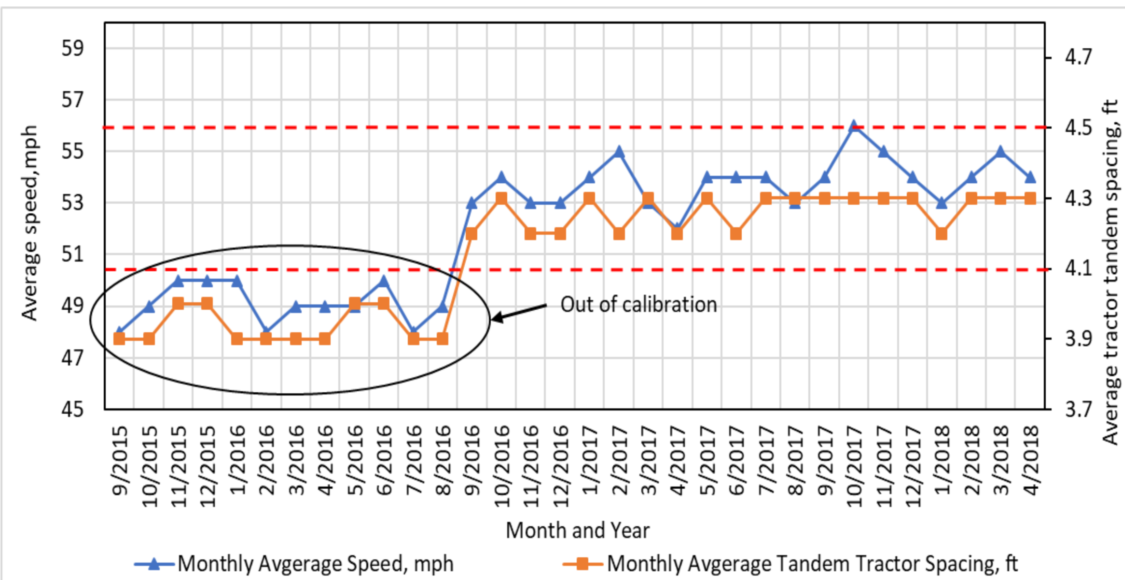


Figure 2-3. Example of Speed and Axle Spacing Monthly Trend Analysis

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

Speed data are also being obtained from other sources. One such source is vehicle probe data. Data collected from vehicle probes, within the overall roadway performance-monitoring program of an agency, should be loaded into the overall traffic monitoring database using the FHWA speed format. The FHWA speed format provides flexibility with a minimum of 15 speed bins to a maximum of 25 speed bins (all in 5 mph increments).

Axle and Gross Vehicle Weight

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 to estimate the static weight of each passing axle. Weights for all axles associated with a given vehicle are then combined to estimate the gross vehicle weight (GVW). Axle spacings are also recorded.

> GVW is gross vehicle weight. This value is reported by the WIM devices as part of the traffic monitoring program. GVWR is gross vehicle rate. It is the maximum rating a vehicle can have for its gross weight. WIM devices do not provide the GVWR values.

The WIM technologies used in the U.S. include piezo-electric (polymer piezo and quartz piezo), bending plates, fiber optic cables, load cells (both hydraulic and mechanical), capacitance mats, and strain gauge strips. Bridges and culverts instrumented with strain gauges are also being 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 and vehicle length. 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 to determine if the observed axles are single axles, tandem axles, tridems, quads, pentads 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; therefore, an adjustment algorithm is used by the WIM system to produce an estimate of static weight.

Motorcycle Counting

The relatively small amount of metal in many motorcycles combined with the fact that many motorcyclists ride near lane lines 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.

Four aspects of traffic counting can be changed to improve accuracy of counting motorcycles:

1. Use of full lane width axle sensors
2. Use of wide loops of (8-foot-wide) in the lane for motorcycle counting
3. Counting by wheel path (see Montana example in Appendix I)
4. Video Detection (might be limited to detection during daytime only)

> To improve accuracy of counting motorcycles, use full lane width axle sensors and 8-foot-wide loops.

Lane Occupancy

Inductive loop detectors and other devices, such as video image-based counters, can produce lane occupancy statistics that describe the percentage of time a vehicle occupies the detection zone. Many urban freeway and arterial performance monitoring programs use lane occupancy measurements to describe the onset and duration of congested conditions.

Headway and Time Gap

Traffic monitoring devices that time stamp the passage of either individual vehicles or the axles of individual vehicles are called event recorders. The collected detailed data not only describe the traffic volume and often vehicle classification, but they explicitly measure the headway between vehicles and thus the vehicle gaps in the traffic stream. Traffic monitoring systems—such as WIM scales—routinely collect time-stamped vehicle records that can be used to report the headway between vehicles and/or the time gap between vehicles. When States collect data using the FHWA IVR format, they should consider reporting lane occupancy, headway, and gap data.

2.2.2 Equipment Selection Considerations

In addition to the basic functional requirements discussed above, roadway agencies should consider a variety of other functions when selecting traffic monitoring technologies, including:

1. Number of data collection lanes performed by any one piece of equipment and/or sensor.
2. Cost of the equipment (initial cost, placement cost, operating cost, and expected maintenance costs).
3. Expected life of the sensors and data collection electronics.

4. Warranties supplied by the manufacturer/vendor.
5. Environmental conditions under which the equipment is expected to operate relative to the strengths and weaknesses of each specific technology.
6. Whether the agency staff has the required knowledge and equipment for placing, annual calibrating, and maintaining the equipment.
7. 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?).
8. Type of power source to be used (AC/DC, solar, luminary, internal battery).
9. 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).
10. Vendor agreement for software support, equipment maintenance, warranty work.
11. Pavement condition for surface sensor like piezo and WIM sensors.
12. Installation materials and methods.

The first four of these issues 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 regarding the first three issues.

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 working poorly in other circumstances. For example, pneumatic 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 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 traffic monitoring data is resource intensive and roadway agencies should consider how much effort is required for any given device.

Selecting Intrusive Versus Nonintrusive Sensors

When deciding about selecting intrusive or non-intrusive sensors, site characteristics need to be carefully considered. See the Sensor and Equipment Location Considerations section later in this chapter for additional details.

Non-intrusive sensors are further divided into overhead-mounted sensors and side-fired sensors. Side-fired sensors have the advantage of being mounted beside the road. This makes it 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 biased 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 1) increases the cost of installation and maintenance; 2) decreases the resolution with which the sensor detects vehicles in the road; and 3) creates movement in the sensor (as the pole on which the sensor sits sways) leading to other forms of accuracy degradation. Manufacturer-recommended installation heights need to be followed.

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 for the sensors to be installed and then each time maintenance is performed because of fears of material dropping onto the roadway during those activities. Closed lanes create potential congestion on high-volume roadways.

The most common reasons for choosing non-intrusive sensors over intrusive are as follows:

- Unsafe conditions for placing or maintaining intrusive sensors, such as high-volume multi-lane facilities.
- Expensive traffic control to place and/or maintain intrusive sensors.
- Poor pavement condition.
- Disruption of traffic occurring with the placing of sensors introduces safety as well as sensor performance issues.
- It is difficult to close the lane because of high traffic

volumes. Intrusive sensors perform best under the following

conditions:

- Even traffic flow at constant speed.
- Traffic follows good lane discipline.
- Straight and flat road section.
- Strong pavement with good surface condition.
- Safe access to the sensors for maintenance using common traffic control protocols.

The performance of in-roadway sensors such as inductive loops 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. In traffic monitoring applications, in-road sensors effectively differentiate 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. 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. These systems only work on a limited set of bridges.)

The main disadvantage is the 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 monitor multiple lanes with one unit.

Table 2-8 describes which sensors are intrusive and which are non-intrusive.

Table 2-8. Intrusive and Non-Intrusive Technologies

Intrusive	Non-Intrusive
Inductive loops	Infrared (passive, active)
Polymer Piezo	Video detection system
Quartz Piezo	Microwave (overhead or side mounted)
Fiber optic	CW Doppler sensor
Magnetometer (most sensor designs)	Acoustic
Tape Switches (pneumatic tubes)	Ultrasonic
WIM systems (bending plates, load cells, and strip strain gauge)	Laser radar

2.2.3 Equipment Selection for Short-Term Temporary Counts

The short-term temporary counts are designed to provide wide geographic coverage at low cost. Most highway agencies perform many short-term counts, 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 additional priorities when selecting the appropriate technologies and equipment for performing short-term counts (in addition to the issues discussed in the previous sections, and the accuracy and price of the equipment). The technologies used for short-term 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).
- Allow placement of the traffic sensors safely.

- The data collection electronics should contain a sufficient 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, 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.)
- All data collection equipment should have clear markings for who owns the devices and a contact number to call should the equipment get lost, stolen, or become misplaced.
- 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 user-friendly and easy to check for proper functionality before the technician leaves the site.

The speed of sensor placement, electronic equipment set up, and calibration are important. The faster sensors and data collection equipment are placed, the more count locations a given staff member can set up in a day and the lower the costs of short-term data collecting are. At the same time, the placement (and pick up) of the sensors must not endanger the staff placing those sensors. This need to safeguard data collection staff, without incurring the high cost of full-scale traffic control, is one of the reasons so much effort has been spent on exploring non-intrusive traffic data collection technologies. However, on lower-volume roads where low-cost road-tube axle sensors can be easily placed without endangering the data collection staff, 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 in 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 for short-term counts, the most common approach 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-term counts are commonly used to collect volume, volume by classification of vehicle (including micromobility) and speed. Portable road-top WIM sensors for vehicle and axle weight estimation are not recommended due to low weight data accuracy. Weight data are collected with a high degree of accuracy only using WIM sensors installed flush with the road surface. This means that most roadway agencies collect axle weight data from permanent data collection sites. Table 2-9 describes the sensor technologies that are commonly used for short-term counts and the motorized vehicle attributes they routinely collect.

Table 2-9. Sensors for Motorized Vehicle Data Collection for Short-Term 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
Pneumatic 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
Pneumatic 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 variations 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 or Axle Based	Multiple	Does not work well in snow, fog, or dust storms	Short-term counter is mounted on an extendible pole on a trailer pulled to the count site; generally slow to set up
Piezo Polymer sensors (piezo-film, piezo-cable)	2 per lane	Axle Based (FHWA 13+)	1 per pair of sensors	Very cold weather often affects 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 degrade performance and large crown in road will block beams; Occlusion	Infrared has an issue of heavy snow accumulation blocks the sensor.
Microwave	1 per direction (side-fired), 1 per lane (overhead)	Length-Based	Multiple	Occlusion issues with heavy or stop-and-go traffic and multiple lanes	Short-term counter is mounted on an extensible pole on a trailer pulled to the count site. Count is not reliable in congested low-speed conditions.

Acoustic	1 sensor	None	Multiple	Background noise/sound often interferes	Short-term 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
Paste-Down Loop	2 per lane	(FHWA 13+) if ILS-based or Length-Based is 2 loops are used without ILS	For 3 or more lanes, home run of the other lanes needs to be taken care of	It must be above freezing to install, unless the marmac tape rated for lower temps is used. Can't be installed in rain or with snow or dew on the roadway	Requires clean, debris free surface to use a paste down loop. Can be peeled back up or left on the roadway after data collection is done.

Source: Based on Hallenbeck and Weinblatt, 2004.

ILS = inductive loop signature card

2.2.4 EQUIPMENT SELECTION FOR CONTINUOUS COUNTS

Continuous counts are collected using permanently installed equipment. Permanently installed, continually operating traffic monitoring equipment provides both current measures of traffic flow and a time series record of traffic flow attributes that describe how traffic flow changes over time at that location.

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, installation, construction, or poor pavement conditions not only do not generate useful data, but they also 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.

Permanent traffic monitoring locations should have:

- Sensors that withstand the harsh roadway environment and operate for multiple years.
- Power sources (either electrical power or solar power with battery backup).
- Communications (land lines or cellular communications).
- Environmental protection (traffic cabinet) for electronic data logger or controller (temperature, moisture, dirt, electrical surge protection on all sensors, power and communications lines, and protection against animal and insect infestation).
- Safe pullout for maintenance vehicles and safe area for technician to access traffic equipment.
- Straight and flat road segment with good quality smooth pavement (at least 300 ft before and 100 feet after the sensor).
- Selected road segment should have even traffic flow during all hours of the day with minimal stop and go traffic queues, not prone to lane changes, mergers, or weaving maneuvers.
- For WIM sites, the turnaround time (one loop of the test vehicle) for calibration truck should be 30 minutes or less.

Unlike short-term 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 is challenging 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 safely work on that equipment when it starts to have performance problems. Of course, not all non-intrusive equipment has this advantage. Non-intrusive equipment placed above the roadway requires lane closures for maintenance. In other instances, side-fired equipment positions come with penalties to the accuracy with which the devices work.

Table 2-10 summarizes the technologies currently used for permanent vehicular traffic monitoring. 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 2-10. Sensors for Motorized Vehicle Data Collection for Permanent Count Locations

Technology	Intrusive or Non-intrusive	Types of Vehicle Classifications Collects WIM?	Number of Lanes of Data Collected by Each Sensor	Environmental and Road Maintenance Issues/Concerns	Other Issues/Concerns
Piezo-Polymer Film or Cable	Intrusive	Axle Based (FHWA 13+) Can be used for WIM-capable	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. Recommended full lane width sensors for motorcycle detection.
Piezo-Quartz Cable	Intrusive	Axle Based (FHWA 13+) A good WIM sensor	1 per set of sensors	Susceptible to damage from mill and resurface and oversized trucks. Susceptible to snowplow damage, if not flush with surface	Sensors are typically ½ lane in width, so a site requires 4 sensors/lane for double threshold WIM; it is possible to instrument only on wheel path, with modest loss of volume and classification accuracy. Doesn't work well in stop-and-go traffic.
Strip Strain Gauge WIM Sensor and other Pressure Sensors	Intrusive	Axle Based (FHWA 13+) WIM-capable	1 per pair of sensors	Susceptible to damage from mill and resurface and oversized trucks. Susceptible to snowplow damage, if not flush with surface	Sensors are typically ½ lane in width, so a site requires 4 sensors/lane for double threshold WIM; it is possible to instrument only on wheel path, with modest loss of volume and classification accuracy. Doesn't work well in stop-and-go traffic.
Inductive Loop (Conventional)	Intrusive	Length-Based	1 per pair of sensors	Susceptible to damage from ditching, mill, and resurface Lifecycle is affected by extreme heat or freeze-thaw cycles	Single loops can be used to collect volume and lane occupancy, from which speed can be estimated. Speed estimation accuracy improves by using loop signatures.
Inductive Loop (Undercarriage Profile)	Intrusive	Various[a]	1 per set of sensors	Susceptible to damage from ditching, mill, and resurface Lifecycle is affected by extreme heat or freeze-thaw cycles	New technology, not currently in widespread use
Side-Mounted Microwave	Non-intrusive	Length-Based	Multiple	Occlusion	Not as accurate as overhead-mounted, forward-, or rear-facing radar (getting close)
Overhead Microwave	Non-intrusive	Length-Based	1 per sensor	Occlusion	N/A

Technology	Intrusive or Non-intrusive	Types of Vehicle Classifications Collects WIM?	Number of Lanes of Data Collected by Each Sensor	Environmental and Road Maintenance Issues/Concerns	Other Issues/Concerns
Doppler Radar	Non-intrusive	None	Multiple	Occlusion	Generally used only for speed data collection, often not accurate as a volume counting device. Count is not reliable in congested low-speed conditions.
Infrared/Laser	Non-intrusive (transmitter + receptor)	Axle Based (FHWA 13+)	Multiple	Fog and heavy snow often degrade performance	Most common device requires equipment on both sides of the right of way
Magnetometer (3-Axis Flux Gate or Magnetic Imaging)	Intrusive[b]	Length-Based	1 lane	Lifecycle is affected by extreme heat or freeze-thaw cycles	N/A
Video Detection System (Object Analysis)	Non-intrusive	Various[c]	Multiple	Often 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 often affect accuracy	New technology, not currently in widespread use
Acoustic	Non-intrusive	None	1 per pair of sensors	Multiple reflective signals	Must be carefully calibrated
Bending Plate	Intrusive	Axle Based (FHWA 13+) A good WIM sensor	1 per set of sensors	Lifecycle is affected by extreme heat or freeze-thaw cycles	Too expensive unless used as a WIM system
Bridge WIM	Non-intrusive	Axle Based (FHWA 13+) a WIM system	1 per set of sensors	Lifecycle is affected by extreme heat or freeze-thaw cycles	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: Based on 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 exist.

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

2.2.5 Sensor and Equipment Location Considerations

State agencies typically consider “site-centric” or “equipment-centric” approaches for traffic monitoring equipment selection. With the site-centric approach, the count location is more important and selected first, followed by selection of the equipment that works best at the selected location. The competitive bidding is an important part of the equipment procurement process. It is advisable to conduct the site selection first and then use a list of locations in the bidding document to provide opportunities for the bidders to assess site characteristics and propose the equipment that operate successfully under known site conditions.

Oftentimes, it is desirable to have similar equipment installed throughout the State to streamline equipment installation, maintenance, calibration, and operation. With this equipment-centric approach, specific locations are selected along the desired candidate road segments that provide the best data accuracy by addressing the manufacturers’ requirements for equipment’s operating conditions. Note that selecting a single type of equipment or vendor poses a higher cost and additional risk, if the vendor changes equipment, requires upgrades, or goes out of business.

Physical Characteristics of Traffic Monitoring Site Locations

Traffic monitoring systems accurately operate only when the equipment is in a physical environment that meets specific criteria:

- Traffic traveling at a speed that does not change while a vehicle is crossing over a sensor array, not prone to stop-and-go conditions, acceleration, deceleration, lane changes, mergers, frequent vehicle passing in sensor lane (i.e., merge or exit lanes), or weaving maneuvers.
- Access to landline power and communications or adequate solar/wind energy and wireless signal strength. If cellular service is planned, its reliability at site location must be tested. If solar power is planned, conditions for its successful operation should be considered in all seasons (recommended minimum of 7 days of data storage available in the memory)
- Safe pullout and parking area for maintenance truck and safe area for technician to access traffic cabinet and equipment for maintenance. Location of electronics outside the clear zone is a must.
- Cabinet location provides clear view of the sensors and traveling vehicles from the traffic cabinet location to validate and verify equipment is working while on site by visually observing and classifying vehicles passing in the monitoring lane(s).
- Cabinet is in the area with a good drainage and not prone to flooding. Cabinet also provides good views of each roadway lane for viewing traffic for calibration purposes.
- No major road or pavement work during the intended data collection period.
- Pavement in a good condition, free of cracks, rutting, or faulting. Sensors installed as part of pavement rehabilitation projects typically have a longer service life.

The following site conditions should be considered for certain type of sensors or applications:

- Avoid power lines
- Avoid water bodies (to prevent water reflection, only if video monitoring is used)
- Avoid installation of counters that point toward traffic (only for infrared counters)
- Avoid areas where people stop and stand around an area (for pedestrian counts)
- Avoid curves (all sensors) – 5700 ft
- Avoid hills (all sensors) – less than 2 percent grade
- Avoid counting at intersections (all sensors) – within 1200 feet
- Avoid traffic queues in the sensor area, if possible (all sensors)
- Look for locations along the facility where a poll, tree, or other structure might be able to serve as part of the counter installation (short-term counts only)

Non-intrusive sensors come with many of the same requirements as above.

Finally, selecting locations that allow collection of ramp lanes in addition to the mainline lanes reduces the number of separate lane counts. However, consideration should be given to data quality issues of such locations due to the potential for more congested conditions, slower speeds and lane changing within interchange areas.

Additional Considerations for WIM Site Locations

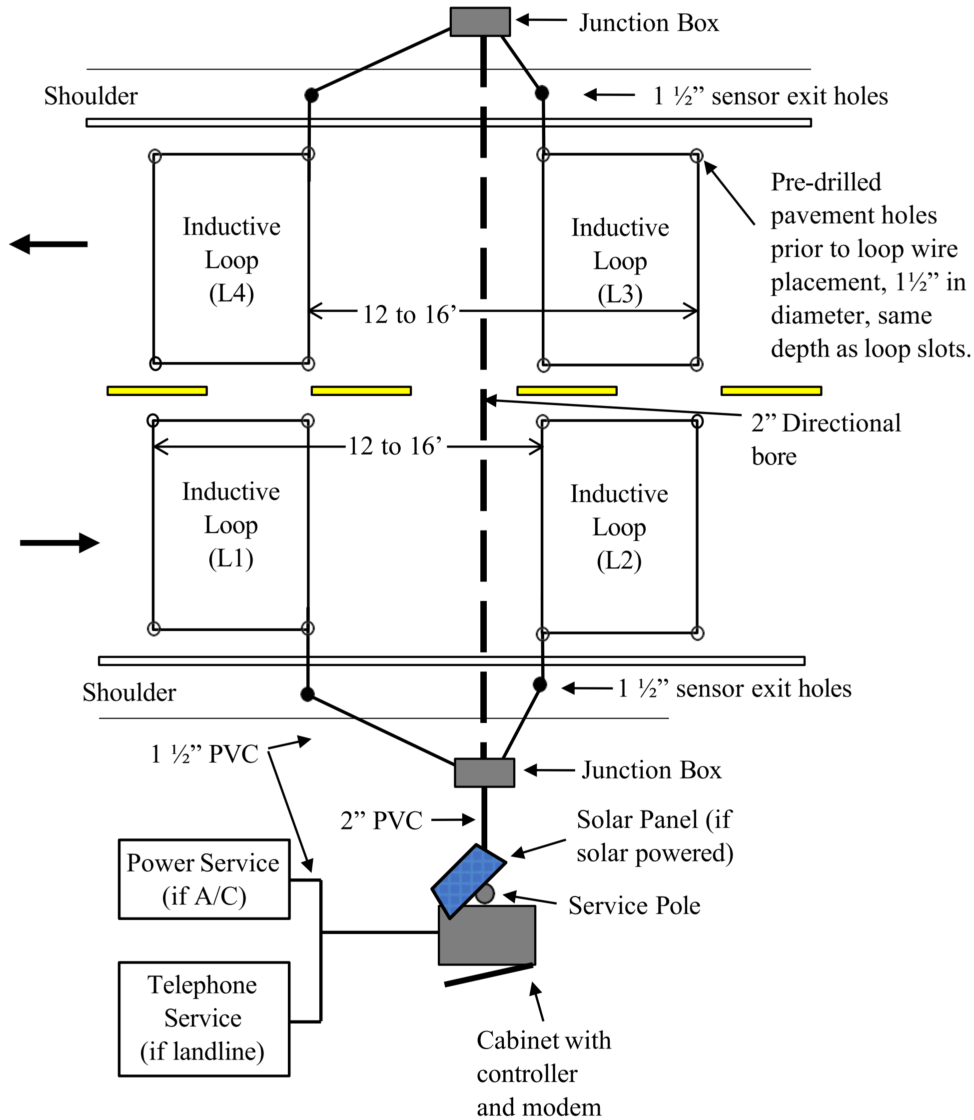
States should place WIM equipment only in pavements that allow for accurate vehicle weighing. An excellent reference for WIM site requirements is *ASTM Standard E-1318-09 Highway Weigh-in-Motion (WIM) Systems with User Requirements and Test Method (ASTM 2017)*. Another excellent source is the *FHWA WIM Pocket Guide (FHWA 2018)*. In addition to general traffic monitoring site characteristics listed in the above section, all WIM sites should have the following characteristics:

- Sufficient truck volumes present on the roadway being monitored.
- Proximity of certified static scales(optional).
- Avoidance of weigh stations or nearby enforcement activities influencing truck composition.
- Straight and flat road segment (in all planes) with cross slope and grade 1% or less and good quality smooth pavement (at least 300 to 400 feet before and 100 feet after the sensor, depending on highway speed); for additional details see *WIM Pocket Guide, Part I* (FHWA 2018).
- Smooth pavement that is in good structural condition with enough strength to adequately support axle weight sensors (it is desirable for the sensor to be installed in the first 1/3 of Asphalt Cement or Portland Cement Concrete layer thickness).
- Pavement should not be scheduled for resurfacing or other maintenance or rehabilitation activity before the end of the expected WIM data collection period.
- The ability to perform calibration of the scales, including a turnaround (one loop of the test vehicle) for test trucks that takes less than 20-30 minutes to complete.
- It is important to have constant vehicle speed for WIM (which limits the use of WIM equipment in many urban and suburban areas where routine congestion occurs) primarily because deceleration and acceleration causes shifts in load from one set of axles to another and creates a dynamic rocking of the vehicle front to back, leading to increased weighing errors.

2.2.6 Sensor Layout and Configuration for Motorized Vehicle Detection

Figure 2-4 through Figure 2-9 provide examples of recommended sensor layouts for intrusive sensors to monitor motorized traffic.

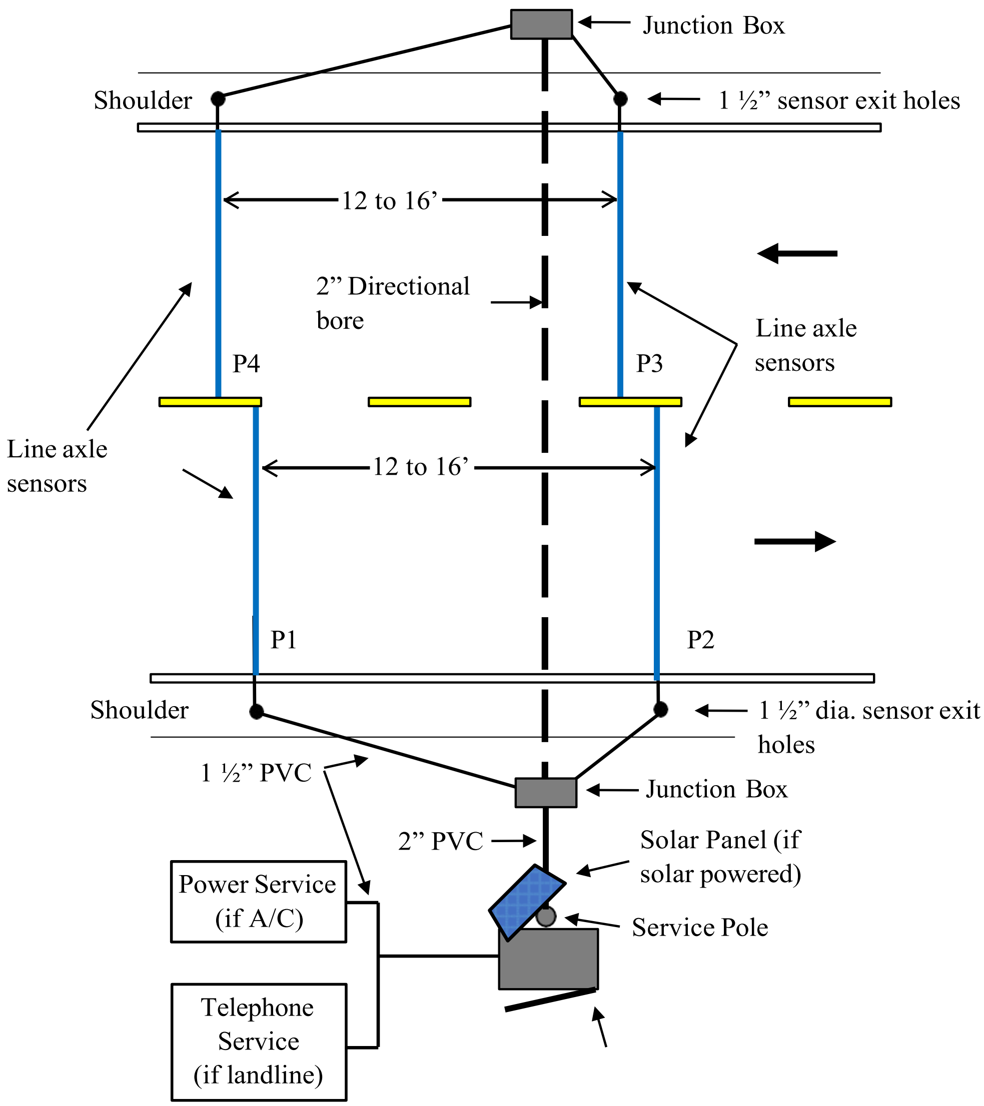
Loop Layout and Configuration



Source: Federal Highway Administration.

Figure 2-4. Example of Loop Sensor Layout

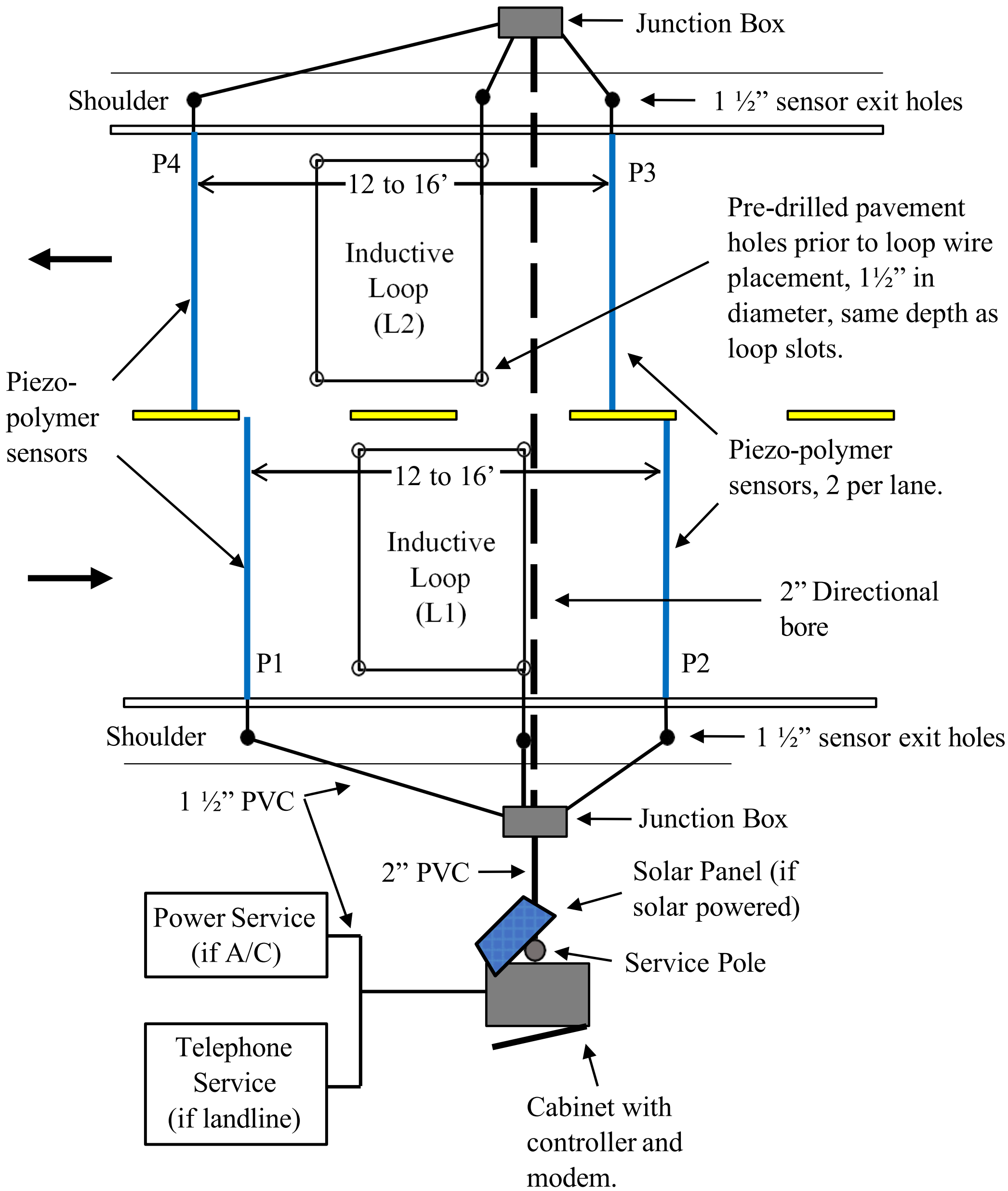
Line Axle Sensor Layout and Configuration



Source: Federal Highway Administration.

Figure 2-5. Example of Piezo Sensor Layout

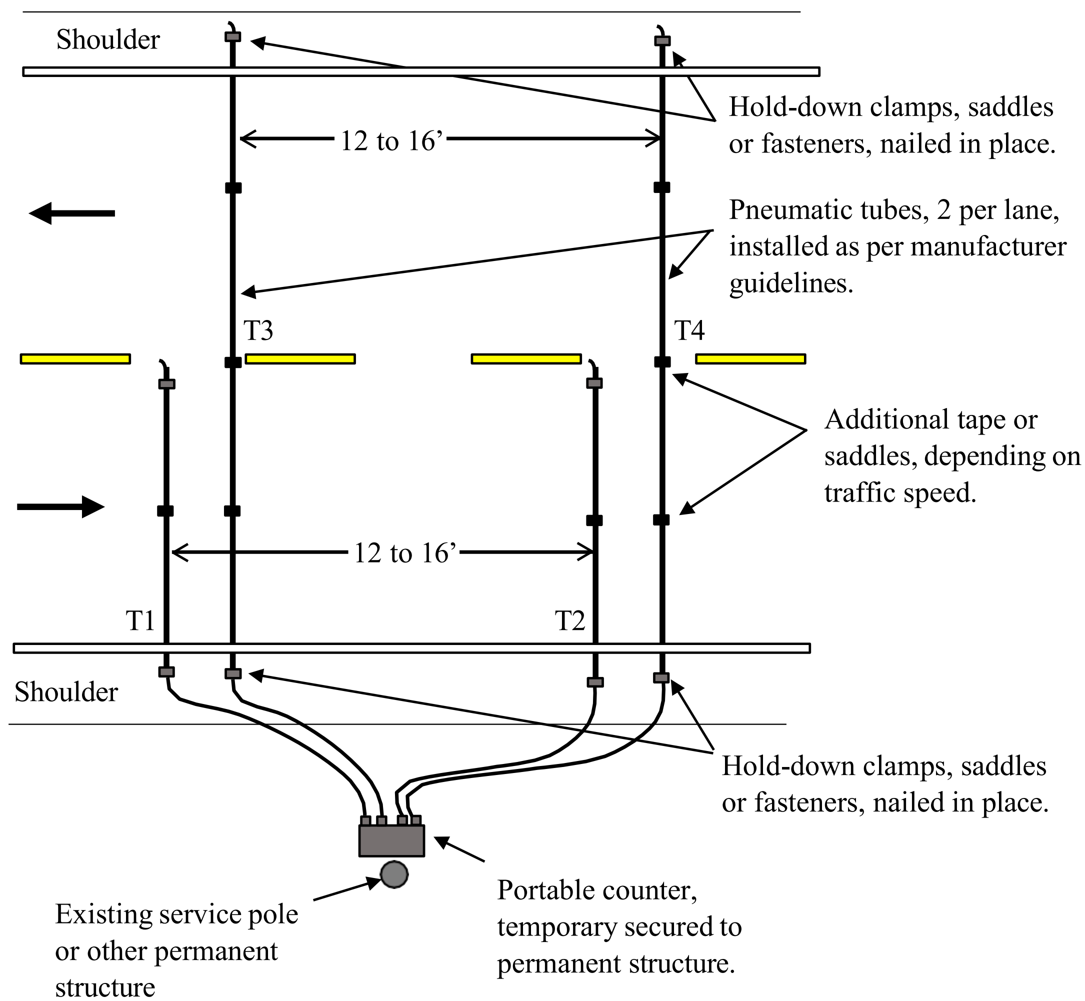
Loop and Piezo Layout and Configuration



Source: Federal Highway Administration.

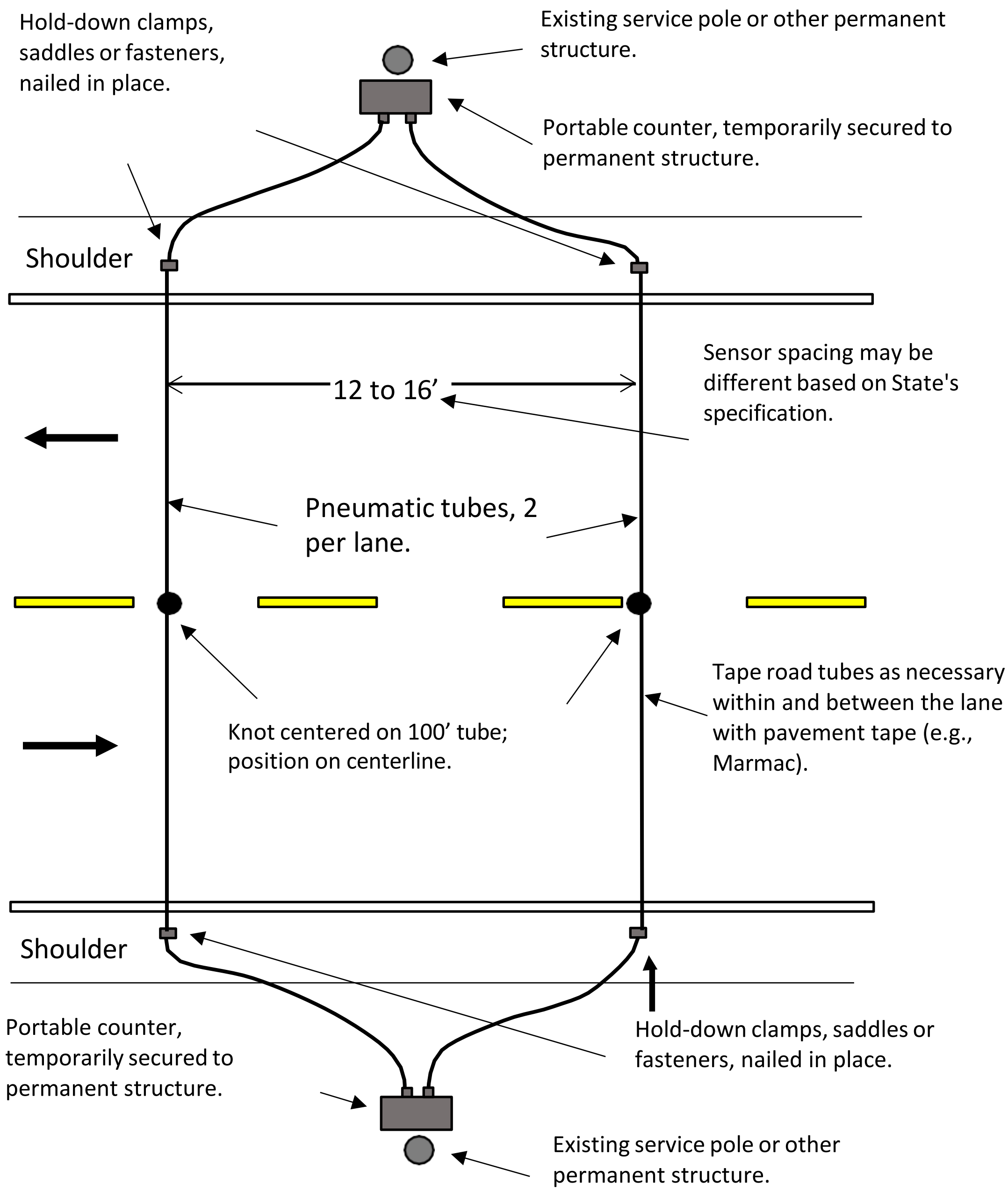
Figure 2-6. Example of Loop and Piezo Sensor Layout

Pneumatic Tube Layout and Configuration



Source: Federal Highway Administration.

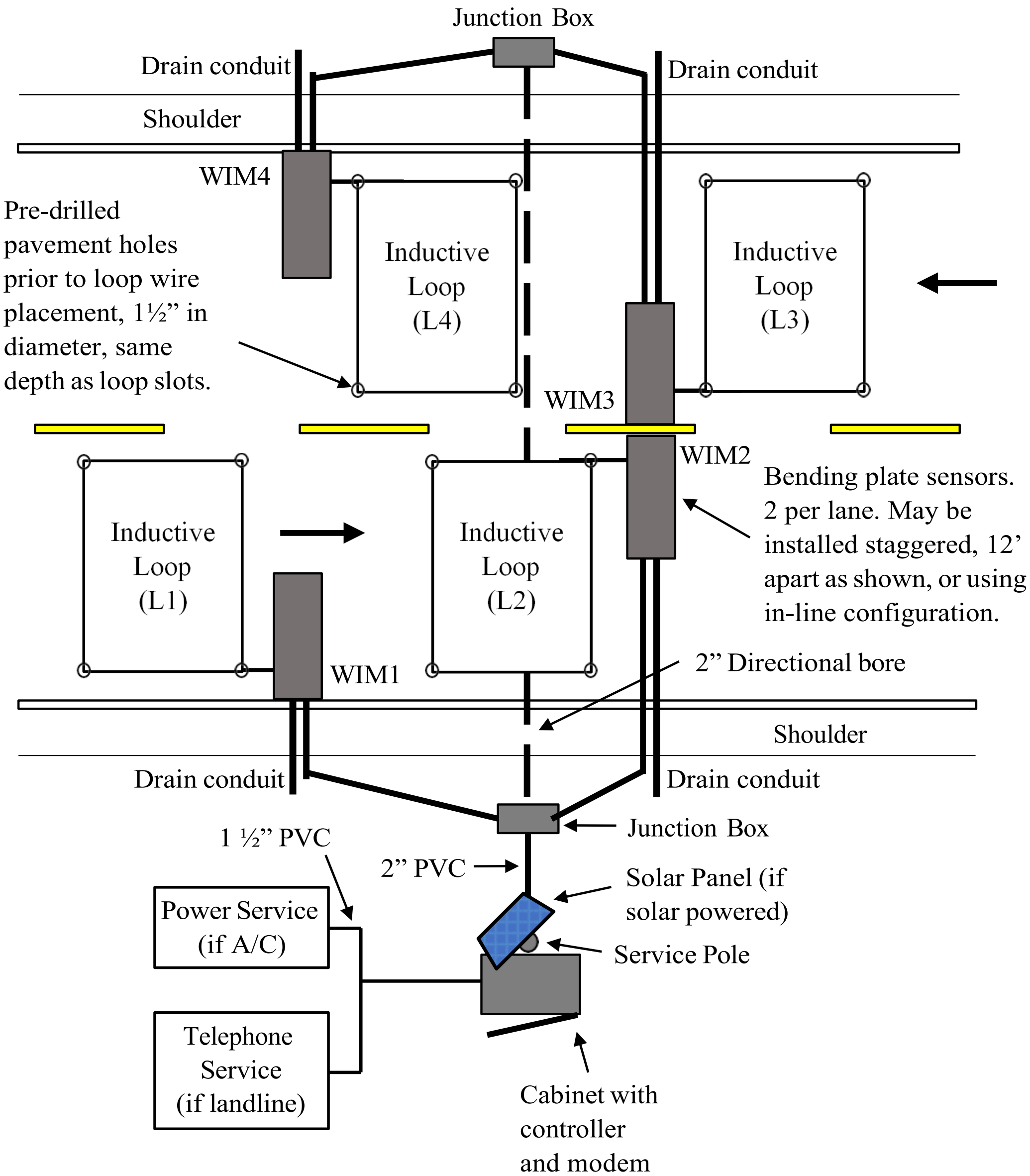
Figure 2-7. Example of Portable Pneumatic Tube Layout



Source: FHWA, adopted from Maine DOT practice.

Figure 2-8. Example of Portable Pneumatic Tube Layout with a Knot and Two Counters

Staggered WIM Sensor Configurations for Plate Sensors (Bending Plate, Load Cell)



Source: Federal Highway Administration.

Figure 2-9. Example of Staggered WIM Sensor Layout for Plate Sensors

2.3 SELECTING MICROMOBILITY COUNTING EQUIPMENT

Proper selection of technologies to count micromobility (i.e., bicyclists, pedestrians, scooters, e-scooters, e-bikes, e-skateboards, hovercrafts, etc.) traffic volumes at fixed locations is an important consideration. This section differentiates between those technologies best suited to count pedestrians versus micro-powered travelers. 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.

2.3.1 CHALLENGES UNIQUE TO MICROMOBILITY COUNTING

Many of the basic technologies for micromobility counting, presented earlier in this chapter in Table 2-4, are similar to those used to count cars and trucks; however, the design/configuration of the sensors and the signal processing methods are often quite different. Therefore, separate equipment typically is used to monitor micromobility. The goal of micromobility counting devices are to accurately count:

1. Pedestrians only
2. Pedestrians and micromobility device users combined
3. Pedestrians and micromobility device users separately

Technological challenges to pedestrians and micromobility device monitoring are as follows:

- micromobility users are less confined to fixed lanes or paths of travel than motor vehicles, and 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 sometimes 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 decrease the accuracy of the sensor equipment.
- micromobility users 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 is counted as one person, and the sensor underestimates the actual counts.

Despite these challenges, several technologies are capable of accurately count micromobility traffic. The growing demand for automatic counters, increased competition in the marketplace, and advancing collective knowledge with existing products have resulted in improvements in equipment accuracy and capabilities.

2.3.2 HOW TO SELECT MICROMOBILITY COUNTING EQUIPMENT TYPE

Commercially available counters use a variety of technologies and features that vary dramatically and affect how, what, where, and how long counts are collected. Even within a specific technology, the accuracy of commercially available products varies significantly based on configuration, installation, and level of use. Cost per data point also varies greatly between counter technologies. Equipment calibration/validation needs must be also considered to ensure that count data are within the bounds of acceptable accuracy. Annual calibration is recommended.

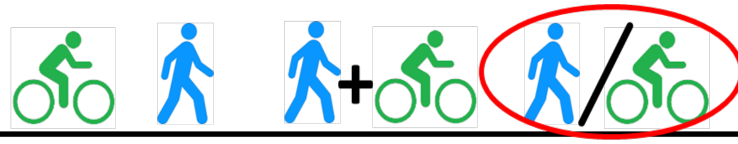
Figure 2-10 presents a simplified flowchart that helps to narrow possible choices based on the two most important aspects of data collection:

1. What are you counting? Only micromobility devices (bicycles, scooters, hoverboards, e-bikes, etc.), only pedestrians, pedestrians and micromobility devices combined, or pedestrians and micromobility devices separately? The *TMG* handles all 4 of these types of counts.
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 desires to count micromobility devices and pedestrians separately on a permanent basis. Using the simplified flowchart in Figure 2-10, the first decision point is “What are you counting?” In this example, the city wants to count both modes separately (note the circled icons in Figure 2-10). 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. Based on budget and commercial availability, a final decision is made about technology to be deployed.

1. What Are You Counting?



2. How Long?	Technology	Miro-Mobility Device Users Only	Pedestrians Only	Pedestrians and Miro-Mobility Device Users Combined	Pedestrians and Micro-Mobility Device Users Separately	Cost
Permanent	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	○	○	○	●	$-$$$
Temporary/ Short Term	Manual Observers	●	●	●	●	$$-$$$

○ 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 2-10. Equipment Selection Process

2.3.3 Sensor Layout and Equipment Set-up

Inductance Loop Detectors for Wheeled Micromobility Counting

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 should 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.

The preferred counting location is where bicycles are free-flowing and/or not likely to stop. Loop detectors for bicycle counting should be placed in lanes primarily used by bicycles. If the loop detectors are placed in lanes shared by motorized traffic and bicycles, special algorithms should be used to distinguish the bicycles from the motorized traffic.

Inductance loop detectors measure the direction of bicyclist travel using at least two possible options:

1. Installing an inductance loop within each directional travel lane and if 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 to infer direction from the timing of detection events for each loop.

The first option is the most used practice to date. For the second option, not all data loggers or controller equipment are 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 2-11). Loop configuration depends on travel behavior and road/trail type.
- 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 should 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 detect bicycles with non-steel frames due to the presence of conductive material in the wheels or other bicycle components.

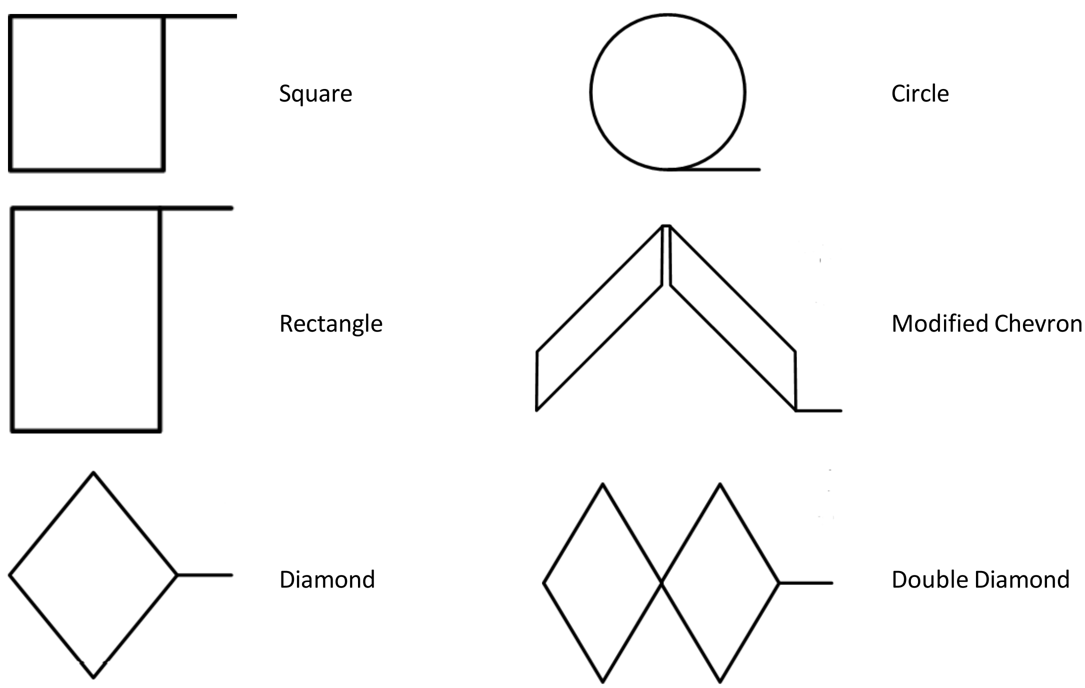


Figure 2-11. Examples of Inductance Loop Detector Shapes for Bicyclist Counting

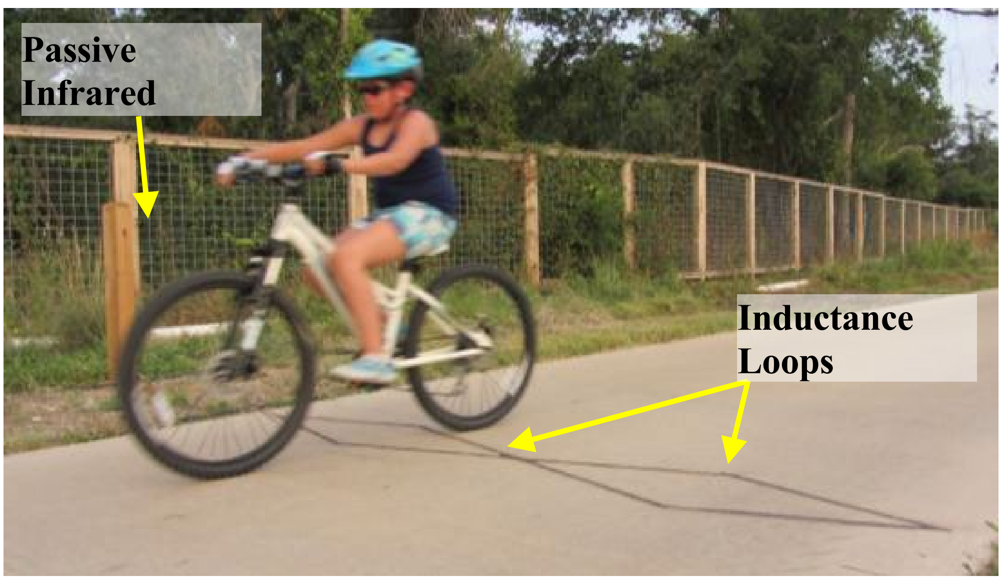
Infrared Sensors

Two types of infrared sensors are used for micromobility detection: active infrared sensors and passive infrared sensors. For portable applications, infrared sensors should 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.

For micromobility counts, infrared sensors are frequently paired with another technology to improve differentiation between multiple persons in a group (i.e., side-by-side or closely spaced front-to-back and between bicyclists and pedestrians. Typical pairings include loops or axle sensors. In addition, use of an overhead gentry makes it easier to detect micromobility users traveling in a group. For example, Figure 2-12 and Figure 2-13 show a permanent monitoring location that combines a passive infrared sensor with inductance loop detectors.

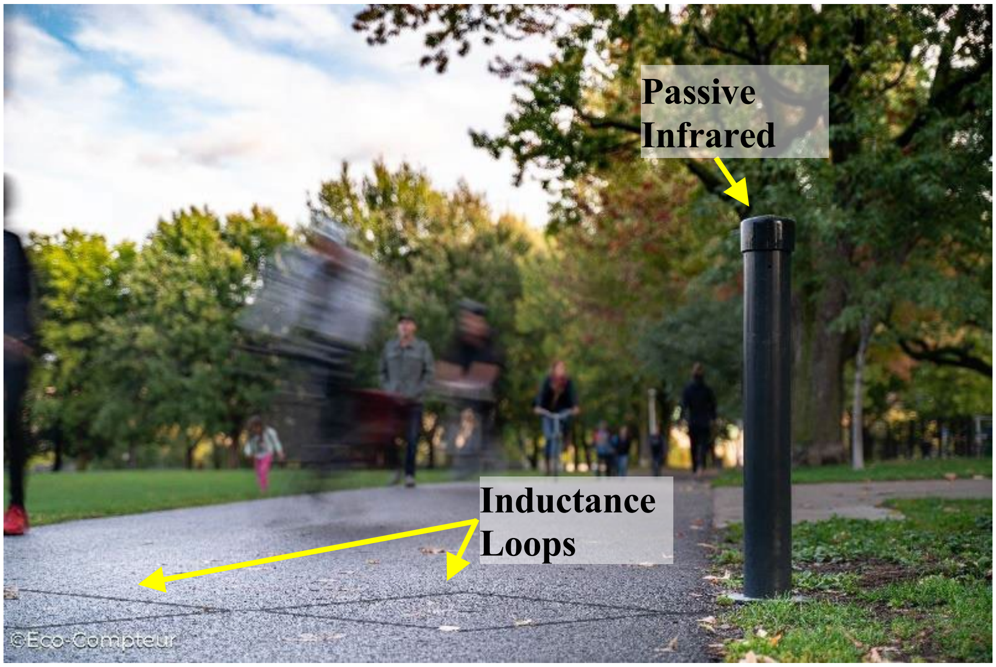
The passive infrared sensors look for heat differentials and their patterns. These sensors have higher error rates when the ambient air temperature approaches normal body temperature (97°-100° Fahrenheit). The error varies among different brands of passive infrared counters.

Figure 2-14 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.



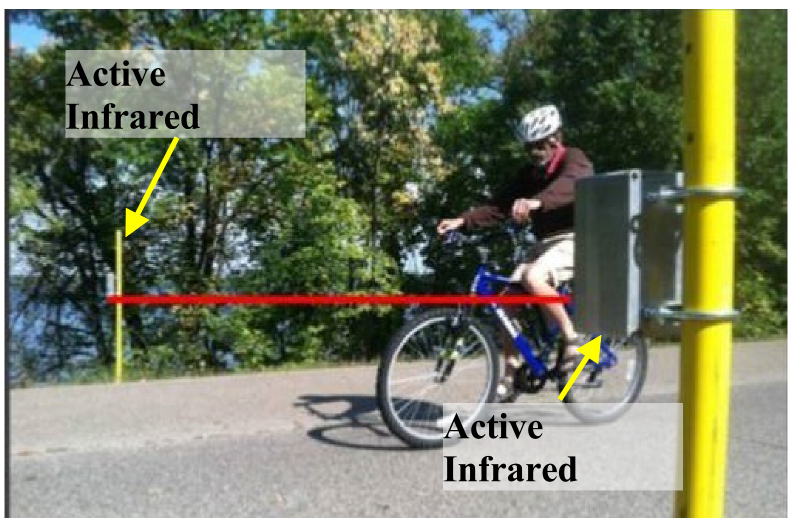
Source: Shawn Turner, TTI.

Figure 2-12. Example a of Passive Infrared Sensor Combined with Inductance Loop Detectors



Source: Louis Queruau, Eco-Counter

Figure 2-13. Example B of Passive Infrared Sensor Combined with Inductance Loop Detectors



Source: Steve Hankey, University of Minnesota (Red horizontal line is provided to visualize the infrared beam.)

Figure 2-14. Typical Configuration for Active Infrared Sensor

Pneumatic Tubes

Pneumatic tubes are a low-cost, portable approach for counting micromobility vehicles (Figure 2-15). The data logger should be set with pre-defined criteria (e.g., axle spacing) and/or algorithms to determine whether a valid vehicle type has passed over the tubes. Pneumatic tubes should be combined with infrared sensors at locations where both bicyclist and pedestrian counts are desired.

Due to their construction (smaller diameter and easier to squeeze due to thinner walls), smaller pneumatic tubes are better at capturing micromobility devices when they are used on dedicated pathways, since they are not also being used to also collect vehicle count data. 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 is 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 should be used (see Figure 2-15), and travel direction should be inferred from the timing of detection events at each tube. For shared roadways with motorized traffic, the classic tube diameter used for detection is 0.50 inches (15mm) and for greenways that do not encounter motorized traffic a thinner, mini-tube is utilized with a diameter of 0.35 inches (9mm).

Source: Louis Queruau, Eco-Counter.

Figure 2-15. Example of Pneumatic Tube Configuration for Counting Directional Bicyclist Traffic

Bicyclist safety is 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. Pneumatic tubes pose a tripping hazard, and it is also known that bikes tend to go around them. Therefore, application of this technology is limited. Usage of this technology is not recommended for bike lanes on shared roadways with cars driving over the tubes and getting counted.

2.3.4 Pressure and Seismic Sensors

Pressure plate 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 nonmotorized wheels. As with other monitoring technologies, pre-defined criteria should be used to determine a valid detection and therefore a valid user to be counted.

Both pressure plate 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 2-16), where burial of the sensor element is typically low-cost and minimally disruptive. However, pressure plate sensors should be used at curbside pedestrian signal waiting areas, as a supplement to or replacement of a pedestrian crosswalk push button.

Some models of pressure plate and seismic sensors are capable of detecting the difference between pedestrians and bicyclists. Placement and size of the pressure plate sensors (also known as pressure mats) is used to gather directional information. When installed properly, pressure and seismic sensors serve as permanent continuous counters.

(a) Pressure sensor on natural surface trail

(b) Pressure sensor on paved surface

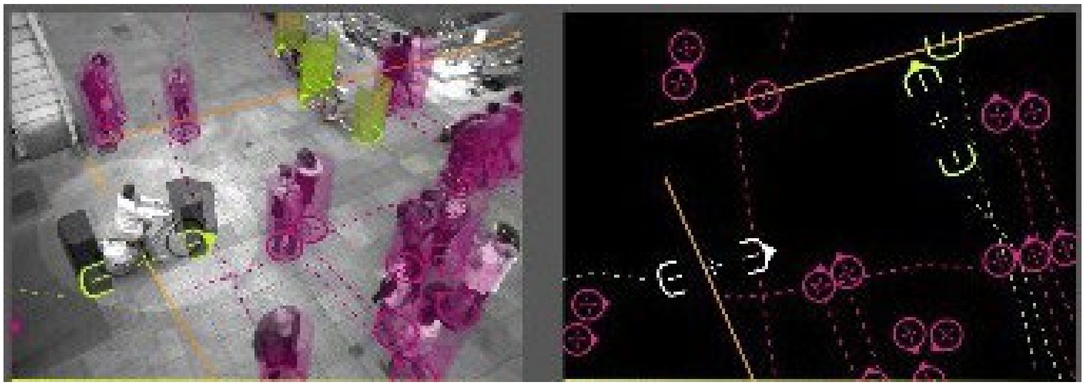
Source: Jean-Francois Rheault, Eco-Counter.

Figure 2-16. Examples of Pressure Sensors on Natural (A) and Paved (B) Surfaces

2.3.5 Video Image Processing

Video image processing operates by using visual pattern recognition algorithms to identify (and sometimes track) a pedestrian or bicyclist traveling through a video camera's field-of-view. Video image processing has the capability to distinguish pedestrians and/or bicyclists traveling in a group or cluster (see Figure 2-17). These capabilities vary, depending on the algorithm implemented in the commercial products. Weather and lighting often reduce the accuracy of this technology. Finally, video image processing typically has the highest equipment costs. This type of sensing technology is rapidly developing, and improvements are being made to overcome bad weather using Lidar. The equipment should be deployed to many more locations, including signalized intersections.

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 it 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. The 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 should be used for quality assurance purposes (i.e., for verification/validation of nearby automated counts).



Source: Louis Queruau, Eco-Counter.

Figure 2-17. Example of Video Capture of Bicycles and Pedestrians

2.4 TRAFFIC MONITORING EQUIPMENT EVALUATION, MAINTENANCE, CALIBRATION, AND QUALITY ASSURANCE CONSIDERATIONS

To assure that the selected equipment performs to the best of its potential and high-quality traffic data are being collected and reported on a continuous basis, the following factors should be carefully and thoroughly addressed: site selection conducive to accurate data collection, use of proven technology, rigorous attention to detail and use of high-quality materials during the installation process, routine equipment maintenance and calibration, and robust data quality assurance process.

2.4.1 Equipment Testing and Technology Evaluation

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 varies 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 produces different results for any given sensor technology is that the data collection electronics and the software that resides in those electronics perform in different ways. (For example, two different video image-counting devices may produce vastly 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 [HCX], and FHWA Long-Term Infrastructure Performance [LTIP]) 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 D.

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.

2.4.2 Equipment Installation, Maintenance, and Operation

Every agency that owns and/or maintains traffic monitoring sites should perform the following tasks to ensure that the equipment they purchase works to the best of its capability:

- The equipment should be tested to assure that it meets the users' data accuracy needs before being placed into service.
- The equipment installation should be inspected by a certified agency's agent to ensure that the equipment is being correctly installed in the field.
- The equipment should be periodically calibrated (annually or per manufacturer's specification).
- The equipment performance should be validated periodically (semiannually or annually) to ensure that it continues to perform as intended and that the performance of the sensors and electronics has not degraded over time due to use and changing environmental conditions.
- The collected data should be routinely subjected to quality assurance tests to identify potential equipment malfunction or degradation.
- 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 are quickly identified by users.
- 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.

2.4.3 Equipment Calibration and Data Monitoring

FHWA recommends annual calibration of all traffic counting equipment for volume counts, classification, weigh-in-motion, volume, speed, and portable hardware.

Calibration ensures that the purchased equipment performs as advertised. Validation checks when equipment is initially installed are an essential first step in that process. After the initial calibration, the equipment should be actively monitored for quality performance, regardless of a vendor's assurances of self-calibration capabilities. The equipment should be periodically calibrated on-site. The FHWA recommends annual calibration of all traffic counting equipment. In addition to on-site calibration, in-office tracking of site information and data comparison and reasonableness checks should occur regularly (daily, monthly, and annually, as needed).

A robust traffic monitoring equipment calibration program should include:

- Implementing software tools that help automate the process.
- Performing daily diligence activities that ensure checking the quality of data as they are collected/processed/stored in the master (centralized or distributed) traffic database.
- Evaluating data using weekly, bi-weekly, monthly, and yearly trends to determine validity and reasonableness (e.g., checking of a specific day like Wednesday each week for trending and issues, making sure the checking is done at the lane level or sensor level).
- Collecting manual counts and comparing counts against portable equipment collected counts.
- Performing field and electronic calibration of classification, weigh-in-motion, volume, speed, and portable hardware annually.

On-site equipment performance validation and 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 identifies 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 result in the collecting, processing, storing, and disseminating of inaccurate traffic statistics. The entire traffic monitoring program credibility is at stake when erroneous data are 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. FHWA's *WIM Pocket Guide* and its Appendix E contain detailed information about WIM equipment calibration. In addition, the *TMG* Appendix D contains compilation of State practices for equipment calibration.

2.4.4 Quality Assurance Considerations

Data collection quality assurance processes should be established and documented to 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.

Once the data have been physically collected, an agency must process (integrate, convert, calculate, QA/QC, store, manage, and provide access, etc.) the data consistently and correctly to convert data into published statistical information. Review of data consistency and data reasonableness should be part of this process, including tests to proactively check for potential equipment issues. Correct and consistent data processing is important for ensuring quality and reliability of AADT estimates. Consistent processes also ensure 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 statistics are being accurately reported and assures decision-makers the data deliverables are appropriate for critical decisions. A compendium of data quality control criteria implemented by State highway agencies is provided in Appendix C.

Chapter 3. METHODOLOGIES FOR TRAFFIC DATA COLLECTION AND PROCESSING

3.1 HOW TO DESIGN A CONTINUOUS COUNT TRAFFIC VOLUME DATA COLLECTION PROGRAM

3.1.1 PURPOSE

The purpose of a continuous traffic volume count program is to collect highly accurate continuous volume data to serve as the foundational temporal dataset for the entire traffic volume data collection program. This program forms the basis for the overall traffic monitoring program and in some States is referred to as the permanent count program. In the *TMG*, the program will be referred to as the continuous count station (CCS) program.

3.1.2 CONTINUOUS COUNT STATION PROGRAM OBJECTIVES (VOLUME)

The objective of the continuous count traffic volume data collection program is to provide travel volume information, including the following traffic data: total volume, volume by direction, lane distribution factors and lane flow rates for lane closure policies, volume by lane by hour, day, month, or year as well as to develop time of day (TOD), day of week (DOW), month of year (MOY) and yearly (YTY) factors to expand short-term traffic volume counts to annual average daily traffic (AADT) volume statistics. This objective is the basis for establishing the number and location of CCSs operated by the State highway agency. Objectives of the continuous count program include the following:

- Provide peak hour, 30th highest hour, and directional distribution data used by travel forecasters and roadway designers
- Track traffic 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 traffic volume sample
- Collect data on roadway sections where it is not possible or prohibitively expensive to collect data with portable counters
- Provide travel statistics for determining historical and current facility usage by travelers, such as the AADT volumes, peak TOD traffic volumes, and traffic volume factors

3.1.3 CONTINUOUS COUNT PROGRAM DESIGN PROCESS (VOLUME)

Each agency develops its own balance between having larger numbers of CCSs (thus, 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.

> The *TMG* recommends that the division responsible for traffic adjustment factor development operates at least the minimum number of continuous count locations needed to meet the accuracy and reliability requirement of the factoring program.

Additional travel and traffic volume 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. 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 these data available to users. Determining how best to obtain, summarize, and report these 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 E and J.

3.1.4 Establishing And Evaluating A Continuous Count Program (VOLUME)

Below is a list of steps that should be followed in establishing and evaluating a continuous count program for statewide traffic monitoring. These steps were designed for (1) developing a new program, and (2) checking and evaluating the existing program to ensure compatibility with the guidance. The results of these steps should be documented to allow for future benchmarking and improvement in the travel monitoring program.

The following steps are primarily focused on the traffic volume program component. Each step is described in detail in the sections following this list.

Continuous Volume Data Program Steps

1. Review Existing Continuous Count Program
    a. Current Program
    b. Traffic Patterns
    c. Data Adjustment
    d. Quality Control
    e. Periodically Review
    f. Summary Statistics
2. Develop Inventory of Available Continuous Count Locations and Equipment
    a. Existing Data Sources for each data type
    b. Other Sources
    c. Data Use
3. Determine the Traffic Time Patterns to be Monitored
    a. Time Patterns
    b. Time of Day (TOD)
    c. Day of Week (DOW)
    d. Month of the Year (MOY)
    e. Year to Year (YTY)
    f. Factor Group Assignment
4. Establish Monthly Pattern Group
    a. Traditional Approach
    b. Cluster Analysis
    c. Volume Factor Groups or other agency specific factor patterns
    d. Recreation Factor Groups
5. Determine the Appropriate Number of Continuous Count Locations
6. Select Specific Count Locations (refer to Chapter 2 to assure that the selected technology or equipment would work in selected locations)
7. Compute Temporal and Axle Correction Factors

3.1.4.1 Step 1: Review the Existing Continuous Count Program

a. Current Program – The first step is to define, analyze, and document the current continuous count program. A clear understanding of the current program, its purpose, and customers 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 are being used, who is using the data.

b. Traffic Patterns – Next, the available data should be reviewed to determine the different temporal traffic patterns that exist in the State and whether previous patterns have changed to establish whether the monitoring process should also change.

c. Data Adjustment – The next step is to review how the data are being adjusted for data discontinuities, and whether those data adjustment steps can be improved or made more efficient. Continuous traffic data are subject to discontinuities because of various reason such equipment malfunctions and sensor recording errors. The way a State identifies and handles errors or anomalies (e.g., due to weather, construction, special events) 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. Truth-in-data implies that agencies maintain a record of how data are collected and adjusted, and that each adjustment has undergone a strong statistically rigorous analysis. The emphasis is on documenting the process and implementing the documented process.

d. Quality Control – 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. Each State highway agency should have formal rules and documented procedures for these important quality control efforts. 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. Periodically Review – The State highway agency should periodically review whether the quality review and data summarization procedures are performed as intended or need to be revised. For States that currently do not have formal quality control procedures, Appendix C 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.

g. Adjustment Factors – The review process should document how the continuous count program is being used to create and apply adjustment factors to short-term traffic counts to estimate AADT, as well as which highway locations require continuous counters because of the importance of tracking volume with a high degree of confidence at those locations. The collection of continuous data to determine AADT should only be necessary at a limited number of locations.

3.1.4.2 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 the continuous count data that are available. 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, the following:

- Continuous classification counters.
- Continuous weigh-in-motion sites.
- Travel and Traffic management systems sites such as ITS Ramp Metering
- Regulatory monitoring sites such as international border crossings and toll plazas.
- National Park Service counters.
- MPO, City, and Town count sites.
- Signalized intersections and ramp metering sites.

b. Other Sources – Posing more challenges are devices operated by other divisions within the State highway agency. Obtaining these data requires internal cooperation within the agency. 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 (such examples are speed signs, toll facilities, ITS data sources, and others). While it may not be possible to obtain this data at the level provided by standard continuous count devices (i.e., hourly or other time increment such as 5, 10, or 15 minute, etc. or records by lane for all days of the year), it is often possible to obtain useful summary statistics such as average daily traffic

(ADT) and weekly, monthly (seasonal) volume patterns from these locations. This 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 the 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 the data can be obtained and integrated.

c. Data Use – Several State DOTs find a data business plan to be a useful tool for documenting the business needs for data and information. 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.

3.1.4.3 Step 3: Determine the Traffic Patterns to Be Monitored

One of the most important tasks of the continuous count program is the monitoring of traffic volume trends and the tracking of temporal patterns around the State. Temporal patterns are used by the agencies to group continuous count sites together for development of traffic volume adjustment factors for factoring data from short-term count sites. Foremost among these trends is the monitoring of AADT at specific highway locations. The FHWA Traffic Monitoring Analysis System (TMAS) is a good source of data to evaluate traffic volume patterns over time, including the following patterns.

a. Time Patterns – Time of Day (TOD), Day of Week (DOW), Month of Year (MOY), and Year to Year (YTY) temporal and recurring event patterns are of great importance in the refinement of the continuous count program, since the effectiveness of the factoring process (and consequently the accuracy of most AADT counts) is a function of the temporal 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 component of the factor review process. Obtaining data from other sources (both volumes and speeds) and integrating the data with existing sources is beneficial for monitoring traffic and congestion patterns for factoring.

b. Time of Day Adjustments – Traffic volume variability by TOD is of great importance. TOD adjustment factors are needed to convert partial day counts to estimates of daily traffic, as well as for studies concerning roadway operations and to compute estimates of delay. FHWA research has shown that including partial day counts (for example more than 48 but less than 72) in the AADT process improves the AADT results.

c. Day of the Week distribution – Volume variation by DOW is related to site location (urban or rural) and the type of travel facility on which observations are made. Agencies would benefit from reviewing DOW traffic patterns to ensure homogenous traffic patterns exist for sites within the same factor group. For more information, see Appendix J that provides typical DOW variation in travel volumes.

d. Monthly Factors – The goal of this review is to assess the degree of monthly variation in traffic volume 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 monthly factors. The review consists of examining the monthly variation (attributed to month of the year or 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 monthly patterns, and whether individual road segments can be correctly assigned to those groups. The review of monthly patterns can be undertaken using one of several analytical tools:

    - Statistical cluster analysis (that can be performed using any one of several major statistical software packages such as SAS or SPSS)
    - Graphical and spatial examination (that uses GIS tools) of seasonal / monthly pattern data from individual sites.

    States use different methods and analytical tools when grouping sites. Appendix J shows several different State practices and their current methods for grouping sites. Another method of reviewing MOY patterns is to visually review data from plotted graphs, making it a simple and easy method to follow. An example of MOY Pattern by the DOW graphs is provided in Figure 3-1. See Appendix J for graphing examples.

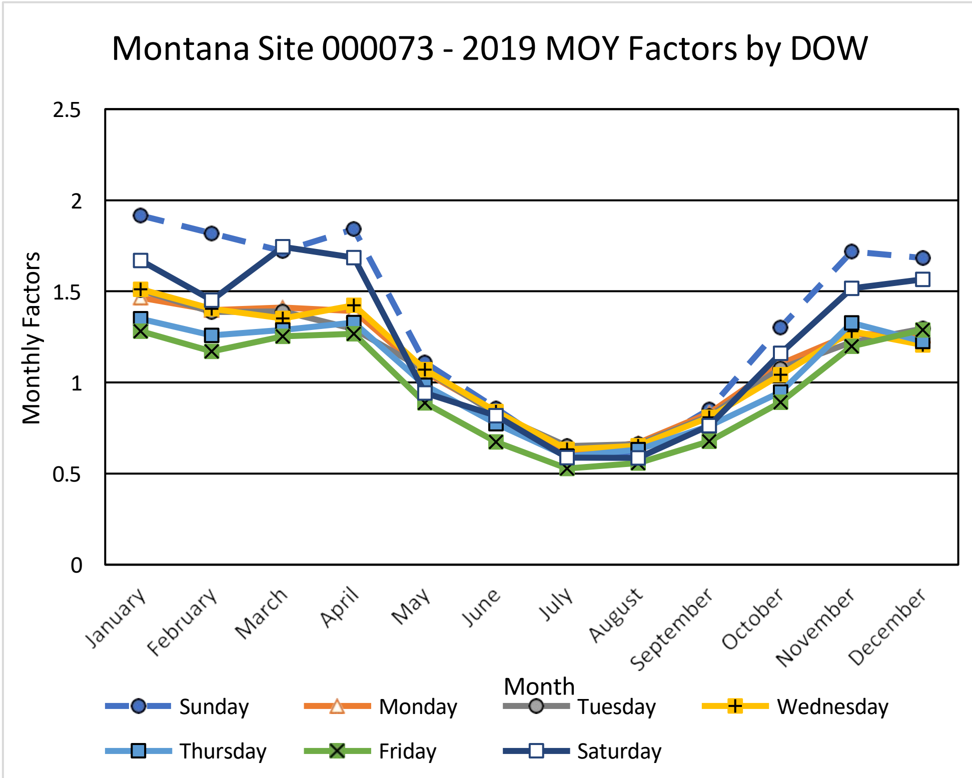


Figure 3-1. Example of Differences in Monthly Travel Patterns By Day of Week in Montana

The review process begins by computing the monthly average daily traffic (MADT) (see Section 3.1.4.7) 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 electronically and printed 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 the continuous count sites that make up each factor group have the same or reasonably similar MOY pattern.

The final 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 travel, and traffic patterns are likely to be reflected in minor changes in the cluster analysis output.

e. Year to Year – Year-to-year comparisons of traffic volumes are also helpful to determine the traffic patterns to be monitored.

f. Factor Group Definition and Assignment – The remaining review step is to make sure that the groups are defined by an easily identifiable characteristic (e.g., site attributes) that allows assignment of each short-term count location to a factor group. The definition of each group must be specific and unambiguous so that analysts can correctly select the appropriate factor for every applicable roadway section. The groups should be defined is such a way that each roadway section can be uniquely assigned to a factor group.

For more details about temporal patterns, see details provided in Section 3.7.1.

Micromobility Traffic Pattern Identification

Like motorized traffic patterns and micromobility data traffic patterns are observed and identified. Traffic data provide patterns that indicate what type of facility usage is currently used such as a facility that has mostly commuters versus recreational traffic. For more information, see Appendix J that provides research findings, example traffic pattern identification graphs, and summarized analyses examples.

> The *TMG* recommends that the division responsible for data collection help data users to track trends and prioritize investments in trail development, safety, and maintenance.

3.1.4.4 Step 4: Establish Temporal Pattern Groups

If the review of factor groups is 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 temporal traffic volume adjustment factor groups can be either the ratio of AADT to MADT, or the ratio of AADT to monthly average weekday traffic (MAWKDT). In many States, there are unique patterns 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 due to the differences in land use, climate, or major industries located in these regions. In addition, for some States clear patterns have failed to emerge.

The three prominent types of analysis to identify factor groups are described as follows. FHWA research "AADT from ADT Duration and Frequency" (FHWA 2014) has found the clustering method to be the most accurate method of the three approaches.

a. Traditional Approach – The more subjective traditional approach to grouping roads and identifying like patterns is based on a general knowledge of the travel patterns for a given road system combined with visual interpretation of the monthly pattern 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 based on some logic/rules defined by the analyst and utilizes known road descriptors. The hypothesis is then tested by examining the variation of the seasonal patterns that occur within these expected groups.

   For example, 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 travel characteristics within the State. Expected revisions include the creation of specific groups of roads that have travel patterns driven by large recreational activities, dominant business activities, or that exhibit strong regional differences.

   Deciding on the appropriate number of factor groups should be based on the actual data analysis results; the analyst's knowledge of specific, relevant conditions; and the desired precision of the traffic estimates. As a general guideline, a minimum of five to six groups is usually needed. More groups may be appropriate if multiple 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 E where the monthly factors (ratio of AADT to MADT) at the continuous count stations are used as the basic input to the statistical procedure. An understanding of the computer software used for statistical clustering procedures is helpful but not required to interpret the software results. 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 identifies 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.

   The cluster analysis procedures have two weaknesses. One is the lack of uniformly agreed upon theoretical guidelines for establishing the optimal number of groups. While a mathematically calculated number of groups can be determined, the optimal number of groups required is hard to quantify and optimization criteria are not well defined. The second weakness in the cluster analysis approach is that the groups that are formed often cannot be adequately defined in terms of common road attributes/characteristics that are readily available to identify the road segments and short-term count locations that should be included in each of the resulting cluster groups.

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 road categories. The interstate system will always be subject to higher data accuracy 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. An example of volume factor groups by aggregated interstate and non-interstate road categories is shown in Table 3-1. The *TMG* recommends these groups to be used as a minimum.

Table 3-1. 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 recreational travel generator(s). 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 is to conduct intercept surveys. 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.

d. Special Considerations for Recreational Roads – Distinct recreational patterns cannot be defined based only on functional class or area boundaries. Recreational patterns are obvious for roads at some locations but nonexistent 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 recreational factor group. 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-term counts based on the judgment and area 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 most 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-term counts will be factored by which continuous count (recreational) location(s). The remaining short-term counts should be assigned based on the groups defined by the State.

FHWA pooled fund study document "*Assessing AADT Accuracy Issues Related to Short-Term Count Durations*" (Krile 2015b) provides the relative accuracy and precision associated with different durations of data collected (example 24 hours versus 48 hours of data). This document also evaluates the impact of day of the week and month of the year for AADT estimation where evaluation results are presented for different factoring methods and different factor grouping methods.

Table 3-2 shows the advantages and disadvantages of different methodologies for development of monthly factor groups.

Table 3-2. Advantages and Disadvantages of Monthly 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 2. Relies on local knowledge and analyst judgment, may be biased
Cluster Analysis* (*FHWA Recommended Method)	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 States 2. The precision of the seasonal factors can be calculated 3. Easier to assign short-term count to a group	1. Functional or road classification may not be based on travel characteristics 2. May not stand statistical scrutiny

3.1.4.5 Step 5: Determine Appropriate Number of Continuous Count Locations

Compute the Statistical Precision of the Factors

The precision of the temporal 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.

In some cases, the mean, standard deviation, and coefficient of variation do not work for the typical factor group listing because the data do not fall within a normal statistical bell-shaped distribution and therefore other methods of computing the statistical precision need to be used to compute the factors.

The mean value for the group is the adjustment factor that should be applied to any short-term count taken on a road section in the group. The standard deviation and coefficient of variation of the factor describe its reliability. The coefficient of variation is a ratio of the standard deviation to the mean value expressed in a percentile form. The precision boundaries with respect to the error in the mean value of the estimate 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.

$$COV = 100\frac{s}{\overline{X}}$$

Where:

COV	=	coefficient of variation
s	=	standard deviation of the factor
$\overline{X}$	=	mean value of a factor

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.

Compute the Number of Sites

After establishing the appropriate temporal factoring groups and allocating 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. Since the existing locations are equivalent to a simple random sample selection, the standard equation for estimating the confidence intervals (i.e., the precision boundaries) can be used.

$$B = \bar{X} \pm t_{1-\frac{\alpha}{2},n-1} \frac{s}{\sqrt{n}}$$

Where:

B	=	upper and lower boundaries of the confidence interval for a composite group factor
$\bar{X}$	=	mean value of a factor
t	=	value of Student's T distribution with $1-\frac{\alpha\alpha}{2}$ level of confidence and n-1 degrees of freedom
n	=	number of continuous count locations used to compute the monthly factor
α	=	alpha level for the selected level of confidence (for 95 percent confidence $\alpha = 1\text{-}0.95$)
s	=	standard deviation of the factor

This formula could be applied to compute factor precision for each month. The formula provides the results in the same units of measure as the factors used to compute mean and standard deviation values.

The results could be used to identify what short-term count months could potentially lead to the highest errors in AADT estimation and eliminate these months from the short-term count schedule. The precision estimation results could also be used to identify months where high variability within the group is observed and to change the grouping of the sites to reduce high variability and improve the precision for certain months.

The above formula can be used to estimate the sample size needed to achieve any desired precision intervals or confidence levels. Specifying the level of precision desired is a trade-off process. 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, the target precision for traffic factors has been plus or minus 10 percent of the mean value. 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 recommended precision (i.e., reliability) levels for the adjustment factors are +/- 10 percent precision with 95 percent confidence for each monthly adjustment factor group, excluding recreational groups where no target precision requirement is specified (under +/-25% is desired).

> For non-recreational roads with moderately stable seasonal traffic volume pattern, typically, **the number of continuous count locations recommended is a minimum of 6 per factor group**, although cases exist where more locations are needed if high traffic variability exists within the factor group.

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.

Select Number of Continuously Counting Sites for Pedestrian and Micromobility Monitoring Program

The micromobility monitoring program is modeled after the motorized traffic monitoring program.

The number of continuous counting sites an agency chooses to invest in is a factor of cost, geographic region, weather, traffic variability, and data sharing opportunities. In general, the number of continuous counting sites required to provide a statistically valid adjustment factors for micromobility monitoring program should follow the best practices and recommendations for the motorized program described in the previous section. It is further recommended that the micromobility program should have at least 5 total continuous counting sites per factor group.

According to the Transportation Research Record paper "*Minimizing Annual Average Daily Nonmotorized Traffic Estimation Errors: How Many Counters Are Needed per Factor Group?"* (NASEM 2019), four or more counters per factor group for bicycle and five or more for pedestrian traffic monitoring are recommended.

The number of sites is driven by: (1) expected standard deviation (or variability) within the group and (2) statistical sampling rules to achieve confidence in computed statistic. A decrease from 6 to 4 sites will result in 50% decrease in statistical measure of precision (or 50% increase in computed expected mean error range) (see values of t-statistic in Figure 3-2 in Section 3.2.6 for 4 and 6 sites).

There are significant differences between micromobility and motorized traffic monitoring. These differences include the number of monitoring sites, the amount of staff to manage the data, and how the data are managed (annual statistics creation and publication). Currently, most micromobility data collection programs have a much smaller number of monitoring locations than motorized vehicle count programs. Because of the smaller number of count stations and the relatively short length of micromobility traveler trips, the potential for determining overall system or network micromobility usage is limited. Without a formal micromobility data collection program, micromobility count locations are often chosen based on highest usage levels and/or a specific project or site need for information such as a strategic area of facility improvement. Establishing a formal micromobility data collection program includes developing standard methods for capturing data that contributes to the entire network or system. This includes following the motorized standard methodologies for selecting sites, purchasing equipment, and analyzing data. For example, one site selection criteria that is established for selecting monitoring sites is a "representative coverage sample" where micromobility sites are selected based on a need for representation of the entire network or system. Without a formal data collection program, limited data are collected with limited resources for specific data or project uses. These limited data collection activities and location samples represent a biased estimate of overall usage and trends for a city or State and are not recommended to be used for network or overall system usage conclusions.

3.1.4.6 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 precision (i.e., 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 may be eliminated. Also, some locations in a given factor group may fall out of the group (change in travel pattern or lack of complete data) for the given year, hence having extras in a group permits these types of small changes. However, it should be noted that additional locations increase the statistical reliability of the data and keeping them for that purpose is recommended. If the surplus is large and the reduction is desired, it should be planned in stages 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 should be carried out by discontinuing locations annually over a period of 3 years. The sample size and precision analysis should be repeated each time prior to the sites being dropped from the group to ensure that the desired precision has been maintained without the data from the sites identified for deletion. Maintaining a few (two to three) additional surplus locations helps supplement the groups and compensate for equipment downtime or missing permanent site data.

Site and location reductions should be carefully considered, including the following:

- 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. Additional locations increase the reliability of the factored data.
- Quality of the traffic data – continuous counter data are subject to many discontinuities due to downtime, which results in missing data, and to the issues of data adjustment and sensor issues.
- Existing locations – available locations from traffic 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.

Micromobility Program Site Distribution

It is critical to understand the travel behaviors and patterns of micromobility travelers to accurately determine where to count. Agencies that are new to micromobility traffic monitoring should follow the method of counting in locations that are most representative of a facility network such as locations that have high, medium, and low volumes and selecting sites that have geographical coverage of the entire network.

For motorized traffic, State DOTs have a short-term data program that provides traffic data for *all* Federal aid roads (spatial coverage) on their State highway system.

The number of short-term count locations for a micromobility program will depend on the available budget and the planned uses of the count data. For most regions getting started with counting micromobility travel, the short-term count program is best developed by working with other key stakeholders interested in collecting and using these data. By discussing needs and budgets, this group can identify and prioritize the special-needs short-term count locations that 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-term 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-term count locations.

The distribution of where to locate continuous counters should include a site selection methodology that is established to determine where an investment in continuous counting equipment is best utilized. Noteworthy practices for selecting sites have been documented and are provided in Appendix H for Nonmotorized Site Selection Methods for Continuous and Short-Term Volume Counting. Agencies should follow these guidelines when determining how many and where to install continuous counting sites.

> As stated in these guidelines, it is recommended that agencies preform a short-term count for at least 2 weeks prior to installing continuous counting equipment to ensure travelers are present on the facility being considered for continuous counting instrumentation.

The reason for collecting a 2-week short-term count prior to installing continuous counting equipment is to ensure travelers are using the facility. It then provides a baseline dataset in which traffic patterns can be evaluated. Evaluating traffic patterns can help to determine if a continuous counter is needed for representation of a traffic volume group such as high, medium, or low volume.

Once general monitoring locations have been identified, the most suitable counter positioning should be determined. It is critical to invest time in the site selection process, as determining where to count is the foundation of a statistically valid micromobility count program. The method for implementing site selection methods can be found in Appendix H – Nonmotorized Site Selection Methods for Continuous and Short-Term Volume Counting

The continuous count locations should provide geographical and volume density representative samples of high, low, and medium volume locations to achieve an overall statistically valid and un-biased estimate of facility usage in a city or statewide geographic region. This also applies to motorized traffic volume data programs.

Micromobility Screen Line (Mid-block) versus Intersection Counts

The two basic location types for nonmotorized traffic monitoring are:

- Screen line counts that are taken at a mid-segment location along a micromobility facility (e.g., sidewalk, bike lane, cycle track, shared-use path).
- Intersection crossing counts that are taken where a micromobility facility crosses another facility of interest.

Screen line (also known as mid-block) counts are typically used to identify general use trends along a facility and are analogous to most short-term 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.

3.1.4.7 Step 7: Compute Temporal Factors

It is critically important to remember AADT statistics represent an estimate of volume. The AADT statistic represents a volume number for any "average" day of a calendar year and is not meant to be a precise number representing the exact number of vehicles on an exact day of the year. Rather, the AADT is an estimate that is significantly influenced by many factors such as (1) duration of count, (2) how well the selected factor represents the monthly and DOW patterns, and (3) traffic volume variability at the site, etc. Generally, for high-quality installation and optimal counting of selected sites, AADT is known to be accurate within count tolerances and bias for traffic volumes on any given day in the published AADT calendar year. AADTs based on short-term counts are calculated by applying adjustment factors to further advance the accuracy of the AADT statistic. FHWA provides a Reference Accuracy table as guidance on calculating AADTs (Table 3-3), which is based on the work performed in the "AADT from ADT Duration and Frequency" pooled fund study (FHWA 2014).

Table 3-3. Reference Accuracy and Precision for AADT Estimates

AADT Volume Range	Minimally 95% Probability, TCE Median Error (Bias) (%)	Minimally 95% Probability, 95% TCE Median Error Range (%)
500 - 4,999 (low)	+/- 2.0	+/- 34.0
5,000 – 54,999 (medium)	+/- 1.5	+/- 28.0
55,000+ (high)	+/- 2.5	+/- 28.0

*TCE – Traffic Count Estimate

a. Select computational approach and temporal dataset. Temporary factors can be developed in one of three ways:
   - Computing using this year's factors.
   - Computing a monthly rolling average (for example, the temporary July 2021 factor would be computed as the factor for the 12 consecutive months from August 2020 through July 2021).
   - Applying last year's factors (if no other options are available).

The first of these approaches is best because it utilizes those values for factoring most closely related to the calendar year the count was taken. The second approach produces the timeliest adjustment factor but also requires the most labor-intensive data handling and processing effort (see Appendix D for an example of computing monthly rolling average). The last of these approaches is the easiest but also the least accurate, because the effects of this and last year's economic/environmental conditions are likely to be different.

The procedures for developing and using monthly factors to adjust short-term volume counts to produce AADT estimates are based on the structure of the traffic monitoring program. The method used should be detailed in the Traffic Monitoring System (TMS) documentation that States keep on record with the local FHWA Division office and update every 3 to 5 years.

MOY and DOW factors are most accurately developed and applied on a year-by-year basis. That is, a short-term count taken in 2019 should be adjusted with factors developed exclusively from continuous count data collected in 2019. This allows the adjustment process to account for economic and environmental conditions that occurred in the same year the short-term count was taken.

This recommendation creates challenges for the timing of factor computation and application. That is, if a short-term 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.

b. Identify statistical parameters necessary for factor computation. The monthly individual 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 / MAWKDT). This term, or a similar monthly or time of day adjustment, can be substituted directly for the ratio of AADT / MADT in the factor grouping and application process if desired.

c. Compute AADT, MADT, and MAWKDT for CCSs included in the factor group. For a counter site that operates 365 days per year without failure, the AADT can be computed by adding all 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 AASHTO AADT formula was first developed over 30 years ago and computes an average daily traffic volume for each of seven DOW for each month and then computes an annual average value from those monthly averages, before finally computing a single annual average daily value (*AASHTO Traffic Data Programs Guidance Book, 2009*). 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 calculation of MADT using AASHTO method is similar to that of AADT. An average DOW traffic volume is first computed for a given month, and then all seven-day values are averaged to obtain MADT value. MAWKDT is similarly computed using average weekday (i.e., working day) values. However, each State can define the specific days present in the MAWKDT calculation. For example, some States do not count Fridays for routine short-term traffic counts and therefore choose not to include Fridays in the computation of MAWKDT.

Since 2016, FHWA has recommended the use of this new AADT procedure.

FHWA recommended procedures for AADT and MADT computation are documented in *Assessing Accuracy Issues with Current Known Methods in AADT Estimation from Continuous Traffic Monitoring Data* (Krile 2015a). The FHWA method produces statistically significant better results and improved AADT estimates. The new

FHWA procedure has several improvements over the above AASHTO procedure, including that it specifically incorporates all valid temporal data records (i.e., volume records for time periods of less than one full day, such as hourly, 5-minute or any time increment count records). This procedure corrects mathematical flaws that exist in the AASHTO AADT computation that slightly undervalue both weekday volumes over the course of a year and the traffic occurring in months of the year with 30 or 31 days. Finally, this method allows for datasets like ITS data that may be valid data but contains missing time increments to be utilized to obtain valid MADT and AADT values from such sources as signalized intersection and ITS archives.

The FHWA procedure first computes monthly average daily traffic, while retaining all valid temporal traffic records (even valid partial day counts) and accounting for the actual number of each day of the week in that month for that year. (That is, in some years, January has five Mondays, and in other years it has four Mondays. This approach specifically takes the number of Mondays into account when computing MADT.) The procedure then averages the 12 monthly values, while accounting for the number of days in each month. The recommended procedure is expressed mathematically below:

$$MADT_m = \frac{\sum_{j=1}^{7} w_{jm} \sum_{h=1}^{24} \left[\frac{1}{n_{hjm}} \sum_{i=1}^{n_{hjm}} VOL_{ihjm} \right]}{\sum_{j=1}^{7} w_{jm}}$$

$$AADT = \frac{\sum_{m=1}^{12} d_m * MADT_{HPm}}{\sum_{m=1}^{12} d_m}$$

Where:

AADT = annual average daily traffic

$MADT_{HPm}$ = monthly average daily traffic for month m

VOL_{ihjm} = total traffic volume for *i*th occurrence of the *h*th hour of day within *j*th day of week during the *m*th month

i = occurrence of a particular hour of day within a particular day of the week in a particular month (i=1,…n_{hjm}) for which traffic volume is available

h = hour of the day (h=1,2,…24) – or other temporal interval

j = day of the week (j=1,2,…7)

m = month (m=1,…12)

n_{hjm} = the number of times the *h*th hour of day within the *j*th day of week during the *m*th month has available traffic volume (n_{hjm} ranges from 1 to 5 depending on hour of day, day of week, month, and data availability)

w_{jm} = the weighting for the number of times the *j*th day of week occurs during the *m*th month (either 4 of 5); the sum of the weights in the denominator is the number of calendar days in the month (i.e., 28, 29, 30, or 31)

d_m = the weighting for the number of days (i.e., 28, 29, 30, or 31) for the *m*th month in the particular year

d. Compute monthly factors for CCSs included in the factor group. Monthly factors for each CCS are computed by the ratio of AADT to MADT or AADT to MAWKDT. These computations are done for each of the 12 calendar months.

e. Compute monthly factors for the factor group. Group monthly factors are computed as the average of the factors for all continuous count sites within the group. These computations are done separately for each of the 12 calendar months. Both the individual continuous count and the group factors should be made available to users in tabular and computer-accessible form.

3.2 HOW TO DESIGN A VEHICLE CLASSIFICATION COUNT (AXLE AND LENGTH) DATA PROGRAM

3.2.1 PROGRAM DESIGN PROCESS OVERVIEW

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 traffic volume count program.

In addition, factoring of vehicle classification counts (i.e., motorcycle and heavy vehicle volume counts) should be performed independently from the process used to compute AADT from short-term volume counts.

Highway agencies should collect classification data (which also supply total volume information) in place of simple volume counts whenever possible.

The general steps required to develop a statewide vehicle classification count program are similar to the volume count program steps presented in Section 3.1. The general continuous count program design guidelines outlined in Section 3.1 also apply to vehicle classification continuous count station program. In addition to these guidelines, the vehicle classification count program design also includes traffic volume patterns by vehicle class review process focused on (1) identifying unique traffic patterns for each major class of vehicle in the State, (2) evaluating if the previously identified patterns have changed, and (3) determining whether the monitoring process should be adjusted. Distributions of vehicle volume by vehicle class should be analyzed and distribution patterns identified for different road types.

The specific guidance for executing vehicle classification count program design steps is provided in the ensuing sections.

Duration of Short Counts

Vehicle classification counts should be a minimum of 48 hours of continuous data. Vehicle counts longer than 48 hours are useful, particularly when those counts extend over the weekend, since they provide more comprehensive volume by vehicle class information by DOW. However, in some locations it is difficult to keep portable axle sensors in place for periods that significantly exceed 48 hours.

> Longer duration counts from 72 hours to 7 days are encouraged and recommended whenever possible. One advantage to a 7-day duration of a short-term count is no DOW factor needs to be applied to annualize the short-term count to an AADT count program.

Other count durations can produce reasonable results in some cases but are not recommended for general use. Equipment that can collect data in time increment (such as 15-minute, hourly, etc.) 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.
- Longevity of the sensors/road tube and equipment has improved to provide longer-duration counts.

According to the *HPMS Field Manual (FHWA 2016)*, "For HPMS reporting, States are permitted to perform counting using durations shorter than 48 hours for roadway functional classes arterial and interstate. For functional classes of collector and local roadways, if a State has a monitoring duration that is less than 48 hours, they must be able to demonstrate no loss in data quality based on documented statistical analysis provided to FHWA's Office of Highway Policy Information via FHWA's Division Office located in their respective States.

Also, for 48-hour counts (two full 24-hour days) are required for all HPMS full extent and sample data including those off the State highway system except where otherwise noted. Where axle correction factors are needed to adjust raw counts, they should be derived from facility-specific vehicle classification or weigh-in-motion (WIM) data obtained on the same route or on a similar route with similar traffic in the same area. Factors that purport to account for suspected machine error in high traffic volume situations shall not be applied to traffic counts used for HPMS purposes, including volume group assignment. In high volume situations and on controlled access facilities, it may be more appropriate to use continuous or short-term ramp counts in conjunction with strategic mainline monitoring than to use short-term counts on all mainline locations (see "ramp balancing" for details)."

3.2.2 Step 1: Review the Existing Continuous Vehicle Classification Count Program

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

Four primary reasons for installing and operating permanent vehicle classifiers for continuous traffic monitoring purposes include the ability to:

a. Provide a highly accurate measure of traffic volume by vehicle class at a limited number of specific sites around the State.

b. Track the changes in those volumes over time with a high degree of accuracy.

c. Determine the temporal patterns (TOD, DOW, MOY) of different vehicle types on different roadways across the State; (if per vehicle data is stored, CVCs can provide axle correction factor data) (see Section 3.7.1 for more detail).

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

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

Highway agencies should check the accuracy of their vehicle classification data collection and take appropriate actions to assure that their vendor-specific classification algorithms correctly classify all vehicle types on their roadways (within 10% of the counting tolerances, bias, and error by class).

The inventory process should document whether and how the continuous vehicle classification program is being used to create and apply adjustment factors to short-term 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. Another item to check: are the CVC classification methods the same as the ones implemented in short-term counting equipment?

3.2.4 Step 3: Determine the Traffic Patterns to Be Monitored

If sufficient data are available, they should be evaluated to determine what unique traffic volume patterns exist for each different class 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 of the above classes of vehicles may be included in one set of factors when these vehicles can be shown to have similar travel patterns.

The review of temporal patterns can be undertaken using one of several analytical methods described in Section 3.2.5.

The intent of the temporal pattern review is to assess the degree of temporal variation that exists in the State as measured by the existing vehicle classification data program and to examine the validity of the existing factor grouping procedures that produce the appropriate temporal factors. If sufficient data are available, they should be evaluated to determine what unique travel and traffic patterns exist for each of the different classes of vehicles.

The review consists of examining the monthly, DOW, and TOD variation in vehicle traffic volume for each class of vehicles (at a minimum for MC, PV, BS, LT, SU, and CU) at the existing vehicle classification locations, followed by a review of how roads are grouped based on common patterns of DOW and monthly variation.

3.2.5 Step 4: Establish Monthly Pattern Groups

3.2.5.1 Understand Differences in Travel Patterns for Different Vehicle Classes

Previous studies have shown that the 6 vehicle types listed above (MC, PV, BS, LT, SU and CU) are likely to have unique TOD, DOW, and monthly (seasonal) patterns (and the corresponding adjustment factors).

Continuously operating classification counters are needed to monitor these travel patterns so that these patterns can be detected and accounted for in the monthly adjustment factors and to support engineering and planning analyses. For example, if the large increases in weekend motorcycle travel are not accounted for, short-term classification counts will significantly underestimate the number of miles traveled annually on motorcycles, thus biasing national and State safety analyses. This effect is even more important due to most short-term class counts taking place on a Monday thru Thursday days of the week and most motorcycle travel takes place on a Friday thru Sunday days of the week.

3.2.5.2 Vehicle Classes Used for Factoring

Regardless of the approach taken for the computation and application of truck volume by class seasonal adjustment factors, **it is recommended that adjustment factors be computed for six generalized HPMS vehicle classes** (see VM-1 and HPMS Summary types listed in Table 3-4).

Table 3-4 maps the six-vehicle class groupings used in one of the HPMS data sets to the FHWA 13-vehicle category classes:

Table 3-4. 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 121” (PV)	2
Group 3: Light trucks over 121” (LT)	3
Group 4: Buses (BS)	4
Group 5: Single-unit vehicles (SU)	5,6,7
Group 6: Combination-unit vehicles (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 show similar patterns, the passenger car and light truck categories can be combined into one set of factor groups.)

Several reasons support these recommendations. There is known to be more variability in the data for lower-volume roadways. 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-vehicle classes (illustrated in Appendix A) will have mathematically unstable patterns simply because their volumes are low.

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.

The *HPMS* reports data for six aggregated vehicle classes. This aggregated vehicle classification reporting eliminates the issue with underrepresented and unstable low volume vehicle classes. Therefore, the *HPMS* 6 vehicle classification groups are recommended for factor development, unless some of the vehicle types included in the *HPMS* aggregated classes have large volumes and different travel patterns than other vehicles included in that aggregated vehicle class.

Micromobility Classes for Factoring

Classifying micromobility travelers is a relatively new and emerging process, as monitoring and detection equipment continues to be improved and adapted to capturing total volumes of these travelers. Two clearly defined classes are micromobility device users. Future classifications of micromobility devices are likely to include bicycle, pedestrian, hoverboards, e-scooters, and other electronically powered vehicles. See Chapter 2 for more details on equipment and Chapter 6 for more information on future third-party data sources that might provide micromobility use datasets.

3.2.5.3 Select Factoring Methodology

The following two recommended factoring procedures both have advantages and disadvantages. Both are complementary and can be combined as appropriate. 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 adjustment factors for each of the groups. There are multiple approaches that can be used for road grouping that are discussed in more details later in this section. States are encouraged to use the presented alternative factor procedures or develop other alternatives that effectively remove temporal bias.

Either applying factors to a road or assigning road segments into groups involves making decisions to resolve issues. 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 complexity in the approach to remove temporal bias.

Two basic elements to the factor development process are the computation of the factors to apply to the short-term 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 Factor Approach

One option is the process implemented by the Virginia Department of Transportation (VDOT). VDOT operates continuous counters on all major roads, and the counters are used to develop road-specific factors. A short-term 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 many 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-term 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. 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 CVC counters are installed.

A second disadvantage is that many roads are quite long and the travel characteristics of any given type of vehicle traffic over their length can change significantly. An adjustment factor taken on a road segment may not be applicable to another segment a few (two to three) miles down the road if a significant vehicle generation activity takes place along that stretch of roadway. When these factors are applied to count locations that are further away from the continuous counter, the potential for error increases and the precision of the estimate diminishes. Traffic patterns change because of economic activity, traffic generators, or road junctions. Caution is recommended when significant traffic generators in the intervening space between the count and the continuous counter exist. Not only does this further increase the number of continuous counters required, but it also creates difficulty in selecting between the two continuous classification counters when a short-term count falls in between.

The high cost may be mitigated by using road-specific factors 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.

Alternative #2: The Traditional Factor Approach

The traditional factor process involves categorizing roads that have similar traffic patterns for all six HPMS vehicle classes. A sample of data collection sites is then selected from within each group of roads, and factors are computed for each of the CVC data collection sites within a group and then averaged for the 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.

The truck travel patterns appear to be governed by the amount of long-distance through-truck 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 factor groups. Developing this understanding requires analysis of the existing continuous vehicle classification data already being collected by the State within the context of the commodity movements and economic activity happening in the State. The steps required to gain this understanding are described below.

Several 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 analytical statistical tools, an examination of all the truck classes used, and the comparison of statistical reliability for the different types of statistics produced, with the users' need for those reliability 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 these simplifications, trade-offs are necessary. No designated 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.

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 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. If a road group has a significant presence of motorcycles, buses, and/or recreational vehicles (typically recreational roads), the road grouping process should focus on temporal similarities in travel for these vehicle types.

3.2.5.4 Create Initial Factor Groups (Traditional Approach)

The creation and application of adjustment factor groups (TOD, DOW, and MOY) by class of vehicle is a topic that is still new. Some State DOTs have yet to develop these factoring procedures, and considerable research still needs to be accomplished. Several methods can be used to create factor groups using the traditional approach, including knowledge-based grouping, statistical clustering, area of influence, and a hybrid approach that combines methods.

Knowledge-Based Grouping

States should use the available classification data and knowledge to begin the development of traffic patterns. Traffic patterns are governed by a combination of local service activity, local economic activity, local freight movements, and through-truck movements. Extensive passenger vehicle and truck through-traffic movements are likely to result in higher night passenger vehicles and truck travel and higher weekend passenger vehicles and truck travel. Through-traffic can flatten the monthly fluctuations present on some roads and create monthly patterns 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 urban 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 an insufficient 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 or the transportation planning and land development offices. The truck volume data patterns, especially TOD patterns from short-term 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-term 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 show large monthly changes (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.

An understanding of the commodity flow within the State is important for road grouping process. Specific commodities tend to be carried by specific types of heavy vehicles (trucks). Understanding the types of heavy vehicles typically 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) within the State.

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 3-5. However, the two keys to the creation of groups are that (1) the data should show that traffic patterns within grouped sites are in fact similar, and (2) those groups should be designed in such a manner that short-term 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 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.

Table 3-5. Example Classification 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 unrestricted truck routes	Other unrestricted truck routes
Other rural roads (e.g., mining areas, agricultural, weather, mountain/coastal, geographic area)	Other roads (non-truck routes)
Special cases (e.g., roads primarily used for recreational travel, roads serving ports, etc.)	

Grouping Using Cluster Analysis

Performing a statistical cluster analysis using truck volumes by vehicle class (as illustrated in Section 3.1.4 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 how many groups are needed.

Grouping Using Hybrid Approach

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 3-5 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 hybrid approach that combines the statistical methods and knowledge-based assignments provides a good way to establish the appropriate groups.

3.2.6 Step 5. Develop Monthly Factors

All roads within the defined factor group should have similar types of vehicle volume by class patterns. To verify this condition, the continuous counter data available within the group should be used to compute the temporal adjustment factors of interest (TOD, DOW, MOY, or combined) for each of the vehicle types desired, and then compute the mean and standard deviation for the group as a whole. Visual assessment of the TOD, DOW, and MOY factor plots can also help to determine whether the travel patterns at the continuous sites are reasonably similar.

The assumptions and computation of the adjustment factors by vehicle class is similar to AADT factors. An example of a combined monthly and weekday factor computation for a vehicle classification site is shown below.

$$Adjustment\ Factor_{C,\ June} = AADTT_C / MAWKDTT_{C,\ June}$$

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 for a vehicle type C

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

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

This formulation assumes a multiplicative application of the computed adjustment factor. $AADTT_c$ is equal to the average 24-hour count for vehicle class *c* times the adjustment factor. Many States use the inverse of the above formula and apply the resulting factor by dividing the average 24-hour volume obtained from their short-term count by the adjustment factor. The example in Table 3-6 demonstrates factors computed for a single month and shows how these monthly adjustment factors differ by vehicle class.

Table 3-6. Example of Monthly Factors by Vehicle Class at a Single Site

Measurement	Motorcycles	Car and Light Trucks	Buses	Single-Unit Trucks	Combination Trucks	Total Volume
MADTc	35	4,874	52	227	1,639	6,826
AADTc	33	5,499	57	288	1,653	7,530
Monthly Factor (AADTc/MADTc)	0.95	1.13	1.10	1.27	1.01	1.10

Computing the mean (or average) for the monthly (e.g., June) factor using data from all sites within the factor group yields the group factor for application to all short-term counts (e.g., 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 compute the precision of the group factor and to estimate the number of continuous classification counter locations needed.

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.

3.2.6.1 Test the Quality of the Selected Groups

The information on estimated precision of group factors must be reviewed to determine whether the roads grouped together have similar individual vehicle travel patterns.

The trade-offs between alternative factor groups should be evaluated considering the value of the precision of each statistic to the data user. 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. 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 (for example, the 95% confidence interval is within +/- 10% of the mean value of each monthly factor), the roads can be considered to have similar characteristics. If the standard deviations are large, the road groupings may need to be revised.

There can be cases where the factors will not improve the annual volume estimates, particularly in high vehicle volume variability situations. An alternative is to take multiple site-specific classification counts at different times during the year to measure monthly changes and develop annual estimate. This can be an effective way to estimate annual traffic volume for individual vehicle classes more accurately for high profile projects, if an agency 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.

3.2.6.2 Determine the Precision of the Factors

Use this formula to compute the precision of the adjustment factor for a selected month for a group of n sites for each vehicle class:

$$D = \pm t_{\alpha/2,\, n-1} \frac{s}{\sqrt{n}}$$

Where:

D = precision of the group factor (95% confidence interval)

α = level of significance, the probability of rejecting the Null Hypothesis when it is true, for the selected level of confidence (for 95 percent confidence *α = 1 - 0.95 = 0.05)*

s = standard deviation of the group factors for the selected month

n = number of sites in factor group

The ratio $\frac{s}{\sqrt{n}}$ is called standard error

Note that the precision of the group is affected by the standard deviation (as a measure of homogeneity or diversity) of group factors and by the sample size. Increasing the number of continuous counter locations within a group will also improve the precision of the group factor for groups made of small number of sites. However, for fairly homogeneous groups increasing the number of continuous classification counter locations beyond 6 only marginally improves the precision of the group factor application at specific roadway sections, as demonstrated in Figure 3-2.

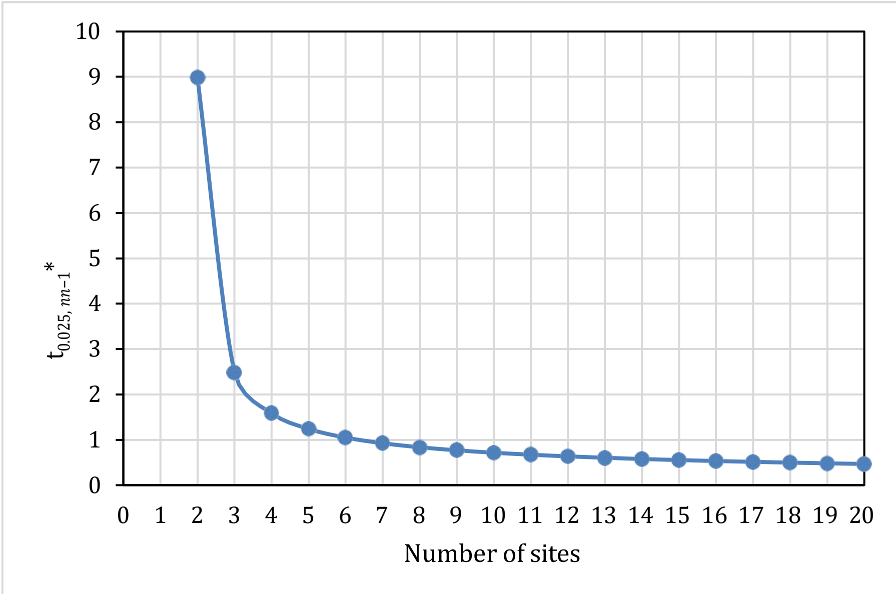


Figure 3-2. Relationship between $t_{0.025,n-1}\frac{1}{\sqrt{nn}}$ = Statistic and Number of Sites

3.2.6.3 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.

3.2.7 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 selected level of precision. Note that because each statistic (i.e., factors computed for different months) 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 typically, 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-term 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 trucks 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.

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.

3.2.7.1 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 every 3 years (or the same review cycle used for the AADT group factor process).

3.2.8 Step 7 Compute Final Group Temporal Adjustment Factors

Current practice applies temporal adjustments to the total volume and then estimates volumes for vehicle types using the observed classification proportions. This approach works if the seasonal traffic volume patterns of individual vehicle types are the same as the total volume profile. Otherwise, traffic volume for some vehicle types will be under-estimated or over-estimated.

A more accurate and appropriate approach is to apply monthly adjustment factors individually to six aggregated FHWA vehicle classes (MC, PV, LT, BU, SU, CU). The following example shows application of adjustment factors to short-term motorcycle count sample. All other vehicle classes will follow the same procedure. For more information on computing temporal adjustment factors, see Section 3.1.4.

Example of Applying Adjustment Factors to Motorcycles

The DOW traffic pattern for motorcycles differs from that of other vehicle types, so short-term counts for motorcycles should be factored separately. 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-term counts are taken on weekends, unless the State performs seven-day short-term counts, so the only data available for weekends are from continuous traffic counters and classifiers. This is a problem for correctly estimating motorcycle VDT, 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 correctly estimate the motorcycle AADT (AADMCT). First, take the data from a continuous automatic vehicle classifier and determine the monthly average daily motorcycle traffic. Next, determine the factor group that the short-term count location belongs to and extract the monthly factors computed for motorcycles. These factors are computed as the ratios of the monthly average daily motorcycle traffic to the AADMCT for each month, see Table 3-7.

Table 3-7. Motorcycle Traffic Volume Estimation

Month	MADT	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
AADMCT	49,948	1.00

Next, use continuous count data to calculate the average daily traffic by vehicle type for each day of the week for the year. For motorcycles, the computed parameter will be ADMCT by DOW. Then compute DOW motorcycle correction factors (MCF) as the ratio of the AADMCT and the DOW ADMCT. Table 3-8 shows an example of the ADMCT by day of week.

Table 3-8. ADMCT by Day of Week

Dav	ADMCT b DOW	Resulting DOW MCF
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
ADMCT	499	

Compute the MCF for each DOW:

- Monday MCF = ADMCT/Monday AADMCT
  = 499/396 = 1.26
- Tuesday MCF = ADMCT/Tuesday AADMCT
  = 499/403 = 1.24
- Wednesday MCF = ADMCT/Wednesday AADMCT
  = 499/405 = 1.23
- Thursday MCF = ADMCT/Thursday AADMCT
  = 499/428 = 1.17
- Friday MCF = ADMCT/Friday AADMCT
  = 499/655 = 0.76
- Saturday MCF = ADMCT/Saturday AADMCT
  = 499/725 = 0.69
- Sunday MCF = ADMCT/Sunday AADMCT
  = 499/483 = 1.03

Therefore, a short-term class count is first factored for seasonality and then for the day of week.

For the motorcycle example, a short-term vehicle classification count was taken on the same route as the continuous site analyzed above, about 10 miles to the south. Vehicle counts by classification were taken on two weekdays in August, with Table 3-9 showing the results for motorcycles.

Table 3-9. ADT Calculation Example

Date	ADT	AADT
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 for each DOW first and then average the adjusted daily 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 ADT_m estimates are then averaged to provide the estimate of $AADT_m$.

(610 + 577) / 2 = 594

Because of the special DOW motorcycle factors, weekday motorcycle counts are increased to more accurately estimate the annual average daily motorcycle travel. This considers 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.

Example of Applying Adjustment Factors to Other Vehicle Classes

The 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 3-10. (Note that this table shows the different day of week and monthly adjustments for each class. This example illustrates the need for adjusting vehicle classification volumes if applicable. Although this example uses a daily total volume count, additional time increments can be used for adjusting vehicle classification volumes such as hour of the day or 15-minute data.

FHWA recommends using all hours if data is collected beyond 24 or 48 hours. FHWA also recommends collecting and storing data in individual vehicle record (IVR) format so all vehicles are captured when collecting and reporting data.

If necessary, deleting the first and last hour is done because the time it takes to set the counter up might not represent the entire hour (or 15-minute time increments) and per-vehicle records need to be represented according the defined time increment.

Table 3-10. ADT Vehicle Type Computation Example

Date	MC Volume	PV Volume	LT Volume	Bus Volume	SU Volume	CU Volume	Total Volume
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 on Tuesday	610	30,380	11,096	50	3033	3030	48,199
AADT Based on Wednesday	518	30,705	11,215	58	4,103	4,162	50,761
Average	494	31,689	11,834	48	3,697	3,469	51,231

ADT 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

Date	MC Volume	PV Volume	LT Volume	Bus Volume	SU Volume	CU Volume	Total Volume
Fraction of Traffic	0.012	0.635	0.234	0.001	0.060	0.058	
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

3.3 HOW TO DESIGN A CONTINUOUS VEHICLE WEIGHT DATA MONITORING PROGRAM (WEIGHT)

3.3.1 Statewide WIM Program

Truck and axle weight data are 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 and rehabilitation 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 are also key components 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.

The Steps required to develop a statewide WIM program are generally similar to volume and class count program steps but also have some differences due to the extent of the program, the intended data uses, and WIM equipment cost and capabilities. The steps to create and maintain the weight portion of the continuous traffic monitoring data program include:

STEP 1 - Review Existing Weight Data Collection Program

STEP 2 - Develop an Inventory of Existing WIM Sites and Assess WIM Site Locations

STEP 3 - Determine the Roadway Groups to Be Monitored by WIM

STEP 4 - Establish Load Factor Groups

STEP 5 - Determine Number of Weight Data Collection Locations

STEP 6 - Select New Sites to Meet WIM Program Needs

STEP 7 - Integrate the WIM Sites with the Remaining Count Program

3.3.2 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, even traffic flow at constant highway speed), and the costliest equipment set up and calibration. It is important to consider these complex requirements during weight data program review.

> An excellent introduction to WIM is provided in the *WIM Pocket Guide* (FHWA 2018). The Guide consists of three main text documents, four instructional video supplements, and six appendices showcasing noteworthy practices. The video supplements and appendices are only available on the FHWA website:
>
> https://www.fhwa.dot.gov/policyinformation/knowledgecenter

3.3.2.1 Heavy Vehicle Weight User Needs

In addition to reviewing the physical requirements for WIM systems, the needs of the end users (customer of the WIM data) should be considered.

Heavy vehicle weight data are 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. These tasks include, but are not limited to, the following:

- Pavement design
- Pavement maintenance
- Bridge design
- Geometric design
- Environmental analysis, such as air quality and noise

- 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
- Determination of the need for and effect of appropriate safety improvements
- Noise abatement
- Highway cost allocation studies
- Axle Correction Factors

3.3.2.2 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) (usually by vehicle class), including average GVW and frequency distribution by weight bins.
- Axle load spectra, which are axle load frequency distributions by load bins. The AASHTOWare Pavement ME Design (PMED) software that follows AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG) Manual of Practice (MOP) requires the normalized (i.e., percentile) axle load spectra by axle group (singles, tandems, tridems, and quads) and vehicle class representing a typical day of each calendar month, other applications also require information about axle load spectra for pentads and other axle groupings.
- Equivalent single axle load (ESAL) values, which are used as key inputs to the traditional AASHTO 93 pavement design procedures. ESAL value of 1 corresponds to 18,000 lb single axle load. In the ESAL method, each axle load is assigned a load equivalency factor (LEF) representing an equivalent number of 18,000 lb loads with respect to pavement damaging potential. The LEFs are multipliers that are applied to the reported axle loads to convert them to ESAL values. LEFs are dependent on axle group, pavement type, and pavement serviceability index. LEF factors are also called ESAL per-axle factors. The cumulative ESAL value estimated for the entire pavement service life is used as input for traditional AASHTO 93 pavement design. ESAL per truck values are used to characterize and compare the pavement damaging potential of different vehicles.

Each of these summary statistics can be developed for a specific vehicle class, specific site, a group of sites, geographic region, or an entire State or, depending on the needs of the analysis and the data collection and reporting procedure. In addition to the summary loading statistics, FHWA requires submission of axle and truck loading data in the IVR format.

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 Figure 3-5) so that these statistics are available when needed for pavement design—such as with the AASHTO MEPDG MOP. It is recommended that axle loading (all vehicle classes or classes 4 to 13) be stored in the IVR format, since it offers the most detail for later reporting. 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 these raw per vehicle data are the only source of other key statistics—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. For AASHTO MEPDG MOP design of jointed plain concrete pavements, axle-to-axle spacing of 12 to 15 feet is an important input parameter for predicting mid-slab cracking.

The 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.

Axle Load Spectra

The basis for all truck loading estimates is the axle load distribution table, also called an axle load spectrum (or the plural form called spectra). An axle load spectrum is computed using IVR data collected by WIM systems for individual vehicle passes over the WIM sensors. It describes the distribution of axle weights for each axle group (single, tandem, tridem, quad, and penta+) and for each class of vehicles. Load spectra are frequently normalized (i.e., expressed as percentile distribution) so that the table shows the fraction of axles within specific load ranges for a given class of vehicles. Table 3-11 shows an example of normalized (i.e., expressed as a percentile frequency distribution) load spectra for single and tandem axles for class 9 trucks obtained from one of Florida DOT WIM sites.

Table 3-11. Example of a Normalized Load Spectrum for Vehicle Class 9 Single and Tandem Axles from FDOT

Steering Axle Distribution		Tandem Axle Distribution	
Load Bin, lb	%	Load Bin, lb	%
0 to 999	0.00	0 to 1999	0.00
1000 to 1999	0.06	2000 to 3999	0.00
2000 to 2999	0.06	4000 to 5999	0.13
3000 to 3999	0.19	6000 to 7999	0.26
4000 to 4999	0.45	8000 to 9999	10.27
5000 to 5999	1.85	10000 to 11999	17.49
6000 to 6999	6.96	12000 to 13999	10.27
7000 to 7999	24.25	14000 to 15999	7.47
8000 to 8999	36.50	16000 to 17999	6.00
9000 to 9999	23.10	18000 to 19999	6.00
10000 to 10999	5.36	20000 to 21999	5.68
11000 to 11999	0.89	22000 to 23999	5.23
12000 to 12999	0.26	24000 to 25999	3.25
13000 to 13999	0.06	26000 to 27999	3.57
14000 to 14999	0.00	28000 to 29999	4.53
15000 to 15999	0.00	30000 to 31999	8.36
16000 to 16999	0.00	32000 to 33999	7.28
17000 to 17999	0.00	34000 to 35999	2.43
18000 to 18999	0.00	36000 to 37999	1.40
19000 to 19999	0.00	38000 to 39999	0.26
20000 to 20999	0.00	40000 to 41999	0.13
21000 or more	0.00	42000 or more	0.00

Understanding and accounting for monthly variations in vehicle weights is becoming increasingly important for both economic analyses and pavement design procedures. The AASHTO MEPDG MOP pavement design procedures require input of a normalized axle loading distribution representing a typical day of each calendar month. Therefore, the traffic data collection process should be able to detect and report differences in loads by month (because the number of trucks or the weights of individual trucks vary) during the year. Appendix F contains AASHTOWare Pavement ME Design (PMED) software requirements for axle loading distribution factor reporting.

Traffic Loading Estimates Derived from Axle Load Spectra

Once developed, axle load spectra are often converted into other statistics, such as ESAL, GVW, or total traffic loading statistics. Thus, agencies should have means to develop the normalized axle loading distributions using their WIM data.

Axle load spectra and the resulting ESAL and GVW statistics can be derived directly only from WIM sites or static weight scales. Because WIM equipment is expensive to install and maintain, WIM data are available at only a few locations in a State. Thus, at most road sites, truck weight data items cannot be measured directly. Instead, the traffic loading estimates are 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 site-specific truck volume statistics (AADTT or MADT by vehicle class) by the normalized axle load spectra and by the number of axles per truck yields site-specific estimate of the annual or monthly average daily traffic loading by vehicle class and axle group for that site. Summing the products across axle groups provides an estimate of the traffic load by vehicle class. Further summation across all vehicle classes provides an estimate of the average daily total traffic load.

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 determine how many axles of each type are present for each class of trucks and the weight of each of those axles. For example, if a road section carries 100 Class 9 trucks in a day, it likely experiences approximately 100 single axles and 200 sets of tandem axles. (Directions for developing and applying representative axle load spectra for load factor group are given later in this chapter.)

Alternatively, if the average GVW for each vehicle class is known or computed based on WIM data, multiplying the number of trucks within a given class by the average GVW for vehicles of that class yields the total number of pounds or total traffic load applied by that class on that roadway. Adding these values across all vehicle classes yields the total load carried by that road.

ESAL Computation

The axle load distribution by axle load range can be converted into an ESAL. To make this conversion, an ESAL per axle factor, also called AASHTO axle load equivalency factor (LEF), is assigned to each axle load measured at the WIM location. ESAL per axle factors can be obtained from the 1993 edition of the AASHTO Guide for Design of Pavement Structures Appendix F Tables D.1 to D.18 Axle Load Equivalency factors. These values vary by pavement type, slab thickness (for rigid pavements), or pavement structural number (for flexible pavements), and pavement terminal serviceability index.

LEF values depend on axle load magnitude, axle group, pavement type, pavement structure (structural number for flexible and slab depth for rigid), and pavement terminal serviceability index. The LEF value times the number of axles within that axle load range yields the number of ESALs for that axle group and load range. Summing these values across all load ranges, all axle groups, and all vehicle classes yields the total number of ESALs applied to the roadway. The number of axles by load range is computed from IVRs collected by WIM equipment.

3.3.3 Step 2. Inventory Existing WIM Sites and Assess WIM Site Locations

The State should conduct a detailed inventory of its WIM assets and assess its existing WIM data collection sites against WIM program goals and objectives. An existing WIM site may require relocation or pavement remediation because of failure of the pavement surrounding the WIM sensors or failure of the WIM equipment. To make this determination, the need for that WIM site should be evaluated. Sites that are still needed should be reinstalled and/or pavement remediated. If that site is no longer needed or if other higher priority locations exist, the WIM equipment should be moved to another site. Based on users' needs, the additional sites may become necessary.

The State should assess if WIM sensor locations are conducive to accurate measurement of the vertical forces applied by vehicle wheels to sensors in the roadway while the truck travels over the sensors. These forces are used for estimating axle and truck weights as if the truck was stationary. The task is complicated by a variety of factors, including the following:

- Each sensor registers the vertical force of each axle for only a brief time.
- The weight estimated by the WIM system based on that measurement varies because while the vehicle is in motion, the truck and its components may experience up and down motion, generating dynamic forces. 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 or the type of load being carried are also in motion, affecting the axle weight at any given instant in time.) The WIM systems are designed to account for this variation but can only account for modest vertical truck movements. Removal or the reduction of vehicle dynamics is an important part of a successful WIM site.
- Some sensors (strip or line sensors) register 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. At a minimum each WIM lane should measure both the left and right axle weight at least once.
- Roadway geometries such as grade, slope, and horizontal and vertical curves can cause shifts in vehicle weight from one axle to another or from one side 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 (head or cross), 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.
- To provide the ability for accurate weight data collection, all WIM sites should have sensors installed flush with the road (i.e., permanently installed sensors).

> Strip or line WIM sensors register only a portion of the tire weight at any given time. Because the sensor is more narrow than the footprint of the tire, the pavement surrounding the sensor physically supports some portion of the axle weight throughout the axle weight measurement.

The effects of many of these factors can be minimized through careful WIM site selection and design of the WIM site. The *WIM Pocket Guide* (FHWA, 2018) provides detailed information about the desired WIM site features, the recommended WIM sensor configurations, strengths, and weaknesses of different WIM sensor technologies.

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. 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 sensors 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 axles; 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 permanent WIM sensors installed flush with the road surface is recommended as a means of improving the quality of the data.

3.3.4 Step 3. Determine the Roadway Groups to Be Monitored

The primary objective of the weight data collection program is to obtain a reliable measure of the axle weights and axle-to-axle spacings and GVW per vehicle for different heavy vehicle classes (primarily for FHWA classes 4 to 13).

The data collection plan for truck weight accounts for the following:

- The needs of State and Federal agencies for truck weight data.
- The capabilities and limitations of WIM equipment.
- The resource constraints found at many State highway agencies.
- The variability of truck weight data.

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.

A single statewide average statistic such as GVW or ESAL per truck is not applicable to all parts of the State or all road types. Trucking characteristics can vary significantly by type of road or by geographic area within a State. Therefore, 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 should identify these differences and include a data reporting mechanism to provide users with data summaries that correctly describe specific truck loading characteristics.

> The procedure is to group the State's roads into load factor categories, so that each of those groups experiences similar per-truck loads, at least for the heavy vehicle classes (including busses and trucks) that are dominant on the roadway. All roads within the same load factor group should have freight traffic with similar characteristics and are subject to similar axle weight and GVW limits, including the monthly variations of these limits.

For example, roads that experience trucks carrying predominantly heavy natural resources should be grouped separately from roads carrying only light, urban delivery loads.

The weight data collection program is analogous to both the CCS and CVC programs for collecting temporal pattern information for volume and vehicle classification data. For the WIM sites that provide data for pavement designs based on AASHTO MEPDG MOP, a minimum of 12 calendar months of WIM data (January to December) are needed to develop monthly axle load distribution inputs for pavement design.

Within each load factor groups, the State should operate several WIM sites (see ensuing sections how to determine the number of sites based on weight data variability and the desired precision of the estimate) with permanently installed in-road sensors. These sites should be used to identify monthly weight patterns, as well as per-truck loads that apply to all roads in the group. Where possible (given budget and staffing limitations), WIM sites within each load factor group should be monitoring truck and axle weights continuously to provide more reliable measures of seasonal changes in traffic loading. The 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.
- User needs and requirements for weight data, including roads and/or bridges that are high priority for WIM data users or WIM program sponsors.
- Monthly truck loading patterns observed for each load factor group (lesser number of continuous sites if monthly variation in per-truck loads is insignificant or very stable and well understood and accounted for in sampling plan).

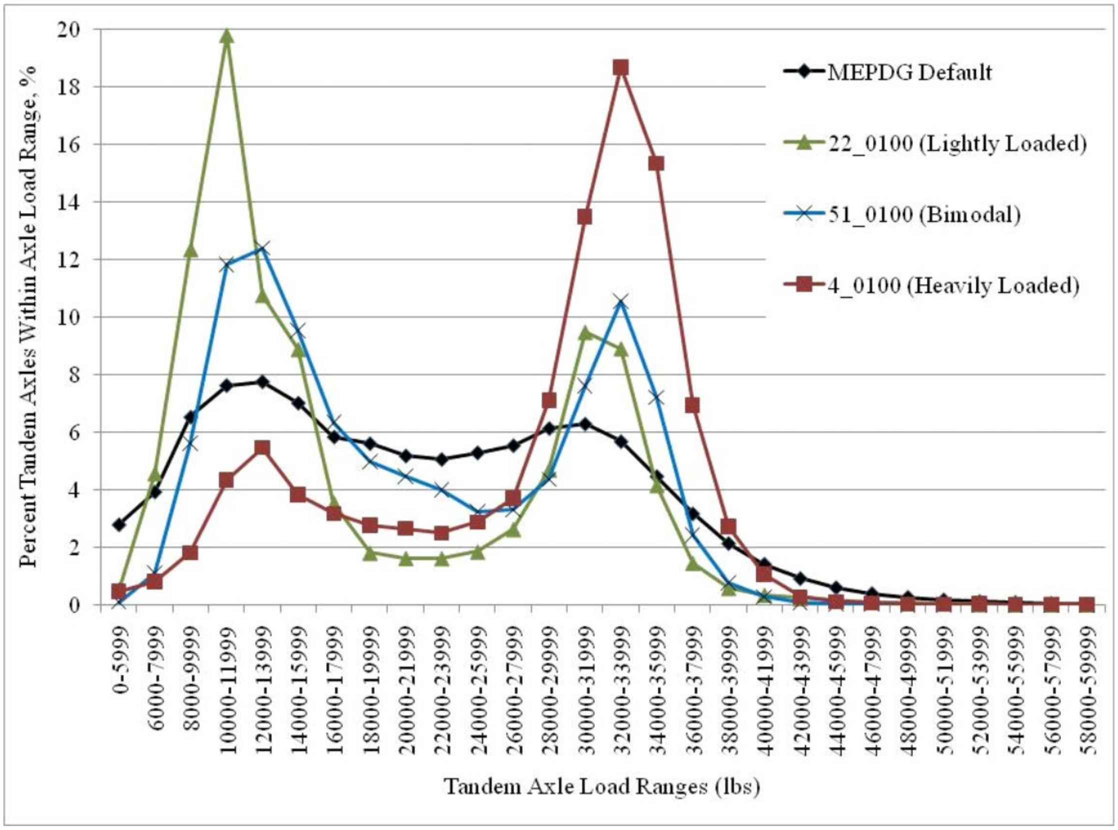
However, if the State has limited data on monthly weight patterns or if prior data collection has shown the pattern to be inconsistent, then a larger number of continuous counters may be needed. Performing additional vehicle weighing, both by operating continuous WIM sensors and by collecting data at 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. To determine the number of sites per group, see Step 5.

WIM sites with permanently installed WIM sensors used for seasonal data sampling, in lieu of continuous monitoring, are being phased out by State agencies due to low cost effectiveness, higher qualified personnel requirements, and availability of reliable remote data downloading options. However, if seasonal WIM data sampling is used, the seasonal monitoring sites should have permanently installed and regularly calibrated WIM sensors (annually or seasonally, in case of temperature-dependent sensors like piezo-polymer) to assure WIM data accuracy.

3.3.5 Step 4. Establish Load Factor Groups

Figure 3-3 illustrates the reason why roads should be stratified into load factor groups. It shows distributions of tandem axle weights for Class 9 trucks at different sites. Each of these distributions exhibits a different set of loading conditions, ranging from very heavily loaded to lightly loaded that would result in different pavement design outcomes.

The key to the design of the truck weight data collection effort 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.



Source: FHWA Report FHWA-HRT-13-090.

Figure 3-3. Tandem Axle Load Distributions with Different Loading Conditions

One important consideration when creating load factor groups is whether different road groups will be created for each class of heavy vehicles or whether each road segment is assigned to only one group that is primarily formed based on the similarities in truck weight of the most common or voluminous heavy vehicles. The most common approach historically has been to assign each roadway to one truck weight road group. However, the FHWA LTPP program has developed MEPDG axle loading defaults by grouping WIM sites independently for each class of vehicles (*MEPDG Traffic Loading Defaults Derived from Traffic Pooled Fund Study* FHWA 2016). As a result, the LTPP created a catalog of axle load spectra for each of FHWA vehicle classes 4 through 13 representing commonly observed, as well as special (such as very heavy or very light) loading conditions and labeled these spectra as light, moderate, heavy, or very heavy loading conditions. The grouping was performed entirely mathematically using a clustering technique. The final groups were subjected to engineering review to confirm whether similarities and differences in the identified loading patterns make sense from a pavement engineering point of view.

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 (or typical per truck loads) at sites within each group should be similar.
- It should be relatively easy to assign each road accurately and consistently in the State to a load factor 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 (such as roads serving primarily resource extraction and agricultural to/from sites). 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.

Selecting Approach to Form Load Factor Groups

As with the factor grouping processes described earlier for both vehicle classification and total volume, the basis for the load factor group formation process can be either intuitive knowledge-based or mathematical, or a 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 loads they carry. This approach is the easiest to apply but often produces groups that have higher variability within the group.

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 using the available data or attributes, making assignment of roadway sections to groups more difficult. As a result, combination approaches are often used that start with basic intuitive groups (e.g., geographic stratifications or descriptive road classifications such as urban/rural or interstate/non-interstate) and then apply cluster analysis to test the initial assumptions or to determine more uniform sub-groups within the basic geographic/roadway classifications.

Intuitive or Local Traffic Knowledge-Based Grouping

With this approach, the initial load factor groups should be based on a combination of known geographic, industrial, agricultural, and commercial truck loading patterns, combined with knowledge of the truck routes 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 indeed have similar patterns. The intent is to identify those roads where large numbers of trucks are heavily loaded versus those routes where large numbers of trucks are not carrying heavy weights.

The resulting road groups should be easily identified by users of truck weight data within the State. They should provide a logical means for discriminating between roads that are likely to have very high load factors (such as ESAL/truck) 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). Unless a road is primarily serving a resource extraction or agricultural facility, it is unlikely that the road (in the direction used by the empty trucks to go to the facility) will have the majority of trucks primarily empty.

In addition, States should incorporate knowledge about specific types of very heavy vehicles into their weight grouping process so that roads that have significant volume of those very heavy trucks (at least 10 percent or more of all trucks with weight exceeding Federal legal limit) 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. Other examples of roads that are likely to have high percentages of heavy trucks are the roads with a high percentage of trucks involved in the following: agricultural goods movement, natural resource extraction, construction, heavy industries (e.g., automotive) and debris/garbage removal.

For a State, it is recommended to start with the initial intuitive groups based on a more simplistic approach. For example, insight into geographic differences in truck travel, combined with the knowledge of road use by heavy commercial trucks (i.e., the percentages of through-trucks and local delivery trucks) can be used 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. (e.g., 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 (within 200 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 approach could then be improved (as needed) over time as more weight data are collected and analyses are carried out. Information can be extracted from existing truck weight databases to determine logical and statistical differences that can be used in the formation of load factor groups. As an example of a load factor group, Washington State developed five basic truck-loading patterns 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.
- Group E – Serves primarily local goods movement and specialized products.

A starting point for developing load factor 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 with high percentage of heavy freight trucks	Interstate and arterial major truck routes with high percentage of heavy freight trucks
Other roads (e.g., regional agricultural with little through trucks)	Interstate and other freeways serving primarily local truck traffic
Other unrestricted truck routes	Other unrestricted truck routes

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.

Grouping Based on Cluster Analysis

MEPDG Traffic Loading Defaults Derived from Traffic Pooled Fund Study (FHWA 2016) contains detailed instructions on how to use a cluster analysis to identify and group similar axle load spectra. This section summarizes and generalizes this approach.

The generic cluster process for forming load factor groups consists of the following steps:

1. Develop a normalized annual axle load spectrum for each vehicle class and 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, a statistic should focus on importance of heavy axle loads. A general ESAL is this type of statistic. A general ESAL is computed by keeping pavement inputs constant in the load equivalency factors LEF or ESAL per axle formula to allow comparison of traffic loading between different roads. If the main use of the load factor group is for estimating total tonnage on State routes, then mean GVW per truck class may be used as the best single statistic).
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 loading patterns for each class of vehicle will be weighed by importance. (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 using traffic loading summary statistic of choice, stopping when clusters reach the point where the difference between clusters becomes large enough that the use of different clusters causes statistically and practically different outcomes when used in planned analyses.

Step 3 is the most challenging task in this process because different classes of trucks are likely to have different loading 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. For example, grouping may be heavily weighted towards similarities in class 9 axle load spectra, if class 9 carry large percentage of heavy loads for the load factor group.

In Step 4, the traffic loading summary statistic (ESAL/truck, average GVW, or load spectra) that represents the vehicle class loading conditions being used to group sites is entered into a statistical clustering program. The output of that process can then be tested to determine the reliability of the groups created.

Hybrid Approach Combining the Intuitive and Clustering Approaches

This approach combines features of the Intuitive and Clustering Approaches. First, professional judgment is used to initially segregate roads into specific categories or groups. For example, based on data from classification and WIM sites, the State may know that specific roads carry large volumes of very heavy 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 Load Factor Groups

The initial formation of load factor groups should be reviewed to determine whether the road segments grouped together have similar truck weight characteristics. More likely it will not be possible to form homogenous groups for different truck classes, and trade-offs will have to be made. Examining available data from the existing WIM sites is the first step. 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 loaded, 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.

If all vehicle classes have equal importance, 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 equally important. Some truck classes are heavier than others and thus, may be more important to the users (pavement and bridge engineers). Class 5 is considered a truck but is generally so light that it creates little pavement damage, while Classes 7 and 10 can be extremely heavy. 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 the traffic stream and contribute a relatively modest amount of total pavement damage. On a few roads, these trucks are very prevalent and drive the pavement design equation. In most cases, however, Class 9 vehicles tend to produce the majority of pavement loading. These trucks tend to be less damaging per vehicle than Classes 7, 10, and 13, but they tend to constitute a very large percentage of truck volumes, thus contributing the most to the cumulative heavy loads (heavy loads are those that exceed ¾ of the legal load limit). Therefore, understanding of loading patterns for Class 9 trucks is very important for weight data users involved in pavement design.

Determination of the relative importance of different truck classes and selection of truck loading grouping statistics is very important. 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. The type of vehicle considered the most important should be given priority (for example, vehicle that contributes 40% or more of the total cumulative traffic load) in the load factor grouping process. This can be computed by multiplying the volume of that class of trucks times their average weight. This simplifies the grouping process, although it downplays the importance of lower volume truck classes in that process.

Determining the Precision of Estimates from Load Factor Groups

An estimate of the precision of the mean of a variable for any load factor group can be computed using the standard deviation of the mean estimate (such as mean single axle load, mean tandem axle load for loaded trucks, mean gross vehicle weight, or mean generic ESAL) and the number of sites in the load factor group. An example of this computation is shown in Table 3-13. 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 these data, it can be assumed that all rural interstate roads in the group have a mean gross vehicle weight of 54,000 lb for Class 9 trucks and 1.63 ESALs per Class 9 truck (the general ESAL computations assumes SN = 3, p_t = 2.5).

Table 3-13. Example of Statistic Computation for Load Factor Group 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, *m*	54,000 lb	1.63
Group Standard Deviation, *s*	7,500 lb	0.18
Coefficient of Variation, $\frac{ss}{mm}$	0.14	0.11
Standard Errors of Mean, $\frac{ss}{\sqrt{nn}}$	2,800 lb	0.07
Estimated Precision of the Mean with 95 Percent Confidence, *D*	+/- 6,900 lb	+/- 0.17

The precision of the group mean can be estimated for the selected confidence level as approximately plus or minus $t_{a/2,\, n-1}$ times the standard error of the mean (which is the standard deviation of the sample *s* divided by the square root of the number of sites *n*):

$$MM = \pm tt_{\alpha\alpha/2, nn-1} \frac{ss}{\sqrt{nn}}$$

Where

D = the desired precision of the estimate, expressed as a fraction

s = the standard deviation for the group, computed using the selected traffic loading statistic

$t_{a/2,\, n-1}$ is a critical value for t-interval that can be found using the Student's *t* distribution tables for the selected level of confidence (For example, α/2 = (1-0.95)/2 = 0.025 for 95 percent confidence level) and appropriate degrees of freedom (i.e., one less than the number of samples, which for seven WIM sites is roughly 2.45.)

n = the number of sites in the group

In the above example, note that the coefficient of variation (computed as standard deviation divided by the mean) for the two statistics (GVW/vehicle and ESAL/vehicle) are different, even though both variables come from the same set of vehicle weights. This is because the ESAL formula applies different ESAL per axle factors to loads of different magnitudes. Therefore, the grouping results are more homogeneous with respect to heavy loads than to average GVW.

The level of precision will be different for each vehicle class due to variability in mean weights and ESALs per truck observed between different sites in the load factor group for each vehicle class. For example, the precision of the mean GVW value for Class 9 trucks will be different from that value for Class 11 trucks.

3.3.6 Step 5. Determine the Appropriate Number of Weight Data Collection Locations

The precision formula can be used to determine how many WIM sites should be included within each load factor group. Each State highway agency should determine what traffic loading summary statistic it wants to use (such as ESAL per truck or GVW), 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 first decision is to determine whether the goal of the load factor groups is to report the 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 + 0.15 with 95 percent confidence) or the default values or load factors that will be applied to other sites in the group to estimate loading. This decision primarily affects the grouping process.
  - If the intention is to develop precise mean values for the group, the key tends to be the number of WIM sites included in each group. (The precision is low for groups with too few sites based on the statistical formula used to estimate the precision.)
  - If the intention is to develop good default values or load factors, 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 load factor 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. Use of multiple statistical parameters (such as load spectra) for grouping is possible but requires more complex multivariate clustering techniques and informed decisions about what weights (by importance) to assign to different statistical parameters. Because the precision of each statistic will vary, a State should select a single statistic that is most meaningful for the analyses that use the truck and axle weight data. Normally, this means selecting a specific vehicle class and a specific weight variable. The recommended statistics for use in selecting sample sizes are either the mean generic ESAL per Class 9 truck or 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 GVW statistic is easily understood by technical and non-technical people and could be converted to measures of commodity flow. However, the average GVW statistic hides some attributes about vehicle loading, such as proportion of heavy tandem axles, typical weight and percentage of loaded truck or percent of overloaded axles. At the other extreme, use of a full axle load spectrum (such as single and/or tandem axle load spectra) for road grouping puts equal weights by importance to all loads in the distribution, resulting in clusters that may not be as meaningful for the end user (e.g., pavement designer) who may be primarily interested in similarities in heavy loads and not interested in similarities in distribution of light loads. The ESAL per truck statistic puts high importance on heavy loads that are important for pavement designers and thus, provides a better parameter for grouping of roads based on similarity in heavy loads. The general ESAL per truck statistic is a good parameter for road clustering, if pavement design is the primary purpose for creating road groups.

- The third 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 of the mean value with 95 percent confidence). Decreasing the size of the acceptable error or requiring higher levels of confidence both increase the number of WIM sites required. Conversely, accepting lower levels of precision and/or confidence allows fewer WIM sites per load factor group and lower data collection costs. However, the low precision or higher error must be acceptable to the weight data users. For example, pavement users require high precision of load factors associated with the heavy loads (80 percent or more of the federal legal load limit) but not with the light loads (*Traffic Loading Defaults Derived from Traffic Pooled Fund Study,* FHWA 2016). For users of ESAL-based pavement design approach, changes in average ESAL per truck of 25 percent or less are not significant from the design perspective, assuming typical highway truck mix scenarios (not movers of super heavy loads).

The number of WIM sites within a group is estimated as:

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

Where:

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

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

α = level of significance, the probability of rejecting the Null Hypothesis when in it is true, for the selected level of confidence for 95 percent confidence α = 1 - 0.95 = 0.05)

s = the standard deviation for the group, using the selected traffic loading statistic

D = the desired precision of the estimate, expressed as a fraction

The parameters are computed from available truck weight data. *D* is selected as part of the previously described decision process (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 heavier vehicle and consequently have increased the mean values and the standard deviations for GVW/vehicle and ESAL/vehicle for the group. These new WIM sites did not improve group homogeneity.

Increasing the number of WIM stations included in the sample to 15 sites (and assuming that those new WIM sites would not increase the standard deviation of the sample) would improve the confidence in the mean value of the GVW/vehicle estimate for the load factor group to 59,000 lb +/- 6,400 lb with 95 percent confidence.

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
Estimate of Precision for the Mean with 95 Percent Confidence*	+/- 8,900 lb	+/-0.17

** for a critical value for t-interval equal to 2.306 for eight degrees of freedom (9 sites minus 1)*

Changing the number of sites included in a load factor group has four effects:

- It changes the computed mean value for the group.
- It changes the computed sample standard deviation for the group. New sites may increase or decrease this value.
- 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. Additional sites would increase this value.
- It changes the value of $t_{a/2}$ used to compute the size of the confidence interval applied to estimates produced for that group. Additional sites would decrease this value.

In general, the more sites (with similar values of the selected summary loading statistic) included in a group, the better the estimates produced by that group. However, those improvements could be lost due to an increased standard deviation, if the new sites would have the mean values of the selected summary loading statistic (GVW and/or ESAL/truck values) that are different from the group mean values, as was demonstrated by the example in Table 3-14.

The benefit of adding sites is significant for small groups but decreases as the number of sites within a group increases. The effect of using the Student's *t* distribution to compute the precision (recall formula $M = \pm t_{\alpha/2,n-1} \frac{s}{\sqrt{n}}$) means that a significant decrease in the value of *t* can be obtained by simply adding locations up to a sample size of six, as demonstrated for 95 percent confidence interval ($\alpha/2$=0.025) and the number of sites *n*. For example, a sample size of six sites has a 20 percent smaller confidence interval at the 95 percent level of confidence than a sample size of five sites, all other things being equal. A sample size of six sites has a 250 percent smaller confidence interval at the 95 percent level of confidence than a sample size of 3 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 or high variability in mean values of a selected weight summary statistic are observed.

Based on this analysis, six WIM sites per load factor 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 quarries) 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 load factor groups, i.e., create new subsets of roads that will serve as the load factor 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.

Selecting the acceptable level of error or a precision of load factor group is an iterative process. First, the desired target precision is selected. Next, the variability of data in the load factor group is examined. This examination may result in the need to collect more data or to adjust the assignment of roads within load factor 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 and the users of the data should be informed about the reduced precision.

3.3.7 Step 6. Select New Sites to Meet WIM Program Needs

The selection of new WIM sites should be based on the needs of the WIM data collection program and the site characteristics of the roadway sections that meet those needs. The WIM site locations should be selected based on specific users' needs and program requirements from a list of candidate sites that meet all site requirements. 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 load factor 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.
- The need to collect weight information on specific commodity movements of importance to the State.

States should place WIM equipment only in pavements that allow for accurate vehicle weighing. See Chapter 2 for description of physical site characteristics of the roadway sections for installation of WIM systems and the recommended configurations for WIM sensor arrays. Additional information about physical site characteristics could be found in the FHWA *WIM Pocket Guide*.

WIM Equipment Selection

The *WIM Pocket Guide* (FHWA, 2018) contains an in-depth discussion about WIM equipment selection. The following are the most critical factors that should be considered when making WIM equipment selection:

- User needs for data accuracy and consistency and length of data collection
- WIM equipment and sensor reliability and longevity
- Type of WIM equipment already installed and agency's prior experience with WIM equipment
- Type of array installed
- Ease of equipment installation, operation, maintenance, and calibration
- Pavement requirements for different WIM sensors
- Number of WIM Lanes

The following issues should be considered when selecting the number of lanes of WIM to install:

- Available funding
- Cost of installation
- Program objectives to be met
- Design of current WIM installations in the State
- Trade-offs between obtaining more complete coverage at each site versus less coverage at each site but getting more sites covered

Significant differences in loads by direction of travel may 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 difficult to generalize, although the outside lanes (referred as "truck lanes" by pavement engineers) typically carry heavier vehicles. For multi-lane facilities, covering two lanes in each direction provides the most cost-effective alternative.

A WIM site covering all lanes and direction of travel provides the most complete data collection coverage. 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 by WIM system. Continuous classification in those lanes is preferable.

3.3.8 Step 7. Integrate the WIM Sites with the Remaining Count Program

In addition to weight, WIM systems also provide counts of vehicle volume by classification, speed, and total volume. Consequently, WIM sites could also provide volume and vehicle classification count data and take the place of volume and classification counts required to meet the needs described in Sections 3.1 and 3.2. However, agencies should note that physical characteristics of many road sections prevent the collection of accurate weight data, and additional resources are needed to maintain and calibrate WIM equipment and process WIM data.

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.

3.3.8.1 Total Size of the Weight Data Collection Program

The size of the weight data collection program should be a function of the variability of the truck weights, accuracy, and precision desired to monitor and report on those weights. WIM program size and coverage should address specific needs of weight data users.

A small State may start with two basic load factor groups of roads: interstate and non-interstate groups, or one group roads with majority of through-way trucks and another group of roads with majority of local delivery trucks. To improve statistical precision, a minimum of 6 WIM sites per load group is recommended, leading to a minimum of 12 weighing locations in a State to support two load factor groups. If more than two loading patterns, meaningful to data users, are identified within a State but the budget can support only a limited number of WIM sites, it is recommended to have fewer sites per group but more groups covering different loading patterns then to have fewer groups with larger number of sites. The number of locations could be further reduced if the State works with surrounding States to collect joint vehicle weight data representing the same load factor group. If the variability in load factors computed for individual sites within a group is too high and leads to significantly different outcomes for the data user (for example, pavement thickness design varies by over 0.5 inches), it is recommended to create an additional load factor group (*MEPDG Traffic Loading Defaults Derived from Traffic Pooled Fund Study*, FHWA 2016).

A larger State with highly diverse trucking characteristics might have as many as 10 or 15 distinct load factor groups of roads, 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.

3.4 HOW TO DESIGN A SHORT-TERM DATA COLLECTION PROGRAM

Short-term 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. Short-term traffic data collection typically includes any of the following: total traffic volume, volume by vehicle classification and micromobility counts.

The recommended short-term 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.

Short-term counts ensure that adequate geographic coverage exists for all roads under the jurisdiction of the highway authority. The coverage counts ensure that at least some data exist for all roads maintained by the agency. How much data to be collected when providing adequate geographic coverage is a function of each agency's policy perspective. Significant utility can be gained from having at least hourly volume estimates by lane at coverage counts, since those data can be used to obtain a much more accurate understanding of travel and traffic volume peaks during the day.

3.4.1 Steps to Develop Short-Term Count Data Collection Program

The following steps should be used to develop a short-term count data collection program. These same steps are applicable to the development of a short-term classification count program:

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 these 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.

3.4.2 Duration of Counts

Longer duration short-term counts produce modest but statistically significant improvements in accuracy of AADT estimates. Details about accuracy gains can be found in *Assessing AADT Accuracy Issues Related to Short-Term Count Durations* (Krile 2015b). For example, if a 48-hour count serves as the basis for the AADT estimate—as opposed to a 24-hour count—there is around a 5 percent increase in the probability that an AADT estimate is within +/- 10 percent of actual AADT. In general, short-term counts on higher-volume roads can be more accurately converted into AADT estimates from shorter duration counts than those from lower-volume roads. Thus, most improvement in accuracy is obtained when counts are conducted for longer periods on lower-volume roads.

Micromobility Duration of Counts

The use of automatic counter equipment can substantially extend the duration of short-term counts. If automatic counters are used, then the minimum suggested duration is 7 days (such that all weekday and weekend days are represented). The *TMG* recommends micromobility short-term data collection programs collect hourly (or more granular, 15-minute, etc.) traffic volumes that include a minimum of seven consecutive days. The Transportation Research Record publication "*Minimizing Annual Average Daily micromobility Traffic Estimation Errors: How Many Counters are Needed per Factor Group?*" (Nordback 2019) states that results from using continuous count data from 102 sites across six cities, findings confirm that mean absolute percent error (MAPE) in estimated AADT is minimized when at least seven-day short-term counts are collected.

> Depending on several other factors for Micromobility (e.g., day-to-day count variability, the total number of short-term monitoring sites, and the number of automatic counters), **the preferred duration of automatic counts is 14 days at each location**.

Having 14 days of hourly count data allows duplicate DOW of data to be collected and provides assurance that for at least one of each DOW is available, in case of weather, equipment failure, or other field-related issues cause one day or one hour to be eliminated due to erroneous data.

Manual counts can be used for validation of the automated equipment and should be used to verify the quality of the data collected from automated equipment. It is recognized that agencies might not have the available resources to purchase automated equipment and may need to partner with other agencies or obtain grant funding for automated portable counters. Partnering with agency traffic operations may allow automated camera technologies to be used, but processing of the video data is labor intensive and may be limited to the collection of 12-hour counts.

If micromobility traffic levels have been counted several times showing results that are high and consistent from day to day, then future counts at the location may be conducted for shorter periods and/or fewer days. However, a longer-duration count period (14 days) will be needed to determine how variable the micromobility traffic is for both TOD and DOW.

3.4.3 Spacing and Geographical Coverage Methods for Grouping Count Locations (for Factoring)

The spacing between short-term counts in a roadway is subject to agency discretion. The method for section length determination should be detailed in the State TMS plan. The primary objective is to count enough locations on a roadway so that the traffic volume estimates available for a given highway segment accurately portray the traffic volume on that segment. Generally, roadway segments are treated as homogenous traffic sections, meaning 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, for example, a 10-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-term 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 AADT volume scale such as the one shown in Table 3-15.

Table 3-15. Estimating Spacing 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%
500 – 999	+/- 60%
250 – 499	+/- 80%
Less than 250	+/- 100% or 250 vehicles (whichever is greater)

Breaking the system into 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 should be 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.

3.4.4 Count Frequency

Once roadway segments are finalized, FHWA recommends as a rule that each roadway segment be counted at least once every 6 years. This ensures that reasonable traffic volume data are 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 3 years for higher functional class roadways.

Not all count locations should be counted on a 6-year basis. Some count locations should be counted more often. According to the *HPMS Manual* (FHWA 2016), count locations should be counted on a minimum 3-year count cycle and the State's traffic monitoring program shall cover all NHS and Principal Arterial System (PAS) roadway sections (i.e., Interstates, Other Freeways and Expressways, and Other Principal Arterials) on a 3-year cycle or better; at least one-third of these roadway sections should be counted each year. The remaining two-thirds counts must be estimated based on a documented process in accordance with the *TMG* and the *Field Manual* (FHWA 2016). The State shall cover all roads on these systems, not just State-owned roads, so data provided by MPOs, cities, or counties should be included in the count cycle.

A minimum of one-third of all NHS and Principal Arterial System (PAS) roadway sections (i.e., Interstates, Other Freeways and Expressways, and Other Principal Arterials) shall be counted each year; all other monitoring should be on a minimum 6-year cycle. The roadway sections to be counted should be randomly selected from each sample stratum (volume group), with minor adjustments as necessary for strata with numbers of sections not divisible by three or having less than three samples. A single count may be used for several sections between adjacent interchanges on controlled-access facilities.

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-term count data collection program itself can be structured in many ways. One simplistic approach is to randomly separate all 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 travel and traffic growth around the State.

In addition, most highway agencies collect data at some sites on a cycle shorter than 6 years. For example, more frequent counts (3-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-term count program. According to the HPMS manual, the Count Cycles and Coverage section states the following:

A State should have minimum count cycles and coverage as follows:

- Minimum 3-year count cycle – The State's traffic monitoring program shall cover all NHS and Principal Arterial System (PAS) roadway sections (i.e., Interstates, Other Freeways and Expressways, and Other Principal Arterials) on a 3-year cycle or better; at least one-third of these roadway sections should be counted each year. The remaining two-thirds counts must be estimated based on a documented process in accordance with the *TMG* and the *Field Manual*. The State shall cover all roads on these systems, not just State-owned roads, so data provided by MPOs, cities, or counties should be included in the count cycle.
- Minimum 6-year count cycle – The State shall also have a traffic count program on a 6-year cycle or better for all non-NHS lower functional system roadway sections (i.e., minor arterials, major collectors, and urban minor collectors). Traffic data for ramps, as defined in Chapter 4, are also to be collected on a 6-year cycle or better.

3.4.5 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's needs. However, there remain traffic data needs that cannot be met by the short-term count program. This is where an effective short-term 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. Non-HPMS data needs vary dramatically from State to State and agency to agency based on factors such as individual agency and State responsibilities and legal environments.

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,
- Point-specific estimates intended to meet project requirements and other studies defined by the highway agency.

All Special Events and Data Need Counts

Scheduled events typically call for the need to collect both continuous and short-term counts. Other events or special needs (such as project-specific counts) also warrant further traffic volume data collection.

Steps to collect special count data include:

a. Request information from the special need requestor (location, purpose, duration, etc.).
b. Schedule the collection of date(s). This schedule typically includes the event dates, and may include the day before the event, and day after the event.
c. Deploy the counters to collect the special count data (typically a mobile/portable counter that can be used in multiple count locations).
d. Download the data collected.
e. Analyze, report, and share the data using tabular and/or graphical representation.

The graphical example of collecting micromobility special needs program counts in a graphical representation is provided in the following example from the *Pedestrian Traffic and Safety on Four Anishinaabe Reservations Case Study* (Lindsey 2020), conducted by the Minnesota DOT. This data collection activity demonstrates the benefit of using an already-existing micromobility counter to collect special event data. The special event data shows an increase in bicycles and pedestrian volumes in 2020, as compared to historical averages. In this study, special need counts were collected using video detection to count bicyclists and pedestrians. Figure 3-4 shows the special 2020 traffic volume event total volume data by month of the year.

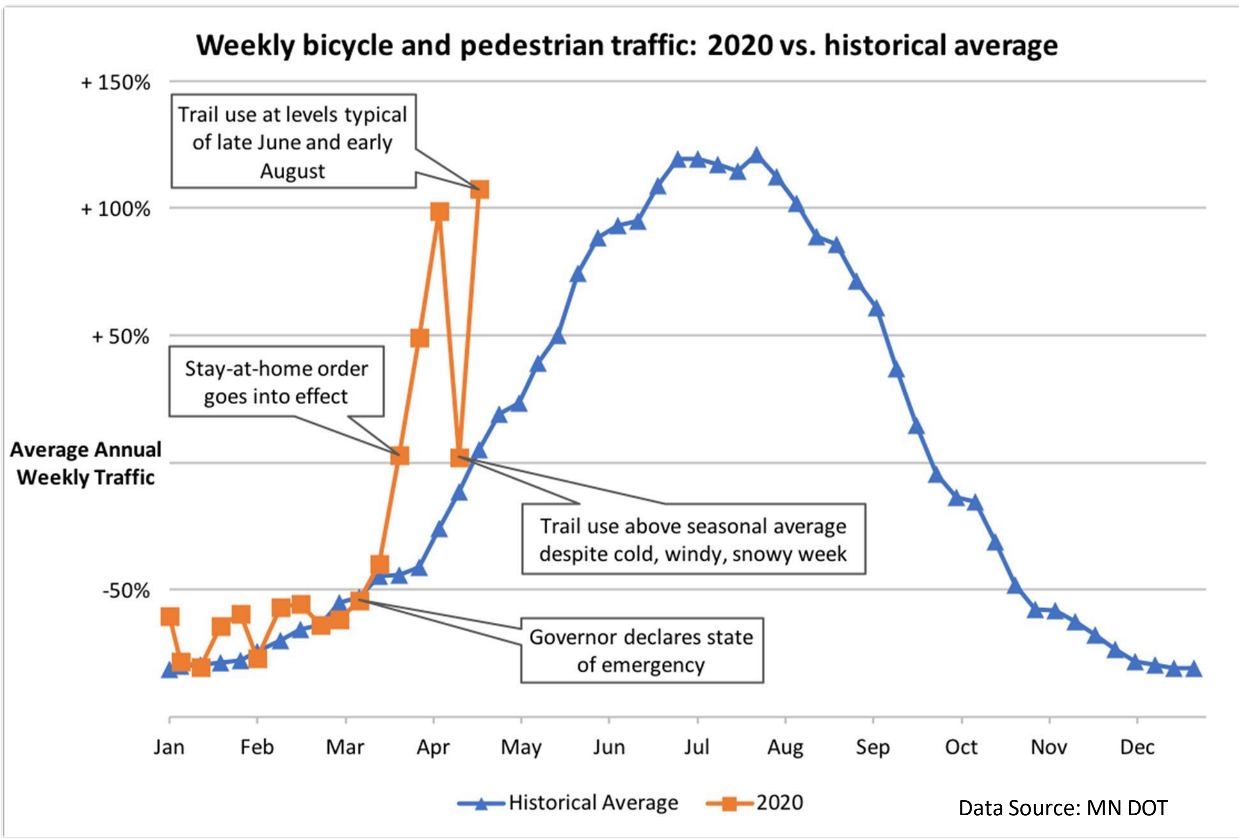


Figure 3-4. Weekly Bicycle and Pedestrian Traffic

Data were requested to obtain information for the purpose of understanding how parks and trails shape the world and conversely how the world shapes parks and trails. Without Minnesota DOT's and Minnesota DNRs permanent micromobility volume counters, there would be no baseline to understand and compare traffic volumes during events such as the 2020 special traffic volume event. Ultimately, data are collected to help make better and more-informed decisions. In the early days of the 2020 special traffic volume event, Minnesota DOT and Minnesota DNR simply wanted to understand, and share, how Minnesota's trails were being impacted. There were many questions: How much of the increase in trail use is attributable to the special traffic volume event? Should trail use be encouraged or cautioned? Are busy trails still safe to use? What time of day will traffic be highest? Although Minnesota DOT and Minnesota DNR could not give definitive answers to all those questions, they wanted to interpret and share the available data to people understand what was happening and make better-informed decisions.

Data collected in Minnesota during the special traffic data event provided useful information, so the Governor was able to visualize the effectiveness of any executive orders that were given to see if people were staying home and not traveling.

The traffic data program in Minnesota provided the funding and installed most of the continuous bicycle and pedestrian counters while working with the Office of Transit and Active Transportation on establishing a counting program like the motorized program. Since the Office of Transit and Active Transportation was seeing increases in the traffic volume, Minnesota leadership and data users were interested in accessing refreshed data daily that provided better information on changes throughout the State. Therefore, Minnesota DOT decided to implement a GIS dashboard showing the daily changes in volume and class.

Minnesota DOT reports that evidence is essential and simply providing counts, estimates of interactions and images from the counting technology, provided a basis for action. Information about the volumes of pedestrian crossings provided an additional rationale for Tribal transportation managers and county and State engineers to review proposed projects and identify opportunities for incremental improvements that could be incorporated into projects already planned and funded such as the trail along Mission Road to TH 210. Proposed countermeasures varied by intersection and included vegetation removal and line-of-sight improvements, new lighting, crosswalk improvements, rectangular rapid flashing beacons with advanced warning signs, ADA-compliant ramps, pedestrian education programs, realignment of intersections, and, at one intersection, a pedestrian hybrid beacon.

3.4.6 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.

The *HPMS Field Manual* (FHWA 2016) and *Sampling Techniques* (Cochran 1977) provides descriptions of how the HPMS samples are 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 needed accuracy and precision of the estimates. Any statistical samples developed should make use of the available data from the short-term 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.

3.4.7 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, HPMS guidance indicates that areas of the State selected for counting in a program year should be selected on a random basis. It further notes that highways with high variability should be counted more often than those with low variability, and highways with high traffic volume should be counted more extensively than those with low volume (HPMS Field Manual page 5-4). However, this quasi-random selection of count locations may not satisfy many site-specific traffic data needs necessary for pavement and bridge design calculations, for example. While statistical techniques are adequate for statewide VMT estimations, these averages or totals are not viable substitutes for actual counts taken at a specified location and time frame.

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-term 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-term 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 need's 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 based on 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.

3.4.8 Coordinating the Short-term and Special Needs Counts

Cost efficiency in the traffic-monitoring program is best achieved by carefully coordinating the different aspects within the program, which includes both the continuous and short-term counts. It also includes the short-term, *HPMS*, and special needs counts.

In theory, the highway agency would start each year with a clear understanding of all 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-term 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 soon, 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 are 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.

3.4.9 Adjusting Short-term Volume Counts to AADT

Short-term volume counts usually require several 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-term counts require adjustments to reduce the effects of temporal bias, if those short-term counts will be used to estimate AADT. In general, a 48-hour axle count is converted to AADT with the following formula:

$$AADT_{hi} = VOL_{hi} \times M_h \times D_h \times T_h \times A_i \times G_h$$

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 monthly (seasonal) factor for factor group *h*

D_h = the applicable DOW factor for factor group *h* (if needed)

T_h = the applicable TOD factor for factor group *h* (if needed for any partial day counts)

A_i = the applicable axle-correction factor for location *i* (if not a traffic volume or class count, i.e., for counts collected using a single pneumatic road tube)

G_h = the applicable yearly change (i.e., growth or decline) rate factor for factor group *h* (if needed)

This formula should be modified, as necessary, to account for the traffic count's specific characteristics. For example, if the short-term 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. For the TOD factor, this may be by hour or other time increment and is meant to adjust for any partial day counts taken. This factor can be a weighted value by hours in the day or other method. It is best to include any valid partial time increments for any portable counts including extra hours in the count duration. Including 49 hours of a 48-hour count improves the result of an annualized short-term count.

3.5 HOW TO COLLECT SPEED DATA USING PORTABLE COUNTS

Traffic monitoring devices used for vehicle classification or WIM can also provide 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 spacing and overall vehicle length. Many 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 important) and that the data collection electronics connected to those sensors have been set to collect the desired speed bins. Crews should perform an on-site calibration process each time they place equipment on the roadway by using a laser 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-term 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 are needed, thus ensuring the inclusion of those data locations within the routine short-term count data collection program.

3.6 HOW TO DESIGN A SHORT-TERM CLASSIFICATION DATA COLLECTION PROGRAM (AXLE AND LENGTH)

Short-term 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 vehicle class data volume information. Vehicle volume information has become particularly important for pavement design, freight mobility, planning, safety, and project programming decisions.

The *TMG* recommends that State highway agencies aim to collect at least 25 to 30 percent of their entire short-term count program with vehicle classification counting equipment.

FHWA's 13-Vehicle Category Classification

Figure 3-5 provides FHWA's 13-vehicle category classification recommended for short-term vehicle classification data collection. The table provides class naming (class 1, class 2, etc.), class types (motorcycle, passenger car, four tire single unit vehicles, etc.), and illustrative images of vehicles that represents each class.

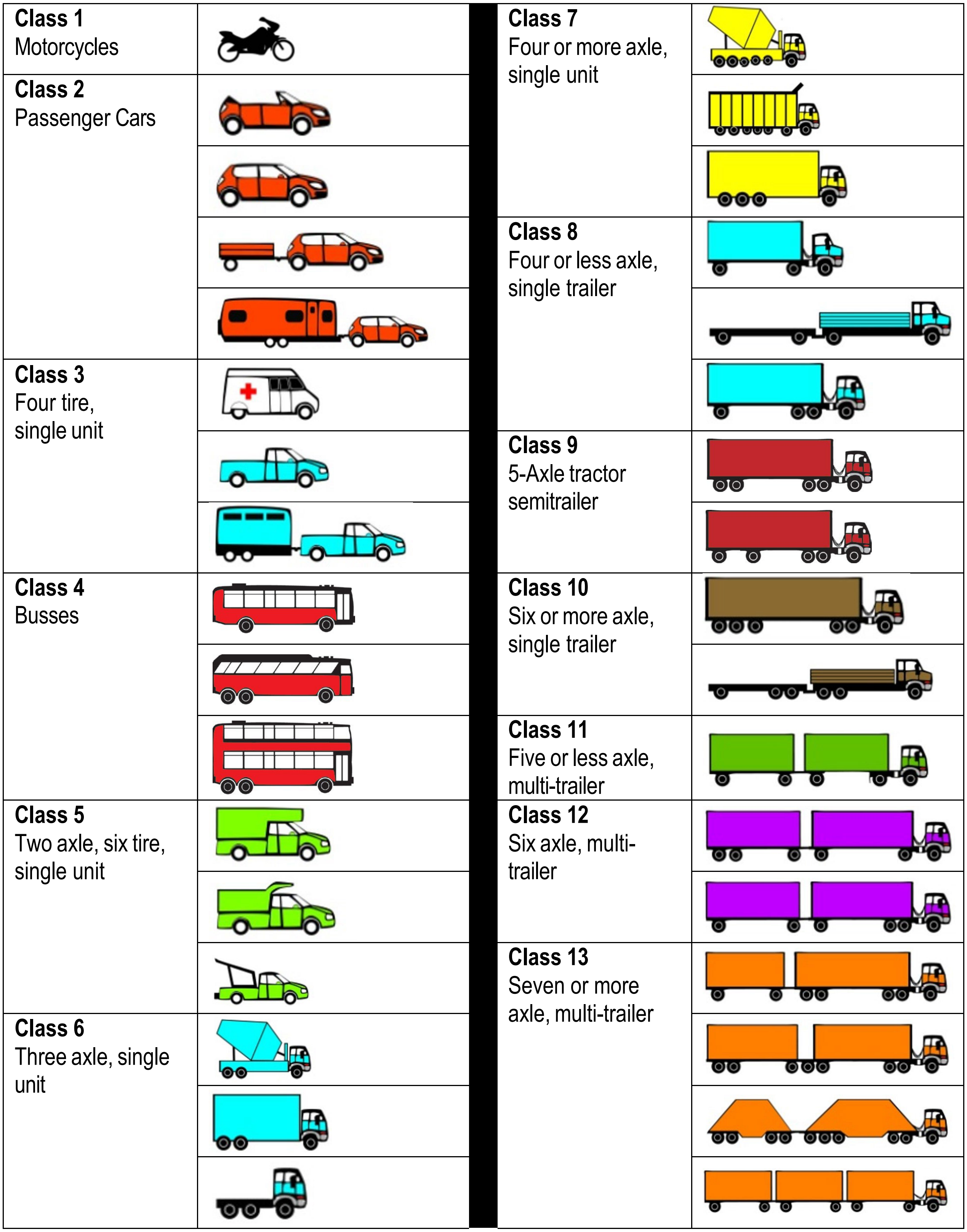
Certain truck configurations utilize axles that can be lifted when the vehicle is empty or lightly loaded. The position of these axles—sometimes called lift axles, drop axles, or tag axles—affects the classification category into which the vehicle falls. To maintain consistency between visual and axle-based 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 that has quarry traffic may exhibit directional differences in vehicle classification even though the same trucks may be traveling one direction loaded (with axles down – class 7) and the other direction empty (with axles lifted – class 6).

Most vehicles can be easily classified into this system by a human observer. 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 methods 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, number of axles, or other vehicle attributes.

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 will 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, which will limit or eliminate the need for staff to place sensors in the lane of travel.



Source: Federal Highway Administration.

Figure 3-5. FHWA'S 13-Vehicle Category Classification

The primary disadvantage of the length-based classification is that it does 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 most often not able to track the number of vehicles pulling one or more other units. The number of units in each 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 Division office for use of length class in any data submitted to FHWA.

Short-term Vehicle Classification Counts

Short-term classification counts are vitally important to the computation and submittal of the HPMS full extent traffic data and vehicle summary table. The vehicle summary table requires VMT by six vehicle types (motorcycles, passenger cars, light trucks, buses, single-unit trucks, and combination trucks) by six classes of roads (interstate, other arterials, and other roads for both urban and rural roads). Consequently, when collecting classification data, States should look to count at least these six vehicle classes whenever possible.

Given the growing need for data on truck volumes, a more comprehensive approach is required to provide classification data than what the *TMG* has historically recommended. The current 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.
- Decreasing the per-count cost of collecting classification data by having more classification counts in the traffic data collection program.

Short-Term Classification Count Program Design Considerations

The classification short-term count program should be designed to operate like a traditional volume coverage program to provide a minimum level of travel by vehicle type data on all system roads. The basic short-term 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 collect 25 to 30 percent of their short-term 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 are 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 segments similar to what is currently performed for volume and described in Section 3.1. Vehicle classification segments should carry a homogeneous volume of each class of vehicle. 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 help 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-term count program. Each agency will have to develop a classification inventory system to cover the roads that meet its needs.

Table 3-16 illustrates some of the considerations used in developing traffic segments and classification coverage programs based on the functional classification (and use) of roadways.

Table 3-16. Traffic Segments and Classification Short-Term 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; 25-30% of volume counts	Depends upon length (extent) of road and level of truck activity; higher the fluctuation in truck activity, the more counts should be taken at locations with changes in traffic volumes; traffic volume segments should encompass the classification segments

In some cases, the individual class of 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 serve significant individual traffic-generating activities (e.g., ports, quarries) will necessitate more classification segments, more classification counts, and more frequent revision than roads through regions that experience little unique by class travel activity.

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 classification counts. 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 3-year cycle.

Traffic engineering judgments are greatly needed to determine how to integrate classification and volume counting. Different agencies will make specific 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 different classes of vehicles, 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 thar classifies rather than only collecting volume data. The trend is to go toward collecting and storing all vehicle types in a per-vehicle format. However, changes in program direction, the acquisition of new equipment, and the implementation of program changes do not occur overnight.

Some lower-volume roads do not have the volume of different classification of vehicles (mainly recording of 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 individual classification volume estimates. In these cases, a decision to save a little time, effort, and funding could be appropriate.

On higher-volume roads, repetitive classification may greatly enhance the understanding of individual classification travel variability and result in better classification estimates. However, on these roads the collection of classification data is often more difficult due to multiple lanes and counting for longer periods in all lanes. 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 different vehicle types (motorcycles, buses, and trucks), and consequently counting of the six vehicle types 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 ensure a minimum of data available annually to represent each road. Where practical, these counts should be taken at existing HPMS volume sample sections to ensure 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 would 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 of a specific vehicle type plays a major role in defining coverage program segments and to ensure quality data are available to meet traffic data 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, it would be best to collect classification counts randomly (by location and time of year). 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 cycle of monitoring for the classification program is 3 years. The schedule of counts should be developed to ensure that coverage of each classification segment occurs at least once within a 6-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 the six types of vehicular travel.

Short-Term Vehicle Classification Count Duration

> The recommended minimum length of monitoring for vehicle classification data 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 (or other time increments such as 5, 10, or 15 minutes, etc.) 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 volume by class estimates of 48-hour counts increase for low-volume classes.
- Significant improvement in quality control capabilities become possible with the comparison of one day's hourly traffic counts against the second day's counts.
- Longevity of the sensors/road tube and equipment has improved to provide longer duration counts.

Counting throughout the day for an entire 24-hour period is important to determine accurate daily volumes, particularly on roads that carry substantial numbers of trucks. Counts that are less than 24 hours are not recommended but if collected, will need to be adjusted to daily totals using a daily adjustment factor to convert the shorter period to a 24-hour estimate that is then used to calculate an AADT. 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 temporal factors. Any deviation to not collecting 48 hours of class and/or 24/48 hour for volume should be detailed in the State TMS plan and approved by the FHWA Division Office.

Vehicle classification counts of longer than 48 hours are useful, and a minimum of 48 hours is recommended particularly when those counts extend over the weekend, since they provide better DOW volume information. Whether a highway agency can conduct longer counts is a function of short-term data collect program size, staff utilization, and other factors. Longer duration counts from 72 hours to 7 days are encouraged.

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-term 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-term program will allow a more complete understanding of specific types of 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), video imaging and various laser-based technologies, can classify accurately in urban conditions when they are correctly placed and calibrated. Traffic monitoring sites that combine multiple technologies help to overcome challenges with monitoring traffic in urban areas.

Studies can be undertaken to identify the classification segments where classification data needs exist. Examples of this include transit studies and motorcycle traveling roadway studies. The first step is to identify current installations where classification data may already be collected by ITS installations, State continuous counters, tolls, “your speed is” signs, bridges, traffic signals, etc. Retrieving those data reduces the need for the use of portable data collection equipment at as many sites. Secondly, 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-term and meet special count needs. Also, State DOTs can obtain counts from data partner agencies such as cities, counties, metropolitan planning organizations, and others to supplement their existing traffic data repositories.

Classification data also offer 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-term Count Program with Other Programs

At first glance, the short-term 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 expansion in the need for truck data. Many States already actively collect substantial amounts of classification data (25-30 percent of all CCS sites are classification stations) to meet their own data needs.

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 there is no need for an axle correction factor.

The short-term 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-term counts. Similarly, existing short-term counts can often supply project information, if the existing short-term count meets the informational needs of the project. Metadata to be included with the short-term count is very important.

Finally, the classification count program should be integrated with other travel and 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 travel and traffic management, safety, and traveler information systems.

3.7 HOW TO ACCOUNT FOR TRAFFIC VARIABILITY

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.

3.7.1 TRAFFIC VARIABILITY

Technology allows agencies to collect enough data to accurately describe how travel and traffic varies over time and space. Travel and traffic varies over a number of different temporal measures including:

- Time of day (time/hour of day, event-driven).
- Day of week.
- Month of the Year (season of the year).
- Year to year.

Travel and traffic varies from place to place and can also vary 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 bus 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 100 motorcycles per day while a nearby road is used by 1,000 partially loaded trucks. Directional variations also exist.

Time-Of-Day Variation

The rate of road usage typically changes during the day. In most locations, traffic volumes increase during the day and decrease at night, as can be seen in Figure 3-6. FHWA studies have 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 (see Figure 3-6), and the other pattern shows almost constant travel throughout the twenty-four-hour day (on predominantly throughway routes or near facilities with deliveries or dispatch 24 hours a day).

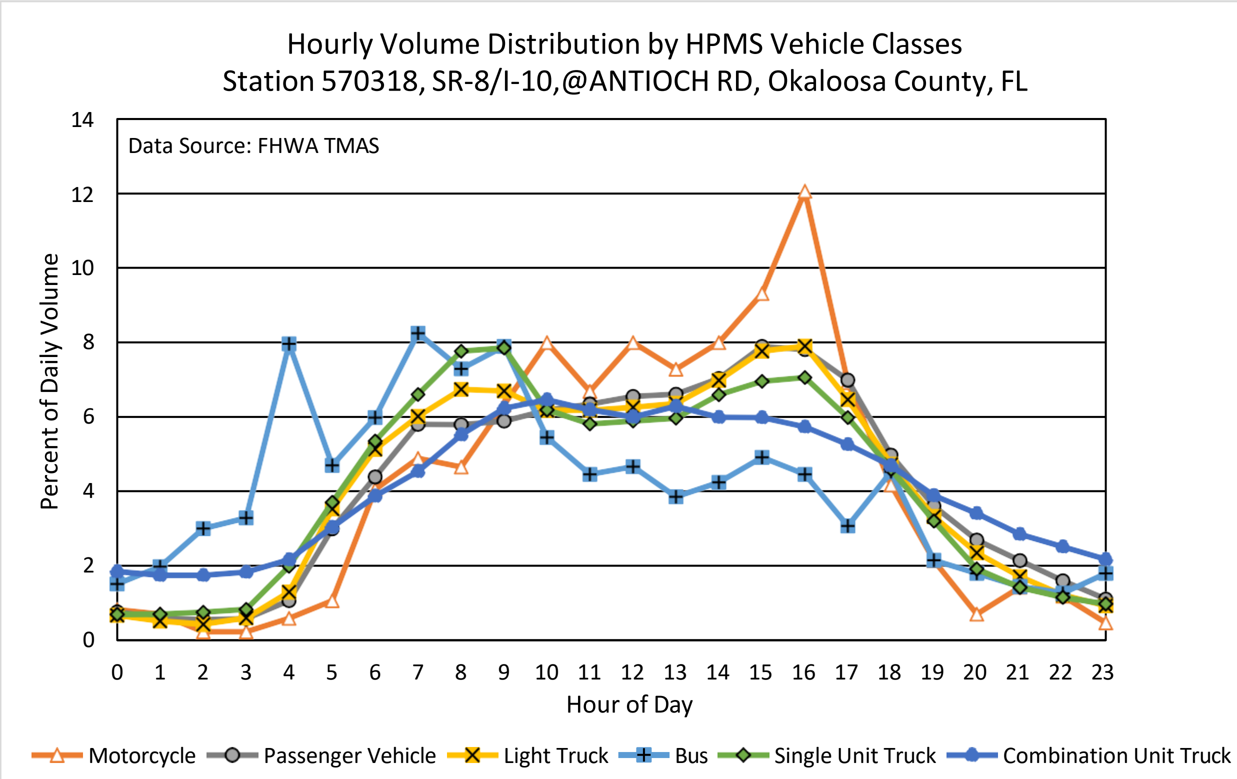


Figure 3-6. Example of Differences in Time-of-Day Traffic Volume by HPMS Vehicle Class

Passenger cars tend to follow either the traditional two-mode urban commute pattern or the single-mode pattern commonly seen in rural areas, where traffic volumes continue to grow throughout the day until they begin to taper off in the evening, as can be seen in Figure 3-6. Trucks serving local deliveries also exhibit a single mode that typically peaks in the early morning (many trucks make deliveries early in the morning to help prepare businesses for the coming workday). 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 because of local trip generation patterns that differ from the norm.

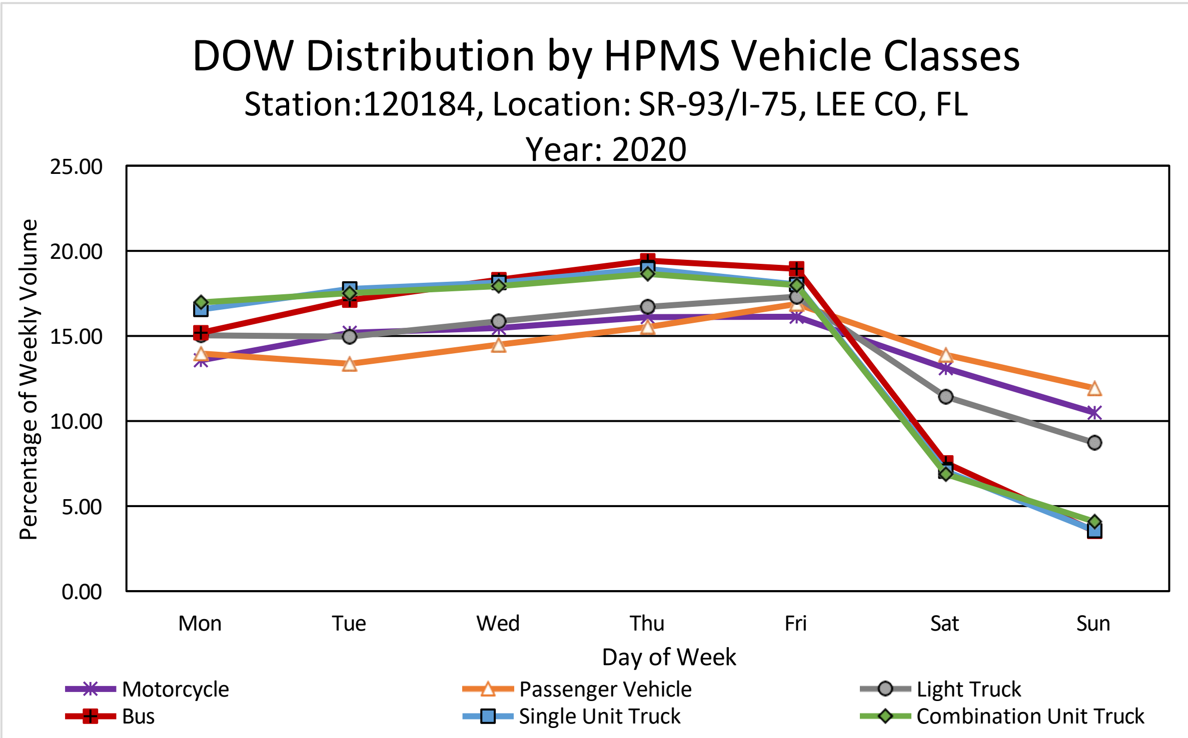
Because the volumes of the six different vehicle types are very different from one site to another, the effect of these different time-of-day patterns on summary statistics such as percent motorcycles, percent buses, percent trucks, percent bicycles, percent pedestrians, and total volume can be unexpected. Often, in daylight hours, urban car volumes are so high in comparison to truck volumes that the car travel pattern dominates, and the percentage of trucks is extremely 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 3-6 shows that during nighttime the TOD percentages of combination unit trucks drop less abruptly than for the other vehicle classes.

Because these changes can be 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.

Every portable class count should be, at a minimum, annualized into the six vehicle types utilized in the HPMS vehicle summary table regardless of the data collection duration (48/72 hours…etc.)

Day-Of-Week Variation

Day of the week patterns provide another way of viewing traffic volume data. Examples of DOW variation can be found in Figure 3-7.

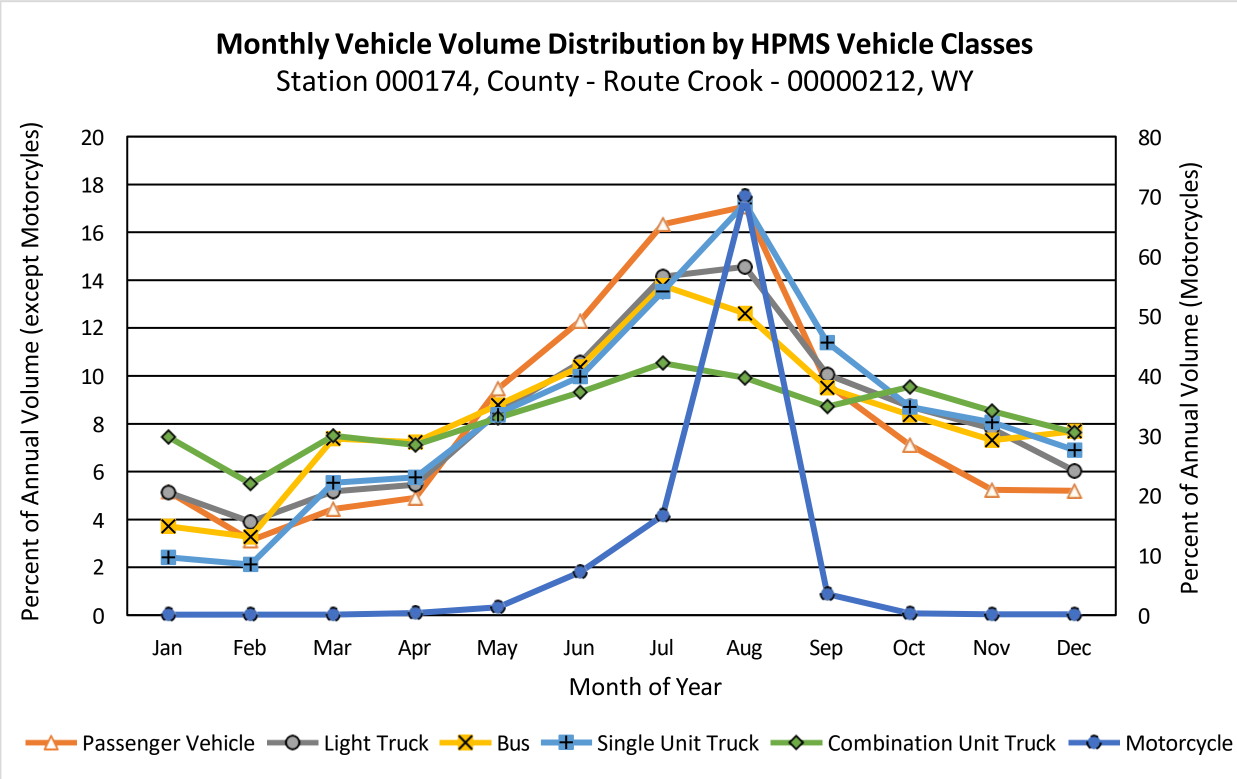


Source: Federal Highway Administration.

Figure 3-7. Example of Differences in Traffic Volume by Day of Week for Florida Site

Month of Year (Seasonal) Variation

Both car and truck traffic change over the course of the year. Monthly changes in volume of traffic have been tracked for many years with permanent traffic counters. Climate, proximity to major metropolitan areas or a major business venue, and primary vehicle use have an effect on seasonal travel pattern. Figure 3-8 shows an example of a typical MOY patterns by HPMS vehicle type for a rural road in Wyoming. Figure 3-8 shows that a higher percentage of annual travel happens during summer months, especially for motorcycles. Combination unit trucks show the least seasonality among the HPMS vehicle classes shown in Figure 3-8.



Source: Federal Highway Administration.

Figure 3-8. Example of Monthly Volume Pattern for a Rural Road in Wyoming

On a monthly basis, most States track travel and traffic 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 DOW 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-term traffic volume count taken in mid-August to account for the fact that August traffic differs from the annual average condition.

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 travelers 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 the six vehicle types.

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.

In areas with high recreational traffic flows, directional movements change the DOW traffic patterns as much as the TOD 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. Another example of directional changes in volumes by vehicle classification are roads leading to/from quarries or landfills. On these roads, single-body trucks with 4+ axles (dump trucks) equipped with liftable axles are reported as Class 7 (when trucks travel loaded and liftable axles are in the lowered position) in one direction and as Class 6 in the opposite direction (when trucks travel empty and liftable axles are in the elevated position).

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

When travel and traffic patterns for all six vehicle types are plotted on traffic flow maps, they often reveal that vehicle traffic routes exist irrespective of the total traffic volume and/or the functional classification of the roads involved. Vehicles use specific routes because those roads lead from the vehicle’s origin to their destination.

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?

3.7.2 Programs and Technology Designs that Account for Traffic Variability

The variability described in this section should be measured and accounted for in a micromobility 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 the following:

- Short-term data collection efforts.
- Permanent, continuously operating, data collection sites.

The short-term 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 TOD variation and can provide data on DOW variation in nonmotorized travel, but they are mostly intended to provide current general traffic volume information throughout the larger monitored network. However, short-term 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-term count. Instead, data collected during short-term counts are factored (adjusted) to create these annual average estimates.

To develop those factors, an agency should have an adequate number of permanently operating traffic monitoring sites. Permanent data collection sites provide temporal data on monthly (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.

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-term 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.

3.7.3 Micromobility Permanent Data Program

Comprehensive information on micromobility travel and traffic variability applies all the same concepts as in the motorized traffic monitoring program if enough data are collected throughout the network. Although comprehensive information on micromobility traffic variability is limited because very few public agencies have collected and analyzed continuous micromobility traffic data to date, it is expected that future analyses will contribute a much better understanding to the traffic monitoring guidance contained here. For this section, a single continuous monitoring location (e.g., Cherry Creek Trail, Denver, Colorado) is used to illustrate variability at that site. This single example may not be indicative of micromobility travel and traffic variability at other U.S. locations, especially those with a mild climate year-round.

There are multiple goals for understanding the TOD, DOW, and monthly variations in micromobility travel. One important goal is to estimate annual average daily use of micromobility facilities from short-term counts. This important statistic, referred to as AADT when applied to motorized vehicle traffic, is the most common reporting and comparison measure of facility use.

The variability described in this section should be measured and accounted for in a micromobility 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 the following:

- A modest number of permanent, continuously operating data collection sites.
- A large number of short-term data collection efforts.

The short-term 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 TOD variation and can provide data on DOW variation in micromobility travel, but they are mostly intended to provide current general traffic volume information throughout the larger monitored network.

However, short-term 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-term count. Instead, data collected during short-term counts are factored (adjusted) to create these annual average estimates.

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.

The process for collecting continuous micromobility traffic data should follow the same steps outlined in the volume traffic program design, 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.
7. Compute monthly, DOW, and hour-of-day (if applicable) factors to use in annualizing short-term counts.

The following sections provide additional detail for implementing these steps.

Pedestrians, bicyclists, scooters, and other micro-powered travelers are grouped together as micromobility traffic. A need exists to provide additional information for separate monitoring of pedestrian, bicycle, scooter, and other micro-powered traffic.

Like motorized traffic monitoring, there are many continuous volume count program design processes that help to define micromobility noteworthy practices for program development. These steps, while similar to motorized, have been documented below for details specific to micromobility travel.

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 (regarding permanent monitoring locations and equipment). This may be a short exercise for some agencies, as permanent continuous counts are much less common than short-term pedestrian and bicyclist counts.

However, these first two steps should not be bypassed simply if an agency does not have permanent count locations. Because nonmotorized 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 MPOs have often been more active than State DOTs in monitoring micromobility traffic.

Therefore, if a State DOT traffic data collection program will monitor micromobility traffic, it should coordinate with local and regional agencies as it inventories and reviews existing continuous counts. Additionally, it should inquire with departments other than the transportation or public works department. The following agencies or entities 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).
- Pedestrian and/or bicyclist advocacy groups.

The process outlined for motorized traffic volume is equally applicable for micromobility traffic.

Traffic Patterns

If existing continuous count data are available, they 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?

Data Processing

In reviewing the current program and existing micromobility data, one should also understand the basics of how data are processed by the field equipment and loaded into the 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 nonmotorized 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 documented and approved procedures should 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 AADT. Because of the greater monthly variability of micromobility traffic, other summary statistics may be more relevant:

- Monthly (seasonal) average daily traffic (seasonal average daily traffic [SADT] is a traffic statistic used by the National Park Service in addition to AADT. SADT computation includes those months that contain at least 80 percent of the annual traffic).
- Average daily traffic by month and day of week.
- 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.

Step 3: Determine the Traffic Patterns to Be Monitored

After reviewing the existing micromobility 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 micromobility 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)?

Once the micromobility network to be monitored has been defined, an agency should determine the most likely types of traffic patterns that are expected on this network. In most cases, the nonmotorized 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 are preferred for this step, but short-term counts (multiple full days, but not 2-hour counts on a single day) may also be used with caution.

Step 4: Establish Monthly Pattern Groups

In the previous step (Step 3), existing nonmotorized data were 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, nonmotorized count data may not be available in Step 3 to determine the most likely traffic pattern groups. In these cases, previous analyses of nonmotorized data from previous studies or of similar locations should be used as a starting point. Once more nonmotorized data are gathered in your region, these traffic pattern groups can be refined based on your local data.

Previous (but limited) research indicates that nonmotorized traffic patterns can be classified into one of these three categories (each with their own unique TOD and DOW patterns):

1. Commuter and work/school-based trips – typically have the highest peaks in the morning and evening.
2. Recreation/utilitarian – may peak only once daily or be evenly distributed throughout the day.
3. Mixed trip purposes (both commuter and recreation/utilitarian) – has varying levels of these two different trips purposes or may include other miscellaneous trip purposes.

For more detailed visualization examples, see Appendix J.

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 TOD and DOW traffic patterns.

Step 5: Determine Appropriate Number of Continuous Monitoring Locations

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 are collected on nonmotorized traffic.

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 Micromobility device 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-term) 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 nonmotorized traffic patterns (while still having moderate nonmotorized 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-term counts. Continuous counts at a high-pedestrian or high-bicyclist location may look impressive but may not yield accurate results when factoring short-term 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.
- For inductance loop detectors, not near high-power utility lines that could disrupt or distort the detection capability.

Step 7: Compute Adjustment Factors

The computation of adjustment factors should follow a similar process as motorized traffic volumes outlined in Section 3.2.5. These adjustment factors will be calculated for each unique nonmotorized traffic factor group as determined in Step 4.

In practice, very few agencies have applied monthly or DOW adjustment factors to short-term nonmotorized counts. The current prevailing practice is to collect short-term 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 nonmotorized count locations are installed.

3.8 TRAFFIC DATA PROCESSING

3.8.1 Calculations and Computations for End-of-Year Processing

This section presents basic statistics or estimates derived from the vehicle classification program. Statistics discussed include:

- MADT – Monthly Average Daily Traffic
- AADT – Annual Average Daily Traffic
- AADTT – Annual Average Daily Truck Traffic (used for pavement design and management purposes)
- AVDT – Annual Vehicle Distance Traveled
- DVDT – Daily Vehicle Distance Traveled

3.8.2 Methods for AADT Calculations for CCS

There are three basic procedures for calculating AADT. The first two have been used historically, while the third is being currently recommended by FHWA to produce a more statistically reliable outcome.

- A simple average of all days.
- An average of averages (the American Association of State Highway Transportation Officials (AASHTO) method) (See Appendix L).
- The new FHWA AADT method with any time increment (Krile 2015a) – this method is recommended over the other two methods.

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. Blocks of missing days of data (for example, data from June 15 to July 15) can bias the annual values by removing data that has 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 often bias the results (this bias depends on what days are missing and how much of the data is missing) when an unequal number of weekday or weekend days are removed from the dataset. Because continuous count stations may have equipment down time during a year thus missing one or more days of data, AASHTO adopted a different approach for calculating AADT. Details of AASHTO method for AADT computation are found in Appendix L.

There are two limitations with the traditional AASHTO method. One limitation is that the AASHTO AADT equation uses only complete days of data. This means that the loss of one or more hours of data due to errors in the data collection process results in the loss of a full day of data from the AADT computation, reducing the number of useful time increments and providing a reduced accuracy of the resulting AADT estimate. The second limitation is that the averaging process used in the AASHTO method produces a small bias in the resulting AADT estimate. There are two biases affecting the AASTHO method, the first is the under valuing of months with fewer than 31 days, and the second is the day-of-week bias caused by the number of days of week present in each month, which varies from month to month and year to year.

As a result, FHWA is recommending the use of the following AADT formulation for computing AADT. This computation is performed in two steps. The first step computes monthly average daily traffic from the available hourly (or other temporal period) count records. The formula will work equally well with any temporal interval data, such as the 5-minute or 1-minute data frequently recorded by ITS-based traffic management systems. The second step then computes AADT from the twelve available monthly values. These two mathematical steps are as follows:

$$MADT_m = \frac{\sum_{j=1}^{7} w_{jm} \sum_{h=1}^{24} \left[\frac{1}{n_{hjm}} \sum_{i=1}^{n_{hjm}} VOL_{ihjm} \right]}{\sum_{j=1}^{7} w_{jm}}$$

and

$$AADT = \frac{\sum_{m=1}^{12} d_m * MADT_m}{\sum_{m=1}^{12} d_m}$$

Where:

AADT = annual average daily traffic

$MADT_m$ = monthly average daily traffic for month m

VOL_{ihjm} = total traffic volume for i^{th} occurrence of the h^{th} hour of day within j^{th} day of week during the m^{th} month

i = occurrence of a particular hour of day within a particular day of the week in a particular month (i=1,…n_{hjm}) for which traffic volume is available

h = hour of the day (h=1,2,…24) – or other temporal interval

j = day of the week (j=1,2,…7)

m = month (m=1,…12)

n_{hjm} = the number of times the h^{th} hour of day within the j^{th} day of week during the m^{th} month has available traffic volume (n_{hjm} ranges from 1 to 5 depending on hour of day, day of week, month, and data availability)

w_{jm} = the weighting for the number of times the j^{th} day of week occurs during the m^{th} month (either 4 of 5); the sum of the weights in the denominator is the number of calendar days in the month (i.e., 28, 29, 30, or 31)

d_m = the weighting for the number of days (i.e., 28, 29, 30, or 31) for the m^{th} month in the particular year

Table 3-17. Example Abbreviated Dataset (Selected Hours) Showing Partial-day Counts

Day	DOW	HR 0	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9
1	**Tue**	78	35	37	70	180	512	599	620	624	641
2	**Wed**	56	38	33	71	165	428	562	582	658	664
3	**Thu**	50	39	30	63	174	483	596	629	644	596
4	**Fri**	22	24	15	56	147	415	431	537	666	624
5	**Sat**	136	78	47	63	98	208	303	451	641	770
6	**Sun**	89	48	34	25	29	34	81	168	226	307
7	**Mon**	65	39	25	56	188	495	615	614	622	642
8	**Tue**	56	32	26	70	167	535	584	M**	M**	595
9	**Wed**	16	12	15	46	142	419	444	404	392	334
10	**Thu**	57	31	22	61	165	485	593	624	644	586
11	**Fri**	16	21	16	60	150	398	422	383	374	391
12	**Sat**	118	67	56	68	107	201	301	446	611	669
13	**Sun**	92	39	DST*	30	18	41	81	118	195	243
14	**Mon**	42	26	16	20	17	65	158	195	218	216
15	**Tue**	39	37	30	65	159	514	597	608	629	660
16	**Wed***	76	31	36	61	182	496	NA	NA	NA	NA

*For more information on this method, please refer to *TRB Paper Number: 16-2477 (2016)*.

**Maintenance

3.8.3 Procedure for AADT Calculation Based on CCS Data Using the FHWA Formula

AADT calculations are demonstrated in the steps below using the new FHWA AADT methodology.

Step 1 – determine the time increment of the data (hourly, 10 minutes, 5 minutes or 1 minute…)

The new FHWA AADT formula will work with data in any time interval. All time intervals need to be the same length.

Apply steps 2 to 6 to each month of data.

Step 2 – sum volumes for all time increments by each day of week

Sum volumes for each time increment for 12:05 am to 12:09:59, and so on for each time increment for each DOW.

For 5-minute increment of data, sum the values for Sunday at 12:00:00 am to 12:04:59 am for each time this data is available for a given month (it could be 1 or up to 5 values that are summed for a given month).

Table 3-18. Example of Hourly Totals for Time-of-Day and Day-of-Week

May 2019 Time	1st Sunday Volume	2nd Sunday Volume	3rd Sunday Volume	4th Sunday Volume	5th Sunday Volume	Total
12:00:00 AM	18	23	21	17	NA	79
12:05:00 AM	15	20	18	16	NA	69
12:10:00 AM	10	21	16	15	NA	62
12:15:00 AM	13	18	16	14	NA	61
12:20:00 AM	16	19	18	NA	NA	53
12:25:00 AM	12	17	15	NA	NA	44
12:30:00 AM	12	16	14	NA	NA	42

May 2019 Time	1st Sunday Volume	2nd Sunday Volume	3rd Sunday Volume	4th Sunday Volume	5th Sunday Volume	Total
12:35:00 AM	10	14	12	12	NA	48
12:40:00 AM	8	15	12	10	NA	45
12:45:00 AM	7	12	10	10	NA	39
12:50:00 AM	8	10	9	8	NA	35
12:55:00 AM	5	8	7	7	NA	27
1:00:00 AM	7	8	9	6	NA	30
1:05:00 AM	6	7	9	7	NA	29

Step 3 – determine the average volume for each time increment for every DOW (Average DOW Increment Volume)

Table 3-19. Example of Day-of-Week Averages

May 2019 Time	1st Sunday Volume	2nd Sunday Volume	3rd Sunday Volume	4th Sunday Volume	5th Sunday Volume	Total	Average DOW Increment
12:00:00 AM	18	23	21	17	NA	79	20
12:05:00 AM	15	20	18	16	NA	69	17
12:10:00 AM	10	21	16	15	NA	62	15
12:15:00 AM	13	18	16	14	NA	61	15
12:20:00 AM	16	19	18	NA	NA	53	18
12:25:00 AM	12	17	15	NA	NA	44	15
12:30:00 AM	12	16	14	NA	NA	42	14
12:35:00 AM	10	14	12	12	NA	48	12
12:40:00 AM	8	15	12	10	NA	45	11
12:45:00 AM	7	12	10	10	NA	39	10
12:50:00 AM	8	10	9	8	NA	35	9
12:55:00 AM	5	8	7	7	NA	27	7
1:00:00 AM	7	8	9	6	NA	30	8
1:05:00 AM	6	7	9	7	NA	29	7

Step 4 – sum all average time increment volumes for each DOW

Step 5 – correctly weight each DOW volumes for how many DOWs are present for the given month/year

For example, when one month has 5 Tuesdays vs. 4 Tuesdays, each DOW volume is weighted by the actual number of individual days that specific day is present in the given month for the given year.

Step 6 – average the DOW volume values across all DOWs to obtain a Monthly Average Daily Traffic (MADT)

Step 7 – correctly weight for the number of days in each of the 12 MADTs (i.e., use the number of days in a month as weighting factors in computing weighted average)

Step 8 – average the DOW values together to obtain an AADT for the year

The limitation of this method is that it requires at least one time increment for each day of week in each month of the year. The disadvantage of the method is that each MADT is not as consistent from year to year as the AASHTO method. The advantages of using this method are that it more accurately provides AADT estimates when data are missing and provides better estimates than the other two AADT methods, it allows for partial day data to be utilized, it removes the known bias in the AASHTO method, it provides for any time increment of data for AADT estimates (e.g., 1 min, 5 min, 15 minute, hourly), and it allows for ITS and other non-traditional sources of data for seamless AADT estimates provided every time increment is present for each day of the week for a given month.

Micromobility AADT Calculations

Calculating AADTs for bicycle, pedestrian, and other micromobility modes is still evolving and how to report these AADTs is also non-uniform across traffic monitoring programs. However, several methods for calculating micromobility AADTs are being researched and studied.

Rounding AADTs

The rounding of AADTs is acceptable for HPMS purposes when following the scheme recommended by the *AASHTO Guide (AASHTO 2009)*. The *TMG* does not recommend this unless it is common practice for the State to round all traffic data in its 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 are available to develop a reasonable AADT estimation from permanent continuous counters for the current year, rounding is not recommended**.**

3.8.4 Computation of AVDT and DVDT

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 FHWA also computes the AVDT for each segment.

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). Aggregate DVDT 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.

The HPMS standard sample sizes are defined in terms of AADT within strata (described in the *HPMS Field Manual* (FHWA 2016)). 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* (Cochran 1977).

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, and a complete discussion of ratio-estimation procedures, is presented in *Sampling Techniques* (Cochran 1977). 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.

The example above provides a rule of thumb and the expected precision of statewide DVDT estimates (excluding local functional class). 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. For example, traffic volumes can vary from year to year but still yield accurate (i.e., unbiased) volume estimates.

3.8.5 Estimating Annual Average Daily Traffic Volumes from Short-Term Counts of More Than 24-Hours

When the data are 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 AADT.
- If a general DOW adjustment (e.g., a single weekday to average DOW adjustment), the individual time increment 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.

Using extra hours of more than 48 but under 72 is recommended by FHWA. However, it is not recommended to truncate a 50-hour count to just 48 to fit the 2-day count number of hours needed. Utilizing the extra hours collected improve the resultant ADT to AADT values. Use of the new FHWA method of calculating AADTs provides less biased and more accurate results than other methods, such as the AASHTO method. There is a published informational guide from this research that describes four preparation steps for safety data integration and an eight-step process for developing a random stratified sampling scheme and AADT estimates for non-Federal aid-system (NFAS) roads (see *Collection and Estimation of AADT on Lower-Volume Roads* (Tsapakis 2016)).

Short-term volume counts require several adjustments to convert a daily traffic volume raw count into an estimate of AADT. See Section 3.4.9 for computational details.

3.8.6 Estimating Annual Average Daily Truck Traffic Volumes from Short-Term Counts

Computation of AADTT (by vehicle class) from a short-term count requires the application of one or more factors that account for differences in TOD, DOW, and monthly (seasonal) travel by vehicle type 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.

3.9 FACTORS

There are two categories of factors—one is the annualization of traffic data and the other is for traffic engineering analyses. 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. The FHWA *Traffic Data Computation Method Pocket Guide* (FHWA 2018) is an excellent source of information about computing different traffic parameters, including factors.

The temporal factors are time-of-day (TOD), day-of-week (DOW), month-of-year (MOY) and year-to-year (YTY) factors. These factors are computed from continuous count station data for use in adjusting short-term count data to estimates of AADT.

3.9.1 Temporal Factors

Time-of-Day Factoring

TOD factoring is an FHWA-recommended methodology that should be implemented in traffic data processing software. TOD factors are used to estimate daily volume from less-than-24-hour samples. Currently, several DOTs use a traffic data processing software platform that does not support or provide the features to support TOD factoring.

Day-of-Week Factoring

DOW factors are used to correct for bias according to the day of the week. For example, Maine uses a DOW factor that averages each hour of the day for Monday, beginning at midnight and ending on Friday at noon. This factoring process is possible in the state of Maine because 98% of the short-term counts are collected during the same timeframe in which the DOW factor is calculated.

Month-of-Year Factoring

The monthly factor is used to correct for MOY bias in short-term counts. Directions on how to create and apply monthly factors are provided in the general discussion of factoring in Section 3.2.5 Step 4. Those procedures are recommended for the HPMS reporting, discussed further in Chapter 5. 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.

Year-to-Year Factoring

States use a YTY factor to account for increases and decreases in traffic volume from year to year. For example, in Washington State, the same factor groups as used for DOW and MOY factoring are used for YTY factoring. Not having distinct growth factor groups can produce sub-optimal results (particularly for the more rural groups and when the groups are not partially defined by geographic area) but no special work is needed to maintain them (a benefit given how much effort is already put into maintaining and refining factor groups).

Another example of YTY factoring is from North Carolina where the State DOT has implemented a county-level factoring process. This is an effective factoring method in North Carolina because the variation of traffic volume from county to county is high, and some rural counties are experiencing a decline in population where other urban areas are gaining population. States should consider developing different YTY factors by vehicle type.

Example of various factors can be found in Appendix J.

3.9.2 Axle Correction Factoring

The traffic data collection 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. Axle correction factors are developed from vehicle classification or WIM counts reported in IVR formats. The Glossary provides definition of axle correction factors.

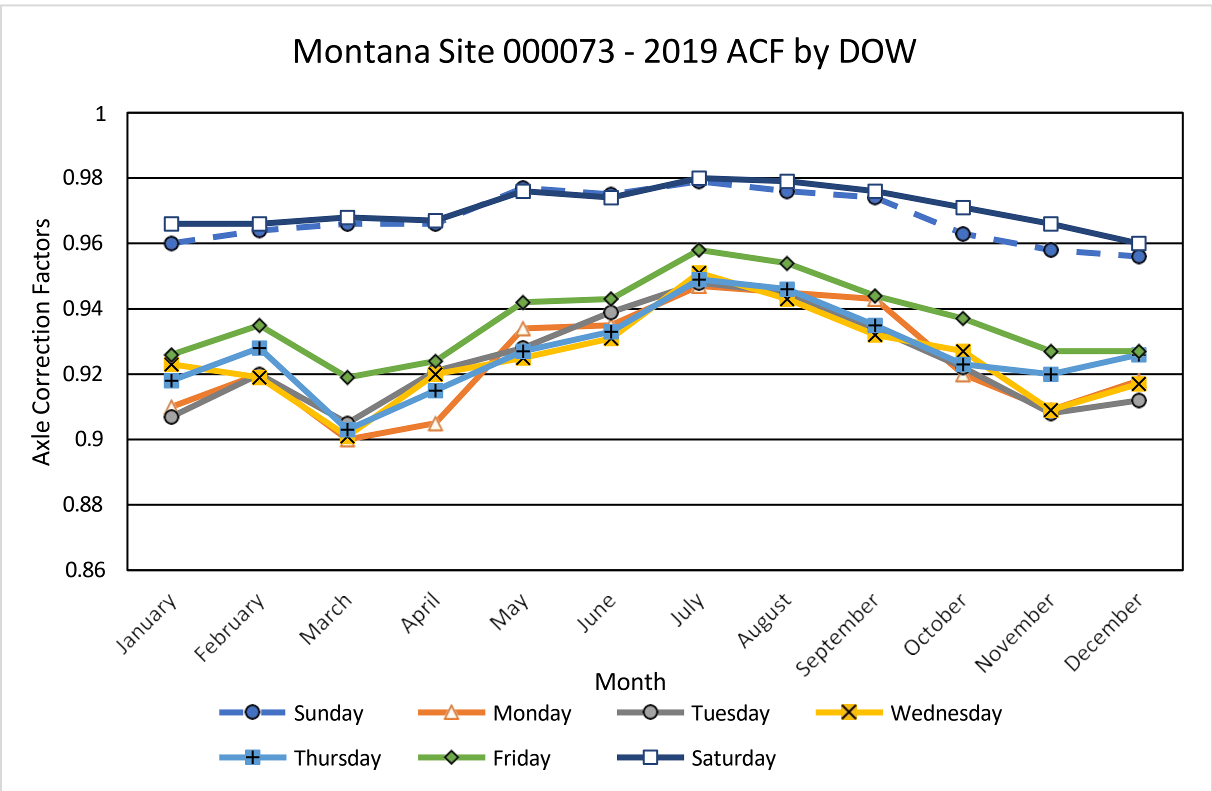
> In general, the higher the percentage of multi-axle vehicles on a road, the more error will be introduced into the data by not using axle correction factors.

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/roadways or from a combination of vehicle classification counts averaged together to represent an entire system of roads or factor grouping. 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 and WIM 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. Figure 3-9 provides an example on how Axle Correction Factors (ACFs) can vary by DOW and MOY.



Source: Federal Highway Administration.

Figure 3-9. Example of Differences in ACF by DOW and MOY in Montana

For roads where these adjustment factors are not available, a system-wide factor is recommended. The system-wide factor should be computed by averaging the ACFs 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 by-vehicle-type route classification system, this classification system may be substituted for the functional class strata.

Computation of Axle Correction Factors

The *TMG* recommends that axle correction factors be developed using individual vehicle records formatted data from continuous counting axle class sites or WIM sites.

Similar to applying factors by each vehicle class, the axle correction factoring methods apply factors by using the minimum six HPMS vehicle classes.

Emphasis on the collection of classification data should minimize the need for ACFs. Whenever possible, ACFs 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 ACF can be estimated from the WIM and continuous classification sites that have per vehicle data. These values should be made publicly available for anyone collecting data from a single road tube count in the state.

Axle correction factors are required for all single road tube counts.

Example of ACF Computation

Table 3-20 provides an example of ACF computation. In the table, vehicle volume is computed by dividing the total number of axles counted by the average number per vehicle. 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 3-20. Example Calculation of the ACF

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

Example of Applying ACF

Table 3-21 illustrates the process of applying ACFs to convert axle counts to traffic volume estimates. The table provides a conservative estimate of the number of axles per vehicle for the FHWA 13-vehicle category classes. 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 3-21. Number of Axles Per Vehicle

FHWA Vehicle Class	Daily Vehicle Volume	Total Number of Axles	Average Number of Axles Per Vehicle
1	100	200.0	2.0
2	1,400	3,080	2.2
3	45	103.5	2.3
4	15	31.5	2.1
5*	20	40.0	2.0
6	40	120.0	3.0
7	5	21.0	4.2
8	15	58	3.9
9	120	600	5.0
10	5	32	6.4
11	15	73.5	4.9
12	5	30	6.0
13	10	75	7.5
Total Volume	1,795		
Total Number of Axles		4,465	
Average Number of Axles Per Vehicle			2.49

**Class 5 – vehicles with trailers should not be put in class 5 (i.e., class 5 cannot have a trailer). For example, an RV with a boat/etc. should not be classified as 5.*

3.9.3 FACTORING SHORT TERM COUNTS

Short-term volume counts require several adjustments to convert a daily traffic volume or vehicle classification raw count into an estimate of AADT.

A factoring process is necessary to adjust short-term counts to best represent an annualized estimate. A similar process should be used to annualize motorized and micromobility 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 or partial days are present in the total multi-day count, this factor adjusts a sub-daily count to a total daily count.
2. Day of week: If data are collected on a single weekday or weekend day, this factor adjusts a single daily count to an average daily weekday count, weekend count, or DOW 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). This factor is applied to correct for known under-biased count results from the occlusion of some of the count results. Documenting the process utilized for occlusion factoring should be included in the TMS.
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. Documenting the process utilized for weather factoring should be included in the TMS.

The last two factors typically apply for micromobility counts only. The micromobility data submittal formats in Chapter 4 provide the capability to report these five types of adjustment factors in five separate factor groups.

Adjustment factors should be 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 traffic counts and permit the short-term counts to be annualized in a way that minimizes error.

Many State DOTs have data warehouse tools that already perform the factoring process for motorized traffic counts. See Section 3.2.8 for a computational example showing application of factors for motorized traffic counts. Many of these tools and factoring processes could be used for micromobility traffic factoring, given some adaptation. Since State DOTs already have motorized traffic monitoring programs in place, many micromobility programs can take advantage of making investments in existing software and trained traffic data analysts.

3.9.3.1 Micromobility Example: Factoring Short-Term Counts

The following simplified example illustrates the process of calculating an estimate of annual average traffic based on a short-term count pedestrian and bicyclist count. The example is for mixed-mode, micromobility 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 (Lindsey 2012).

For this example, 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). The 24-hour mixed-mode traffic count for Friday was 175 and the 24-hour count for Saturday was 250. What is a reasonable estimate of annual 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 3-22 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.
- 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:

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.

1. Estimate the MADT for February 2012.
2. Use the MADT/AADT ratio from February 2011 to estimate the 2012 AADT and 2012 annual traffic.
3. Use the 2011 Friday and Saturday mean daily traffic rations for February to calculate an average adjustment factor for the February 2012 48-hour monitoring period. From Table 3-22, 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)/2) / 1.16 = 183
5. From Table 3-22, 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 2-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 3-22. 2011 Mixed-Mode Traffic Count Statistics for Midtown Greenway Near Hennepin Avenue, Minneapolis, Minnesota

Measurement	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	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.

Other resources providing information on micromobility data formatting can be found in the *Guidebook on Pedestrian and Bicycle Volume Data Collection* (NASEM 2014).

3.9.3.2 Micromobility Weather Factor

Weather can be a significant factor in the level and variability of micromobility traffic and should be considered when developing a short-term micromobility program. Monthly (seasonal) weather patterns (such as cold winters or hot/humid summers) are expected by micromobility travelers 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-term 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 7 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 micromobility traffic, weather conditions should be recorded in a nonmotorized traffic monitoring program. The micromobility data submittal format in Chapter 4 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.

Months/Seasons of Year for Data Collection

The specific months/seasons of the year for short-term 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 nonmotorized traffic levels.

Short-term 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 micromobility traffic.

3.9.4 Considerations for Collecting Motorcycle Data and Correction Factoring

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:

- 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 are the denominator for exposure and crash rates):
- Motorcycle exposure data are used to inform national decisions and establish motorcycle-related policies and safety countermeasure programs.
- Motorcycle exposure data are an important part of current safety performance measures, which measure the number of motorcycle fatalities per vehicle registrations and per million miles traveled.
- 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 are a critical element for developing effective safety countermeasures.

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. Virginia and Wisconsin DOTs also use length-based classification devices of about 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 (Schinkel 2008). One of these bins, Bin 21, is used for vehicles whose length is less than 7 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 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, buses, 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-term 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-term counts to estimates of AADT that specifically factor short-term 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-term classification counts yield biased annual estimates of motorcycle travel.

As noted in the *HPMS Field Manual* (FHWA 2016), although motorcycles are a small percent of travel, they have significant safety issues that require attention for estimating their travel exposure. Continuous counters provide an understanding of how typical motorcycle travel varies by day of the week and month of the year. To provide motorcycle specific adjustment factors, States should account for motorcycle travel patterns when selecting locations for permanent vehicle classification counters.

To capture motorcycle movements and more effectively estimate annual motorcycle VMT, some short-term counts should be conducted in places and times where motorcyclists are known to travel such as weekend rallies, runs, and shows and on other roads used for recreational motorcycle travel. Some of these data should be collected using thoughtfully sited, permanent count sites placed on recreational routes with motorcycle travel. This data collection effort yields basic motorcycle traffic statistics including geographic variability and the TOD distribution.

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 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*, FHWA 2016).

Traffic data collection, including motorcycle data collection, is eligible for Federal funding under a wide range of Federal-aid highway programs.

Considerable improvement in the accuracy of motorcycle counts area has been made in the past few years. Montana utilizes bi-wheel path counting for proper motorcycle counting, which is especially effective during motorcycle rallies where motorcycles may be doubled-up into one lane. Many State DOTs use a wider 6’ by 8’ loop in the lane to provide a large lane coverage that prevents motorcycles from not being detected by 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:

- Motorcycles in parallel or staggered formation may confuse detectors unless wheel path counting sensor set-up or segmented sensor technology is used.
- Adjusting detector sensitivity for trucks may lead to reduced detection of motorcycles.
- 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.

> Full-lane width sensors should be installed for the most accurate classification detection of vehicles, unless by wheel path counting is being done.

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 and when installing piezos, the full lane width should be used. Full lane width for road tube sets for class counts are also recommended.

Quadrupole loops also known as figure-8 style loop detectors have enhanced sensitivity for detecting motorcycles, bicycles, and smaller cars. The Montana DOT provides an example of loop lane configuration placement installation diagrams illustrating a best practice, see Appendix I.

Sensors that cover a small area such as magnetometers have problems detecting motorcycles or groups of motorcycles.

All vehicle classifiers should be annually calibrated and regularly 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 FHWA *Pooled Fund Program Report TPF-5[192], Loop and Length Based Vehicle Classification* (Minge 2012) prepared for Minnesota DOT provides more information.

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 represent travel and traffic conditions.

3.10 QUALITY ASSURANCE – STARTS WITH THE DATA QUALITY ACT 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.

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

FHWA recommends traffic monitoring programs consider the following seven data quality principles:

1. Data quality is more than correcting data.
2. Data assessment identifies process improvements.
3. Quality control process checks for valid data, not necessarily accurate data.
4. Data need to be useful, not just accurate.
5. Quality problems are not (necessarily) caused by people.
6. Inserted non-quality data does not improve quality.
7. Recounts and poor decisions are more costly than ensuring initial data quality.

Appendix C provides a compendium of data quality control criteria for State highway agency implementation.

Chapter 4. TRAFFIC MONITORING DATA FORMATS

4.1 INTRODUCTION

This chapter provides coding instructions and detailed record formats for the traffic data to be reported to FHWA as part of each State's traffic monitoring program. ASCII text files are used for both the historical fixed-width column format and the new pipe-delimited format.

Data formats are provided for two types of data:

- **Motorized** data include station description, traffic volume, vehicle speed, vehicle classification, weight, and Individual Vehicle Record (IVR) data.
- **Micromobility** data include count station description and count data.

With the exception of motorized station data, traffic monitoring data can be submitted to FHWA's Travel Monitoring Analysis System (TMAS) using the historical fixed-width column formats. Motorized station data must be submitted using the new pipe-delimited format.

Starting with the release of this version of the *Traffic Monitoring Guide,* State and local agencies will also have the option to submit all traffic data using a pipe-delimited format by following the new specifications outlined in this chapter. For the pipe-delimited format, TMAS uses the pipe "|" character. State highway agencies can submit the traffic data using the fixed-width or pipe-delimited format but not both in one file.

Fields for the fixed-width column format 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 is shorter than the fixed width of that field. For example, if a field is five characters 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.

Blank Fill or Zero Fill is not required for fields in the pipe-delimited format.

Each data record type includes many data elements. These data elements are classified as Required, Optional, or Required/Optional. A designation of Required means that a record cannot be processed by the TMAS software without these fields being supplied. An Optional designation indicates that the data are not required for the record to be processed by TMAS. Fields designated as Required/Optional could be either Required or Optional based on values used for other related fields. Also, note that data reporting requirements described in the TMG are in English units (e.g., pounds for weight, tenths of feet for distance, tenths of miles per hour for speed, and degrees Fahrenheit for temperature), not SI (i.e., metric) units.

4.1.1 DATA SUBMISSION FREQUENCY

Table 4-1 provides the recommended data submittal frequency to FHWA. This frequency applies regardless of whether files being submitted are fixed-width or pipe-delimited formats.

Table 4-1. Data Submission Frequency

Data Type	Submittal Frequency
Station Description Data	Annually, or when a change occurs
Traffic Volume Data	Monthly, by 25 days after close of the month for which the data were collected
Vehicle Speed Data	Monthly, by 25 days after close of the month for which the data were collected
Vehicle Classification Data	Monthly, by 25 days after close of the month for which the data were 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 were collected
IVR Data	Data type submissions follow the above timelines
Micromobility Data	Minimum quarterly by the 25th of the month after the end of the quarter

States should submit all data files 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 at the given location for that time period. If the files are large, it is preferable that a file compression program be used to condense them. For further information, contact the FHWA Office of Highway Policy Information Travel Monitoring and Surveys Division (https://www.fhwa.dot.gov/policyinformation/).

4.1.2 File Naming Recommendations

An example file naming convention for traffic monitoring data 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 year

yyyy = year of data

TYP = type of data using the following three-character names:

Motorized Data

STA = station description data

VOL = traffic volume data

SPD = speed data

CLA = axle classification data

LEN = length classification data

WGT = weight data

IVR = Individual Vehicle Record data

Micromobility d DataSNM = count station data

VNM = count data

FHWA recommends the use of consistent file naming conventions as this helps identify files, helps States and local public agencies 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, States are not required to use this example file naming convention. Including the TMG format information in the filename is also recommended (e.g., including "FMT2022" for data in the TMG 2022 format).

4.2 STATION DESCRIPTION DATA FORMAT (PIPE DELIMITED ONLY)

Prior to the 2022 version of the TMG, the traffic monitoring station format used a fixed-width field format where the length of each data field was a predetermined number of characters. From the 2022 version (this edition) forward, the traffic monitoring station data format requires variable-length fields using a pipe-delimited format with the pipe, also known as the vertical bar symbol (|), as the delimiter.

The TMG will continue to support both fixed-width and pipe-delimited records for most record types. The exception is the Station Description record for motorized data, which must be a pipe-delimited record. Other record types can be either fixed width or pipe delimited.

The Station Description record format is needed for reporting all motorized data. If a Station Description record is omitted, no other motorized data will be processed by TMAS. The Station Description TMAS table contains one record per traffic monitoring station, per direction, per lane (unless lanes are combined by the data collection device), per year. However, updated station records can be submitted at any time during the year.

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 ensure the records are current and reflect which stations are being used to collect data.

4.2.1 File Naming Recommendation

It is recommended that the file extension .STA be used for all Station Description data files. The filename should be descriptive to facilitate the deciphering of the file and its contents.

An example file naming convention for the Station Description record is:

ssabcxyzmmyyyy.STA

4.2.2 Station Description – Pipe-Delimited Format

Table 4-2 summarizes the Station Description record using the pipe-delimited format.

Table 4-2. Station Description Record

Field	Width	Description	Type	Importance
1	1	Record Type (RT)	Alphanumeric	Required
2	2	State FIPS Code (SFIPS)	Alphanumeric	Required
3	20	Station ID (ID)	Alphanumeric	Required
4	1	Direction of Travel (DIR)	Integer	Required
5	1	Lane of Travel (LN)	Integer	Required
6	4	Year of Data (YR)	Integer	Required
7	2	Functional Classification (FC)	Alphanumeric	Required
8	1	Number of Lanes in Direction Indicated (NL)	Integer	Required
9	2	Vehicle Classification Groupings (VCG)	Integer	Req./Opt.
10	1	Calibration of Weighing System (CWS)	Alphanumeric	Req./Opt.
11	1	Type of Sensor (TS1)	Alphanumeric	Required
12	1	Second Type of Sensor (TS2)	Alphanumeric	Optional
13	11	Latitude (LAT)	Decimal	Required
14	11	Longitude (LONG)	Decimal	Required
15	20	Previous Station ID (PREVID)	Alphanumeric	Optional
16	4	Year Station Established (YREST)	Integer	Required
17	4	Year Station Discontinued (YRDIS)	Integer	Optional
18	3	County FIPS Code (CFIPS)	Alphanumeric	Required
19	1	National Highway System (NHS)	Alphanumeric	Required
20	2	Posted Route Signing (PRS)	Integer	Required
21	8	Posted Route Sign Number (PRSN)	Alphanumeric	Required
22	50	Station Location Description (STALOC)	Alphanumeric	Required

Note: Fields designated as Required *must be reported.*

Fields designated as Optional *are not required to be reported.*

Fields designated as Required/Optional *could be either required or optional based on values used for other related fields.*

The fields for the Station Description record are:

1. Record Type – *Required*

   S = station description record (Code the letter "S" in the first column.)

2. State FIPS Codes – *Required*

   Table 4-3 lists the codes for each lane.

Table 4-3. 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	Ohio	39	Northern Mariana Islands	69
Kentucky	21	Oklahoma	40	Virgin Islands of the U.S.	78
Louisiana	22	Oregon	41		

Canadian Provinces may use TMAS with the following codes (based on the LTPP):

Province	Code	Province	Code	Province	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 – *Required*

   Alphanumeric designation for the station where the data are collected. Station identification field entries must be identical in all records for a given station. Differences in characters, including spaces, hyphens, etc., prevent a proper match.

4. Direction of Travel – *Required*

Combined directions are permitted for volume stations only. Table 4-4 lists the codes for each direction. There should be a separate record for each direction of travel for the station.

Table 4-4. 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 – *Required*

Each lane can be considered separately (1-9) or all lanes in each direction can be combined (0). Table 4-5 lists the codes for each lane. Figure 4-1 shows an example of direction and lane coding.

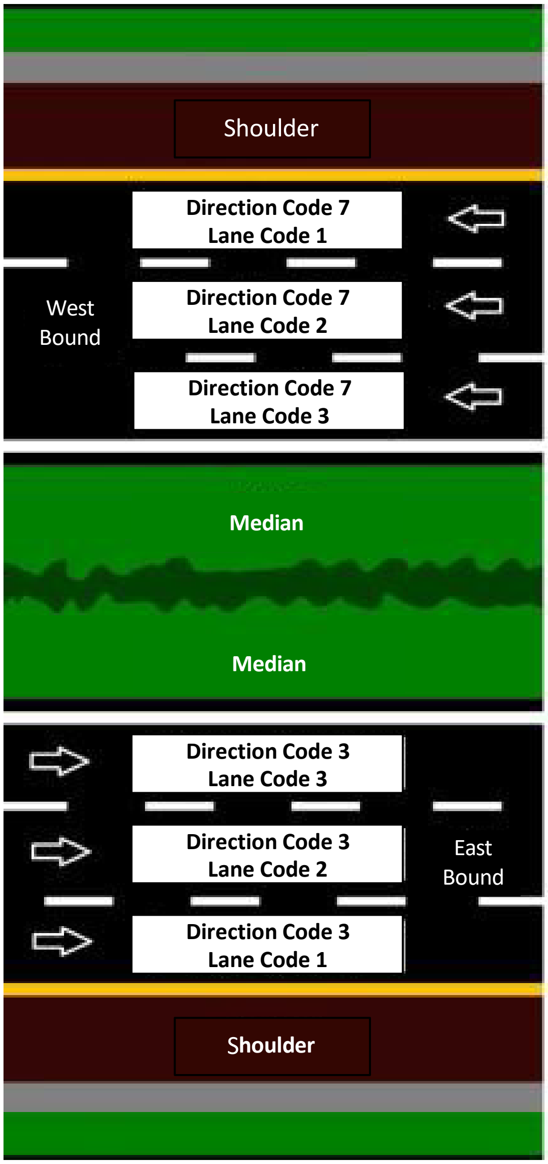
All data for volume, class, and speed should be reported with the same resolution of lane/direction or lanes combined/ direction as specified in the station record.

All data in either weight or IVR must be submitted by individual lane and by individual direction.

Table 4-5. 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.



Source: Federal Highway Administration.

Figure 4-1. Direction and Lane Code Example

6. Year of Data – *Required*

   The four-digit year in which the data were collected.

7. Functional Classification – *Required*

   One of the functional classification codes listed in Table 4-6 concatenated with 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 4-6. 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

* Note that the Micromobility Station record has two additional functional classification options (i.e., 8 and 9). See Table 4-37

8. Number of Lanes in Direction Indicated – *Required*

   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. Vehicle Classification Groupings – *Required/Optional*

   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 A) is being used. Other vehicle classification systems may be based on the HPMS or specific State classification schema defined in the State's Traffic Monitoring System (TMS) documentation. The value determines the number of count fields needed on the Vehicle Classification record (see Section 4.5). In Table 4-7, the numbers in parentheses refer to the 13 FHWA classes and describe how the FHWA classes relate to the classes being reported.

Table 4-7. Values Corresponding to Vehicle Classification Groupings

Value	Typology	How Vehicles are Classified
02	Two class groups	(classes 1-3) vehicles (classes 4-13) vehicles
03	Three class groups	(classes 1-3) vehicles (classes 4-7) single-unit vehicles (classes 8-13) combination vehicles
04	Four class groups	(classes 1-3) vehicles (classes 4-7) single-unit vehicles (classes 8-10) single-trailer combination vehicles (classes 11-13) multiple-trailer combination vehicles
44	Four class groups	(class 1) motorcycles (classes 2-3) two-axle, four-tire vehicles (classes 4-7) single-unit vehicles (classes 8-13) combination vehicles
05	Five class groups	(class 1) motorcycles (classes 2-3) two-axle, four-tire vehicles (classes 4-7) buses and single-unit vehicles (classes 8-10) single-trailer combination vehicles (classes 11-13) multiple-trailer combination vehicles
06	Six class groups	(class 1) motorcycles (classes 2-3) two-axle, four-tire vehicles (class 4) buses (classes 5-7) single-unit vehicles (classes 8-10) single-trailer combination vehicles (classes 11-13) multiple-trailer combination vehicles
66	Six class groups (HPMS definition)	(class 1) motorcycles (class 2) passenger cars (class 3) light-duty trucks (class 4) buses (classes 5-7) single-unit vehicles (classes 8-13) combination vehicles

Value	Typology	How Vehicles are Classified
07	Seven class groups	(class 1) motorcycles (class 2) passenger cars (class 3) light-duty trucks (class 4) buses (classes 5-7) single-unit vehicles (classes 8-10) single-trailer combination vehicles (classes 11-13) multiple-trailer combination vehicles
13	Thirteen class groups	FHWA's standard 13 class system
14	Fourteen class groups	FHWA's standard 13 class system plus one group*
15	Fifteen class groups	FHWA's standard 13 class system plus two groups*
Other Positive Integers		number of classes (unsupported by TMAS software)

**Note: For class 14 or 15 vehicles – use either of these two classes for vehicles that may not be classified, have multiple configurations, or specific for vehicles that need to be kept separate from other classes (e.g., special purpose vehicles).*

10. Calibration of Weighing System – *Required/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.

    A = ASTM Standard E1318 (yearly)

    B = Subset of ASTM Standard E1318 (yearly)

    C = Combination of test trucks and trucks from the traffic stream (but not ASTM E1318) (yearly)

    D = Other sample of trucks from the traffic stream (yearly)

    M = Statistical average of the steering axle of class nines (yearly)

    R = LTPP Calibration Method (yearly)

    S = Static calibration (yearly)

    T = Test trucks only (yearly)

    U = Uncalibrated

    Z = Other method (yearly)

11. Type of Sensor – *Required*

    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 or other sensors mounted on bridge components

H = Human observation (manual)

I = Infrared

J = In-line strain gauge load cell

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)

Y = Segmented strain gauge

Z = Other

12. Second Type of Sensor – *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.

13. Latitude – *Required*

    Latitude of the station location on the centerline of the roadway using decimal degree coordinates. If the value is 039.178 412 (Illinois), then the field is coded as |39.178412|. It is recommended to provide a resolution to the 6th decimal degree.

14. Longitude – *Required*

    Longitude of the station location on the centerline of the roadway using decimal degree coordinates. If the value is -88.352 543 (Illinois), then the field is coded as |-88.352543|. It is recommended to provide a resolution to the 6th decimal degree.

15. Previous Station ID – *Optional*

    If the station replaces another station, give the station ID that was used previously.

16. Year Station Established – *Required*

    The four-digit year that the station was first established.

17. Year Station Discontinued – *Optional*

    The four-digit year that the station was permanently discontinued or abandoned.

18. County FIPS Code – *Required*

    The three-digit FIPS county code (see Federal Information Processing Standards Publication 6, *Counties of the States of the United States*).

19. National Highway System – *Required*

    N = No, not on National Highway System

    Y = Yes, on National Highway System

20. Posted Route Signing – *Required*

    This is the same as Route Signing in *HPMS Field Manual.* Table 4-8 lists the possible codes.

21. Posted Route Signed Number – *Required*

    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.*

    If the station is located on a city street, zero-fill this field.

Table 4-8. 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

22. Station Location Description – *Required*

    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.

No pipe characters are permitted in the Station Location Description field.

Examples

Station Description Record Examples

Delimited Station Data Format

RT|SFIPS|ID|DIR|LN|YR|FC|NL|VCG|CWS|TS1|TS2|LAT|LONG|PREVID|YREST|YRDIS|CFIPS|NHS|PRS|PRSN|STALOC

Example for a Volume Station (4-lane site with all directions and lanes combined)

S|17|1810A|9|0|2020|1R|2|||L||41.883650|-87.896019||2001||35|Y|2|0|.6 miles east of milepost 105 interchange

Example for a Classification Station (8-lane site with lanes combined)

S|17|1811B|1|0|2020|1R|4|13|P|L||40.903984|-88.908715||1945||49|Y|1|70|.5 miles past Steven City near County Line Road

S|17|1811B|5|0|2020|1R|4|13|P|L||40.903984|-88.908715||1945||49|Y|1|70|.5 miles past Steven City near County Line Road

Example for **a Classification Station** (4-lane site with lanes combined and a more-than-8-digit station ID)

S|28|KLM908792|1|0|2021|3U|2|13|A|K||39.067471|-77.114321||1966||31|Y|9||0.5 miles south of Veirs Mill Road

S|28|KLM908792|5|0|2021|3U|2|13|A|K||39.067471|-77.114321||1966||31|Y|9||0.5 miles south of Veirs Mill Road

Example for a Weight Station (2-lane site)

S|17|18142C|3|1|2020|5R|1|13|A|Q|L|39.359508|-88.692127||1965||49|N|6|708|.7 miles past Steven City near Route 16

S|17|18142C|7|1|2020|5R|1|13|A|Q|L|39.359508|-88.692127||1965||49|N|6|708|.7 miles past Steven City near Route 16

A double pipe symbol || means a missing value for that field

4.3 TRAFFIC VOLUME DATA FORMAT (FIXED WIDTH OR PIPE DELIMITED)

One record is used for each calendar day for which traffic monitoring data are being submitted. Each record contains a field for traffic volume occurring during each of the 24 hours of the day. Partial day data is fully acceptable with this format—meaning if there is only 8 hours of data for the given day, sending in those 8 valid hours is recommended. Full days of data are no longer required.

The 2022 TMG offers additional formatting flexibility to report traffic volume data. States and other agencies can submit traffic volume data to FHWA's TMAS system via either the historical fixed-width format or the new pipe-delimited format.

Up to 20-digits can be used for station IDs. For the fixed-width format, the station ID field needs to be right-justified and padded with zeros.

4.3.1 File Naming Recommendation

It is recommended that the file extension .VOL be used for all Volume data files. The filename should be descriptive to facilitate the deciphering of the file format and its contents.

An example file naming convention for the Traffic Volume record is:

ssabcxyzmmyyyy.VOL

4.3.2 Traffic Volume Data – Fixed-Width Format

With the historical fixed-width format, all numeric fields should be right-justified and padded with blanks. Blank fill fields for which no data are being reported. Table 4-9 summarizes the Traffic Volume record using the fixed-width format.

Table 4-9. Traffic Volume Record – Fixed-Width Format

Field	Columns	Width	Description	Type	Importance
1	1	1	Record Type (RT)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-5	2	Functional Classification (FC)	Alphanumeric	Required
4	6-25	20	Station Identification (ID)	Alphanumeric	Required
5	26	1	Direction of Travel (DIR)	Integer	Required
6	27	1	Lane of Travel (LN)	Integer	Required
7	28-31	4	Year of Data (YR)	Integer	Required
8	32-33	2	Month of Year (MOY)	Integer	Required
9	34-35	2	Day of Month (DOM)	Integer	Required
10	36	1	Day of Week (DOW)	Integer	Required
11	37	1	Restrictions (R)	Integer	Required
12	38	1	Time Increment (TI)	Alphanumeric	Optional
13 – 36	39-158	5	Hourly Traffic Volume Counted, see Table 4-10	Integer	Optional

Note: Fields designated as Required *must be reported.*
Fields designated as Optional *are not required to be reported.*
Fields designated as Required/Optional *could be either required or optional based on values used for other related fields.*

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 4.2):

1. Record Type (Column 1) – *Required*

   3 = Traffic volume record (Code the value "3" in the first column.)

2. State FIPS Code (Columns 2-3) – See Section 4.2, Field #2. – *Required*
3. Functional Classification Code (Columns 4-5) – See Section 4.2, Field #7. – *Required*
4. Station Identification (Columns 6-25) – See Section 4.2, Field #3. – *Required*
5. Direction of Travel (Column 26) - See Section 4.2, Field #4. – *Required*
6. Lane of Travel (Column 27) – See Section 4.2, Field #5. – *Required*
7. Year of Data (Columns 28-31) – The four-digit year when the data were collected. See Section 4.2, Field #6. – *Required*
8. Month of Year (Columns 32-33) – *Required*

   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 Month (Columns 34-35) – *Required*

   The two-digit day of the month when data were collected.

10. Day of Week (Column 36) – *Required*

    1 = Sunday

    2 = Monday

    3 = Tuesday

    4 = Wednesday

    5 = Thursday

    6 = Friday

    7 = Saturday

11. Restrictions (Column 37) – *Required*

    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

    6 = none-regular event/trend

    7 = special event one day

    8 = special event more than one day

12. Time Increment (Column 38) – *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 volume data.

    For 15-minute binned intervals of volume data use the following:

    Code 1 for the hourly interval 0.0-14.999

    Code 2 for the hourly interval 15.0-29.999

    Code 3 for the hourly interval 30.0-44.999

    Code 4 for the hourly interval 45.0-59.999

    For 5-minute binned intervals of volume data use the following:

    Code A for the hourly interval 0.0-4.999

    Code B for the hourly interval 5.0-9.999

    Code C for the hourly interval 10.0-14.999

    Code D for the hourly interval 15.0-19.999

    Code E for the hourly interval 20.0-24.999

    Code F for the hourly interval 25.0-29.999

    Code G for the hourly interval 30.0-34.999

    Code H for the hourly interval 35.0-39.999

    Code I for the hourly interval 40.0-44.999

    Code J for the hourly interval 45.0-49.999

    Code K for the hourly interval 50.0-54.999

    Code L for the hourly interval 55.0-59.999

13. 60-Minute Traffic Volume Counted, see Table 4-10 (Columns 39-158) – *Optional*

    15-Minute Traffic Volume Counted, see examples with each hour having sub-hour parts for each line (4 parts for 15-minute intervals) – *Optional*

    5-Minute Traffic Volume Counted, examples with each hour having sub-hour parts for each line (12 parts for 5-minute intervals) – *Optional*

    If the data are missing, blank fill the appropriate columns.

Table 4-10. Time Covered Fields – 60-Minute Data

Field	Columns	Width	Description	Type	Importance
13	39-43	5	Traffic Volume Counted, after 00:00 – to 01:00 (BIN1)	Integer	Optional
14	44-48	5	Traffic Volume Counted, after 01:00 – to 02:00 (BIN2)	Integer	Optional
…	…	…	…	…	…
36	154-158	5	Traffic Volume Counted, after 23:00 – to 24:00 (BIN24)	Integer	Optional

An example Traffic Volume record is shown in Table 4-11.

Table 4-11. Traffic Volume Record Example
(60-minute Time Interval – 4 Lanes with All Lanes and Directions Combined)

Column Number:	**1**	**2-3**	**4-5**	**6-25**	**26**	**27**	**28-31**	**32-33**	**34-35**	**36**	**37**	**38**
Content Example:	3	17	2R	JacksonRoad1710A1234	9	0	2012	04	25	4	0	Blank

continued

Column Number:	**39-43**	**44-48**	**49-53**	**54-58**	**59-63**	**64-68**	**69-73**	**74-78**	**79-83**	**84-88**	**89-93**	**94-98**	**99-103**
Content Example:	00046	00022	00014	00013	00029	00030	00075	00136	00179	00218	00264	00293	00322

continued

Column Number:	**104-108**	**109-113**	**114-118**	**119-123**	**124-128**	**129-133**	**134-138**	**139-133**	**144-148**	**149-153**	**154-158**
Content Example:	00401	00439	00366	00261	00202	00143	00098	00054	00022	00019	00008

4.3.3 Traffic Volume Data – Pipe-Delimited Format

State highway agencies can also submit traffic volume data using the pipe-delimited format. The key difference between the fixed-width format and the pipe-delimited format is that with the pipe-delimited file, data elements no longer need to match the starting and ending columns. Length of data elements can be equal or shorter than the specified lengths. The field order for the pipe-delimited format is identical to the order for the fixed-width format (see Table 4-9). The difference in this format is that the fields are separated by a pipe symbol (|) instead of beginning in specified columns. Example records in this format are provided below. Given it is less demanding on the format, States are encouraged to use the pipe-delimited format for volume data recording and reporting.

Example:

Delimited Volume Record Format

RT|SFIPS|FC|ID|DIR|LN|YR|MOY|DOM|DOW|R|TI|BIN1|BIN2|BIN3|BIN4|BIN5|BIN6|BIN7|BIN8|BIN9|BIN10|BIN11|BIN12|BIN13|BIN14|BIN15|BIN16|BIN17|BIN18|BIN19|BIN20|BIN21|BIN22|BIN23|BIN24

Example for 60-Minute Volume with 2 directions

3|26|1U|xyz123|3|1|2020|6|23|3|0||100|88|76|40|20|32|120|200|300|260|232|200|248|262|312|400|500|372|360|292|248|196|132|112

3|26|1U|xyz123|7|1|2020|6|23|3|0||130|88|76|40|20|32|120|200|300|260|232|200|248|262|312|400|500|372|360|292|248|196|132|112

Example for 15-Minute Volume with 2 directions

3|26|1U|xyz123|3|1|2020|6|23|3|0|1|25|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|26|1U|xyz123|3|1|2020|6|23|3|0|2|24|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|26|1U|xyz123|3|1|2020|6|23|3|0|3|23|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|26|1U|xyz123|3|1|2020|6|23|3|0|4|27|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|26|1U|xyz123|7|1|2020|6|23|3|0|1|32|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|26|1U|xyz123|7|1|2020|6|23|3|0|2|30|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|26|1U|xyz123|7|1|2020|6|23|3|0|3|35|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|26|1U|xyz123|7|1|2020|6|23|3|0|4|33|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|26|1U|xyz123|3|1|2020|6|24|4|0|1|21|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

Example for 5-Minute Volume with 2 directions

3|49|3U|lmnopq|3|1|2020|4|25|5|0|A|25|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|B|24|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|C|23|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|D|27|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|E|26|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|F|23|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|G|22|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|H|28|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|I|26|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|J|24|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|K|22|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|3|1|2020|4|25|5|0|L|26|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|A|28|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|B|24|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|C|23|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|D|22|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|E|24|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|F|29|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|G|27|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|H|25|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|I|24|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|J|22|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|K|21|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

3|49|3U|lmnopq|7|1|2020|4|25|5|0|L|27|22|19|10|5|8|30|50|75|65|58|50|62|68|78|100|125|93|90|73|62|49|33|28

Example for 60-Minute Volume **with only hours 10:00 am to 06:00 pm (8 hours) reported** *

3|26|7U|abcdefg|7|4|2020|5|23|4|12|R|||||||||||24|0|6|120|100|160|480|835|1200|||||

* The double pipe symbol | | means there is a missing value.

4.4 VEHICLE SPEED DATA FORMAT (FIXED WIDTH OR PIPE DELIMITED)

The vehicle 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 are being reported and indicates that time interval as a field in the record.

Vehicle speed records must have a minimum of 15 bins up to a maximum of 25 bins and should supply data in 5-mph speed bins as defined in the TMG. Any vehicle speed records that do not meet these specifications are purged by the TMAS software. All records should follow the record formats defined in the TMG.

When submitting data 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.

States may also submit one or two additional speed bins for slow-traveling vehicles. States 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.

The 2022 TMG offers additional formatting flexibility to report vehicle speed data. States and other agencies can submit vehicle speed data to FHWA's TMAS system via either the historical fixed-width format or the new pipe-delimited format.

Up to 20-digits can be used for station IDs. For the fixed-width format, the station ID field needs to be right-justified and padded with zeros.

4.4.1 FILE NAMING RECOMMENDATION

It is recommended that the file extension .SPD be used for all Speed data files. The filename should be descriptive to facilitate the deciphering of the file and its contents.

An example file naming convention for the Vehicle Speed record is:

ssabcxyzmmyyyy.SPD

4.4.2 VEHICLE SPEED DATA – FIXED-WIDTH FORMAT

With the historical fixed-width format, all numeric fields should be right-justified and padded with blanks. Blank fill fields for which no data are being reported. The most critical aspect for this data format is that each of the data elements has its starting column and ending column locations. Data element sequencing must be followed. If missing data or length of a data element is shorter than specified, zeros (0) must be used to prefix the blank columns.

Table 4-12 summarizes the Vehicle Speed record fixed-width column format.

Table 4-12. Vehicle Speed Record – Fixed-Width Format

Field	Columns	Width	Description	Type	Importance
1	1	1	Record Type (RT)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-23	20	Station Identification (ID)	Alphanumeric	Required
4	24	1	Direction of Travel (DIR)	Integer	Required
5	25	1	Lane of Travel (LN)	Integer	Required
6	26-29	4	Year of Data (YR)	Integer	Required
7	30-31	2	Month of Year (MOY)	Integer	Required
8	32-33	2	Day of Month (DOM)	Integer	Required
9	34-35	2	Hour of Day (HOD)	Integer	Required
10	36	1	Speed Data Time Interval (I)	Integer	Optional
11	37	1	Definition of First Speed Bin (F)	Integer	Optional
12	38-39	2	Total Number of Speed Bins Reported (TN)	Integer	Optional
13	40	1	Restrictions (R)	Integer	Required
14	41-45	5	Total Interval Volume (TVOL)	Integer	Required
15	46-50	5	Bin 1 Count (BIN1)	Integer	Required
16	51-55	5	Bin 2 Count (BIN2)	Integer	Required
17	56-60	5	Bin 3 Count (BIN3)	Integer	Required
18	61-65	5	Bin 4 Count (BIN4)	Integer	Required
19	66-70	5	Bin 5 Count (BIN5)	Integer	Required
20	71-75	5	Bin 6 Count (BIN6)	Integer	Required
21	76-80	5	Bin 7 Count (BIN7)	Integer	Required
22	81-85	5	Bin 8 Count (BIN8)	Integer	Required
23	86-90	5	Bin 9 Count (BIN9)	Integer	Required
24	91-95	5	Bin 10 Count (BIN10)	Integer	Required
25	96-100	5	Bin 11 Count (BIN11)	Integer	Required
26	101-105	5	Bin 12 Count (BIN12)	Integer	Required
27	106-110	5	Bin 13 Count (BIN13)	Integer	Required
28	111-115	5	Bin 14 Count (BIN14)	Integer	Required
29	116-120	5	Bin 15 Count (BIN15)	Integer	Required
30	121-125	5	Bin 16 Count (BIN16)	Integer	Req./Opt.
31	126-130	5	Bin 17 Count (BIN17)	Integer	Req./Opt.
32	131-135	5	Bin 18 Count (BIN18)	Integer	Req./Opt.
33	136-140	5	Bin 19 Count (BIN19)	Integer	Req./Opt.
34	141-145	5	Bin 20 Count (BIN20)	Integer	Req./Opt.
35	146-150	5	Bin 21 Count (BIN21)	Integer	Req./Opt.
36	151-155	5	Bin 22 Count (BIN22)	Integer	Req./Opt.
37	156-160	5	Bin 23 Count (BIN23)	Integer	Req./Opt.
38	161-165	5	Bin 24 Count (BIN24)	Integer	Req./Opt.
39	166-170	5	Bin 25 Count (BIN25)	Integer	Req./Opt.

Note: Fields designated as Required *must be reported.*

Fields designated as Optional *are not required to be reported.*

Fields designated as Required/Optional *could be either required or optional based on values used for other related fields.*

The fields for the Vehicle Speed record are defined as follows:

1. Record Type (Column 1) – *Required*

   T = Vehicle Speed record

2. State FIPS Code (Columns 2-3) – *Required*

   See Section 4.2, Field #2.

3. Station Identification (Columns 4-23) – *Required*

   See Section 4.2, Field #3.

   This field should be right-justified with unused columns zero-filled.

4. Direction of Travel (Column 24) – *Required*

   See Section 4.2, Field #4.

5. Lane of Travel (Column 25) – *Required*

   See Section 4.2, Field #5.

   Note: The Station ID, Direction of Travel, and Lane of Travel make up the Station Code. No combined lanes are allowed. There should be one Station Description record per Station Code.

6. Year of Data (Columns 26-29) – *Required*

   See Section 4.2, Field #6.

7. Month of Year (Columns 30-31) – *Required*

   See Section 4.3, Field #8.

8. Day of Month (Columns 32-33) – *Required*

   See Section 4.3, Field #9.

9. Hour of Day (Columns 34-35) – *Required*

   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 36) – *Optional*

    A 60-minute time interval is assumed if this column is left blank. This field can be used to designate either 15-minute or 5-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 37) – *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 provide more detail of vehicles traveling at slower speeds, it may supply data in one or two additional slow speed bins. A value of "1" is indicates that the first speed bin is defined as "all vehicles traveling at equal to or slower than 15 mph." A value of "2" indicates that 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 38-39) – *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 120 columns wide.

If the State is supplying data in additional speed bins, indicate the total number of speed bins being reported. This value is used to determine the correct record length (Table 4-13).

When used in conjunction with Definition of First Speed Bin (Column 37) it is possible to determine the definition of all speed bins being submitted.

Table 4-13. Total Number of Speed Bins

Total Number of Speed Bins (Defined in Columns 24-25)	Record Length (Number of Columns)
15	120
16	125
17	130
18	135
19	140
20	145
21	150
22	155
23	160
24	165
25	170

13. Restrictions (Column 40) – *Required*

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

6 = none-regular event/trend

7 = special event one day

8 = special event more than one day

14. Total Interval Volume (Columns 41-45) – *Optional*
This numeric field is the total traffic volume for the interval covering all speed bins. For example, for the interval of 0.0-14.999 for hour 1 of April 11, 2020, the Volume data are total number of vehicles counted in all the speed bins during that time period. If all are measured and counted, this number will be equal to the summation of counts for all speed bins for that time interval. 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.

15. Bin 1 Count (Columns 46-50) – *Required*
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, Definition of First Speed Bin (Column 37) 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.

16. Bin 2 Count (Columns 51-55) – *Required*
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."

17. Bin 3 Count (Columns 56-60) – *Required*
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."

18. Bin 4 Count (Columns 61-65) – *Required*
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."

19. Bin 5 Count (Columns 66-70) – *Required*
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."

20. Bin 6 Count (Columns 71-75) – *Required*
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."

21. Bin 7 Count (Columns 76-80) – *Required*
    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."
22. Bin 8 Count (Columns 81-85) – *Required*
    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."
23. Bin 9 Count (Columns 86-90) – *Required*
    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."
24. Bin 10 Count (Columns 91-95) – *Required*
    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."
25. Bin 11 Count (Columns 96-100) – *Required*
    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."
26. Bin 12 Count (Columns 101-105) – *Required*
    Bin 12 includes the number of vehicles in the twelfth 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 13 Count (Columns 106-110) – *Required*
    Bin 13 includes the number of vehicles in the thirteenth 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 14 Count (Columns 111-115) – *Required*
    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."
29. Bin 15 Count (Columns 116-120) – *Required*
    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."
30. Bin 16 Count (Columns 121-125) – *Required/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 38-39) 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".

31. Bin 17 Count (Columns 126-130) – *Required/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 38-39) should contain a value equal to or greater than 17. 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 18 Count (Columns 131-135) – *Required/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 38-39) should contain a value equal to or greater than 18. 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 19 Count (Columns 136-140) – *Required/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 38-39) should contain a value equal to or greater than 19. 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 20 Count (Columns 141-145) – *Required/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 38-39) should contain a value equal to or greater than 20. 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 21 Count (Columns 146-150) – *Required/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 38-39) should contain a value equal to or greater than 21. 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 22 Count (Columns 151-155) – *Required/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 38-39) should contain a value equal to or greater than 22. 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 23 Count (Columns 156-160) – *Required/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 38-39) should contain a value equal to or greater than 23. 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 24 Count (Columns 161-165) – *Required/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 38-39) should contain a value equal to or greater than 24. 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."

39. Bin 25 Count (Columns 166-170) – *Required/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 38-39) should contain a value equal to or greater than 25. 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."

Example Vehicle Speed records are shown in Table 4-14 through Table 4-16.

Table 4-14. Speed Record Example (15 Bins, 2 lanes, with Lanes or Directions Not Combined, at 5-Minute Intervals, with No Restrictions) – Fixed-Width Format

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36	37
Content 01 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	A	Blank
Content 02 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	B	Blank
Content 03 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	C	Blank
Content 04 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	D	Blank
Content 05 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	E	Blank
Content 06 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	F	Blank
Content 07 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	G	Blank
Content 08 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	H	Blank
Content 09 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	I	Blank
Content 10 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	J	Blank
Content 11 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	K	Blank
Content 12 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	L	Blank
Content 13 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	A	Blank
Content 14 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	B	Blank
Content 15 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	C	Blank
Content 16 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	D	Blank
Content 17 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	E	Blank

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36	37
Content 18 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	F	Blank
Content 19 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	G	Blank
Content 20 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	H	Blank
Content 21 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	I	Blank
Content 22 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	J	Blank
Content 23 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	K	Blank
Content 24 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	L	Blank

continued

Column Number:	38-39	40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85
Content 01 Example:	15	0	00375	00000	00000	00000	00000	00000	00000	00000	00000
Content 02 Example:	15	0	00305	00000	00000	00000	00000	00000	00000	00000	00004
Content 03 Example:	15	0	00266	00000	00000	00000	00000	00000	00000	00000	00000
Content 04 Example:	15	0	00268	00000	00000	00000	00000	00000	00000	00000	00000
Content 05 Example:	15	0	00248	00000	00000	00000	00000	00000	00000	00000	00001
Content 06 Example:	15	0	00231	00000	00000	00000	00000	00000	00000	00000	00000
Content 07 Example:	15	0	00197	00000	00000	00000	00000	00000	00000	00000	00000
Content 08 Example:	15	0	00183	00000	00000	00000	00000	00000	00000	00000	00000
Content 09 Example:	15	0	00173	00000	00000	00000	00000	00000	00000	00000	00000
Content 10 Example:	15	0	00159	00000	00000	00000	00000	00000	00000	00000	00000
Content 11 Example:	15	0	00154	00000	00000	00000	00000	00000	00000	00000	00000
Content 12 Example:	15	0	00145	00000	00000	00000	00000	00000	00000	00000	00000
Content 13 Example:	15	0	00373	00000	00000	00000	00000	00000	00000	00000	00000
Content 14 Example:	15	0	00307	00000	00000	00000	00000	00000	00000	00000	00000

Column Number:	38-39	40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85
Content 15 Example:	15	0	00268	00000	00000	00000	00000	00000	00000	00000	00000
Content 16 Example:	15	0	00294	00000	00000	00000	00000	00000	00000	00000	00000
Content 17 Example:	15	0	00277	00000	00000	00000	00000	00000	00000	00000	00000
Content 18 Example:	15	0	00260	00000	00000	00000	00000	00000	00000	00000	00000
Content 19 Example:	15	0	00272	00000	00000	00000	00000	00000	00000	00000	00000
Content 20 Example:	15	0	00242	00000	00000	00000	00000	00000	00000	00000	00000
Content 21 Example:	15	0	00212	00000	00000	00000	00000	00000	00000	00000	00000
Content 22 Example:	15	0	00198	00000	00000	00000	00000	00000	00000	00000	00000
Content 23 Example:	15	0	00185	00000	00000	00000	00000	00000	00000	00000	00000
Content 24 Example:	15	0	00155	00000	00000	00000	00000	00000	00000	00000	00000

continued

Column Number:	86-90	91-95	96-100	101-105	106-110	111-115	116-120	121-125	126-130
Content 01 Example:	00007	00012	00048	00165	00086	00031	00021	00005	00000
Content 02 Example:	00005	00008	00025	00143	00079	00025	00013	00003	00000
Content 03 Example:	00003	00003	00032	00131	00058	00026	00011	00001	00001
Content 04 Example:	00002	00004	00037	00128	00043	00039	00012	00003	00000
Content 05 Example:	00001	00003	00039	00119	00039	00028	00015	00004	00000
Content 06 Example:	00002	00002	00025	00108	00042	00032	00015	00005	00000
Content 07 Example:	00000	00001	00018	00099	00035	00028	00011	00005	00000
Content 08 Example:	00000	00000	00013	00098	00032	00027	00009	00004	00000
Content 09 Example:	00000	00000	00008	00095	00031	00028	00008	00003	00000
Content 10 Example:	00000	00000	00007	00092	00028	00025	00005	00002	00000
Content 11 Example:	00000	00000	00011	00088	00025	00026	00003	00001	00000
Content 12 Example:	00000	00000	00012	00084	00021	00024	00004	00000	00000
Content 13 Example:	00008	00013	00049	00156	00087	00032	00022	00006	00000
Content 14 Example:	00006	00009	00026	00141	00082	00027	00011	00005	00000
Content 15 Example:	00002	00003	00031	00128	00061	00025	00013	00004	00001
Content 16 Example:	00000	00001	00035	00134	00065	00036	00015	00007	00001
Content 17 Example:	00000	00007	00031	00121	00058	00031	00021	00008	00000
Content 18 Example:	00000	00002	00026	00115	00055	00032	00022	00007	00001
Content 19 Example:	00000	00004	00027	00122	00056	00035	00023	00005	00000
Content 20 Example:	00000	00003	00021	00114	00049	00033	00018	00004	00000
Content 21 Example:	00000	00000	00015	00104	00048	00024	00019	00002	00000
Content 22 Example:	00000	00000	00012	00098	00047	00025	00013	00003	00000
Content 23 Example:	00000	00000	00008	00087	00051	00024	00012	00003	00000
Content 24 Example:	00000	00000	00005	00076	00044	00021	00009	00000	00000

Table 4-15. Speed Record Example (21 Bins, 4 Lanes with Lanes or Directions Not Combined at 60-Minute Interval with No Restrictions, Total Volume Not Recorded) – Fixed Width Format

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36	37	38-39	40
Content 01 Example:	T	17	JacksonDouglas181141	1	1	2012	06	20	00	Blank	1	21	0
Content 02 Example:	T	17	JacksonDouglas181141	1	2	2012	06	20	00	Blank	1	21	0
Content 03 Example:	T	17	JacksonDouglas181141	5	2	2012	06	20	00	Blank	1	21	0
Content 04 Example:	T	17	JacksonDouglas181141	5	1	2012	06	20	00	Blank	1	21	0

continued

Column Number:	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Content 01 Example:	Blank	00000	00000	00000	00000	00000	00000	00000	00000	00005	00034	00054
Content 02 Example:	Blank	00000	00000	00000	00000	00000	00000	00000	00000	00007	00030	00046
Content 03 Example:	Blank	00000	00000	00000	00000	00000	00000	00000	00000	00010	00028	00056
Content 04 Example:	Blank	00000	00000	00000	00000	00000	00000	00000	00000	00008	00026	00036

continued

Column Number:	101-105	106-110	111-115	116-120	121-125	126-130	131-135	136-140	141-145	146-150
Content 01 Example:	00021	00015	00002	00001	00000	00000	00000	00000	00000	00000
Content 02 Example:	00024	00013	00003	00002	00000	00000	00000	00000	00000	00000
Content 03 Example:	00031	00021	00005	00004	00003	00000	00000	00000	00000	00000
Content 04 Example:	00029	00018	00003	00003	00002	00001	00000	00000	00000	00000

Table 4-16. Speed Record Example (25 Bins, 2 Lanes with Lanes or Directions Not Combined at 60-Minute Interval) – Fixed Width Format

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36	37
Content 01 Example:	T	17	JacksonDouglas181141	3	1	2012	06	20	00	Blank	2
Content 02 Example:	T	17	JacksonDouglas181141	7	1	2012	06	20	00	Blank	2

continued

Column Number:	38-39	40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95
Content 01 Example:	25	0	000683	00000	00000	00000	00000	00000	00000	00000	00000	00000	00005
Content 02 Example:	25	0	000681	00000	00000	00000	00000	00000	00000	00000	00000	00000	00004

continued

Column Number:	96-100	101-105	106-110	111-115	116-120	121-125	126-130	131-135	136-140	141-145
Content 01 Example:	00014	00026	00056	00086	00109	00121	00095	00082	00042	00021
Content 02 Example:	00012	00028	00064	00085	00098	00127	00094	00081	00041	00018

continued

Column Number:	146-150	151-155	156-160	161-165	166-170
Content 01 Example:	00015	00011	00000	00000	00000
Content 02 Example:	00013	00013	00003	00000	00000

4.4.3 VEHICLE SPEED DATA – PIPE-DELIMITED FORMAT

State highway agencies can also submit vehicle speed data using the pipe-delimited format. The key difference between the fixed-width format and the pipe-delimited format is that with the pipe-delimited file, data elements no longer need to match the starting and ending columns. Length of data elements can be equal or shorter than the specified lengths. The field order for the pipe-delimited format is identical to the order for the fixed-width format (see Table 4-12). The difference in this format is that the fields are separated by a pipe symbol (|) instead of beginning in specified columns. Example records in this format are provided below. Given it is less demanding on the format, States are encouraged to use the pipe-delimited format for vehicle speed data recording and reporting.

Delimited Format Examples

Speed Data for 25 Speed Bins with Delimited Fields – Detailed

```
RT|SFIPS|ID|DIR|LN|YR|MOY|DOM|HOD|I|F|TN|R|TVOL|BIN1|BIN2|BIN3|BIN4|BIN5|BIN6|BIN7|BIN8|BIN9|BIN10|BIN11|BIN12|BIN13|BIN14|BIN15|BIN16
|BIN17|BIN18|BIN19|BIN20|BIN21|BIN22|BIN23|BIN24|BIN25
```

60-Minute Speed Data for 15 Speed Bins with 6 Lanes, No Restrictions with no Restrictions

```
T|54|123ABC|1|1|2021|4|25|00|||15|0|97|0|0|0|0|0|0|0|2|7|36|32|12|4|2|2|0
T|54|123ABC|1|2|2021|4|25|00|||15|0|94|0|0|0|0|0|0|0|2|7|34|31|12|4|2|2|0
T|54|123ABC|1|3|2021|4|25|00|||15|0|91|0|0|0|0|0|0|0|2|7|30|32|12|4|2|2|0
T|54|123ABC|5|1|2021|4|25|00|||15|0|109|0|0|0|1|0|0|1|8|14|33|30|15|5|2|0|0
T|54|123ABC|5|2|2021|4|25|00|||15|0|110|0|0|0|1|0|0|1|8|14|33|30|16|5|2|0|0
T|54|123ABC|5|3|2021|4|25|00|||15|0|113|0|0|0|1|0|0|1|8|14|35|30|15|7|2|0|0
```

15-Minute Speed Data for 20 Speed Bins, 4 Lanes, at 2:00 pm on Memorial Day with Construction in One Direction with no Restrictions

```
T|24|hijk12|2|1|2020|5|25|14|1|2|20|4|298|72|55|50|49|35|20|15|2|0|0|0|0|0|0|0|0|0|0|0|0|
T|24|hijk12|2|1|2020|5|25|14|2|2|20|4|322|68|51|48|47|43|30|20|10|5|0|0|0|0|0|0|0|0|0|0|0|
T|24|hijk12|2|1|2020|5|25|14|3|2|20|4|342|63|42|45|45|48|40|27|19|10|3|0|0|0|0|0|0|0|0|0|0|
T|24|hijk12|2|1|2020|5|25|14|4|2|20|4|370|60|39|40|43|52|50|36|25|16|7|2|0|0|0|0|0|0|0|0|0|
T|24|hijk12|2|2|2020|5|25|14|1|2|20|4|309|73|56|51|51|36|22|17|3|0|0|0|0|0|0|0|0|0|0|0|0|
T|24|hijk12|2|2|2020|5|25|14|2|2|20|4|330|70|53|50|48|44|30|20|10|5|0|0|0|0|0|0|0|0|0|0|0|
T|24|hijk12|2|2|2020|5|25|14|3|2|20|4|350|63|42|46|46|49|41|28|20|11|4|0|0|0|0|0|0|0|0|0|0|
T|24|hijk12|2|2|2020|5|25|14|4|2|20|4|375|61|40|41|44|53|50|36|25|16|7|2|0|0|0|0|0|0|0|0|0|
T|24|hijk12|6|1|2020|5|25|14|1|2|20|4|211|0|0|0|0|0|0|0|2|4|26|38|55|46|28|8|3|1|0|0|0|
T|24|hijk12|6|1|2020|5|25|14|2|2|20|4|221|0|0|0|0|0|0|0|3|5|27|39|56|47|29|9|4|2|0|0|0|
T|24|hijk12|6|1|2020|5|25|14|3|2|20|4|232|0|0|0|0|0|0|0|3|5|28|49|56|47|29|9|4|2|0|0|0|
T|24|hijk12|6|1|2020|5|25|14|4|2|20|4|252|0|0|0|0|0|0|0|3|5|28|56|61|52|32|9|4|2|0|0|0|
T|24|hijk12|6|2|2020|5|25|14|1|2|20|4|221|0|0|0|0|0|0|0|3|5|27|39|56|47|29|9|4|2|0|0|0|
T|24|hijk12|6|2|2020|5|25|14|2|2|20|4|231|0|0|0|0|0|0|0|4|6|28|40|57|48|31|11|4|2|0|0|0|
T|24|hijk12|6|2|2020|5|25|14|3|2|20|4|242|0|0|0|0|0|0|0|4|5|30|52|59|48|30|8|4|2|0|0|0|
T|24|hijk12|6|2|2020|5|25|14|4|2|20|4|262|0|0|0|0|0|0|0|3|5|28|56|66|57|32|9|4|2|0|0|0|
```

5-Minute Speed Data for 22 Speed Bins with 2 Lanes, Weather Restriction Travel

```
T|48|js1234|3|1|2021|11|23|11|A|1|22|5|627|0|0|0|0|0|0|5|52|97|111|149|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|B|1|22|5|628|0|0|0|0|0|0|5|52|97|112|149|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|C|1|22|5|629|0|0|0|0|0|0|5|53|97|111|149|99|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|D|1|22|5|630|0|0|0|0|0|0|5|52|98|112|150|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|E|1|22|5|631|0|0|0|0|0|0|5|54|97|111|150|100|68|35|10|1|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|F|1|22|5|632|0|0|0|0|0|0|5|55|98|111|150|100|68|35|9|1|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|G|1|22|5|634|0|0|0|0|0|0|6|55|98|111|150|101|68|35|9|1|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|H|1|22|5|635|0|0|0|0|0|0|7|55|98|111|150|101|68|35|9|1|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|I|1|22|5|637|0|0|0|0|0|0|8|56|98|111|150|101|68|35|9|1|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|J|1|22|5|639|0|0|0|0|0|0|10|56|98|111|150|101|68|35|9|1|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|K|1|22|5|641|0|0|0|0|0|1|11|56|98|111|150|101|68|35|9|1|0|0|0|0|0|0|
T|48|js1234|3|1|2021|11|23|11|L|1|22|5|645|0|0|0|0|0|3|13|56|98|111|150|101|68|35|9|1|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|A|1|22|5|630|0|0|0|0|0|1|7|52|97|111|149|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|B|1|22|5|631|0|0|0|0|0|1|8|52|97|111|149|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|C|1|22|5|632|0|0|0|0|0|1|8|53|97|111|149|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|D|1|22|5|634|0|0|0|0|0|1|9|53|97|112|149|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|E|1|22|5|635|0|0|0|0|0|1|10|53|97|112|149|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|F|1|22|5|637|0|0|0|0|0|2|11|53|97|112|149|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|G|1|22|5|639|0|0|0|0|0|2|11|54|98|112|149|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|H|1|22|5|640|0|0|0|0|0|2|11|54|98|112|150|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|I|1|22|5|641|0|0|0|0|0|3|11|54|98|112|150|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|J|1|22|5|644|0|0|0|0|0|3|12|55|99|112|150|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|K|1|22|5|647|0|0|0|0|0|3|12|56|100|113|150|98|67|34|12|2|0|0|0|0|0|0|
T|48|js1234|7|1|2021|11|23|11|L|1|22|5|650|0|0|0|0|0|3|13|56|101|113|151|98|67|34|12|2|0|0|0|0|0|0|
```

4.5 VEHICLE CLASSIFICATION DATA FORMAT (FIXED WIDTH OR PIPE DELIMITED)

The Vehicle Classification file contains one variable-length record for each time period (e.g., by 5 minute, 15 minute, or hour of the day) for which data are being submitted. That record includes the traffic volume by vehicle classification for that hour. The length of the record (number of columns in each record) is determined by the value in "Vehicle Classification Groupings," 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 Station 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. A single file can contain data from multiple stations and/or locations.

The 2022 TMG offers additional formatting flexibility to report vehicle classification data. States and other agencies can submit vehicle classification data to FHWA's TMAS system via either the historical fixed-width format or the new pipe-delimited format.

Up to 20-digits can be used for station IDs. For the fixed-width format, the station ID field needs to be right-justified and padded with zeros.

4.5.1 File Naming Recommendation

It is recommended that the file extension .CLA be used for all Vehicle Classification data. The filename should be descriptive to facilitate the deciphering of the file and its contents.

An example file naming convention for the Vehicle Classification record is:

ssabcxyzmmyyyy.CLA

4.5.2 Vehicle Classification – Fixed-Width Format

Table 4-17 summarizes the Vehicle Classification record format.

Table 4-17. Vehicle Classification Record – Fixed-Width Format

Field	Columns	Width	Description	Type	Importance
1	1	1	Record Type (RT)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-23	20	Station Identification (ID)	Alphanumeric	Required
4	24	1	Direction of Travel (DIR)	Integer	Required
5	25	1	Lane of Travel (LN)	Integer	Required
6	26-29	4	Year of Data (YR)	Integer	Required
7	30-31	2	Month of Year (MOY)	Integer	Required
8	32-33	2	Day of Month (DOM)	Integer	Required
9	34-35	2	Hour of Day (HOD)	Integer	Required
10	36	1	Classification Data Time Interval	Integer	Req./Opt.
11	37	1	Restrictions (R)	Integer	Required

Field	Columns	Width	Description	Type	Importance
12	38-42	5	Total Interval Volume (TVOL)	Integer	Required
13	43-47	5	Class 1 Count (BIN1)	Integer	Required
14	48-52	5	Class 2 Count (BIN2)	Integer	Required
15	53-57	5	Class 3 Count (BIN3)	Integer	Req./Opt.
16	58-62	5	Class 4 Count (BIN4)	Integer	Req./Opt.
17	63-67	5	Class 5 Count (BIN5)	Integer	Req./Opt.
18	68-72	5	Class 6 Count (BIN6)	Integer	Req./Opt.
19	73-77	5	Class 7 Count (BIN7)	Integer	Req./Opt.
20	78-82	5	Class 8 Count (BIN8)	Integer	Req./Opt.
21	83-87	5	Class 9 Count (BIN9)	Integer	Req./Opt.
22	88-92	5	Class 10 Count (BIN10)	Integer	Req./Opt.
23	93-97	5	Class 11 Count (BIN11)	Integer	Req./Opt.
24	98-102	5	Class 12 Count (BIN12)	Integer	Req./Opt.
25	103-107	5	Class 13 Count (BIN13)	Integer	Req./Opt.
26	108-112	5	Class 14 Count (BIN14)	Integer	Req./Opt.
27	113-117	5	Class 15 Count (BIN15)	Integer	Req./Opt.

Note: Fields designated as Required *must be reported.*
Fields designated as Optional *are not required to be reported.*
Fields designated as Required/Optional *could be either required or optional based on values used for other related fields.*

The fields for the Vehicle Classification record are:

1. Record Type (Column 1) – *Required*

   C = Vehicle classification record (Code the letter "C" in the first column)

2. FIPS State Code (Columns 2-3) – *Required*

   See section 4.2, Field #2.

3. Station Identification (Columns 4-23) – *Required*

   See Section 4.2, Field #3.

   This field should be right-justified with unused columns zero-filled.

4. Direction of Travel (Column 24) – *Required*

   See Section 4.2, Field #4.

5. Lane of Travel (Column 25) – *Required*

   See Section 4.2, 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 26-29) – *Required*

   See Section 4.2, Field #6.

7. Month of Data (Columns 30-31) – *Required*

   See Section 4.3, Field #8.

8. Day of Data (Columns 32-33) – *Required*

   See Section 4.3, Field #9.

9. Hour of Data (Columns 34-35) – *Required*

   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 36) – *Optional/Required*

    A 60-minute time interval is assumed if this column is left blank (optional). This field can be used to designate either 5-minute or 15-minute binned classification data (required).

    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. Restrictions (Column 37) – *Required*

    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

6 = none-regular event/trend

7 = special event one day

8 = special event more than one day

12. Total Interval Volume (Columns 38-42) – *Required*
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 13 to 27:
The following class count fields are numeric fields with the traffic volume by vehicle class for each hour of data. "Vehicle Classification Groupings" in the Station Description Record determines the number of classes expected from a given station. This value also determines how many columns are expected in the remainder of each record submitted in each 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 67 columns wide.)
The default classification system is the FHWA 13-class system (see Appendix A). Where a classification (grouping) system other than FHWA's 13-class system is used, the total number of columns for which data are entered will change from that described below. When no vehicles of a class being monitored are counted during a given hour, zero fill 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 FHWA 13-vehicle types are reported, the Vehicle Classification record would not be larger than 107 columns, with Classes 1-13 (fields 13-25) all considered to be *Required*. In this case, the vehicle classification grouping provided in the Station record (see Table 4-7) determines how many columns of class data are imported by TMAS. TMAS allows users to set a limit for each class count as part of its automated quality assurance checks.

13. Class 1 Count (Columns 43-47) – *Required*
Class 1 is for Motorcycles when using the 13 FHWA classification groups. If the FHWA 13-class 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 48-52) – *Required*
Class 2 is for Passenger Cars when using the 13 FHWA classification groups. If the FHWA 13-class 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 53-57) – *Required/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-class 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 58-62) – *Required/Optional*
Class 4 is for Buses when using the 13 FHWA classification groups. If the FHWA 13-class 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 63-67) – *Required/Optional*
Class 5 is for Two-Axle, Six-Tire, Single-Unit Trucks when using the 13 FHWA classification groups. If the FHWA 13-class 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 68-72) – *Required/Optional*
    Class 6 is for Three-Axle, Single-Unit Trucks when using the 13 FHWA classification groups. If the FHWA 13-class 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 73-77) – *Required/Optional*
    Class 7 is for Four-or-More Axle, Single-Unit Trucks when using the 13 FHWA classification groups. If the FHWA 13-class 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 78-82) – *Required/Optional*
    Class 8 is for Four-or-Less Axle, Single-Trailer Combination Vehicles when using the 13 FHWA classification groups. If the FHWA 13-class system is not being used, this field will contain the traffic volume for the eighth class of vehicles being reported.21.
21. Class 9 Count (Columns 83-87) – *Required/Optional*
    Class 9 is for Five-Axle, Single-Trailer Combination Vehicles when using the 13 FHWA classification groups. If the FHWA 13-class 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 88-92) – *Required/Optional*
    Class 10 is for Six-or-More Axle, Single-Trailer Combination Vehicles when using the 13 FHWA classification groups. If the FHWA 13-class 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 93-97) – *Required/Optional*
    Class 11 is for Five-or-Less Axle, Multiple-Trailer Combination Vehicles when using the 13 FHWA classification groups. If the FHWA 13-class 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 98-102) – *Required/Optional*
    Class 12 is for Six-Axle, Multiple-Trailer Combination Vehicles when using the 13 FHWA classification groups. If the FHWA 13-class system is not being used, this field will contain the traffic volume for the twelfth class of vehicles being reported.
25. Class 13 Count (Columns 103-107) – *Required/Optional*
    Class 13 is for Seven-or-More Axle, Multiple-Trailer Combination Vehicles when using the 13 FHWA classification groups. If the FHWA 13-class system is not being used, this field will contain the traffic volume for the thirteenth class of vehicles being reported.

    The agency may code special vehicle types or unclassified vehicles as either class 14 or 15 vehicles.

    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.)
26. Class 14 Count (Columns 108-112) – *Required/Optional*
27. Class 15 Count (Columns 113-117) – *Required/Optional*

Example Vehicle Classification records are shown in Table 4-18 through Table 4-19.

Table 4-18. Vehicle Classification Record Example (3 Length-Class Bins, 4 Lanes with Lanes and Directions not Combined at 60-Minute Interval for 2 Hours) – Fixed Width Format

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36	37	38-42	43-47	48-52	53-57
Content 01 Example:	C	17	JohnHeisman01231811B	1	1	2012	04	25	00	Blank	0	00099	00051	00038	00010
Content 02 Example:	C	17	JohnHeisman01231811B	1	2	2012	04	25	00	Blank	0	00020	00005	00014	00001
Content 03 Example:	C	17	JohnHeisman01231811B	5	2	2012	04	25	00	Blank	0	00011	00002	00008	00001
Content 04 Example:	C	17	JohnHeisman01231811B	5	1	2012	04	25	00	Blank	0	00066	00023	00037	00006
Content 05 Example:	C	17	JohnHeisman01231811B	1	1	2012	04	25	01	Blank	0	00072	00042	00021	00009
Content 06 Example:	C	17	JohnHeisman01231811B	1	2	2012	04	25	01	Blank	0	00017	00005	00011	00001
Content 07 Example:	C	17	JohnHeisman01231811B	5	2	2012	04	25	01	Blank	0	00011	00002	00007	00002
Content 08 Example:	C	17	JohnHeisman01231811B	5	1	2012	04	25	01	Blank	0	00057	00021	00029	00007

Table 4-19. Vehicle Classification Record Example (13 Axle-Class Bins, 2 Lanes with Lanes or Directions not Combined at 15-Minute Interval) – Fixed Width Format

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36	37	38-42
Content 01 Example:	C	17	JohnHeisman012318140	3	1	2012	12	01	00	1	0	00054
Content 02 Example:	C	17	JohnHeisman012318140	7	1	2012	12	01	00	1	0	00055
Content 03 Example:	C	17	JohnHeisman012318140	3	1	2012	12	01	00	2	0	00051
Content 04 Example:	C	17	JohnHeisman012318140	7	1	2012	12	01	00	2	0	00058
Content 05 Example:	C	17	JohnHeisman012318140	3	1	2012	12	01	00	3	0	00060
Content 06 Example:	C	17	JohnHeisman012318140	7	1	2012	12	01	00	3	0	00067
Content 07 Example:	C	17	JohnHeisman012318140	3	1	2012	12	01	00	4	0	00064
Content 08 Example:	C	17	JohnHeisman012318140	7	1	2012	12	01	00	4	0	00063

continued

Column Number:	43-47	48-52	53-57	58-62	63-67	68-72	73-77	78-82	83-87	88-92	93-97
Content 01 Example:	00000	00037	00006	00000	00001	00000	00000	00002	00007	00000	00000
Content 02 Example:	00001	00038	00009	00000	00000	00000	00000	00003	00005	00000	00000
Content 03 Example:	00000	00039	00008	00000	00001	00001	00000	00001	00008	00000	00000
Content 04 Example:	00000	00037	00010	00000	00000	00000	00000	00002	00009	00000	00000
Content 05 Example:	00001	00037	00006	00000	00000	00001	00000	00004	00012	00001	00000
Content 06 Example:	00000	00036	00005	00000	00001	00000	00000	00000	00015	00002	00000
Content 07 Example:	00001	00034	00009	00001	00001	00000	00000	00002	00016	00000	00001
Content 08 Example:	00000	00038	00008	00000	00000	00000	00000	00003	00013	00000	00000

continued

Column Number:	98-102	103-107	108-112	113-117
Content 01 Example:	00000	00001	00000	00000
Content 02 Example:	00000	00000	00000	00000
Content 03 Example:	00000	00001	00000	00000
Content 04 Example:	00000	00000	00000	00000
Content 05 Example:	00000	00000	00000	00000
Content 06 Example:	00000	00000	00000	00000
Content 07 Example:	00000	00000	00000	00000
Content 08 Example:	00000	00001	00000	00000

4.5.3 Vehicle Classification – Pipe-Delimited Format

State highway agencies can also submit vehicle classification data using the pipe-delimited format. The key difference between the fixed-width format and the pipe-delimited format is that with the pipe-delimited file, data elements no longer need to match the starting and ending columns. Length of data elements can be equal or shorter than the specified lengths. The field order for the pipe-delimited format is identical to the order for the fixed-width format (see Table 4-17). In this format, the fields are separated by a pipe symbol (|) instead of beginning in specified columns. Example records in this format are provided below.

Delimited Format Examples

Class Data for 15 Vehicle Bins with Delimited Fields – Detailed

RT|SFIPS|ID|DIR|LN|YR|MOY|DOM|HOD|I|R|TVOL|BIN1|BIN2|BIN3|BIN4|
BIN5|BIN6|BIN7|BIN8|BIN9|BIN10|BIN11|BIN12|BIN13|BIN14|BIN15

Hourly Class Data for 15 Class Bins with 2 Directions with No Restrictions

C|39|XYZ123|3|1|2021|4|25|00||0|132|5|67|13|10|2|3|1|7|16|2|1|1|0|3|1
C|39|XYZ123|7|1|2021|4|25|00||0|126|3|63|12|5|4|5|1|10|13|4|3|0|0|1|2

15-Minute Class Data for 5 Class Bins with 2 Directions and 4 Lanes with No Restrictions

C|39|ABC123|1|1|2021|4|25|00|1|0|96|5|67|13|10|1
C|39|ABC123|1|2|2021|4|25|00|1|0|236|10|175|35|14|2
C|39|ABC123|1|3|2021|4|25|00|1|0|215|8|168|32|5|2
C|39|ABC123|1|4|2021|4|25|00|1|0|89|4|67|12|4|2
C|39|ABC123|5|1|2021|4|25|00|1|0|102|3|73|14|10|2
C|39|ABC123|5|2|2021|4|25|00|1|0|235|5|185|30|15|0
C|39|ABC123|5|3|2021|4|25|00|1|0|230|7|173|36|13|1
C|39|ABC123|5|4|2021|4|25|00|1|0|97|5|67|13|10|2
C|39|ABC123|1|1|2021|4|25|00|2|0|102|4|68|24|6|0
C|39|ABC123|1|2|2021|4|25|00|2|0|201|3|167|23|7|1
C|39|ABC123|1|3|2021|4|25|00|2|0|192|5|147|30|8|2
C|39|ABC123|1|4|2021|4|25|00|2|0|97|5|65|15|10|2
C|39|ABC123|5|1|2021|4|25|00|2|0|91|1|64|22|4|0
C|39|ABC123|5|2|2021|4|25|00|2|0|179|0|147|26|6|0
C|39|ABC123|5|3|2021|4|25|00|2|0|212|5|167|34|4|2
C|39|ABC123|5|4|2021|4|25|00|2|0|78|2|57|13|6|0
C|39|ABC123|1|1|2021|4|25|00|3|0|102|4|68|24|6|0
C|39|ABC123|1|2|2021|4|25|00|3|0|201|3|167|23|7|1
C|39|ABC123|1|3|2021|4|25|00|3|0|192|5|147|30|8|2
C|39|ABC123|1|4|2021|4|25|00|3|0|97|5|65|15|10|2
C|39|ABC123|5|1|2021|4|25|00|3|0|91|1|64|22|4|0
C|39|ABC123|5|2|2021|4|25|00|3|0|179|0|147|26|6|0
C|39|ABC123|5|3|2021|4|25|00|3|0|212|5|167|34|4|2
C|39|ABC123|5|4|2021|4|25|00|3|0|78|2|57|13|6|0
C|39|ABC123|1|1|2021|4|25|00|4|0|102|4|68|24|6|0
C|39|ABC123|1|2|2021|4|25|00|4|0|201|3|167|23|7|1
C|39|ABC123|1|3|2021|4|25|00|4|0|192|5|147|30|8|2
C|39|ABC123|1|4|2021|4|25|00|4|0|97|5|65|15|10|2
C|39|ABC123|5|1|2021|4|25|00|4|0|91|1|64|22|4|0
C|39|ABC123|5|2|2021|4|25|00|4|0|179|0|147|26|6|0
C|39|ABC123|5|3|2021|4|25|00|4|0|212|5|167|34|4|2
C|39|ABC123|5|4|2021|4|25|00|4|0|78|2|57|13|6|0

4.6 WEIGHT DATA FORMAT (FIXED WIDTH OR PIPE DELIMITED)

The Weight Data Format is the mechanism currently used to submit weight data to TMAS. FHWA prefers that States submit weight data using the Individual Vehicle Record Formats (IVR) described in Section 4.7. Weight data should be submitted using the “W” or “Z” variants of the IVR record format (Sections 4.7.4 and 4.7.5, respectively).

For States still wishing 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. Agencies have the option to submit all vehicle types in weight data format as opposed to just sending in classes 4-13.

Up to 20-digits can be used for station IDs. For the fixed-width format, the station ID field needs to be right-justified and padded with zeros.

As a reminder, all weight data are to use English units.

4.6.1 FILE NAMING RECOMMENDATION

It is recommended that the file extension .WGT be used for all Weight data files. The filename should be descriptive to facilitate the deciphering of the file and its contents.

An example of the file naming convention for the Weight record is:

ssabcxyzmmyyyy.WGT

4.6.2 WEIGHT – FIXED-WIDTH FORMAT

The fixed-width column data element format is the legacy TMAS data format. States can continue to submit data in such format. However, States can elect to submit the weight data via the new pipe-delimited file format described in Section 4.6.3.

Table 4-20 summarizes the Weight fixed-width column record format.

Table 4-20. Weight Record – Fixed-Width Format

Field	Columns	Width	Description	Type	Importance
1	1	1	Record Type (RT)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-23	20	Station Identification (ID)	Alphanumeric	Required
4	24	1	Direction of Travel (DIR)	Integer	Required
5	25	1	Lane of Travel (LN)	Integer	Required
6	26-29	4	Year of Data (YR)	Integer	Required
7	30-31	2	Month of Year (MOY)	Integer	Required
8	32-33	2	Day of Month (DOM)	Integer	Required
9	34-35	2	Hour of Day (HOD)	Integer	Required
10	36-37	2	Vehicle Class (CLS)	Integer	Required
11	38-40	3	Open (O)	Integer	Optional
12	41-46	6	Total Weight of Vehicle (GVW)	Integer	Required
13	47-48	2	Number of Axles (NAX)	Integer	Required
14	49-53	5	Axle Weight 1 (AW1)	Integer	Required
15	54-57	4	Axles 1-2 Spacing (ASP1)	Integer	Required
16	58-62	5	Axle Weight 2 (AW2)	Integer	Required
17	63-66	4	Axles 2-3 Spacing (ASP2)	Integer	Req./Opt.

Field	Columns	Width	Description	Type	Importance
18	67-71	5	Axle Weight 3 (AW3)	Integer	Req./Opt.
19	72-75	4	Axles 3-4 Spacing (ASP3)	Integer	Req./Opt.
20	76-80	5	Axle Weight 4 (AW4)	Integer	Req./Opt.
21	81-84	4	Axles 4-5 Spacing (ASP4)	Integer	Req./Opt.
22	85-89	5	Axle Weight 5 (AW5)	Integer	Req./Opt.
23	90-93	4	Axles 5-6 Spacing (ASP5)	Integer	Req./Opt.
24	94-98	5	Axle Weight 6 (AW6)	Integer	Req./Opt.
25	99-102	4	Axles 6-7 Spacing (ASP6)	Integer	Req./Opt.
26	103-107	5	Axle Weight 7 (AW7)	Integer	Req./Opt.
27	108-111	4	Axles 7-8 Spacing (ASP7)	Integer	Req./Opt.
28	112-116	5	Axle Weight 8 (AW8)	Integer	Req./Opt.
29	117-120	4	Axles 8-9 Spacing (ASP8)	Integer	Req./Opt.
30	121-125	5	Axle Weight 9 (AW9)	Integer	Req./Opt.
31	126-129	4	Axles 9-10 Spacing (ASP9)	Integer	Req./Opt.
32	130-134	5	Axle Weight 10 (AW10)	Integer	Req./Opt.
33	135-138	4	Axles 10-11 Spacing (ASP10)	Integer	Req./Opt.
34	139-143	5	Axle Weight 11 (AW11)	Integer	Req./Opt.
35	144-147	4	Axles 11-12 Spacing (ASP11)	Integer	Req./Opt.
36	148-152	5	Axle Weight 12 (AW12)	Integer	Req./Opt.
37	153-156	4	Axles 12-13 Spacing (ASP12)	Integer	Req./Opt.
38	157-161	5	Axle Weight 13 (AW13)	Integer	Req./Opt.

Note: Fields designated as Required *must be reported.*

Fields designated as Optional *are not required to be reported.*

Fields designated as Required/Optional *could be either required or optional based on values used for other related fields.*

The number of axles determines the number of axle weight and spacing fields.

For those vehicles with fourteen or more axles, add the appropriate number of additional fields.

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) – *Required*

   W = Truck weight record (Code the letter "W" in the first column.)

2. FIPS State Code (Columns 2-3) – *Required*

   See Section 4.2, Field #2.

3. Station Identification (Columns 4-23) – *Required*

   See Section 4.2, Field #3.

This field should be right-justified with unused columns zero-filled.

4. Direction of Travel Code (Column 24) – *Required*

   See Section 4.2, Field #4.

5. Lane of Travel (Column 25) – *Required*

   See Section 4.2, 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 26-29) – *Required*

   See Section 4.2, Field #6.

7. Month of Data (Columns 30-31) – *Required*

   See Section 4.3, Field #8.

8. Day of Data (Columns 32-33) – *Required*

   See Section 4.3, Field #9.

9. Hour of Data (Columns 34-35) – *Required*

   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. Vehicle Class (Columns 36-37) – *Required*
    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 38-40 – *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 41-46) – *Required*
    Enter the gross vehicle weight to the nearest pound. For example, 110,200.2 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 47-48) – *Required*
    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.

> Axle weights are to be reported to the nearest pound. Axle spacings are reported to the nearest tenth of a foot. All values should be right-justified with leading blanks as needed

14. Axle Weight 1 (Columns 49-53) – *Required*

15. Axles 1-2 Spacing (Columns 54-57) – *Required*

16. Axle Weight 2 (Columns 58-62) – *Required*

17. Axles 2-3 Spacing (Columns 63-66) – *Required/Optional*
18. Axle Weight 3 (Columns 67-71) – *Required/Optional*
19. Axles 3-4 Spacing (Columns 72-75) – *Required/Optional*
20. Axle Weight 4 (Columns 76-80) – *Required/Optional*
21. Axles 4-5 Spacing (Columns 81-84) – *Required/Optional*
22. Axle Weight 5 (Columns 85-89) – *Required/Optional*
23. Axles 5-6 Spacing (Columns 90-93) – *Required/Optional*
24. Axle Weight 6 (Columns 94-98) – *Required/Optional*
25. Axles 6-7 Spacing (Columns 99-102) – *Required/Optional*
26. Axle Weight 7 (Columns 103-107) – *Required/Optional*
27. Axles 7-8 Spacing (Columns 108-111) – *Required/Optional*
28. Axle Weight 8 (Columns 112-116) – *Required/Optional*
29. Axles 8-9 Spacing (Columns 117-120) – *Required/Optional*
30. Axle Weight 9 (Columns 121-125) – *Required/Optional*
31. Axles 9-10 Spacing (Columns 126-129) – *Required/Optional*
32. Axle Weight 10 (Columns 130-134) – *Required/Optional*
33. Axles 10-11 Spacing (Columns 135-138) – *Required/Optional*
34. Axle Weight 11 (Columns 139-143) – *Required/Optional*
35. Axles 11-12 Spacing (Columns 144-147) – *Required/Optional*
36. Axle Weight 12 (Columns 148-152) – *Required/Optional*
37. Axles 12-13 Spacing (Columns 153-156) – *Required/Optional*
38. Axle Weight 13 (Columns 157-161) – *Required/Optional*

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

Example Weight records are shown in Table 4-21.

Table 4-21. Weight Record Example – Fixed-Width Format

WEIGHT SITE WEIGHT FILE

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36-37	38-40	41-46
Content 01 Example:	W	17	JohnHeisman012318140	3	1	2012	11	07	16	09	Blank	057886
Content 02 Example:	W	17	JohnHeisman012318140	3	1	2012	11	07	16	04	Blank	018351
Content 03 Example:	W	17	JohnHeisman012318140	3	1	2012	11	07	16	06	Blank	047289

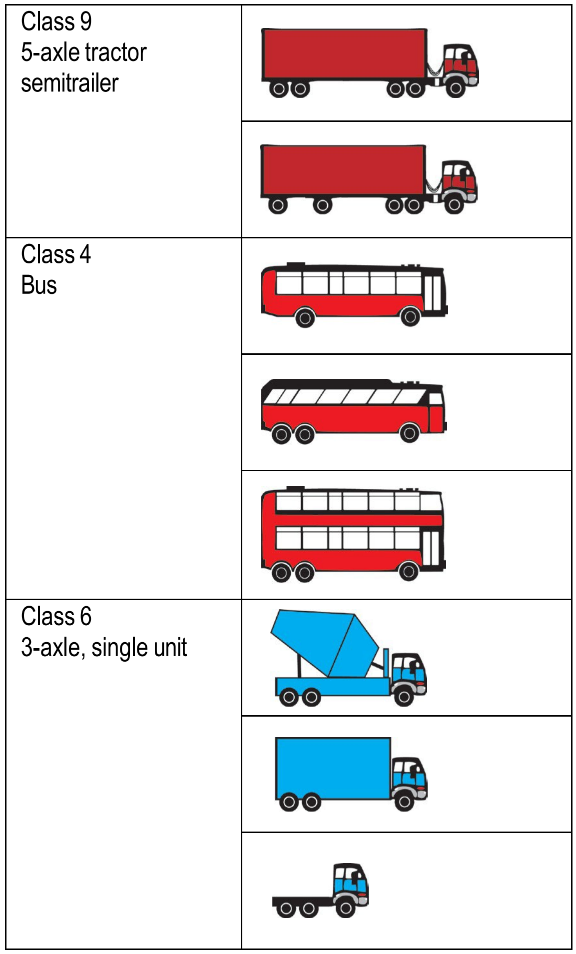
continued

Column Number:	47-48	49-53	54-57	58-62	63-66	67-71	72-75	76-80	81-84	85-89	90-93	94-98	99-102
Content 01 Example:	05	11210	0151	12300	0045	13730	0214	09815	0048	10831	Blank	Blank	Blank
Content 02 Example:	02	08522	0252	09829	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 03 Example:	03	09818	0131	19125	0046	18346	Blank	Blank	Blank	Blank	Blank	Blank	Blank

continued

Column Number:	103-107	108-111	112-116	117-120	121-125	126-129	130-134	135-138	139-143	144-147	148-152	153-156	157-161
Content 01 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 02 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 03 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank

In the Weight Record examples listed above, the Vehicle Class field (columns 36-37) indicates either class 09 (semi-trailer), class 04 (bus), or class 06 (dump-truck; 3-axle single unit) as illustrated below in Figure 4-2.



Source: Federal Highway Administration.

Figure 4-2. Illustration of Class 09 - Semi-Truck, 04 - Bus, and 06 - Dump-Truck

4.6.3 WEIGHT DATA – PIPE-DELIMITED FORMAT

State highway agencies can submit the weight data using the pipe-delimited format. The key difference between the fixed-width format and the pipe-delimited format is that with the pipe-delimited file, data elements no longer need to match the starting and ending columns. Length of data elements can be equal or shorter than the specified lengths. The field order for the pipe-delimited format is identical to the order for the fixed-width format (see Table 4-20). In this format, the fields are separated by a pipe symbol (|) instead of beginning in specified columns. Example records in this format are provided below.

Delimited Format Examples

Weight Format – Detailed

RT|SFIPS|ID|DIR|LN|YR|MOY|DOM|HOD|CLS|O|GVW|NAX|AW1|ASP1|AW2|ASP2|AW3|ASP3|AW4|ASP4|AW5|ASP5|AW6|ASP6|AW7|ASP7|AW8…

2-Lane Roadway with 9 Individual Vehicles Recorded

W|35|123456|3|1|2021|4|25|00|9||61837|5|10500|145|12000|43|12500|210|13450|46|13387
W|35|123456|7|1|2021|4|25|00|5||14874|2|8462|185|6412
W|35|123456|3|1|2021|4|25|00|4||25886|3|9750|240|7680|45|8456
W|35|123456|3|1|2021|4|25|00|9||54828|5|9873|135|11678|42|10985|23|11245|45|11047
W|35|123456|7|1|2021|4|25|00|8||40561|4|9504|130|11546|205|9728|45|9783
W|35|123456|3|1|2021|4|25|00|9||70044|5|11620|165|12895|43|12530|220|16750|82|16249
W|35|123456|7|1|2021|4|25|00|10||79973|6|11463|145|10486|43|10876|43|10562|240|18045|46|18541
W|35|123456|7|1|2021|4|25|01|13||71753|8|10876|138|9540|42|9163|42|9405|180|8741|46|8523|160|7652|46|7853
W|35|123456|3|1|2021|4|25|01|9||72741|5|11231|165|14780|43|15345|275|15245|46|16140

4.7 DETAILED INDIVIDUAL VEHICLE RECORD (IVR) DATA FORMAT (FIXED WIDTH OR PIPE DELIMITED)

As an *optional* and recommended way to submit traffic monitoring data to FHWA, State and local highway agencies may submit traffic volume, speed, vehicle classification, and vehicle weight data as individual vehicle records (IVR) rather than using the more traditional formats described earlier in this chapter. TMAS will accept IVRs in the formats described below.

IVRs require more disk space than aggregated records, but they also allow much more detailed analysis of traffic patterns. Agencies are encouraged to submit data in these IVR 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 several 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 IVR data file will:

- Meet all of the FHWA reporting needs for the TMS.
- Allow for more detailed QC checks to be performed.
- Provide better quality data for use in national statistics.

Up to 20-digits can be used for station IDs. For the fixed-width format, the station ID field needs to be right-justified and padded with zeros.

Table 4-22 provides a quick reference for the units of measurement to be reported for weight, length, speed, and temperature.

Table 4-22. 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 Individual Vehicle Record format. Each of these variations corresponds to a specific type of data collection device. All of the formats use a fixed-width record structure, and the first 13 fields of data are the same for all five record formats. The final (14th) field contains a variable that describes the type of data contained in that record. After the first 14 fields, 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 Individual Vehicle Record Format (variant letter to use) are described in the following sections:

- Traffic Volume Only Format (V)
- Speed, Length Classification Data Formats (T)
- Axle Classification Data Format (C)
- Weight Data Format for Reporting Axle Weights (W)
- Vehicle Classification and Wheel Weights (Z)

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, tenths of feet for distance, tenths of miles per hour for speed, and degrees Fahrenheit for temperature). All unused entries are to be blank filled.

A dummy vehicle signature of ‘m’ indicates that traffic data for an hour are missing. A dummy vehicle signature of ‘d’ indicates that traffic data for this hour are not missing, and there were no IVR records for the hour. Without these indications, no IVR records for an hour might be interpreted to mean that the traffic system was not working. These dummy records can be utilized for any of the IVR variants.

The first 13 fields contain the same information (with unique direction, lane, date, time, and signature codes) for all individual vehicle records.

An example of the file naming convention for the Individual Vehicle Record record is:

ssabcxyzmmyyyy.IVR

4.7.1 Traffic Volume Only Format (V)

Table 4-23 describes the data to be included in the first 13 fields of all Individual Vehicle Record records submitted to FHWA, regardless of which one of the five record types is being submitted.

Table 4-23. Individual Vehicle Record Collected by Volume Device (V Variant) – Fixed-Width Format

Field	Columns	Width	Description	Type	Importance
1	1	1	Record Type (RT)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-23	20	Station Identification (ID)	Alphanumeric	Required
4	24	1	Direction of Travel (DIR)	Integer	Required
5	25	1	Lane of Travel (LN)	Integer	Required
6	26-29	4	Year of Data (YR)	Integer	Required
7	30-31	2	Month of Year (MOY)	Integer	Required
8	32-33	2	Day of Month (DOM)	Integer	Required
9	34-35	2	Hour of Day (HOD)	Integer	Required
10	36-37	2	Minute of Hour (MOH)	Integer	Required
11	38-39	2	Second of Minute (SOM)	Integer	Required
12	40-41	2	Sub Second of Second (SSOS)	Integer	Required
13	42	1	Type of Base Counting Device (V)	Alphanumeric	Required
14	43-47	5	Vehicle Signature/Other Use (VS)	Integer	Optional

Note: Fields designated as Required *must be reported.*

Fields designated as Optional *are not required to be reported.*

Fields designated as Required/Optional *could be either required or optional based on values used for other related fields.*

1. Record Type (Column 1) – *Required*

   I = Individual Vehicle Record

2. FIPS State Code (Columns 2-3) – *Required*

   See Section 4.2, Field #2.

3. Station Identification (Columns 4-23) – *Required*

   See Section 4.2, Field #3.

   This field should be right-justified with unused columns zero-filled.

4. Direction of Travel Code (Column 24) – *Required*

   See Section 4.2, Field #4.

5. Lane of Travel (Column 25) – *Required*

   See Section 4.2, 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 26-29) – *Required*

   See Section 4.2, Field #6.

7. Month of Year (Columns 30-31) – *Required*

   See Section 4.3, Field #8.

8. Day of Month (Columns 32-33) – *Required*

   See Section 4.3, Field #9.

9. Hour of Day (Columns 34-35) – *Required*

   hh = Hour in which record was taken

   Code the beginning of the hour 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

10. Minute of Hour of Data (Columns 36-37)

    mm = Minute in which record was taken

    Code the beginning of the minute 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

11. Second of Minute of Data (Columns 38-39)

    ss = Second in which record was taken

    Code the beginning of the second 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

12. Sub-Second of Second (Columns 40-41)

    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 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

13. Type of Base Counting Device (Column 42) – *Required*
    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 software reads the number of columns that is expected 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 47)

14. Vehicle Signature or Other Use Field (Columns 43-47) – *Optional*

    Enter the vehicle unique loop or magnetic signature using the right-most digits first.

    Digit 1 (Column 43) contains the vehicle type code:

    Motorcycle (FHWA Class 1) =1

    Passenger car (FHWA Class 2) = 2

    Light Truck (FHWA Class 3) = 3

    Bus (FHWA Class 4) = 4

    Single-unit vehicle (FHWA Classes 5, 6, and 7) = 5

    Single-trailer combination vehicle (FHWA Classes 8, 9, and 10) = 6

    Multiple-trailer combination vehicle (FHWA Classes 11, 12, and 13) = 7

    Utilize a “m” as a dummy record when counts are missing for the given hour

    Utilize a “d” as a dummy record when counts were not present for the given hour but the traffic device was working.

    Digit 2 (Column 44) – the # of axles for the vehicle. If more than 9 axles are observed, code alphanumerically, where 10 = A, 11 = B, etc.

    Digit 3 (Column 45) – body type (body style defined by FHWA in Table 4-24 and Table 4-25)

    Digit 4 (Column 46) – specific body style (body style defined by FHWA in Table 4-24 and Table 4-25)

    Digit 5 (Column 47) – pulling additional part attribute

    0 = No additional part

    1 = FHWA 1, FHWA 2, FHWA 3 pulling a trailer/platform/vehicle/etc.

    3 = Single unit truck (FHWA 4-7) pulling a FHWA 2/FHWA 3/tractor/single unit truck

    5 = Single unit truck (FHWA 4-7) or Combination unit truck pulling an auto trailer

    7 = Single unit truck (FHWA 4-7) pulling a trailer/platform (trailer truck type)

    9 = Others

This signature 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 columns 46 and 47 (XXXX.X)

Table 4-24. Individual Codes for Class and Body Type 1<5

Code 3	Body Type (Body Style)	Code 4	Specific Body Type (Specific Body Style)
0	Blocked (may be blocked or N/A)	0	N/A
1	Motorcycles (FHWA1)	0	Blocked
		1	Moped, Motorcycle
		2	2-front tire motorcycle
		3	2-rear tire motorcycle
		4	Sidecar motorcycle
		9	Others
2	Passenger car (FHWA2)	0	Blocked
		1	Sedan/SUV/Minivan (up to 8 seats)/Coupe/Sta. wagon/Sports car/Jeep
		9	Others
3	Non-passenger car (FHWA3)	0	Blocked
		1	Pickup, non-full-size
		3	Pickup, modified
		4	Panel van/Passenger van (9-15 seats)
		5	Limousine (e.g., Car limousine, SUV limousine, Hummer limousine)
		6	Mini motorhome/Minibus
		8	Ambulance
		9	Others
4	Bus (FHWA 4)	0	Blocked
		1	School, small
		2	School, mid/large
		3	City bus, small
		4	City bus, mid/large
		5	City bus, articulated
		6	Motorcoach (e.g., Greyhound)
		7	Shuttle bus (16 or more seats)
		9	Others
9	Bicycle	0	N/A

Table 4-25. Individual Codes for Class and Body Type when Code 1>=5

Code 3	Body Type (Body Style)	Code 4	Specific Body Type (Specific Body Style)
0	Blocked	0	Blocked
1	Van	0	Blocked
		1	Enclosed van/Open-top/Grain van/Curtain-side/Beverage van (for Code 1 <= 6 only)
		2	Delivery/Multi-stop/Step van
		3	Drop-frame van/Furniture van (for Code 1 >= 6 only)
		4	Tilt van (for Code 1 >= 6 only)
		5	Same type vans (for Code 1 = 7 only)
		6	Different type vans (for Code 1 = 7 only)
		9	Others
2	Platform	0	Blocked
		1	Basic platform/Double deck platform
		2	Low Boy Platform/Gooseneck
		3	Platform with device at front end
		4	Platform with device at rear end
		9	Others
3	Tanker	0	Blocked
		1	Chemical truck/Gas truck/Septic truck
		3	Dry bulk truck/Pneumatic truck
		9	Others
5	Service Truck	0	Blocked
		1	2-axle 6-tire Pickup
		2	Concrete mixer
		3	Bucket/Wrecker/Winch
		4	Garbage truck
		5	Flatbed tow truck (single/Double deck)
		6	Crane/Concrete pumper truck/Oil rig
		7	Ambulance/Fire truck
		9	Other Utility truck (Landscaping/Street sweeper/etc.)
6	Semi-tractor	0	Blocked
		1	Conventional cab/Day cab
		2	Extended cab/Sleeping cab
		3	Cab-Over Engine (COE) cab
		9	Others
7	Intermodal chassis	0	Blocked
		1	20 ft (1TEU) box container
		2	40 ft (2TEU)/53 ft box container
		5	Same type containers (for Code 1 = 7 only)
		6	Different type containers (for Code 1 = 7 only)
		7	Container chassis only
		9	Others

8	Dump	0	Blocked
		1	End/Side dump
		2	Bottom/Belly dump
		9	Others
9	Other specialty	0	Blocked
		1	Auto Carrier
		2	Mini motorhome
		3	Full size motorhome
		4	Livestock
		5	Logging/Pipe/Pole
		6	Agriculture
		9	Others (e.g., Armored personnel carrier)

Example V Variant records are shown in Table 4-26.

Table 4-26. Individual Vehicle Record (Volume Site) Example (Southbound Lane 1, Note – Record Length Ends With 5 Blanks) – Fixed-Width Format

Column Number:	**1**	**2-3**	**4-23**	**24**	**25**	**26-29**	**30-31**	**32-33**	**34-35**
Content 01 Example:	I	17	JohnHeisman012318140	5	1	2022	11	07	13
Content 02 Example:	I	17	JohnHeisman012318140	5	1	2022	11	07	13
Content 03 Example:	I	17	JohnHeisman012318140	5	1	2022	11	07	13

continued

Column Number:	**36-37**	**38-39**	**40-41**	**42**	**43-47**
Content 01 Example:	28	46	87	V	Blank
Content 02 Example:	34	50	54	V	Blank
Content 03 Example:	38	31	89	V	Blank

All units are given in English units with vehicle length in tenths of feet, inter-axle spacing in tenths of feet, axle weights in pounds, tenths of miles per hour for speed, and degrees Fahrenheit for temperature. All unused entries are to be blank filled.

State highway agencies can submit the IVR (V variant) data using the pipe-delimited format. The key difference between the fixed-width format and the pipe-delimited format is that with the pipe-delimited file, data elements no longer need to match the starting and ending columns. Length of data elements can be equal or shorter than the specified lengths. The field order for the pipe-delimited format is identical to the order for the fixed-width format (see Table 4-23). In this format, the fields are separated by a pipe symbol (|) instead of beginning in specified columns. Example records in this format are provided below.

Delimited Format Examples

Volume Format – Detailed

RT|SFIPS|ID|DIR|LN|YR|MOY|DOM|HOD|MOH|SOM|SSOS|V|VS|

8-Lane Roadway with 12 Individual Vehicles Recorded (No Vehicle Signatures Reported)

I|18|123|3|4|2021|4|25|2|12|5|31|V||
I|18|123|7|3|2021|4|25|2|12|5|37|V||
I|18|123|3|2|2021|4|25|2|12|7|4|V||
I|18|123|3|1|2021|4|25|2|12|8|23|V||
I|18|123|7|1|2021|4|25|2|12|9|89|V||
I|18|123|3|1|2021|4|25|2|12|12|15|V||
I|18|123|7|1|2021|4|25|2|12|15|85|V||
I|18|123|7|3|2021|4|25|2|12|15|92|V||
I|18|123|7|3|2021|4|25|2|12|17|14|V||
I|18|123|7|2|2021|4|25|2|12|17|90|V||
I|18|123|3|3|2021|4|25|2|12|18|1|V||

4.7.2 Speed and Length Classification Data Format (T)

This section includes columns 48-59 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 42 columns, place the letter "T" in column 42, and optionally add vehicle signature data in columns 43-47, then add data to columns 48-59 as described below in Table 4-27. Blank fill all columns for which data are not available.

Table 4-27. Speed and Length Classification Individual Vehicle Record (T Variant) – Fixed-width Format

Field	Columns	Width	Description	Type	Importance
1	1	1	Record Type (RT)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-23	20	Station Identification (ID)	Alphanumeric	Required
4	24	1	Direction of Travel (DIR)	Integer	Required
5	25	1	Lane of Travel (LN)	Integer	Required
6	26-29	4	Year of Data (YR)	Integer	Required
7	30-31	2	Month of Year (MOY)	Integer	Required
8	32-33	2	Day of Month (DOM)	Integer	Required
9	34-35	2	Hour of Day (HOD)	Integer	Required
10	36-37	2	Minute of Hour (MOH)	Integer	Required
11	38-39	2	Second of Minute (SOM)	Integer	Required
12	40-41	2	Sub Second of Second (SSOS)	Integer	Required
13	42	1	T	Alphanumeric	Required
14	43-47	5	Vehicle Signature/Other Use (VS)	Integer	Optional
15	48-51	4	Vehicle Speed (SPD)	Integer	Required
16	52-53	2	Vehicle Classification (CLS)	Integer	Req./Opt.
17	54-55	2	Number of Axles (NAX)	Integer	Req./Opt.
18	56-59	4	Total Vehicle Length (bumper to bumper) (TVL)	Integer	Req./Opt.

Note: R=Required, O=Optional, R/O=Required/Optional,
Fields designated as Required *must be reported.*
Fields designated as Optional *are not required to be reported.*
Fields designated as Required/Optional *could be either required or optional based on values used for other related fields.*

For Fields 1 – 14 Descriptions, see V Variant Descriptions.

15. Vehicle Speed (Columns 48-51 – *Required*

    The speed of the vehicle to the nearest tenth of a mph. The decimal is implied between digits 50 and 51. Blank fill if unused.

    Example – for a 104.1 mph vehicle, it would be coded as 1041. For 55.0 mph, it would be coded 0550.

16. Vehicle Classification (Columns 52-53) – *Required/Optional* according to the following: Required for C, W and Z devices, Optional for T devices

    The classification of the vehicle from FHWA classes 1 to 13. Blank fill if unused.

17. Number of Axles (Columns 54-55) – *Required/Optional* according to the following: Required for C, W and Z devices, Optional for T devices

    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 Required. Otherwise, the remainder of the fields through column 59 should be blank filled. The record should end after column 59 if no axle spacing data are available (record formats C, W, and Z).

18. Total Vehicle Length (bumper to bumper) (Columns 56-59) – *Required/Optional*

    The total length of the vehicle from bumper to bumper to the nearest tenth of a foot. The decimal is implied between digits 58 and 59. 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 59 characters in length.

Example T Variant records are shown in Table 4-28.

Table 4-28. Individual Vehicle Record (Speed Site) Example (Northbound Lane 2) – Fixed-Width Format

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36-37
Content 01 Example:	I	17	JohnHeisman012318140	1	2	2012	11	07	09	24
Content 02 Example:	I	17	JohnHeisman012318140	1	2	2012	11	07	09	33
Content 03 Example:	I	17	JohnHeisman012318140	1	2	2012	11	07	09	42

continued

Column Number:	38-39	40-41	42	43-47	48-51	52-53	54-55	56-59
Content 01 Example:	58	38	T	Blank	0624	03	02	0163
Content 02 Example:	12	78	T	Blank	0613	09	05	0691
Content 03 Example:	14	36	T	Blank	0648	02	02	0097

State highway agencies can submit the IVR (T variant) data using the pipe-delimited format. The key difference between the fixed-width format and the pipe-delimited format is that with the pipe-delimited file, data elements no longer need to match the starting and ending columns. Length of data elements can be equal or shorter than the specified lengths. The field order for the pipe-delimited format is identical to the order for the fixed-width format (see Table 4-27). In this format, the fields are separated by a pipe symbol (|) instead of beginning in specified columns. Example records in this format are provided below.

Delimited Format Examples

Speed Format – Detailed

RT|SFIPS|ID|DIR|LN|YR|MOY|DOM|HOD|MOH|SOM|SSOS|T|VS|SPD|CLS|NAX|TVL|

6-lane Roadway with 12 individual vehicles recorded (No Vehicle Signatures, Vehicle classifications, Number of axles or Total Vehicle Lengths reported)

```
I|15|ABC123|1|3|2021|4|25|2|12|5|31|T||554||||
I|15|ABC123|5|3|2021|4|25|2|12|5|37|T||762||||
I|15|ABC123|1|2|2021|4|25|2|12|7|4|T||605||||
I|15|ABC123|1|1|2021|4|25|2|12|8|23|T||600||||
I|15|ABC123|5|1|2021|4|25|2|12|9|89|T||552||||
I|15|ABC123|1|1|2021|4|25|2|12|12|15|T||571||||
I|15|ABC123|5|1|2021|4|25|2|12|15|85|T||557||||
I|15|ABC123|5|3|2021|4|25|2|12|15|92|T||721||||
I|15|ABC123|5|3|2021|4|25|2|12|17|14|T||728||||
I|15|ABC123|5|2|2021|4|25|2|12|17|90|T||654||||
I|15|ABC123|1|3|2021|4|25|2|12|18|1|T||570||||
I|15|ABC123|1|2|2021|4|25|2|12|19|34|T||611|||
```

4.7.3 AXLE CLASSIFICATION DATA FORMAT (C)

This section only applies to those individual records designated with a "C" in Field 13, column 42. The data to be included are described in Table 4-29.

The "C" variant of the Individual 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 54-55 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 155 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) + 59

Where: *number of axles* is the value found in columns 40 and 41 of that record.

Table 4-29. Individual Vehicle Record by Classification (Axle) Device (C Variant) – Fixed width

Field	Columns	Width	Description	Type	Importance
1	1	1	Record Type (RT)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-23	20	Station Identification (ID)	Alphanumeric	Required
4	24	1	Direction of Travel (DIR)	Integer	Required
5	25	1	Lane of Travel (LN)	Integer	Required
6	26-29	4	Year of Data (YR)	Integer	Required
7	30-31	2	Month of Year (MOY)	Integer	Required
8	32-33	2	Day of Month (DOM)	Integer	Required
9	34-35	2	Hour of Day (HOD)	Integer	Required
10	36-37	2	Minute of Hour (MOH)	Integer	Required
11	38-39	2	Second of Minute (SOM)	Integer	Required
12	40-41	2	Sub Second of Second (SSOS)	Integer	Required
13	42	1	C	Alphanumeric	Required
14	43-47	5	Vehicle Signature/Other Use (VS)	Integer	Optional
15	48-51	4	Vehicle Speed (SPD)	Integer	Required
16	52-53	2	Vehicle Classification (CLS)	Integer	Required
17	54-55	2	Number of Axles (NAX)	Integer	Required
18	56-59	4	Total Vehicle Length (bumper to bumper) (TVL)	Integer	Optional
19	60-63	4	Axles 1-2 Spacing (ASP1)	Integer	Required
20	64-67	4	Axles 2-3 Spacing (ASP2)	Integer	Req./Opt.
21	68-71	4	Axles 3-4 Spacing (ASP3)	Integer	Req./Opt.
22	72-75	4	Axles 4-5 Spacing (ASP4)	Integer	Req./Opt.
23	76-79	4	Axles 5-6 Spacing (ASP5)	Integer	Req./Opt.
24	80-83	4	Axles 6-7 Spacing (ASP6)	Integer	Req./Opt.
25	84-87	4	Axles 7-8 Spacing (ASP7)	Integer	Req./Opt.
26	88-91	4	Axles 8-9 Spacing (ASP8)	Integer	Req./Opt.
27	92-95	4	Axles 9-10 Spacing (ASP9)	Integer	Req./Opt.
28	96-99	4	Axles 10-11 Spacing (ASP10)	Integer	Req./Opt.
29	100-103	4	Axles 11-12 Spacing (ASP11)	Integer	Req./Opt.
30+	Use additional spacing in 4-digit increments up to 25 axles			Integer	Req./Opt.

Note: R=Required, O=Optional, R/O=Required/Optional,

Fields designated as Required *must be reported.*

Fields designated as Optional *are not required to be reported.*

Fields designated as Required/Optional *could be either required or optional based on values used for other related fields.*

The definitions of the data to be contained in columns 1 – 59 for the "C" format are described in Section 4.7.1. The data to be included in columns 60 and later are defined as follows:

19. Axle 1 to 2 Spacing (Columns 60-63) – *Required for C, W, and Z record variants*
    Enter the total spacing between axles 1 and 2 as a right-justified 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."
20. Axle 2 to 3 Spacing (Columns 64-67) – *Required/Optional*

    Enter the total spacing between axles 2 and 3 as a right-justified, value, in units of feet.
21. Axle 3 to 4 Spacing (Columns 68-71) – *Required/Optional*

    Enter the total spacing between axles 3 and 4 as a right-justified, value, in units of feet.
22. Axle 4 to 5 Spacing (Columns 72-75) – Required/Optional

    Enter the total spacing between axles 4 and 5 as a right-justified, value, in units of feet.
23. Axle 5 to 6 Spacing (Columns 76-79) – *Required/Optional*

    Enter the total spacing between axles 5 and 6 as a right-justified, value, in units of feet.
24. Axle 6 to 7 Spacing (Columns 80-83) – *Required/Optional*

    Enter the total spacing between axles 6 and 7 as a right-justified, value, in units of feet.
25. Axle 7 to 8 Spacing (Columns 84-87) – *Required/Optional*

    Enter the total spacing between axles 7 and 8 as a right-justified, value, in units of feet.
26. Axle 8 to 9 Spacing (Columns 88-91) – *Required/Optional*

    Enter the total spacing between axles 8 and 9 as a right-justified, value, in units of feet.
27. Axle 9 to 10 Spacing (Columns 92-95) – *Required/Optional*

    Enter the total spacing between axles 9 and 10 as a right-justified, value, in units of feet.
28. Axle 10 to 11 Spacing (Columns 96-99) – *Required/Optional*

    Enter the total spacing between axles 10 and 11 as a right-justified, value, in units of feet.
29. Axle 11 to 12 Spacing (Columns 100-103) – *Required/Optional*
    Enter the total spacing between axles 11 and 12 as a right-justified, 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 155 columns.

Example C Variant records are shown in Table 4-30.

Table 4-30. Individual Vehicle Record (Classification Site) Example (Eastbound Lane 4) – Fixed-Width Format

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36-37	38-39	40-41	42	43-47	48-51	52-53	54-55
Content 01 Example:	I	17	JohnHeisman012318140	3	4	2012	11	07	18	58	33	48	C	Blank	0582	07	04
Content 02 Example:	I	17	JohnHeisman012318140	3	4	2012	11	07	18	59	57	75	C	Blank	0627	02	02
Content 03 Example:	I	17	JohnHeisman012318140	3	4	2012	11	07	19	00	13	58	C	Blank	0606	13	08

continued

Column Number:	56-59	60-63	64-67	68-71	72-75	76-79	80-83	84-87	88-91	92-95	96-99
Content 01 Example:	0584	0135	0251	0048	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 02 Example:	0102	0076	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 03 Example:	0845	0152	0043	0154	0045	0128	0147	0046	Blank	Blank	Blank

State highway agencies can submit the IVR (C variant) data using the pipe-delimited format. The key difference between the fixed-width format and the pipe-delimited format is that with the pipe-delimited file, data elements no longer need to match the starting and ending columns. Length of data elements can be equal or shorter than the specified lengths. The field order for the pipe-delimited format is identical to the order for the fixed-width format (see Table 4-29). In this format, the fields are separated by a pipe symbol (|) instead of beginning in specified columns. Example records in this format are provided below.

Delimited Format Examples

Classification Format – Detailed

RT|SFIPS|ID|DIR|LN|YR|MOY|DOM|HOD|MOH|SOM|SSOS|C|VS| SPD|CLS|NAX|TVL|ASP1|ASP2|ASP3|ASP4|ASP5|...|ASP10|ASP11|

4-Lane Roadway with 12 Individual Vehicles Recorded

I|32|AB456|1|1|2021|4|25|2|12|5|31|C||554|3|2|135|112
I|32|AB456|5|1|2021|4|25|2|12|5|37|C||762|2|2|113|98
I|32|AB456|1|2|2021|4|25|2|12|7|4|C||605|6|3|245|150|45
I|32|AB456|1|1|2021|4|25|2|12|8|23|C||600|4|2|354|230
I|32|AB456|5|1|2021|4|25|2|12|9|89|C||552|9|5|680|155|43|260|47
I|32|AB456|1|1|2021|4|25|2|12|12|15|C||571|9|5|695|140|43|200|46
I|32|AB456|5|1|2021|4|25|2|12|15|85|C||557|3|2|154|128
I|32|AB456|1|2|2021|4|25|2|12|15|92|C||721|5|2|215|178
I|32|AB456|5|1|2021|4|25|2|12|17|14|C||728|2|2|120|87
I|32|AB456|5|2|2021|4|25|2|12|17|90|C||654|2|2|123|93
I|32|AB456|1|2|2021|4|25|2|12|18|1|C||570|9|5|651|160|44|190|100
I|15|AB456|1|2|2021|4|25|2|12|19|34|C||611|3|2|135|112

4.7.4 Weight Data Format for Reporting Axle Weights (W)

This section only applies to those individual records designated with a W in Field 13, Column 42. Table 4-31 describes the data to be included.

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 54-55. 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.

A dummy vehicle signature of 'm' indicates that traffic data for this hour are missing. A dummy vehicle signature of 'd' indicates that traffic data for this hour are not missing, and thus if there are no traffic records for the hour, then there were no trucks during that hour. Without these indications, no traffic records for an hour might be interpreted to mean that the traffic system was not working.

The maximum record size permitted for "W" formatted records is 284 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) × 9) + 68

Where:

number of axles is the value found in columns 54-55 of that record. Based on this 'last column' calculation, some optional fields could become required if it is determined that more than 2 axles are on the given vehicle being reported in the record.

Table 4-31. Individual Vehicle Record by Weight (Axle) Device (W Variant) – Fixed Width Format

Field	Columns	Width	Description	Type	Importance
1	1	1	Record Type (RT)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-23	20	Station Identification (ID)	Alphanumeric	Required
4	24	1	Direction of Travel (DIR)	Integer	Required
5	25	1	Lane of Travel (LN)	Integer	Required
6	26-29	4	Year of Data (YR)	Integer	Required
7	30-31	2	Month of Year (MOY)	Integer	Required
8	32-33	2	Day of Month (DOM)	Integer	Required
9	34-35	2	Hour of Day (HOD)	Integer	Required
10	36-37	2	Minute of Hour (MOH)	Integer	Required
11	38-39	2	Second of Minute (SOM)	Integer	Required
12	40-41	2	Sub Second of Second (SSOS)	Integer	Required
13	42	1	W	Alphanumeric	Required
14	43-47	5	Vehicle Signature/Other Use (VS)	Integer	Optional
15	48-51	4	Vehicle Speed (SPD)	Integer	Required
16	52-53	2	Vehicle Classification (CLS)	Integer	Required
17	54-55	2	Number of Axles (NAX)	Integer	Required
18	56-59	4	Total Vehicle Length (bumper to bumper) (TVL)	Integer	Optional
19	60-62	3	Pavement Temperature (PT)	Integer	Optional
20	63-68	6	Gross Vehicle Weight (GVW)	Integer	Required

Field	Columns	Width	Description	Type	Importance
21	69-73	5	Axle Weight 1 (AW1)	Integer	Required
22	74-77	4	Axles 1-2 Spacing (ASP1)	Integer	Required
23	78-82	5	Axle Weight 2 (AW2)	Integer	Required
24	83-86	4	Axles 2-3 Spacing (ASP2)	Integer	Req./Opt.
25	87-91	5	Axle Weight 3 (AW3)	Integer	Req./Opt.
26	92-95	4	Axles 3-4 Spacing (ASP3)	Integer	Req./Opt.
27	96-100	5	Axle Weight 4 (AW4)	Integer	Req./Opt.
28	101-104	4	Axles 4-5 Spacing (ASP4)	Integer	Req./Opt.
29	105-109	5	Axle Weight 5 (AW5)	Integer	Req./Opt.
30	110-113	4	Axles 5-6 Spacing (ASP5)	Integer	Req./Opt.
31	114-118	5	Axle Weight 6 (AW6)	Integer	Req./Opt.
32	119-122	4	Axles 6-7 Spacing (ASP6)	Integer	Req./Opt.
33	123-127	5	Axle Weight 7 (AW7)	Integer	Req./Opt.
34	128-131	4	Axles 7-8 Spacing (ASP7)	Integer	Req./Opt.
35	132-136	5	Axle Weight 8 (AW8)	Integer	Req./Opt.
36	137-140	4	Axles 8-9 Spacing (ASP8)	Integer	Req./Opt.
37	141-145	5	Axle Weight 9 (AW9)	Integer	Req./Opt.
38	146-149	4	Axles 9-10 Spacing (ASP9)	Integer	Req./Opt.
39	150-154	5	Axle Weight 10 (AW10)	Integer	Req./Opt.
40	155-158	4	Axles 10-11 Spacing (ASP10)	Integer	Req./Opt.
41	159-163	5	Axle Weight 11 (AW11)	Integer	Req./Opt.
42	164-167	4	Axles 11-12 Spacing (ASP11)	Integer	Req./Opt.
43	168-172	5	Axle Weight 12 (AW12)	Integer	Req./Opt.
44, 46, 48, …	Use additional spacing in 4-digit increments up to 25 axles	4	Use additional spacing in 4-digit increments up to 25 axles	Integer	Req./Opt.
45, 47, 49, …	Use additional weights in 5-digit increments up to 25 axles	5	Use additional weights in 5-digit increments up to 25 axles	Integer	Req./Opt.

Note: R = Required, O = Optional, R/O = Required/Optional

Fields designated as Required *must be reported.*

Fields designated as Optional *are not required to be reported.*

Fields designated as Required/Optional *could be either required or optional based on values used for other related fields.*

The data to be provided in columns 1 – 59 are described earlier in Sections 4.7.1 and 4.7.2. The data to be included in columns 60 and later are defined as follows:

19. Pavement Temperature (Columns 60-62) – *Optional*
    Enter the pavement temperature rounded to the nearest integer Fahrenheit value. A negative sign may be placed in column 60 if appropriate. If the pavement temperature is unknown blank fill these digits.
20. Gross Vehicle Weight (Columns 63-68) – *Required*
    Enter the total vehicle weight (GVW) as a right-justified, decimal value, in units of pounds. For example, the axle weight measured as 90,250 pounds could be entered as "_ 90250" or as "090250" (where "_" represents a blank space.) This value should equal the sum of all of the individual axle weights.

21. Axle Weight 1 (Columns 69-73) – *Required*
    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.)
22. Axle 1 to 2 Spacing (Columns 74-77) – *Required*
    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 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).
23. Axle Weight 2 (Columns 78-82) – *Required*

    Enter the total axle 2 weight as a right-justified value, in units of pounds.
24. Axle 2 to 3 Spacing (Columns 83-86) – *Required/Optional*

    Enter the total spacing between axles 2 and 3 as a right-justified value, in units of tenths of feet.
25. Axle Weight 3 (Columns 87-91) – *Required/Optional*

    Enter the total axle 3 weight as a right-justified, decimal value, in units of pounds.
26. Axle 3 to 4 Spacing (Columns 92-95) – *Required/Optional*

    Enter the total spacing between axles 3 and 4 as a right-justified value, in units of tenths of feet.
27. Axle Weight 4 (Columns 96-100) – *Required/Optional*

    Enter the total axle 4 weight as a right-justified, value, in units of pounds.
28. Axle 4 to 5 Spacing (Columns 101-104) – *Required/Optional*

    Enter the total spacing between axles 4 and 5 as a right-justified value, in units of tenths of feet.
29. Axle Weight 5 (Columns 105-109) – *Required/Optional*

    Enter the total axle 5 weight as a right-justified value, in units of pounds.
30. Axle 5 to 6 Spacing (Columns 110-113) – *Required/Optional*

    Enter the total spacing between axles 5 and 6 as a right-justified value, in units of tenths of feet.
31. Axle Weight 6 (Columns 114-118) – *Required/Optional*

    Enter the total axle 6 weight as a right-justified value, in units of pounds.
32. Axle 6 to 7 Spacing (Columns 119-122) – *Required/Optional*

    Enter the total spacing between axles 6 and 7 as a right-justified value, in units of tenths of feet.
33. Axle Weight 7 (Columns 123-127) – *Required/Optional*

    Enter the total axle 7 weight as a right-justified value, in units of pounds.
34. Axle 7 to 8 Spacing (Columns 128-131) – *Required/Optional*

    Enter the total spacing between axles 7 and 8 as a right-justified value, in units of tenths of feet.
35. Axle Weight 8 (Columns 132-136) – *Required/Optional*

    Enter the total axle 8 weight as a right-justified value, in units of pounds.
36. Axle 8 to 9 Spacing (Columns 137-140) – *Required/Optional*

    Enter the total spacing between axles 8 and 9 as a right-justified value, in units of tenths of feet.

37. Axle Weight 9 (Columns 141-145) – *Required/Optional*

    Enter the total axle 9 weight as a right-justified value, in units of pounds.

38. Axle 9 to 10 Spacing (Columns 146-149) – *Required/Optional*

    Enter the total spacing between axles 9 and 10 as a right-justified value, in units of tenths of feet.

39. Axle Weight 10 (Columns 150-154) – *Required/Optional*

    Enter the total axle 10 weight as a right-justified value, in units of pounds.

40. Axle 10 to 11 Spacing (Columns 155-158) – *Required/Optional*

    Enter the total spacing between axles 10 and 11 as a right-justified value, in units of tenths of feet.

41. Axle Weight 11 (Columns 159-163) – *Required/Optional*

    Enter the total axle 11 weight as a right-justified value, in units of pounds.

42. Axle 11 to 12 Spacing (Columns 164-167) – *Required/Optional*

    Enter the total spacing between axles 11 and 12 as a right-justified value, in units of tenths of feet.

43. Axle Weight 12 (Columns 168-172) – *Required/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 284 columns.

Example W Variant records are shown in Table 4-32.

Table 4-32. Individual Vehicle Record (Weight Site) Example (Westbound Lane 3) – Fixed-Width Format

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36-37	38-39	40-41	42	43-47	48-51
Content 01 Example:	I	17	JohnHeisman012318140	7	3	2012	11	07	05	12	34	72	W	Blank	0551
Content 02 Example:	I	17	JohnHeisman012318140	7	3	2012	11	07	05	12	38	21	W	Blank	0572
Content 03 Example:	I	17	JohnHeisman012318140	7	3	2012	11	07	95	12	43	78	W	Blank	0560

continued

Column Number:	52-53	54-55	56-59	60-62	63-68	69-73	74-77	78-82	83-86	87-91	92-95	96-100	101-104	105-109
Content 01 Example:	03	02	0174	065	008660	03215	0142	05445	Blank	Blank	Blank	Blank	Blank	Blank
Content 02 Example:	05	02	0211	064	012143	05620	0187	06523	Blank	Blank	Blank	Blank	Blank	Blank
Content 03 Example:	09	05	0753	064	076978	12518	0152	15790	0043	16250	0285	16535	0085	15885

continued

Column Number:	110-113	114-118	119-122	123-127	128-131	132-136	137-140	141-145	146-149	150-154	155-158	159-163	164-167	168-172
Content 01 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 02 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 03 Example:	Blank	Blank	Blank	blank	Blank	Blank	Blank	Blank	Blank	Blank	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

State highway agencies can submit the IVR (W variant) data using the pipe-delimited format. The key difference between the fixed-width format and the pipe-delimited format is that with the pipe-delimited file, data elements no longer need to match the starting and ending columns. Length of data elements can be equal or shorter than the specified lengths. The field order for the pipe-delimited format is identical to the order for the fixed-width format (see Table 4-31). In this format, the fields are separated by a pipe symbol (|) instead of beginning in specified columns. Example records in this format are provided below.

Delimited Format Examples

Weight (Axle) Format – Detailed

RT|SFIPS|ID|DIR|LN|YR|MOY|DOM|HOD|MOH|SOM|SSOS|W|VS|SPD|CLS|NAX|TVL|PT|GVW|AW1|ASP1|AW2|ASP2|AW3|ASP3|AW4|ASP4|…|AW11|ASP11|AW12|ASP12|…

4-Lane Roadway with 15 Individual Vehicles Recorded

I|12|135750|1|1|2021|4|25|2|12|5|31|W|65310|554|9|5|694|70|61837|10500|145|12000|43|12500|310|13450|46|13387
I|12|135760|5|1|2021|4|25|2|12|5|37|W|52810|762|5|2|275|69|14874|8462|185|6412
I|12|135760|5|2|2021|4|25|2|12|5|68|W|12120|648|1|2|75|69|232|88|53|144
I|12|135760|1|2|2021|4|25|2|12|7|4|W|43460|605|4|3|452|70|25886|9750|246|7680|43|8456
I|12|135760|1|1|2021|4|25|2|12|8|23|W|65227|600|9|5|585|70|54828|9873|173|11678|43|10985|300|11245|40|11047
I|12|135760|5|2|2021|4|25|2|12|8|68|W|22290|648|2|2|162|69|2438|1890|97|548
I|12|135760|5|1|2021|4|25|2|12|9|89|W|64220|552|8|4|429|69|40561|9504|130|11546|175|9728|41|9783
I|12|135760|1|1|2021|4|25|2|12|12|15|W|65949|571|9|5|560|70|70044|11620|165|12895|43|12530|230|16750|82|16249
I|12|135760|5|2|2021|4|25|2|12|8|68|W|22219|648|2|2|145|68|4096|3348|88|748
I|12|135760|5|1|2021|4|25|2|12|15|85|W|66227|557|10|6|708|69|79973|11463|152|10486|48|10866|48|10562|355|15995|42|16541
I|12|135760|1|2|2021|4|25|2|12|15|92|W|65950|721|9|5|546|70|72741|11231|175|14780|40|15345|235|15245|39|16140
I|12|135760|1|1|2021|4|25|2|12|17|14|W|32340|728|3|2|213|69|3243|1710|132|1533
I|12|135760|5|2|2021|4|25|2|12|17|90|W|32321|654|3|3|360|68|13114|2590|128|2824|167|7700
I|12|135760|5|1|2021|4|25|2|12|20|54|W|22210|728|2|2|125|69|1884|1088|87|796
I|12|135760|5|2|2021|4|25|2|12|27|92|W|42420|654|4|2|400|68|22580|14600|241|7980

4.7.5 Vehicle Classification and Wheel Weights (Z)

This section only applies to those individual records designated with a Z in Field 13, column 42. The data to be included are described in Table 4-33.

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. These data are available when independent weight sensors are placed in the two wheel paths, which 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 54-55 as described in Section 4.7.2. This value is used by the TMAS software to determine how many remaining columns to expect 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 418 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) + 68

Where:

number of axles is the value found in columns 54-55 of the record.

Table 4-33. Individual Vehicle Record Collected by Weight (Left and Right) Device (Z Variant) – Fixed-Width Format

Field	Columns	Width	Description	Type	Importance
1	1	1	Record Type (RT)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-23	20	Station Identification (ID)	Alphanumeric	Required
4	24	1	Direction of Travel (DIR)	Integer	Required
5	25	1	Lane of Travel (LN)	Integer	Required
6	26-29	4	Year of Data (YR)	Integer	Required
7	30-31	2	Month of Year (MOY)	Integer	Required
8	32-33	2	Day of Month (DOM)	Integer	Required
9	34-35	2	Hour of Day (HOD)	Integer	Required
10	36-37	2	Minute of Hour (MOH)	Integer	Required
11	38-39	2	Second of Minute (SOM)	Integer	Required
12	40-41	2	Sub Second of Second (SSOS)	Integer	Required
13	42	1	Z	Alphanumeric	Required
14	43-47	5	Vehicle Signature/Other Use (VS)	Integer	Optional
15	48-51	4	Vehicle Speed (SPD)	Integer	Required
16	52-53	2	Vehicle Classification (CLS)	Integer	Required
17	54-55	2	Number of Axles (NAX)	Integer	Required
18	56-59	4	Total Vehicle Length (bumper to bumper) (TVL)	Integer	Optional
19	60-62	3	Pavement Temperature (PT)	Integer	Optional
20	63-68	6	Gross Vehicle Weight (GVW)	Integer	Required

Field	Columns	Width	Description	Type	Importance
21	69-73	5	Weight 1 Left Wheel Path (LW1)	Integer	Required
22	74-78	5	Weight 1 Right Wheel Path (RW1)	Integer	Required
23	79-82	4	Axles 1-2 Spacing (ASP1)	Integer	Required
24	83-87	5	Weight 2 Left Wheel Path (LW2)	Integer	Required
25	88-92	5	Weight 2 Right Wheel Path (RW2)	Integer	Required
26	93-96	4	Axles 2-3 Spacing (ASP2)	Integer	Req./Opt.
27	97-101	5	Weight 3 Left Wheel Path (LW3)	Integer	Req./Opt.
28	102-106	5	Weight 3 Right Wheel Path (RW3)	Integer	Req./Opt.
29	107-110	4	Axles 3-4 Spacing (ASP3)	Integer	Req./Opt.
30	111-115	5	Weight 4 Left Wheel Path (LW4)	Integer	Req./Opt.
31	116-120	5	Weight 4 Right Wheel Path (RW4)	Integer	Req./Opt.
32	121-124	4	Axles 4-5 Spacing (ASP4)	Integer	Req./Opt.
33	125-129	5	Weight 5 Left Wheel Path (LW5)	Integer	Req./Opt.
34	130-134	5	Weight 5 Right Wheel Path (RW5)	Integer	Req./Opt.
35	135-138	4	Axles 5-6 Spacing (ASP5)	Integer	Req./Opt.
36	139-143	5	Weight 6 Left Wheel Path (LW6)	Integer	Req./Opt.
37	144-148	5	Weight 6 Right Wheel Path (RW6)	Integer	Req./Opt.
38	149-152	4	Axles 6-7 Spacing (ASP6)	Integer	Req./Opt.
39	153-157	5	Weight 7 Left Wheel Path (LW7)	Integer	Req./Opt.
40	158-162	5	Weight 7 Right Wheel Path (RW7)	Integer	Req./Opt.
41	163-166	4	Axles 7-8 Spacing (ASP7)	Integer	Req./Opt.
42	167-171	5	Weight 8 Left Wheel Path (LW8)	Integer	Req./Opt.
43	172-176	5	Weight 8 Right Wheel Path (RW8)	Integer	Req./Opt.
44	177-180	4	Axles 8-9 Spacing (ASP8)	Integer	Req./Opt.
45	181-185	5	Weight 9 Left Wheel Path (LW9)	Integer	Req./Opt.
46	186-190	5	Weight 9 Right Wheel Path (RW9)	Integer	Req./Opt.
47	191-194	4	Axles 9-10 Spacing (ASP9)	Integer	Req./Opt.
48	195-199	5	Weight 10 Left Wheel Path (LW10)	Integer	Req./Opt.
49	200-204	5	Weight 10 Right Wheel Path (RW10)	Integer	Req./Opt.
50	205-208	4	Axles 10-11 Spacing (ASP10)	Integer	Req./Opt.
51	209-213	5	Weight 11 Left Wheel Path (LW11)	Integer	Req./Opt.
52	214-218	5	Weight 11 Right Wheel Path (RW11)	Integer	Req./Opt.
53	219-222	4	Axles 11-12 Spacing (ASP11)	Integer	Req./Opt.
54	223-227	5	Weight 12 Left Wheel Path (LW12)	Integer	Req./Opt.
55	228-232	5	Weight 12 Right Wheel Path (RW12)	Integer	Req./Opt.
56+	Use 4 columns for each axle up to 25 axles (include 10 columns of weight prior to the next axle distance)	4	Axle spacing	Integer	Req./Opt.
57+	Use 5 columns for each additional axle for the left wheel path weight, up to 25 axles	5	Weight Left Wheel Path	Integer	Req./Opt.

Field	Columns	Width	Description	Type	Importance
58+	Use 5 columns for each additional axle for the right wheel path weight, up to 25 axles	5	Weight Right Wheel Path	Integer	Req./Opt.

Note: R=Required, O=Optional, R/O=Required/Optional,

Fields designated as Required *must be reported.*

Fields designated as Optional *are not required to be reported.*

Fields designated as Required/Optional *could be either required or optional based on values used for other related fields.*

The definitions of the data to be contained in columns 1 – 59 for the "Z" format are described in Sections 4.7.1 and 4.7.2. The data to be included in columns 60 and later are defined as follows:

19. Pavement Temperature (Columns 60-62) – *Optional*

    Enter the pavement temperature rounded to the nearest integer Fahrenheit value. A negative sign may be placed in Column 60 if required. If the pavement temperature is unknown blank fill these digits.

20. Gross Vehicle Weight (Columns 63-68) – *Required*

    Enter the total vehicle weight (GVW) as a right-justified, decimal value, in units of pounds. For example, the axle weight measured as 90,210 pounds could be entered as "_ 90210" or as "090210" (where "_" represents a blank space.) This value should equal the sum of all of the individual axle weights.

21. Weight 1 Left Wheel Path (Columns 69-73) – *Required*

    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". If no left weight measured leave the field empty.

22. Weight 1 Right Wheel Path (Columns 74-78) – *Required*

    Enter the right axle 1 weight as a right-justified value, in units of pounds. If no right weight measured leave the field empty

23. Axle 1 to 2 Spacing (Columns 79-82) – *Required*

    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 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."

24. Weight 2 Left Wheel Path (Columns 83-87) – *Required*

    Enter the left axle 2 weight as a right-justified value, in units of pounds.

25. Weight 2 Right Wheel Path (Columns 88-92) – *Required*

    Enter the right axle 2 weight as a right-justified value, in units of pounds.

26. Axle 2 to 3 Spacing (Columns 93-96) – *Required/Optional*

    Enter the total spacing between axles 2 and 3 as a right-justified value, in units of tenths of feet.

27. Weight 3 Left Wheel Path (Columns 97-101) – *Required/Optional*

    Enter the left axle 3 weight as a right-justified value, in units of pounds.

28. Weight 3 Right Wheel Path (Columns 102-106) – *Required/Optional*

    Enter the right axle 3 weight as a right-justified, decimal value, in units of pounds.

29. Axle 3 to 4 Spacing (Columns 107-110) – *Required/Optional*

    Enter the total spacing between axles 3 and 4 as a right-justified value, in units of tenths of feet.

30. Weight 4 Left Wheel Path (Columns 111-115) – *Required/Optional*

    Enter the left axle 4 weight as a right-justified value, in units of pounds.

31. Weight 4 Right Wheel Path (Columns 116-120) – *Required/Optional*

    Enter the right axle 4 weight as a right-justified value, in units of pounds.

32. Axle 4 to 5 Spacing (Columns 121-124) – *Required/Optional*

    Enter the total spacing between axles 4 and 5 as a right-justified value, in units of tenths of feet.

33. Weight 5 Left Wheel Path (Columns 125-129) – *Required/Optional*

    Enter the left axle 5 weight as a right-justified value, in units of pounds.

34. Weight 5 Right Wheel Path (Columns 130-134) – *Required/Optional*

    Enter the right axle 5 weight as a right-justified value, in units of pounds.

35. Axle 5 to 6 Spacing (Columns 135-138) – *Required/Optional*

    Enter the total spacing between axles 5 and 6 as a right-justified value, in units of tenths of feet.

36. Weight 6 Left Wheel Path (Columns 139-143) – *Required/Optional*

    Enter the left axle 6 weight as a right-justified value, in units of pounds.

37. Weight 6 Right Wheel Path (Columns 144-148) – *Required/Optional*

    Enter the right axle 6 weight as a right-justified value, in units of pounds.

38. Axle 6 to 7 Spacing (Columns 149-152) – *Required/Optional*

    Enter the total spacing between axles 6 and 7 as a right-justified value, in units of tenths of feet.

39. Weight 7 Left Wheel Path (Columns 153-157) – *Required/Optional*

    Enter the left axle 7 weight as a right-justified value, in units of pounds.

40. Weight 7 Right Wheel Path (Columns 158-162) – *Required/Optional*

    Enter the right axle 7 weight as a right-justified value, in units of pounds.

41. Axle 7 to 8 Spacing (Columns 163-166) – *Required/Optional*

    Enter the total spacing between axles 7 and 8 as a right-justified value, in units of tenths of feet.

42. Weight 8 Left Wheel Path (Columns 167-171) – *Required/Optional*

    Enter the left axle 8 weight as a right-justified value, in units of pounds.

43. Weight 8 Right Wheel Path (Columns 172-176) – *Required/Optional*

    Enter the right axle 8 weight as a right-justified value, in units of pounds.

44. Axle 8 to 9 Spacing (Columns 177-180) – *Required/Optional*

    Enter the total spacing between axles 8 and 9 as a right-justified value, in units of tenths of feet.

45. Weight 9 Left Wheel Path (Columns 181-185) – *Required/Optional*

    Enter the left axle 9 weight as a right-justified value, in units of pounds.

46. Weight 9 Right Wheel Path (Columns 186-190) – *Required/Optional*

    Enter the right axle 9 weight as a right-justified value, in units of pounds.

47. Axle 9 to 10 Spacing (Columns 191-194) – *Required/Optional*

    Enter the total spacing between axles 9 and 10 as a right-justified value, in units of tenths of feet.

48. Weight 10 Left Wheel Path (Columns 195-199) – *Required/Optional*

    Enter the left axle 10 weight as a right-justified value, in units of pounds.

49. Weight 10 Right Wheel Path (Columns 200-204) – *Required/Optional*

    Enter the right axle 10 weight as a right-justified value, in units of pounds.

50. Axle 10 to 11 Spacing (Columns 205-208) – *Required/Optional*

    Enter the total spacing between axle 10 and 11 as a right-justified value, in units of tenths of feet.

51. Weight 11 Left Wheel Path (Columns 209-213) – *Required/Optional*

    Enter the left axle 11 weight as a right-justified value, in units of pounds.

52. Weight 11 Right Wheel Path (Columns 214-218) – *Required/Optional*

    Enter the right axle 11 weight as a right-justified value, in units of pounds.

53. Axle 11 to 12 Spacing (Columns 219-222) – *Required/Optional*

    Enter the total spacing between axle 11 and 12 as a right-justified value, in units of tenths of feet.

54. Weight 12 Left Wheel Path (Columns 223-227) – *Required/Optional*

    Enter the total axle 12 weight as a right-justified value, in units of pounds.

55. Weight 12 Right Wheel Path (Columns 228-232) – *Required/Optional*
    Enter the total axle 12 weight as a right-justified value, in units of pounds.

    For each additional axle beyond the twelfth axle, an additional fourteen columns should be entered. The first four of these columns contain the axle spacing from the previous 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 418 columns.

Example Z Variant records are shown in Table 4-34.

Table 4-34. Individual Vehicle Record (Left and Right Site) Example (Westbound Lane 1) – Fixed-Width Format

Column Number:	1	2-3	4-23	24	25	26-29	30-31	32-33	34-35	36-37	38-39	40-41	42	43-47	48-51	52-53
Content 01 Example:	Z	17	RobertPlantLane18119	7	1	2021	11	09	07	10	34	74	Z	Blank	0561	01
Content 02 Example:	Z	17	RobertPlantLane18119	7	1	2021	11	09	07	10	38	38	Z	Blank	0605	02
Content 03 Example:	Z	17	RobertPlantLane18119	7	1	2021	11	09	07	10	58	81	Z	Blank	0593	07
Content 04 Example:	Z	17	RobertPlantLane18119	7	1	2021	11	09	07	10	80	45	Z	Blank	0585	10
Content 05 Example:	Z	17	RobertPlantLane18119	7	1	2021	11	09	07	20	25	13	Z	Blank	0601	09

continued

Column Number:	54-55	56-59	60-62	63-68	69-73	74-78	79-82	83-87	88-92	93-96	97-101	102-106	107-110	111-115	116-120
Content 01 Example:	02	0074	071	000265	00075	00065	0051	00065	00060	Blank	Blank	Blank	Blank	Blank	Blank
Content 02 Example:	02	0174	071	003130	00780	00770	0078	00800	00780	Blank	Blank	Blank	Blank	Blank	Blank
Content 03 Example:	04	0174	070	041061	07335	06742	0128	03478	03765	0038	05200	04797	0045	04935	04809
Content 04 Example:	08	0778	071	085300	06025	06055	0161	05705	05885	0042	05870	05940	0042	05778	05822
Content 05 Example:	05	0652	070	077940	05410	05397	0158	08301	08304	0043	08305	08338	0257	08475	08473

continued

Column Number:	121-124	125-129	130-134	135-138	139-143	144-148	149-152	153-157	158-162	163-166	167-171	172-176	177-180	181-185	186-190
Content 01 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 02 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 03 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 04 Example:	0284	04719	04781	0043	04714	04735	0043	04820	04832	0043	04804	04815	Blank	Blank	Blank
Content 05 Example:	0044	08461	08476	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank

continued

Column Number:	191-194	195-199	200-204	205-208	209-213	214-218	219-222	223-227	228-232
Content 01 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 02 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 03 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 04 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
Content 05 Example:	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank

Use 14 columns for each additional axle spacing up to 25 axles (include 5 columns of left weight and 5 for the right axle weight prior to the next axle distance)

State highway agencies can submit the IVR (Z variant) data using the pipe-delimited format. The key difference between the fixed-width format and the pipe-delimited format is that with the pipe-delimited file, data elements no longer need to match the starting and ending columns. Length of data elements can be equal or shorter than the specified lengths. The field order for the pipe-delimited format is identical to the order for the fixed-width format (see Table 4-33). In this format, the fields are separated by a pipe symbol (|) instead of beginning in specified columns. Example records in this format are provided below.

Delimited Format Examples

Weight (Left and Right) Format – Detailed

RT|SFIPS|ID|DIR|LN|YR|MOY|DOM|HOD|MOH|SOM|SSOS|Z|VS|SPD|CLS|NAX|TVL|PT|GVW|LW1|RW1|ASP1|LW2|RW2|ASP2|LW3|RW3|…|ASP12|LW12|RW12|…

2-Lane Roadway with 15 Individual Vehicles Recorded

I|12|135750|1|1|2021|4|25|2|12|5|31|Z|65310|554|9|5|694|70|61837|5200|5300|145|5995|6005|43|5830|6670|310|6720|6730|46|6695|6694
I|12|135760|5|1|2021|4|25|2|12|5|37|Z|52810|762|5|2|275|69|14874|4101|4361|185|3052|3360
I|12|135760|5|2|2021|4|25|2|12|5|68|Z|12120|648|1|2|75|69|232||88|53||144
I|12|135760|1|2|2021|4|25|2|12|7|4|Z|43460|605|4|3|452|70|25886|4405|5345|246|3604|4076|43|4046|4410
I|12|135760|1|1|2021|4|25|2|12|8|23|Z|65227|600|9|5|585|70|54828|4507|5366|173|5521|6157|43|5274|5711|300|5505|5740|40|5294|5753
I|12|135760|5|2|2021|4|25|2|12|8|68|Z|22290|648|2|2|162|69|2438|852|1038|97|261|287|
I|12|135760|5|1|2021|4|25|2|12|9|89|Z|64220|552|8|4|429|69|40561|4503|5001|130|5438|6108|175|4508|5220|41|4597|5186
I|12|135760|1|1|2021|4|25|2|12|12|15|Z|65949|571|9|5|560|70|70044|5605|6015|165|5947|6948|43|6032|6498|230|8001|8749|82|7943|8306
I|12|135760|5|2|2021|4|25|2|12|8|68|Z|22219|648|2|2|145|68|3096|1140|1208|88|344|404|
I|12|135760|5|1|2021|4|25|2|12|15|85|Z|66227|557|10|6|708|69|75963|5353|6110|152|5006|5480|48|5216|5650|48|5100|5462|355|7899|8146|42|8105|8436
I|12|135760|1|2|2021|4|25|2|12|15|92|Z|65950|721|9|5|546|70|72741|5600|5631|175|7357|7423|40|7651|7694|235|7605|7640|39|8023|8117
I|12|135760|1|1|2021|4|25|2|12|17|14|Z|32340|728|3|2|213|69|3243|845|865|132|740|793
I|12|135760|5|2|2021|4|25|2|12|17|90|Z|32321|654|3|3|360|68|14114|1250|1340|128|1874|1950|167|3781|3919
I|12|135760|5|1|2021|4|25|2|12|20|54|Z|22210|728|2|2|125|69|1884|531|557|87|391|405
I|12|135760|5|2|2021|4|25|2|12|27|92|Z|42420|654|4|2|400|68|22580|7320|7280|241|3952|4028

4.8 MICROMOBILITY STATION RECORD DATA FORMAT (FIXED WIDTH OR PIPE DELIMITED)

Collecting and reporting Micromobility travel is growing in importance due to an increased number of users selecting more active modes of transportation (e.g., walking, biking, scootering, and other battery-powered devices). It is important to track the changes in walking, biking, and scootering that may result from changes in public attitudes, land use, new policy implementation, and the construction of new facilities.

Two types of records are needed for submitting Micromobility data to FHWA's TMAS system.

- Micromobility Station Record – Section 4.8
- Micromobility Count Record – Section 4.9

A Micromobility Station Record is needed for reporting all Micromobility data to FHWA. The Station Record provides data and information related to the location of the monitored site and other relevant data that can be used in conjunction with the Count Record for specific data analyses. If a Micromobility Station Record is omitted, any succeeding records containing Micromobility data will not be able to be processed by TMAS.

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 ensure the records are current and accurately reflect what is in the field.

A Station Record file is a text file often designated by the .txt file extension. Before uploading the file to TMAS, it is recommended to use .SMM as the file extension where SMM stands for Station Micromobility.

Below is an example Station Record file naming convention:

StationABC123.SMM

General Guidance

The Station Record consists of the data fields listed in Table 4-35. These data fields can be organized either by Pipe (|) Delimited format or Fixed Width Column format. The Pipe (|) Delimited format is recommended due to its flexibility and easy-to-use nature.

It is highly recommended to use the Pipe (|) delimited format.
With this format, there is no need to keep track of entry column locations.

Regardless of the format that is used, the length of each data field cannot exceed the specified field length (column width). Information exceeding the allowed field length (column width) in the Pipe-Delimited file will be truncated, while information less than the allowed width will be accepted as provided.

When using the Fixed Width Column format, any misalignment of the data field will lead to errors and the rejection or misinterpretation of the data.

Table 4-35. Summary of the Micromobility Station Record Data Fields

Field	Columns	Width	Description	Type	Importance
1	1	1	Micromobility Station Record Indicator (MSRI)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-6	3	County FIPS (CFIPS)	Integer	Required
4	7-16	10	Reporting Agency Indicator (RAI)	Alphanumeric	Required
5	17-76	60	Station ID (SID)	Alphanumeric	Required
6	77-87	11	Latitude (LAT)	Real	Required

Field	Columns	Width	Description	Type	Importance
7	88-98	11	Longitude (LONG)	Real	Required
8	99-100	2	Function Class and Area Type (FCAT)	Alphanumeric	Optional
9	101	1	Type of Sensor (TS)	Alphanumeric	Optional
10	102	1	Primary Count Purpose (PCP)	Alphanumeric	Optional
11	103-106	4	Year Station Established (YEARE)	Integer	Optional
12	107-110	4	Year Station Discontinued (YEARD)	Integer	Optional
13	111-112	2	Posted Route Sign (PRS)	Alphanumeric	Optional
14	113-120	8	Posted Route Sign Number (PRSN)	Alphanumeric	Optional
15	121-220	100	Other Notes (ON)	Alphanumeric	Optional

Specific Data Fields Explanation

A Station Record offers information characterizing where the traveling bicyclists and/or pedestrians are as well as other relevant information described in the data items. These variables help to efficiently analyze the data.

1. Micromobility Station Record Indicator (MSRI) (Width 1) – *Required*
   - The letter "L" is always coded to indicate that file is a Micromobility (bicycle and/or pedestrian) Station Record. This field is not case sensitive.
2. State FIPS (SFPIS) (Width 2) – *Required*
   - Refer to state_county_city_FIPS_codes to obtain the State's FIPS code. The State FIPS code indicates in which State the station is located.
3. County FIPS (CFIPS) (Width 3) – *Required*
   - The County FIPS code ranges from 1 to 3 digits.
   - County FIPS codes for all U.S. counties are maintained by the U.S. Census Bureau and can be found online at state_county_city_FIPS_codes.
4. Reporting Agency Indicator (RAI) (Width 10) – *Required*
   - The Reporting Agency Indicator field has a maximum of 10 alphanumeric characters (containing only letters and/or numbers) and identifies the agency reporting the data to TMAS.
   - If a State transportation department (e.g., FL DOT) or a contracting entity (e.g., ABC Company) acting on behalf of a State transportation department submits the record, the field should be coded with the letter "S".
   - If a Metropolitan Planning Organization (MPO), a Council of Government (COG), or a contracting entity (e.g., ABC Company) acting on behalf of the MPO or COG submits the data, the field should be coded with the abbreviation of the MPO or COG.
     Example 1: The Baltimore Regional Transportation Board (BRTB), would enter BRTB as their abbreviation code.
     Example 2: The Susquehanna Economic Development Association Council of Governments (SEDA-COG), would enter SEDA as their abbreviation code.
   - If a county/city (or equivalent) reports the Station Record information, the field should be coded with the county's or city's FIPS code. This can be found online at state_county_city_FIPS_codes.
   - Other entities submitting data but not covered in the above categories should use their entity abbreviation.
     Example 3: The University of North Carolina (UNC) Highway Safety Research Center (HSRC) could enter either UNC_HSRC or HSRC_UNC as their abbreviation code.

5. Station ID (SID) (Width 60) – *Required*

    - The Station ID field has a maximum of 60 characters and is created by the reporting agency. It represents a unique identifier for a counting location and counting technology arrangement. A counting technology arrangement refers to the types of sensors or technologies used. A counting arrangement may encompass different sensors or technologies in order to capture different travelers.

      For example, a site has both infrared and loop sensors to count pedestrians and bicycles. If the final data to be submitted to TMAS combines pedestrian and bicycle data into a single file, this multi-sensor or technology arrangement at this site should have one station ID. However, if the data submitted to TMAS are two files with one for pedestrian and the other one for bicycle, then the site will have two unique Station IDs.

      The goal is to enable agencies to use their native Station IDs for TMAS reporting. When combined with data field #4 (Reporting Agency Indicator), the entered values will create a unique record within a State regardless of how many entities submit data to TMAS.

      Example 1: If a counting site has two different counting devices monitoring different travelers and generating different count datasets to report, then that would constitute two stations. Therefore, two station records with different Station IDs should be created.
    - The Station ID must be alphanumeric (containing only letters and/or numbers). No other symbols such as a star *, exclamation mark !, dash -, hashtag #, parenthesis (), ampersand & or dots… can be used.

6. Latitude (LAT) (Width 11) – *Required*

    - Latitude refers to the geolocation of the Micromobility counting site in decimal degree format.
    - The latitude needs to be reported to 6 decimal places.
    - The latitude field has a total of 11 allocated digits (columns) in length.
    - If the latitude coordinate is less than 11 columns in length and a fixed-width column format is used, the entry should be right justified, and blank spaces entered in the most left columns to ensure the 11-column length.
    - A site's latitude is based on the World Geodetic System 1984 (WGS84) defined and maintained by the U.S. National Geospatial Intelligence Agency. All U.S. satellite-based survey, navigation, and mapping systems are based on the WGS84.
    - All U.S. locations except American Samoa are in the northern hemisphere with a positive latitude as XX.XXXXXX degree. For example, the U.S. Capital Visitor Center has a latitude of 38.889601 degrees. The latitude entry for this site should be coded as 38.889601. American Samoa has a latitude of -14.271012 degrees. Its latitude entry should be coded as -14.271012.

7. Longitude (LONG) (Width 11) – *Required*

    - Longitude refers to the geolocation of the Micromobility counting site in decimal degree format.
    - The longitude needs to be reported to 6 decimal places.
    - The longitude field has a total of 11 allocated digits (columns) in length.
    - If the longitude coordinate is less than 11 columns in length and a fixed-width column format is used, the entry should be right justified, and blank spaces entered in the most left columns to ensure the 11-column length.
    - A site's longitude is based on the World Geodetic System 1984 (WGS84) defined and maintained by the U.S. National Geospatial Intelligence Agency. All U.S. satellite-based survey, navigation, and mapping systems are based on the WGS84.
    - All U.S. locations except Guam and the Northern Mariana Islands are in the western hemisphere with a negative longitude as -XXX.XXXXXX degrees. For example, the Golden Gate Bridge in San Francisco has a longitude of –122.478611 degrees. The longitude entry for this site should be coded as -122.478611. The U.S. Capital Visitor Center has a longitude of -77.009056 degrees. Its longitude entry should be coded as -77.009056.

8. Function Class and Area Type (FCAT) (Width 2) – *Optional*

   - This two-digit field identifies the Function Class (FC) and Area Type of a trail or roadway that the bicycle lane(s) and/or sidewalks are part of (Table 4-36). The first digit represents the FC and the second digit signifies the area type.
   - Bicycle lanes and sidewalks can be and are often part of public streets/roadways where motorized, non-motorized, and micro-powered e-device travel occurs.
   - When the bicycle travel lanes and/or sidewalks are part of a roadway, use one of the 7 FHWA Roadway Function Classes to code the road's class.
   - When bicycle travel lane(s) or other non-motorized travel lanes are not part of the roadway or public street (independent alignment), the bicycle lane(s) are referred to as trails or shared-use paths and code 8 should be used.
   - For scenarios that are not covered by codes 1 through 8, use code 9.
   - Area Type can be either urban or rural. The letter "U" is the code for an urban area and the letter "R" is the code for a rural area.

Table 4-36. Function Class and Area Type Codes

Code	Description
1U	Urban-Interstate
2U	Urban-Principal Arterial – Other Freeways and Expressways
3U	Urban-Principal Arterial – Other
4U	Urban-Minor Arterial
5U	Urban-Major Collector
6U	Urban-Minor Collector
7U	Urban-Local
8U	Urban-Trail or Shared-Use Path (walking, running and bicycling on an independent alignment)
9U	Urban-Other Facility Type
1R	Rural-Interstate
2R	Rural-Principal Arterial – Other Freeways and Expressways
3R	Rural-Principal Arterial – Other
4R	Rural-Minor Arterial
5R	Rural-Major Collector
6R	Rural-Minor Collector
7R	Rural-Local
8R	Rural-Trail or Shared-Use Path (walking, running and bicycling on an independent alignment)
9R	Rural-Other Facility Type

9. Type of Sensor (TS) (Width 1) – *Optional*

   - This field indicates the specific sensor technology used to conduct the count. Use one of the codes in Table 4-37.

Table 4-37. Type of Sensor Codes

Code	Description
1	Video Image with Manual Reduction at a later time
2	Active Infrared (emits an infrared beam to a receiver)
3	Pressure sensor/mat
H	Human Observation
I	Passive Infrared (captures radiation emitted by surrounding objects. e.g., infrared camera)
K	Laser/Lidar
L	Inductive Loop
M	Magnetometer
P	Piezoelectric
Q	Quartz Piezoelectric
R	Air Tubes
S	Sonic/Acoustic
T	Tape Switch
U	Ultrasonic
V	Video Image with Automated or Semi-automated Reduction
W	Microwave Radar
X	Radio Wave Radar
Z	Other Type Not Listed
9	Multi sensors (e.g., a location has both infrared and loop sensors to count ped and bicycle separately but report the ped and bicycle data in a single count data file.)

10. Primary Count Purpose (PCP) (Width 1) – *Optional*
    - The field indicates the primary purpose of the data collection. If the data serves multiple purposes, select the purpose considered the most important or the greatest impetus for establishing the data collection location (Table 4-38).

Table 4-38. Primary Count Purpose Codes

Code	Description
E	Enforcement
L	Facility design
O	Operations and facility management
P	Planning or statistic reporting
R	Research
S	Related to Safe Routes to School effort
T	Reason not mentioned above

11. Year Station Established (YEARE) (Width 4) – *Optional*
    - This field is used to code the four-digit year the count station was established.
12. Year Station Discontinued (YEARD) (Width 4) – *Optional*
    - This field is used to code the four-digit year the count station was discontinued.
    - When a station is discontinued, it is recommended to state the reason (e.g., due to a facility being realigned, or a permanent counter being removed) in Field #15.

13. Posted Route Sign (PRS) (Width 2) – *Optional*
    - This field indicates the type of route based on the HPMS Field Manual. Use one of the codes below (Table 4-39).

14. Posted Sign Route Number (PRSN) (Width 8) – *Optional*
    - This field is used to record the route number appearing on the posted sign of the route identified in the previous field.
    - If the route number is less than 8 digits, leading or trailing spaces are ignored.
    - Leave this field blank if Field #13 (Posted Route Sign) is coded with a blank or 11.

15. Other Notes (ON) (Width 100) – *Optional*
    - This field is used to record any special circumstances and may contain any printable character. It is limited to 100 characters.
    - For example, if the station is used to count crosswalks of an intersection, it can be described here.

Table 4-39. Posted Route Sign Codes

Code	Description
10	Bureau of Indian Affairs
11	Not Signed
12	Interstate
13	U.S.
14	State
15	Off-Interstate Business Marker
16	County
17	Township
18	Municipal
19	Parkway Marker or Forest Route Marker
20	U.S. Bicycle Route
21	State or Local Bicycle Route
22	None of the above

Micromobility Station Record Pipe-delimited Format State Example

The example below has all the information needed for the Station Record. It shows that the record is for Micromobility data (MSRI=L). The station is in Maryland (SFIPS=24) and within Montgomery County (CFIPS=31). The Maryland DOT is reporting the data (RAI=S). The monitoring station (Station ID SID=ABC123) has a latitude of 39.086437 degrees (LAT =39.086437) and longitude of -77.161263 degrees (LONG=-77.161263). The site is part of a local road in an urban area (FCAT=7U). The count at the station is taken by human observation (TS=H) for the primary purpose of planning (PCP=P). The station was established in 2022 (YEARE=2022) and no information is offered on whether it is discontinued or not (YEARD=blank). The facility is on County Route 220 (PRS=16 and PRSN=220) with a note stating "Jones Creek Path belongs to Montgomery County, Maryland Public Works Department for O&M. The path is about 3.1 miles long."

Header

```
MSRI|SFIPS|CFIPS|RAI|SID|LAT|LONG|FCAT|TS|PCP|YEARE|YEARD|PRS|PRSN|ON
```

Actual Data

```
L|24|31|S|ABC123|39.086437|-77.161263|7U|H|P|2022||16|220|Jones Creek Path
belongs to Montgomery County, Maryland Public Works Department for O&M.
The path is about 3.1 miles long.
```

4.9 MICROMOBILITY COUNT RECORD DATA FORMAT (FIXED WIDTH OR PIPE DELIMITED)

Two types of records are needed for submitting Micromobility data to FHWA's TMAS system.

- Micromobility Station Record – Section 4.8
- Micromobility Count Record – Section 4.9

The Micromobility Count Record is used to report the actual count data to FHWA. The Count Record provides data and other information related to the count, which can be used in conjunction with the Station Record for specific data analyses. To submit a Count Record to FHWA's TMAS, a corresponding Station Record must first be uploaded and approved by TMAS. If a Micromobility Station Record has not been uploaded into TMAS, then the Count Record will not be processed. A Count Record file is a text file often designated by the .txt file extension.

Below is an example Count Record file naming convention:

CountABC123.CMM

General Guidance

The Count Record consists of the data fields listed in Table 4-40. These data fields can be organized either by Pipe (|) Delimited format or Fixed-Width Column format. The Pipe (|) Delimited format is recommended due to its flexibility and easy to use nature.

It is highly recommended to use the Pipe (|) delimited format.
With this format, there is no need to keep track of entry column locations.

Regardless of the format that is used, the length of each data field cannot exceed the specified field length (column width). Information exceeding the allowed field length (column width) in the Pipe Delimited file will be truncated while information less than the allowed width will be accepted as provided.

When using the Fixed-Width Column format, any misalignment of the data field will lead to errors and the rejection or misinterpretation of the data.

Table 4-40. Summary of the Micromobility Count Record Data Fields

Field	Columns	Width	Description	Type	Importance
1	1	1	Micromobility Count Record Indicator (MCRI)	Alphanumeric	Required
2	2-3	2	State FIPS Code (SFIPS)	Integer	Required
3	4-13	10	Reporting Agency Indicator (RAI)	Alphanumeric	Required
4	14-73	60	Station ID (SID)	Alphanumeric	Required
5	74	1	Type of Count (TC)	Alphanumeric	Required
6	75	1	Helmet Usage (HU)	Alphanumeric	Optional
7	76	1	Age (AGE)	Alphanumeric	Optional
8	77-80	4	Year of Counts (YEAR)	Integer	Required
9	81-82	2	Month of Counts (MONTH)	Alphanumeric	Required
10	83-84	2	Day of Counts (DAY)	Alphanumeric	Required
11	85-88	4	Count Start Time (in military time) (CST)	Integer	Required
12	89-90	2	Count Interval (in minutes) (CI)	Integer	Required

Field	Columns	Width	Description	Type	Importance
13	91-94	4	Count Data Reporting Scheme (CDRS)	Alphanumeric	Required
14	95-99	5	Counts (COUNTS)	Integer	Required

Specific Data Fields Explanation

A Count Record allows Micromobility data items to be reported at a variety of time intervals. The following data items should be reported when gathering Micromobility counts. Each Count Record should correspond to an existing Station Record already uploaded in TMAS.

1. Micromobility Count Record Indicator (MCRI) (Width 1) – *Required*
   - The letter “N” is always coded to indicate that the file is a Micromobility (bicycle and/or pedestrian) Count Record. This field is not case sensitive.
2. State FIPS (SFIPS) (Width 2) – *Required*
   - Refer to state_county_city_FIPS_codes to obtain the State’s FIPS code. The State FIPS code indicates in which State the station is located.
3. Reporting Agency Indicator (RAI) (Width 10) – *Required*
   - The Reporting Agency Indicator field has a maximum of 10 alphanumeric characters (containing only letters and/or numbers) and identifies the agency reporting the data to TMAS.
   - Enter the same Data Reporting Agency Indicator that was used in the corresponding Station Record.
4. Station ID (SID) (Width 60) – *Required*
   - The Station ID field has a maximum of 60 characters and is created by the reporting agency. It represents a unique identifier for a counting location and counting device. The goal is to enable agencies to use their native Station IDs for TMAS reporting. When combined with data field #3 (Reporting Agency Indicator), the entered values will create a unique record within a State regardless of how many entities submit data to TMAS.
   - Enter the same Station ID that was used in the corresponding Station Record.
5. Type of Count (TC) (Width 1) – *Required*
   - This field indicates the type of traveler being counted. Use one of the codes from Table 4-41.
   - If the count data has subclassifications, ensure all types of counts are included by using a record (row) for each type.
     Example 1: Station 12345678AB counts pedestrians and bicycles separately. Count data for each count interval (per specific year, month, day, and time) should be provided in row 1 for pedestrians (code 1) and row 2 for bicyclists (code 2).
     Example 2: Station 12345678CD counts pedestrians, electric bicycles, and nonelectric bicycles separately. Count data for each count interval (per specific year, month, day, and time) should be provided in three rows: the first row for pedestrians (code 1), the second row for electric bikes (code E), and the third row is for non-electric bikes (code N).
     Example 3: Station 12345678EF counts all traffic together. Count data for each interval will have only one row with a Type of Count of 9.

Table 4-41. Type of Count Codes

Code	Description
1	Pedestrians (walking and running) without electric-assisted devices
4	Wheelchair (manual or electrical)
5	Pedestrians (walking, running) with electric-assisted devices (e.g., electric skates, electric skateboards, electric scooters, Segways, and hoverboards)
Y	Pedestrians (walking and running) total (the sum of codes 1 and 5)
N	Manual Bicycles
E	Electric Bicycles including electric minibikes (i.e., small electric motorcycles without pedals)
2	Bicycles total (manual and electric)
7	Bicycle and Pedestrians total (the sums of codes 1, 5, N, and E)
3	Equestrians only
6	All-terrain vehicles on a trail (e.g., snowmobile or some other ATV)
8	All Micromobility traffic (the sum of codes 1,4, 5, N, and E
9	All traffic using the facility (the sum of codes 1, 4, 5, N, E, 3 and 6)
0	Animals other than horses counted under Equestrians

6. Helmet Usage (HU) (Width 1) – *Optional*
   - The field indicates the traveler helmet usage. Use one of the codes from Table 4-42.

Table 4-42. Helmet Usage Codes

Code	Description
N	Helmet usage is not collected.
B	Helmet usage is collected - # of travelers not wearing a helmet
W	Helmet usage is collected - # of travelers wearing a helmet
X	Helmet usage is collected - # of travelers wearing a helmet cannot be ascertained.

7. Age (AGE) (Width 1) – *Optional*
   - This field indicates the age of the traveler. Use one of the codes from Table 4-43.

Table 4-43. Age Codes

Code	Description
N	Age is not collected (no age identification is attempted)
C	Age identification is attempted - cases with child (pre-teen) identified
A	Age identification is attempted - cases with adult (teen or older) identified
X	Age identification is attempted - cases when age can't be ascertained

8. Year of Counts (YEAR) (Width 4) – *Required*
   - Code the four digits of the year in which the data was collected.
9. Month Of Counts (MONTH) (Width 2) – *Required*
   - Code the two digits (leading zero Is not required) for the month in which the data was collected.
10. Day of Counts (DAY) (Width 2) – *Required*
    - Code the two digits (leading zero Is not required) for the day in which the data was collected.

11. Count Start Time in Military Time (CST) (Width 4) – *Required*
    - This is the starting counting time. For example, Station ABCD123456 starts to count for the day at 6:00 am.
    - Record the local time in effect on the date of the count using the 24-hour military (e.g., 13:30 pm is corded as 1330) format except no zero should be used as a prefix for hours prior to 10:00 am (e.g., 6:00 am is recorded as 600 not 0600.)
    - The count start time must be divisible by 5. Hourly records are expected to start on the hour. 15-minute records are expected to start at 0, 15, 30, or 45 minutes past the hour. For a 5-minute interval, the count must start at a time ending in either 0 or 5.
    - Due to daylight savings time, it has been typical practice with motorized counts to "overwrite an hour of data" in the fall and have a "missing hour" in the spring. This practice is continued for the TMG Micromobility format.
    - If a count session continues past midnight, a new record with a new date should commence with the first interval that starts after midnight.
12. Count Interval in Minutes (CI) (Width 2) – *Required*
    - The TMG allows for 5-, 10-, 15-, 20-, 30-, or 60-minute intervals.
    - Counts should be collected and reported for the shortest feasible intervals (shorter if automated equipment is used, longer if manual counts are conducted).
13. Count Data Reporting Scheme (CDRS) (Width 4) – *Required*
    - This field identifies how the actual count data are reported to TMAS.
    - Report non-intersection-related count data by following codes in Table 4-44.
    - Non-intersection-related count data can be reported either by individual travel direction or by combining both travel directions.

Table 4-44. Count Data Reporting Scheme for Non-Intersection Traveled Way Scenarios

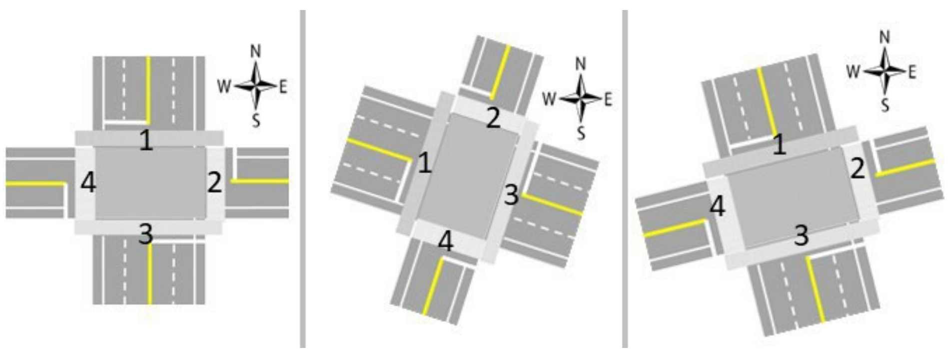
Code	Description
DDCC	Dual directional (combining counts) count reporting (e.g., combining north and south counts into a single combined count to report).
SDCN	Single directional count reporting for travel direction 1. Travel directions for direction 1 includes northwest, north, or northeast.
SDCS	Single directional count reporting for direction 2. Travel directions for direction 2 includes southwest, south, or southeast.
SDCE	Single directional count reporting for the east travel direction.
SDCW	Single directional count reporting for the west travel direction.

- Report intersection-related count data by following codes in Table 4-45 and the further protocols explained below.
  - A typical intersection may have 4 crosswalks where a T intersection has 3 crosswalks. A crosswalk most likely allows dual direction travel.
  - When reporting intersection crosswalk counts, report the combined direction count for each crosswalk.
  - Crosswalk counts for a typical four-way or a "T" intersection should be coded as ICW1, ICW2, ICW3, and/or ICW4.
  - For intersections where there are more than 4 legs (5 or more crosswalks), codes should be continued as ICW5, ICW6 … as needed.

- The crosswalk located in the northwest quadrant of a typical intersection is labeled as Intersection Crosswalk 1 (ICW1). Continue to identify the rest of the crosswalks sequentially in a clockwise direction.
- When there is not an intersection leg located in the northwest quadrant of an intersection, the crosswalk located in the north direction shall be identified as Intersection Crosswalk number 1 (ICW1). Continue to identify the rest of the crosswalks sequentially in a clockwise direction.
- When there are no intersection legs located in the northwest quadrant or the direct north direction, the crosswalk located with the leg in the northeast quadrant is labeled as Intersection Crosswalk number 1 (ICW1). Continue to identify the rest of the crosswalks sequentially in a clockwise direction.
- When there are no intersections legs located in the northwest quadrant, the direct north direction, or the northeast quadrant, the crosswalk located with the leg in the east direction is labeled as Intersection Crosswalk number 1 (ICW1). Continue to identify the rest of the crosswalks sequentially in a clockwise direction.
- See further illustrations with Figures 4.3, 4.4, and 4.5.

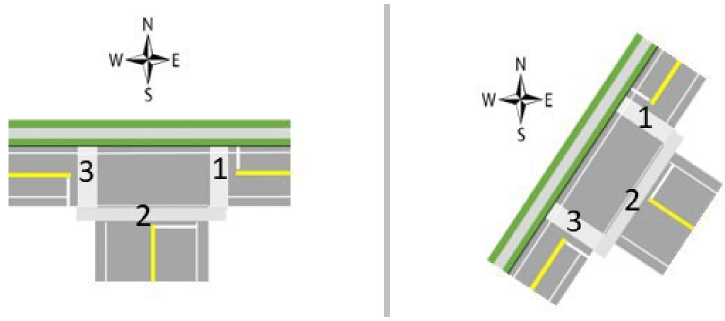
Table 4-45. Count Data Reporting Scheme for Intersection Crosswalk Counting Scenarios

Code	Description
ICW1	Combined directional counts for crosswalk # 1
ICW2	Combined directional counts for crosswalk # 2
ICW3	Combined directional counts for crosswalk # 3
ICW4	Combined directional counts for crosswalk # 4
ICWn	Combined directional counts for crosswalk # n



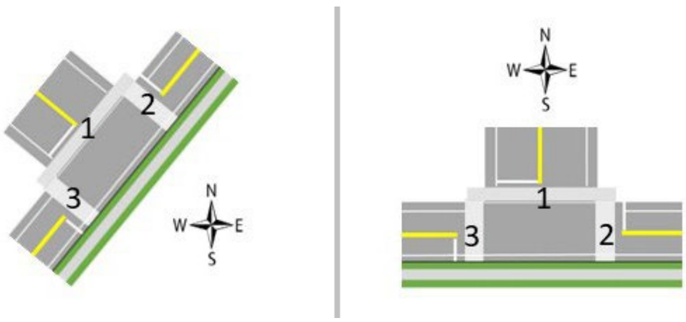
Source: Federal Highway Administration.

Figure 4-3. A Regular Intersection Crosswalk Numbering Illustration



Source: Federal Highway Administration.

Figure 4-4. A "T" Intersection Crosswalk Numbering Illustration 1



Source: Federal Highway Administration.

Figure 4-5. A "T" Intersection Crosswalk Numbering Illustration 2

14. Counts (COUNTS) (Width 5) – *Required*
    - This field is used to record the actual count data observed during each interval.
    - For any count intervals when the counter is not operating or the count data are not available, there is no need to include any records (rows) in the data file to indicate data are missing.
    - If a counter is operating but no subjects were observed, 0 (zero), should be entered.

Micromobility Count Record Pipe Delimited Format Examples

Example 1

The Maryland Department of Transportation (Reporting Agency Indicator RAI=S and SFIPS=24) reports Micromobility counts (Micromobility Count Reporting Indicator MCRI=N) for a monitoring site (SID=abc123456789) counting pedestrian travel (TC=1) without identifying the traveler's helmet usage (HU=blank) or age (AGE =blank) for May 15, 2024 (YEAR=2024, MONTH=5, DAY=15) with a count start time at 8:00 am (CST=800) and an interval time of 60 minutes (CI=60). Counts are dual directional combined counts (CDRS=DDCC).

Header

```
MCRI|SFIPS|RAI|SID|TC|HU|Age|Year|Month|Day|CST|CI|CDRS|Counts
```

Actual Data

```
N|24|S|abc123456789|1|||2024|5|15|800|60|DDCC|200
N|24|S|abc123456789|1|||2024|5|15|900|60|DDCC|250
N|24|S|abc123456789|1|||2024|5|15|1000|60|DDCC|150
N|24|S|abc123456789|1|||2024|5|15|1100|60|DDCC|200
N|24|S|abc123456789|1|||2024|5|15|1200|60|DDCC|90
N|24|S|abc123456789|1|||2024|5|15|1300|60|DDCC|70
N|24|S|abc123456789|1|||2024|5|15|1400|60|DDCC|20
N|24|S|abc123456789|1|||2024|5|15|1500|60|DDCC|70
N|24|S|abc123456789|1|||2024|5|15|1600|60|DDCC|150
N|24|S|abc123456789|1|||2024|5|15|1700|60|DDCC|200
N|24|S|abc123456789|1|||2024|5|15|1800|60|DDCC|100
N|24|S|abc123456789|1|||2024|5|15|1900|60|DDCC|50
N|24|S|abc123456789|1|||2024|5|15|2000|60|DDCC|40
N|24|S|abc123456789|1|||2024|5|15|2100|60|DDCC|0
N|24|S|abc123456789|1|||2024|5|15|2200|60|DDCC|5
N|24|S|abc123456789|1|||2024|5|15|2300|60|DDCC|1
N|24|S|abc123456789|1|||2024|5|16|0|60|DDCC|1
```

Example 2

The Maryland Department of Transportation (Reporting Agency Indicator RAI=S and SFIPS=24) reports Micromobility counts (Micromobility Count Reporting Indicator MCRI=N) for a monitoring site (SID=abc123456789) counting pedestrians and bicyclist separately (TC=1 and TC=2) without identifying the traveler's helmet usage (HU=blank) or age (AGE =blank) for May 15, 2024 (YEAR=2024, MONTH=5, DAY=15) with count start time at 8:00 am (CST=800) and an interval time of 60 minutes (CI=60). Counts are dual directional combined counts (CDRS=DDCC).

Header

```
MCRI|SFIPS|RAI|SID|TC|HU|Age|Year|Month|Day|CST|CI|CDRS|Counts
```

Actual Data

```
N|24|S|abc123456789|1|||2024|5|15|800|60|DDCC|200
N|24|S|abc123456789|2|||2024|5|15|800|60|DDCC|50
N|24|S|abc123456789|1|||2024|5|15|900|60|DDCC|250
N|24|S|abc123456789|2|||2024|5|15|900|60|DDCC|90
N|24|S|abc123456789|1|||2024|5|15|1000|60|DDCC|150
N|24|S|abc123456789|2|||2024|5|15|1000|60|DDCC|60
N|24|S|abc123456789|1|||2024|5|15|1100|60|DDCC|200
N|24|S|abc123456789|2|||2024|5|15|1100|60|DDCC|80
N|24|S|abc123456789|1|||2024|5|15|1200|60|DDCC|90
N|24|S|abc123456789|2|||2024|5|15|1200|60|DDCC|80
N|24|S|abc123456789|1|||2024|5|15|1300|60|DDCC|70
N|24|S|abc123456789|2|||2024|5|15|1300|60|DDCC|50
N|24|S|abc123456789|1|||2024|5|15|1400|60|DDCC|20
N|24|S|abc123456789|2|||2024|5|15|1400|60|DDCC|10
N|24|S|abc123456789|1|||2024|5|15|1500|60|DDCC|70
N|24|S|abc123456789|2|||2024|5|15|1500|60|DDCC|50
N|24|S|abc123456789|1|||2024|5|15|1600|60|DDCC|150
N|24|S|abc123456789|2|||2024|5|15|1600|60|DDCC|60
```

Example 3

The Maryland Department of Transportation (Reporting Agency Indicator RAI=S and SFIPS=24) reports Micromobility counts (Micromobility Count Reporting Indicator MCRI=N) for a monitoring site (SID=abc123456789) counting only bicyclist (TC=2) with the capability of identifying the traveler's helmet usage (HU=B, W, or X) and age (AGE=C, A, or X) for May 15, 2024 (YEAR=2024, MONTH=5, DAY=15) with count start time at 8:00 am (CST=800) and an interval time of 60 minutes (CI=60). Counts are dual directional combined counts (CDRS=DDCC).

Header

```
MCRI|SFIPS|RAI|SID|TC|HU|Age|Year|Month|Day|CST|CI|CDRS|Counts
```

Actual Data

```
N|24|S|abc123456789|2|B|C|2024|5|15|800|60|DDCC|200
N|24|S|abc123456789|2|B|A|2024|5|15|800|60|DDCC|11
N|24|S|abc123456789|2|B|X|2024|5|15|800|60|DDCC|5
N|24|S|abc123456789|2|W|C|2024|5|15|800|60|DDCC|201
N|24|S|abc123456789|2|W|A|2024|5|15|800|60|DDCC|8
N|24|S|abc123456789|2|W|X|2024|5|15|800|60|DDCC|4
N|24|S|abc123456789|2|X|C|2024|5|15|800|60|DDCC|12
N|24|S|abc123456789|2|X|A|2024|5|15|800|60|DDCC|1
N|24|S|abc123456789|2| X|X|2024|5|15|800|60|DDCC|1
N|24|S|abc123456789|2|B|C|2024|5|15|900|60|DDCC|250
N|24|S|abc123456789|2|B|A|2024|5|15|900|60|DDCC|36
N|24|S|abc123456789|2|B|X|2024|5|15|900|60|DDCC|12
N|24|S|abc123456789|2|W|C|2024|5|15|900|60|DDCC|267
N|24|S|abc123456789|2|W|A|2024|5|15|900|60|DDCC|66
N|24|S|abc123456789|2|W|X|2024|5|15|900|60|DDCC|21
N|24|S|abc123456789|2|X|C|2024|5|15|900|60|DDCC|6
N|24|S|abc123456789|2|X|A|2024|5|15|900|60|DDCC|3
N|24|S|abc123456789|2|X|X|2024|5|15|900|60|DDCC|1
N|24|S|abc123456789|2| B|C|2024|5|15|1000|60|DDCC|198
N|24|S|abc123456789|2| B|A|2024|5|15|1000|60|DDCC|35
N|24|S|abc123456789|2| B|X|2024|5|15|1000|60|DDCC|21
N|24|S|abc123456789|2|W|C|2024|5|15|1000|60|DDCC|10
N|24|S|abc123456789|2|W|A|2024|5|15|1000|60|DDCC|1
N|24|S|abc123456789|2|W|X|2024|5|15|1000|60|DDCC|2
N|24|S|abc123456789|2|X|C|2024|5|15|1000|60|DDCC|12
N|24|S|abc123456789|2|X|A|2024|5|15|1000|60|DDCC|11
N|24|S|abc123456789|2|X|X|2024|5|15|1000|60|DDCC|3
```

Chapter 5. FEDERAL DATA REPORTING REQUIREMENTS AND TOOLS: HPMS AND TMAS

5.1 HIGHWAY PERFORMANCE MONITORING SYSTEM (HPMS) REQUIREMENTS FOR TRAFFIC DATA

The Federal Highway Administration (FHWA) is responsible for assuring that adequate highway transportation data and systems performance information is available to support its functions and responsibilities, as well as those of the Administration and United States Congress. The Highway Performance Monitoring System (HPMS) is used for reporting these metrics. Additionally, HPMS data are widely used throughout the transportation community, including other governmental entities, business and industry, institutions of higher learning for transportation research purposes, and the general public. HPMS data may also be used for performance measurement purposes in national, State, and local transportation decision-making to analyze trade-offs among the different modes of transportation as part of the metropolitan and statewide transportation planning process.

The *HPMS Field Manual* (FHWA) provides a comprehensive overview of the HPMS program and describes in detail the data collection and reporting requirements for HPMS. The HPMS Field Manual includes detailed information on technical procedures, a glossary of terms, and various tables to be used as reference by those collecting and reporting HPMS data. Information related to the use of the HPMS software web application is contained in a separate document.

> Users of this Guide are encouraged to refer to the latest revision of the *HPMS Field Manual*, as traffic data requirements may have changed.

This chapter provides guidance to States in meeting the traffic reporting requirements of the HPMS program since traffic data comprise a significant portion of the HPMS data submission. Although most traffic monitoring programs include the collection of volume, classification, weight, and speed data, the primary focus of the guidance in the *Highway Field Manual* is on volume and classification data. The traffic data reported in HPMS should match the data managed by the State's traffic monitoring program so that information published by the State and FHWA are as similar as possible. This goal is best achieved when HPMS traffic data are developed in a cooperative process among the State's HPMS, traffic monitoring, and traffic demand modeling personnel.

A limited amount of background information is provided here to offer an overview of how the HPMS is organized. The main difference between traffic monitoring data collection and HPMS data submission is that HPMS-based traffic data elements, including VMT, are reported by road sections to correlate with road inventory data. HPMS data are reported by full extent, sample panel, or partial extent.

The following definitions for each of these types of data are from the *HPMS Field Manual* (FHWA).

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.

Sample panel data consist 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.

Partial extent data refer 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.

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 program provides the location of sample sections to the traffic monitoring program as new sections are added or removed for each HPMS data collection year. The addition of these sections, which may require additional traffic data collection effort, is determined by using the sample management process within the HPMS system. This iterative process allows the traffic monitoring program to either establish permanent count stations at those locations or take short-term coverage counts at specific locations to provide count data for use with HPMS.

For sampling purposes, HPMS uses the Table of Potential Samples (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 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 5-1 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.

Route ABC					
AADT	62000		90000		70000
Functional System	2		1		2
Through Lanes	6		8		6
Urban Code			9645		
Facility Type			2		
Route ABC TOPS	A	B	C	D	E
Distance	0 Mile 8 Mile		10 Mile 20 Mile	22 Mile	26 Mile

Source: HPMS Field Manual.

Figure 5-1. HPMS TOPS Development Process

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 can be 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 are 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* (FHWA) contains additional information on TOPS.

The remainder of this chapter includes the following sections:

5.2 HPMS Requirements – This section describes traffic data reporting requirements for HPMS.

5.3 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.

5.4 Calculation of Data Items – This section provides guidance about how to compute the HPMS data items and includes references.

5.2 HPMS REQUIREMENTS

While traffic data are collected and reported on a full extent, sample, and partial extent basis for HPMS, State DOTs may not need to physically conduct traffic counts at all locations. In some cases, States may rely on local governments to collect and supply the traffic data 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. In all cases, State DOTs are responsible for the quality, completeness, and accuracy of all HPMS-related traffic data within their State boundaries.

Specific emphasis is placed on the collection of vehicle classification data on HPMS sample sections, since these data are used in many nationally significant analyses. While not reported at the section level within the HPMS submittal, vehicle classification data on motorcycle, bus, and light truck percentages are also required by State highway agencies in order to compute the HPMS vehicle summary table.

When this table is computed, State highway agencies should account for the different monthly travel patterns of each class of vehicles when the percentage of travel is being annualized. To accurately compute the fraction of statewide VMT by class, it is also necessary to account for the functional classification and location of these counts when they will be used to estimate total VMT by vehicle class and functional classification of roadway. FHWA has provided online training on preparing HPMS Vehicle Summary Data, available through its knowledge center found at https://www.fhwa.dot.gov/policyinformation/knowledgecenter/vmt_training/.

These volume data are also used to support the assessment of the Nation's transportation system and help to ensure a fair distribution of Federal funds to maintain that system.

5.2.1 HPMS DATA MODEL

The HPMS Data Model is a logical abstraction of the data elements contained within the HPMS and includes 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 elements listed in Table 5-1 are defined in the HPMS data catalog.

Table 5-1. 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_DH_SINGLE_UNIT	Decimal to nearest 0.01% (one-hundredth)	2.12
24	AADT_COMBINATION	Numeric	30,000
25	PCT_DH_COMBINATION	Decimal to nearest 0.01% (one-hundredth)	0.33
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		

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.

AADT_SINGLE_UNIT – is the Annual Average Daily Traffic for single-unit trucks and buses and is required for all NHS and Sample Panel sections (HFM 4.4). This item requires detailed vehicle classification data and includes FHWA vehicle classes 4-7.

PCT_DH_SINGLE_UNIT – Percent Design Hour Single-Unit Trucks and Buses is the Design Hour single-unit truck and bus volume as a percentage of the applicable roadway section's Design Hour volume rounded to the nearest hundredths of a percent (0.01%). This percent shall not be rounded to the nearest whole percent or to zero percent if minimal vehicles exist. The Design Hour is considered to be the 30th largest hourly volume for a given calendar year.

AADT_COMBINATION – is the Annual Average Daily Traffic for Combination Trucks and must be reported for the entire NHS and all Sample Panel sections. This item requires detailed vehicle classification data and includes FHWA vehicle classes 8-13.

PCT_DH_COMBINATION – Percent Design Hour Combination Trucks is the Design Hour combination truck volume as a percentage of the applicable roadway section's Design Hour volume rounded to the nearest hundredths of a percent (0.01%). This percent shall not be rounded to the nearest whole percent or to zero percent if minimal vehicles exist. The Design Hour is considered to be the 30th largest hourly volume for a given calendar year.

K_FACTOR – is the design hour volume (i.e., 30^{th} highest hourly volume) expressed as a percentage of total AADT. This item is needed for all Sample Panel sections. It is best developed from hourly ATR data. The different methods used for developing short-term and continuous count K-FACTORs are described in more detail in Chapter 3.

DIR_FACTOR – is the percent of design hour volume flowing in the peak direction and is required for all Sample Panel sections.

Section 5.4 provides additional information for calculating values for each of these elements.

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 State's 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
- Traffic Metadata

5.2.2 AADT Reporting on Mainlines and Ramps

AADT data are 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 3 years with yearly factored values provided for the intervening years.
- Mainline counts for the non-principal arterial system and non-sample panel sections must be conducted at least once every 6 years, with yearly factored values provided for the intervening years. This recommendation is designed to ensure that the reported road volumes account for the impacts of changes in levels of economic activity that occur on land that generates the traffic on each road.

- Counts at grade-separated interchange ramp sections must be conducted at least once every 6 years with yearly factored values provided for the intervening years.
- All traffic data reported for HPMS should be based on a minimum of 24-hour counts for roads with volumes of greater than 5,000 AADT and 48-hour counts for roads where volumes are less than 5,000 AADT. Where volume by vehicle classification is counted, 48-hour counts are recommended. Vehicle classification data should be collected on between 25 and 30 percent of all HPMS sample sections. 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 are 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 based on balancing intersection turning movements can be used. 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).
- 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, the eastbound on ramp and westbound off ramp can be counted and then mathematical equations can be used 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.

Refer to Appendix K for typical ramp and interchange configurations and computational examples.

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.

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
- 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.

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.

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.

The third approach uses the previously determined urban system growth rate of -3.6% based on all permanent counters in urban areas. The current year traffic volume estimate is therefore 42,898, which is rounded to 43,000.

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.

5.2.3 Rounding AADTs

The following guidance should be followed regarding rounding of AADTs:

> When sufficient data are available to develop a reasonable AADT estimation from permanent continuous counters for the current year, rounding is not recommended. Rounding can be used to estimate AADT for HPMS purposes when there is no current year data available from permanent continuous counters, as discussed in the four previous examples.

The rounding of AADTs is acceptable for HPMS purposes when 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 its 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.

5.2.4 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 D.

5.2.5 Vehicle Classification Counts

Vehicle classification data are 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 percentage data are reported for the various types of records in HPMS. These data are used to analyze the impact of truck traffic on pavement deterioration and also for reporting in summary tables in HPMS.

Since classification 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 classification counts by the permanent classifiers as further described in *TMG* Chapter 3.

5.2.6 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 A provides additional information on the 13-vehicle classifications.

In addition to truck AADT for single and combination trucks, two additional types of truck data are required. These are the percentage of single-unit trucks and buses (PCT_DH_SINGLE_UNIT) and percentage of combination trucks (PCT_DH_COMBINATION) traveling on a section of road during the design hour.

5.2.7 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 5-2.

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 5-2. 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.

5.2.8 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.

5.2.9 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 are reported from the State traffic database only; or if the data are 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.)
- 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*.

5.3 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 averages 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.

For HPMS reporting purposes, metadata tied with the Annual Average Daily Traffic (AADT), the Single-Unit Truck & Bus (AADT_SINGLE_UNIT), and the Combination Truck AADT (AADT_COMBINATION) have the following definitions regarding data sources:

Code A: Derived directly from actual short-term or continuous counts consistent with procedures outlined in the *TMG* by a State or local government agency.

Code B: Derived not directly from actual short-term or continuous counts (even though short-term count or continuous counts may be used for method calibration or validation data) through methods such as travel demand modeling, statistical trending analysis, or cellular data modeling by a State or local government agency.

Code C: Derived directly from actual short-term or continuous counts consistent with procedures outlined in the *TMG* that are purchased or acquired from a private business or non-governmental entity.

Code D: Derived not directly from actual short-term or continuous counts (even though short-term count or continuous counts may be used for method calibration or validation data) through methods such as travel demand modeling, statistical trending analysis, or cellular data modeling purchased or acquired from a private business or non-governmental entity.

Code E: Other: Data are developed or acquired using a method not identified in A, B, C, or D.

Code	Source (who Conducted/Derived the Count)	Type (Direct Input or Mechanism)	Method
A	State or local government agency	Actual count	Consistent with short-term count factoring procedures outlined in the *TMG*
B	State or local government agency	Travel demand model output, statistical trend analysis, cellular data modeling, or similar	Alternative methods not identified in the *TMG*
C	Private business or non-governmental agency	Actual count	Consistent with short term count factoring procedures outlined in the *TMG*
D	Private business or non-governmental agency	Travel demand model output, statistical trend analysis, cellular data modeling, or similar	Alternative methods not identified in the *TMG*
E	Data are developed or acquired using a method not identified in A, B, C, or D		

Several guidelines should be followed when collecting and processing traffic data to ensure that the highest quality traffic data are provided to HPMS. This section describes the following guidelines:

- Permanent (continuous) counts
- Short term counts
- Ramp counts
- Vehicle classification counts
- Equipment calibration

5.3.1 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 counter; however, States are encouraged to use engineering judgment. The NHS is defined in 23 U.S.C. 103(b) and includes the Interstate System and over 117,000 miles of other roads and connections to transportation facilities serving major population centers and intermodal facilities. 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.

5.3.2 Short-Term Counts

The *TMG* recommends that the short-term 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-term 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 term 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 3 years.

While short-term traffic counts can be taken for anywhere from just a few hours to more than a week, the *TMG* recommends a minimum of a 24-hour monitoring period for roads with traffic volumes of greater than 5,000 AADT and a 48-hour monitoring period for lower-volume roads and any effort involving the collection of vehicle classification data. The 48-hour minimum count duration is recommended for smaller roads and classification counts because traffic variability is high for both low-volume roads and for most truck counts. The additional 24 hours of counting increases the statistical reliability of the AADT estimates computed from these more variable counts. This is 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.

5.3.3 Ramp Counts

A minimum of one count every 6 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.

5.3.4 Vehicle Classification Counts

Vehicle classification counts reported in HPMS should follow the guidelines outlined in Chapter 3 of the *TMG* and the latest *HPMS Field Manual*. Counts should be performed for a minimum of 48 hours and should contain at least six vehicle classes: Motorcycles, Passenger cars, Light trucks, Buses, Single-Unit trucks, and Combination trucks. Hourly vehicle classification data by direction should be used for all the truck related data items, including PCT_DH-SINGLE_UNIT (trucks) and PCT_DH_COMBINATION (trucks).

5.3.5 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 D.

5.4 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 the following:

- AADT
- AADT_SINGLE_UNIT
- PCT_DH_SINGLE_UNIT
- AADT_COMBINATION
- PCT_DH_COMBINATION
- K_FACTOR
- DIR_FACTOR
- FUTURE_AADT

The calculation methods for these data items are described in the following paragraphs.

5.4.1 AADT

AADT 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.
- AADT changes by Functional Class from year to year checked against the Travel Monitoring Analysis System (TMAS) Growth Factors report.

5.4.2 AADT_SINGLE_UNIT

AADT 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 (based on the FHWA 13 category system). 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 AADT. 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.
- GIS check will be performed on AADT_SINGLE_UNIT by area.

5.4.3 PCT_DH_SINGLE_UNIT

PCT_ DH_SINGLE_UNIT is the single-unit truck and bus volume during the design hour shown as the percentage of the section AADT, to the nearest hundredth of a percent (0.01%). For example, if the section AADT is 3,000 and the volume of single-unit trucks and buses in the design hour is 65, then the PCT_DH_SINGLE_UNIT data item is shown as 2.17%. 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_DH_SINGLE_UNIT data:

If (PCT_DH_SINGLE_UNIT/100) × AADT > AADT_SINGLE_UNIT, there is an error.

5.4.4 AADT_COMBINATION

AADT for Combination Trucks 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 AADT. 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.
- GIS check will be performed on AADT_COMBINATION by area.

5.4.5 PCT_DH_COMBINATION

PCT_DH_COMBINATION is the percent of design combination trucks during the design hour. The percent of peak combination trucks is the combination truck traffic volume during the design hour shown as the percentage of section AADT, to the nearest hundredth of a percent (0.01%). For example, if the section AADT is 5,000 and the volume of combination trucks in the design hour is 164, then the PCT_DH_COMBINATION trucks is shown as 3.28%. 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_DH_COMBINATION data:

If (PCT_DH_COMBINATION/100) > AADT_COMBINATION, there is an error.

5.4.6 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 30^{th} 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 30^{th} 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.
- GIS check will be performed on adjacent samples with related K_FACTORs.

5.4.7 DIR_FACTOR

DIR_FACTOR the percent of design hour volume flowing in the peak direction. The DIR_FACTOR is reported as the percentage of design hour volume (30^{th} highest hour) flowing in the peak direction. For example, a DIR_FACTOR of 60 indicates that 60 percent of the design hour volume is flowing in the peak direction. A value of 100 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 non-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.
- GIS check will be performed on adjacent samples with related DIR_FACTORs.

5.4.8 FUTURE_AADT

FUTURE_AADT may not be an item reported as part of a State's traffic monitoring program, although it is 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 are not available, then 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.
- FUTURE_AADT > 300% of AADT.

5.5 TRAFFIC MONITORING AND ANALYSIS SYSTEM (TMAS)

The FHWA Travel Monitoring Analysis System (TMAS) serves as the national traffic data repository and offers broad ranges of analytical functions. The current TMAS enables the production of the monthly Traffic Volume Trends (TVT) report and various outputs associated with the Vehicle Travel Information System (VTRIS).

TMAS processes data from all 50 States and District of Columbia monthly. Currently there are over 6,000 volume, 2,800 classification, and 600 weigh-in-motion permanent site data in TMAS. The TVT functionality estimates vehicle miles traveled by functional classification by utilizing both HPMS (yearly) and TMAS (monthly) data. TMAS provides a national consistent process and QC approach to all TMG-formatted data. A complete list of QC codes and QC methods for each data type is provided in Appendix B. Data from other public entities other than State highway agencies can also be uploaded, processed, and stored with TMAS. To gain access rights to TMAS or data available from TMAS, please contact the Office of Highway Policy Information.

The purpose of TMAS is to provide an online method for States to submit their station, volume, classification, and weight data to FHWA. This section of the *TMG* provides all the necessary FHWA TMAS data requirements for ensuring the highest quality traffic dataset. Developing and maintaining a quality data program is the most critical program activity that agencies perform and requires careful data evaluation and continuous data checking. Maintaining a quality data program helps agencies to provide customers with a quality dataset and helps to establish and ensure program resources are available for the data program.

TMAS is FHWA’s data uploading, processing, validating, storing, and reporting traffic volume software system. TMAS has many customers and users organized into three categories including data providers, data users, and system administrators. The TMAS data requirements are critically important to State DOTs, as well as other data providers to TMAS. The most important report that TMAS supplies data to on a monthly basis is the TVT report that provides traffic volume data that are summarized by geographic regional trends across the United States.

TMAS provides FHWA with a national traffic volume dataset. All traffic data currently provided from TMAS users and contributors comes from continuous counting stations that also supply information to HPMS. Within the HPMS reporting requirements, TMAS traffic volume datasets allow for the calculation of many traffic volume statistics such as AADT), K-FACTOR (design hour volume), and D-FACTOR (directional distribution) traffic volume statistics. HPMS reporting allows FHWA to calculate Federal highway funding formulas that allocate funds to State DOTs based on statewide traffic volumes and linear miles of roadway.

5.5.1 TMAS Requirements and Features

FHWA has developed TMAS to automatically provide feedback to the user using the most efficient and expeditious electronic methods possible. Providing feedback is critically important to ensuring the necessary collaborative communication between FHWA and the agency. For example, feedback to the data provider is automatically generated and sent to the data provider once data files are submitted and data files are processed in TMAS. The agency can print and save this feedback, helping the data provider keep track and demonstrate agency compliance with FHWA submittal requirements (e.g., showing the submittal of data was completed by the 25th day of every month). This feedback loop is also important for all agencies so that communication across Federal, State, and other agencies continually occurs. TMAS historically has demonstrated that, as the TMAS features and communication tools are enhanced over time, more data are submitted that are higher quality and pass more quality checks.

Several reports can be generated using the TMAS system. For example, a daily volume report provides all the hours within a day of data that are loaded into the system to be displayed and formatted in a report that can be printed. Reports are organized by daily, monthly, or annual reporting and can be generated for any site that contains data that passed all TMAS system checks.

Daily Traffic for Daily, Monthly, and Annual Volume Data

State DOTs collect traffic volume data and perform validation processing (quality assurance and quality checking – QA/QC) of the data from continuous counting stations. These data can be collected, stored, and processed by individual vehicle record recording every event of a vehicle or a total number of vehicles by hour. After performing validation processing, the data are uploaded to FHWA's TMAS software for further evaluation, data processing, storage, and reporting.

State DOTs upload daily traffic volume data that are then averaged to create a Monthly Average Daily Traffic (MADT) statistic. MADTs are used in the TVT report to calculate vehicle miles traveled by month. All TVT reports are organized by month of the year and are available to State DOTs.

State DOTs collect daily and monthly traffic volume data that are then analyzed and processed for annual statistical calculations such as the K-factor (design hour that is typically the 30^{th} highest hourly volume of the year). Although the TVT report does not report annual traffic volume statistics, the TVT provides all monthly traffic volume data by year.

TMAS Data for Travel Volume Trends Reporting

Traffic Volume Trends is a monthly report based on hourly traffic count data reported by the States. These data are collected at approximately 5,000 continuous traffic counting locations nationwide and are used to estimate the percent change in traffic for the current month compared with the same month in the previous year. Estimates are re-adjusted annually to match the vehicle miles of travel from the HPMS and are continually updated with additional data. All *Travel Volume Trend* reports can be accessed via the Office of Highway Policy Information website.

Chapter 6. Third-Party Traffic Data

Third-party traffic data refers to traffic data collected by entities without following the *TMG, AASHTO Guidelines for Traffic Data Programs* (AASHTO 2009), and State highway agency established written procedures. Such data often rely on alternative technologies, data analytics, and modeling under the name of big data and big data analytics. When a Federal, State, or local transportation agency is planning to acquire such data for its transportation program and project development, the agency should take a comprehensive review on: (a) data needs within the agency's different offices, (b) data quality, (c) data ownership, and (d) data cost.

6.1 DATA NEEDS

An agency's data needs are the drivers for collecting and acquiring traffic and travel data. Before considering acquiring any third-party data, it is critical to assess what data the agency currently possesses and understand how such data are collected, stored, and disseminated. No further efforts regarding third-party data should occur until such an inventory is done.

There are three scenarios that may be encountered during the inventory process. The first scenario is that the agency does not possess the needed data. The second case is that the agency does have the data but would like to determine whether the third-party data is a more effective route for acquiring such data. The third scenario is that the agency does have the data and is not planning to pursue any further with the third-party data.

When faced with scenarios one and two, the agency should coordinate with other agency units and offices (e.g., planning's modeling and forecasting office, NEPA and project development offices, design offices, asset management offices, freight program offices, operations, ITS, Federal-aid office, construction office for maintenance of traffic decisions) to refine the needs of the data regarding the exact nature of the data item. An understanding of the needs for each unit, office, and/or program for a specified data item and how often this data item is needed will put the data collection and acquisition on a solid path forward.

Remember, data needs are the main driver for all other actions. The goal of this coordination step is to ensure that only the needed data are acquired. Once the data are acquired, they can and will meet expectations and will be fully utilized by all necessary offices and units, achieving the goals of acquiring the data properly once and using them multiple times by multiple users.

6.2 DATA QUALITY

Given that the data being considered for acquisition is out of the agency's jurisdiction regarding how they are obtained, it is critical for the acquiring agency to understand and know the quality aspects of the data. Both data accuracy and biases are the two common parameters used to characterize data quality.

An agency representative, at a minimum, should ask the potential vendors about the following aspects regarding their data quality:

- What is the data methodology?
- What is the source of benchmark (the ground truth) data?
- How are the data evaluated against the benchmark data?
- What are the conclusions of the evaluation and how they will be used? Is there persistent over or under estimations comparing to benchmark data? Is there a statistically significant difference between the benchmark data and their corresponding third-party data at no lower than an 85% level of significance? What are the various percentages of differences between benchmark data and the third-party data?

Additionally, more specific questions such as these listed below may also be inquired with the vendors:

- What data are to be used to calibrate the result (e.g., permanent, portable)?
- What is the acceptable margin of errors for different factor groups (e.g., FHWA roadway functional classes 1 to 7) and area types (urban and rural)?
- What is the percentage median or mean error as compared with the benchmark data (e.g., AADT from third party vs. AADT from continuous count data)?

- What are the limitations of the method?
- What traffic data QC procedures does the agency have in place for the third-party data vendor to follow?

In addition to inquiring about the data quality with the vendors, the agency should conduct its own data quality testing and review. Data quality testing and reviewing should rely on sound statistical methodologies, be systematic, and follow established traffic engineering methods wherever possible.

Lastly, on the data quality front, data to be acquired from a third-party vendor should be delivered in a format compatible with the agency's current software usages. The agency should avoid allowing the third-party data vendor's software as the only software capable of handling the data.

6.3 DATA OWNERSHIP

Acquiring third-party traffic data could be carried out with many different contractual specifications. Agencies should be fully versed with the implications of different contractual terms which may limit the agency's rights for the data. Specifically, the agency should pay attention to the items listed below.

6.3.1 DATA STORAGE AND POSSESSION

Will the agency have the data in its own system, or will the data stay in the vendor's system? Are the data going to be transferred to the agency or the agency's designated recipient? How will the agency integrate the third-party traffic data with its current traffic database? These are very important decisions that need to be made. If the data are going to reside at the platform of the third-party data supplier, questions related to how the agency is going to access the data, how many people in the agency can access the data at the vendor's platform, and how many years such data will be residing on the vendor's platform should be specified in writing. In addition, when the contracting time expires, how the agency retains these data should also be specified, thereby preventing the agency from losing the data due to time.

If the agency is going to store the acquired data on its platform, make sure such data are acquired in a compatible data format. This is especially true if the data are being acquired for roadway link (segments of roadways) based data (e.g., AADT for Route 100 from Major Avenue to Capitol Boulevard). These links should be compatible with the agency's roadway geospatial network. In other words, link-based data must be readily conflated to the agency's highway network. Many agencies are finding proper conflation of datasets to be of significant concern due to possible dynamic assignment of traffic data onto incorrect segments in the host agency's network. Exercising caution and proper oversight of this element when acquiring data is most helpful to having a successful and useful product.

6.3.2 DATA RIGHTS

The ownership of the acquired third-party data should be clearly stated. With the specification of ownership, other terms need to be specified regarding the freedom of using such data for the agency's purposes such as publishing, sharing, and releasing the data.

The agency should establish the ownership rights for all data to be acquired and fully understand any unlimited rights to use, share, publish, and release such data without further consent from the third-party vendor or compensation to the third-party vendor in perpetuity. The agency may need to establish sharing limitations (i.e., share the data with other local agencies, but not with private parties). The interested agency should avoid the practice of renting or leasing data from the third-party supplier.

6.3.3 VERSION CONTROL

Version control refers to updating the same data produced earlier. Each dataset delivered should have a version specification so the agency can properly reference back to the supplier of the data in the future.

6.4 COSTS

Cost is a significant factor in any agency's decision-making process regarding data acquisition. Understanding both the total cost of the vendor's product and any ongoing expenses is key to understanding the vendor's full cost. For example, will new software licenses be required? Will the data be acquired on an ad hoc (as needed) or a reoccurring basis (multiple times, multiple years)? What will be the cost of additional licenses if they are needed? The agency also needs to consider the costs from having agency staff or consultants assist in managing the data program.

Given the data acquired are typically well-defined, agencies are encouraged to use a firm fixed price approach in acquiring such data. Agencies should avoid negotiation for software packages used to handle such data as part of the data acquisition package. Data delivered by the third-party should avoid the situation where only the third-party data supplier software can handle the data.

6.5 SUMMARY

When an agency is planning to acquire third-party traffic data, considerations to concerns and factors from four areas should be exercised. These areas are data needs, data quality, data ownership, and data cost. Begin by clarifying the data needs. The data needs are the drivers for collecting and acquiring traffic and travel data. Then, it is critical for the acquiring agency to understand and know the quality aspect of the data. Next, the agency needs to be clear on the data ownership. Under data ownership, the acquiring agency needs to be fully versed with the implications of different contractual terms which may limit distribution rights for the data. Lastly, but equally important, is the data cost. Understanding both the total cost of the vendor's product and any ongoing expenses are key to understanding the whole agency cost.

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GLOSSARY

Term	Short Definition	Long Definition
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.
AADBT	Annual Average Daily Bicycle Traffic	Annual Average Daily Bicycle Traffic identifies the volume of bike traffic for the average one day (24-hour period) during a data-reporting year at a specific location or specific segment of road or trail.
AADMCT	Annual Average Daily Motorcycle Traffic	Annual Average Daily Motorcycle Traffic identifies the volume of motorcycle traffic for the average one day (24-hour period) during a data-reporting year at a specific location
AADMT	Annual Average Daily Micromobility Traffic	Annual Average Daily Micromobility Traffic identifies the volume of bike, pedestrian, and other nonmotorized traffic for the average one day (24-hour period) during a data-reporting year at a specific location.
AADPT	Annual Average Daily Pedestrian Traffic	Annual Average Daily Pedestrian Traffic identifies the volume of pedestrians for the average one day (24-hour period) during a data-reporting year at a specific location.
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-term count requires the application of one or more factors that account for differences in time-of-day, DOW, and monthly 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.
ACF	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 proper axle correction factors.
Active IR Sensor	Active Infrared Sensor	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 time interval, then an event or count is registered.
ADMCT	Average Daily Motorcycle Traffic	The total motorcycle volume during a given time interval (in whole or partial days), greater than one day and less than one year, divided by the number of days in that time interval. ADMCT is also known as raw data and unadjusted or non-factored data.
ADT	Average Daily Traffic	The total volume during a given time interval (in whole or partial days), greater than one day and less than one year, divided by the number of days in that time interval. ADT is also known as raw data and unadjusted or non-factored data.

ATR Site	Automatic Traffic Recorder Site	The location of an automated traffic recorder (permanent station) used for collecting traffic volume data; now use the term CCS.
AVDT	Annual Vehicle Distance Traveled	Annual Vehicle Distance Traveled identifies the distance traveled by vehicles over a 1-year (365-day) period.
Axle Spacing	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*).
Axle Weight	Axle Weight	The weight (normal force) placed on the road by all wheels of one axle.
Blank-Fill	Blank-Fill	When the value in a field does not consume all 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.
Classification Scheme	Classification Scheme	A classification scheme provides detailed information about how travelers are organized within a structured naming convention. For example, the most common vehicle classification scheme is a 13-bin structure, where 13 different groups of travelers are organized. There is an example of the 13-bin classification scheme in appendix A.
Continuous Count	Continuous Count	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.
CCS	Continuous Count Station	Permanent counting site that provides 24 hours a day and 7 days a week of data for either all days of the year or at least for a monthly (seasonal) collection. Different types of counters (vehicle volume counter, speed, classifier, and WIM) could be installed at a CCS.
Continuous Data Program	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.
Count	Count	Refers to how the data are 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*.
Coverage Count	Coverage Count	Special temporary count taken on a 24-hour to 7-day basis for a specific segment of road, usually associated with HPMS sections.
DANA	Database for Air Quality and Noise Analysis	A tool created by FHWA to combine traffic data (HPMS and TMAS) from existing data sources into a single database and process the combined data into properly formatted inputs to EPA's Motor Vehicle Emission Simulator (MOVES) model and FHWA's Traffic Noise Model Aide (TNMAide).

DVDT	Daily Vehicle Distance Traveled	The DVDT is calculated by multiplying the section AADT by the section length (miles or km) 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). These are then summed for an entire stratum to compute DVDT.
DVMT	Daily Vehicle Miles Traveled	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).
D-Factor (D)	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% (+/-2%) with traffic volumes equal for both directions.
Extent	Extent	Spatial coverage for which the data are to be reported: functional system, NHS, sample, paved, etc.
FAF	Freight Analysis Framework	The Freight Analysis Framework (FAF), produced through a partnership between the Bureau of Transportation Statistics (BTS) and FHWA, integrates data from a variety of sources to create a comprehensive picture of freight movement among States and major metropolitan areas by all modes of transportation.
Federal-Aid Highways	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.
Full Extent	Full Extent	A population comprising 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	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	Functional systems result from the grouping of highways by the character of service they provide. The functional systems (classifications) designated by the States in accordance with 23 CFR 470 are used in the HPMS.
Gap	Gap	The distance between the back bumper of one vehicle and the start of the next vehicle.
Headway	Headway	The time between the front of one vehicle and the front of the next vehicle.
Inductance loop detector	Inductance loop detector	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 (1/2 the field height corresponding to the shortest leg of the loop), 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.

Intrusive Sensor	Intrusive Sensor	Traditionally, most vehicle detection sensors 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.
K-Factor (K)	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 AADT. 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 AADT.
Lane Occupancy	Lane Occupancy	The percentage of time a vehicle occupies the detection zone. This can be used to describe congested conditions.
Metadata	Metadata	Describe how data are collected or converted for reporting; explain variations in data that do not warrant the establishment of a collection requirement (e.g., type of equipment used, sampling frequency).
MADT	Monthly Average Daily Traffic	This can be computed by adding the daily volumes during any given month, dividing by the number of days in the month, and weighting the number of specific days in the month with the associated weighting factor for those number of DOWs in the given month. For MADT, most of the calendar month of data should be included with a minimum of at least one time increment for each DOW. 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. The new FHWA AADT/MADT method is recommended for all MADT calculations.
MAWKDT	Monthly Average Weekday Daily Traffic	The MADT for Monday through Friday are summed and then divided by five, or values calculated using just the weekdays are used.
MAWKNDT	Monthly Average Weekend Daily Traffic	The MADT for Saturday and Sunday are summed and then divided by two, or values calculated using just the weekdays are used.
Micromobility Detector	Micromobility Detector	A traffic counter specially configured to collect pedestrian and micromobility (bicycle, e-bike, scooter, hoverboard, etc.) travel volume counts on roads, trails, and sidewalks; also reports data on type of traveler (pedestrian, bicycle, scooter, etc.) using pre-programmed algorithms that classify micromobility devices based on speed, axle spacing, and other distinguishing attributes.
Monthly (Seasonality) Factor	Monthly (Seasonality) Factor	The monthly (seasonality) factor is used to correct for month-of-year bias in short term 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 5. 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.
NHS	National Highway System	The NHS 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.

NPMRDS	National Performance Management Research Data Set	A national data set of average travel times on the NHS for performance measures and management activities. This data set is also available to State DOTs and MPOs to use for their performance management activities.
Non-intrusive sensors	Non-intrusive sensors	Non-intrusive sensors can be overhead-mounted sensors, under-the-roadway 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.
Occlusion	Occlusion	Occlusion is the traffic being obscured from the side-fired non-intrusive sensors by vehicles (and particularly trucks) traveling in the lanes closer to the sensor. 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.
Passive IR Sensor	Passive Infrared Sensor	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.
PHF	Peak Hour Factor	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.
PTR	Portable Traffic Recorder or Counter	A vehicle counter or classifier that is portable/mobile (can be moved to different locations) and not permanently installed in the infrastructure, including sensors placed across the road.
Sample Panel (HPMS)	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.
Speed	Speed	The velocity measurement by redundant sensors or attribute of the measured traveler; this provides the instantaneous velocity of the traveler. Most often reported to the whole unit of mile per hour or kilometers per hour.
STC	Short Term Count	Counts that are collected for less than a continuous basis. This allows the temporal data to be expanded to other areas. Consequently, these could be considered as supplying spatial data. Count taken on a 24-hour to 7-day basis for roadway segment-specific locations. These counts may be used in special studies.
System or Network Usage	System or Network Usage	System or Network Usage refers to activity data that provides information about the number of travelers at or along a facility over a time period. The collection of activity data is used for performance measures and data driven decision-making of transportation investments that can be justified by tangible benefits.
Traffic Counter	Traffic Counter	Any device that collects pedestrian, bicycle, micromobility devices, and vehicular characteristics data (such as volume, classification, speed, weight). A traffic counter is placed at specific locations to record the distribution and variation flow by hour of the day, day of the week, and/or month of the year. It may be used to collect data continuously at a permanent site or at any location for shorter periods.
TOPS	Table of Potential Samples	A collection of roadway sections spanning the public road network that provides the sampling frame for selection of the HPMS Sample Panel.

TMAS	Travel Monitoring Analysis System	The FHWA-provided online software used by States, MPOs, and cities to submit traffic data for Federal purposes.
UPACS	User Profile and Access Control System	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	Vehicle	Vehicles include one powered unit and may include one or more unpowered full-trailer or semi-trailer units (*ASTM E17.52*). Assembly of one or more units coupled for travel on a highway.
Vehicle Axle	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, E1318-17*).
Vehicle Axle Spacing	Vehicle Axle Spacing	For each vehicle axle, the horizontal distance between the center of that axle and that of the preceding axle.
Vehicle Class	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.
Vehicle Count	Vehicle Count	The activity of measuring and recording traffic characteristics such as vehicle volume, classification, speed, weight, or a combination of these characteristics.
VDT	Vehicle Distance Traveled	The distance traveled by all vehicles for a given period, usually measured in miles (or metric in km) 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.
Vehicle Length	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 Occupancy	Vehicle Occupancy	Number of persons inside a vehicle.
VMT	Vehicle Miles Traveled	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). 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.

WIM	Weigh in Motion	A measure of the vertical forces (normal) applied by axles to sensors in the roadway. This is used to measure the weight carried by vehicles (trucks) to determine the appropriate pavement design.
WIM System	Weigh in Motion System	A device that measures the dynamic tire forces of a moving vehicle to estimate the wheel, axle loads, and/or gross vehicle weight of the static vehicle. WIM systems also collect information about traffic and truck volume, speeds, vehicle classification, and axle spacing.
Zero-Fill	Zero-Fill	When the value in a field does not consume all 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.

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Appendix A –

Vehicle Types

Appendix A. 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.

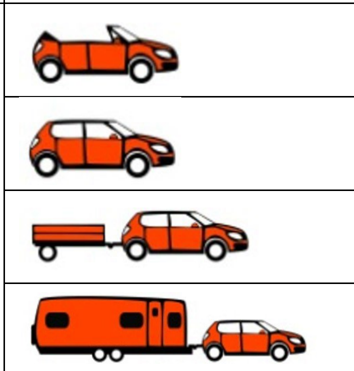
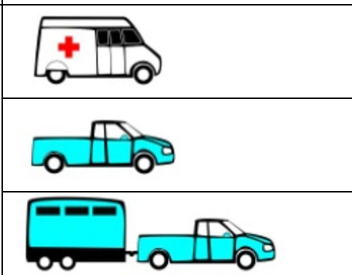
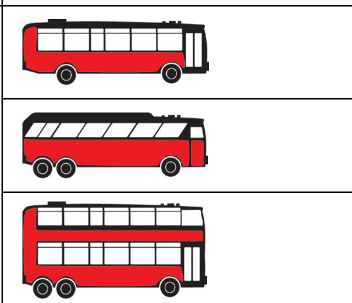
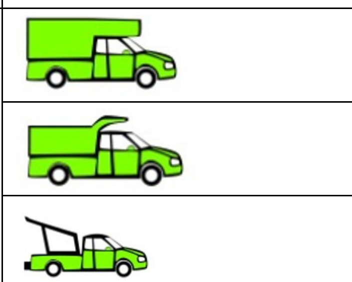
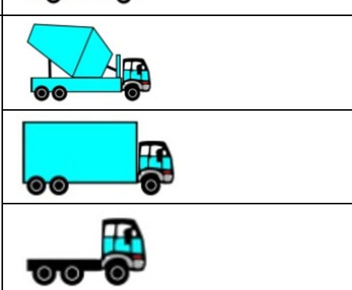
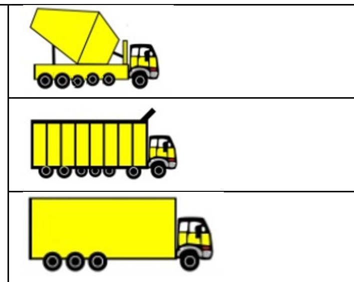
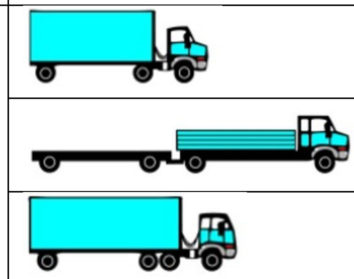
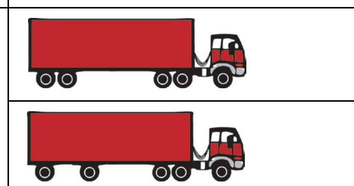
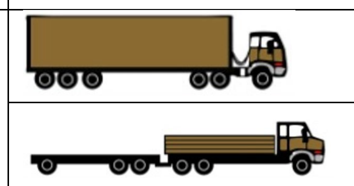
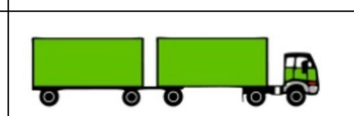
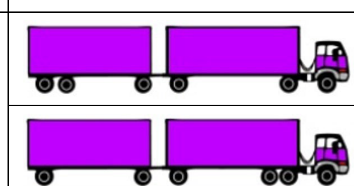
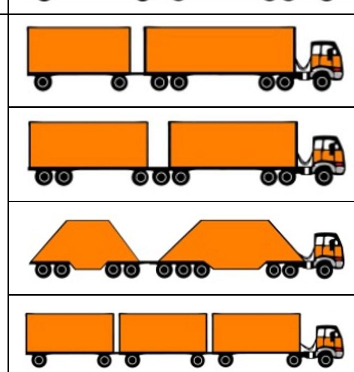
Five or Fewer Axle Multi-Trailer Trucks – All vehicles with five or fewer axles consisting of three or more units, one of which is a tractor or straight truck power unit.

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 A-1 lists the 13 vehicle category classifications used by FHWA.

FIGURE A-1 FHWA 13 VEHICLE CATEGORY CLASSIFICATION

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

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 B –

TMAS Quality Control Checks

APPENDIX B. TMAS QUALITY CONTROL CHECKS

TMAS 3.0 will read TMG formats 2001, 2013 and 2022 for motorized and 2016 and 2022 for micromobility

Station data

Fatal errors

no S or 1 in the 1st digit of the record
record length is less characters based on data type sent in
no station ID in the record

Critical errors occur if:

blank or invalid direction or lane
blank or invalid functional classification
blank or invalid state code
improper vehicle classification designated
(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 (not for 2022 format), 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
any two records that are not exact duplicates within the batch but match same key fields.
User must select the appropriate proper record to utilize.

Note: 2022 TMG Station format is piped delimited only and the station ID can be from 6 to 20 digits. When utilizing 7 or more digits for the station ID, all other TMG formatted data must also be piped delimited.

Volume Data (TMG 3-card) - monthly

Fatal errors occur if:

- no 3 in the 1st digit of the record
- record length is less characters based on data type sent in
- no station ID in the record
- no corresponding station in National Database

Critical errors occur if (by system or by station parameters accepted):

- 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% unless the state marks data as restricted column
- when any 3 to 4 AM volume is >= 3 to 4 PM volume for the same station ID and day
- identical count check – for any consecutive series of reported values there will be no more than 3 values in a row (values other than 0's) with the same values. This check is performed on the individual submitted resolution

Warning flags occur if:

- any two or more records that have all digits being exact duplicates will have one record removed
- any two records that are not exact duplicates within the batch but match same key fields. User must select the appropriate proper record to utilize.

Classification Data (TMG C-card) - monthly

Fatal error occurs if:

no C in the 1st digit of the record
record length is less characters based on data type sent in
no station ID in the record
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 and classification system for vehicle classification for determining the length of the given record.

Caution flags occur if (by system or by station parameters accepted):

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 percentage variance from the incoming same DOW. Threshold value is utilized and when historical value is above the threshold the % is utilized. When below the threshold the number of vehicles for the given class being checked is utilized with 100%, 75% and 25% of the threshold value utilized in incremented lower values used from the threshold down to zero vehicles.
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
any two records that are not exact duplicates within the batch but match same key fields. User must select the appropriate proper record to utilize.

Speed Data (TMG T-card) - monthly

Fatal error occurs if:

no T in the 1st digit of the record
record length is less characters based on data type sent in
no station ID in the record
no corresponding station in National Database

Critical errors occur if:

volume checks done on all classification data – see volume section above
if the associated weight data is loaded and the weight average tandem spacing check was within range then all speed checks don't need to be completed
historical 8 weeks check of 85% speeds with +/- 20% for same DOW
extreme low – over 10% or daily volume under 20 mph
extreme high – over 10% of daily volume over 85 mph
3 to 4 AM average speed is <= 3 to 4 PM average speed for the same station ID and day
all speed data utilizes the speed file speed data time interval, definition of first speed bins reported and total number of speed bins reported in the vehicle speed format for determining the length of the given record.

Caution flags occur if (by system or by station parameters accepted):

Weight Data (TMG W-card) - monthly

Note – TMAS 3.0 permits all vehicle classes to be submitted as weight data.

Fatal error occurs if:

- no W in the 1st digit of the record
- record length is less characters based on data type and class sent in
- no station ID in the record
- any record with more than 25 axles will not be kept in TMAS 3.0

Critical error occurs if:

- none

Caution flags

- total weight not equal to the sum of all axle weights
- every axle weight not within acceptable range (100 lbs. 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 average tandem weight check for 8 weeks of data using the average tandem weight for the same DOW by day by lane check based on class 9 vehicles
- 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 axles will not be processed in TMAS 3.0 but will be placed in a special database.
- any two records that have all digits being exact duplicates will have one record removed

IVR Data (TMG I-card) - monthly

Fatal error occurs if:

- no I in the 1st digit of the record
- record length is less characters based on data type and class sent in
- no station ID in the record

Critical error occurs if:

- none

Caution flags

- volume checks done on all IVR data – see volume section above
- class and/or speed checks done on all same associated data – see section above
- every axle weight not within acceptable range (100 lbs 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
- left and right axle weight balancing checked (when Z variant reported) within +/- 20%
- gap between vehicles (when 15' to 32') with class 6 and class 1 check – report when over 5 per day found

Warning flags

- any record with more than 25 axles will not be processed in TMAS 3.0 but will be placed in a special database.
- any two records that have all digits being exact duplicates will have one record removed
- any two records that have all primary key digits and time stamp being exactly the same remove secondary record(s)

Micromobility Station Data (TMG) - quarterly

Fatal error occurs if:

- no L in the 1st digit of the record
- record length is less characters based on data type and class sent in
- no station ID in the record

Critical error occurs if:

- blank or invalid direction or lane
- blank or invalid functional classification
- blank or invalid state code

Caution flags

- missing Latitude/Longitude
- missing year established
- missing route number
- missing number of lanes for count
- missing type of sensor
- (all caution errors are correctable in TMAS)

Warning flags

- any two records that have all digits being exact duplicates will have one record removed
- any two records that have all primary key digits and time stamp being exactly the same
    - remove secondary record(s)

Micromobility Count Data (TMG) - quarterly

Fatal error occurs if:

no N in the 1st digit of the record

record length is less characters based on data type and class sent in

no station ID in the record

Critical error occurs if:

no state FIPS code

no county FIPS code

no functional classification of road

no direction or location to the roadway code

Caution flags

historical check for 6 weeks of prior approved data based on the same DOW for each class of vehicle by day percentage variance from the incoming same DOW. Threshold value is utilized and when historical value is above the threshold the % is utilized. When below the threshold the number of vehicles for the given class being checked is utilized with 100%, 75% and 25% of the threshold value utilized in incremented lower values used from the threshold down to zero vehicles.

year over year MADT = 20% (same month for the prior year MADT +/- tolerance) consecutive zero's = 7(no overlapping days – any count interval consecutive 0's)

any zero adjacent hour check when over 50 (check both sides of any zero unless interval is first or last one for the day)

total hourly count (maximum) = 4,000 (sum all count intervals and directions for the hour)

total minimum daily count = 100 (sum all count intervals and lanes/directions for the day)

total maximum daily count = 10,000 (sum all count intervals and lanes/directions for the day)

multiple identical counts for any 3 consecutive identical counts – independent of time interval counted)

3 am to 4 am < 3 pm to 4 pm comparison check

Warning flags

any two records that have all digits being exact duplicates will have one record removed

any two records that have all primary key digits and time stamp being exactly the same remove secondary record(s)

Appendix C –

Compendium of Data Quality Control Criteria

Appendix C. COMPENDIUM OF DATA QUALITY CONTROL CRITERIA

C.1 CASE STUDY: LOCAL AGENCY DATA SHARING DELAWARE VALLEY REGIONAL PLANNING COMMISSION (DVRPC)

C.1.1 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.

C.1.2 CONTINUOUS TRAFFIC COUNTS

VTrans is currently operating 60 continuous volume counters, 21 WIM, and 2 continuous vehicle classification counters.

C.1.3 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.

C.1.4 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. Various off-the-shelf products are under consideration, as well as possibly another consultant designed system.

C.1.5 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 thatthe data is accurate. When the count is picked-up, the field technician downloads and reviews the dataon 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 C-3 QUALITY CHECKS FOR VEHICLE CLASSIFICATION COUNTS

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%
uses	> 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.

C.1.6 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.

C.2 CASE STUDY #2 NEW YORK STATE DOT (NYSDOT) QA/QC SYSTEMS FOR TRAFFIC DATA

C.2.1 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. The responsibility for collecting, processing, and disseminating the traffic data at NYSDOT resides with the Highway Data Services Bureau. NYSDOT uses a variety of counters and classifiers with 175 operating continuous count stations used to collect the volume, class, and/or speed data. Twenty-six of those sites collect weigh-in-motion (WIM) data. The following information provides an overview of the use of continuous count stations statewide.

C.2.2 NYSDOT Continuous Count Stations

The New York State continuous count stations are strategically placed in varying geographical locations, population densities, and roadway functional classes, as well as differing volume groups within these locations. The number of individual continuous count sites in each group can increase with additional sites or decrease with equipment failure or removal. 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 C-1 provides an illustration of the New York State Thruway network and the continuous count sites.

FIGURE C-1 NEW YORK STATE THRUWAY AND CONTINUOUS COUNT SITES

Source: New York State Department of Transportation.

C.2.3 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 QA/QC procedures presented in this section provide a high-level overview of these processes, with more detailed information documented in Appendix C 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.

C.2.4 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.

C.2.5 WEIGHT DATA

Validation of weight data at NYSDOT typically follows these steps:

- Data collected at counter.
- Data automatically polled daily to office PC.
- 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?
- Data imported and stored once per week in polling database.
- Monthly data checks performed.
- Data edited.

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 D.

C.2.6 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
- No error is given for vehicles changing speed over sensors.

C.2.7 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.

C.2.8 FUTURE ENHANCEMENTS

The most prominent enhancement to NYSDOT QA/QC procedures is the addition of a comprehensive data system. The traffic monitoring group intends to use a comprehensive data system 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 a comprehensive data system 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 D –

Equipment Calibration

Appendix D. EQUIPMENT CALIBRATION

D.1 CASE STUDY – ARIZONA DOT WIM CALIBRATION PROCEDURES

To improve quality of WIM data collection, Arizona DOT has developed and implemented the following procedure for routine (i.e., periodic) WIM equipment calibration.

D.1.1 WIM SYSTEM CALIBRATION PURPOSE

For Weigh-in-Motion (WIM), calibration is the process of evaluating the measured weight and distance values reported by the WIM system against the known weights and distances and making necessary adjustments to the WIM system operating parameters to compensate for those errors. WIM calibration is performed to ensure that the data accuracy remains consistent and within the performance specification. As a result of the calibration, the mean error in WIM measurements should be reduced to as close to zero as possible. The WIM system calibration shall be performed by a qualified WIM technician in accordance with the manufacturer's specifications and requirements/guidelines set in ASTM E1318-09.

D.1.2 WIM SYSTEM REQUIREMENTS

The ASTM E1318-09 performance specifications for Type I and Type II WIM Systems are provided in Table D-1.

TABLE D-1. FUNCTIONAL PERFORMANCE REQUIREMENTS FOR WIM SYSTEMS PER ASTM E1318-09

Function	Tolerance for 95 % Compliance	
	Type I	Type II
Wheel Load	25%	N/A
Axle Load	20%	30%
Axle-Group Load	15%	20%
Gross Vehicle Weight	10%	15%
Speed	1 mph (2 km/h)	
Axle-Spacing and Wheelbase	0.5 ft (0.15 m)	

D.1.3 REFERENCE DOCUMENTATION

Available reference sources for WIM System calibration include:

- WIM Manufacturer's Operations Manual or WIM Vendor Maintenance Guides.
- ASTM E1318-09 - Standard Specification for Highway Weigh-in-Motion (WIM) Systems with User Requirements and Test Methods.
- LTPP Field Operations Guide for SPSWIM Sites (FHWA 2012).
- Guides or specifications developed by State highway agencies (FL, TX)

D.1.4 TOOLS AND EQUIPMENT

- Manufacturer's Operations Manual
- Communication equipment for connecting to the WIM system
- Laptop
- Multimeter
- Jeweler's screwdriver
- 100' measuring tape
- Flashlight
- Tire Pressure Gauge
- Tire Depth Gauge
- Cabinet Key
- Temperature Gauge
- Laser Speed Gun

D.1.5 SUPPORTING FORMS AND DOCUMENTATION

The Arizona DOT should develop a *WIM Calibration Form* to be used by WIM technician to record information about WIM site, static weights, and length measurements for the test trucks, data collected for the test truck runs, operational characteristics of the on-site equipment, pavement assessments, existing and new WIM compensation factors, classification study data, and photograph logs.

In addition, preventive maintenance forms should be provided to record test data from the pre-calibration WIM system electronic and electrical checks.

A template or content requirements for the *WIM Calibration Summary Report* should be developed by ADOT and used by WIM personnel for all WIM site calibrations for consistency in the reporting and to keep a historic record of WIM site performance. A sample WIM Calibration Summary Report from VDOT is provided in Appendix B.

If vehicle classification accuracy testing is desired during WIM calibration visits, ADOT vehicle classification algorithm implemented at the WIM site should be provided to the calibration field crew.

D.2 SCHEDULING WIM SYSTEM CALIBRATION

In order to maintain consistent WIM accuracy, and therefore uniform data quality throughout the year, it is important to periodically check WIM system performance and use WIM calibration activities to systematically compensate for the WIM system bias that tend to develop over time.

D.2.1 WIM SYSTEMS WITH PIEZO-QUARTZ SENSORS

WIM systems using piezo-quartz sensors should be calibrated every 12 to 18 months, however, the frequency of calibrations may be affected by factors, such as:

- Recent maintenance or hardware change performed
- Demonstrated system dependency on pavement smoothness
- Sensors installed in pavements subjected to seasonal changes in pavement stiffness.

- System shows the repeatable drift from past calibration at a higher rate over time, whatever the reason.
- Presence of commodity shipment cycles
- Changes in truck classification distribution
- Changes in average truck speed
- If key weight statistics (such as class 9 GVW) drift more than 5 percent from the benchmark values, the system should also be calibrated out of normal cycle.

D.2.2 WIM Systems with Piezo-Polymer Sensors

Systems with piezo-polymer sensors that are used for collection of axle weight data, should be calibrated seasonally or have other means for consistent compensation of temperature effect on weigh measurement accuracy. If seasonal calibrations cannot be scheduled due to some constraints, users should be informed about seasonal deviations in weight measurement accuracy. If seasonal calibrations are not feasible, calibrate every 12 month during the season that has daily temperature as close to the annual average temperature as possible to avoid introduction of extreme bias, as could be in the case of calibrating during the seasons with either extremely cold or extremely hot temperatures.

The data processing and/or quality assurance personnel can provide inputs on when a WIM site needs to be calibrated based on the comparison analysis of the loading statistics based on the recently downloaded WIM data against the statistics based on the comparison data set. As stated earlier, for sites that have other contributing factors that lead to changes in "typical" truck weights observed at the site, such as seasonal crop or other commodity movement, these factors must be accounted for during data checks to determine if the data are "typical" or unexpected deviations have occurred.

D.3 Calibration Procedure

The calibration of each WIM systems includes three parts: pre-visit, on-site, and post-visit activities. Combined, the WIM calibration process can be presented using the following roadmap.

- Part 1 – Pre-Visit Activities
  - Step 1 – Pre-Visit WIM Data Analysis
  - Step 2 – Selection of Test Trucks
- Part 2 – On-Site Activities
  - Step 1 – Site Assessment
  - Step 2 – Measurement of Test Trucks
  - Step 3 – Verify Communications with Test Truck Driver
  - Step 4 – Pre-Calibration Test Runs
  - Step 5 – Test Truck Run Data Analysis to Evaluate WIM Performance
  - Step 6 – System Calibration
  - Step 7 – Post-Calibration Test Runs and Evaluation
  - Step 8 – Speed and Classification Accuracy Validation
- Part 3 – Post-Visit Activities
  - Step 1 – Post-Visit Data Analysis
  - Step 2 – Comparison Data Set Development
  - Step 3 – Reporting of Results

D.3.1 PART 1 – PRE-VISIT ACTIVITIES

The activities performed prior to the on-site visit are aimed to provide the field team with the information needed to establish the requirements for the test truck vehicles, including type, weight and speed. A pre-visit data analysis provides information on the current operational status of the WIM system and possible deviations in weight and length measurements from the values recorded in the comparison data set (CDS).

Step 1 – Pre-Visit WIM Data Analysis. Prior to the site visit, collect a recent data sample (2-4 weeks) from the WIM system and analyze the data to determine the current site characteristics that will be used to determine the types of trucks, loads and speeds for the calibration. From the pre-visit data analysis, annotate the following information on the WIM Calibration Form:

- Most common heavy truck type for the site (typically FHWA vehicle class 9) to be used as a test vehicle.
- 85th percentile truck speed and a range of speeds for calibration test truck runs.
- GVW distribution for the prevalent truck type (typically FHWA vehicle class 9) and target weight of calibration truck.
- Axle spacing for the prevalent truck type.

Criteria: the range of the test truck speeds should represent a 10 to 20 mph range of typical truck speeds that includes the 85th percentile speed for trucks at the site. Testing at three different speed points is recommended to minimize error dependency on speed.

Test truck body type, suspension, axle spacing, and loads should be representative of the trucks observed at the site.

Compare the expected traffic flow characteristics developed based on the data collected immediately after the most recent validation/calibration (the comparison data set – CDS) with the traffic characteristics based on the recently collected WIM data. Use the results to assess likelihood of calibration effort and to establish the likely range of compensation factors to be applied in the field. Annotate the following information on the WIM Calibration Form:

- Changes in the GVW of most common heavy vehicle type.
- Changes in vehicle class distributions.
- Changes in average truck speeds.

If available, analyze the most recent profile data (i.e. IRI data) from the WIM site location.

- Process profile data using the LTPP WIM Smoothness Index software and compare the software outputs with the threshold indices provided in Table D-2 to provide an indication of whether or not the pavement roughness may affect the operation of the WIM equipment.
- Process profile data using ProVal or similar software to identify locations of highest IRI values within the WIM scale approach section (200 feet before and 100 after WIM scale location).
- Annotate findings on the WIM Calibration Form.

Criteria: When all values are less than the lower Smoothness Index threshold, it is unlikely that pavement conditions will significantly influence sensor output. Values between the Smoothness Index threshold values may or may not influence the accuracy of the sensor output and values above the upper Smoothness Index threshold would lead to sensor output that would preclude achieving the research quality loading data.

Table D-2. Recommended WIM Smoothness Index Thresholds

Index	Lower Threshold (m/km)	Upper Threshold (m/km)
Long Range Index (LRI)	0.50	2.1
Short Range Index (SRI)	0.50	2.1
Peak LRI	0.50	2.1
Peak SRI	0.75	2.9

Step 2 – Selection of Test Trucks. When calibrating a WIM site, it is very important to accurately represent the population of the dominant heavy trucks (i.e. trucks in vehicle classes 4, 6-13) for that particular site. For instance, if the most frequently observed vehicles in the heavy truck categories are Class 9 and Class 10 trucks, it is vital that a Class 9 and a Class 10 truck be used for the calibration. Additionally, if 40% of the trucks at the site are fully loaded Class 9 trucks, and 35% are partially loaded Class 9 trucks, both types of loadings must be represented during the calibration. Lastly, if the dominant speed for trucks is 65 mph at a particular site, it is important that the test trucks make several runs at this speed or as close to this speed as possible without exceeding the speed limit.

Criteria: The truck configuration is an important consideration. The type of truck body, the load and its placement and suspension must be inspected to ensure that they will not induce adverse truck dynamics into the test. The load must be evenly distributed along the trailer, must be firmly secured to prevent sliding or shifting and must be covered to prevent the introduction of moisture in rainy weather conditions. The suspension must be closely inspected to ensure that airbags are not leaking, springs are not cracked or broken.

The test truck tandem axle spacing for the primary (heavily loaded) truck must be standard – typically 4.0 feet to 4.4 feet apart for the truck and trailer. The tandem spacing for secondary (partially loaded) truck must be standard for the truck, however, the trailer tandem may be split if it represents a large percentage of the truck population for the site. It is important to remember, however, that the split tandem configuration on the trailer may induce different dynamic effects and its behavior is different from that observed for a group of axles; thus, making the calibration more difficult.

- Determine the type of test truck to be used for the calibration, including classification, weight, suspension configuration, and speed (based on 85th percentile speed for trucks and speed limit).
- Whenever possible, use more than one calibration truck to better calibrate to variety of loading conditions encountered at the site.
- Locate nearest certified WIM scale location to the WIM site.

D.3.2 PART 2 – ON-SITE ACTIVITIES

The on-site activities include verification of the WIM system operation, measuring and evaluating the weight and distance measurement accuracies of the WIM system, and calibration.

Step 1 – Site Assessment. Perform the site assessment to determine the possible effect of pavement, equipment and site conditions on the accuracy of WIM weight and distance measurements.

Pavement Inspection

- Conduct visual pavement distress survey from the shoulder to identify surface anomalies that may affect truck motions across the sensors.

- Identify such items as potholes, patches, rutting, and asphalt-concrete transition. In addition, the information from the most recent pavement profile data is used to determine specific locations that may need to be more closely examined during the on-site calibration activities.
- Annotate on the WIM Calibration Form and photograph any pavement distresses that may affect the accuracy of the WIM scale measurements.

Vehicle-Pavement Interaction

Observe several trucks while they pass over the site to determine if truck traffic is showing adverse characteristics such as bouncing, swerving, braking, or accelerating within one hundred thirty-five feet (forty meters) of the sensors.

If feasible, determine whether the truck tires are in full contact with the sensors.

Document observed truck dynamics on the WIM Calibration Form, noting any adverse movements that are within the WIM scale approach area and that may affect the measurement accuracy of the WIM system. Include location from the WIM scale area.

Equipment Inspection

- Perform a visual inspection and static electrical and electronic tests of all WIM site support components.
- Identify and record deficiencies involving the equipment that will require repair.
- Identify all items whose present or deteriorating condition will eventually adversely affect the operation and/or accuracy of the WIM equipment.
- If the system uses an auto-calibration routine, it should be turned off during calibration.
- Document findings on the standard WIM Site Preventive Maintenance Form.

Criteria: If any discrepancies or deficiencies exist that will affect the measurement accuracies and cannot be remedied on-site, postpone the calibration.

Step 2 – Measurement of Test Trucks. This activity involves use of certified static scales. Certified scales should have been tested by the relevant agency within the past three years. Axle weight scales are preferred to platform scales.

- Use certified scales to obtain static weights, axle spacing, and overall length of test trucks. Measure the calibration truck twice at a certified truck scale.
- Inspect the truck tires and suspension for defects.
- Annotate all measurements on the WIM Calibration Spreadsheet.

Step 3 – Verify Communications with Test Truck Driver. Review the calibration procedures with the truck driver, including proper speeds and turnarounds. Review safety procedures.

- Establish communications with the test truck driver.
- Instruct the driver to make at least ten runs over the WIM scales at three different speeds.

Criteria: The truck cannot accelerate or decelerate in the WIM scale area and must travel down the center of the travel lane.

Step 4 – Pre-Calibration Test Runs. Pre-calibration test runs are conducted to quantify any potential system bias and overall measurement errors and consist of ten or more test truck runs over the range of speeds determined during the pre-visit analysis. After initial pre-calibration test truck runs, the system should be calibrated to minimize bias, and then the same number of post-calibration test truck runs should be performed to validate the system and quantify measurement data accuracy.

Criteria: The test truck runs must be conducted at the widest possible ranges of speeds and temperatures observed at the site. A sufficient number of pre-calibration runs should be performed to quantify WIM measurement error percent): at least ten test runs per truck, per lane.

Pavement Temperature

If WIM system shows measurement accuracy dependency on speed, it is important to collect the test truck data over the greatest range of temperatures as possible in order to minimize temperature-induced measurement bias. Although it is anticipated that all of the pre- or post-calibration test truck data will be collected in one day, due to cloudy or rainy weather conditions, it may be necessary to collect the test truck run data over the course of two days. The best times to do this would be in the early afternoon of the first day, and then as early as possible on the second day.

Criteria: A 30 degree Fahrenheit minimum pavement temperature range is the target for calibrating WIM performance under varying pavement temperatures. For systems that are using temperature compensation, the function should remain on.

- For each pass of the test truck, take a pavement surface temperature reading at a location near, but not on the WIM sensor and record it on the WIM Calibration Form.

It is recommended that for WIM sites that utilize the piezo-polymer sensor for weight measurement, and any other WIM sites that demonstrate measurement error dependency on temperature, that a review of prior calibration be performed to assist in determining the proper calibration of the WIM system based on seasonal temperatures. Data collected over seasons can eventually be used to fine tune the WIM systems temperature compensation curve, typically performed by the manufacturer.

Test Truck Runs

The number of test truck runs depends on the data variability observed at given WIM site. Sites that have consistent data errors (i.e. low variability of error) require less test runs that sites that have high error variability to collect a representative sample. Generally, this requires:

- At least 10 runs for the sites that have the spread of GVW errors for the test truck of 5 percent or less after 10 truck runs (FDOT, NMDOT, VADOT, PennDOT).
- At least 20 test runs for the sites that have the spread of GVW errors for the test truck over 5 percent after 10 truck runs or demonstrate measurement error dependency on pavement temperature (LTPP Field Guide for SPS WIM Sites).
- For WIM systems utilizing speed-based compensation factors, conduct at least four test truck runs at each of the three WIM system speed points (LTPP Field Guide for SPS WIM Sites).
- For WIM systems that demonstrate measurement error dependency on pavement temperature, conduct test runs be over a 30-degree temperature range or the widest temperature range possible (LTPP Field Guide for SPS WIM Sites).

Data Collection and Recording

For each pass of test truck, obtain the WIM system's output for axle weights and axle spacings.

- Use laser or radar gun to obtain test vehicle's speed when it is crossing the sensor for comparison with the WIM system's output.
- Use a hand-held laser temperature device, positioned approximately 30" from the pavement surface, to collect pavement surface temperature after each test ruck passage over sensors.
- Record the following data from the WIM system for each test truck pass on the WIM Calibration Form:
    - The sequence number of the test run

- The date of the test run.
- The time of the test run.
- Axle weights of the test trucks as they pass over the scale.
- Spacing between each axle on the test truck.
- Speed of the test truck.
- Pavement temperature at the time of each test run.

Step 5 – Test Truck Run Data Analysis to Evaluate WIM Performance. Once the data have been collected in the field, statistics must be computed to determine whether the WIM site meets the required accuracy parameters stated in WIM performance specification, which is typically the ASTM E1318-09 specification. The WIM system performance parameters can be evaluated using one of the two methods described below.

LTPP Method

The basic statistic required for this test is the error expressed as a percentage of the known value. The percentage of error calculated from the data collected for each run is then used to compute a series of summary statistics. These summary statistics are used to determine whether the scale is the acceptable quality data using the following procedure.

- Using a sample of test truck runs, compare weights reported by the WIM system with the known static weights for each test truck run.
- Compute percentage errors between the known static and the WIM weight measurements and determine the mean error, standard deviation (use t-distribution for sample sizes less than 38) and the statistical confidence interval (that represents the range of errors for 95 percent confidence level).
- Combine the mean error and confidence interval values (mean error +/- 2 standard deviations of error) to compute the overall error.
- Compare the resulting overall error range with the tolerance levels specified in ASTM E1318-09 for Type I or Type II systems to check whether the WIM system is producing weight measurements within specified tolerances.
- If the overall error is within the tolerance levels specified in ASTM E1318-09 for Type I or Type II systems (select appropriate values from Table D-1 based on the type of installed WIM system) and the mean error (i.e. system bias) is close to zero (i.e. less than 2%) for GVW, axle groups and front axle weight measurements, then the system does not require calibration. Otherwise, calibration is required.
- Note on the WIM Calibration Form: the WIM system measurement bias (i.e. the mean error between static and WIM weight measurements), the computed overall errors for GVW, axle groups and front axle for each of the test truck speed groups, and whether WIM system requires calibration.

ASTM E1318-09 Method

The test method for determining compliance with these requirements under prevailing site conditions is:

- For each test vehicle pass, calculate the percent difference in the WIM-system value and the corresponding reference value (i.e. static measurement) for each parameter listed in Table D-1.
- Using all passes of the test vehicles over the sensors, determine the number of calculated differences that exceeded the tolerance value shown in Table D-1 for each data item and express this number as a percent of the total number of observed values of this item (i.e. percent of all test measurements for a given data item (like GVW) that exceed the tolerance).

- If any specified WIM-system function failed, or if more than 5% of the calculated differences for any applicable data item from Table D-1 exceed the specified tolerance for that item, declare the WIM system failed.
- If mean errors (like GVW mean error) calculated based on all test passes significantly deviate from zero (user specified value, 2% or more is recommended), then the WIM system measures with a systematic bias and calibration has failed and should be repeated until it passes or it has failed on three successive attempts, which indicates that the system or WIM sensors are malfunctioning and require corrective maintenance.
- Document findings in a *WIM Calibration Form*.

Step 6 – System Calibration. Generally, the purpose of WIM calibration is to reduce the WIM system's dependency on speed, temperature, or in the case where multiple test trucks are used, truck type. However, the primary focus of calibration should be on reducing the dependency of error on speed under temperature conditions observed on the day of calibration. The dependency of error on temperature changes beyond those observed during calibration visit typically cannot addressed during routine calibration visit, as this requires access to the temperature compensation algorithm embedded in the WIM system's firmware which is not usually available to WIM operator without manufacturer assistance or specialized training. Also, unless multiple test trucks are used, the WIM systems accuracy as a function of type of truck cannot be effectively improved.

- Based on the WIM system measurement error calculated during pre-validation runs, calculate the adjustments to the current WIM system weight and distance error compensation factors using the following formulas:

  For weight: New Factor = (Old Factor * Static Weight)/WIM Weight

  For spacing: New Factor = (Old Factor * WIM Measure)/Static Measure

- Annotate all changes to the WIM system compensation factors on the WIM Calibration Form.
- Enter the new compensation factors into the WIM system firmware for Post-validation testing.

Step 7 – Post-Calibration Test Runs and Evaluation. Repeat Step 4-6, until WIM system performance parameters are within tolerances specified in Table D-1, up to 3 times if needed. The minimum of ten post-validation test truck runs may be performed if the system does not demonstrate the following:

1. A temperature dependency, or the weather conditions on the day of testing do not provide conditions for the wide range of temperature changes.

2. The data from the test runs demonstrate that the speed dependency at each speed point has been eliminated or minimized (less than 2 percent average error for the each speed point).

3. The overall system bias computed based on the data from the available test runs is as close to zero as possible, (less than 2 percent error for the mean error).

4. None of the individual runs are outside of the ASTM E1318-09 tolerance range for 95 percent conformance (1 run outside of the range is allowed for samples of 20 runs or larger) or the 95 percent confidence range computed based on the test data is within the acceptable LTPP WIM performance tolerances.

If a particular site demonstrates a dependency on temperature, up to 20 runs per test truck spread over longer period of time may be required to accurately determine WIM measurements and confirm that calibration worked as expected.

- Annotate final values of each WIM system performance parameter from Table D-1 and final changes to the WIM system compensation factors on the WIM Calibration Form.
- Install the new compensation factors into the WIM system firmware.

Step 8 – Speed and Classification Accuracy Validation. To determine whether the equipment is classifying vehicles correctly at the site, use a sample of vehicles to compare the classifications based on the visual observations to the WIM classifier output. This sample should include a minimum of one hundred heavy vehicles (FHWA classes 4-13) unless such a sample would require more than three hours of collection effort (use 3-hour sample in the latter case).

Criteria: The number of classification errors involving truck classifications in vehicle classes 6 and higher should be less than 2% of the truck volume for the same set of vehicles. The percentage of "unclassified" vehicles should be no greater than 2%.

- Conduct a comparison of observed classifications for a 100 sample of heavy vehicles (FHWA classes 4 -13), with the classifications provided by the WIM system.
- Annotate the misclassification percentage for heavy trucks (classes 4, 6-13) and for all trucks (classes 4-13) and the percentage of unclassified vehicles in these classes, if any.
- Document findings in a WIM Calibration Form (provided at the end of this procedure).

D.3.3 PART 3 – POST-VISIT ACTIVITIES

The post-visit activities include a data comparison analysis between the data samples from just prior to and immediately following the calibration. It is conducted to evaluate the effectiveness of the calibration. Then, the post-calibration sample is used to develop benchmark values for future data evaluation.

Step 1 – Post-Visit Data Analysis. For this analysis, a traffic data sample from the 14 days (30 days for low truck volume roads) immediately following the calibration is collected and compared with the CDS from the previous calibration event and the pre-visit data sample. These data are used to compare weight and distance measurements collected after calibration with the measurements based on the data from the previous CDS and the pre-visit data sample. The post-visit analyses is used to evaluate/confirm the effectiveness of the calibration. To conduct post-visit analyses, follow these steps:

- Download a data sample for the period of two to four weeks immediately after the calibration visit.
- Compare the following parameters between the pre-visit data sample and the post-visit data sample.
  - Class 9 average GVW and GVW distribution by load bins
  - Class 9 average front axle weight and front axle weight distribution by load bins
  - Class 9 tractor average tandem axle spacing
- Note whether differences from the previous CDS observed in Pre-visit data set have been resolved or reduced.
- Determine if the calibration had the desired effect on the data values by comparing the change in the computed parameters with the changes made to the WIM system calibration factors.
- Document findings in a WIM Calibration Summary Report.

Step 2 – Comparison Data Set Development. The data used for the post-visit analysis and statistics computed based on these data are considered the Data Comparison Set. These data and statistics could be used to periodically (bi-weekly or once a month) to compare with the statistics based on current data and prior to scheduling calibration visits. Depending on the analysis results (i.e. changes in average weight and length measurement values or shifts in the weight distributions over 5 percent), site calibration schedule may be accelerated or postponed.

- Use the two- to four-week data sample to develop statistics for the CDS and use these parameters for data QC checks:
    - Average Class 9 GVW
    - Average Class 9 front axle weight
    - Average Class tractor tandem spacing
    - Class 9 GVW distribution
    - Class 9 front axle distribution
    - 85th percentile speed for heavy trucks
    - Vehicle class distribution (FHWA classes 4-13)

Step 3 – Reporting of Results. Prepare a *WIM Calibration Summary Report* as shown below within two weeks after site calibration visit, including the following information:

- Test date.
- Equipment status.
- Pavement condition and temperature during testing.
- Calibration trucks characteristics.
- WIM System weight and distance measurement accuracy before and after calibration, including mean error, 2 standard deviations, and overall error range (mean +/_ 2 standard deviations) for 95% confidence level.
- Calibrate/do not calibrate decision and reasoning.
- Changes made to WIM system parameters.
- Pre-visit and Post-visit data analyses and findings.
- Required corrective actions and recommendations.
- Vehicle classification evaluation, if conducted.
- Supplemental documentation including photographs.

REPORT OF WIM CALIBRATION

Calibration Date: January 0, 1900 Start - 12:00 AM End - 12:00 AM

Calibration Technician:

Name: 0 Phone: -

Site Information:

Site ID: 0

Route: ____ Milepost: ____ Lanes: ____

Latitude: ____ Longitude: ____

WIM System:

ASTM E1318 WIM Type: ____

Sensor Type: ____

Controller Type: ____

Test Truck Data: Number of Test Trucks Used - 0

	Class	GVW	Suspension		Configuration	
			Truck	Trailer	Truck	Trailer
Truck 1:						
Truck 2:						

WIM Calibration Results:

Performance Specifications: ____

Parameter	Requirement (+/- % error tolerance)
steering axle %	
tandem axles %	
GVW %	
veh. length (ft)	
axle length (ft)	

WIM Performance Summary:

Parameter	Lane 1	Lane 2	Lane 3	Lane 4
steering axle -				
tandem axles -				
GVW -				
vehicle length (ft) -				
axle length (ft) -				

Lane 1

Summary of Calibration results:

Parameter	95% Confidence Interval (% error)	Pass/Fail:
steering axle %		
tandem axles %		
GVW %		
vehicle length (ft)		
axle length (ft)		

Number of truck passes: ________

Number of speeds: ________

Speed ranges (MPH):

	low	high	runs
Medium			

Calibration factors:

	Speed Point	Sensor Factors			
		1	2	3	4
1					
2					
3					
4					
5					

Is auto-calibration used: 0

If yes, provide auto-calibration value: ________

Based on adherence to contract, standard, and WIM manufacturer specifications and standards, lane 1 of the WIM system was:

Additional Notes (why system did not pass performance specification and corrective actions)**:**

Lane 2

Summary of Calibration results:

Parameter	95% Confidence Interval (% error)	Pass/Fail:
steering axle %		
tandem axles %		
GVW %		
vehicle length (ft)		
axle length (ft)		

Number of truck passes: ________

Number of speeds: ________

Speed ranges (MPH):

	low	high	runs
Medium			

Calibration factors:

	Speed Point	Sensor Factors			
		1	2	3	4
1					
2					
3					
4					
5					

Is auto-calibration used: 0

If yes, provide auto-calibration value: ________

Based on adherence to contract, standard, and WIM manufacturer specifications and standards, lane 2 of the WIM system was:

Additional Notes (why system did not pass performance specification and corrective actions)**:**

Lane 3

Summary of Calibration results:

Parameter	95% Confidence Interval (% error)	Pass/Fail:
steering axle %		
tandem axles %		
GVW %		
vehicle length (ft)		
axle length (ft)		

Number of truck passes: ________

Number of speeds: ________

Speed ranges (MPH):

	low	high	runs
Medium			

Calibration factors:

	Speed Point	Sensor Factors			
		1	2	3	4
1					
2					
3					
4					
5					

Is auto-calibration used: 0

If yes, provide auto-calibration value: ________

Based on adherence to contract, standard, and WIM manufacturer specifications and standards, lane 3 of the WIM system was:

Additional Notes (why system did not pass performance specification and corrective actions)**:**

Lane 4

Summary of Calibration results:

Number of truck passes: _________

Number of speeds: _________

Speed ranges (MPH):

Calibration factors:

Is auto-calibration used: 0

If yes, provide auto-calibration value:

Based on adherence to contract, standard, and WIM manufacturer specifications and standards, lane 4 of the WIM system was:

Additional Notes (why system did not pass performance specification and corrective actions)**:**

Appendix E –

NCDOT Clustering Method for MEPDG

Appendix E - CLUSTERING METHODOLOGY FOR NC TRAFFIC DATA INPUTS FOR MEPDG

E.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
- 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 datasets. 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 datasets 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.

E.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 also supported.
- 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 (HDFs), Monthly Adjustment Factors (MAFs), Vehicle Class Distributions (VCDs), and Axle Load Distribution Factors (ALFs). 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 these 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 (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.

E.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 for flexible pavement are provided in Table E-1 and rigid pavement (JPCP) in Table E-2.

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 E-1 SENSITIVITY OF MEPDG TO NORTH CAROLINA BASED TRAFFIC INPUTS FOR FLEXIBLE PAVEMENT

MEPDG Input	Total Rut Depth (in)	Fatigue Cracking (%)	IRI (in/mile)
Hourly Distribution Factors	no	no	no
Monthly Adjustment Factors	no	no	no
Vehicle Class Distributions	yes	yes	yes
Axle Load Distribution Factors	yes	yes	yes

Source: North Carolina Department of Transportation

TABLE E-2 SENSITIVITY OF MEPDG TO NORTH CAROLINA BASED TRAFFIC INPUTS FOR RIGID PAVEMENT

MEPDG Input	Faulting (in)	Slabs Cracked (%)	IRI (in/mile)
Hourly Distribution Factors	no	no	no
Monthly Adjustment Factors	no	no	no
Vehicle Class Distributions	no	no	yes
Axle Load Distribution Factors	no	no	no

Source: North Carolina Department of Transportation

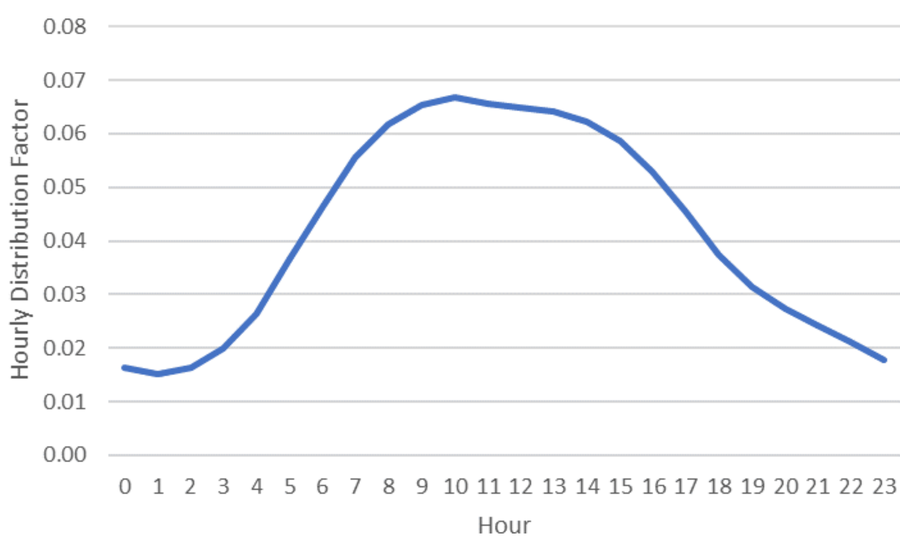
There are naturally occurring clusters in the HDF and MAF datasets. The lack of sensitivity of the models to these inputs (excluding the longitudinal cracking results), based on North Carolina data, eliminates the need for clustering data for these inputs. Statewide average values were generated using the average of the 44 WIM datasets 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, a clustering analysis was performed on the VCD and ALF data to generate grouped datasets for Level 2 inputs.

E.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 E-1 provides a plot of the average HDF that is used in the design process.

FIGURE E-1 NORTH CAROLINA HOURLY DISTRIBUTION FACTORS

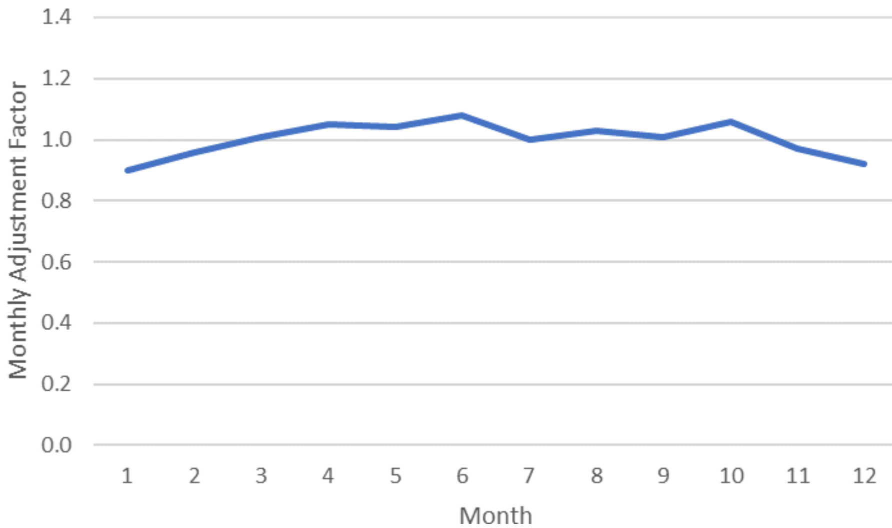


Source: North Carolina Department of Transportation.

E.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 E-2 provides a plot of the average MAF that is used in the design process.

FIGURE E-2 NORTH CAROLINA MONTHLY ADJUSTMENT FACTORS



Source: North Carolina Department of Transportation.

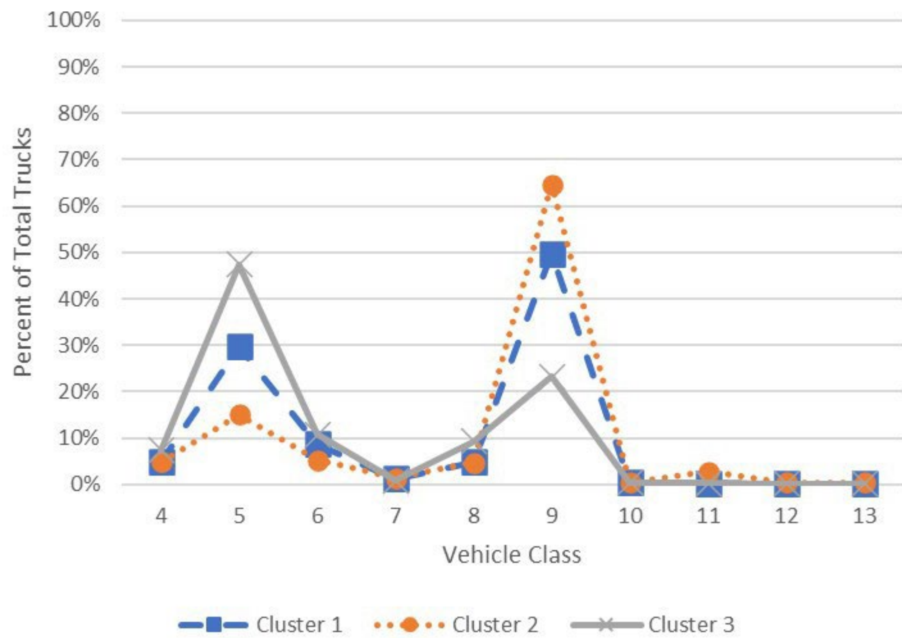
E.6 VEHICLE CLASS DISTRIBUTION INPUT

Due to the sensitivity of most of the models to VCD inputs, a clustering analysis was performed on these 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
- 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 dataset. Three clusters were identified for the VCD input and are shown in Figure E-3.

FIGURE E-3 NORTH CAROLINA VEHICLE CLASS DISTRIBUTION 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 a 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.

E.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. SU trucks (Class 4 to 7) have similar business day travel patterns, and MU 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 were 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)
    - AADTT MU (1), MADTT MU (12), Day of Week Factor MU (84)

These data are suitable for factoring short-term counts collected on typical days when at or near a WIM station location and were 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
- 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
- Step 3: Audit Confidence Intervals of Seasonal Factors

Since a primary output of the factoring process is VCD, this attribute, and how it varies throughout 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 its underlying patterns within the VCD patterns. This generates groupings specific to what is being factored.

Phase 1 – Analysis of Monthly VCD Seasonal Patterns

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 E-3.

TABLE E-3 PRINCIPAL COMPONENTS OF NORTH CAROLINA MONTHLY VEHICLE CLASS DISTRIBUTIONS

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	No	**Yes**	**Yes**	No	**Yes**	**Yes**	No	**Yes**	No	No
February	No	**Yes**	**Yes**	No	**Yes**	**Yes**	No	**Yes**	No	No
March	**Yes**	**Yes**	**Yes**	No	No	**Yes**	No	**Yes**	No	No
April	**Yes**	**Yes**	**Yes**	No	No	**Yes**	No	**Yes**	No	No
May	**Yes**	**Yes**	**Yes**	No	No	**Yes**	No	**Yes**	No	No
June	**Yes**	**Yes**	No	No	**Yes**	**Yes**	No	**Yes**	No	No
July	**Yes**	**Yes**	No	No	**Yes**	**Yes**	No	**Yes**	No	No
August	**Yes**	**Yes**	**Yes**	No	No	**Yes**	No	**Yes**	No	No
September	No	**Yes**	**Yes**	No	**Yes**	**Yes**	No	**Yes**	No	No
October	No	**Yes**	**Yes**	No	**Yes**	**Yes**	No	**Yes**	No	No
November	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	No	**Yes**	No	No
December	**Yes**	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**	No	No

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
- 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 Single Unit Truck (SU) and Multi Unit Truck (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.

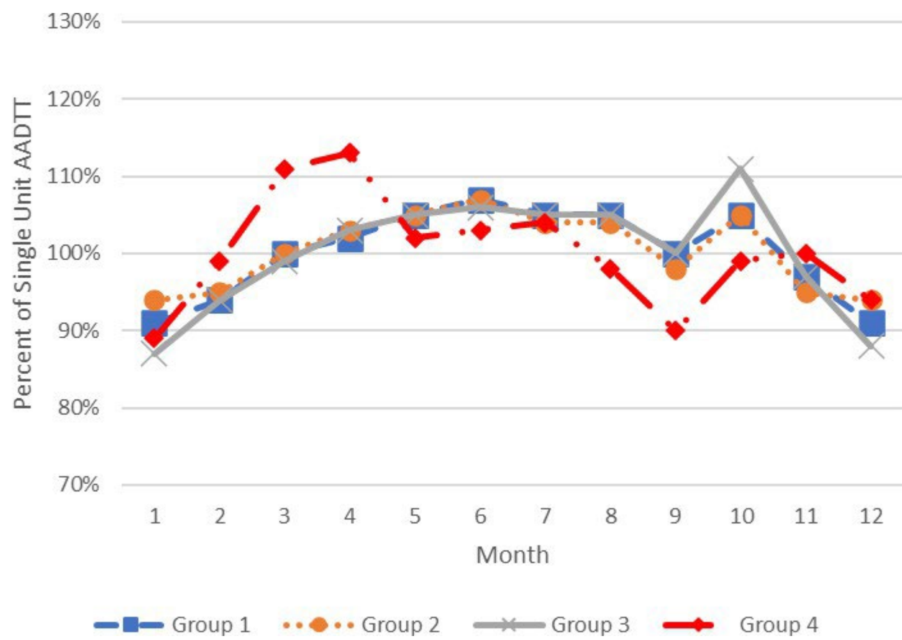
Step 2: A separate principal component analysis of the ratio of MADTT to AADTT for SU and MU was performed. This process identified individual WIM stations that are not consistent with the pattern in principal components among a group. These were eliminated from the grouping when they occurred.

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 seasonal patterns for each factor group based on monthly percent of class AADTT for Single Unit Trucks in Figure E-4 and Multi Unit Trucks in Figure E-5.

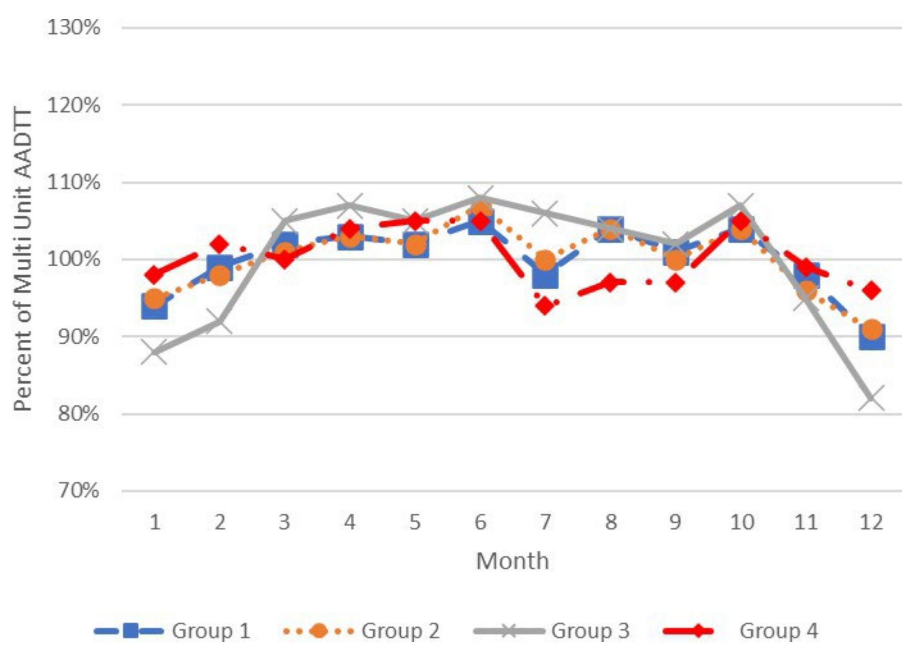
In general, selection of a factor group/station for application of seasonal factors to a short-term portable vehicle classification (PVC) count has been correlated to the route the count is located on and the class distribution identified in the count. The route location is used to determine if the I-95 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 class types counted during a 48- hour short- term count period and the seasonal factor group assignment is determined using the criteria provided in Table E-4.

FIGURE E-4 NORTH CAROLINA SINGLE UNIT TRUCK SEASONAL FACTOR GROUP SEASONAL PATTERNS



Source: North Carolina Department of Transportation.

FIGURE E-5 NORTH CAROLINA MULTI UNIT TRUCK SEASONAL FACTOR GROUP SEASONAL PATTERNS



Source: North Carolina Department of Transportation.

TABLE E-4 SHORT-TERM CLASS COUNT ASSIGNMENT CRITERIA TO NORTH CAROLINA SINGLE UNIT TRUCK SEASONAL FACTOR GROUPS BASED ON SINGLE UNIT TRUCKS/TOTAL TRUCKS

Minimum	Maximum	Single Unit Group
0.09	0.33	1
0.34	0.49	2
0.50	0.70	3

Source: North Carolina Department of Transportation.

TABLE E-5 SHORT-TERM CLASS COUNT ASSIGNMENT CRITERIA TO NORTH CAROLINA MULTI UNIT TRUCK SEASONAL FACTOR GROUPS BASED ON MULTI UNIT TRUCKS/TOTAL TRUCKS

Minimum	Maximum	Multi Unit Group
0.67	0.91	1
0.50	0.66	2
0.29	0.49	3

Source: North Carolina Department of Transportation.

The criteria provided in Tables E-4 and E-5 do not cover the extreme ends of the spectrum of the 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:

For Single Unit Seasonal Factor Group Assignments

If Single Unit Trucks/Total Trucks < 0.09 assign to SU Group 1

If Single Unit Trucks/Total Trucks > 0.70 assign to SU Group 3

For Multi Unit Seasonal Factor Group Assignments

If Multi Unit Trucks/Total Trucks < 0.29 assign to MU Group 3

If Multi Unit Trucks/Total Trucks > 0.91 assign to 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.

E.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:

- Convert axle spacing and axle weight measurements into axle load data
- Generate ALF for each WIM station (Level 1 inputs)
- Identify the ALF factors that most impact the pavement design process
- Perform a principal component analysis to eliminate outliers/aggregate load bins
- Perform a clustering analysis to identify groups of similar ALF patterns
- 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 these 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. Minor adjustments were made to the spacing thresholds specified in the ASTM method to align the North Carolina's vehicle classification tree.

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 ALFs 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 ALFs 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 ALFs 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 datasets 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.

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 E-6 specifies the load bins retained based on this evaluation.

TABLE E-6 LOAD BINS RETAINED FOR AXLE LOAD FACTOR CLUSTER ANALYSIS

Single	Tandem	Tridem	Quad
3,000 lbs. - 20,999 lbs.	6,000 lbs. - 49,999 lbs.	None	None

Source: North Carolina Department of Transportation.

Step 4 – Analyze Principal Components

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.

The 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 effect of variability in individual load bins. This resulted in aggregated bins for single axles for 6,000 lbs. to 10,999 lbs. and 11,000 lbs. to 20,999 lbs., a light tandem bin of 6,000 lbs. to 21,999 lbs., and a heavy tandem bin of 22,000 lbs. to 49,999 lbs. identified as principal components. The standard bins for single axles for 3,000 lbs. to 3,999 lbs., 4,000 lbs. to 4,999 lbs., and 5,000 lbs. to 5,999 lbs. were also found to be principal components and were retained for the clustering analysis.

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.

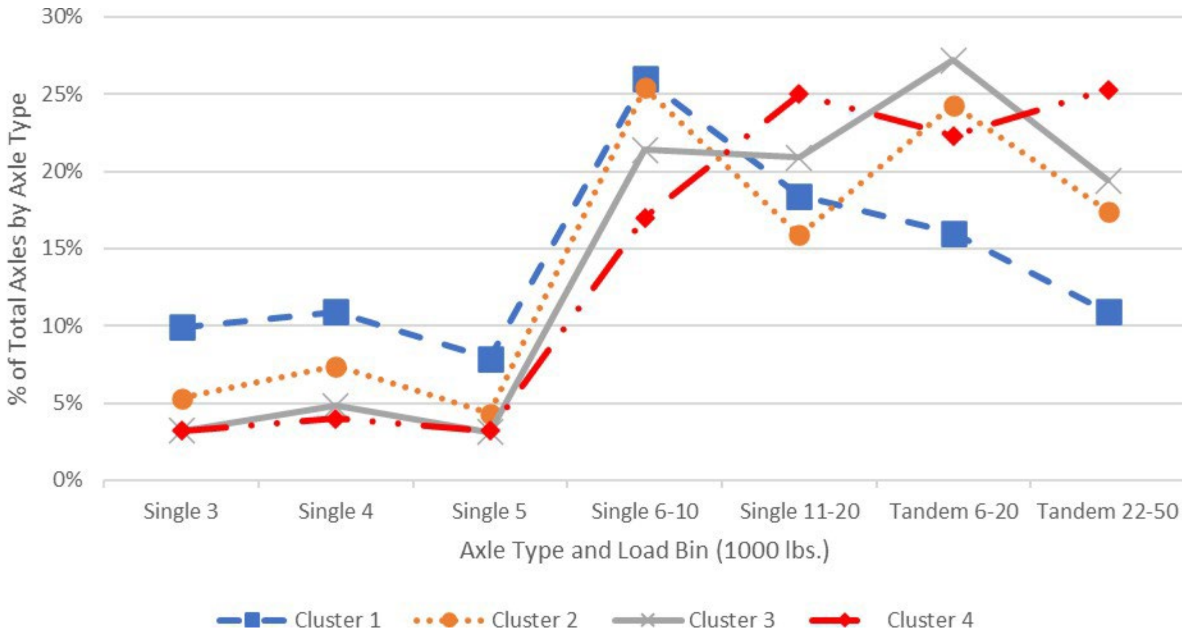
- Statistic – ALF for Single and Tandem Axle Types for 7 Aggregated Load Bins
- Technique – Two-Dimensional Hierarchal Clustering
- Measure – Sum of Least Squares of the Difference in ALF by axle type/load bin

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 pair 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 E-6 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 E-7. This plot helps us to understand the patterns observed in Figure E-6. Observations based on these two figures include:

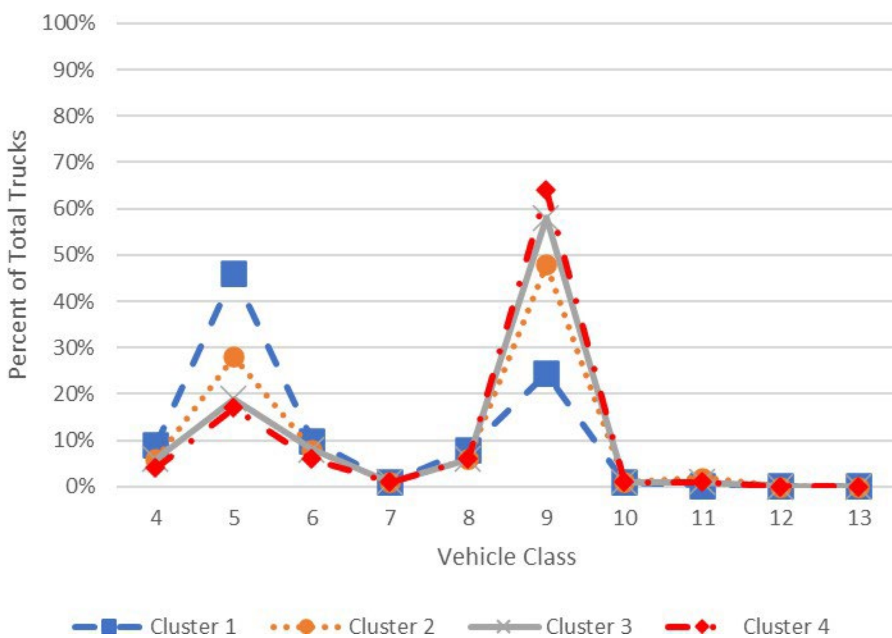
- The VCD for Cluster 1 exhibits a much higher proportion of SU trucks compared to MU trucks; this correlates with the higher frequency of the single axle load bins and a lower frequency in the tandem, especially the heavy tandem bin as compared to the other three clusters.
- The VCD for Clusters 2, 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.
- 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 E-6 AVERAGE SINGLE AND TANDEM AXLE AGGREGATE AXLE LOAD FACTORS FOR TWO-DIMENSIONAL CLUSTERS



Source: North Carolina Department of Transportation.

FIGURE E-7 AVERAGE VEHICLE CLASS DISTRIBUTIONS FOR TWO-DIMENSIONAL AXLE LOAD FACTOR CLUSTERS

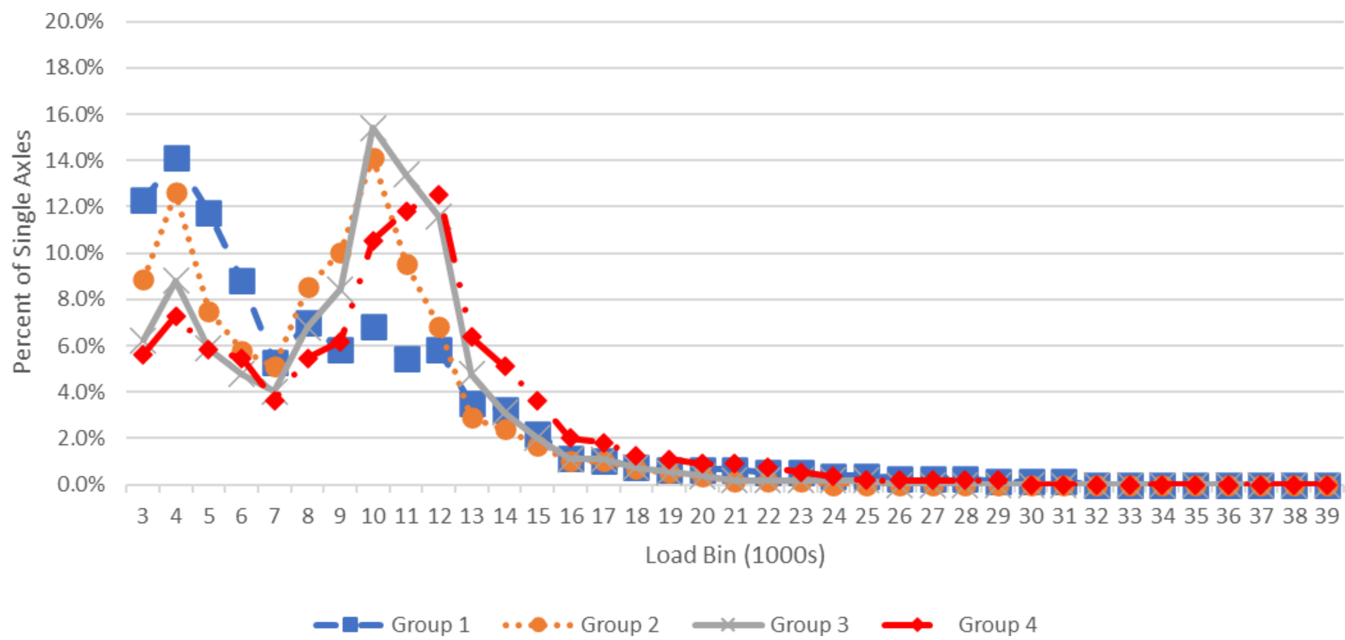


Source: North Carolina Department of Transportation.

It appears that as the proportion of MU trucks increases, the frequency in the heavier load bins also increases. This indicates that the type of facilities that serve long- haul MU trucks will experience the heaviest loading. Although this conclusion can be somewhat intuitive, it is validated by the results of the cluster analysis.

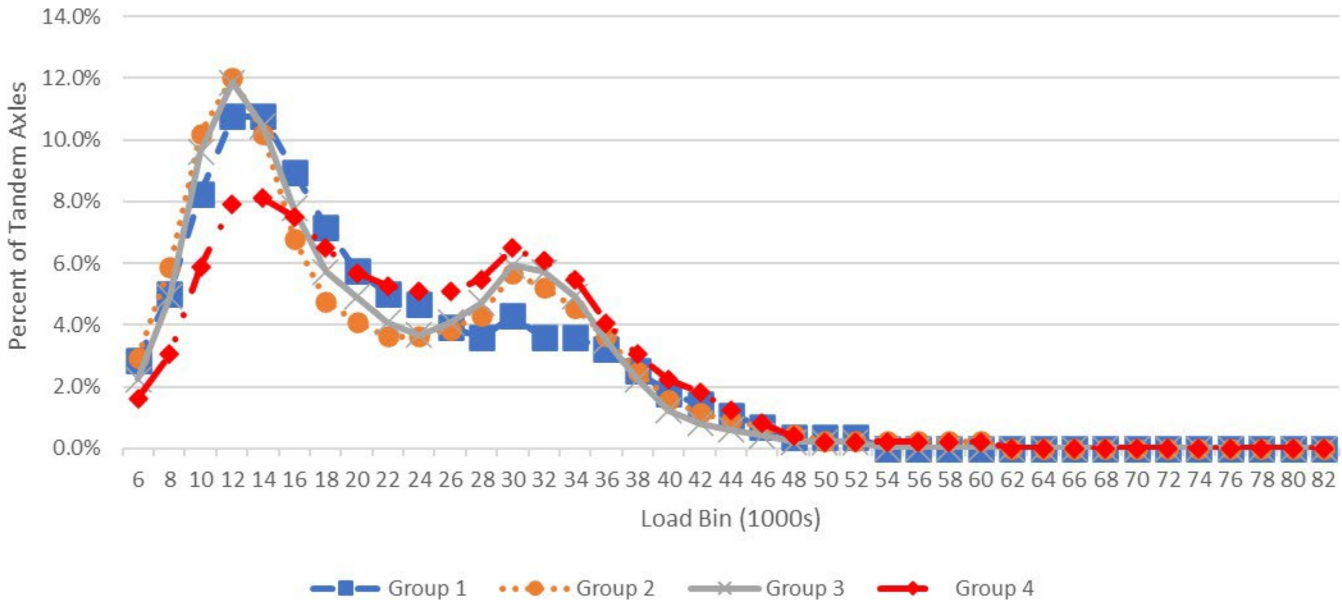
The clusters identified in the analysis were adopted by the NCDOT as axle load groups for designing pavements in North Carolina. Plots of the average ALF for each of the axle load groups for Single and Tandem axle types are provided in Figures E-8 and E-9, respectively. These are representative of the 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 group to provide these inputs also.

FIGURE E-8 AVERAGE SINGLE AXLE LOAD DISTRIBUTIONS FOR NORTH CAROLINA AXLE LOAD FACTOR GROUPS



Source: North Carolina Department of Transportation.

FIGURE E-9 AVERAGE TANDEM AXLE LOAD DISTRIBUTIONS FOR NORTH CAROLINA AXLE LOAD FACTOR GROUPS



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 for 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 E-7.

TABLE E-7 SELECTION CRITERIA FOR NORTH CAROLINA ALF

Parameter	Route Category	ALF
Project Route Location = WIM Route Location	N/A	WIM Station 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 E-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.

E.9 SUMMARY

The study analyzed WIM datasets 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 Trees – Data collected using different technologies for traffic inputs should use the same class tree. 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 datasets. 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 dataset are critical, as well as 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 cannot be used without developing a method for selecting the appropriate clustered dataset 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.

E.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.

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Link to Final Report for NCDOT 2008-11
https://connect.ncdot.gov/projects/research/pages/ProjDetails.aspx?ProjectID=2008-11

Appendix F –

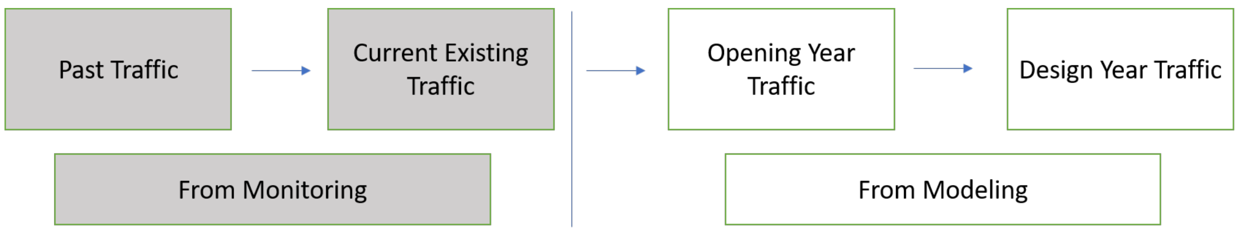
Traffic Data for Pavement Design

Appendix F. TRAFFIC DATA FOR PAVEMENT DESIGN

F.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 should cover the entire life expectancy, which is between the opening year and the last year of life expectancy (Figure F-1). The last year of life expectancy of pavement is often referred to as the design year. For detailed guidance, see AASHTO *Guide for Design of Pavement Structures* Appendix D.

FIGURE F-1 TEMPORAL DATA SEQUENCE



Source: Federal Highway Administration.

Traditionally, the traffic impact on pavement design is through the concept of equivalent single-axle loads (ESAL). One ESAL unit is equates to a 18,000 lbf (pound force) single-axle load of damage applied over the pavement design life. Traffic modeling and design traffic professionals project cumulative ESAL data from all vehicles for the entire pavement life expectancy.

The AASHTO *Mechanistic-Empirical Pavement Design Guide (MEPDG) Manual of Practice* (*MOP*) provides a design method where pavement performance can be modeled with very specific traffic-related parameters. The MEPDG method requires significant traffic data from demand forecasting professionals, which in turn necessitates significant field monitoring data for both vehicle classification and weigh-in-motion (WIM) data.

F.2 VEHICLE RELATED TERMINOLOGIES AND SOURCES OF DATA

The FHWA's 13 vehicle category classification system relies on mainly vehicle axle spacing to differentiate various vehicles. Vehicle data classified under this system are referred to as vehicle class data.

Vehicle axle configuration refers to the different axle groups that a vehicle may have. Pavement design typically uses the following axle groups: single, tandem, tridem, and quad (other than the AASHTO MEPDG, some use penta and penta plus axle groups).

Under each vehicle axle configuration, the weight on the axle/axles is called axle loading that are grouped by axle spacings closer than eight feet into either single, tandem, tridem quad or penta axle groupings. The weight is typically collected by WIM systems and reported in the units of mass (pounds). Axle load reflects both the weight of a vehicle itself and the cargo it carries and is reported by vehicle class and axle group. This is called load spectra.

The primary sources of traffic data for pavement design are vehicle classifiers and WIM systems. Vehicle classifiers provide truck volume by vehicle class counts. WIMs, in addition to truck volume by vehicle class counts, provide axle grouping, axle spacing, and axle weight information.

F.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 F-1 Traffic Data Summary

Item	Description
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.

F.3.1 W_{18} – Cumulative Two-Way ESAL

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 are needed. While the number of axles for various axle grouping configurations under various axle loads can be obtained from traffic projection professionals, axle load equivalence factors are to be obtained from AASHTO's *Guide for Design of Pavement of Structures* Appendix D.

F.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 Tables D.1 to D.18. Values in column C are dependent on axle group, pavement type, slab thickness (for rigid pavements) or pavement structural number (for flexible pavements), and pavement terminal serviceability index.

14. Fill out Column D with forecasted cumulative traffic expected over pavement service life, measured in number of axles by axle load from traffic forecasting professionals.

15. Column E = Column C × Column D.

16. Summarize Column E to obtain the W_{18}.

TABLE F-2 ESAL COMPUTATION ILLUSTRATION

Axle Type	AASHTO Guide Table Axle Loads (KIPS)	AASHTO Guide Table Axle Load Equivalence Factor	Traffic Forecasting Cumulative Number of Axle	ESALs (Columns C X D)
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
	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.

F.4 Traffic Data Associated with Mechanistic and Empirical Pavement Design

AASHTO MEPDG MOP 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. These data are used as the base for future traffic growth projection over pavement design life. This 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. Monthly Adjustment Factor (MAF) for Each FHWA Vehicle Class 4 to 13

   The MAF reflects truck travel patterns throughout the year. There are 10 truck types (FHWA vehicle class 4-13) that require 10 temporal pattern inputs for each of 12 calendar months. Mathematically, the monthly adjustment factor for a given vehicle class and a given month is obtained by dividing the monthly average daily truck traffic (MADTT) for the month by the summation of all the 12 monthly MADTT values and then multiplying by 12. There are a total of 120 MAFs [10 vehicle classes × 12 months = 120 individual MAFs].

   The MAF formula for vehicle class i and month k is shown in the following equation.

$$\mathrm{MAF_{ik}} = \frac{\mathrm{MADTT_{ik}} \times 12}{\sum_{kk=1}^{kk=12} \mathrm{MADTT_{ik}}}$$

   Tables F-3 and F-4 show an example of MAF computation. $\mathrm{MADTT_{ik}}$ values should be computed using TMG procedures for MADT computation.

TABLE F-3 MADTT FOR MAF COMPUTATION

Month	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

Source: Federal Highway Administration. (MADTT is monthly average truck traffic and MAF is monthly adjustment factor)

TABLE F-4 MAF COMPUTED FROM MADTT

Month	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. (MADTT is monthly average truck traffic and MAF is monthly adjustment factor)

5. Vehicle Class Distribution

Vehicle class distribution (VCD) refers to AADTT distribution among the 10 vehicle types (FHWA vehicle class 4 to 13), expressed in percentages. The percentage data are computed from vehicle classification data using the following formula.

$$\mathrm{VCD_i} = 100 \frac{\mathrm{AADTT_i}}{\sum_{ii=4}^{ii=13} \mathrm{AADTT_i}}$$

Where VCD_i is the truck distribution factor for vehicle class i truck and $AADTT_i$ is the AADTT for vehicle class i truck. $AADTT_i$ values should be computed using TMG procedure for AADTT computation.

TABLE F-5 VEHICLE CLASS DISTRIBUTION COMPUTATION ILLUSTRATION

Parameter	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13	Total
$AADTT_i$	235	654	961	1,620	1,240	654	598	103	1,245	4,621	11,931
$VVVVVV_{ii}$,%	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.

6. Hourly Adjustment Factor (HAF) for FHWA Vehicle Classes 4-13

Truck hourly distribution factor refers to the percentage of hourly AADTT among a 24-hour period starting at midnight. There are 24 HAFs. One set of 24 HDF factors is computed using AADTT (for FHWA vehicle classes 4-13 combined) using the following formula.

$$\mathrm{HAF_h} = 100 \frac{\mathrm{AADTT_h}}{\mathrm{AADTT}}$$

Where HAF_h is the truck hourly distribution factor for the h^{th} hour of the day, $AADTT_h$ is the AADTT for hour h for vehicles in FHWA classes 4–13 combined, and the AADTT is vehicles in FHWA classes 4–13 combined. $AADTT_h$ and AADTT values should be computed using TMG procedures for AADTT computation.

TABLE F-6 TRUCK HOURLY DISTRIBUTION FACTOR COMPUTATION ILLUSTRATION

Start Time	End Time	$AADTT_h$	HAF, %
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	$AADTT_h$	HAF, %
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 (AADTT)		1,279	100.0

Source: Federal Highway Administration. (AADTT is annual average daily truck traffic and HAF is hourly adjustment factor)

7. Axle Load Distribution Factors

FHWA vehicles in classes 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 Distribution Factors (ALDFs) provide information about the percentage of axle counts expected within each defined load bin. The distributions are provided for a typical day of each calendar month (January through December) for each FHWA vehicle class (classes 4 through 13) and each axle group (single, tandem, tridem, and quad). In the current guide, the quad axle group includes axle groups with four or more axles. This is one of the most demanding datasets. Mathematically, the ALDF is the percentage of axles within a given axle load range (or load bin) among all axles counted or estimated for a given vehicle class, axle configuration, and calendar month. The computation of the ALDF is based on monthly axle load data for a particular vehicle class, axle configuration, and axle load group, if at least 7 DOW of axle loading data are present in the calendar month. For the months with less than 7 DOW of axle loading data, ALDFs are computed using ALDF values for adjacent months (by averaging) or using annual axle count summaries.

7a. Single Axle Load Distribution Factors

There are 39 axle load groups or bins for single axles. The axle loading reporting starts with a load bin containing the percentage of axles weighing between 0 and 3,000 lbs. and ends with a load bin for axles weighing 41,000 lbs. or more. All load bins have increments of 1,000 lbs., except the first one. Table F-7 provides an example of single axle load distribution factors for selected months and vehicle classes.

7b. Tandem Axle Load Distribution Factors

There are 39 axle load group for tandem axles. For tandem axles, the axle loading reporting starts with the load bin containing the percentage of axles weighing between 0 and 6,000 lbs. and ends with the load bin for axles weighing 82,000 lbs. or more. All load bins have increments of 2,000 lbs., except the first one.

7c. Tridem Axle and Quad Axle Load Distribution Factors

There are 31 axle weight groups for tridem and quad axles. For both tridem and quad axle vehicles, the axle weight group starts with a load bin containing the percentage of axles weighing between 0 and 12,000 lb. and ends with a load bin for axles weighing 102,000 lbs. or more. All other load bins have increments of 3,000 lbs.

7d. Default Axle Load Distribution Factors

FHWA Long-Term Pavement Performance Program has developed a library of axle loading defaults for each FHWA vehicle class 4–13 and axle group (single, tandem, tridem, quad). For more information, see FHWA Report FHWA-HRT-13-089.

TABLE F-7 ILLUSTRATION OF SINGLE AXLE LOAD DISTRIBUTION FACTORS FOR JANUARY, FEBRUARY AND DECEMBER FOR SELECTED VEHICLE CLASSES

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.) (Ending Load Bin Values):	**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
	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

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**
	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
% of Total		100	100	100	100	100	100	100	100	100	100	100	100	100

Source: Federal Highway Administration.

8. Number of Axles per Truck Class for Each Axle Group

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). An example of axles per truck is shown in Table F-8.

TABLE F-8 AVERAGE NUMBER OF AXLES PER AXLE GROUP PER VEHICLE CLASS

FHWA Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.43	0.57	0.00	0.00
Class 5	2.00	0.00	0.00	0.00
Class 6	1.00	1.00	0.00	0.00
Class 7	1.26	0.20	0.63	0.15
Class 8	2.62	0.49	0.00	0.00
Class 9	1.27	1.86	0.00	0.00
Class 10	1.09	1.15	0.79	0.05
Class 11	5.00	0.00	0.00	0.00
Class 12	4.00	1.00	0.00	0.00
Class 13	1.59	1.26	0.69	0.31

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 F-9 summarizes traffic data requirements for MEPDG. Each parameter listed in Table F-9 requires a representative value or a set of values computed using hourly, monthly, or annual traffic summary statistics.

TABLE F-9 TRAFFIC DATA SUMMARY

Item #	Item Name	# of Data Points	Summarization Level	Foundation Data	Data Dimension
1	Annual Average Daily Truck Traffic	1	One annualized value	AADTT	By sum of all trucks
2	% of Truck Traffic in Design Direction	1	One annualized value	AADTT	By sum of all trucks and travel direction
3	% of Truck Traffic in Design Lane	1	One annualized value	AADTT	By sum of all trucks, travel direction, and travel lane
4	Monthly Adjustment Factors	120	One set of monthly values	MADTT	MADTT by truck class for each month in a year
5	Vehicle Class Distribution	12	One set of annualized values	AADTT	AADTT by truck class
6	Hourly Adjustment Factors	24	One set of annualized values	AADTT by hour	AADTT by sum of all trucks by hour of the day
7	Axle Load Distribution Factors – Single Axle	4680	One set of representative values for each calendar month	Monthly axle counts by weight	Monthly axle count data by truck class, axle configuration, and axle weight group
	Axle Load Factor – Tandem	4680	One set of representative values for each calendar month	Monthly axle counts by weight	Monthly axle count data by truck class, axle configuration, and axle weight group
	Axle Load Factor – Tridem	3720	One set of representative values for each calendar month	Monthly axle counts by weight	Monthly axle count data by truck class, axle configuration, and axle weight group
	Axle Load factor – Quad	3720	One set of representative values for each calendar month	Monthly axle count by weight	Monthly axle count data by truck class, axle configuration, and axle weight group
8	Number of Axles Per Truck	40	One set of annualized values	Annualized axle counts	Monthly axle count data by truck class and axle configuration
9	Axle Spacing – tandem, tridem, and quad	3	One set of annualized values	Annualized axle spacing summary	Annual axle count by axle configuration
10	Wheelbase – short, medium, and long categories)	3	One set of annualized values	Annualized axle spacing summary	Annual axle count by wheelbase

Source: Federal Highway Administration.

F.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.

F.6 SCREENSHOTS OF AASHTOWARE PAVEMENT ME DESIGN SOFTWARE GUIS FOR TRAFFIC INPUTS

The following tables, figures and text describe the traffic inputs from AASHTOWARE Pavement ME Design software, version 2.6.0.

TABLE F-10 VEHICLE CLASS DISTRIBUTION AND GROWTH RATE INPUTS

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	0.90	3.5	Compound
Class 5	9.64	3.5	Compound
Class 6	3.53	3.5	Compound
Class 7	1.59	3.5	Compound
Class 8	3.63	3.5	Compound
Class 9	74.42	3.5	Compound
Class 10	0.58	3.5	Compound
Class 11	4.25	3.5	Compound
Class 12	1.31	3.5	Compound
Class 13	0.15	3.5	Compound
Total	100.00	3.5	Compound

Source: AASHTOWare Pavement ME Design™ Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

TABLE F-11 MONTHLY ADJUSTMENT INPUTS

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
February	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
March	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
April	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
May	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
June	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09
July	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
August	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
September	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
October	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
November	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
December	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92

Source: AASHTOWare Pavement ME Design™ Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

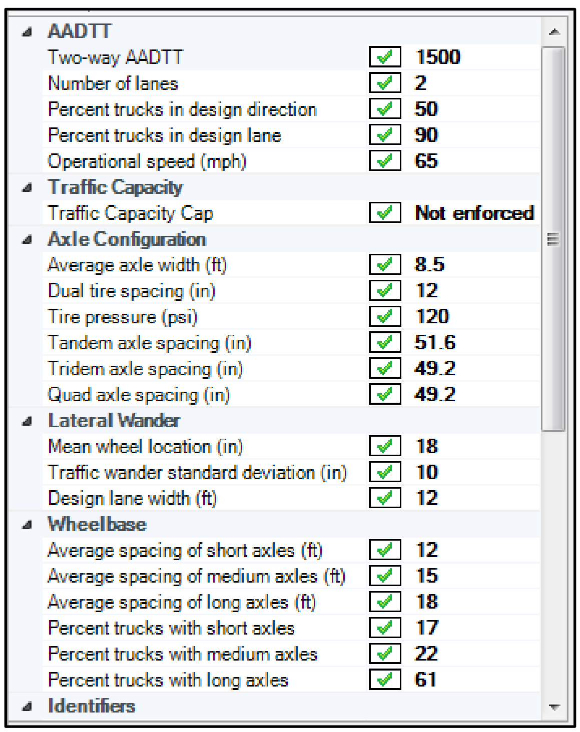
TABLE F-12 AXLES PER TRUCK INPUTS

Vehicle Class	Single	Tandem	Tridem	Quad

Class 4	1.61	0.39	0.00	0.00
Class 5	2.03	0.06	0.00	0.00
Class 6	1.03	0.98	0.00	0.00
Class 7	1.05	0.02	0.97	0.00
Class 8	2.24	0.79	0.00	0.00
Class 9	1.28	1.84	0.00	0.00
Class 10	1.13	1.02	0.92	0.00
Class 11	4.94	0.00	0.00	0.00
Class 12	3.37	1.28	0.00	0.00
Class 13	1.39	0.77	0.81	0.27

Source: AASHTOWare Pavement ME Design™ Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

FIGURE F-1. AADTT, TRAFFIC CAPACITY, AXLE CONFIGURATION, LATERAL WANDER, AND WHEELBASE INPUTS.



Source: Screen capture from the AASHTOWare Pavement ME Design™ Software. Reference: AASHTOWare Pavement ME Design™ Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

Note 1: Average axle width, mean wheel location, design lane width, and all wheelbase inputs shown in Figure F-1 are only used for rigid pavement analyses.

Note 2: The green checkmarks shown in Figure F-1 mean that the values entered are within the minimum and maximum input values for which the software was designed.

AXLE LOAD DISTRIBUTION FACTORS INPUTS

Axle load distribution tables will show for each month of the year the classes 4 through 13 values of axle loading for each of the axle loading groups (single, tandem, tridem and quad) in various 1,000 lbs. increment ranges with single axle in 1,000 lbs. increment ranges, tandem in 2,000 lbs. increment ranges and tridem and quad in 3,000 lbs. increment ranges. These often are referred to load spectrum by vehicle class.

TABLE F-13 HOURLY ADJUSTMENT INPUTS FOR EVERY HOUR OF THE DAY

Time of Day	Percentage
12:00 am	2.50
1:00 am	2.28
2:00 am	2.26
3:00 am	2.44
4:00 am	2.77
5:00 am	3.37
6:00 am	4.20
7:00 am	4.66
8:00 am	4.90
9:00 am	5.14
10:00 am	5.31
11:00 am	5.39
12:00 pm	5.37
1:00 pm	5.43
2:00 pm	5.56
3:00 pm	5.58
4:00 pm	5.38
5:00 pm	5.05
6:00 pm	4.63
7:00 pm	4.20
8:00 pm	3.84
9:00 pm	3.59
10:00 pm	3.28
11:00 pm	2.87
Total	100.00

Source: AASHTOWare Pavement ME Design™ Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

Note 4: Hourly adjustments are only used in rigid pavement analyses.

Appendix G –

Length Based Class Memo

Appendix G. LENGTH BASED CLASS MEMO

INFORMATION:

Reporting of Length Based Vehicle Classification Data to the Highway Monitoring System (HPMS) February 24, 2000

Director, Office of Highway Policy Information HPPI-30

Division Administrators

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 H –

Bike/Ped Site Selection Process/Publication –

Florida Department of Transportation (FDOT's) Nonmotorized Site Selection Methodology (excerpts from the Statewide Non-Motorized Traffic Monitoring Program Recommendations Report December 2018)

Appendix H. Bicycle and Pedestrian Site Selection Process/Publication

(Publication Content Extracted from Section 5, Florida Department of Transportation Traffic Monitoring Program: Recommendations Report, December 2018 Contract # C9T46)

H.1 FDOT's Site Selection Methodology

There are four steps in FDOT's site selection methodology that are described below so that data partners and supporting agencies and private data collection partners can follow a statewide standardized process when determining where to collect bicycle and pedestrian volume. All four steps are summarized below, and details are described for how to implement each step.

H.2 Site Selection Method Steps Summarized

Nationally accepted and documented methods for selecting sites in which to collect non-motorizedtraffic data include:

1. Conduct agency outreach – contact agency and private data partners (include all governmental agencies including metropolitan planning organizations, counties and cities) (See attachment E, Survey Form at the end of this Appendix H section)

2. Create and document site selection criteria

3. Assess site recommendations

4. Create preliminary installation schedules and start coordinating installation resources

FDOT is following these nationally accepted and documented methods and as of September 2018, FDOT completed steps 1-3 and continues on-going work on step #4 as listed above. Here are the specific detailed tasks that FDOT has completed:

- Created and distributed a survey to potential agency data partners
- Developed a tracking worksheet for survey responses
- Analyzed responses using selection criteria that was also created
- Conducted virtual site visits at 406 proposed sites
- Conducted a total of 50 on-site visits
- Prioritized and organized sites within the tracking worksheet
- Finalized site selection for installation of continuous counting equipment

There also needs to be both a system and how many factor groups and portables are going to be needed, the budget required, and the staff to maintain the system.

Below are the detailed steps defined and methods to follow for the development of a statewide non-motorized data program.

H.3 Site Selection Step Details

Developing a non-motorized traffic counting program requires that both temporary and permanent bicycle and pedestrian counters be installed to estimate long-term (continuous counting) trends, to collect volume data before and after construction, and to test and work with various vendor technologies.

H.3.1 Step 1 – Agency Outreach (Statewide designated Data Wrangler)

Step 1 is to conduct agency outreach that provides a venue for outreach, communication, and coordination to data partner agencies located within the state of Florida. Agencies interested in collecting bicycle and/or pedestrian volume count data should begin by contacting the statewide data wrangler within the state who is Eric Katz as listed below. A statewide data wrangler is an individual that works as a multiple agency resource to coordinate, gather, and update the state of Florida's bicycle and pedestrian data collection activities. FDOT is organized and in a strategic position to coordinate statewide data collection activities and as such is considered the state's data wrangler. As the statewide designated data wrangler, FDOT is helping the state of Florida by coordinating schedules, resources (including equipment and staff), access to data, and the development of statewide adopted data collection standard.

In effort to complete Step 1 – conduct agency outreach, FDOT developed survey questions that were e-mailed using the survey monkey technology software solution. Communication methods with stakeholders also included sending e-mail, calling agencies, and hosting an in-person stakeholder meeting. Within the survey, data partners and contributors provided site location recommendations that were then evaluated for statewide continuous counting site installation. The e-mail request to complete the survey was sent on June 4, 2018 to every data partner and contributor in the state of Florida. The Survey that was sent out is presented at the end of this Appendix.

Survey Results

Survey results included 406 data collection site recommendations for collecting bicycle and pedestrian traffic volume count data. The recommendations made were from a total of 178 different agencies.

The top 50 recommendations were identified during the survey. Since the completion of this recommendations report, new recommendations have been and will continue to be made over time. It is expected that tracking recommendations over time is a dynamic process that will likely include the need to be to be updated regularly.

H.3.2 Step 2 – Create and Document Site Selection Criteria

Updating and evaluating sites requires the development of site selection criteria which is Step 2. This step provides a way to standardize the method of site selection for both short and/or long-term counting and establishes the foundation for all sites that are selected to collect bicycle and pedestrian volume count data. Completing this step provides a way, as described in subsequent steps, to prioritize and select sites for collecting data. The FDOT non-motorized site selection criteria has been established and is listed below. This selection criteria are also dynamic and are subject to change over time with changes in technology, staff, and agency policies. The selection criteria were developed based on standard motorized traffic data collection methodologies in mind.

An agency that is ready to start collecting and recommend collecting bicycle and pedestrian volume data in the state of Florida should review, evaluate, and update sites based upon the following site selection criteria.

FDOT Site Selection Criteria:

Site selection criteria provides a way to evaluate and prioritize requests for bicycle and pedestrian counting volume data. The site selection criteria listed below is not meant to be all-encompassing nor isit meant to eliminate sites that might need data collected for other purposes such as project specific economic development purposes, before and after construction studies, health impact studies, etc.

1. LOCATION - Location should be within the state of Florida. Sites that are on (or close to connectors) to FDOT owned facilities should be given priority.

2. DURATION - Sites selected and recommended should include automated collection technology used to collect data on a continuous (365 days/year) or short-term (minimum 24 hours of hourly consecutive hourly count data, with a preferred a 14-day count) basis. If 2- hour manual counts are possible, manual counts should be used as a validation count (Quality Assurance and Quality Control - QA/QC) for where automated continuous and short-term counting equipment is installed. Using manual counts for validation requires coordination of the automated and manual counting resources. Manual counts should be collected at the same location on the same date and time as automated counters and each hourly count should be compared and validated.

3. FACTOR GROUP DESIGNATION - Sites selected and recommended for data collection shouldinclude an evenly distributed representation of the state of Florida's factor groups.

ASSUMPTIONS:

- Factor groups are subject to change over time with data informing theprocess of establishing factor groups
- There are only a few existing continuous counting stations within the state of Florida that might be able to create factors but these are not owned by the Florida Department of Transportation and currently there is not enoughdata (short term or continuous counting data) to inform the process of creating factor groups.
- Over time, additional factor groups will be established and additional continuous counting stations will be installed to collect volume data
- The state of Florida will use factor groups to calculate factors from continuous count stations that can be applied to short-term counts for thepurpose of calculating annual traffic statistics that can be published annually, a full-years' worth of data must be collected to calculate and publish these statistics

The State of Florida Factor Groups (as of December 2018)

1. Urban Commute
2. Urban Mixed
3. Urban Recreational
4. Rural Commute
5. Rural Mixed
6. Rural Recreation
7. Mixed Commute
8. Mixed Recreational
9. Mixed Mixed
10. University (Schools) Commute
11. University (Schools) Recreational
12. University Mixed

This factor group list will be updated as more information is available such as conducting on-site visits to gather on-site information along with collecting and analyzing data from short-term counts...

4. **FACILITY IMPROVEMENTS** – Sites selected and recommended for data collection should receive higher priority when sites fall within an area where a known facility improvement(such as adding stripes, bike lanes, etc.) will occur. Given the relatively small number of count sites in the state of Florida, staff will not use a lack of counter locations or data to disqualify locations in project selection or to determine eligibility for federal funding.

5. **MULTIPLE AGENCY SUPPORT** - Sites selected and recommended for data collection shouldreceive higher priority when sites fall within an area where multiple agency resources are available, ready, and willing to help in installing, maintaining, and evaluating data collectedfrom a site

Other Agency's Site Selection Criteria Example

With several agencies across the country starting up bicycle and pedestrian volume data collection programs, there has been several different selection criteria established across the nation. Below is a sample of some of the criteria used to select sites for collecting bicycle and pedestrian volume data.

- Must have a mix of sites that cover all anticipated factor groupsExample: include on-street and trail locations
- Example: include urban, commuter, mixed Example: include low, medium, high volume
- Sites that are targeted for facility improvements (example: adding bike lanes)
- Sites that are on a DOT facility or are a connector to a DOT Facility
- Sites where local agencies resources are available, ready, and willing to help
- Sites represent a variety of conditions within the overall network (example: economically challenged area, near transit stations, near hospitals, on greenways, etc.)

H.3.3 STEP 3 – ASSESS SITE RECOMMENDATIONS

Once the site selection criteria are developed, the next step is to assess, evaluate and prioritize potential sites for collecting data. Recommended sites are organized and prioritized according to the site selection criteria. This process is typically managed electronically within a spreadsheet and recommendations are sorted by the site selection criteria. Further evaluation of each site is then conducted using a virtual site audit process and an on-site evaluation of the site as described below.

Virtual Site Audits

Conducting virtual site audits are completed in addition to on-site visits. Virtual site visits allows a preliminary site visit to occur virtually prior to visiting the site inperson. Using technology tools allows an agency to evaluate a site prior to conducing an on-site visit. The following recommendations allow sites to be prioritized and should be considered when conductinga virtual site audit:

1. Avoid power lines
2. Avoid water bodies
3. Avoid installation of counters that point towards traffic (Infrared counters)
4. Avoid areas where people stop and stand around an area (avoid queues)
5. Avoid curves
6. Avoid hills
7. Select locations with pinch points (choke points) that allows a counter to capture all travelers on the facility (such as right before a bridge)
8. Avoid counting at intersections, preferred counting locations are mid-block so that an entire segment can be assigned a traffic volume statistic
9. Look for locations along the facility where a pole, tree, or other structure might be able to serve as part of the counter installation (example: light pole where a video camera can be installed)
10. Review the types of pedestrians and bicyclists traveling on the facility (example, do travelers have

backpacks, paniers, or business attire which would typically indicate commuter travel versus active wear that would indicate recreational travel.)

Conducting virtual site visit requires keeping in mind the next step in the process which is to conduct an on-site field visit. In preparation for visiting the site in person, printing out maps, photographs, or google earth images while conducting the virtual site audit may help when conducting the on-site visit. Bringing notes and stakeholder comments to the site may also help.

On-site Field Visits

The next step is to conduct an on-site field visit. This process can require several days or weeks depending on the number of sites recommended. In preparation for conducting on-site visits, FDOT developed an automated form that could be printed and manually completed on-site as well as electronically filled out on a tablet or laptop. (This form can be provided upon request.)

FDOT strategically collected a lot of information about each site using this electronic form and a separate on-site workbook report has been prepared and finalized.

The process FDOT followed to prepare for each on-site visit includes following the on-site preparation list for conducting the on-site visits listed below.

1. Follow all safety procedures, example: wear boots, hard had, eye protection, ear protection and safety vest when near traffic while conducting on-site visits.

2. Develop schedules with estimated time to drive to sites and on-site evaluation time

3. Schedule site recommendation contacts (stakeholders) to meet on-site (this includes meeting other agency representatives that recommended the site)

4. Printing maps/photos/google earth images and notes provided from the stakeholders

5. Bring paper to take notes about the site conditions while on-site

6. Bring laptop to access electronic forms and workbook sheets as well as prioritization spreadsheet (and print), google maps, etc.

7. Bring camera (phone that takes pictures) to take on-site pictures

8. Bring 100 Foot tape measure

Many observations can be made while on-site that should be noted by documenting site conditions on paper/laptop while on-site. These observations that should be documented include:

1. Observe bicycle, pedestrian, and motorized traffic behaviors (on path, on roadway, direction of travel, etc.)

2. Take pictures of bicycle/pedestrian travelers to determine the best counter installation location

3. Look for the choke points where all travelers will pass within a 12 to 15’ detection zone

4. Look for overhead and underground utilities (it is best to test inductance at the location while on-site to see if there will be any interference)

5. Look at the surface type and note whether it is asphalt, concrete, brick, gravel, etc.

6. Look at facilities to count on-site and make note of sidewalks, roadway, trails, dirt, etc.

7. Look for high traffic volume generators such as hospitals, shopping malls, schools, beaches, etc.

8. Sites should be evaluated as a potential short-term versus continuous counting site (For example, low or no volume sites might only require short-term counting)

9. Document the type of technology suitable for the site (tube, infrared, video, etc.)

Note: all items listed above can be found in the On-Site workbook.

H.3.4 STEP 4 – CREATE PRELIMINARY SITE INSTALLATION SCHEDULES AND START COORDINATING SITE INSTALLATION RESOURCES

Since equipment is not always stocked by vendors, there is typically a gap of time before the equipment is delivered. Agencies can use this gap of time to schedule and coordinate installation resources. Here are a few tips to consider for scheduling and coordinating installation resources:

- Execute partnership agreements – determine if a formal partnership agreement is necessary. For example, if one agency manages the data and the other agency will maintain the equipment, this might be documented in a formal (signed) memorandum of agreement (MOA) outlining responsibilities of each agency.
- Strategically coordinate existing resources – try to optimize resources by finding agencies that have staff that can install and maintain equipment that are already trained and well-versed in traffic counting technologies. Also look for resources that can manage, process, publish, and distribute data.
- Reducing installation costs while increasing equipment purchases – if agency stakeholders have internal or contract staff that can provide the installation of loops, tubes, or cameras, the agency should consider using these resources for the installation of Non-Motorized equipment. If these resources do not exist, the cost of installing equipment will need to be factored into the cost of the data collection at the site. Upon contacting stakeholders, if internal or contract staff can provide equipment installation, additional budgeted funds can be used for purchasing more counting equipment. These strategically coordinated efforts among agencies around the country are partnering and coordinating installation and equipment purchasing to optimize resources and funding.

APPENDIX H – SURVEY FORM

1. What agency do you represent? Please provide contact information – Name, Phone, Email, Agency
Name
Title
Agency
City/Town
Email Address
Phone Number

2. Are any bicycle and pedestrian counts being conducted by your agency?
Yes
No

3. If yes, please provide duration of counts (click all that apply)
0-4 hours
5-24 hours
2 days
7 days
Continuous
Not Sure
Other (please specify)

4. Availability of data? Click all that apply
Electronic file or webpage
Hard copy report
Not Sure
Other (please specify)

5. Format of the data? Click all that apply
Microsoft Excel
Microsoft Access
ArcGIS Shapefile
Other (please specify)

6. Frequency of data collection? Click all that apply
Cyclical (same location(s) over multiple periods of time)
Non-Cyclical (different location(s) over multiple periods of time)
One-time count
Not Sure
Other (please specify)

7. Type of data collection technology used? Click all that apply
Video camera
Tube counts
Passive infrared
Active Infrared
Bluetooth detectors
Loop detection
Microwave or ultrasonic

Manual counts
Not Sure
Other (please specify)

> Within this section, you will be asked to provide recommended locations for an FDOT data collection device. For each location, detailed follow-up questions about the location will follow. You will be offered up to 5 locations to recommend. If you have less than 5 locations to recommend, simply select "No" when asked if you have another location to recommend, and the survey will skip you towards the next section.

8. Within your jurisdiction, where do you recommend FDOT place a data collection device? Please provide the facility name, intersection, and GPS coordinates (if possible). For example: Capital Cascades Trail; Suwannee Street @ E Lafayette Street; 30.4376617,- 84.2754362,21z

Location

9. What is the roadway surface type at the recommended location?
Asphalt
Concrete
Cobblestone/Brick
Gravel/dirt
Other (please specify)

10. What is the purpose of collecting data at this location? Please click all that apply
Safety study
Design study
Before and After infrastructure installation study
Economic study
Transit study
Bicycle/Pedestrian facility usage study
Traffic operations study
General data collection purposes
Other (please specify)

11. What agency is responsible for managing this facility?
Local community (non-government)
City/Town
County
State
Federal
Not sure
Other (please specify)

12. What pedestrian volumes are estimated at this location?
Low (0-100 per day)
Medium (101-500 per day)
High (500+ per day)

13. What bicycle volumes are estimated for this location?
Low (0-100 per day)
Medium (101-500 per day)
High (500+ per day)

14. Do you have a second location to recommend? If you answer "No", you will be skipped to the next section of the survey.
Yes
No

15. Within your jurisdiction, where do you recommend FDOT place a data collection device? Please provide the facility name, intersection, and GPS coordinates (if possible). For example: Capital Cascades Trail; Suwannee Street @ E Lafayette Street; 30.4376617,- 84.2754362,21z
Location

16. What is the roadway surface type at the recommended location?
Asphalt
Concrete
Cobblestone/Brick
Gravel/dirt
Other (please specify)

17. What is the purpose of collecting data at this location? Please click all that apply

Safety study
Design study
Before and After infrastructure installation study
Economic study
Transit study
Bicycle/Pedestrian facility usage study
Traffic operations study
General data collection purposes
Other (please specify)

18. What agency is responsible for managing this facility?
Local community (non-government)
City/Town
County
State
Federal
Not sure
Other (please specify)

19. What pedestrian volumes are estimated at this location?
Low (0-100 per day)
Medium (101-500 per day)
High (500+ per day)

20. What bicycle volumes are estimated for this location?
Low (0-100 per day)
Medium (101-500 per day)
High (500+ per day)

21. Do you have a third location to recommend? If you answer "No", you will be skipped to the next section of the survey.

Yes
No

22. Within your jurisdiction, where do you recommend FDOT place a data collection device? Please provide the facility name, intersection, and GPS coordinates (if possible). For example: Capital Cascades Trail; Suwannee Street @ E Lafayette Street; 30.4376617,- 84.2754362,21z
Location

23. What is the roadway surface type at the recommended location?
Asphalt
Concrete
Cobblestone/brick
Gravel/dirt
Other (please specify)

24. What is the purpose of collecting data at this location? Please click all that apply
Safety study
Design study
Before and After infrastructure installation study
Economic study
Transit study
Bicycle/Pedestrian facility usage study
Traffic operations study
General data collection purposes
Other (please specify)

25. What agency is responsible for managing this facility?
Local community (non-government)
City/Town
County
State
Federal
Not sure
Other (please specify)

26. What pedestrian volumes are estimated at this location?
Low (0-100 per day)
Medium (101-500 per day)
High (500+ per day)

27. What bicycle volumes are estimated for this location?
Low (0-100 per day)
Medium (101-500 per day)
High (500+ per day)

28. Do you have a fourth location to recommend? If you answer "No", you will be skipped to the next section of the survey.
Yes
No

29. Within your jurisdiction, where do you recommend FDOT place a data collection device? Please provide the facility name, intersection, and GPS coordinates (if possible). For example: Capital Cascades Trail; Suwannee Street @ E Lafayette Street; 30.4376617,- 84.2754362,21z
Location

30. What is the roadway surface type at the recommended location?
Asphalt
Concrete
Cobblestone/brick
Gravel/dirt
Other (please specify)

31. What is the purpose of collecting data at this location? Please click all that apply
Safety study
Design study
Before and After infrastructure installation study
Economic study
Transit study
Bicycle/Pedestrian facility usage study
Traffic operations study
General data collection purposes
Other (please specify)

32. What agency is responsible for managing this facility?
Local community (non-government)
City/Town
County
State
Federal
Not sure
Other (please specify)

33. What pedestrian volumes are estimated at this location?
Low (0-100 per day)
Medium (101-500 per day)
High (500+ per day)

34. What bicycle volumes are estimated for this location?
Low (0-100 per day)
Medium (101-500 per day)
High (500+ per day)

35. Do you have a fifth location to recommend? If you answer "No", you will be skipped to the next section of the survey.
Yes
No
This is your fifth and final location to recommend. If you have more than five locations to recommend, please email additional locations directly to Eric.Katz@dot.state.fl.us
OK

36. Within your jurisdiction, where do you recommend FDOT placing a data collection device? Please provide the facility name, intersection, and GPS coordinates (if possible). For example: Capital Cascades Trail; Suwannee Street @ E Lafayette Street; 30.4376617,- 84.2754362,21z w 0
Location

37. What is the roadway surface type at the recommended location?
Asphalt
Concrete
Cobblestone/brick
Gravel/dirt
Other (please specify)

38. What is the purpose of collecting data at this location? Please click all that apply
Safety study
Design study
Before and After infrastructure installation study
Economic study
Transit study
Bicycle/Pedestrian facility usage study
Traffic operations study
General data collection purposes
Other (please specify)

39. What agency is responsible for managing this facility?
Local community (non-government)
City/Town
County

Appendix I –

Motorcycle Data Collection Methods

APPENDIX I. FHWA MOTORCYCLE DATA COLLECTION AND ANALYSIS IN MONTANA

Safety on our nation's highways, including motorcycle safety, is a principal feature of the Infrastructure Investment and Jobs Act (IIJA), the current Federal Transportation Bill. These State and Federal agencies will, eventually, develop motorcycle-related safety programs based on Federal guidelines and will implement these programs with Federal aid monies. For these programs to be successful, the first step must be the collection of reliable motorcycle data. Reliable data results in reasonable motorcycle VMT estimates, necessary to help target areas for safety improvement programs. While the Montana Department of Transportation (MDT) has done limited research on what other states do to collect accurate motorcycle data, the research, coupled with a comprehensive look at MDT's ability to collect accurate motorcycle data, leads us to believe there may be other states that may not know or completely understand motorcycle travel within their respective state as it relates to implementing safety programs.

The principal reasons DOTs may not be able to quantify the accuracy of their motorcycle data can be summarized as follows:

1. Traditionally, motorcycles have not been considered "important" in terms of standard vehicle data collection practices as they make up a small percentage of overall traffic volumes and have minimal impact on road design.

2. Current vehicle data collection equipment and technology focuses on Federal Highway Administration (FHWA) vehicle classification types 2-13; overlooking motorcycles (FHWA type 1). Data collection equipment that does detect motorcycles, does not always classify them correctly. In states like Montana, where laws allow motorcycles to travel side-by-side in a single lane of traffic, accurate motorcycle data collection with currently deployed equipment is virtually impossible.

3. Coverage count collection practices outlined in the Traffic Monitoring Guide do not normally take weekend or special event data into account therefore, motorcycle data estimates derived from current traffic data, are statistically inaccurate. In Montana, a significant amount of motorcycle travel is recreational, or event driven. Missing these aspects of travel can lead to false assumptions about the extent of motorcycle travel. States where weather (seasonality) plays a part in motorcycle travel can be even further off in motorcycle travel estimates if they do not develop solid seasonal factors exclusively for motorcycles.

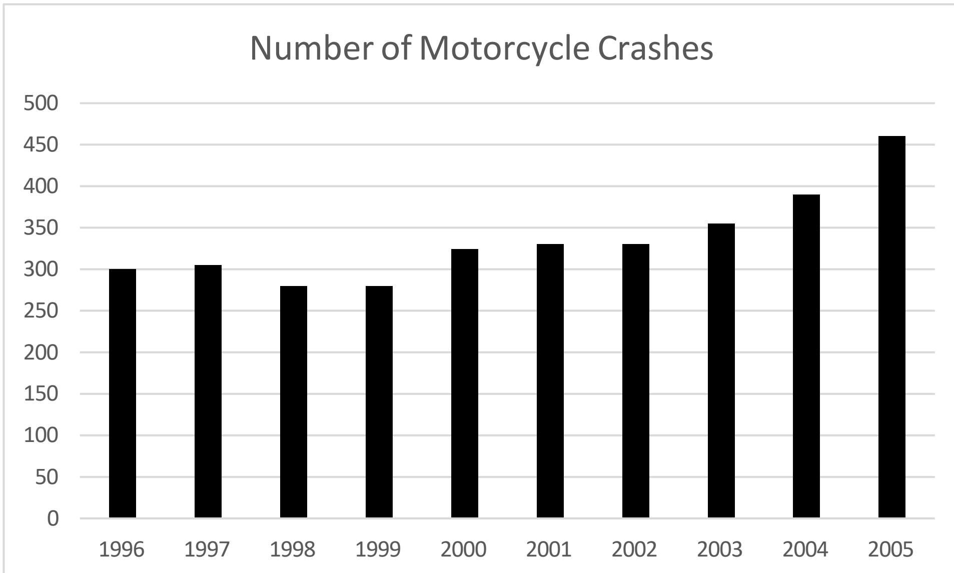
4. Finally, Montana, as is likely the case with other states, is not blessed with surplus resources to properly implement the data collection efforts needed for this type of program.

The FHWA issued an Action memo addressing the collection of motorcycle travel data (January 2007). [1] In the memo, FHWA and the National Highway Traffic Safety Administration (NHTSA) point to an increasing number of motorcycle fatalities nationwide. FHWA concludes better motorcycle data must be obtained to implement a motorcycle-focused safety program. As a result, this memo directed states to report motorcycle travel data, beginning with 2007 HPMS data, in June 2008. FHWA and NHTSA further state that the quality of the data is important and encourages states **"to develop their vehicle classification programs to ensure quality data for this type of vehicle without sacrificing other vehicle classification data."** And, while they are **"confident States will provide quality data that truly reflect motorcycle travel in their State as they fully develop this component of their vehicle classification program considering the guidance in the FHWA Traffic Monitoring Guide"**, FHWA has not put forward guidelines or solutions as to how this data collection is to be accomplished, nor was there a concerted effort put forth to inform or work with the vendors of traffic data collection equipment to try and develop any kind of data collection

[1] ACTION: Motorcycle Travel Data, issued January 30, 2007 by J. Richard Capka, Administrator, FHWA, and Nicole R. Nason, Administrator, NHTSA.

solution.

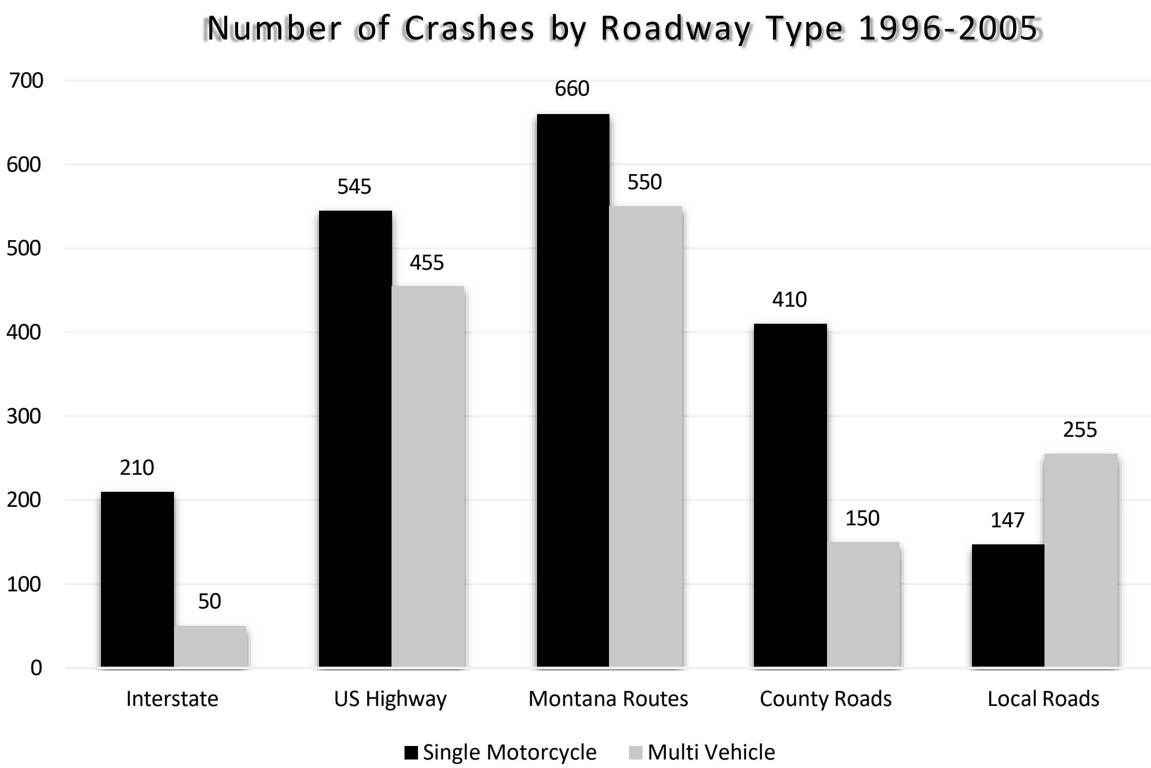
The rise in Montana's motorcycle crashes over the last few years aligns with the national trend. Data compiled by MDT's Safety Management Section shows an increase in motorcycle crashes and indicates that most of the crashes occur on lower functionally classified roads where traffic data collection is limited and cost prohibitive due to the size of the road network.



Source: MDT Safety Management Section

FIGURE I-1: NUMBER OF MOTORCYCLE CRASHES BY YEAR (MONTANA)

Graph from the Montana Department of Transportation's Safety Management Section showing the number of motorcycle crashes occurring in Montana from 1996-2005.



Source: MDT Safety Management Section

FIGURE I-2: MOTORCYCLE CRASHES BY ROADWAY TYPE (MONTANA 1996-2005)

Graph from the MDT's Safety Management Section showing that motorcycle crashes involving 1 or more vehicles occur most frequently on State Highways. Note: Montana Routes includes signed state and secondary routes; County Roads are roads under county jurisdiction, and Local Roads are city streets.

As a result of FHWA's directive, MDT's Traffic Data Collection and Analysis Section (TDCA) was given the task of evaluating its current motorcycle data collection and analysis methods and determining if improvements were needed, and if so, what those improvements might be.

A review of Montana's current motorcycle data collection procedures determined the data will not produce statistically sound motorcycle VMT. As outlined earlier, it is possible to collect motorcycles (FHWA class 1), but MDT's equipment and installation layout principally targets the collection of accurate FHWA classes 2-13.

MDT's continuous count stations use magnetic loop technology (like the loops used to control traffic lights) to detect vehicles. These loops are designed and installed to detect vehicles in a lane of traffic, particularly FHWA classes 2-13. Detecting motorcycles with loops designed for the larger vehicle classes is difficult.[2] Additionally, if a motorcycle is detected by a loop, it must also pass over an axle detection sensor to have its axles counted and the spacing measured to be properly classified in the FHWA scheme. Classification from length-only data is not defined in FHWA schemes for types 1-13.

The problem of capturing accurate motorcycle data with a detecting loop and axle sensor is further compounded by Montana's law which allows motorcycles to travel two abreast in a single lane of traffic. This law (MCA 61-8-359) listed on the official 2007-2008 Montana Highway Map under the "Safety Tips"

[2] See attached document entitled "Motorcycle Classification Issues". Listed in attachments.

section, item 3, states “No more than two motorcycles may be operated in a single traffic lane.”[3] There are no traffic data collection devices currently deployed in Montana that are designed to capture more than one vehicle per lane of travel. Regardless of the technology in use or its capability to detect a motorcycle, detecting and properly classifying two vehicles traveling adjacent to each other in a single lane of traffic with our existing equipment is not possible.

These problems led MDT to look for alternate solutions. The goals are to find ways to collect accurate motorcycle data at permanent and portable sites and produce data files requiring little or no manipulation in the traffic data analysis software. And, since using loops to detect motorcycles pose more problems than it solves, MDT wants to eliminate the loop from the detection system.

One approach to the problem which did not require a change to traffic data collection infrastructure is through statistical analysis of the motorcycle data MDT feels is reliable. This is data obtained during manual counts, conducted at continuous count stations each quarter to verify the accuracy of the data. Cambridge Systematics, Inc. is currently looking into a statistical methodology to estimate motorcycle travel on Montana roads. At the time of this writing, that task has not yet been completed.

FHWA also proposed using odometer readings and motorcycle registration data to estimate motorcycle travel and VMT. At first glance, this appears to be a cost effective and simple method to implement. Unfortunately, upon closer review, utilizing this approach in Montana would produce inaccurate results.

For an odometer readings-based methodology to be statistically sound, the majority of motorcycle owners traveling in Montana have to participate. That would require a legislative act and could only ensure compliance of motorcycle owners living in Montana. Gathering data from local groups, such as motorcycle clubs or associations, to make statistical calculations would skew the statistics as these groups represent only a small part of motorcycle travel in Montana. Tourists and travelers visiting or passing through Montana on the way to an event or destination is a significant component of motorcycle travel within the state. Miles traveled by those groups would not be reported in Montana’s odometer readings, and thus would not be reported in the state’s VMT. Conversely, groups participating in a Montana volunteer program may also travel out of state, making their reported mileage invalid, unless reported by in-state vs. out-of-state travel. It was determined that utilizing odometer readings to estimate Montana’s motorcycle travel is not feasible, especially since the accuracy and completeness of the information would not be easily verifiable.

There are also issues with utilizing motorcycle registration data to estimate travel. In Montana, registration is for the lifetime of the motorcycle, where “lifetime” is defined as the length of time a motorcycle is owned by an individual owner. Some motorcycles used strictly for off-road purposes, may not be registered, while other motorcycles are registered, but rarely, if ever driven, have been sold for parts, etc. Based on this, there is no effective way to use the registration database to estimate motorcycle travel in Montana, whether owned by Montana residents or not. Also, there is no way to estimate out-of-state motorcycle travel in Montana based on registration.

Using motorcycle registration and motorcycle odometer readings would produce questionable motorcycle travel estimates. Montana will not use this methodology even if it is deemed acceptable by FHWA, because the quality of data Montana provides for safety programs will be in doubt.

Next was to look at other technologies. Staff performed internet searches and communicated with several companies looking for a technology that was developed and available for the collection of motorcycle data. This included radar, laser imaging, image (or pattern) recognition, acoustic, and video capture systems. Each system has some limited development in traffic-related applications. For example, radar, acoustic, and video systems are already used to provide traffic volumes and limited classification information (class by length) across multi-lane highways. The problems for these systems are specific identification of a vehicle and identifying vehicles travelling adjacent to each other in a single lane of traffic. As these systems are not mounted in the lanes of travel they can suffer from occlusion if used in a side-fire configuration

[3] 2007-2008 Montana Highway Map is produced by Department of Commerce’s Travel Montana and the Montana Department of Transportation.

(detecting traffic from the side of the road instead of overhead). Video can experience problems of night detection unless the view of the camera is enhanced with a visible or infrared light source or placed in an area with ambient light. Data storage requirements for video can be an issue, as video in any form requires many more bytes of storage than the records produced by radar or acoustic systems. Image recognition systems used to capture and identify license plate numbers or faces in a crowd (airport security) would seem ideal for identifying vehicles, but that type of application is not yet available. This is also true for the laser imaging systems. They have not yet been adapted to vehicle detection. Many of the companies contacted indicated motorcycle detection was "an interesting idea" and they were willing to undertake a research project to develop the technology. Montana does not have the resources to dedicate to this development project. While it is possible that with advancing technology, new systems for accurate classification of vehicles will be developed, that development is not yet widespread.

Since the non-intrusive and emerging technologies did not provide a workable solution, staff took a fresh look at the technologies currently in use in Montana to see if adaptation for accurate motorcycle data collection was possible and practical. More internet research and discussions with neighboring states, Utah, Idaho, and Wyoming, led staff to conclude it is possible to adapt a portable as well as a continuous counter to collect motorcycle data. Additionally, the idea of using video as a means to classify motorcycles by having staff conduct visual counts of the recorded video would allow us to classify all vehicles, thus making the data valuable as an overall classification tool, not just a motorcycle data gathering method. Reviewing recorded video is extremely labor intensive, and with limited resources, MDT cannot implement this as the only method of motorcycle data collection. At this time, video data collection will be limited to urban areas, where the data will be useful for classifying all vehicles, not just motorcycles. We will be able to take advantage of urban street lighting, which will prevent the loss of data at night, eliminating the concern of using non-lighted video recording technology. The implementation of video data collection will develop slowly as Montana does not have the resources to deploy and maintain any substantial number of video collection sites.

Update-February 2014: Montana is implementing video technology to collect data using portable camera systems developed by Miovision Technologies. The accuracy of motorcycle detection with the Miovision system is 90+% using their proprietary video processing software. MDT verified the accuracy by performing visual analysis of several video recordings.

Update-May 2020: Montana uses Miovision's camera technology to conduct between 250 to 300 video counts each year. Montana has not yet expanded collection to capture weekends or special motorcycle events.

Internet research provided MDT with a portable motorcycle count setup known as the "Blocker".[4] This device blocks off road tubes in one half of the lane, effectively dividing a lane of travel into two "half-lanes".[5] Setting the road tubes 6 feet apart gives a reasonably small footprint for the layout, which minimizes misclassification due to vehicles potentially passing while traversing the sensors. [6] The blockers are held in place using nylon webbing that is nailed to the pavement, thus eliminating issues with using asphalt tape (dirty road, rain, removal after use, etc.). The road tubes cover the entire lane allowing classification of FHWA types 2-13 as well. Each "half-lane" simultaneously records the class of type 2-13 vehicles, while individually recording motorcycles. Adjacent motorcycles are recorded as one vehicle in each "half-lane". A single counter with 4 road tube inputs captures classification data for each of the two "half-lanes" (one lane of travel) in one data file. The files are from data collection equipment MDT currently uses so the data format is compatible with the traffic processing software. The type 1 counts from each "half-lane" are totaled together to give the motorcycle volume for that lane of travel. It was decided that totals for types 2-13 from the shoulder-side "half-lane" will represent the class totals for that lane of travel. Two counters will be used per setup to cover both lanes of travel on a two-lane road. This system relies on

[4] Trigg Industries, www.triggindustries.com

[5] See attached drawing: Motorcycle Classification: Temporary and Permanent Layout.

[6] See attached pictures of the layout.

axle detection via road tube impact only: no loops are involved. Being portable, this system can be deployed to target those areas where motorcycle traffic is frequent in Montana, and where we currently have no other data collection coverage.

Testing of this layout proved successful in detecting single as well as grouped motorcycles. The only potential drawback is in the case of tailgating between motorcycles in single file. If the distance between motorcycles, or any two vehicles, is less than 40 feet apart, the two vehicles will be misclassified. The reason for the 40-foot limit is to allow the system to correctly classify the other FWHA types, especially large trucks. Shortening the 40-foot minimum spacing requirement would result in misclassification of those larger vehicles; a consequence of eliminating the loop. While 40 feet seems like a long distance, it is actually the distance from leading edge to leading edge of the center striping on a highway[7]. At posted daylight speed limits, (75 mph for interstate, 70 mph for two lane roads) this distance is covered between 0.36 and 0.39 seconds. While it will occur, operating vehicles this closely together is well beyond the bounds of safety and common sense. From direct observation at various sites throughout Montana, we feel misclassification due to vehicles operating in this unsafe manner will be minimal and will not significantly impact the accuracy of the data.

MDT will put seven to nine of these systems into use this year (2008). This will allow us to collect and analyze data while also focusing our resources to optimize motorcycle data collection efforts.

Update-February 2014: Montana abandoned the portable motorcycle setup for two primary reasons:

1. The labor required to properly set up and maintain the system in the original design configuration is too great to be practical for field technicians to implement along with their other counting duties.

2. The "Blockers" themselves are not constructed to work well with the size of road tube Montana uses and tend to break apart when hit repeatedly by heavy trucks. While there is a specialized road tube that can be purchased for use with the "Blocker", it was decided the extra expense and effort required was not worth the limited amount of data we would collect.

Using the results learned from the portable system, MDT determined it is possible to re-configure a current continuous count system to achieve the same results. Referring to the attached drawing, "Motorcycle Classification: Temporary and Permanent Layout"[8], a potential layout for the conversion of a permanent system shows the placement of the sensors to divide the lanes of travel into "half-lanes", and the elimination of the loop as a means to detect vehicles. The potential tailgating drawback still applies. In this case, one permanent unit can handle four "half-lanes", thus creating one file for the entire two-lane site. MDT will install two continuous count stations in this manner during 2008 and obtain 24/7 data for motorcycle data analysis.

The solutions MDT will implement are designed to target two-lane roadways. Traffic safety information indicates this is where Montana's greatest problems lie. MDT knows this is only the start and coverage will need to be expanded beyond two-lane roadways. Additionally, we need to collect weekend as well as event-type motorcycle travel to develop a more complete picture of motorcycle travel in Montana. Resource availability, particularly manpower, will play a large part in the extent of data collection and how fast the motorcycle element of the program can be expanded. Technology will also have to move ahead so we have more proven methods of accurate motorcycle data collection available to apply to differing collection needs. MDT will work toward greater coverage throughout the state.

Once the data has been collected it needs to be processed and analyzed to provide the information necessary to correctly target motorcycle safety needs in Montana. As mentioned earlier, Cambridge Systematics is currently developing a method for Montana to statistically calculate motorcycle numbers using existing data. This method is not yet complete, so we have not yet assessed its validity. Should it

[7] See attached drawing: Motorcycle Classification: Temporary and Permanent Layout.

[8] See attached drawing: Motorcycle Classification: Temporary and Permanent Layout.

prove to be acceptable, it will be valuable at the start of this program while our data collection capability is still limited.

Update-February 2014: The Cambridge Systematics method relies on insurance and registration records, which, as stated in this report, do not work in Montana due to our registration laws. Also, due to MDT's limited availability of motorcycle data, Cambridge Systematics was not able to provide a viable estimation solution.

To produce accurate VMT estimates, a baseline must be established. This baseline must take weekends and event-based travel into account, along with seasonality and off-system route travel information. Initially, Montana will use the portable setups to target many off-system and local roads, as our database is lacking data on these roadways. Coupled with the first two permanent sites, located on NHS non-Interstate routes, we will get a look at motorcycle travel in Montana and evolve the process to produce better data. Given the current limited capacity, this will take some years to achieve, meaning initial estimates will be very rough. While that may not sound like the best solution, it will be much better than any number produced using motorcycle data collected by previous methods, and it has the built-in potential to improve as more motorcycle capable continuous count sites are converted or installed. Motorcycle VMT procedures and processes needed are being developed and should be in place by the end of 2008.

Update-February 2014: We have successfully implemented a continuous count station with the motorcycle configuration. Initial tests and subsequent verifications have shown the system to be accurate to 97%.

Update-July 2020: Montana currently has 17 of these continuous count stations and plans to install or upgrade other sites. Montana verifies all continuous count stations, for accuracy every quarter (4 times per year) and continue to see greater than 95% accuracy across all classes including motorcycles.[9]

In summary, working to meet the Federal requirements to implement an effective motorcycle data collection and analysis program, the results of which will be used to implement motorcycle safety programs, is not just a Montana problem, but a national problem as well. MDT is concerned that the rapidly implemented Federal requirements will catch some states unprepared to deal with this problem; a problem they may not even know they have. Without cohesive guidelines or support, the results will be poorly targeted and/or result in poorly implemented motorcycle safety efforts, which may not produce the desired benefits. By using and adapting existing technology, MDT believes we can begin moving toward the goals put forth by FHWA in their January 2007 Action Memo. And while collecting accurate motorcycle data is important, understanding the purpose and use of that data, and producing the types of refined data products our data customers need is also important. The better we understand our customer's needs, the better we can design our data collection and analysis program to meet those needs. As we implement MDT's motorcycle data collection and analysis program, the Data and Statistic Bureau will be meeting with the Traffic Safety Bureau and the Safety Management Section to have detailed discussions about their specific motorcycle data needs so we can tailor our motorcycle data collection program accordingly. Montana is taking a pro-active approach to this problem, and while by no means complete or perfect, this approach provides a foundation for an accurate and comprehensive motorcycle data collection and analysis program.

[9] See attached summary and pictures.

List of Attachments

Designed and Implemented by the Montana Department of Transportation Traffic Data Collection and Analysis Section's Electronics Equipment Unit.

Staff: Randy Herbst, Electronic Technologist
John Adams, Electronic Technologist
John McDougall, Electronic Technologist
Ron Wuertley, Electronics Engineer

Author: Ron Wuertley

Updates: Bill Cloud
Tedd Little

Written March 2008

Updated February 2014

Updated July 2020

Updated January 2023

ACTION: Motorcycle Travel Data

January 30, 2007

Mr. J. Richard Capka (Original signed by J. Richard Capka)

Administrator, Federal Highway Administration (FHWA)

(Original signed by Nicole R. Nason)

Ms. Nicole R. Nason, Administrator, National Highway

Traffic Safety Administration (NHTSA)

DWinter x64631

FHWA Division Administrators

NHTSA Regional Administrators

Motorcycle fatalities and the related fatality rate have been significantly increasing over the last 10 years. This has become a serious safety issue for NHTSA and FHWA. Between 1996 and 2005, motorcyclist fatalities increased more than 110 percent and now account for more than 10 percent of all motor vehicle traffic crash fatalities. Over this period, motorcycle registrations increased 61 percent, while the reported Vehicle Miles of Travel (VMT) for motorcycles increased only 8.6 percent, resulting in a 94 percent increase in the motorcycle fatality rate. Since fatality rates based on VMT are the best measure of exposure risk for motor vehicle crashes, it is critical that FHWA receive accurate, complete, and timely VMT data to determine accurate crash rates and to monitor trends. These VMT data (and particularly motorcycle VMT) have been the discussion of recent Highway Performance Monitoring System (HPMS) Reassessment workshops documented in the HPMS Reassessment Safety Issue Paper.

As many of you know, motorcycles are one of the 13 vehicle types monitored by each State's vehicle classification program. These programs are the source of the annual travel data reported by States in the HPMS ("Travel Activity by Vehicle Type" form). Currently, the reporting of motorcycle VMT data in HPMS is optional and consequently, many States choose not to report it. We appreciate the efforts of those States that already are reporting this data, and encourage all States to report these data as part of their 2006 HPMS submittal in June 2007. **The reporting of motorcycle travel will be required for all States beginning with the 2007 HPMS data reported in June 2008.**

The quality of motorcycle travel data is important and we encourage States to develop their vehicle classification programs to ensure quality data for this vehicle type without sacrificing other vehicle classification data. Given the recent trends, there is an immediate need for an accurate measure of motorcycle travel to more clearly determine nationwide crash rates, which will enable us to confidently illustrate trends, to assess impacts of Federal programs, and to perform safety analysis to identify future emphasis areas. We are confident States will provide quality data that truly reflect motorcycle travel in their State as they fully develop this component of their vehicle classification program considering the guidance in the FHWA Traffic Monitoring Guide.

Federal funding for collecting these data is currently available from the Statewide Planning and Research (SPR) program and from NHTSA's Section 408 State Traffic Safety Information System Improvement Grant funds, provided it is included in the Section 408 Strategic Plan.

Please discuss this immediate and critical data need with your State traffic and HPMS staff to assure that these data, if available, are submitted in 2007, and to provide necessary resources and priority for reporting in 2008. Information on funding and technical assistance is available from the following individuals:

HPMS questions:

David Winter at 202-366-4631

Traffic Data Collection questions:

Ralph Gillmann at 202-366-5042

Highway Safety Improvement Program questions:

Robert Pollack at 202-366-5019

NHTSA Safety Program Funding questions

Jack Oates at 202-366-2730

Crash Data Collection Program questions

Dennis Utter at 202-366-5351

We appreciate your continued support of the highway safety programs in your State and look forward to receiving motorcycle travel data in 2007.

Cc: FHWA Directors of Field Services

Motorcycle Classification Issues

Why are motorcycles difficult to classify automatically?

The physical size of the motorcycle compared to the roadway means that motorcycles:

- Can be anywhere in the lane of travel.
- Can be ridden "side by side" in a single lane if more than one motorcycle is present. (See attached drawing and a more detailed explanation below).

Motorcycles are seasonal vehicles with primary usage occurring in the summer months. During this time, many motorcycle-oriented events are conducted throughout Montana and neighboring states.

- The big rallies such as in Sturgis, SD and Billings draw a large number of participants from all over the country.
- Local events held in Montana sponsored by local clubs or dealerships for charity, promotional, or other causes.
- Many local events take advantage of more scenic less congested "back roads" where automatic classification equipment does not exist.
- A large majority of participants in all these activities travel in groups.

Why does the motorcycle's size make it difficult to classify with MDT's current systems?

Typical motorcycle dimensions have a wheelbase of less than six feet, and a width between 18 to 30 inches (not counting the handlebars). There are, of course exceptions to this general description:

- "Hogs" with extra-large saddle bags or front faring.
- "Choppers", which have extended front forks, can make the wheelbase greater than 6 feet.
- Motorcycles with side cars.
- Motorcycles pulling trailers.
- "Tricycles"—motorcycles with a rear axle having two wheels.

To accurately classify any vehicle within the FHWA Scheme F classification definitions, three things must be known:

- The beginning and end of a vehicle. (Identifying a single vehicle).
- The number of axles.
- The spacing between each axle.

Referring to the attached drawing, a typical classification site is laid out to detect vehicles that are:

- In single file.
- Are a minimum of 30 feet apart.
- Occupy at least 50% of the lane width.

To detect an axle, a wheel, or wheels, must physically strike the sensor. As shown in the drawing, the piezo sensor, which counts the number of axles a vehicle has, extends from the shoulder toward the center of the lane covering half of the lane, and is designed to detect the wheels, thus the axles, on the right-hand side of the vehicles. Typical Weigh-In-Motion (WIM) sites utilize piezos that span the entire lane width so all wheels on a given axle are detected at the same time to collect total axle weight.

The loops in the classifier system, which utilize magnetic fields for detection, indicate the presence of a vehicle, the beginning and end and speed of the vehicle, which is used to calculate the space between axles. Note, for a WIM system, a single loop is used to determine the "presence", beginning, and end of a vehicle, while the two piezos are used to determine the number of axles and the speed of the vehicle.

For a loop to detect a vehicle:

- Its magnetic field must be sufficiently "disturbed" to cause a disruption in the flow of the field.
- Disruption is typically caused by passing a metallic mass through the field.
- A large mass (like engine blocks, axles, frames, etc.) passing through a significant portion of the field will achieve detection.
- A small mass (small wheels, small trailers) will not disrupt the field enough to cause detection to occur.

For a system to correctly classify a vehicle, all the sensors must be activated in the proper order. Any sensor that is not activated when a vehicle passes will cause an error in the system, resulting in a classification error.

Given safety factors, legal and other issues, most vehicles are operated in the center of the lane, typically defined by wheel paths that are visual or physical (ruts), or both. Because of their width, most vehicles occupy at least 50% of the lane width and travel in single file.

Motorcycles may legally occupy any part of the travel lane the operator chooses. Because of their width, motorcycles typically occupy less than 30% of the lane, and typically run near the center line or near the shoulder stripe.

Motorcycles:

- Running near the center of the lane will miss the piezo sensor in a typical classification system, causing an error, and will not be classified.
- Running near the center line or near the shoulder stripe will not put enough metal mass into the loop field to cause the disruption necessary for detection. This causes an error and classification will fail.

Why not change the "layout" of the loops to increase the size of the detection field to pick up motorcycles traveling at the edge of the lane?

As noted in the attached drawing, loops are typically centered in the lane, and for maintenance and operational purposes, have traditionally been are placed directly across from each other in adjacent lanes.

Loops:

- Generate a cylindrical magnetic field from each of their "legs" (sides and ends).

- Are sized and placed in a lane so that the bulk of the magnetic field will cover the central part of the lane, but not overlap the adjacent lane.

A rectangular shape for the loop is used so the resultant magnetic detection field is also rectangular in shape. This rectangular field is formed by cylindrical shaped fields generated in each leg of the loop. The cylindrical fields generated by a loop have, in theory, a diameter equivalent to the distance between parallel legs in the loop. Thus, a 5 by 7-foot rectangular loop would generate a theoretical magnetic field with its outside edges forming a rectangle that measures 10 by 14 feet. The interior edges of the cylinders meet at the center of the loop, while the outside edges form the boundaries of the magnetic field at the dimensions listed above. Again, this is the theoretical size and shape of the field but there are many exterior factors that can affect the field.

Some of the factors that affect the size and shape of a magnetic field are:

- Metallic reinforcement material in the pavement (typically in concrete-rebar, metal netting, metal dowel pens, etc.)
- Minerals that are part of the aggregate used in the making asphalt, concrete, and the road base.
- Depth of the loop within the pavement. Think of a barrel floating in a lake that slowly fills with water and begins to sink. As the barrel sinks, its visible width decreases.

As expected, the strongest, or densest, part of the magnetic field lies closest to the physical boundaries of the loop wires. Vehicles traveling legally in a lane will cross some physical part of the loop and place the bulk of their metallic mass within the stronger part of the field and create the necessary disruption to cause detection. Motorcycles that pass through the physical boundaries of a loop may also disturb it enough to cause detection, but as noted before, motorcycles that pass through the edge of the detection field may not disturb it enough for detection.

However, vehicles passing through the edge of the detection field can put sufficient metal mass into the field to cause detection. This is why loops are sized so their fields do not exceed the boundaries of the lanes. Vehicles that drive legally in the lane, but are hugging the center line, can cause detection to occur in the adjacent lane if that adjacent field is sufficiently disturbed.

Physically increasing the size of the loop to occupy more of the lane width will:

- Cause a proportional increase in the magnetic field that will overlap adjacent lanes.
- Provide enough overlapped field area to cause vehicles driving legally in a lane to be incorrectly detected in the adjacent lanes, even if they are not hugging the center line.
- Potentially cause electronic "crosstalk" between loops that are directly opposite each other in adjacent lanes

Staggering the expanded loops by moving them physically apart so they are not opposite each other in adjacent lanes will:

- Cure the electronic "crosstalk" between loops that are directly opposite each other.
- Still cause a field to be generated that will overlap the adjacent lane, resulting in errors being generated by the detection of vehicles that pass in that adjacent lane.

- Provide enough overlapped field area to cause vehicles driving legally in a lane to be incorrectly detected in the adjacent lanes, even if they are not hugging the center line.

Why do groups or "packs" of motorcycles cause classification problems?

Because of their small size, motorcycles traveling in groups tend to ride abreast of each other, something other vehicles cannot legally do, as well as closer to each other in the direction of travel (tailgating distance).

Given the physical size of the loop-piezo configuration:

- It is possible for multiple motorcycles to be within the detection area of the sensors at the same time.
- WIM or classification systems are not capable of separating multiple vehicles, including motorcycles, that are detected at the same time in a single lane of travel.
- The systems see simultaneous detection of multiple vehicles in a single lane as one vehicle.. With motorcycles this means incorrect axle counts and axle spacing.

The results are no classification of any of the motorcycles.

Are other methods or systems available to correctly classify motorcycles and will they work?

There are other technologies available for classification of vehicles that don't use loop-piezo sensors to detect and classify vehicles. Some of these technologies are:

- Road tube (short term counters).
- Infra-red and laser sensor detectors.
- Acoustic sensor detectors.
- Digital radar detectors.
- Video classification systems.
- Video tape.
- Manual observations.

Given the three requirements needed to classify any vehicle within FHWA scheme F definitions:

- The beginning and end of a vehicle. (Identifying a single vehicle).
- The number of axles.
- The spacing between each axle.

Road tube, infra-red/laser, and acoustic sensors can satisfy the three requirements, just like loop-piezo systems. They are also subject to one of the same flaws: ***they cannot distinguish an individual vehicle when multiple vehicles pass through the sensor field at the same time in the same lane of travel.*** They do a better job of identifying single vehicles passing through their sensor fields because they do not rely on metallic mass to determine the "presence" of a vehicle. Road tube and infra-red/laser sensors detect the wheels, thus axles of a vehicle, and acoustic sensors determine the location of the axles by identifying the noise the tires make as they travel on the pavement. These detectors all cover the entire lane with their sensors, so the area of the lane occupied by an individual motorcycle does not necessarily cause a problem.

Digital radar and video classification systems cannot determine the number of axles a vehicle has. They can only determine the beginning and end of a vehicle and they cannot distinguish an individual vehicle when multiple vehicles pass through the detection zone at the same time in the same lane of travel.

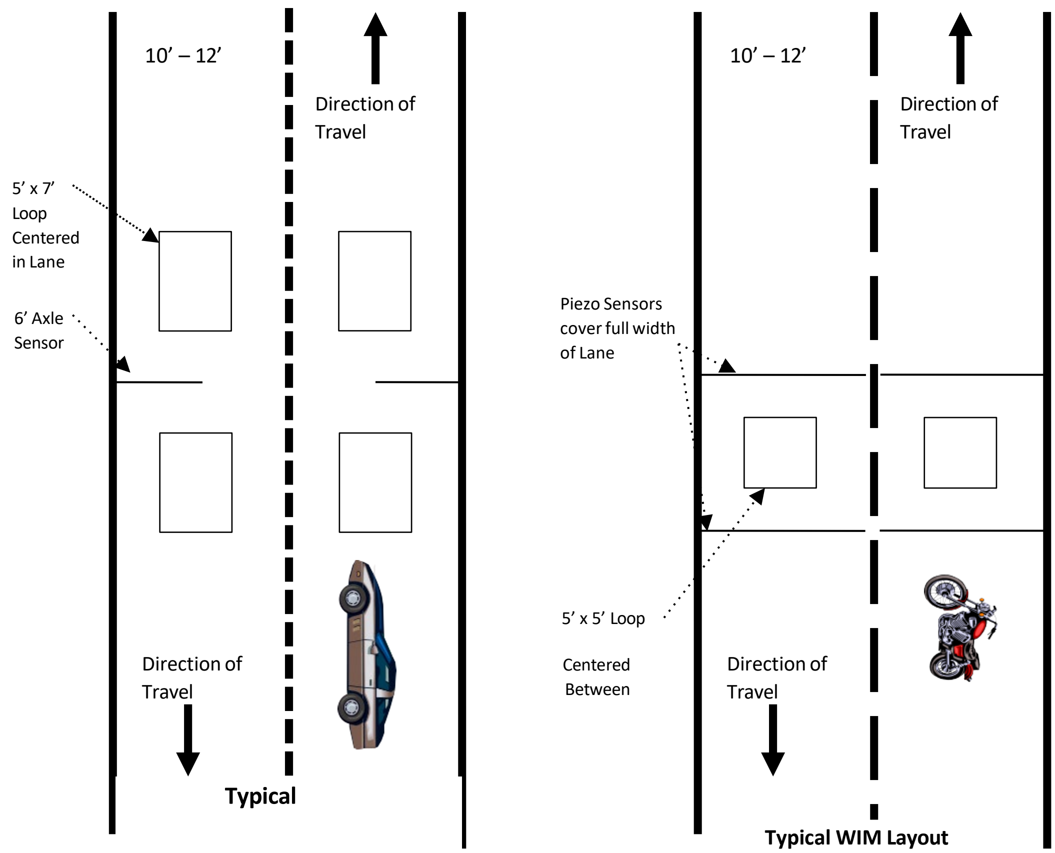
Video tape produces the most accurate recording of the vehicles traveling in a lane but requires someone to manually classify vehicles by watching the video tape. While capable of recording long time periods (using surveillance-type equipment), this method, while potentially 100% accurate, is extremely labor intensive. Reviewing multiple hours of video tape is subject to human error due to fatigue or inattention.

Manual classification has the same pros and cons as video tape with the added problem of being a "one time" observation. Any potential error in observation cannot be reviewed, as could be done with a video tape. An additional problem is the duration of a manual count, which is again subject to human capabilities. The statistical value of manual counts, typically conducted for four hours, to determine actual numbers of motorcycle travel, is highly questionable.

Motorcycle Classification: Temporary and Permanent Layout

Summary

Classification systems are intended to produce accurate class data for all classes of vehicles. Motorcycles, due to their extremely low percentage of the overall volume of vehicles traveling, do not significantly impact the accuracy of a system. Montana is not aware of a vehicle classification system currently available that targets motorcycles only. Trying to adapt current available systems to target motorcycle classification still requires the ability of the system to identify individual motorcycles. As long as motorcycles are not restricted to single-file operation in a lane of travel, accurate individual identification will not be possible with the current technologies used in their present form.



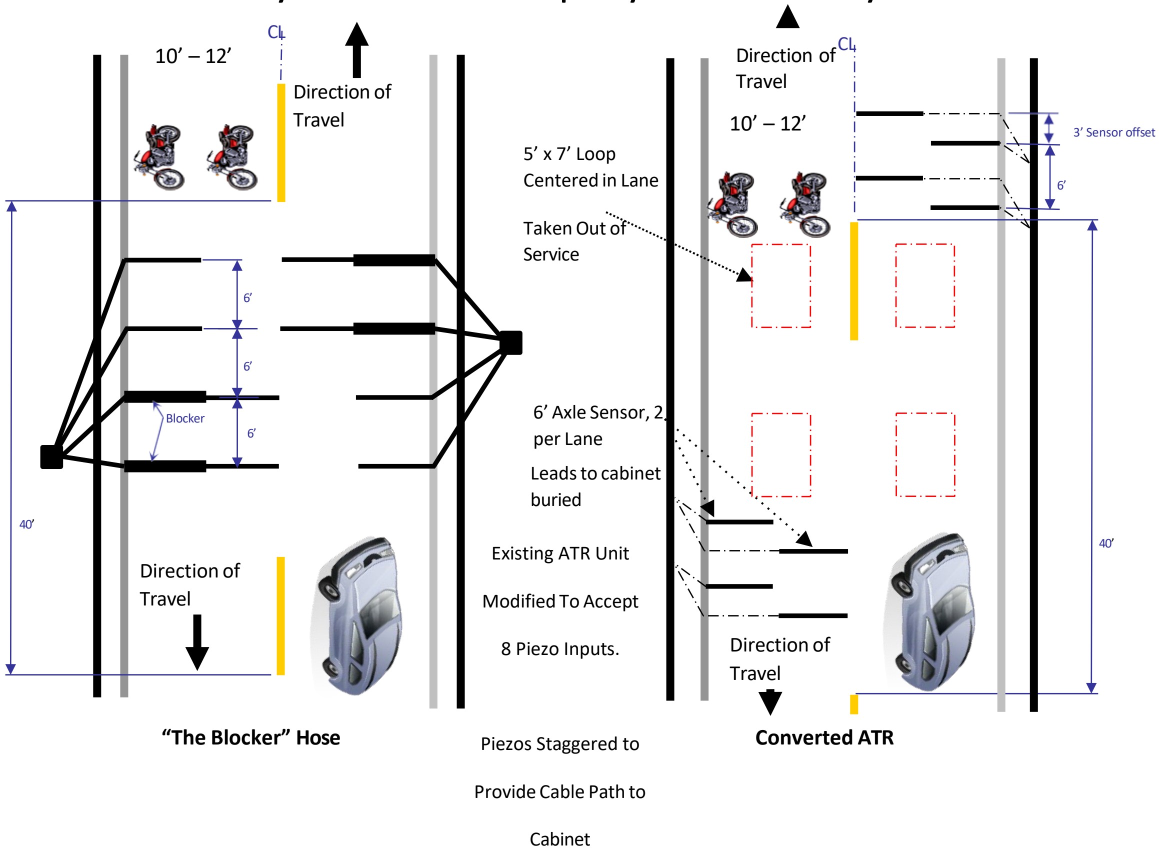
Source: Ron Wuertley, Electronics Engineer, January, 2008

FIGURE I-3: MOTORCYCLE CLASSIFICATION

These diagrams depict typical classification and weigh-in-motion sensor layouts used in Montana.

Note, the layout designs will not accurately classify motorcycles traveling side-by-side.

Motorcycle Classification: Temporary and Permanent Layout

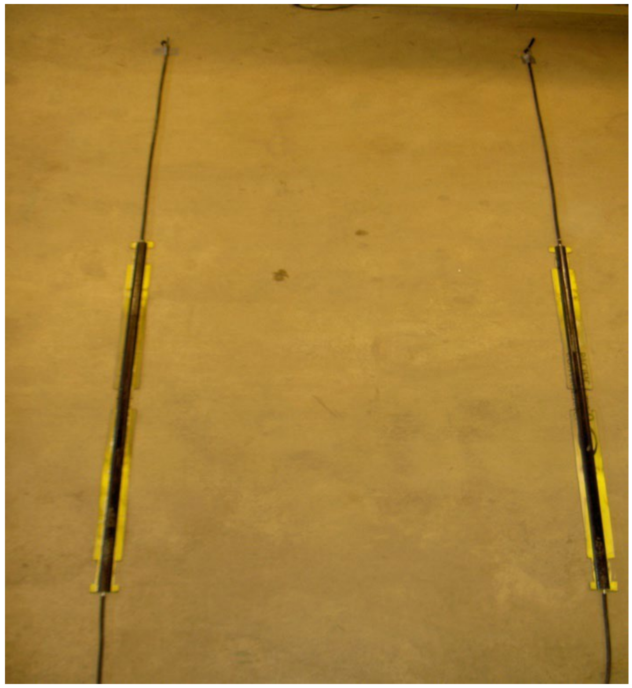


This diagram shows a portable layout using blockers and hoses, and a permanent layout showing potential sensor locations that might be used when converting an existing classification site into a motorcycle-capable class site. The loops have an "X" through them to indicate they will be disabled. Distances between sensors are approximations and will be changed to fit site specific requirements. The portable setup sensor distances work well. The 10-foot spacing between the blockers and the next pair of hoses is not critical, and in practice will probably be reduced to 6 feet.

Source: MDT Traffic Data Collection and Analysis Section

FIGURE I-4: BLOCKER SETUP

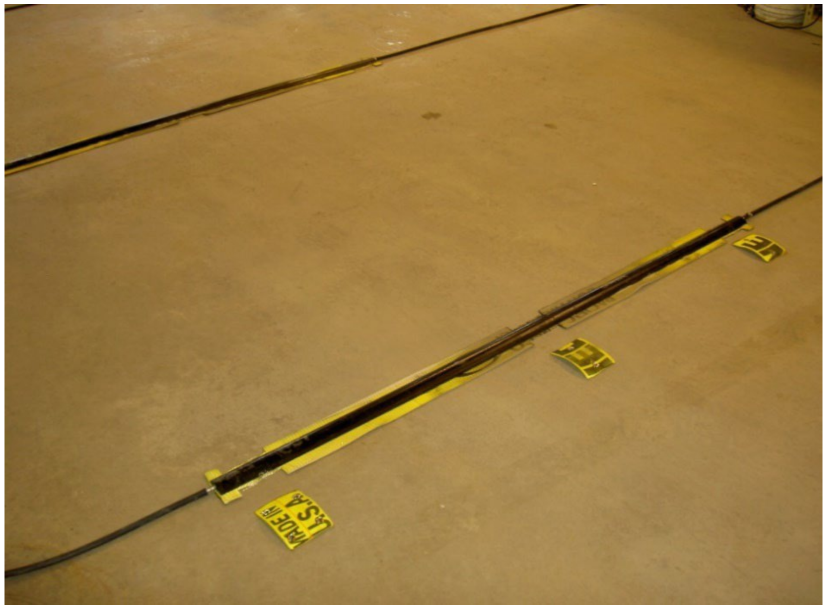
Blocker setup. The blockers are located on the first two hoses at the far left. They "block" the left-hand half lane. The last two hoses, on the other side of the blockers end even with the end of the blockers. They provide the detection for the left-hand half lane. The two short hoses attached to the ends of the blockers and extending out to the right provide the detection for the right-hand half lane.



Source: MDT Traffic Data Collection and Analysis

FIGURE I-5: CLOSE UP OF BLOCKER SETUP

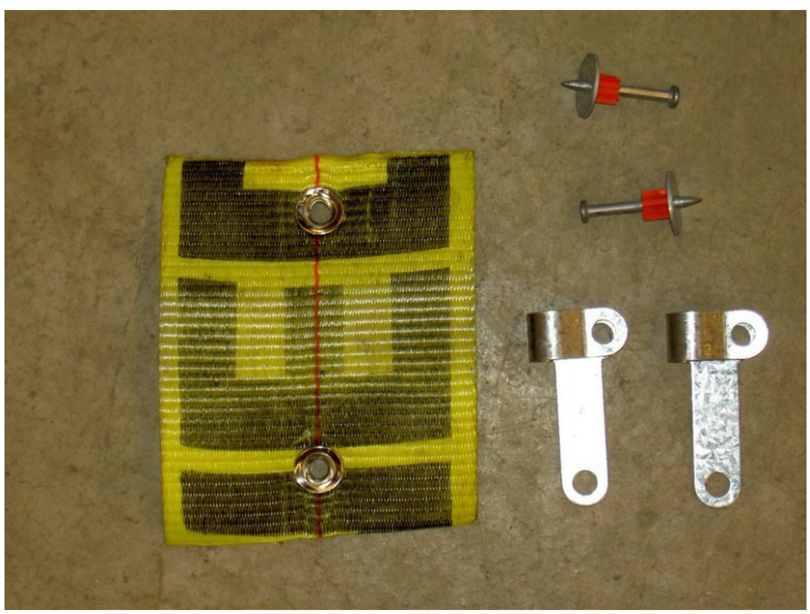
Close up of blockers showing short hoses that detect vehicles in a half lane connected to the ends (hoses at top of picture). The hoses connected to the end of the blocker at the bottom of the picture would go to the counter. The blockers are mounted on a piece of nylon webbing using polyurethane glue. In the grove on the underside of the blocker is a plastic tube with couplers pushed into it, allowing the hoses to be attached to each end of the blocker.



SOURCE: MDT TRAFFIC DATA COLLECTION AND ANALYSIS

FIGURE I- 6: BLOCKER AND STRAPS

Shown next to the blocker are the straps used to hold it in the road. They are placed in the areas where the strap has been notched.



Source: MDT Traffic Data Collection and Analysis

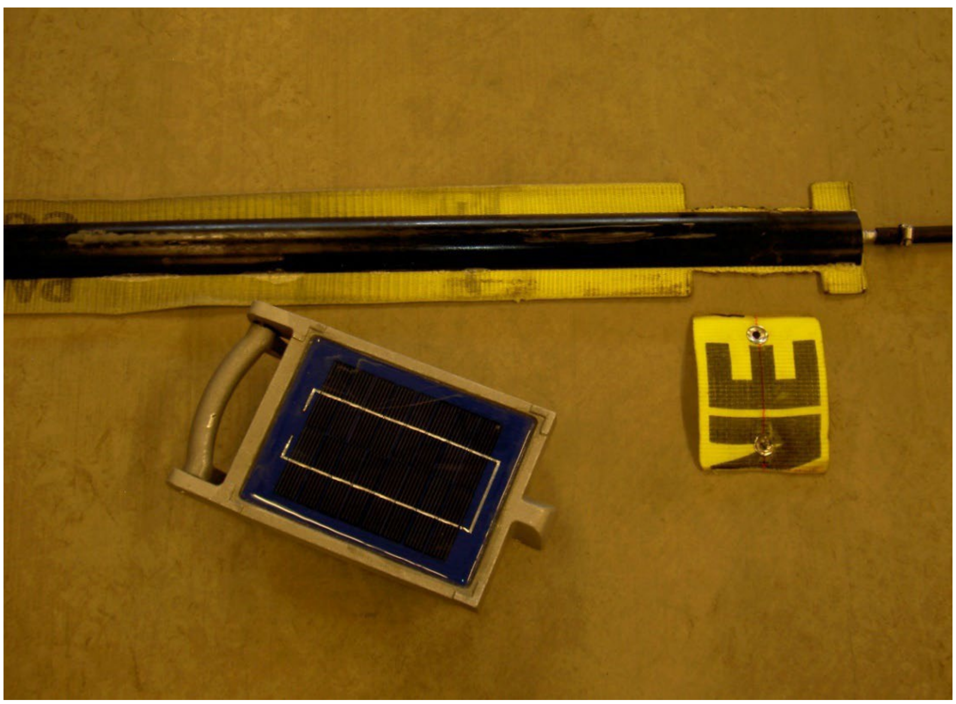
FIGURE I-7: CLOSEUP ON HOLD DOWN STRAP AND HARDWARE

Close up of hold down strap and hardware. The two metal clamps on the right are put over the grommets of the strap, the strap is placed over the blocker, then attached to the road using the construction nails shown at the upper right. The metal clamps provide protection for the grommet and nylon strap material during installation and removal of the nails. The metal clamps are the same ones used with road tube to connect the tube to the pavement.

Source: MDT Traffic Data Collection and Analysis

FIGURE I-8: TUBING WITH COUPLER

The tubing with a coupler placed in the groove of the blocker prior to having the nylon strap glued to the bottom of the blocker. The tube is cut short just for this picture. It normally extends the length of the blocker and has a connector in each end.



Source: MDT Traffic Data Collection and Analysis

FIGURE I-9: TYPICAL COUNTER

Typical counter used to collect data from the blocker setup. Note the hose connected to the end of the blocker is held in place with a small hose clamp.

Motorcycle Site Configuration Details

- **Sensor Type:** MSI-BL Class 1 6 ft. sensor.
- **Electronics: Diamond Traffic Products "Phoenix" model.**
  - Phoenix configured with two piezo boards to handle 8 piezos.
- **Configuration:** Two channels per lane.
- **Layout: 6 ft. spacing between sensors in each wheel path.**
  - Layout is interleaved so the total distance is 9 ft. from first to last sensor in the lane.
- **Maximum axle spacing setting: 40 ft.**
  - Any spacing over 40 feet delineates vehicles.
- **Classification is FHWA 1-13.**
  - Motorcycle totals for each lane are the combined motorcycles from each of the two channels in the lane.
  - FHWA types 2-13 totals may be taken from either channel in a lane MDT uses the outside wheel path channel for these totals.

Sensor Installation Particulars

- **Sensor slot size:**
  - Length—77 in., Width—0.75 in., Depth—1.25 in.
- **Sensor lead cuts:**
  - Width: 0.5 in., Depth:1.5 in. minimum, Length: As needed.
- **Sensor lead protection: Pex tubing.**
  - Pex O.D.: 0.5 inches.
  - Pex I.D.: 0.375 inches (3/8 in.)
  - Pex is purchased as 3/8 inch tubing from retailers that sell Pex-type tubing.
  - The Pex runs from the lead/sensor interface to the pull box, with typically a 1 ft. tail inside the pull box.
- **Installation resin:** MDT uses ECM brand P6G. There are suitable resins available from other vendors.
  - P6G comes in 6 Kg bags w/ One 150 gram bag of catalyst per bag of epoxy
  - Amount of epoxy required per site depends on lane size, shoulder size, cut sizes, and layout configuration. Amounts can vary from 8 to 14 bags depending on the aforementioned parameters.

Pros and Cons of the Design

The Pros

- **Layout Pros:**
  - Tested and verified accuracy is 97% for motorcycle detection. Montana currently operates 17 motorcycle capable sites
    - Note: All of Montana's continuous counter sites (100+) are checked for accuracy once per quarter.
  - Two channels per lane gives accurate motorcycle detection for motorcycles riding side by side in the lane. Montana state law allows this practice on all roadways.
  - No loops. Eliminates the fickle properties of using loops to detect motorcycles.
  - Configuration allows collection of all FHWA classes—not just motorcycles.
  - 6 ft. sensor spacing/9 ft. array spacing allows possible placement of array between transverse cracks in roadway, dependent on transverse crack spacing.
  - Can be installed in roads with ruts due to the flexible nature of the BL sensor.
  - 9 ft. array size minimizes errors due to motorcycles (or any vehicle) passing or changing travel paths while passing over the array.

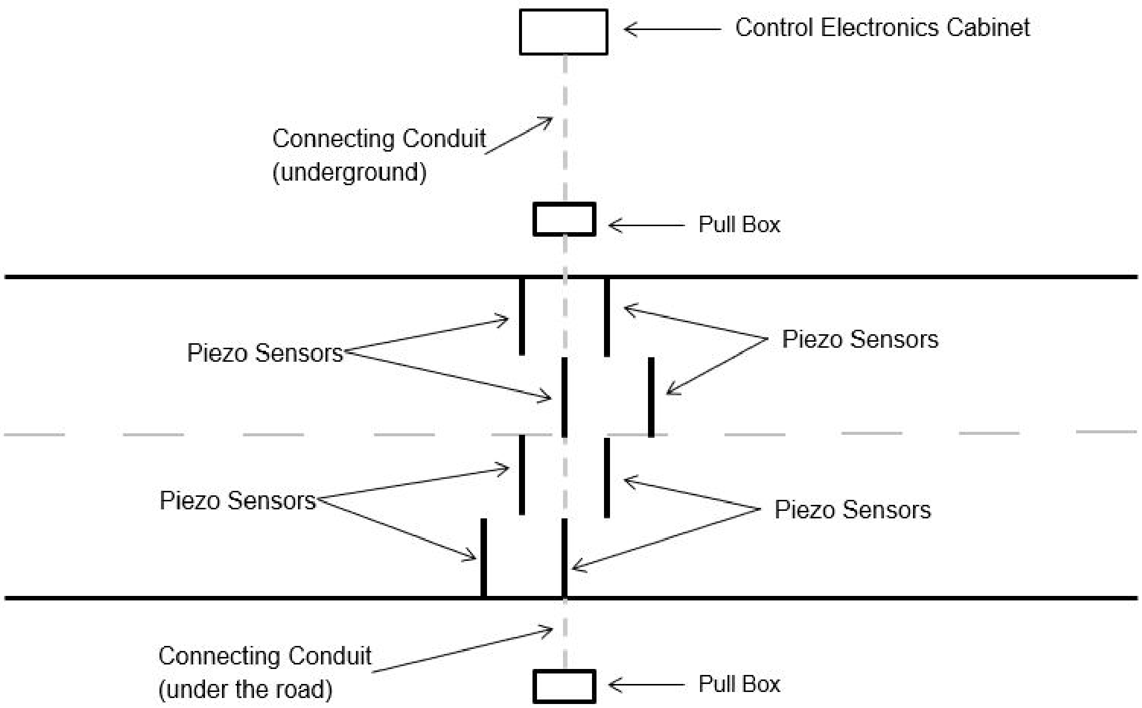
- **Pex Tubing Pros:**
  - Protects the sensor leads from damage due to cracking.
  - Runs directly to the pull box, eliminating the need for conduit between the edge of the pavement and the pull box.
  - Sealing the end of the Pex tubing inside the pull box minimizes freeze-related damage to the sensor leads.
  - If a sensor fails in the road, the only cut that has to be made to replace the sensor is the actual sensor cut itself.
  - The Pex tubing installed with the original installation can be reused for the sensor lead from the road to the pull box without the need for additional cuts.

Pros and Cons of the Design:

The Cons

- **Layout Cons:**
  - Cannot be used in areas where traffic does not flow freely.
  - Cannot be used in areas where traffic regularly tailgates closer than 40 feet apart.
  - Multiple cuts in the road in proximity of each other can cause pavement deterioration issues if the pavement is of poor quality.
  - Multiple cuts of this depth (1.25 to 1.5 inches) can lead to cracking in thin pavements. Minimum pavement thickness of 3 inches is necessary to minimize these effects.
  - Pex tubing cuts must be at least 1.5 inches in depth to ensure an adequate epoxy cap over the Pex tubing in the cut. Most epoxy resins will not adhere to the Pex tubing itself.
  - Although the Pex tubing normally fits snuggly in the cut, variations in cut width can lead to installation issues including loose Pex tubing in the cut. Loose Pex can float up during the resin application, making the cap too thin, which results in resin coming apart and leaving the cut.
  - All epoxy in travel lanes (and shoulders if possible) must be ground or sanded flat with the contours of the road in order to minimize epoxy damage due to traffic.

Schematic Layout of a Continuous Count Site
Motorcycle Configuration

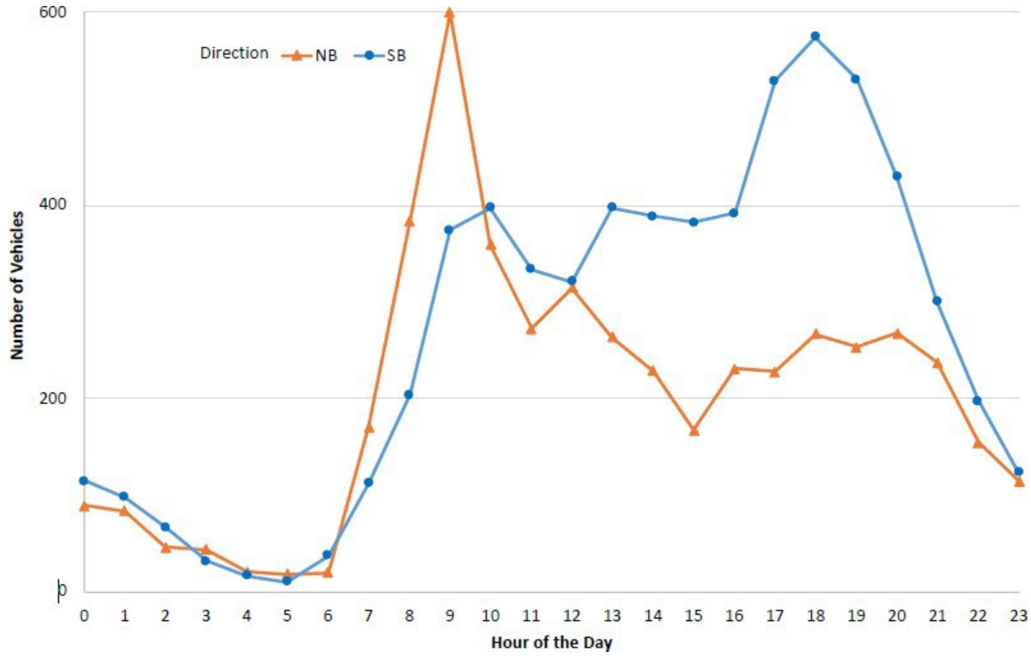


Appendix J –

Traffic Pattern Examples

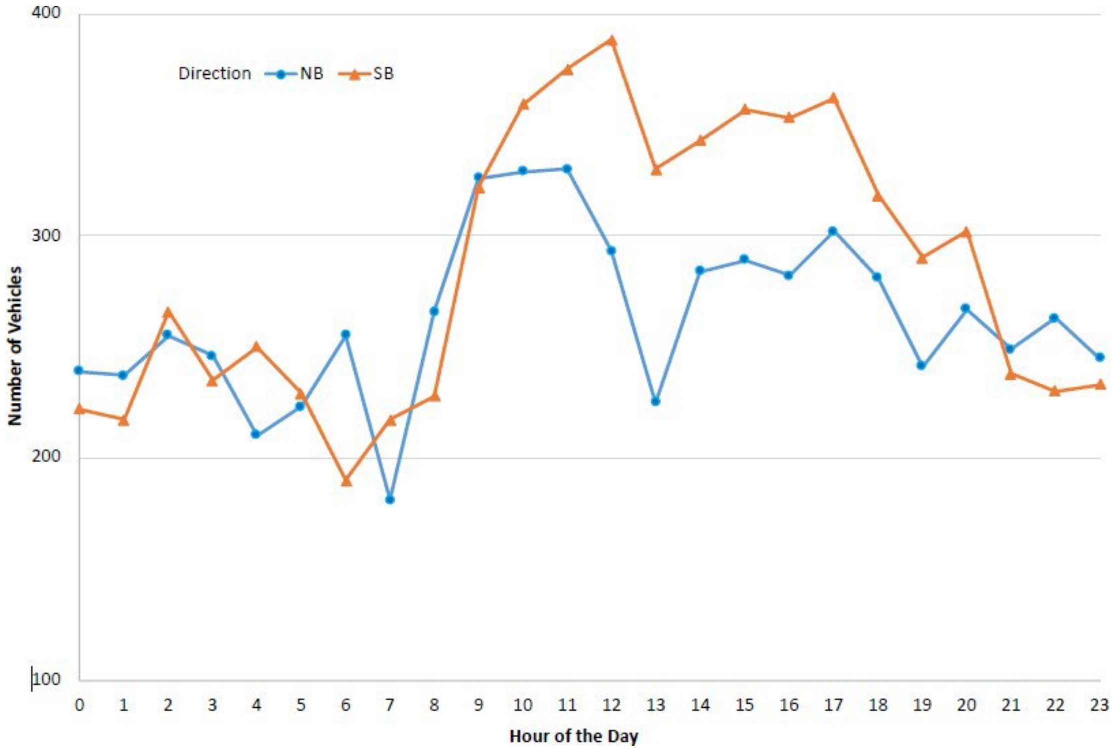
Appendix J. FHWA Traffic Pattern Examples

J.1 Micromobility And Motorized: Hour Of The Day (HOD) And Time Of Day (TOD) Examples



Source: Minnesota DOT

Figure J-1: Hour Of The Day – Passenger Vehicles, Minnesota DOT



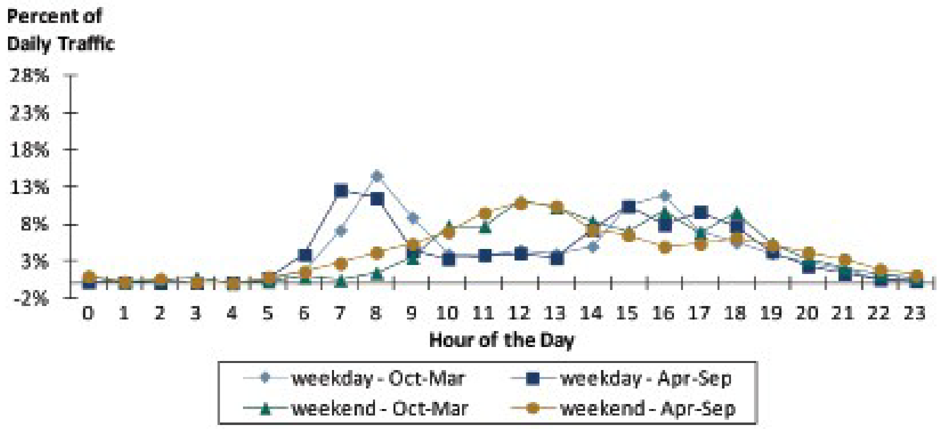
Source: Minnesota DOT

FIGURE J-2: HOUR OF THE DAY – HEAVY COMMERCIAL VEHICLES, MINNESOTA DOT

Figure J-2 has TOD for heavy commercial vehicles.

Figures J-3 shows typical traffic patterns for a permanent monitoring location that has a higher percentage of commuting-based trips:

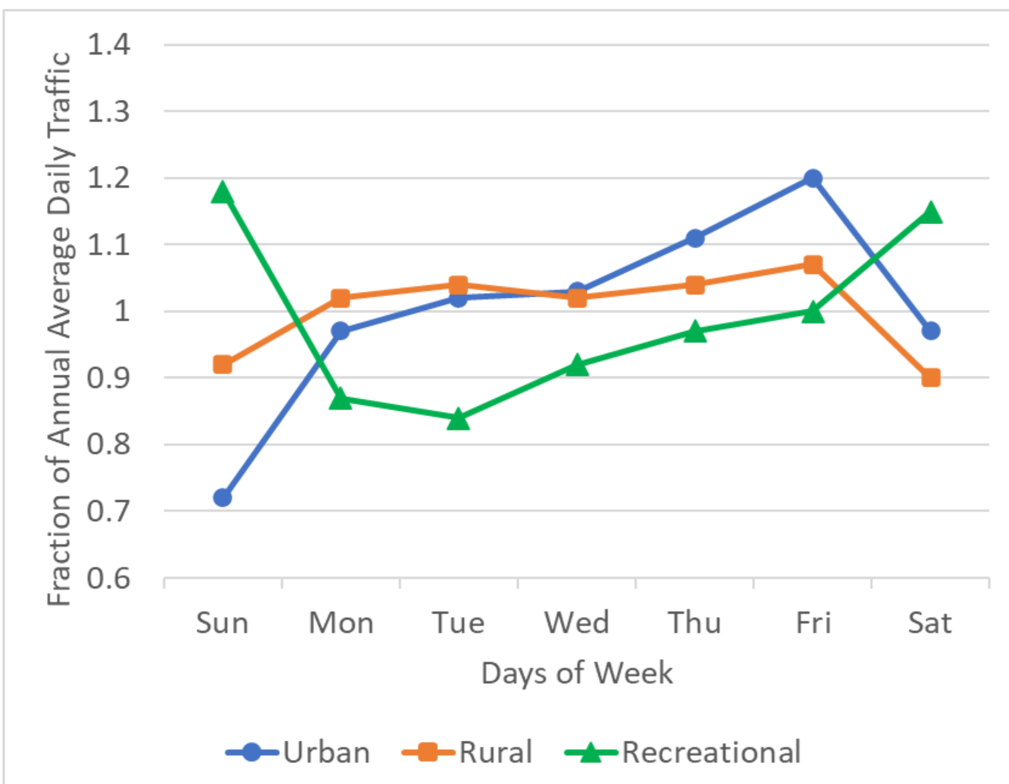
- The time-of-day patterns show strong peaks during the morning and evening, with less traffic during mid-day.
- The DOW patterns show more traffic occurring during the weekdays than the weekends, and the pattern is consistent across all months.
- The month-of-year patterns show less variation throughout the year, regardless of season or climate.



Source: Continuous Count Data, Colorado Department of Transportation, 2010-2011.

FIGURE J-3: 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

J.2 MOTORIZED HOUR OF THE DAY EXAMPLE



Source: Federal Highway Administration. (TTI, Ioannis, Tsapakis)

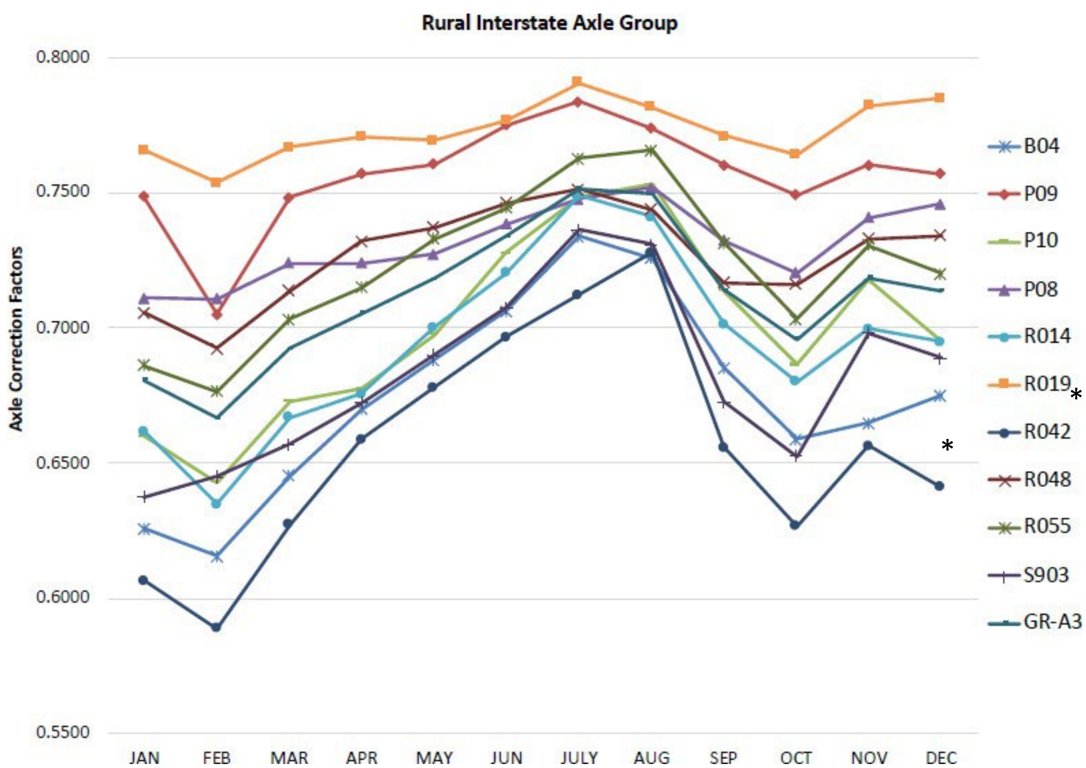
FIGURE J-4: DAY OF THE WEEK VOLUMES (FRACTION OF ANNUAL AVERAGE DAILY TRAFFIC (AVERAGE DAY OF WEEK VOLUME/AADT)) FOR URBAN, RURAL, AND RECREATIONAL SITES

J.3 MOTORIZED MONTH OF THE YEAR EXAMPLE

In the example below, the State of Washington provides an example of a Rural Interstate MOY Axle Factor Group showing data from motorized continuous counting stations.

The chart provided below represents the CY2019 average mid-week (Tue-Thur) axle correction factors by month for the permanent sites making up the Rural Interstate factor group (GR-A3). The average GR-A3 curve is also included in the chart.

This example does not utilize cluster analysis but relies on visual observation of the patterns which is simple and easy to understand and requires no statistical knowledge. As seen in the graph, some sites show an increase in axle factor correction for calculating traffic volumes during the month of June and a decrease in factor corrections in traffic volumes in the month of January.

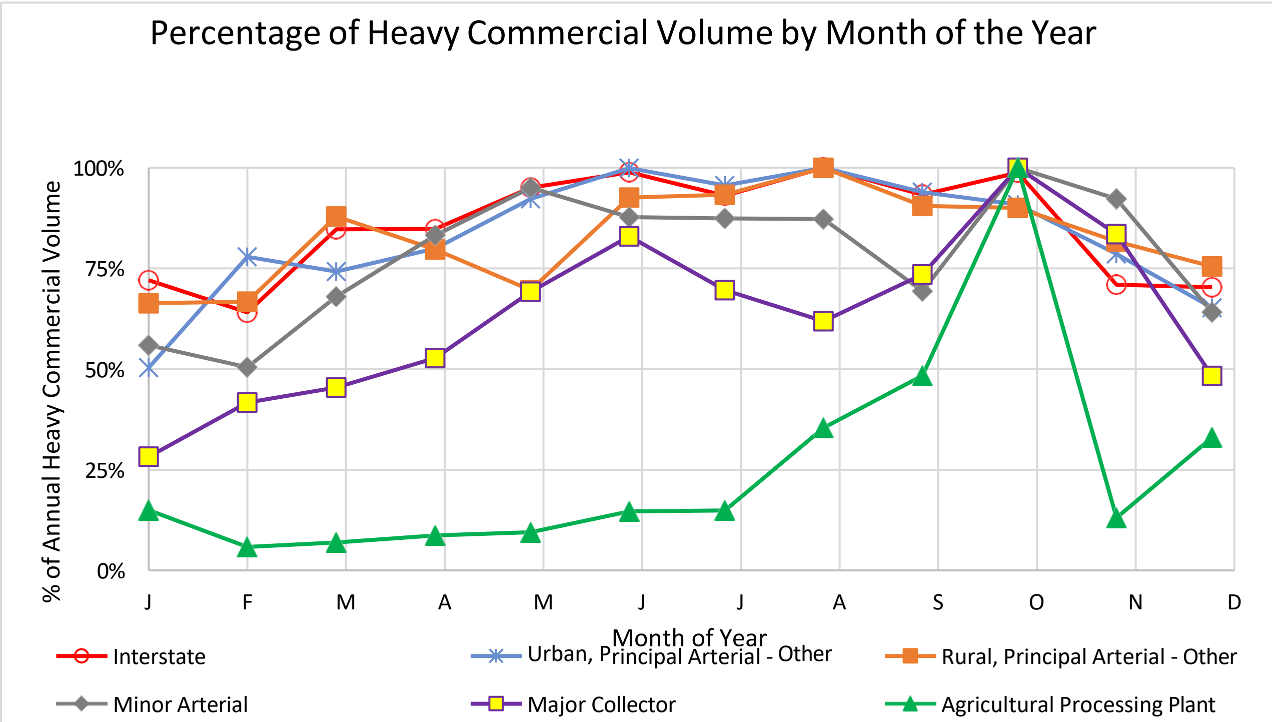


Source: Washington State DOT

FIGURE J-5: MONTH OF THE YEAR – RURAL INTERSTATE AXLE FACTOR GROUP, WASHINGTON STATE DOT

J.4 MOTORIZED WIM DATA MONTH OF THE YEAR EXAMPLE

The WIM station Graph below provided by the Minnesota DOT provides a Month of the Year look at heavy commercial volume by month of the year.

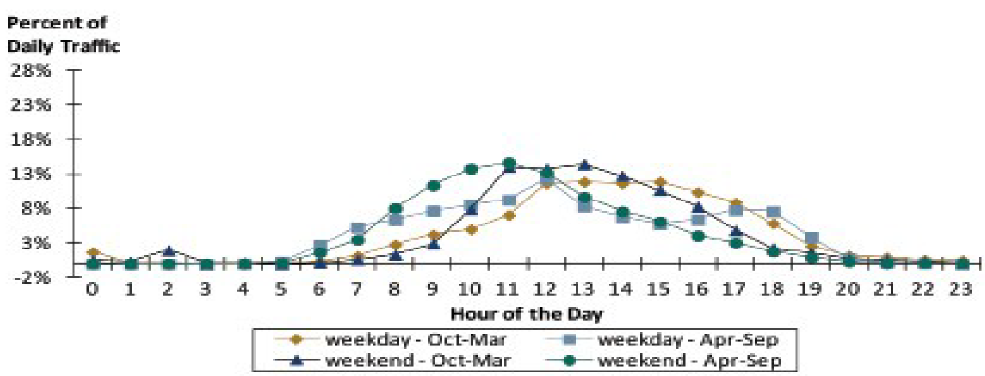


Source: Minnesota DOT

FIGURE J-6: MONTH OF THE YEAR – HEAVY COMMERCIAL VOLUME BY MONTH OF THE YEAR, MINNESOTA DOT

When working with pedestrian and micromobility data, normalizing data helps to illustrate traffic patterns. Data is normalized by taking the MADT and dividing it by the AADT. The figures below show the difference between MADTs and normalized traffic data for identifying MOY traffic patterns for pedestrian and micromobility volume data in Colorado.

J.5 MICROMOBILITY HOD, DOW AND MOY EXAMPLES



Source: Continuous Count Data, Colorado Department of Transportation, 2010-2011.

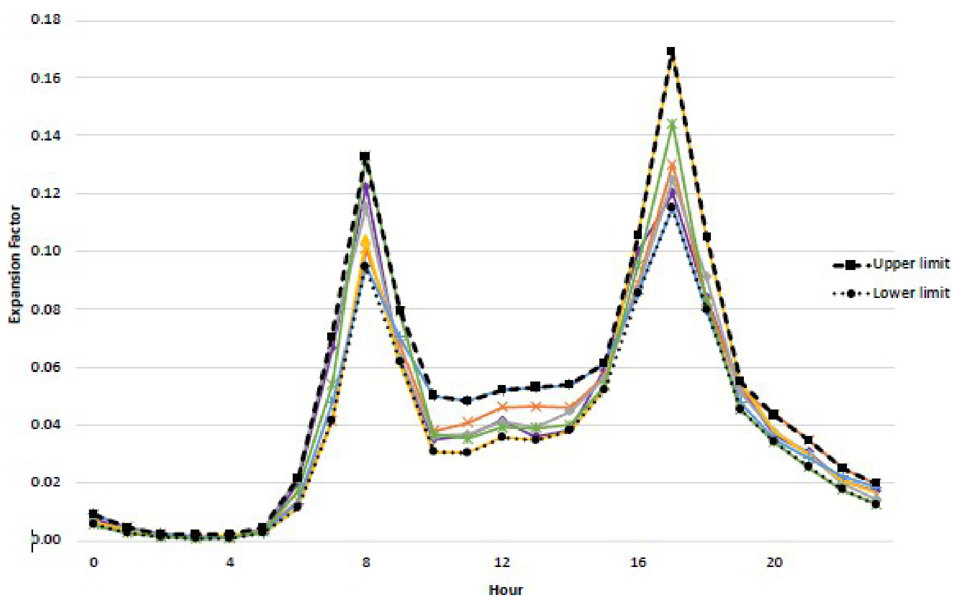
FIGURE J-7: TYPICAL TRAFFIC PATTERNS FOR LOCATIONS WITH HIGHER PERCENTAGE OF RECREATIONAL TRIPS; B90004 US36; 1/1/2011-12/31/2011 – HOUR OF DAY

J.5.1 MICROMOBILITY TRAFFIC PATTERNS

Research findings documented in the "*Monitoring Trail Traffic in the Cincinnati Metropolitan Region, Ohio*" report JPRA-2019-9179, using 78 locations along 15 trail corridors in 2017 showed most traffic patterns indicate the trails are used mostly for recreation use (cycling and walking) and less for commuting. This report also states, recreation mangers should use these results to track trends and prioritize investment in trail development, safety, and maintenance.

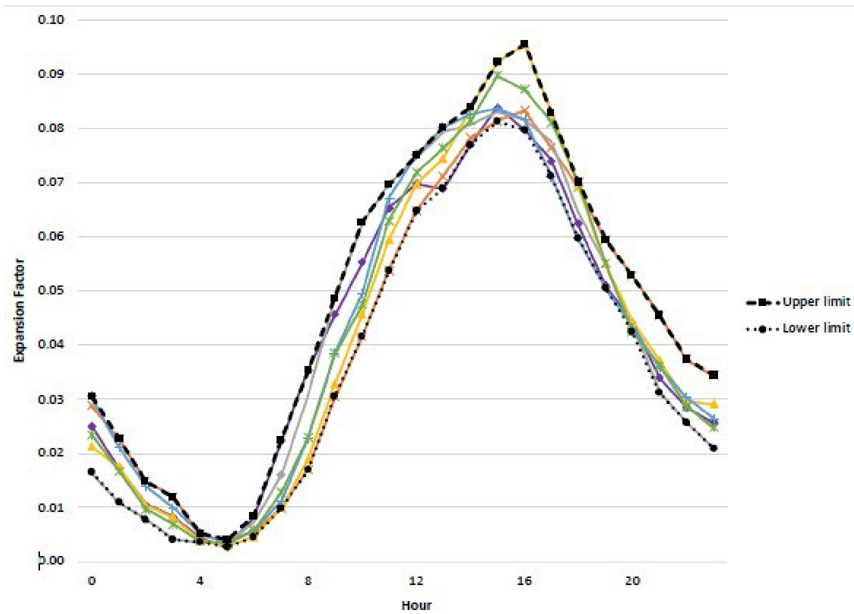
> The TMG recommends that the division responsible for data collection help data users to track trends and prioritize investments in trail development, safety, and maintenance.

Another study, "*Classification of Bicycle Traffic Patterns in Five North American Cities*" (reference Luis F. Miranda-Moreno, Thomas Nosal, Robert J. Schneider and Frank Proulx) provides a summarized analyses results of pedestrian and micromobility data collected stating that seasonal patterns across four different categories of the study location were found to have consistent hourly and weekly traffic patterns across cities, despite considerable differences between the cities in their weather, size and urban form. The study also found that count data showed that the bicycle volume patterns at each location could be classified as utilitarian, mixed utilitarian, mixed recreational, and recreational. Figure J-8 shows data graphed by time of the day (TOD) from the data collected for the study.



Source: "Classification of Bicycle Traffic Patterns in Five North American Cities." Luis F. Miranda-Moreno, Thomas Nosal, Robert J. Schneider and Frank Proulx.

Figure J-8: Time Of The Day (TOD) - Pedestrian And Micromobility Data A

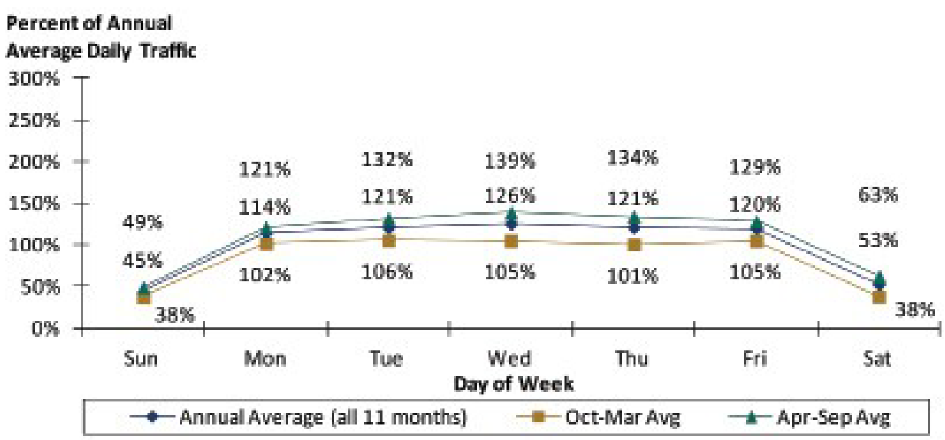


Source: "Classification of Bicycle Traffic Patterns in Five North American Cities." Luis F. Miranda-Moreno, Thomas Nosal, Robert J. Schneider and Frank Proulx.

FIGURE J-9: TIME OF THE DAY (TOD) - PEDESTRIAN AND MICROMOBILITY DATA B

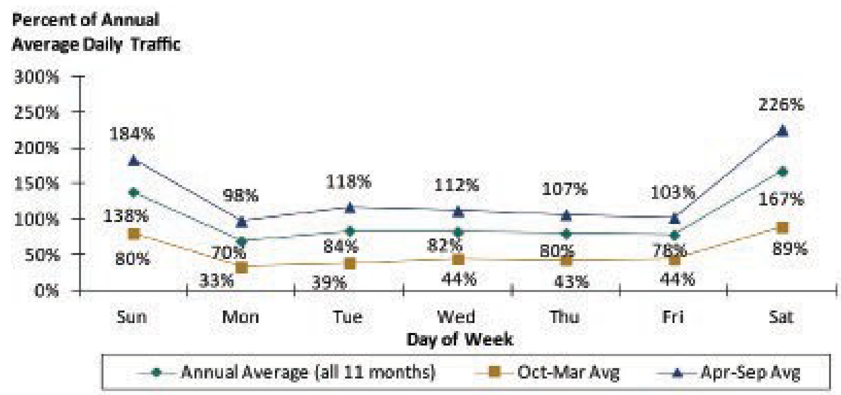
J.5.2 PEDESTRIAN AND MICROMOBILITY TIME OF DAY EXAMPLE

The time-of-day variation for mixed-mode (i.e., pedestrians and bicyclists), nonmotorized traffic at a single location is shown in Figure J-9. The time-of-day patterns for nonmotorized traffic data will vary by location and trip purposes. Diurnal peaking patterns can be seen during the weekdays for nonmotorized traffic; however, the nonmotorized peaks are less pronounced than the car and truck peaks. The weekend profiles for nonmotorized traffic have a single peak (same as rural cars), but the nonmotorized peak is mid-day (as opposed to an evening peak for rural cars) and is much more pronounced (12%-13% for nonmotorized as compared to 8% for rural cars). For this trail in Colorado, the time-of-day patterns for nonmotorized traffic do vary by season of the year.



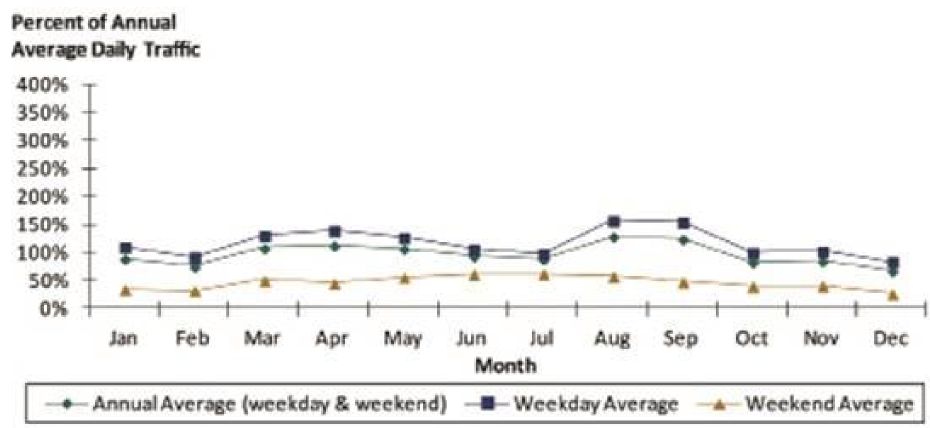
Source: Continuous Count Data, Colorado Department of Transportation, 2010-2011.

Figure J-10: TOD For Mixed-Mode Nonmotorized Traffic at Single Location



Source: Continuous Count Data, Colorado Department of Transportation, 2010-2011.

FIGURE J-11: 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 J-12: TYPICAL TRAFFIC PATTERNS FOR LOCATIONS WITH HIGHER PERCENTAGE OF COMMUTING TRIPS; B90007 6TH AVENUE/VAUGHN STREET; 1/1/2011-12/31/2011 – MONTH OF YEAR

Figure J-12 shows typical traffic patterns for a permanent monitoring location that has a higher percentage of recreation-based trips:

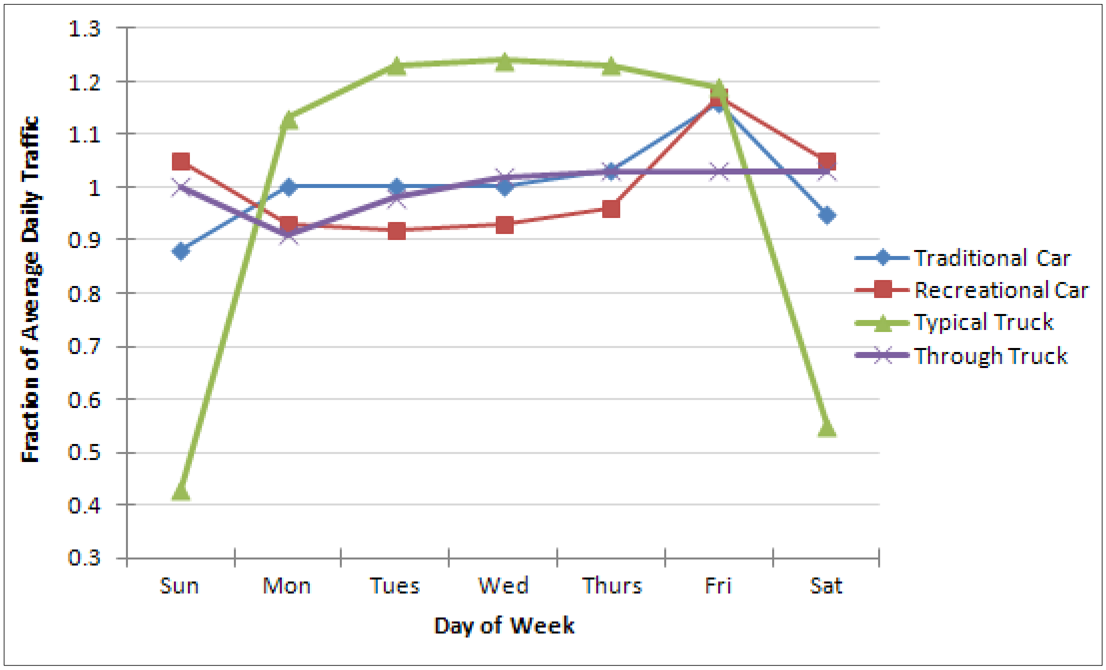
- The time-of-day patterns (Figure J-7) show a single strong peak during the middle of the day, with little or no morning and evening peaks.
- The DOW patterns (Figure J-11) show more traffic occurring during the weekends than the weekdays, and the levels vary by season.

J.6 TRUCK DAY OF THE WEEK VARIATION EXAMPLE:

J.6.1 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 J-13. 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.



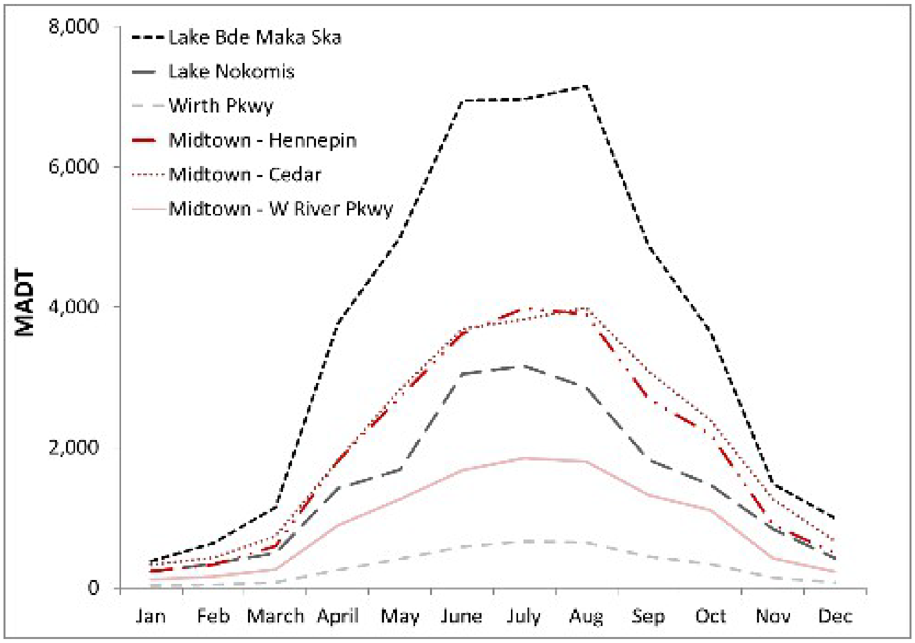
Source: *Hallenbeck, et al.,* Vehicle Volume Distributions by Classification, *1997.*

FIGURE J-13: TYPICAL DAY-OF-WEEK TRAFFIC PATTERNS

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 vastly 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.

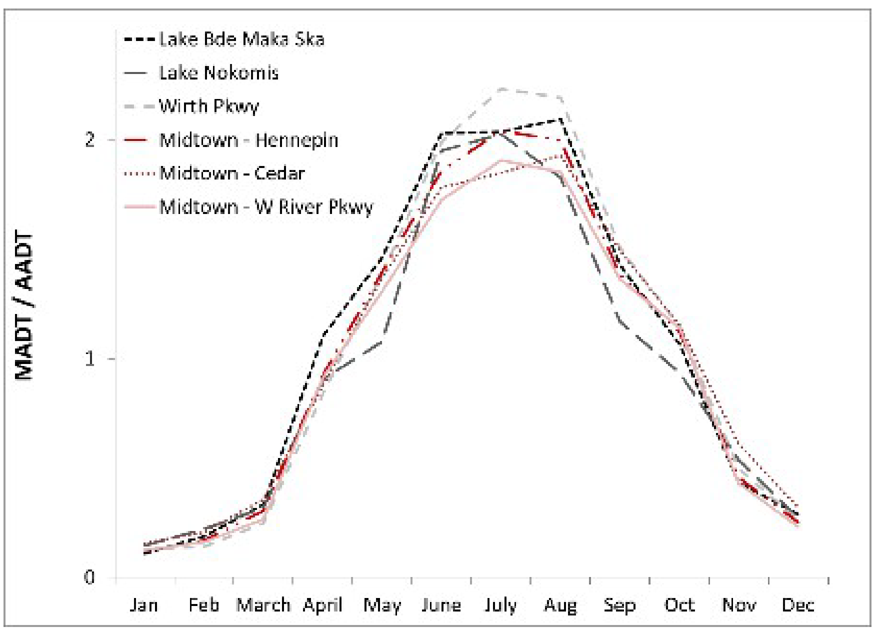
These significant changes in traffic volumes during the week have several effects on the traffic monitoring program. Most importantly, the monitoring program should collect data that allow a State to describe these variations. Second, the monitoring program should allow this knowledge to be shared with 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.

J.7 MICROMOBILITY MONTH OF THE YEAR EXAMPLE:



Source: Hankey, S., Lindsey, G., & Marshall, J. (2014). Day-of-year scaling factors and design considerations for nonmotorized traffic monitoring programs. Transportation Research Record, 2468(1), 64-73

FIGURE J-14: MONTHLY AVERAGE DAILY TRAFFIC (MADT) BY MONTH OF THE YEAR AT SIX LOCATIONS



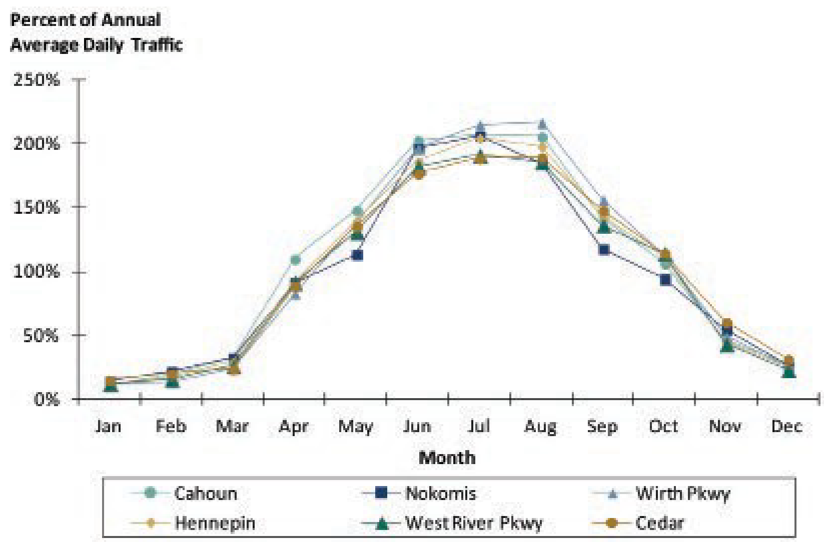
Source: Hankey, S., Lindsey, G., & Marshall, J. (2014). Day-of-year scaling factors and design considerations for nonmotorized traffic monitoring programs. Transportation Research Record, 2468(1), 64-73

FIGURE J-15: MADT/AADT (ANNUAL AVERAGE DAILY TRAFFIC) RATIOS FOR MIXED MODE TRAFFIC AT SIX LOCATIONS

Monthly Average Daily Traffic (MADT; Figure J-14) and MADT normalized (Figure J-15) by Annual Average Daily Traffic (AADT) for 6 urban trail locations in Minneapolis, MN. Grey scale lines are for predominantly recreational trails around waterways; red scale lines are for locations on the Midtown Greenway. Although total traffic volumes vary greatly among locations, when normalized by AADT, all locations demonstrate similar seasonal patterns.

Figure J-14 shows an example of a typical TOD distribution for total traffic volume from a monitoring site in Minnesota that collects traffic data in different directions for the same roadway. 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 show a single daily peak (as travelers go to and from their recreational destination). TOD factors for trucks are typically different than those observed for cars or for total volume. Temporal TOD distributions can be obtained from data collected at both short-term and permanent count sites. TOD factors obtained from permanent count sites provide insights into how travel by TOD changes by day of week, and for specific times of year—such as summer weekend traffic patterns.

Below are some examples showing TOD traffic monitoring patterns provided by the Minnesota DOT. These graphs show the TOD for passenger vehicles and for heavy commercial vehicles. WIM equipment is installed between a staging area for sugar beets and processing plants that are generally in operation 24 hours a day during the harvest season.

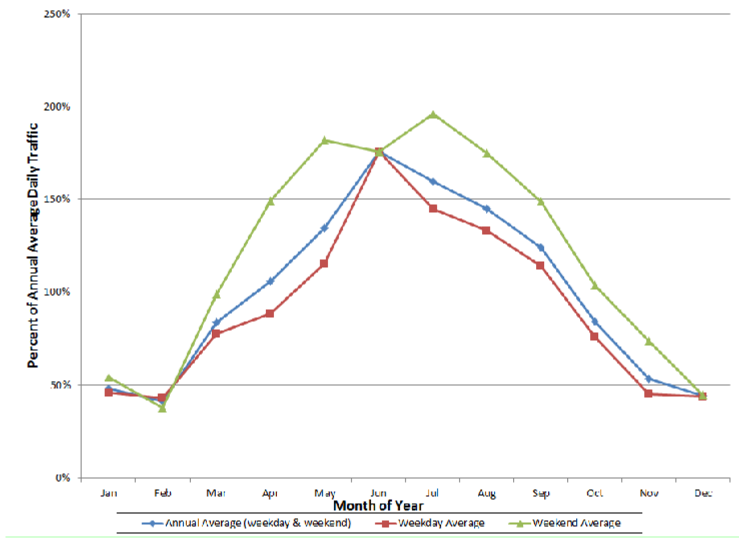


Source: Greg Lindsey, University of Minnesota.

FIGURE J-16: MONTHLY PATTERNS FOR SIX SHARED USE PATH LOCATIONS IN MINNEAPOLIS, MINNESOTA

J.7.1 PEDESTRIAN AND MICROMOBILITY MONTHLY VARIATION EXAMPLES

The monthly variation for mixed-mode, nonmotorized traffic at a single location in Colorado is shown in Figure J-17. The overall monthly patterns are like the rural car and truck patterns; however, the monthly patterns over time (seasonality) for pedestrian and micromobility traffic is much more pronounced. For example, the peak summer pedestrian and micromobility traffic during July is about 200%, or nearly twice the annual average. The winter pedestrian and micromobility traffic (November through February) is about 50%, or one-half of the annual average. Figure J-17 clearly demonstrates the monthly (seasonal) effects on nonmotorized traffic at this Colorado location.

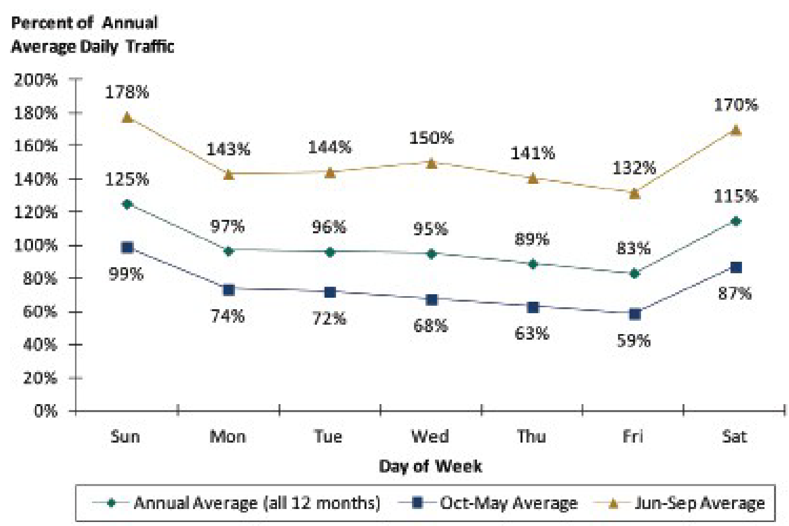


Source: Cherry Creek Trail continuous count data, Colorado Department of Transportation, 2010.

FIGURE J-17: MONTHLY PATTERNS FOR A COLORADO SHARED USE PATH

J.7.2 PEDESTRIAN AND MICROMOBILITY DAY OF WEEK EXAMPLE

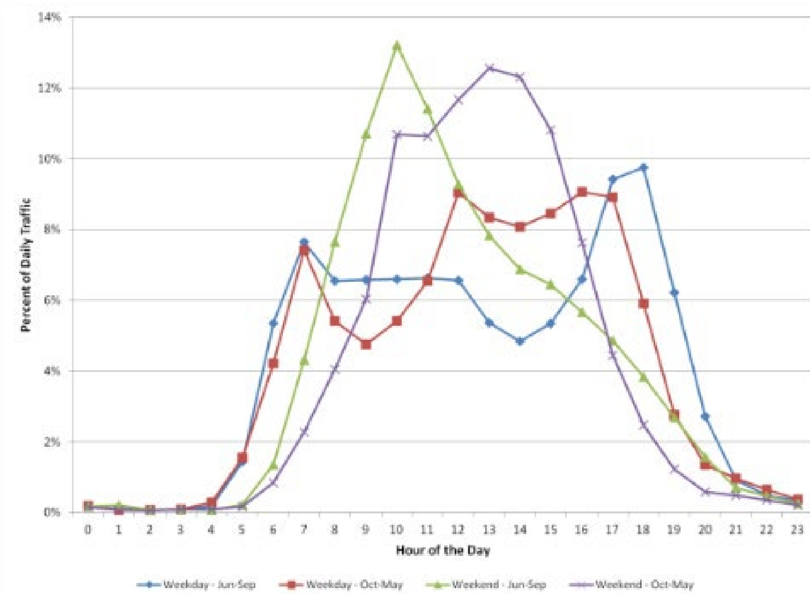
The DOW variation for mixed-mode nonmotorized traffic at a single location is shown in Figure J-18. The overall profile of the nonmotorized traffic is similar to the recreational car or through truck as shown in Figure J-13. However, the weekend traffic is more pronounced for the nonmotorized trail traffic. The other significant difference is how the magnitude varies by season of the year.



Source: Cherry Creek Trail continuous count data, Colorado Department of Transportation, 2010.

FIGURE J-18: DOW PATTERNS FOR A COLORADO SHARED USE PATH

The DOW patterns shown in Figure J-18 are averaged over a full year. The actual day-to-day variation of nonmotorized 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 nonmotorized traffic.



Source: *Cherry Creek Trail continuous count data, Colorado Department of Transportation, 2010.*

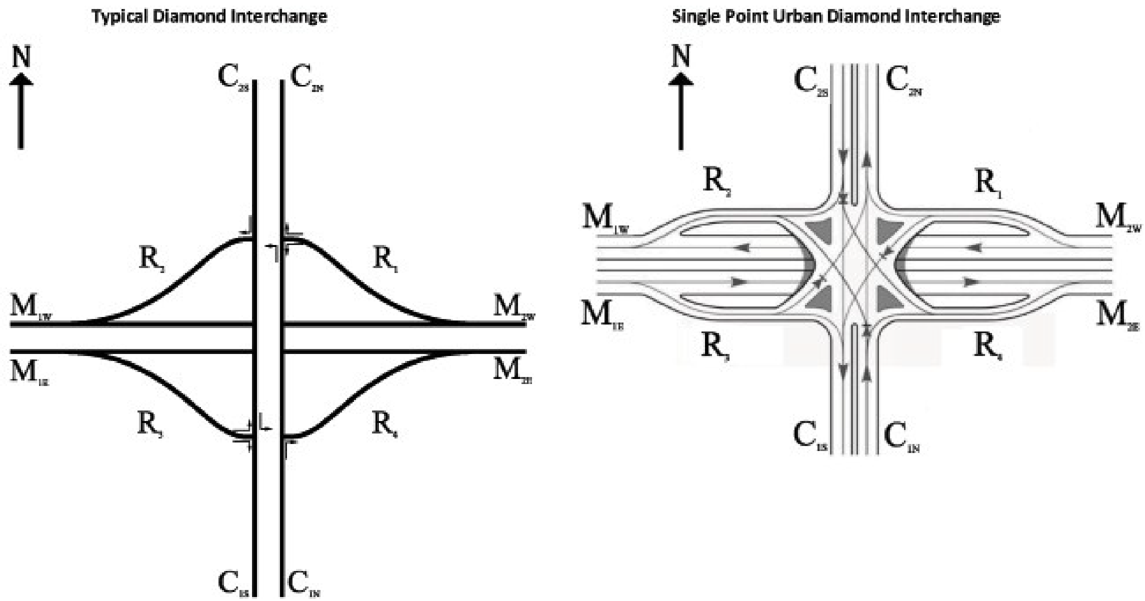
Figure J-19: Time-Of-Day Patterns For A Colorado Shared Use Path

Appendix K –

Typical Interchange AADT Estimation

Appendix K. TYPICAL INTERCHANGE AADT ESTIMATION

The following are equations and example computations of using relevant data to compute unknowns rather than field counting for the most common interchange configurations.



Source: Federal Highway Administration.

FIGURE K-1. TYPICAL DIAMOND INTERCHANGES

Mathematical Formulas

$$R_1 = \left(\frac{C_{1S}+C_{2S}}{C_{1S}}\right)[C_{1S} - C_{2S}] + \left(\frac{C_{2S}}{C_{1S}}\right)[R_2 - R_4] - R_3 \quad (1)$$

$$R_2 = (M_{1W} - M_{2W}) + R_1 \quad (2)$$

$$R_3 = \left(\frac{C_{1N}+C_{2N}}{C_{2N}}\right)[C_{2N} - C_{1N}] + \left(\frac{C_{1N}}{C_{2N}}\right)[R_2 + R_4] - R_1 \quad (3)$$

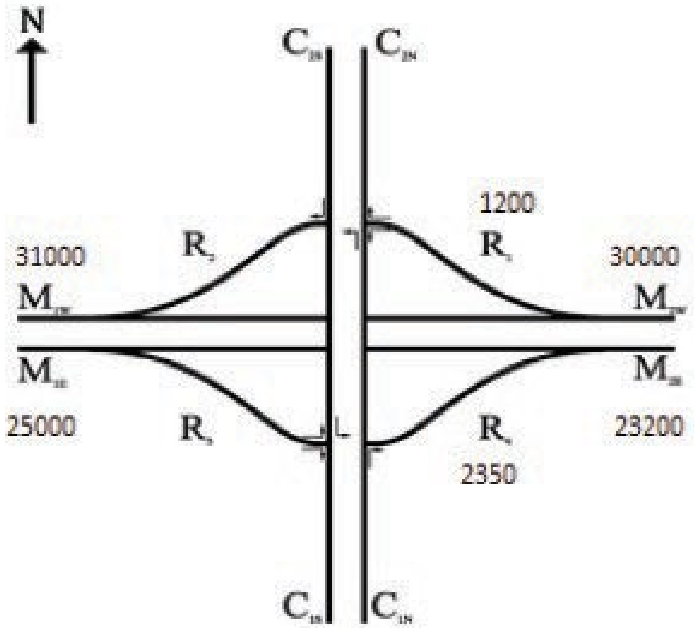
$$R_4 = (M_{2E} - M_{1E}) + R_3 \quad (4)$$

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 are now known:

M_{1E}	=	25,000	R_1	=	1,200
M_{2E}	=	23,200	R_4	=	2,350
M_{1W}	=	31,000			
M_{2W}	=	30,000			



Source: Federal Highway Administration.

FIGURE K-2. DIAMOND INTERCHANGE RAMP ESTIMATION PROBLEM

R_2 = $(M_{1W} - M_{2W}) + R_1$

R_2 = (31,000 - 30,000) + 1,200

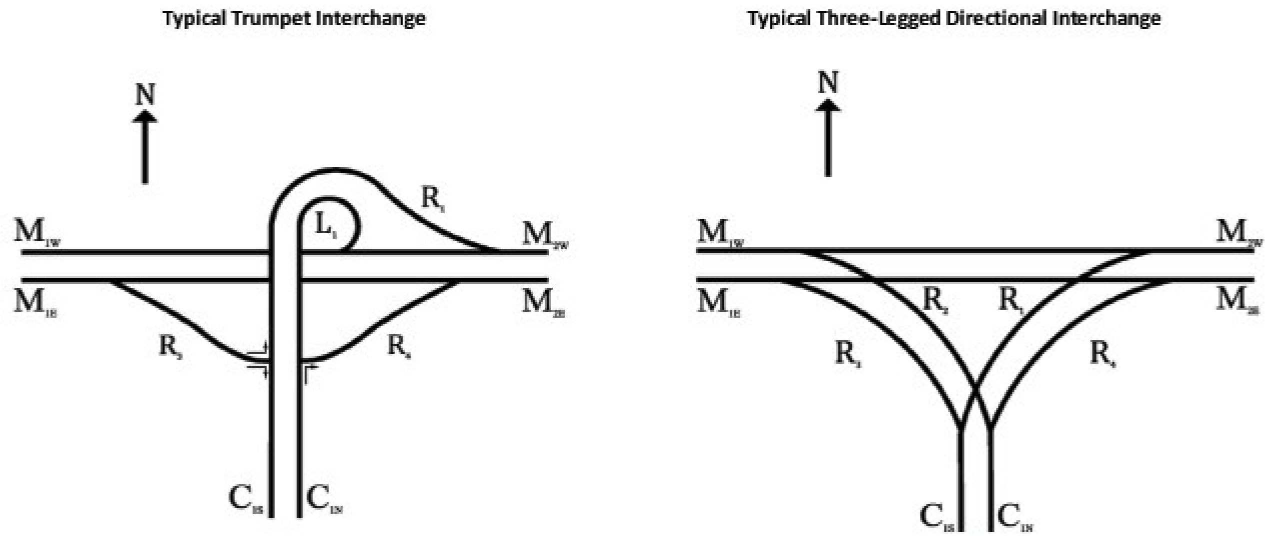
R_2 = 2,200

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



Source: Federal Highway Administration.

FIGURE K-3. TYPICAL TRUMPET AND THREE-LEGGED DIRECTIONAL INTERCHANGES

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 are now known:

M_{1E} = 21,000

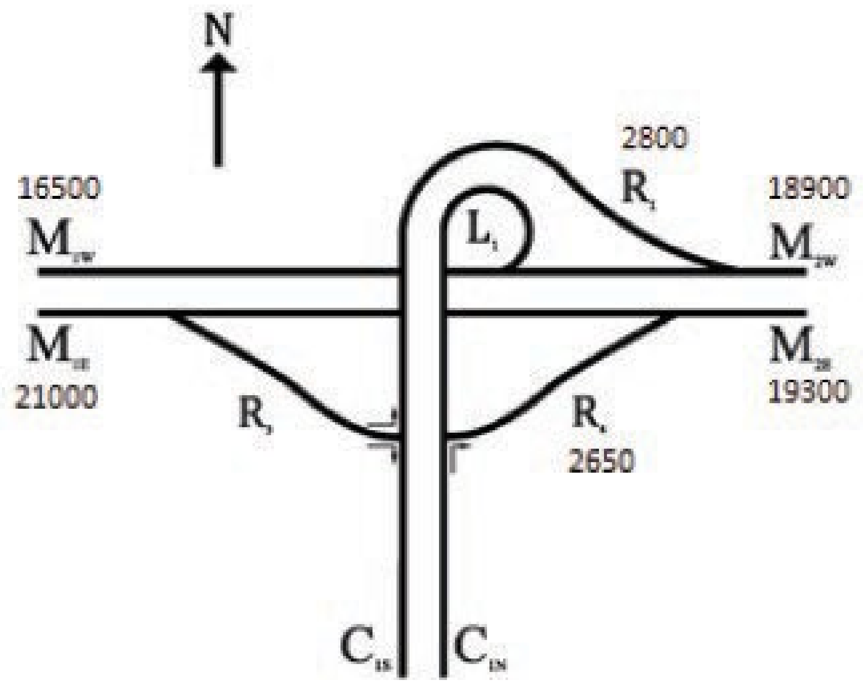
M_{2E} = 19,300

M_{1W} = 16,500

M_{2W} = 18,900

R_1 = 2,800

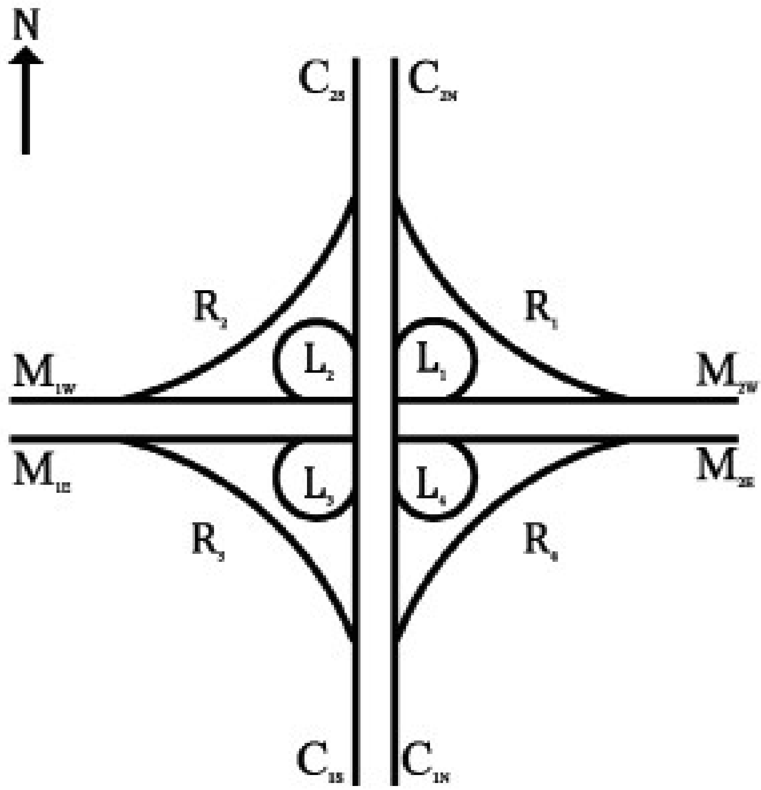
R_4 = 2,650



Source: Federal Highway Administration.

FIGURE K-4. TRUMPET INTERCHANGE RAMP ESTIMATION PROBLEM

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



Source: Federal Highway Administration.

FIGURE K-5. TYPICAL CLOVERLEAF INTERCHANGE

Cloverleaf interchanges are the most complex and data intensive scenario for volume to ramp count relationships.

Formulas (9) through (12) can be used directly assuming some combination of mainline, cross street, and ramp volumes are known for a given year.

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 are 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 are now known:

M_{1E} = 54,000

M_{2E} = 51,500

M_{1W} = 58,500

M_{2W} = 59,000

R_1 = 2,500

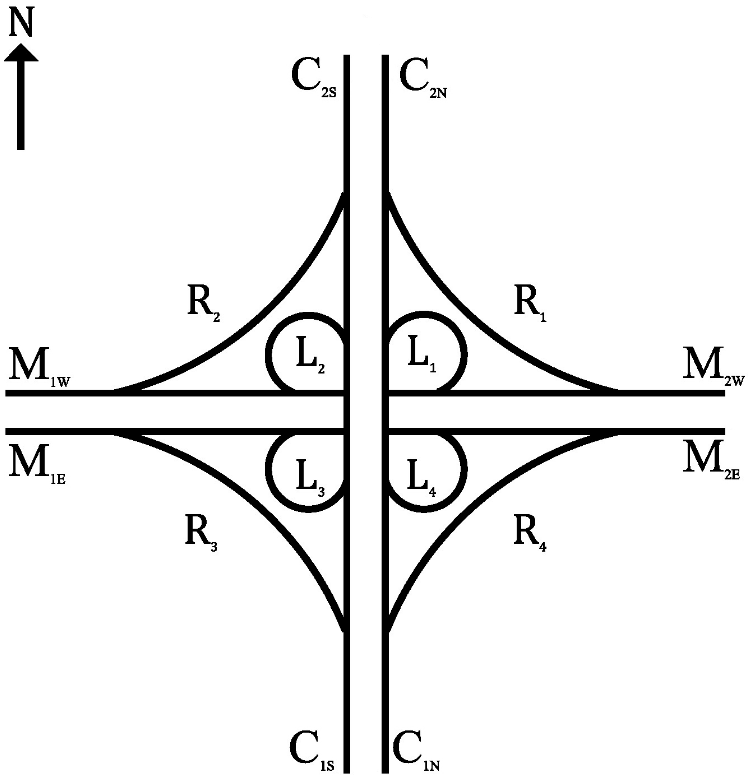
L_1 = 2,100

R_2 = 2,800

R_3 = 2,200

L_3 = 2,450

R_4 = 2,500



Source: Federal Highway Administration.

FIGURE K-6. CLOVERLEAF INTERCHANGE RAMP ESTIMATION PROBLEM

$R_1 = (M_{2W} - M_{1W}) + (L_1 - L_2) + R_2$

$2{,}500 = (59{,}000 - 58{,}500) + (2{,}100 - L_2) + 2{,}800$

$2{,}500 = 5{,}400 - L_2$

$L_2 = 2{,}900$

$R_3 = (M_{1E} - M_{2E}) + (L_3 - L_4) + R_4$

$2{,}200 = (54{,}000 - 51{,}500) + (2{,}450 - L_4) + 2{,}500$

$2{,}200 = 7{,}400 - L_4$

$L_4 = 5{,}250$

Appendix L –

AASHTO AADT Calculation

APPENDIX L. AASHTO AADT CALCULATION

This appendix provides equations to obtain AADTs using the AASHTO method.

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.

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. 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 AASHTO method for computing AADT is currently the adopted practice through both FHWA's TMG and AASHTO's Guidelines for Traffic Data Program. This is because it allows factors to be computed reasonably accurately even when a considerable number of data are missing from a year at a site, and because it works accurately under a variety of data conditions (both with and without missing data).

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)

Recent work performed in 2015 by Battelle Memorial Institute for FHWA and reported in *Assessing Roadway Traffic Count Duration and Frequency Impacts on Annual Average Daily Traffic Estimation* (Krile,et. al.), FHWA-PL-16-008, has shown that there are two limitations with the traditional AASHTO method. One limitation is that the above equation uses only complete days of data. This means that the loss of one hour of data due to errors in the data collection process results in the loss of a full day of data from the AADT computation, reducing the potential accuracy of the resulting AADT estimate. The second limitation is that the averaging process used in the AASHTO method produces a small amount of bias in the resulting AADT estimate by slightly under-valuing both weekday traffic and traffic occurring in months with 31 days in comparison to months with fewer days.

As a result, FHWA is offering the use of an alternative modified formulation for computing AADT. This computation is performed in two steps. The first step computes monthly average daily traffic from the available hourly (or other temporal period) count records. The formula will work equally well with any temporal interval data, such as the 5-minute or 1-minute data frequently recorded by ITS-based traffic management systems. The second step then computes AADT from the twelve available monthly values. These two mathematical steps are as follows:

$$MADT_m = \frac{\sum_{j=1}^{7} w_{jm} \sum_{h=1}^{24} \left[\frac{1}{n_{hjm}} \sum_{i=1}^{n_{hjm}} VOL_{ihjm} \right]}{\sum_{j=1}^{7} w_{jm}}$$

and

$$AADT = \frac{\sum_{m=1}^{12} d_m * MADT_m}{\sum_{m=1}^{12} d_m}$$

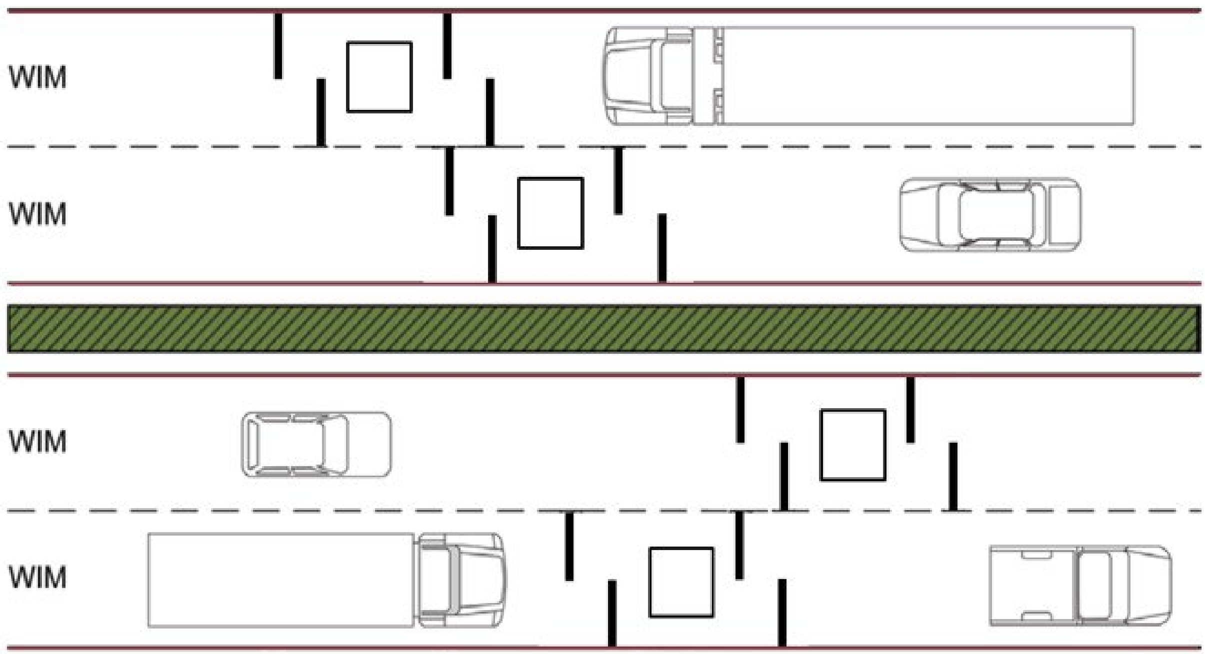
Where:

AADT =		*average annual daily traffic*
$MADT_m$ =		*monthly average daily traffic for month m*
VOL_{ihjm}=		total traffic volume for i^{th} occurrence of the h^{th} hour of day within j^{th} day of week during the m^{th} month
i	=	occurrence of a particular hour of day within a particular day of the week in a particular month (i=1,…n_{hjm}) for which traffic volume is available
h	=	hour of the day (h=1,2,…24) – or other temporal interval
j	=	day of the week (j=1,2,…7)
m	=	month (m=1,…12)
n_{hjm}	=	the number of times the h^{th} hour of day within the j^{th} day of week during the m^{th} month has available traffic volume (n_{hjm} ranges from 1 to 5 depending on hour of day, day of week, month, and data availability)
w_{jm}	=	the weighting for the number of times the j^{th} day of week occurs during the m^{th} month (either 4 of 5); the sum of the weights in the denominator is the number of calendar days in the month (i.e., 28, 29, 30, or 31)
d_m	=	the weighting for the number of days (i.e., 28, 29, 30, or 31) for the m^{th} month in the particular year

Appendix M – Double Threshold WIM Array

APPENDIX M. Double Threshold WIM Array

This array is the FHWA preferred WIM array to use.



Source: FHWA 2016 TMG

U.S. Department of Transportation

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