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16. Abstract

Three of the most essential metrics of highway system operation are the volume, composition and weight of traffic using the roadway and street network. Agencies need timely and reliable traffic information to perform their varied duties in the areas of planning, design, construction, maintenance and operation of roads. If the collected data are not current and accurate, decisions made by the agency may be delayed or incorrect.

This report identifies appropriate measures to ensure that high-quality traffic data are collected, processed, analyzed and reported in an optimal and cost-effective way by the New Mexico Department of Transportation. This is achieved through an in-depth review of the Department's current procedures, including interviews with individuals, both inside and outside of the agency, who have traffic data responsibilities. A survey of best practices in traffic data collection at the national level, as identified in the technical literature, and an examination of programs in selected states was also undertaken.

Particular attention has been given to the traffic data needs associated with the implementation of new pavement design procedures specified by the Mechanistic-Empirical Pavement Design Guide (MEPDG).

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STATEWIDE TRAFFIC DATA COLLECTION, PROCESSING, PROJECTION AND QUALITY CONTROL

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PREFACE

The research evaluated herein documents a comprehensive survey and analysis of the traffic data needs of the New Mexico Department of Transportation. The Department's current policies and procedures, a survey of the technical literature, and the best practices of other agencies regarding traffic monitoring are examined. Recommendations regarding optimal technology, equipment and staffing are made as well as suggestions for the development of a web-based data management system.

NOTICE

DISCLAIMER

ABSTRACT

Three of the most essential metrics of highway system operation are the volume, composition and weight of traffic using the roadway and street network. Agencies need timely and reliable traffic information to perform their varied duties in the areas of planning, design, construction, maintenance and operation of roads. If the collected data are not current and accurate, decisions made by the agency may be delayed or incorrect.

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CHAPTER 1: INTRODUCTION

1.1 Overview

This Final Report for NMDOT Project Number NM10DSN-01, Statewide Traffic Data Collection, Processing, Projection and Quality Control, covers the period from the effective contract execution date of March 4, 2010 through the completion of project activities on November 4, 2011. In conformance with the requirements specified in the Department's "*Information and Instructions for Preparing Proposals in the NMDOT Transportation Program*," (the "*Manual*") and as specified in Contract No. CO5339, the report documents all of the activities described in the Scope of Work, including the identification of the Department's traffic data needs and its current policies and procedures, a comprehensive survey of the literature and the current technical practices of other agencies documenting best practices in traffic monitoring, recommendations regarding optimal technology, equipment, and staffing as well as the development of a web-based data management system, and the implementation of the research results. These activities are detailed in subsequent sections of the report and in the accompanying appendices. The report is accompanied by a multi-media presentation in electronic form and on CD as well as a separate implementation plan.

1.2 Research Need

One of the most essential metrics of highway system operation is the volume of traffic using the roadway and street network. The New Mexico Department of Transportation (NMDOT) needs timely and reliable traffic volume information to perform its varied duties in the areas of planning, design, construction, maintenance and operation of roads. If volume data collected by the NMDOT and others are not current, decisions made by the department may be delayed or incorrect.

On the other hand, if the data are current but erroneous, then any decisions made on the basis of faulty data will certainly be wrong. Part of the challenge, however, is that the collection, processing, and storage of traffic volume data is decidedly not glamorous, and, like all traffic studies, is subject to cutbacks in financial support when department resources are tight.

There can easily be adverse financial consequences for not collecting and maintaining traffic volume data in a manner consistent with recommended practices. In several recent tort liability cases, in fact, (*References 1, 2, 3*) the department was found negligent and assessed damages primarily because its employees had performed faulty traffic volume data collection and analysis.

A new situation with potential financial implications arises as the NMDOT moves toward adoption of the Mechanistic-Empirical Pavement Design Guide (MEPDG) method of pavement design. These improved techniques for pavement design require reliable data on the current and predicted traffic volume and composition (vehicle types and weights). Errors in any of these parameters could result in under-design of pavement thickness, causing premature pavement failure, or over-design of pavement thickness, resulting in unnecessary present costs of construction.

To avoid errors in pavement design, and to improve the results of other applications of traffic data, the NMDOT foresees a need to:

Identify inefficiencies, inaccuracies and redundancies in the department's current practices of data collection, analysis, and forecasting; and,

Develop justifiable recommendations for enhancing data collection, quality control, and data use.

1.3 Background

Volume studies are performed to obtain factual information about the movement of vehicles at selected points on the road network. Common volume counting data applications are listed below (*4*).

Annual Traffic, in vehicles or vehicle-miles per year, is used for:

Determining travel and volume trends in a geographic area,

Estimating expected highway user revenue,

Computing crash rates,

Monitoring long-term pavement performance.

Average Annual Daily Traffic (AADT) or Annual Average Weekday Traffic (AAWDT), in vehicles per day (vpd), is used for:

Measuring or evaluating the present demand for service by the street or highway,

Developing the major or arterial street system,

Locating areas where new facilities or improvements to existing facilities are needed,

Programming capital improvements.

Hourly Traffic, in vehicles per hour, is used for:

Determining the length and magnitude of peak periods,

Evaluating roadway capacity deficiencies,

Assessing the need for traffic control device installation,

Guiding geometric design or redesign of streets and intersections.

Short Term Counts (typically 5- or 15-minute intervals) are usually expanded into hourly flow rates. Such counts are primarily used to analyze:

Maximum flow rates,

Flow variations within peak hours, especially the Peak Hour Factor (PHF),

Capacity limitations on traffic flow,

Characteristics of peak volumes.

The techniques for counting traffic volume are well documented (*4*, *5*). The process involves three basic steps:

Detecting the traffic,

Recording the count data,

Storing and presenting the count information.

Traffic is detected with human observers or with equipment placed on or adjacent to the roadway. Manual detection is commonly used for short-term counts, counts by traffic lane, counts in conjunction with vehicle occupancy studies, and pedestrian and bicycle counts. The most common equipment used to detect traffic are:

Hollow pneumatic tubes stretched across the roadway; this device counts axles rather than vehicles.

Magnetic loops embedded in the pavement; the inductance of the loop changes when a vehicle passes over the top.

Microwave sensors, placed by the roadside, send out a low-powered signal and receive reflections from passing vehicles. Sonic sensors, placed over a traffic lane, *hear* sounds from passing vehicles.

Vehicle magnetic imaging (VMI), placed on or in the pavement, detects changes in the earth's magnetic field caused by a vehicle passing over the sensor.

Video cameras, coupled with video image processing technology, count vehicles by creating *virtual loops*; they are most commonly used for vehicle detection at signalized intersections.

A variety of devices are available for recording traffic count data. Indeed, there have been fairly dramatic improvements in the availability, quality, reliability, and power requirements of traffic recording equipment. Older manual tally count boards have been replaced by electronic count boards that automatically record on computer memory at predetermined intervals, thus eliminating formerly common field transcription errors. In a similar manner, the older count recorders that accepted input from pneumatic tubes and recorded data on printed tape, punched tape, and even magnetic tape, have virtually disappeared, having been replaced by devices that record volume data on computer memory chips. Unlike the old, heavy Streeter-Amet counters of the 1960s, with a wind-up clock, cumbersome printer mechanism, and powered by a heavy 6-volt wet cell battery, today's counters are more compact and are powered by lightweight batteries.

Modern-day portable counters accept input from multiple pneumatic road tubes, enabling a single counter to determine the traffic volume by lane by subtracting the counts from the road tubes crossing one, two, three, or even four lanes. Portable vehicle magnetic imaging traffic counters such as the Hi-Star VMI with internal power measure only approximately 6"×6"×0.8" thick. These units can be buried under a weatherproof cover in the center of a traffic lane and detect vehicles, vehicle speed and vehicle length (in 15 speed bins and 8 length bins), as well as roadway surface temperature, wet/dry surface condition, and roadway occupancy (percent of time that a vehicle is positioned over the device). The information can then be wirelessly transmitted in real time to a remote data collection location.

Other devices, such as the "Groundhog," a permanent count version of the Hi-Star VMI with a one to three year battery, can be buried in the center of each traffic lane on a roadway and wirelessly transmit volume counts, speed, and classification, at predetermined intervals, to a roadside data collector, which can store data for up to 16 traffic lanes. The roadside collector can then forward the information by land line, fiber optic cable, or wireless signal to a data collection center. Manufacturer data suggests that the "Groundhog" has a volume count accuracy of 97% or greater.

The third step in the traffic volume data collection process is to store the information electronically and then present it to potential users in an appropriate format. This is especially challenging because of the numerous potential users of traffic volume information. In addition to the potential uses to the department as suggested in section **1.2**, other individuals and organizations that may be interested in reliable traffic volume information on New Mexico highways include:

Both Federal (FHWA) and Local (MPOs) Agencies,
Law Enforcement,
Consultants,
Researchers.

Potential traffic volume data users also have different needs and expectations. For the most part, engineers will accept the somewhat boring presentation of traffic volume data in tables, with volumes expressed on either a daily or hourly basis. Others might benefit from a time-series comparison, as represented by a plot of traffic volume at a site or screenline (a natural or artificial boundary subdividing an area) from year to year. Many, even those with little technical expertise, can appreciate the information provided by a traffic flow map, where the width or color of route segments indicates the traffic volumes.

In summary, the equipment used to collect traffic volume data on highways has improved dramatically in recent years. Improved time monitoring now ensures that an hour count is actually a count for 60 minutes. Data storage tools have evolved to the point where massive amounts of information can be readily stored and retrieved. Despite the advances in technology, however, care must be taken to ensure that data is timely and reliable and that the data collection process is consistent with current recommended practices.

1.4 Research Objectives

In its Invitation to Propose of May 2009, the NMDOT identified five objectives that this project was to address and resolve:

> Identify and implement appropriate measures to ensure that high quality traffic data are collected, processed, analyzed, and used in the most optimal and cost-effective way possible, in accord with the *Traffic Monitoring Guide* (*6*).
>
> Complete an in-depth process review of the Department's current methods of collecting, processing, and projecting traffic data, including all units that currently collect traffic data: the Traffic Data Collection Section within the Data Management Bureau of the NMDOT, NMDOT Districts, MPOs, and others.
>
> Identify the most effective and accurate means of collecting and projecting traffic data consistent with requirements for the implementation of the MEPDG; identify the traffic input format for the MEPDG.
>
> Recommend a new web-based application that stores all traffic data in a meaningful manner for use by NMDOT personnel, other agencies, and the general public, to be widely available and easily accessible for both internal and external customers.
>
> Develop an implementation plan describing necessary actions to incorporate research findings into NMDOT policies and procedures.

1.5 Report Outline

The remainder of this report describes both the current needs and existing resources at the NMDOT in Chapter 2. The chapter details current counting procedures as well their relationships to national standards for traffic monitoring. Chapter 3 summarizes the results of a survey of various NMDOT and other agency personnel regarding agency policies and practices to identify problems and opportunities. Results of this survey are used in a comparison of procedures utilized nationally and in selected states as described in Chapter 4. Chapter 5 details a quality control procedure developed to apply to New Mexico's weigh-in-motion data and Chapter 6 discusses web-based data management, reporting and training. Finally, Chapter 7 presents the conclusions and recommendations of the report and briefly discusses the implementation plan and suggested training procedures.

CHAPTER 2: TRAFFIC DATA MONITORING AT THE NMDOT

2.1 Background

In the late 1980's, the then New Mexico State Highway and Transportation Department determined that there were problems with the quality and reliability of its traffic monitoring data (*7*). This conclusion was reached after interviews with those responsible for collecting and analyzing the data. The study found that:

> A primary source of error in traffic monitoring was inconsistent use of professional judgment in factoring traffic data. Professional judgment was applied to adjust base data and complete missing data. The judgment of professionals resulted in multiple modifications of the same data set. Traffic counts were modified up to eight separate times by individuals unaware of the previous or subsequent modifications.

The study pointed out several consequences of the faulty data. For example, a gravity model computer simulation for Taos using faulty data initially reached the wrong conclusion that a bypass was needed. Fortunately, results from a follow-up volume count corrected the error. More relevant to this project, the study reported that:

> Pavement thickness was determined by the department to be sensitive to differences in traffic volume data summarization. Inaccurate current-year data typically establish future trends that, when forecast to design year, result in under-building or over-building a facility.

In response to these findings, the department drafted and refined a set of initial traffic monitoring standards. A May 1988 departmental administrative memorandum adopted the standards, which went into effect on October 1 of that year. Among other things, the standards provided that "missing or inaccurate data may not be completed, filled-in, or replaced for any type of traffic count, at any location, under any circumstances." The standards also required that monthly data from continuous automatic traffic recorders, (ATRs, also known as permanent count stations) must be based on a minimum of two complete days for each day of the week. Finally, the standards provided for enhanced quality control; for example:

> When the same recorded traffic volumes, other than zero, occur at an ATR for four successive hours, an error message will be displayed and the day's data will be excluded from calculation. When eight hours of successive zeros occur at an ATR, an error message will be displayed and the day's data will be excluded from calculation.

Since their initial adoption, the standards continue to be reviewed and refined on a three-year basis, or as required, by the Traffic Monitoring Review Committee which is coordinated by the department's Traffic Data Reporting Unit within the Planning Bureau. The most recent version is for the years 2011/2013 (*8*).

2.2 New Mexico's Role in the Development of National Standards

Thanks, in part, to efforts initiated by New Mexico, early efforts at the national level resulted in improvements in the standardization of traffic monitoring practices. In 1990, for example, the NMSHTD Planning/Research Bureau conducted a survey of the practices employed by state DOTs (*9*). As part of the survey, representatives of all fifty states participated in phone interviews. The survey was conducted five years after FHWA published the first edition of its *Traffic Monitoring Guide* (*10*). The results summarized below indicate that many of the DOTs had adopted some of the practices recommended by the guide.

Of the respondents, 37 reported conducting short-term traffic volume counts and 40 reported conducting short-term vehicle classification counts. The most common durations for short-term traffic volume counts were 48 hours (21 respondents) and 24 hours (16), but the range of responses was from one hour to 336 hours (two weeks). The shortest count durations appear to be associated with intersection turning movements. The corresponding question regarding the duration of vehicle classification counts found that 48 hours (21 respondents) and 24 hours (11) were the most frequently cited, but responses ranged from four hours to 168 hours (one week). The question "If the equipment fails before the indicated length of time is complete, are the counts retaken or the missing data estimated?" generated 44 "retaken" and 13 "estimated," responses with some states doing both. The most common duration of retaken counts was 24 hours (15 respondents) with responses ranging from five hours to 48 hours.

Another question inquired into the timeliness of traffic volume counts by asking the average number of years between the time a road is counted and then factored for annual growth until another count is taken. The most common time period was three years, followed by two years and then one year. However, in some states annual growth factors weren't applied until four, five, six, and even nine years after the initial count. In response to other questions, 44 states reported applying seasonal correction factors to short-term traffic volume counts, but only 40 states applied axle correction factors to these same counts; failure to make these corrections results in incorrect count information. Finally, the survey asked what a state would do if the data from a permanent count station are determined to be incorrect (e.g., several successive hours with reported counts of zero). The responses indicated that 27 states would leave the day's data blank while 23 would estimate (i.e., make up) the counts.

In the years since this survey, there have been several very important changes in standard practices for traffic monitoring. The first, which again resulted in part from leadership provided by New Mexico, was the *AASHTO Guidelines for Traffic Data Programs* (*11*). This 1992 report (with a 2nd edition published in 2009) was prepared by the Joint Task Force on Traffic Monitoring Standards of the AASHTO Highway Subcommittee on Traffic Engineering. In addition to general recommendations, the report provides guidance for traffic data collection needs, field equipment and procedures, editing traffic data, summarizing traffic data, reporting traffic data, retaining traffic data, and quality control. The six foundational principles established by this AASHTO document are:

The guidelines will move toward a common traffic monitoring practice.

The guidelines will establish a phased program to achieve a common practice.

The guidelines will be practical and capable of implementation.

What is practical in the guidelines will be directed by the need to provide quality traffic data for decision making.

Truth-in-Data, which is the disclosure of practice and estimate of data variability, is central to the guidelines to ensure appropriate data quality and use.

The guidelines will present a dynamic approach to traffic data programs. Further development will be encouraged through the clarity and integrity of common practice.

In 2001, federal regulations were published implementing *23 U.S.C 303(b)* which directed the Secretary of Transportation to ". . . issue guidelines and requirements for State development, and implementation of a traffic monitoring system for highways (TMS/H)" (*12*). FHWA subsequently published an updated and expanded *Traffic Monitoring Guide*. Specifically, the guide included sections on monitoring traffic volume, vehicle classification, and truck weight with particular emphasis on the importance of truck classification and weight. An April 2008 supplement addressed the monitoring of motorcycle traffic; this subject has become important because of the dramatic increase in motorcycle fatalities, the technological difficulties of actually detecting/identifying motorcycles, and the highly variable motorcycle volume by day, season and road type.

The final significant consequence of the New Mexico survey and the AASHTO guidelines were the development of an American Society for Testing and Materials (ASTM) *Standard Practice for Highway Traffic Monitoring Truth-in-Data* (*13*) which addresses ". . . how data are managed from field data collection through evaluation, acceptance, summarization and reporting."

Additional details comparing New Mexico's current traffic monitoring activities with national guidelines and standards will be discussed in subsequent sections of this report.

2.3 MEPDG Data Needs in New Mexico

Traffic data are one of the key data elements required for the design and analysis of pavement structures. The NMDOT currently uses the 1972 pavement design equation for designing pavement structures with a probabilistic design procedure (*14*). The AASHTO 1972 pavement design equation is expressed in the following functional form:

$$W_{18} \text{ or } ESAL_{predicted} = f(t, R\text{-}value, RF, P_t) \qquad Eq. (1)$$

where: t = layer thickness, *ESAL* = Equivalent Single Axle Load, *R-value* = subgrade resistance value, *RF* = regional factor, P_t = terminal serviceability index. In the probabilistic procedure, layer thickness and *R-value* are represented by probability density distribution functions.

Using these density distribution functions, several inputs of *t* and *R*-value are generated to run simulations using Eq. (1). The simulation outputs are used to plot the probability density distribution function of *ESALs* and to determine mean predicted $ESAL_{predicted}$. The $ESAL_{predicted}$ is then compared to the actual $ESAL_{actual}$ statistically to predict reliability in design. A thickness design governs when the predicted reliability (i.e., the probability that the $ESAL_{predicted}$ will be greater than or equal to the actual $ESAL_{actual}$) exceeds a target minimum design reliability. The NMDOT design procedure, as well as the AASHTO 1993 procedure, thus requires converting the wheel loads of various magnitudes and repetitions ("mixed traffic") to an equivalent number of "standard" or "equivalent" loads based on the amount of damage they do to the pavement (*15*,16).

The commonly used standard load is the 18,000 lb. equivalent single axle load. Using the ESAL method, all loads (including multi-axle loads) are converted to an equivalent number of 18,000 lb. single axle loads, which is then used in the design equation (Eq. 1). A "load equivalency factor" represents the equivalent number of ESALs for the given weight-axle combination. As a rule-of-thumb, the load equivalency of a particular load is roughly related to the load by a power of four. For example, a 36,000 lb. single axle load will cause about 16 times the damage as an 18,000 lb. single axle load.

The major problem with the use of ESALs is that the load equivalency factors are based on the present serviceability index concept (a regression equation developed based on data from the 1960s, when the load was only 1.1 million trucks) and depend on the pavement type and structure. Recent studies have shown that these factors also are influenced by pavement condition, distress type, failure mode, and other parameters (*17, 18)*. It is known that loads, along with the environment, damage pavement over time. The standard model asserts that each individual load inflicts a certain amount of unrecoverable damage. This damage is cumulative over the life of the pavement, and when it reaches some maximum value the pavement is considered to have reached the end of its useful service life. Service life, however, differs significantly when using ESALs compared to the actual traffic volume and vehicle classification in the pavement design.

A rational approach, therefore, to the analysis and design of pavement structures should involve procedures that use both mechanistic and empirical principles to estimate the effects of actual traffic on pavement response and distress. This has been done in the Mechanistic-Empirical Pavement Design Guide (*17, 18, 19*) for new and rehabilitated pavement structures developed as part of NCHRP Project 1- 37A. For evaluating or designing for specific distresses using mechanistic-based pavement performance models, the use of ESAL data is limited and unwarranted. Although ESALs have been used in the past**,** mechanistic-based distress prediction models require the use of axle load and vehicle classification data**.** In other words, the actual traffic data measured along roadways are used, rather than the conversion of that data into a number that is distress, pavement type and thickness dependent. MEPDG uses load spectra, which is a change from ESAL calculations and consists of classifying the traffic loading in terms of the number of load applications of various axle configurations (single, dual, tridem and quad) within a given weight classification. Load spectra analysis is conducted by counting, classifying, and weighing vehicles for a given time period. The design traffic (load spectra) for the pavement design life is calculated using a traffic growth factor based on historical and anticipated traffic on the pavement. Because these traffic data inputs differ from those currently used in pavement design and analysis, there is a need for research to provide clear information on traffic data and forecasting and to provide guidance on selection and operation of the equipment needed for collecting these data.

2.4 The Importance of Traffic Data in Pavement Design in New Mexico

Because of the constraints on resources available in state and local highway agencies for traffic data collection, the MEPDG allows for various levels of traffic data collection and analysis. The MEPDG defines three broad levels or degrees of traffic data input:

> Level 1 – The designer has a very good understanding of the actual loads (truck volume, classification, and weight) to be applied.
>
> Level 2 – The designer has a modest understanding of the actual loads to be applied.
>
> Level 3 – The designer has a poor understanding of the actual loads to be applied.

For those roadways where both truck volumes and weights are well known, a high level of reliability is expected in the traffic-loading estimate. This equates to a much more reliable pavement design. Where the traffic loads (truck volumes and weights) are less well known, the traffic-loading estimates are treated by the design software as being less reliable, and consequently, the pavement design becomes less reliable. The design engineer must make his/her design decisions accordingly.

Because truck volumes and weights can vary considerably from road to road, and even from location to location along a specific road, a very good understanding of traffic loads can only be obtained if both volume and weight data have been collected on the roadway to be designed, and at a point that provides the designer with strong confidence that the traffic monitored will cross the pavement section without significant change.

Where only site-specific truck volume data are available for the roadway in question, but the designer has the ability to predict with reasonable certainty the basic pattern of loads those trucks will carry, the design process assumes a modest understanding of traffic exists. Where the designer must rely on default values for weights (e.g., statewide averages), and/or relatively little truck volume information, the design process assumes a poor understanding of traffic loads exists.

2.5 Current Data Collection Activities in New Mexico

The State of New Mexico has approximately 68,000 centerline miles of roadway (20). Over 14,000 of these miles are on non-local roads which are monitored by the NMDOT with both short-term volume (coverage) counts and approximately 150 active permanent count locations. The permanent count sites include both Automatic Traffic Recorders (ATRs) recording volume, speed, and classification data, 15 Automatic Weight and Classification (AWAC) sites collecting weigh-in-motion data in addition to volume and classification, and 30 ITS/camera sites, primarily in the Albuquerque area. A map of the permanent site locations is shown in Figure 1 and a complete listing of the permanent sites may be found in a separate document. The number of active sites may vary slightly due to maintenance and construction schedules as well as down time caused by incidents.

Equipment installed at a typical volume, classification and speed site includes both inductive loops and piezoelectric sensors; the weigh-in-motion sites have either bending plates, piezoelectric sensors, or load cells along with inductive loops while the ITS sites have Smart Sensors (microwave) and cameras installed to provide both volume and speed data. For data polling from the ATR and AWAC sites the NMDOT uses TDP (Peek) and TRADAS software developed by Chaparral Systems for data processing and analysis. Traffic count data is stored in an Oracle database.

Based on the Department's Consolidated Highway Data Base (CHDB – recently replaced by TIMS – Transportation Information Management System) a total of 14,853 short-count (coverage count) roadway sections have been identified; it appears that these sections were established based not only on ADT, (the TMG suggests that homogeneous segments have traffic volumes that remain within +/- 10%) but also by the lengths of various construction projects, the location of political boundaries, and physical reference points such as interchange or intersection locations. Broken down by Functional Classification, these sites, along with their roadway mileages, as reported to FHWA for 2009, are shown in Table 1.

Counts at locations on these sections, except for the urban local system and rural minor collectors and local roads, are supposed to occur for 48 hours on a three-year cycle for the higher functional classes and on a six-year cycle for the lower functional classes. For example, in preparing the count program for the years 2012, 2013, and 2014, all of the high functional class sections counted in 2011 would be placed on the 2014 count program, 2010 sections would be counted again in 2013, and the remaining sections would be placed on the 2012 program. The traffic technician conducting the count may place the counter anywhere in the section where it is safe to do so. While the department has approximately 120 portable counters, only about 90 are currently being used because of staff shortages.

While the current number of identified short count roadway sections is adequate given the rural nature of the state, not enough sections in the lower functional classifications (minor arterials, collectors) are actually being counted because of staff and funding shortages. Information from the Data Management Bureau, in fact, indicate that a total of only 1,597 short term counts from all agencies were conducted in 2009 and 1,690 in 2010. While these numbers may indicate adequate coverage of the Principal Arterials on a three-year cycle, they show that little coverage was provided to the lower functional classes.

Within the NMDOT, the counter shop at the General Office in Santa Fe conducts the counts statewide. District offices do not provide count data to the GO although they may conduct specific counts (turning movements, speed, etc.) within their jurisdictions. Although there is no seasonal rule on when short counts are performed, the technicians try to avoid snow plows which tend to tear up the road tubes. Otherwise, counts are performed anytime the technician is in the area.

NMDOT traffic monitoring efforts are also supplemented by MPOs which provide data on many road sections within their jurisdictions. In the Albuquerque metropolitan area, for example, the Mid-Region Council of Governments (MRCOG) collects traffic data for all major state and non-state roads in Bernalillo, Valencia, Torrance, Sandoval, and southern Santa Fe counties. MRCOG collects 48-hour data at a location every three years, usually on a Monday or Tuesday. Growth factors are applied to the counts during off-years and classification data from MRCOG is also available. Among the products produced by the MRCOG are annual traffic flow maps. The 2009 map is shown as Figure 2. Currently, traffic monitoring activities have not been contracted to any consultants by either the State or the MRCOG.

2.5.1 Data Collection at the NMDOT ITS Bureau

The ITS Bureau maintains a number of camera and sensor locations in the Albuquerque metropolitan area, primarily along Interstates I-25 and I-40. XML data feeds from sensor locations provide lane by lane count, speed, and occupancy information by one minute intervals. Average speeds and volumes are also computed and a four bin length-based classification system is collected. The data collected is used primarily for traffic management and emergency response applications and is being archived and shared with MRCOG for Federal reporting, and other, purposes.

2.5.2 Other Agency Programs

The New Mexico Department of Public Safety (NMDPS) Smart Roadside program uses electronic screening to improve its commercial vehicle enforcement operations. It employs imaging systems for automatic USDOT number and license plate recognition and provides alerts to roadside inspectors for high risk vehicles. Real time safety information as well as pass/fail indications for compliance with weight/distance tax requirements and various registration requirements is gained. Three fixed sites (at the ports of entry at San Jon, Gallup, and Anthony) and one mobile reader (in the Albuquerque area) are operational with an additional seven fixed and two mobile sites planned.

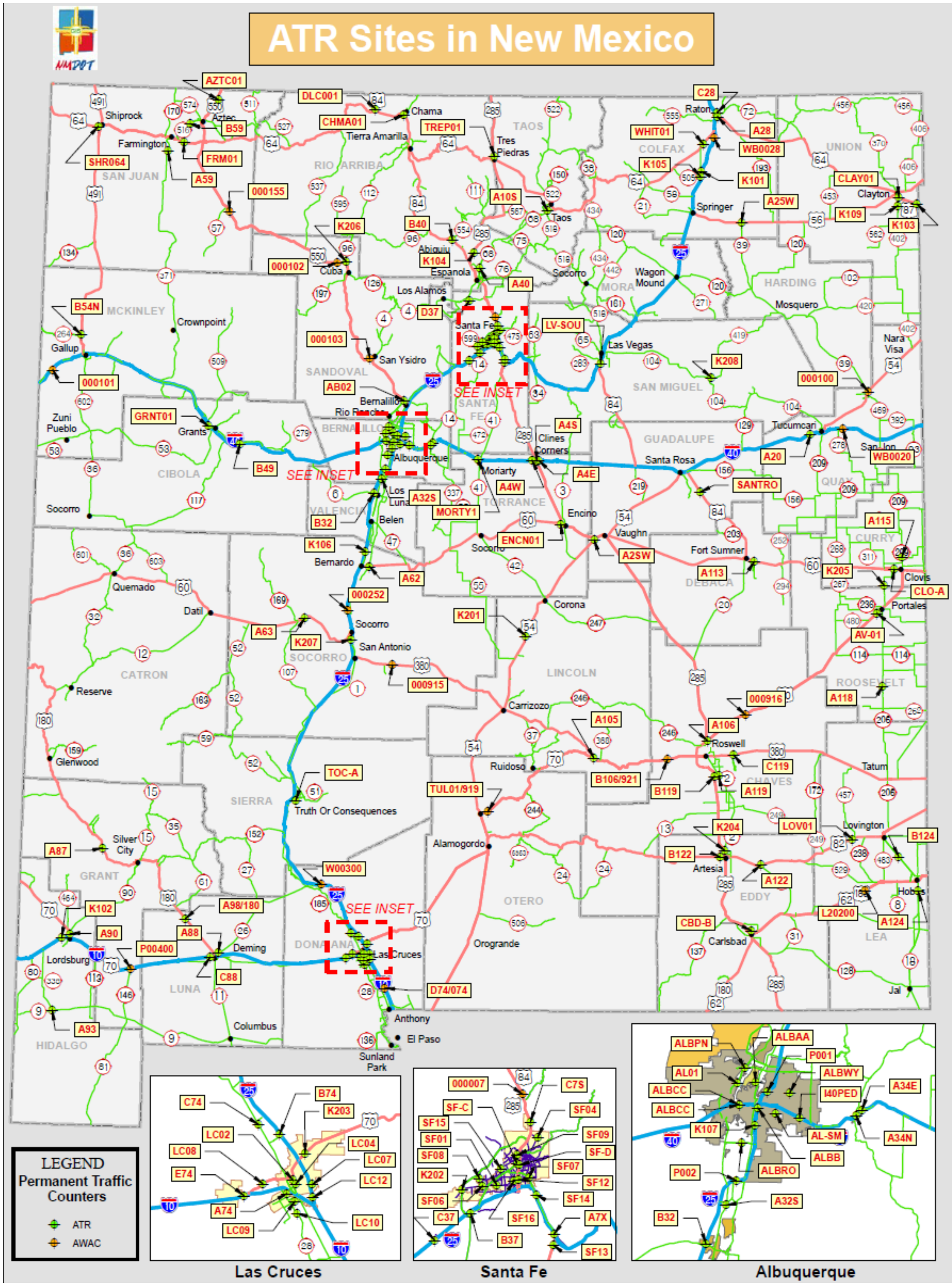


FIGURE 1 ATR and AWAC Sites in New Mexico

TABLE 1 Short Count Sections by Functional Class

Functional Classification	No. of Sites	Miles of Rwy.
Urban		
Principal Arterial – Interstate	529	156
Principal Arterial – Other Freeways	1	5
Principal Arterial – Other	1,117	706
Minor Arterial	1,111	611
Collector	1,552	1,503
Local System	987	5,012
Total Urban	5,297	7,993
Rural		
Principal Arterial – Interstate	966	844
Principal Arterial – Other	298	1,841
Minor Arterial	252	1,953
Major Collector	513	3,882
Minor Collector	598	3,150
Local System	6,929	48,721
Total Rural	9,556	60,391
GRAND TOTAL	14,853	68,384

Source: Elizer Pena email, 6/11

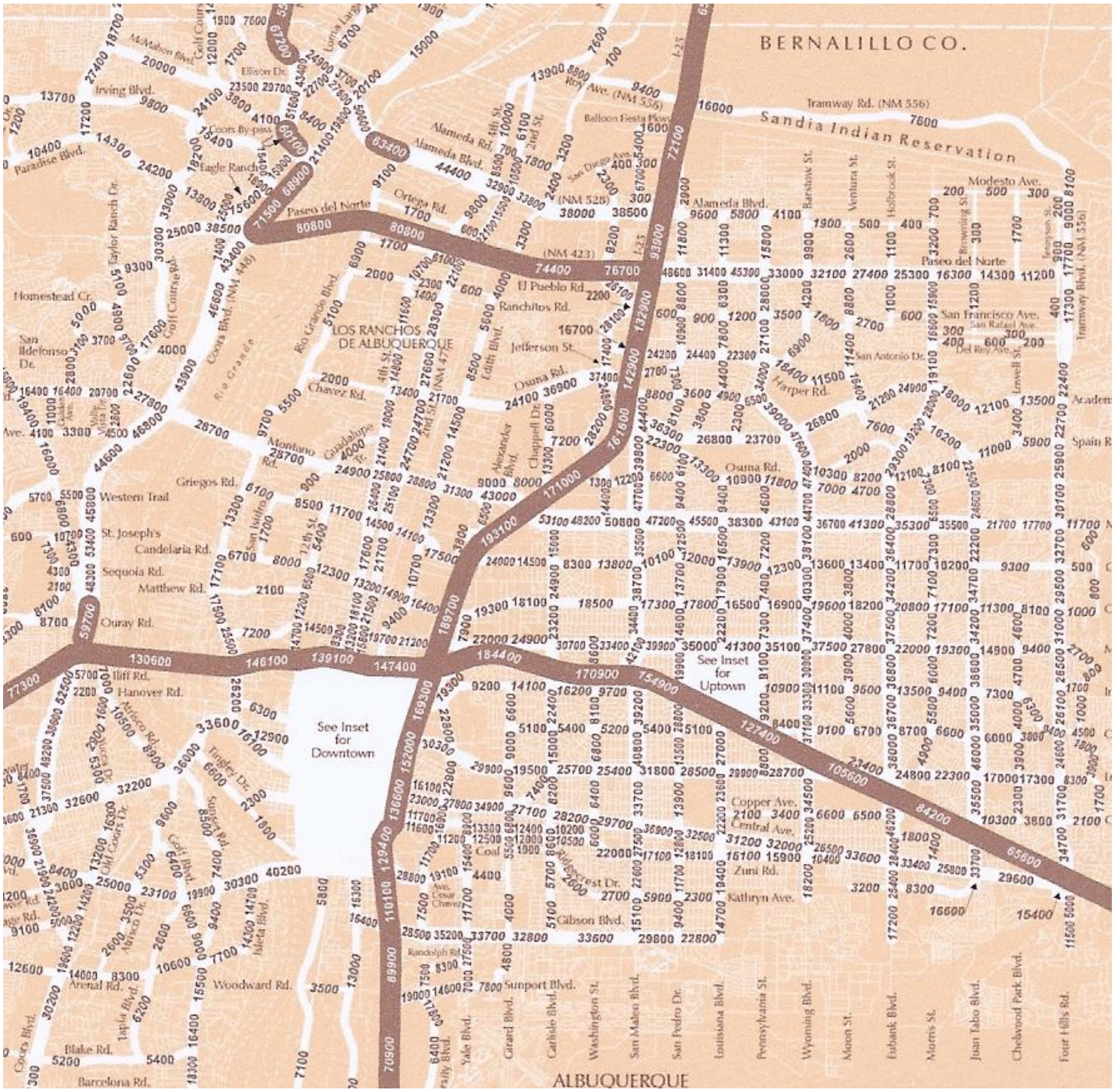


FIGURE 2 2009 Traffic Flow Map – Albuquerque

Short term counts for volume and classification (because of unreliable data, no short-term (portable) WIM data is collected) take place over a 48-hour period of time, while speed data, when required, is ordinarily obtained over a 24-hour period. Turning movement data, typically used by the Districts or by consultants for traffic impact analyses, is collected for a total of nine hours, focused around the AM, Mid-Day, and PM peaks. AADTs and AAWDTs, however, are never calculated from turning movement counts.

Equipment failure prior to the completion of the indicated data collection time requires the entire count to be retaken for the entire 48 hour period. Missing values from permanent counters are never estimated; that day's data is left blank. Seasonal correction factors are calculated from similar functionally classified routes and are applied to all short term counts. Axle correction factors are calculated from the ATR classification sites and are also applied to all short-term counts.

Vehicle occupancy data is required by 23 CFR 500 Part B. 500.202(e) further states that this data is to be collected on the average number of persons per automobile, light two-axle truck, and bus, as appropriate to support the data uses identified in 500.203(a). One of those uses is in transportation management systems, such as those at the MRCOG. Similarly, while speed data can be collected at ATR sites, it is not clear whether/how this information is reported/used.

2.5.3 Current WIM Technology in NM

Currently, the type of sensors that NMDOT are using for their 15 WIM stations are: Piezo sensors (Mikros Raktel 8000, all except US 550) and Bending Plates (IRD 1058, three locations on US 550). In 2011, the bending plates at the three US 550 locations (San Ysidro, Cuba and Bloomfield) will be replaced by PAT plates. Also, the three counters will be replaced at the same time at these three WIM sites. Table 2 shows the name, code, location, and type of technology of each of the WIM sites.

TABLE 2 Location and Type of WIM Technology in NM

Site Name	Site Code	County	Road Name	Milepost	Technology
Hatchita	4	Grant	I-10	50.05	Piezo
Logan	100	Quay	US-54	328	Piezo
Gallup	111	McKinley	I-40	10.7	Piezo
Hobbs	202	Lea	US-62/180	84	Piezo
Lemitar	252	Socorro	I-25	158.8	Piezo
Rincon	300	Dona Ana	I-25	37.2	Piezo
Tucumcari	B20	Quay	I-40	340.9	Piezo
Raton	B28	Colfax	I-25	445	Piezo
Roswell	916	Roosevelt	US-70	354.3	Piezo
Vado	74	Dona Ana	I-10	155.6	Piezo
Tularosa	919	Otero	US-70	231.65	Piezo
San Antonio	915	Socorro	US-380	15.7	Piezo
San Ysidro	103	Sandoval	US-550	24.738	Bending Plate
Cuba	102	Sandoval	US-550	71.051	Bending Plate
Bloomfield	155	San Juan	US-550	121.5	Bending Plate

Performance and accuracy of the bending plate sensors is much better than that of the piezo sensors, but they are much more expensive and difficult to install. However, reliability and accuracy of piezo sensors is good regardless of the surface of the road if calibration is performed often.

The main reasons for inaccuracy in collected WIM data appear to be lack of calibration and the influence of temperature. Changes in temperature produce a bias in the weight measured by the sensor. If the temperature gets lower, the weight measured decreases, and vice-versa. Temperature sensors at all piezo WIM sites could correct the error due to temperature; currently, these stations do not have such a sensor.

Bending plate sensors are calibrated twice a year. Piezo sensors have not been calibrated since 2008, although it is recommended they be calibrated at least once a year. Therefore, some inaccuracy in the weight data collected by piezo WIM sites is not surprising. Calibration is not being carried out more frequently due to budget constraints. There are two new WIM sites that are planned to be installed soon, one on I-25 and one on I-40.

The Long Term Pavement Performance (LTPP) program also has two WIM sites located in New Mexico for specific pavement studies (SPS). These two sections are: 350110, located on I-25 North at M.P. 36.1 and 350500, located on I-10 East at M.P. 50.2. The data at both sites is processed and the corresponding axle load spectra is available in the LTPP database. The department may find this data useful, particularly for implementation of the MEPDG.

2.5.4 NMDOT Data Reporting

In addition to monthly data submitted to FHWA for truck weight studies and volume trends, HPMS (Highway Performance Monitoring System) data for the previous calendar year is required to be submitted annually to FHWA by June 15. This data is used not only by the DOT for pavement design but is also input at the Federal level for apportionment of highway funding, the development of performance measures such as crash rates, and summary reports to Congress.

The traffic survey data collected by the NMDOT is broken down into classification, volume, and weight categories. Classification data is further divided into annual class summaries and percentages, both overall and by day of the week. Class percentages of monthly average daily traffic (MADT) at all continuous count sites are also provided, as is the overall percentage of traffic statewide at the permanent sites by functional classification. Typical examples for 2009 are shown in a separate document.

Volume information is also broken down into several categories. In addition to annual volume summaries by site which compare AADT, AAWDT, and AAWET totals to the previous year, annual day of week, the 500 highest hours, and hourly day of week tables are provided. Tables listing day-of-week percentages, a commercial AADT summary and the highest hours by direction are also reported. Typical examples are again provided separately.

WIM data, by lane, direction, and for the entire roadway, is provided from each AWAC site for each of the 13 FHWA classifications. “Off Scale” and “Unclassified” data columns are also listed. The tables list number of vehicles, EASLs for both flexible and rigid pavements (calculated by equations provided in the table) and gross vehicle weight.

Tables providing growth factors, axle factors, and daily/seasonal factors, all by both site and functional class, are also provided as part of the annual report. Tables of daily vehicle miles of travel (DVMT), by county, NMDOT district and functional class are also provided. Examples of all are included in attachments.

2.6 Summary of New Mexico Practice

The documents describing New Mexico's traffic monitoring program appear to be in compliance with both Federal Regulations and the several guidelines and standards available at the national level; in actual practice, however, the State is not. For example, while the number of counts on those roads classified as urban or rural Principal Arterials appears to be adequate this is not the case on roads of lower functional classification. This is somewhat surprising since the State has been a leader in the development and enhancement of traffic monitoring activities since the late 1980s.

However, like many agencies currently, the traffic monitoring program suffers from a lack of resources, both personnel and equipment, necessary to increase and improve data collection efforts on minor roadways in both urban and rural areas. Additional resources are also necessary to improve the data collection activities at weigh-in-motion sites. This critical item could be provided either in-house or through contract personnel.

Specific recommendations on program improvements, based both on internal surveys and information from external sources, will be described in subsequent sections of the report.

CHAPTER 3: PROBLEMS/OPPORTUNITIES WITH TRAFFIC DATA COLLECTION IN NM

3.1 Background

Task 2 of this project required the researchers to identify current NMDOT traffic data procedures, policies, practices, and capabilities. The task specifically involved interviews with NMDOT employees and selected individuals from other agencies, both public and private, who collect, process, store, or utilize traffic data. The survey instrument developed for this purpose, as well as a complete list of contacts, is presented in Appendix 1.

3.2 Interviews

At the project's quarterly progress meeting in July 2010, technical panel members were asked to recommend a set of individuals who should be interviewed. The recommendations included 26 individuals, including persons from the planning bureau, traffic engineers at headquarters and in the districts, pavement engineers, ITS experts, and individuals from three consulting firms, FHWA, and MRCOG. In mid-August, Drs. Hall and Brogan interviewed the following nine persons: Tony Abbo, Antonio Abeyta, Brad Julian, Billy Larranaga, Josh McClenahan, Richard Mobarak, Pat Oliver Wright, Nancy Perea, and Adam Romero. Dr. Tarefder conducted an interview with Jeff Mann later in August. Additional interviews were conducted via an email survey of individuals not previously contacted in person. A second round of surveys with a more detailed questionnaire was conducted in early 2011. The following sections summarize the input the researchers received from all of these efforts.

3.2.1 In-Person Interviews

The in-person interviews followed the first questionnaire format shown in Appendix 1.

Question 1 asked if the individual or his/her office collected traffic data. Not surprisingly, all except Mr. Mann reported that they did. Some actually did collect data, others processed the data, and still others supervised the data collection.

Question 2 inquired about the types of data collected. The emphasis of the planning bureau was on traffic volume, vehicle classification, and weigh-in-motion (WIM). According to the interviewees, the department maintains about 122 permanent count stations, and conducts shorter-term counts with portable counters, principally in the southern part of the state during the late fall, winter, and early spring, and in the northern part of the state during the remainder of the year. NMDOT has 120 portable traffic volume counters, but is currently using only about 90 due to staffing shortages. The department has 15 permanent weigh-in-motion sites; formerly the department employed portable WIMs on a 3-year cycle at about 95 sites. The bureau is able to collect speed data, in bins, and believes that it may be required to do so in the future.

The district traffic engineers collect a more diverse traffic data set; in addition to daily traffic volume, they routinely collect manual traffic volume counts, spot speed data, and vehicle delay for traffic signal warrants, citizen complaints, speed zoning, and lane blockage/lane rental in construction zones. None of the individuals interviewed reported that they conducted travel time studies.

Question 2a asked why the individuals/offices collected the traffic data. Individuals at the planning bureau gave two primary reasons for the data collection: Federal reporting requirements, both monthly and annual, and in support of engineering purposes. The traffic engineers had more varied reasons for their data collection. In addition to concerns expressed by citizens, these engineers must conduct studies to document the need for traffic control devices, as specified in the *Manual on Uniform Traffic Control Devices (22)*. They reported that data for turning movement volume counts at intersections and short-term counts at other locations are not available from Santa Fe, although these data were more commonly available in the past.

Question 2b addressed the issue of processing the traffic data. Planning indicated that they use the TRAffic Data System (TRADAS) from Chaparral Systems Corporation for collecting, editing, summarizing, and reporting traffic data. The software meets the data processing requirements of AASHTO's *Guidelines for Traffic Data Programs* and FHWA's *Traffic Monitoring Guide*. Because of the diversity of traffic data collected by the district traffic engineers, their data processing was more varied. For example, the data collected by consultants for traffic impact analyses (TIAs) is processed in accord with the state's *Access Management Manual (23)*. These studies also make use of ITE's *Trip Generation Manual (24)*. Except for special circumstances, traffic volume data in the districts are only collected on Tuesdays, Wednesdays, and Thursdays. None of the state's counts are done using traffic cameras. The pavement engineer reported the need for data processing to address future MEPDG requirements.

Question 2c asked who the data are reported to. The planning bureau indicated that a primary use of the data was for making reports to FHWA, although they also respond to requests for data from others within the department as well as consultants and the public. The reporting by the district traffic engineers appears to vary among the districts. For the most part, the data are used by the districts for the purposes for which it was collected, but is rarely, if ever, shared with Planning. As a result, there is no central database that contains all the traffic data collected by the NMDOT, other agencies or consultants.

Question 3 inquired about documents prepared by the interviewees or their offices related to traffic data collection, policies, or practices. The planning bureau relies on the state's traffic monitoring standards, which are essentially an updated version of the standards developed by the Planning/Research Bureau in 1989-90. None of the districts have developed their own documents; they reportedly rely to some extent on guidance from ITE's latest *Manual of Transportation Engineering Studies (25)*.

This question also elicited the response that there is no communication among those in different districts collecting traffic data. The researchers believe that information sharing among the districts and between the districts and the General Office could be beneficial.

Question 4 asked about the use of documents on traffic data collection prepared by others, either inside or outside of the department. Planning reportedly uses AASHTO's *Guidelines*. The districts do use ITE's *Manual,* but individuals suggested that there is a need for a department manual on setting up equipment so that data are consistent among the districts and to allow input to a common database. Engineers involved with pavement design rely on AASHTO documents regarding traffic volume, vehicle classification, weight and related issues.

Question 5 sought input on the use of traffic data. Planning primarily collects the data, reports it to FHWA and upper management, and shares it with others inside or outside the department who request it. The districts clearly use the traffic data for making decisions regarding design and operations. District 3 has some interaction with MRCOG regarding traffic data.

Question 6, regarding the types of data used and the purposes for using the data, was essentially addressed in the responses to other questions. However, the pavement engineer mentioned the specific needs for ESALs, vehicle volume and classification, and traffic growth rates as essential parameters for the work of his office.

Question 7 asked the individuals how they accessed the information and the format in which it is stored. Planning indicates that they respond to requests from individuals within and outside the department. Based on the researchers' experience on previous projects, an email request to the bureau for volume information is typically accommodated in two days or less. The department is working to get the information available online for all to use. In Santa Fe, the data are stored in TIMS, which is the new version of the former consolidated highway database.

Question 8 inquired about the completeness, reliability, accuracy, and timeliness of the data. With respect to completeness, some concerns were expressed about the WIM devices. The devices used in New Mexico include bending plates and piezoelectric sensors. The specific problems mentioned include power failures and the tendency of both devices to lose their calibration, sometimes after just a short period. Portable counters are placed for a 48-hour count, and are deployed on a three-year cycle. The traffic engineers commented on the lack of turning movement counts and the lack of "k" factors, the ratio of the 30th highest hourly volume to the average daily traffic. The pavement engineer felt that the data were complete for AASHTO's current design policy, but incomplete/insufficient for the MEPDG.

With respect to reliability, planning reports that the traffic volume counts are adjusted to AADT using computed daily and seasonal factors. Procedures exist to promptly identify ATRs that are producing suspicious or erroneous data, and technicians are dispatched to resolve the problems. The interviewees note, however, that the ATRs are aging and that some need replacement. A concern was expressed about the quality control for traffic data.

Regarding the accuracy of the traffic data, there was a sense that the data meet current needs but are not perfect. Planning is considering the use of manual or portable counters near permanent ATR's to verify accuracy. There were no comments on the accuracy of vehicular speed or traffic delay data.

The respondents seemed to be pleased with the timeliness of traffic data. The WIM data are reported monthly and the ATRs are auto-polled on a daily basis. The traffic engineers were satisfied with the timeliness of data that their offices collected, but somewhat less with data collected by others. The proposed move to making traffic data available online was welcomed by all as a means of enhancing both timeliness and accessibility.

The final question sought input on current or projected data needs that are not being met by the existing system. The pavement engineer expressed a need for the inputs required for MEPDG, including axle load spectra, seasonal adjustment factors, and speed data. The limited number of WIM sites was also a concern; the need for the use of portable WIM sites to provide data for MEPDG was mentioned. Traffic engineers felt there was a greater need for TIA data for proposed developments. Some concern was also expressed about the reliability of traffic projections.

The interview participants provided a number of other comments that may be useful. Several of the more important points are noted below:

The current cost for an ATR is in the range of $50,000 to $60,000.

The planning bureau uses TimeMark traffic volume counters.

Traffic engineers use turning movement counters from Jamar and Nu-Metrics (the NC200).

Turning movement counts are used for signal warrant purposes; they typically count three hours in the morning peak, three hours mid-day, and three hours in the evening peak.

All traffic data equipment must be purchased from approved vendors.

WIMs using bending plates are better than those using piezoelectric sensors.

The bending plates on US 550 are recalibrated every six months.

Traffic engineers would appreciate improved access to traffic crash data; currently, data are provided by the NM Traffic Safety Bureau.

3.2.2 Additional Written Interviews

In addition to the interviews described in the previous section, Drs. Brogan and Tarefder obtained input from thirteen additional individuals, ten from the original list developed in July as well as three later identified by the researchers. These individuals represented not only NMDOT personnel from the General Office, the ITS bureau, MRCOG, and District Traffic Engineering staffs, but several private consultants. Particularly helpful was a very detailed response provided by the New Mexico Division of FHWA. Additional input was also provided by a representative of the NM Department of Health with an interest in traffic data from an epidemiological standpoint.

The complete contact list is shown in Appendix 1 and the responses to the survey form are summarized below.

Question 1: All but one of the additional respondents indicated that they either collect, process, or use traffic data. One of the engineering consultants indicated that they do not collect the data themselves but rather hire sub-consultants who specialize in data collection. Only one response, from the software firm that developed TRADAS, indicated that, while they do not collect data, they do software development related to data collection.

Question 2: Planning groups, especially at the NMDOT and, to a lesser extent at the MRCOG, report collecting volume, speed, classification, and WIM data. Consultants, in addition, collect turning movements, and also some crash and pedestrian volume data. One consultant reported collecting origin-destination data through license plate surveys as well as GPS-based travel time studies. Another consultant expressed a need (desire?) for gap data. The NM Department of Health routinely collects data on EMS (ambulance) patient data.

Question 2a: Data is used internally for project planning and design, as well as for Federal reporting requirements.

Question 2b: The NMDOT Planning Bureau processes the data through TRADAS, their traffic data software. One consultant uses video data collection software from Miovision Technology, while the NMDOT ITS bureau uses a third party who configures and manages the data from their Traffic Management Center in a SEQUEL environment.

Question 2c: Data from the ITS Bureau is shared with MRCOG and with contractors who are posting travel times on NMROADS. Consultant data is for internal use or is shared with clients. NMDOT district counts are used internally and not usually shared with the General Office. MRCOG data goes into its database and is shared with NMDOT Planning.

Question 3: Some consultants routinely detail data collection and processing procedures in reports to their clients.

Question 4: The AASHTO *Guidelines* and the FHWA *Traffic Monitoring Guide* were mentioned by several respondents.

Question 5: Traffic data is used for design decisions at the NMDOT. It is also used by Traffic and Planning groups within consulting firms. The NMDOT ITS Bureau uses data to configure its Dynamic Message Signs.

Question 6: Consultants use data for their own studies including classification and WIM data for LTPP studies. They also report using volume data for marketing studies as well as engineering analyses.

Question 7: Data is typically stored on agency/company servers in Excel, .pdf or .csv formats. Backup is by hard copy in project folders. GIS shape files and .dbt tables are also used for storage. NMDOT ITS has data accessible in a web environment; its contractor stores in a SEQUEL database.

Question 8: Most responses indicate completeness, accuracy, reliability, and timeliness as "sufficient for our needs," particularly if the data were collected in-house. There was some concern relating to WIM sensors going out of calibration and the need for better monitoring. Some consultants also expressed concern with the currency of the MRCOG database and the need for more frequent volume counts. MRCOG, for its part, laments the "significant lack of ATR or continuous count locations," and NMDOT's inability to preserve the ATRs that it does have.

Question 9: NMDOT ITS still has some gaps in Interstate coverage, particularly on flyovers; it expects to have these completed soon. Some respondents would like to see turning movement counts to be a "standard inventory requirement," (stored in a central database, along with weights, classifications, etc.) as well as the establishment of a central data collection tool. The MRCOG would like link speeds and travel times on non-interstate facilities to aid in their congestion management process.

3.2.3 Detailed Written Interviews of Project Technical Panel

A series of advanced questions, based on Transportation Research Circular E-C120, *Traffic Monitoring Data and Successful Strategies in Collection and Analysis,* (*26*) was distributed to the project's Technical Panel at the April 13, 2011 Quarterly Meeting. This section is an attempt to summarize the four completed questionnaires that were returned, three from NMDOT personnel and one from a representative of the Federal Highway Administration. The questionnaire is also in Appendix 1; a summary of the Technical Panel's responses with those detailed in the Circular is described below.

3.2.3.1 NMDOT Responses

The problems facing the NMDOT in regard to traffic monitoring revolve around money, politics and the resulting inability to assure that the data collection meets all of the Federal requirements. A long-standing lack of funding has affected both the ability to collect the data that is required by Federal agencies through insufficient staff as well as through inadequate installation, calibration, and repair of data collection equipment. Funding constraints have also resulted in little or inadequate staff training involving proper data collection procedures as well as inadequate database maintenance and reporting, with only static annual reports available on the web. Very few new traffic data initiatives are being worked on with only a microwave detection system currently being evaluated.

Although the data from properly calibrated WIM sites is viewed as meeting program needs, there is a sense that the current number of WIM sites is not extensive enough to satisfy MEPDG requirements. Calibration of WIM sites is scheduled for twice a year on US 550 and annually at other locations; even this is not frequently enough and schedules sometimes (usually?) slip due to both funding and personnel shortages. When calibrations are performed, using both in-house and contractor personnel, the *ASTM Standard Specification for Highway Weigh-in-Motion (WIM) System with User Requirements and Test Methods* (*27*) appears to be followed. WIM data is downloaded weekly, although no automated quality control checks are performed. Manually flagged data is investigated and a technician is sent to review conditions at the site.

Other traffic data from continuous monitoring is downloaded and reviewed daily; automated data quality checks are applied, and flagged or suspect data is investigated, including sending a technician to examine the site. Unexplained large data variations are purged and recounts scheduled.

3.2.3.2 NM FHWA Response

There is concern at the FHWA as to whether some of the Federal reporting requirements are being satisfactorily addressed; this may be attributed to the department’s less-than-complete understanding of the *Traffic Monitoring Guide* (TMG). For example, the TMG calls for a three-year counting cycle on the National Highway System (NHS), on Principal Arterials, and on HPMS sample sections. Every major system section should be monitored to provide truck counts.

The Traffic Monitoring System (*TMS/H, 23 CFR 500 Subpart* B) also calls for vehicle occupancy monitoring and a testing program for field equipment. These requirements are currently not being met.

Finally, while realizing that keeping counters working is always a challenge, operational counters used to determine the annual growth rates need enhancement and additional counters are needed to provide statistical validity.

3.2.3.3 Research Circular E-C120 Summary

Representatives from the Mid-Atlantic region (Delaware, Maryland, Pennsylvania, Virginia, and the District of Columbia) reported on their issues and challenges in a recent workshop entitled, *Traffic Monitoring Data: Successful Strategies in Collection and Analysis*, sponsored by the Transportation Research Board. Their concerns, which in many respects mirror the Technical Panel’s responses, focused on the following:

- Politics and funding,
- Personnel, including training,
- Incorporating ITS and GPS data into traffic monitoring,
- Counts on ramps and bridges,
- Motorcycles counts,
- Safety at high volume locations,
- The frequent replacement of failed piezos,
- Non-intrusive detection issues,
- Site calibration issues, especially with WIM

All five agencies use consultants, especially for coverage counts and all share data, both with MPOs and online. All have centralized operations for data collection, except Delaware, who indicates that decentralizated operation is much of their problem. Staff sizes, both office and field personnel, range from a total of four in Delaware to 15 in Virginia.

3.3 Details of the NMDOT Current WIM Data Analysis Procedures

The NMDOT has currently available a system of weigh-in-motion (WIM) stations located throughout the state to collect volume, classification and weight traffic data on a continuous basis and provide this information to users. These data are stored in 4-card (traffic classification data) and 7-card (axle weight data) formats as follows:

> 4-card is a tabulation of 50 digits for each vehicle passing over the WIM station. These data record the number of vehicles for each class passing that road segment during the day.
>
> 7-card is a tabulation of 50 digits for each vehicle passing over the WIM station. These data record, among other information, the number of axles, type and weight of each axle, and the spacing between axles.

KELTRIS is a vehicle classification system and computer application available at NMDOT's disposal that can process large amounts of 4- and 7-card data (WIM data), yielding the following information for each vehicle (*29*):

> Vehicle class (4 through 13),
>
> Number of axles,
>
> Axles on power unit,
>
> Wheelbase,
>
> Total weight,
>
> Direction of travel,
>
> Date and time,
>
> Number of axles and distribution,
>
> Type, spacing and weight for each axle,
>
> ESAL for each axle,
>
> Total ESAL by equation and interpolation.

KELTRIS performs ESAL calculations in accord with the 1993 *Pavement Design Guide*, and produces reports and graphics to document the following:

> Report of ESALs computed for each class and each direction, and total ESALs.

Correction factors for missing hours.

Report of overweight vehicles.

Graphic of ESALs for each day of the week and each direction of travel.

Graphic of ESALs for each hour of the day and each direction.

Graphic of ESALs for each vehicle class and each direction.

Graphic of traffic volume for each vehicle class and each direction.

3.3.1 WIM Data Analysis Procedures Needed for MEPDG

One of the most important goals of the NMDOT is to provide the users with reliable and current traffic monitoring data. Specifically in pavement design, the NMDOT needs to provide the users of the MEPDG with the traffic data required. The traffic data collected from WIM sites include all the information required to get the MEPDG inputs; it is only necessary to process these data to develop site-specific volume adjustment factors (vehicle classification, and monthly, hourly, and growth factors) and axle load spectra.

With the 4- and 7-cards, the data are available to develop volume adjustment factors and axle load spectra. The main challenge is that KELTRIS does not provide results that are inputs required by MEPDG. Due to time constraints, it is not feasible to introduce and process these data manually in MS Excel to create the tables and plots corresponding to the volume adjustment factors and axle load spectra.

It is essential to automate the processing, classification, and computation of traffic data. This can be accomplished by opening the 4- and 7-cards in MS Excel, and then using the programming language Microsoft Visual Basic to create programming codes that process the data and create the desired volume adjustment factors and axle load spectra. The software can be subsequently improved using another programming language to create a program with a user-friendly interface and more sophisticated features.

Table 3 compares the inputs required for the traffic module of the MEPDG software with the outputs from KELTRIS (*28, 29*). As noted earlier, KELTRIS does not provide the inputs needed. The table also shows the parameters that the new hypothetically developed software would compute; these parameters satisfy the inputs required by MEPDG.

TABLE 3 Comparison of MEPDG, KELTRIS, and a New Developed Program

MEPDG Required Inputs	KELTRIS Outputs	New Program Outputs
Traffic Volume		
Initial two-way AADTT	Total is not given	From processing 4-cards
No. Lanes in design direction	Design parameter	Design parameter
Trucks in design direction (%)	Must be computed	From processing 4-cards
Trucks in design lane (%)	Experience/special count	From processing 4-cards
Vehicle operational speed	Design parameter	Design parameter
Volume Distribution Factors		
Vehicle class distribution factors	No	From processing 4-cards
Monthly distribution factors	No	From processing 4-cards
Hourly distribution factors	No	From processing 4-cards
Traffic growth factors	No	AADT for various years
Axle load distribution factors	No	From processing 7-cards
General Traffic Inputs		
Mean wheel location	Design parameter	Design parameter
Traffic wander standard deviation	Design parameter	Design parameter
Design lane width	Design parameter	Design parameter
No. Axle types/truck class	Not computed	From processing 7-cards
Axle configuration	Design parameter	Design parameter
Wheelbase	Design parameter	Design parameter

3.4 Summary

Not unlike many states, New Mexico's problems relating to traffic data collection revolve around a lack of resources. While the State continues to maintain an acceptable traffic monitoring program, inadequate funding to purchase and maintain equipment, hire and train staff, and calibrate sensors to reflect current standards is an increasing concern.

The possibility of additional Federal requirements and the anticipated needs of new pavement design procedures require an increased focus on better and more efficient data collection procedures. Specific problems related through interviews with NMDOT and other agency staff have been identified and will be addressed in the recommendations of Chapter 7.

CHAPTER 4: NATIONAL STATE OF THE PRACTICE IN TRAFFIC DATA MONITORING

4.1 North American Travel Monitoring Exposition and Conference (NATMEC)

Prior to the literature search conducted as part of Task 3 of the project, it was decided that the then principal investigator should attend the 14th Annual NATMEC Conference to assess the current state-of-the-practice in traffic monitoring as well as to solicit input on both successful practices and those policies, procedures, practices, and equipment that have proved troublesome. Conference attendance also allowed contact to be established with those states with superior traffic monitoring programs as well as with vendors of current equipment, software, and services. The following section provides a summary of selected Conference proceedings. Accompanying slides of selected presentations are in an attachment. While the format of the discussion is sketchy and the points raised may seem redundant and repetitive, the outline leads to more detailed and focused discussions later in the report.

NATMEC 2010, *Improving Traffic Data Collection, Analysis, and Use,* sponsored by the Transportation Research Board, was held in Seattle, WA on June 21-24. The conference attracted over 250 professionals and 33 vendors of equipment, software, and services, including 88 individuals from 31 state Departments of Transportation. Attendees were distributed by affiliation as follows:

State DOTs - 88
Domestic Universities/Research Centers - 46
Consultants - 37
USDOT, FHWA, FMCSA - 22
Foreign Transportation Agencies - 19
Suppliers - 17
Metropolitan Planning Organizations - 10
Miscellaneous - 9
Transportation Research Board - 8
County Transportation Agencies - 8
Foreign Universities/Research Centers - 6

Points raised by the conference speakers are presented below in an outline format.

4.1.1 Opening Session

- The NATMEC conference was started in 1983; the 2010 conference is the 14th
- Themes of this conference: 1) data quality, 2) tools of the trade/technology, 3) data's connection to operations
- WA State DOT will be putting real-time travel time data on the web; motorists appreciate variable message signs showing travel times
- WSDOT has analyzed I-90 EB travel time data by hour of the day; results shared with the media
- Department prepares a quarterly performance data report, the "Gray Notebook"

• Reaching a transition point with private sector traffic data; need to maintain credibility
• Who owns the data collected?
• Collect data once - use multiple times
• Treat data as an asset
• Contemporary issues: safety, climate changes, livability
• Challenges: 1) common need for traffic data, a key for apportionment, 2) maximize resources by working with others, 3) data quality, including competence, procedures and policies, 4) need to embrace new technology, including satellite GPS and Bluetooth

4.1.2 Traffic Monitoring Fundamentals: Back to the Basics

Oregon DOT utilizes manual traffic studies by video, employing Miovision

• Why ODOT uses manual counts: 1) equipment testing, setup, and verification (new sensors) gain confidence in equipment, axle splits, 2) turning movements, classifications, 3) safety concerns - high volume, speed, limited sight distance, 4) urban areas with parking, multiple lanes, stop and go driving conditions

Why switch to video data collection:

• 1) safety of counters, avoiding bad areas, 2) vary playback speed, turn it back, 3) loss of data - breaks by data collectors, 4) documentation at public meetings

Issues:

• 1) error decreases in moving from 24 h to 48 h to 72 h counts, 2) mounting cameras on poles creates concerns with ladder safety (or mount cameras on trailers with 30 foot boom), 3) formerly used professional video tape and equipment because of stops and starts (getting new equipment), 4) now using a claw that climbs pole

WSDOT Best Practices

• For permanent traffic recorder, use Roadtrax BL sensors for a class 1 WIM
• Good success with Diamond and IRD counters
• Setup employs loop/axle/loop, with a 6 foot loop and 10 foot spacing
• PTR - 97% accurate for vehicle classification

Siting considerations:

• Consider safety and closures
• Clear zones, coordinate with guardrail placement
• Don’t place in a wide lane
• Consider possible future road work that may disrupt site
• Road surface condition, cracks, holes, wear in tire tracks
• Proglass one-piece plastic hill barrier for setting equipment into hillside
• 6 foot square loop, 45° corners, 0.25 inch diamond saw cut, 4 turns
• Asphalt 3 inches deep, 2.5 inches in PCC
• Agency has built a 6 foot square PVC template for marking the edges for cutting pavement

Changing Core Priorities of the ILDOT

- 1) why change, 2) low priorities/no longer doing, 3) technology and resources
- Safety: ILDOT had an early morning fatality involving a data collector
- Resources: losing staff for data collection and analysis
- Able to use SPR funds for this work
- FHWA requirements are changing

No longer doing:

- Stopped paper traffic volume maps, moved to the internet; public was quite accepting
- Not spending much time or effort on motorcycles
- Little effort on updating seasonal factors by functional class or geographical area, because they weren't changing much over time
- Low priority for local roads

Technology:

- www.gettingroundillinois.com, Shapefile
- www.dot.il.gov Raw data from counters, updated every year
- dot.ms2soft.com/tcds 24 h volume/classification data
- Video collection on high AADT routes
- ATR sites installed with stimulus money
- G-10 weather stations (groundhog)
- ILDOT has employed the infrared traffic loggers (TIRTLs)
- More use of consultants, funded with SPR
- More use of university graduate student interns

4.1.3 TRB Committee ABJ35, Highway Traffic Monitoring, Mid-Year Meeting

- TRB Fall 2011 conference: Strategies for Meeting Critical Data Needs for Decision Making in State and Metropolitan Transportation Agencies
- NCHRP 870? - report available in Summer 2010 ?
- FHWA Pooled-fund study on alternative classification studies
- ASTM subcommittee on truth in data and turning movements; mentioned input by David Albright

4.1.4 Traffic Monitoring Equipment Basics: Installation and Maintenance

WSDOT Short Duration Traffic Count Field Equipment and Procedures

- Has staff of 10, with 3 lost to budget cuts
- Training plan for all new employees - 8 weeks, including safety issues
- Office conducts annual count proficiency tests near permanent count stations using video
- Monitor 1,200 HPMS locations, March 1 through November 31
- Conducts about 3,000 short duration counts annually
- 162 Permanent Traffic Recorders, some periodic 3 h validations
- Conduct about 10 Before-After studies annually, primarily for mobility projects

• WSDOT's Annual Traffic report is accessed over 10,000 times per year
• Locating count sites - Google map, street atlas
• Validate setups with 100 vehicles
• Uses Diamond counters and count boards
• Control Specialists – TIRTL

Idaho DOT Permanent Traffic Counter and WIM Sites

• Supervises a staff of six
• 48 h counts in the "summer," ATR validation in the winter
• 180 ATR, with loops, + 25 WIM, 21 piezos; ECM Hestia and IRD TCC 540
• Web site - milepost location, links to count data
• Diamond traffic system
• Data collected: Volume, WIM, Raw data, Bin data
• ATR with RWIS sites - need AC power and phone land line
• Formerly IDDOT installed sensors, now done by contractors with supervision
• Calibrate WIM using truck with a known weight
• WIM sites called every Monday, ATR sites polled nightly
• Red flag if there is a 5% difference in validation
• Several good thoughts on sealing sensors: dry, clean
• 75% of 2009 ATR counts below historic highs at the sites
• Check web site itd.idaho.gov/planning/

4.1.5 Traffic Monitoring Equipment: Challenges, Lessons Learned and Relationship to the Traffic Enforcement Community

Michigan DOT

• 133+ vehicle counters, 92 speed monitors, 43 vehicle classifiers, 40 truck axle weight
• Challenges: economic, resource, business needs, Federal mandate
• Need staff to monitor contractors during equipment installation
• Special reporting for holidays (Memorial Day, 4th of July), although desirable, requires accommodation for staff as well as overtime pay
• Business needs - for business design and bridge loading
• Consider the needs of the weight enforcement community
• Data are also provided for research and public use
• Federal reporting for travel trends and analysis, and air quality monitoring
• Capturing axle weight in all lanes is expensive, but necessary to avoid truckers using the roadway's left lane
• Help enforcement officers - *they carry guns*
• Catch *bad guys* - modify enforcement strategies by time of day
• DOT employs Permanent Intermittent truck weigh stations at rest areas, weigh stations

Developing Specifications for Permanent Site Installation, Alaska DOT

- ATR site installation - contracts this work out
- Passive systems, no power or communications, 7-day counter in a box
- Continuous systems, 24/7, power, communication, piezos
- Site design: piezo-loop-piezo, 6 ft × 6 ft, 12-14 gauge wire, 3 or 4 loops
- In PCC: 2.0-2.5 inch deep, using MMM loop epoxy
- AK employs an innovative sub-pavement design, where a 6 × 6 prefab loop with PVC. Schedule 40 conduit is prepared and placed in the subgrade prior to resurfacing
- Class 3 piezo works well in AK's soft asphalt
- State utilizes IRD epoxy for piezo
- Use duct tape masking to create clean installation - mentioned by several states
- State grinds down installation to match road cross-section
- Count season - late May through September
- Passive count - permanent box (CBA1 cabinet), loops, 7-day count, any time of the year, high ADT roads, coordinate with new construction
- CBA2 - has power, communication, insulation, heater

4.1.6 The Mechanistic-Empirical Pavement Design Guide (MEPDG)

PrepME for WIM Data Processing for MEPDG, FHWA

- "Traffic Inputs for Pavement Design" workshop – September 2010?, Buffalo, NY
- Don't have sufficient funds to provide great pavements everywhere
- Machine data from WIM - use software to create input to MEPDG
- DARWin ME software - AASHTOWare, available by December 31, 2010
- Enterprise software, single user $5,000/yr, site licenses available, educational licenses in 2012
- Features: error checking, batch mode (What ifs?), Integrated Reports
- PrepME - software developed by Calvin Wang, University of Arkansas
- PrepME imports raw data into database tables, performs traffic data check, interpolates traffic data, and prepares 11 files that can be directly imported into MEPDG software
- Trend toward using better sensors
- Read 20 gigabytes of original data from AR DOT computer
- Weight data check screen
- Load Spectra - Class 4 through Class 13
- Vehicle classification data check
- Traffic file generation for DARWin ME input
- Software includes a data dictionary
- Construction and related testing module, Maintenance module
- University of Arkansas began this project about 5 years ago
- Future work on a Pooled-Fund study being undertaken by Zhongjie Zhang at LA DOTD

• Rewrite software for universal usage
• Integrate with efforts in PMS, materials, and construction
• Adapt database for use with SQL express

Leveraging Truck Traffic Data from Mechanistic Empirical Pavement Design to Support Other Transportation Engineering Decisions, Montufar and Associates

• Transportation engineering decisions
• Work being performed at the University of Manitoba
• Partnership with Manitoba DOT - DOT collects data, University polishes and distributes information
• Truck traffic exposure - volume, class, weight, axle configuration, speed
• Data hierarchy: Level 1 (permanent count), Level 2 (14 h classification count), Level 3 (don't have vehicle classification data)
• Truck Traffic Classification Groups based on classes 5-7, 9, 10, and 13
• Manitoba developed six groups with differing characteristics: urban, long-distance rural, intra-provincial, near forestry (45% class 13), North Manitoba, and Manitoba to US
• Link truck data to emissions data in Winnipeg
• Exposure for LCVs to calculate accident rate
• Gross vehicle weight for bridges

Data Warehouse Integration of WIM and Vehicle Class Data: Application Developments of MEPDG, Adjustment Factors, and Reporting, University of Minnesota, Duluth

• University houses 5,000 sets of loop detector data since 1998 at its data center
• Researchers found that generating a uniform report from machines manufactured by different companies is not a simple task; no solution was given to this challenge
• Working with binary data is also challenging
• Warehouse - easy to manage and understand
• UMD initially received raw data, then sent it to MNDOT; subsequently moved operation to MNDOT computers
• Importance of data standardization
• Convert IRD data
• Bull Guide Software - creates MEPDG traffic input

4.1.7 Implementing the MEPDG: A Practitioner's Perspective

Implementing MEPDG in Wisconsin, Wisconsin DOT

• Pavement design done in 5 regions, disconnect from traffic folks, all of whom are in Madison
• Phase I: 15 permanent WIMs, 15 portable WIMs, 43 vehicle classification stations
• MEPDG Basic Traffic Input Screen, monthly adjustment by class 4-13
• Recommend TTC grouping by highway function type

• Traffic growth factors based on historical data
• State plans to implement MEPDG when DARWin ME becomes available
• Can we use defaults? Which traffic inputs are the most sensitive to the results?

Implementing MEPDG in Florida, PBS&J

• Traffic inputs: adjustments for month, vehicle class, hourly distribution, traffic growth, axle load distribution
• General traffic inputs: number of axles, axle configuration, wheelbase
• Climate, structures
• Phase 1 - site specific, analyzed with WIM data
• Florida found a skew toward axle loads heavier than the default
• Specifically, found different axle load spectra for NB and SB on I-75
• In steady-state, Florida plans to use a 5-year moving average
• Decision criteria for combining data: <100 trucks/yr?, use defaults

Traffic Inputs for MEPDG: The North Carolina Experience, NC DOT

• North Carolina uses Level 2 when site is not near a WIM site
• Historically, NC has had about 45 WIM sites
• Key traffic inputs: AADTT, vehicle classification (VCD), hourly, monthly, axle load, axles/class, future AADTT/VCD; use defaults for all other parameters
• Examine sensitivity issues - site specific versus clustering
• Flexible pavement design is sensitive to VCD and axle load factors
• NC is in the process of developing an ALF decision tree
• SU traffic growth is similar that of total traffic
• MU growth - existing and planned land use are the keys
• NC pavement researcher estimated the need for 600 WIMs; the speaker, representing the traffic survey unit, expects that 60 would meet the need
• Don't need many WIMs on I-95, the major N-S route

Implementing MEPDG in Arkansas, University of Arkansas

• Pavement design = f(climate, materials, traffic, structure, response, damage, distress)
• DARWin ME is also a tool for forensic analysis
• PrepME software generates 11 traffic files for use in DARWin ME
• Many WIM sites (in AR or broader?) do not pass quality checks
• Researchers are developing a design handbook
• Climate - generate a virtual weather station
• Tie information into *Site Manager*
• Consistent with current pooled-fund study 1) revise software for use by all states and any WIM, and 2) allow manual processing of traffic data by user
• PrepME is/will be available for free with a user guide

• PrepME is better than TrafLoad, which uses just traffic data and ignores climate, materials

4.1.8 Weigh-in-Motion: Equipment, Experiences, and Applications

Minnesota's WIM System, an Update, MNDOT

- Began with a load cell WIM in 1980
- Removed bending plates in 1998 due to a freak accident that resulted in a motorist death
- WIM systems are on the Interstate and other principal arterials
- DOT has received requests from MN State Patrol for monthly reports on vehicle weights
- Routinely prepares plots of traffic volumes by day of the month
- 20 K single axle, 80 K for 5-axle, increase by 10% in winter with permit
- Up to 5% of MN trucks are overweight
- Speed data: monitoring stations find highest percentage of speeders 3-6 am
- MN has observed problems with calibration
- Systems typically last for 6-7 years (not clear if equipment wears out or becomes obsolete)
- WIM report available online at www.dot.state.mn.us/traffic/data/html/wim_reports.html

Performance Measure for Monitoring and Improving WIM Devices, Oak Ridge National Laboratory

- Portable WIM
- Dynamic weighing
- Employs mathematical techniques to enhance data
- Experimental setups
- Innovative setup for military vehicles; prompted by an airplane loaded with overweight Stryker vehicles that crashed
- WIM devices sensitive to correct setup and correct vehicle speed
- Claims that the technical literature reports WIM accuracy as follows: piezo, ±25%; weight sensor, ±15%; bending plates, ±10%; scales, sensor plates, ±5%; axle weight scales with load cells, ±1%
- Where is the error being introduced: 1) low and high frequency oscillations, 2) vehicles moving too fast
- Use modeling to improve the results - *what would you expect from a national lab?*
- Can get accuracy down to ±0.1% at slow speeds, <16 mph
- Claims that research has shown that commercial products could be improved
- Errors in signals from equipment, but algorithms could address these
- Information at www.csiirornl.gov/abercrombie

Dual-Purpose Bridge Health Monitoring and WIM System, CT DOT

• Began program after Manus bridge collapse in the 1980s
• Placed a simple WIM system on a simple bridge, approximately 0.5 mile in advance of a permanent truck weigh station
• Experiment utilized this site, took a video, employed a control vehicle; report is available online
• 38 sensors are deployed on I-91 NB bridge

Integration of WIM Data into Archived Data User System, Berkeley Transportation Systems

• Performance Measurement System (PeMS)
• SR 99-N near Sacramento, April 2010
• State currently has 184 WIM sites
• www.pems.dot.ca.gov
• Supplies data for MEPDG
• One possible use: a lane closure will create delay for motorists, with a higher unit cost for trucks, estimated in CA as $28.70/h

Best Practices for the Installation of MSI Brass Linguini Piezo WIM Systems, WSDOT

• Washington has been using Brass Linguini (BL) piezo devices
• WSDOT contends that one Class 9, 80,000 lb truck = 26,000 passenger vehicles
• WIM challenges: cost, installation time, accuracy
• WSDOT does device installation, to ensure that device works accurately
• WSDOT has a standard site layout drawing
• State believes that piezo depth is important; see their installation guide
• WSDOT has made changes to standard software: use 40 temperature bins, rather than 30; use 3 speed bins rather than 1
• Calibration of devices is essential, and a challenge
• Maintenance: often ignored, but all systems require maintenance

4.1.9 Data Quality Needs for Traveler Information

Assessing the Quality of Traffic Data, CA Center for Innovative Transportation

• Procurement and use of private sector data
• North American Traffic Working Group (NATWG); members include ITS America, Sirius/XM, INRIX, CCIT, BMW, TTI, Total Traffic, NAVTEC, TraffiCast
• End users relatively clueless about information quality
• No widespread metrics or evaluation procedures to measure data quality
• Harmonizing bench marking would benefit both suppliers and customers
• NATWG - agree on and publish guidelines on how to measure and report traffic information quality
• Focus on speed information (mph, travel time, speed buckets, free flow, heavy congestion)
• Addressing the freeway environment

- TMC location codes/route/entire area

Statistical Issues Related to Evaluating the Quality of Traveler Information, University of Virginia

- Pooled fund study TPF-5(200) Standard Test Procedure for Travel Time Data Quality
- Travel time is a random variable with unknown mean and variance
- Accuracy - measure of distance from estimate to the "true value"
- Data accuracy over both space and time
- Ground truth: 1) floating car method, 2) re-identification with multiple observations
- 1 mile, mean = 60 s, standard deviation s = 6 s, CV = 10%
- For a 95% CI with CV = 10%, a sample of n = 7 should be sufficient
- Empirical data from Houston Trans Star toll tag monitoring
- 274 million observations in 2008
- Analyzed in 5-minute intervals
- Factors affecting high travel time variation: access point density >2.0/mile, ADT/lane >50,000 vpd, change in ADT downstream
- Found that CV is somewhat higher in the afternoon

Section 1201: Requirements for Traveler Information, FHWA

- This section of SAFETEA-LU addresses real-time system management information program
- No new funding, but permissible to use Federal-aid funds
- Timeline: all Interstate highways within 2 years, metropolitan and routes of significance within 4 years
- Draft rule addressing comments is under US DOT review
- Expect final rule within 6 months
- IntelliDrive Mobility graphic
- Ties in with 511
- www.datacaptive.noblis.org

4.1.10 Getting Creative with Collecting Truck Traffic Data

Online Freight Data Collection Effort in United States, University of Illinois, Chicago

- Online survey - information on individual shipments
- Utilize public data - run micro simulation of freight movement
- Freight Activity Micro simulation Estimator
- Drawback - lack of information
- Aggregate annual commodity flow among various firm types
- Break annual shipments into shipment size
- Traffic assignment and performance measures
- Surveyed sample of firms regarding five recent shipments, subdivided into 10 commodity types

Using GPS Data to Estimate Link Speed, University of Washington

- Space mean speed - based on GPS
- Is this procedure sufficiently accurate?
- 2,500 trucks in Puget Sound area
- Data read every 15 minutes, or when truck stops
- Loop detector speeds from WSDOT for all vehicles
- Case study: SR 167, 20 miles long split into 10 segments
- In most cases /loop speed - GPS speed/ </= 5 mph
- Link - may include multiple segments
- Conclusion: GPS data are consistent with loop detector data

Estimation of Truck Travel Times and O-D Volumes from Regular WIM Signature Data, Berkeley Transportation Systems

- Estimate of truck travel times and O-D volumes from regular WIM data
- Very rich set of data
- Try to match between sites
- PeMS from Caltans site
- Restrict to class 9 vehicles
- Use axle spacing for vehicle signature
- Pick two stations 6 miles apart on I-5 in Southern California
- Another experiment picked two stations on I-8 about 50 miles apart east of San Diego
- A third experiment utilized a pair of stations on SR 99, 80 miles apart on non-access controlled roadway
- Compared weight between two sites - found a consistent bias, suggesting that at least one site is out of calibration

The Use of Private Sector Truck GPS Data by Public Organizations, University of Washington

- Private sector has GPS truck fleet data, which it's willing to sell
- Prime sources in Puget Sound area include Trimble and Qualcomm
- Devices are in about 25% of the trucks in the area
- Use data to assess before and after performance
- Companies had data in different formats, but were willing to cooperate with researchers
- Data cost: \$0.20 - \$0.50/truck/day
- Needed a contract with the vendors; this got the attorneys involved
- Essential to maintain the privacy of the truckers and trucking companies
- Information: longitude, latitude, time/date stamp, travel direction, instantaneous speed, truck ID
- Researchers don't know truck's size, class, or cargo
- Numerous technical challenges
- Study was able to identify truck speed bottlenecks

4.1.11 Using Private Sector Speed Data in Congestion Monitoring and Performance Reporting

Evaluation of Nonintrusive Traffic Detection Technologies: Phase III, SRF Consulting Group, Inc

- MNDOT is doing testing at a site on I-394
- 14 states are participating in this pooled fund study
- Emphasis on sites with heavy congestion in urban areas
- Data collected includes volume, speed, and class
- Six devices employed in test
- Wavetronix SmartSensor HD 125, 30 foot offset, 28 foot high; volume error 1.6%
- GTT Canoga Microloops, poor on vehicle length; volume error 2.5%
- ISS Canada RTMS G4 Detectors - closely spaced vehicles are grouped
- Peek AxleLight, placed close to pavement - issues with calibration, speed is low
- TIRTL (The infrared traffic logger) - deploy in traffic barrel, with one unit on each side of the road. Volume error 3.8%; for axle spacing, TIRTL is better than axle light.
- Miovision, intended for turning counts, no speed data, vendor processes video file, error <0.5%
- More details at http://portal.srfconsulting.com/NITPhase3/

Low-Cost Minimally Intrusive, Light-Based Sensors for Vehicle Detection, University of Washington

- Holy grail - search for a detector that will do everything
- Low power, wireless communication, low-cost, on-board computing
- Traditional - video image based detection, expensive, complex processing
- Alternative, monitor vehicle shadows by looking up at vehicle
- Develop a device based on an upward-facing single-pixel camera
- Hollowed out an RPM, placed device inside
- Off-the-shelf parts included microprocessor, wireless module, battery, photocell
- Approach is promising, feasible, and cheap

Collecting and Monitoring Arterial Travel Times from Wireless Solar-Powered RFID Readers, Rensselaer Polytechnic Institute

- Project sponsored by FHWA and NYDOT
- Use RFID technology, specifically the EZ Pass toll tag used in 14 northeast states
- 21 million EZ Pass tags deployed; 20-30% penetration rate on NY arterials
- Wireless, solar-powered, non-intrusive
- Detection equipment placed on a small trailer, like the light trailers used in work zones

• Antenna on mast, with pan/tilt capabilities
• Project to assess component performance
• Problems with Pocket PC, Bluetooth adapter; inadequate battery storage for NY winters
• Installed in pairs near the NY State Fair; system detected much longer travel times due to a traffic accident

4.1.12 Closing Session

Impacts of Transportation Technologies on Traffic Data Programs, USDOT RITA

- What is RITA doing? Non-military GPS
- Critical issues, including high-speed rail
- Secretary LaHood is emphasizing solid data and quality research
- Key priorities: 1) safety, 2) livable communities, 3) state of good repair, 4) economic competitiveness, 5) environmental sustainability
- Part of the open government initiative - see www.data.gov/
- Tri-met website shares transit information
- BTS - ramp meters
- Technological advancements - locational GPS, wireless, computing power
- IntelliDrive - connectivity among vehicles, operators, wireless devices, and infrastructure
- Requires real-time data capture and management
- More details available at www.intellidriveusa.org
- TRB conference on intellidrive: http://guest.cvent.com/EVENTS/Info/Summary.aspx?e=7fbf628b-1ce1-4328-b473-3d8c894a7cce
- Forecast environment with some information from traveler, much more information from vehicle, some information from infrastructure

Looking Ahead: The Federal Highway Administration - Proponent of Traffic Data Community

- Find out what data we actually need to collect
- Know how your data are being used
- Freight volumes on a flow map
- Truck speed map - based on GPS data from 500K trucks

The visual aids for many of the NATMEC presentations are available online at http://onlinepubs.trb.org/onlinepubs/conferences/2010/NATMEC/FinalProgram.pdf.

4.2 Current National Practices in Data Collection from the Literature

Traffic data needs vary with different traffic agencies and traffic applications. A nationwide study conducted by the Volpe National Transportation Systems Center (*30*) on traffic monitoring programs in urbanized areas with populations of over 200,000 revealed that traffic volume, vehicle classification, and speed/travel time were the traffic data most needed. The following sections summarize a literature review heavily excerpted from this reference as well as from several other documents (*31-45)*.

4.2.1 Minnesota Department of Transportation

The Minnesota Department of Transportation conducted a survey of state transportation agencies about their method of data collection. Table 4 summarizes their findings.

TABLE 4 Traffic Data Collection Methods

Data Collected	Collection Method
Count	Loops, road tubes, piezoelectric, manual
Speed	Loops, road tubes, piezoelectric, radar
Classification	Loops, road tubes, piezoelectric, axle counters, manual
Weigh in motion	Loops, portable capacitance mats, weigh in motion stations

Source: Reference (*32).*

4.2.2 Arizona Department of Transportation

The Arizona Department of Transportation conducted a survey of the different technologies used by the 50 states. Their survey also required the agencies to show their level of satisfaction with the technology in terms of its use, disadvantages, identified frequency of use, and manufacturer name. The survey results are shown in Table 5 on the following page. The disadvantages of the various techniques are shown in Table 6 and the level of satisfaction (on a scale of 1 to 5) are shown in Table 7. The low totals associated with several of the non-invasive technologies no doubt are due to their relative scarcity in 2001 when the survey was published.

The survey shows the most common methods used for different data types are:

Count: Inductive loop, pneumatic road tube, piezoelectric sensor,
Speed: Inductive loop, piezoelectric sensor, pneumatic rubber tube,
Classification: pneumatic rubber tube, piezoelectric sensor, manual observation,
Weight: piezoelectric sensor, bending plate.

TABLE 5 Method of Data Collection

Sensor Technology	Number of states reporting:			
	Count	Speed	Weight	Classification
Manual observation	26	5	6	29
Bending plate	15	11	23	20
Pneumatic tube	47	20	4	43
Piezoelectric sensor	28	23	39	40
Inductive Loop	47	32	14	24
Passive magnetic	3	1	0	1
Radar	15	3	0	0
Passive acoustic	4	1	0	0
Video image detect	2	1	0	4

Source: Reference (*31*).

TABLE 6 Disadvantages Reported by the States

	Number of States Reporting	Weather Interference	Equipment Cost	Data Accuracy	System Failure	Installation Requirements	Lanes Monitored	Maintenance Requirements	Ease of Calibration
Inductive Loop	50	2	4	4	7	21	1	13	2
Pneumatic Rubber Tube	49	30	1	27	8	11	32	2	0
Piezoelectric Sensor	47	12	8	12	25	22	0	18	16
Manual Observation	41	17	4	14	1	1	13	0	0
Bending Plate	25	2	18	3	7	13	0	13	6
Radar	17	4	6	7	2	6	2	1	8
Video Image Detection	5	3	3	2	2	4	0	0	1
Passive Acoustic	4	1	2	1	0	3	1	0	1
Passive Magnetic	4	0	1	2	1	1	0	0	0

Source: Reference (*31*).

TABLE 7 Usage and Level of Satisfaction

	Inductive Loop	Pneumatic Rubber Tube	Piezoelectric Sensor	Manual Observation	Bending Plate	Radar	Video Image Detection	Passive Acoustic	Passive Magnetic
Number of States Reporting	50	49	47	41	25	17	5	4	4
Percent Usage	100	98	94	82	50	34	10	8	8
Average Level of Satisfaction	4.4	3.8	3.5	4.0	3.4	3.4	3.0	2.8	3.3

Source: Reference (31).

The survey results show that inductive loops, pneumatic rubber tubes and piezoelectric sensors were the most commonly used detectors when the study was conducted. The Arizona DOT survey concludes by showing about 24 out of 50 states using some nonintrusive detectors in data collection. Inductive loops are viewed as most consistently accurate device used in traffic data applications.

4.2.3 Review of Detector Technology

There are two main categories into which traffic collection equipment can be grouped: intrusive and nonintrusive.

4.2.3.1 Intrusive Technologies

The intrusive methods basically consist of a data recorder and a sensor placed on or in the pavement. Intrusive detectors include inductive loops, pneumatic road tubes, piezoelectric sensors, magnetic sensors and weigh-in-motion detectors. All these have been employed for many years.

4.2.3.1.1 Inductive Loops

An inductive loop is a wire embedded into or underneath the roadway in a variety of shapes. The primary components of an inductive loop are: a detector oscillator that serves as a source of energy for the detector, a lead-in cable and one or more turns of insulated loop wire. The loop utilizes the principle that a magnetic field introduced near an electrical conductor causes an electrical current to be induced. Data collected by loops include volume, speed, occupancy and presence.

4.2.3.1.2 Pneumatic Road Tubes

These are rubber tubes that are placed across the road lanes to detect vehicles by pressure changes that are produced when a vehicle tire passes over the tube. The pulse of air that is created is recorded and processed by a counter located on the side of the road. Pneumatic road tubes can be used to detect volume, speed, and classification by axle counting and spacing. These detectors are typically used for short-term traffic counting.

> ***Drawback*:** this technology has limited lane coverage and its efficiency is subject to weather, temperature and traffic conditions.

4.2.3.1.3 Magnetic Loops

The loops are embedded in roadways in a square formation that generates a magnetic field. The detector generates a voltage by measuring the distortion in the magnetic flux lines. The information is then transmitted to a counting device placed on the side of the road. There are two primary types of magnetic loops: induction magnetometer and dual-axis fluxgate magnetometer. Magnetic detectors can be used to detect volume, presence, and occupancy.

> ***Drawback***: The loops generally have a short life expectancy because they can be damaged by creeping pavements and heavy vehicles although they are not usually affected by bad weather conditions. Implementation and maintenance costs can be expensive.

4.2.3.1.4 Piezoelectric Sensors

These sensors are placed in a groove along the roadway surface of the lane(s) being monitored. The principle is to convert mechanical energy into electrical energy. Mechanical deformation of the piezoelectric material modifies the surface charge density of the material so that a potential difference appears between the electrodes. The amplitude and frequency of the signal is directly proportional to the degree of deformation. This system can be used to measure weight, speed, volume, and vehicle classification.

4.2.3.2 Nonintrusive Technologies

Nonintrusive detectors are gaining prominence because of today's congested freeways and an increase in the number of signalized intersections. Due to the development of intelligent transportation systems, the closing of a heavily traveled lane for maintenance activities, and the exposure of workers to hazardous traffic conditions during the installation of intrusive detectors, there is a need to move towards greater use of nonintrusive technologies. Nonintrusive detector systems can also be used on bridge decks, where the installation of permanent inductive loop detectors is generally not accepted (*32, 33*). Nonintrusive sensors are employed in vehicle counts and classification. Some nonintrusive sensors can count vehicle axles, but early models are limited in their application and have exhibited installation problems. These first generation systems can count only one lane of traffic and are unable to detect a vehicle or axle when blocked by an intervening vehicle; hence, they are unable to accurately count axles. As a result, most nonintrusive sensors classify vehicles by overall length, which does not track with the vehicle classes commonly collected at WIM sites.

Further efforts are required to process these data in order to meet FHWA protocols, but this requires time. The data collection agency's most important consideration is to mount these sensors at locations conducive to the proper functioning of the sensor. Sensor height and angle of view are important for overhead-mounted sensors that collect data on more than one travel lane (*47*).

4.2.3.2.1 Passive and Active InfraRed

These methods detect the presence, speed and type of vehicles based on the infrared energy radiating from the detection area. Infrared detectors find radiation ranging from 100 to 105GHz. The detectors convert the received energy into electrical signals to determine the presence of a vehicle through real-time signal processing.

> **Drawback**: The efficiency of this method is weather dependent and has limited lane coverage.

4.2.3.2.2 Microwave Radar

This technology can detect moving vehicles and speed through either Doppler radar or frequency modulated continuous wave (FMCW) detectors. Doppler microwave detection devices transmit a continuous signal of low-energy microwave radiation at a target area on the pavement to analyze the reflected signal. FMCW detectors, sometimes referred to as true-presence microwave detectors, transmit continuous frequency modulated waves at the detection zone. The detectors measure the range of time from the detector to the vehicle to determine vehicle presence. Both record count data, speed and simple vehicle classification and are not affected by weather conditions.

4.2.3.2.3 Passive Magnetic

Passive magnetic devices detect the disruption in the earth's natural magnetic field caused by the movement of a vehicle through the detection area. In order to detect this change, the device must be relatively close to the vehicles. Magnetic sensors are fixed under or on top of the roadbed. They count volume, speed and classification.

> **Drawback**: Under some operating conditions the sensors have difficulty differentiating between closely spaced vehicles.

4.2.3.2.4 Ultrasonic and Passive Acoustic

The ultrasonic devices emit sound waves and measure the time for the sound to be reflected back to the device. The ultrasonic sensors are placed over the lane to be monitored. A passive acoustic device utilizes the sound energy in a different manner. These systems consist of a series of microphones aimed at the traffic stream. The device detects the sound from a vehicle passing through the detection zone and compares the sound to a set of sonic signatures preprogrammed to identify various classes of vehicles. The primary source of sound is the noise generated by the contact between the tire and road surface. These devices are best used in a side-fire position, pointed at the tire track in a lane. Data collected include count, speed, and classification data (length based).

Drawback: The devices can also be affected by bad weather conditions (e.g., low temperatures, snow).

4.2.3.2.5 Video Image Detection

Video image detection devices use a microprocessor to analyze the video image input from a camera. Video cameras record vehicle numbers, type and speed by means of different video techniques such as trip line and tracking. Trip line techniques monitor specific zones on the roadway to detect the presence of a vehicle. Video tracking techniques employ algorithms to identify and track vehicles as they pass through the field of view.

Drawbacks: The following factors have been shown to adversely affect video system performance:

Shadows (both stationary and moving shadows cast by vehicles),
Direct sunlight,
Reflections caused by wet pavement and headlights,
Transitions from light to dark or dark to light,
Wind-induced pole movement,
Environmental degradation of the video image, caused by water on the camera lens, icicles hanging in front of the camera lens, salt grime on the camera lens, and cobwebs on the camera lens,
Limited visibility, caused by such phenomena as heavy snow, heavy mist, or dust storms,
Video systems can be sensitive to meteorological conditions (*4*

4.2.4 Recent Improvements in Detector Technologies

Recent extensive research has shown that few changes in the methods employed in data collection have occurred in the last decade. Rather, steps are being taken to improve the various technologies involved.

4.2.4.1 Inductive Loops

Inductive loop manufacturers are attempting to improve vehicle classification by employing vehicle signatures. Each vehicle has its own features. Two examples of classification devices using forms of this technology are Peek's Idris® Smart Loops AVC System and U.S. Traffic Corporation's IVS-2000. With the Smart Loops System, the classification scheme is based on a per-vehicle record that is composed of vehicle length, number and spacing of axles, presence of dual tires and vehicle profile. The system can be set up and operated by remote telemetry. The manufacturer claims separation accuracy at > 99.96% and axle class accuracy at > 99.4%.

The IVS-2000 system uses a complete "inductive signature" to classify vehicles using advanced neural network software. The system classifies vehicles into 23 different classes - all 13 FHWA classes plus ten additional classes. The accuracy rate is reported by the manufacturer to be 85 to 90 percent using one or two loops. With the IVS system, a per-vehicle, time-stamped record is created that is used to process classification data. The system operates with one or two loops per lane and can be used with existing loops (*33*).

4.2.4.2 Passive Acoustic Devices

The concept of neural networks for data collection and interpretation has potential beyond inductive loops. This pattern-matching technology also is being used with acoustic sensors to improve on vehicle classification accuracy. Similar to the inductive loops, an "acoustic signature" is developed with the use of microphones and digital audiotape records. The neural net then uses this information to classify vehicles based on their unique acoustic signature (*31*).

4.2.4.3 PiezoElectric Sensors

In the area of piezoelectric sensors, Kistler Instruments Corporation is using quartz-based material in its force transducer design. Since the piezoelectric force transducers are ideally suited for measuring dynamic events, they cannot perform truly static measurements. Quartz has an ultra-high insulation resistance that makes it ideal for static measurements. The Kistler system can routinely measure large forces for minutes and perhaps even hours. The quartz sensor can be used for either direct or indirect force measurements. The Maine Department of Transportation reports considerable success with the use of quartz sensors for collection of weight data (*34*).

4.2.5 Detector Performance

The type of detector to be selected for data collection depends on the data type, data accuracy, cost, ease of installation and maintenance. Although detectors may belong to the same type of detector technology, different detector devices may provide different data types.

The Minnesota Department of Transportation and SRF consulting firm have conducted extensive research on the performance of nonintrusive detectors in traffic monitoring compared to intrusive detectors, specifically inductive loop detectors. Surveys have also been conducted by other state transportation departments. The different technologies that were evaluated are: passive and active infrared, magnetic, radar, Doppler microwave, pulse ultrasonic, passive acoustic and video image processing from different vendors. The tests were conducted on freeways and intersections under free flow and congested traffic flows. In this research, each type of equipment was mounted by the vendors to ensure that mounting height, angle, distance from roadway and calibration were done according to specification and by the experts.

4.2.5.1 Baseline Data

Inductive loop detectors are the most widely used detectors in data collection and are known to provide accurate results. The Minnesota Department of Transportation tested inductive loop detectors as a baseline source. The loop count values at a freeway ranged from 0.1% to 3% of actual over a one hour period. At an intersection, the counts varied from 2.8% to 8.6% of actual. The average difference between the loop speed and probe vehicle speed was 1.2% for both the right and left lanes and 3.3% for the center lane on the freeway (*35*).

4.2.5.2 Passive Infrared

MnDOT tested both the IR 254 and IR 224 technologies from ASIM Technology Ltd. of Switzerland. ASIM IR 254 is a single lane detector that can be mounted either overhead or slightly to the side of the roadway and should face oncoming traffic. Calibration is quite simple. At a freeway overpass, IR 254's volume accuracy ranged from 0 to 10% during off-peak periods and undercounted by more than 10% during peak periods. Speed data were underestimated by 10% on average (*35*).

The ASIM IR 224, designed to be mounted either overhead or slightly to the side of the road, must face oncoming traffic. At freeway locations, the count data were within 1% of baseline data during a 24-hour count. One device was observed to undercount during a snowfall, which may have resulted from vehicles traveling outside the sensor's detection zone (*36*).

Model 833 by Eltec Instruments, Inc is a self-contained detector that is easy to mount and calibrate. This type of detector can be mounted overhead or by the side of the road; it can monitor either oncoming or departing traffic. This device overcounted vehicles at intersections by approximately 15% on most days (*36*).

4.2.5.3 Active InfraRed

The Schwartz Autosense II is a single-lane active infrared sensor designed for overhead installations only. MnDOT tested the Autosense II and found it provided volume data which varied 0.7% from the baseline data. For speed data, a 24-hour test found a deviation of 5.8% from the baseline data. The report shows that this device performed consistently throughout all six months of continuous testing (*35*).

The Autosense I was also tested by MnDOT at a freeway site and was found to be very accurate except under certain weather conditions. Heavy snowfall was found to cause the Autosense I to both undercount and overcount vehicles. The detector undercounted vehicles by 23% and 16.6% on two snowy days. It overcounted vehicles by 9.1% on another snowy day. The undercounting was attributed to vehicles traveling out of the detection zone and the overcounting due to falling snow reflecting the laser beams causing false detections (36).

The nonintrusive monitoring system (NTMS) by Spectra Research is designed to be installed on the ground to monitor traffic from the side of the freeway. Proper calibration requires careful sensor placement and leveling. The collected volume data ranged from 0.2 % to 13% undercounting on lane 1, 0 to 6.5% undercounting on lane 2, and 0.3 to 8.9% undercounting on lane 3. The undercounting was attributed to intermittent slow-moving traffic, tailgating and a maximum axle configuration in the host device (35).

4.2.5.4 Microwave Radar

The Whelen TDN 30 undercounted vehicles when mounted overhead at a freeway bridge at a rate of 2.5% to 13.8% when compared to baseline data. The speed data differed by less than 1% from the baseline data. The TDN 30 could only detect large free-flow vehicles at intersections and thus could not be used for intersection monitoring (36*)*.

The Remote Traffic Microwave Sensor (RTMS) by EIS is a true presence microwave detector. RTMS undercounted vehicles by 2% when mounted overhead and 5% when mounted as a sidefire when compared to baseline data. Speed data were 7.9% higher than loop speed. Speed data, however, varied depending on the mounting location, with the overhead position being the most accurate (*36*).

The Texas Transportation Institute (TTI) also tested RTMS. Their test indicated volume data for lanes 2, 3 and 4 were almost always within 5% of loop counts. On lane 1, the variation was within 10% of the loop data during off-peak periods. During peak periods, on all lanes, RTMS counts varied more from baseline data than during off-peak periods but were usually within 10%. Average speed was within 5 to 10 mph of baseline speed during off-peak periods (3*6*).

The Accuwave 150LX by NATZEC was also tested by TTI at a freeway, although it is primarily designed for intersections. The sensor count was within 10% of the baseline count during midday hours but provided errors ranging between 30 and 40% at other times (*38).*

4.2.5.5 Passive Acoustic

The Smart Sonic TSS-1 was easy to install and calibrate. When mounted on a freeway bridge, it undercounted traffic in the range of 0.7 to 26%. This undercounting may be due to the echo-filled environment underneath a bridge. When mounted at an intersection, this device also undercounted by 10% of the loop count (*36*).

The SmarTek SAS – 1 monitored three lanes of traffic and was mounted at five different heights with a freeway sidefire. When mounted within the vendor-recommended offset range of 15 feet, the sensor provided better results for lanes 2 and 3 than for lane 1. The 24-hour count was within 8% of the baseline count for lane 2 and 3 for all heights and between 12 and 16% for lane 1 with heights below 30 feet. The device provided good results under free-flow conditions but undercounted during congested periods. For speed, the SAS-1 count was 8% below the loop count most of the time and between 12% and 16% lower for lane 1 for heights less than 30 feet. The sensor produced the best results for lanes 2 and 3 when aimed at a 45 degree angle downward. When mounted at an intersection, the sensor performed 100% measuring vehicle presence. SmarTek is easy to install and calibrate (*35*).

TTI also tested the SAS-1 and found that it undercounted most of the time in both peak and off-peak conditions. In lane 1, the count ranged from 0 to 20% less than the baseline for all intervals. Two thirds of the undercounts in lane 2 were between 0 and 10% below the baseline in the peak periods. During off-peak periods, 80% of the intervals were undercounts and 20% were overcounts by as much as 30%. The speed estimates were within 5 to 10 mph of baseline during some peak periods but larger in others. Off-peak speed was usually within 5 mph of baseline speed (*38*).

4.2.5.6 Ultrasonic

The MS Sedco TC 30 may be mounted overhead or sidefire. Data from the device at a freeway test site ranged from 0.7% overcounting to 2% undercounting. It overcounted at an intersection site with a range of 10% to 300%. Manual observations revealed the device counted a vehicle multiple times when it stopped in the detection area (*36*).

The Novax Lane King can be mounted overhead or sidefire. When mounted at a freeway site, Lane King undercounted between 1.2% and 0.2% of the daily baseline count. At intersection test sites, the device overcounted as a result of double counting *(36*).

4.2.5.7 Magnetic

The 3M Microloops by 3M Intelligent Transportation Systems consisted of three components: Canoga Model 702 Non-Intrusive microloop probes, Canoga C800 series vehicle detectors and 3M ITS Link Suite application software. MnDOT tested microloops on a freeway. When installed under the pavement, the volume data were within 2.5% of the baseline count. For speeds, the test system generated 24-hour test data ranging from 1.4 to 4.8% of baseline for all three lanes (*36*).

A TTI test on 3M at College Station, TX indicated that for a six-day period, 3M counts were almost always within 5% of the baseline counts 99.4% of the time in the right lane (dual probes) and 94.5% of the time in the left lane (single probe). A comparison between 3M microloops and RTMS baseline one-minute interval speeds found the mean difference to be -0.25 mph and the standard deviation to be 3.6 mph (*37*).

4.2.5.8 Multiple Technologies

The ASIM DT 272 Passive Infrared/Pulse Ultrasonic device incorporates two technologies: passive infrared and pulse ultrasonic. It is a single lane detector that can be installed overhead or as sidefire. It is designed to detect vehicles in a short distance (no more than 39 feet). When tested on a freeway, the count compared with the loop data was within 8.7% when mounted overhead. The device, however, performed inconsistently when mounted sidefire, but on one of the count days, its count data was 0.8% from the loop data. When mounted at an intersection sidefire, the presence data collected by the device was 100% accurate when compared to manual observation (*35*).

The ASIM TT 262 Passive Infrared/Pulse Ultrasonic/Doppler Radar is a triple technology sensor that uses ultrasonic, passive and Doppler radar to enhance accuracy and reliability. This device can only provide real-time data. MnDOT tested this device at a freeway overhead bridge. Results indicated that volume data were within 2.1% of baseline data at 21 feet high and within 4.9% at 17 feet high. Speed measurements showed a difference of 4.4% at 21 feet high and 3% at 17 feet high (*35*).

4.2.5.9 Trafcon NV Video

MnDOT tested this device at both freeway and intersection locations. When mounted on a freeway bridge, 21 feet high, the differences between its volume count and the loop count were under 5% for all three lanes. At 30 feet high, the sensor count was less than 5% during off-peak periods but undercounted during peak periods between 10% and 50% of the baseline data. The undercounting may have resulted from snow flurries or improper calibration. At a height of 21 feet, the average difference between device and baseline count was 3% in lane 1, 5.8% in lane 2 and 7.2% in lane three. (*35*).

When installed sidefire at the freeway site and tested on all three bases with five different heights, the count differences decreased from 10% to 15% at 25 to 30 feet. It also decreased to fewer than 5% at a 45 foot height. The average speed difference at all five heights ranged from 2 to 12% for all three lanes. When tested at an intersection, Traficon was mounted at 37 feet facing traffic. The sensor overcounted traffic in the right lane by 17% and undercounted traffic by 13% in the through lane (*35*).

4.2.5.10 Autoscope Solo

This sensor can be mounted overhead or by the side of the roadway. When mounted on a freeway overhead bridge at a 30 foot height, the difference between the sensor data and loop data was under 5% for all three lanes. For speed, the average difference was 7% in lane 1, 3.1% in lane 2 and 2.5% in lane 3. When installed sidefire on the freeway, the device counted traffic at all three bases at different heights. The count data differed by less than 5% for all three lanes. Average speed differences were less than 8% for all three lanes. When tested at an intersection site at a height of 37 feet facing on-coming traffic, the sensor overcounted in the right lane by 18% and in the through lane by 19% (*35*).

4.2.6 Weigh-in-Motion Systems Technology

Weigh-in-Motion (WIM) is a technology for measuring the weight of moving trucks. The American Society for Testing and Materials defines WIM as the process of measuring the dynamic tire forces of a moving vehicle and estimating the corresponding tire loads of the static vehicle (4*0*). WIM tasks are complicated by the dynamic motion of trucks being weighed since trucks bounce as they move. The degree to which they bounce is a function of pavement roughness, vehicle load, environmental conditions such as wind, and each vehicle's design and suspension systems (*40, 41, 47*).

The selection of the type of equipment to use is very important due to the inherent strengths and weaknesses of the equipment. Some equipment may function nearly flawlessly in a rural area and in moderate environmental conditions but that same equipment may work poorly in urban stop-and-go conditions where snow conditions disrupt driver lane discipline. Some equipment may work accurately in good weather conditions but less accurately in harsh weather conditions (*40, 41, 47*). The greater the amount of vertical motion that a vehicle exhibits, the more difficult the task for WIM systems to accurately estimate static axle loads. Thus, for all WIM technologies, a key issue for collecting accurate weight data is to select locations for data collection that minimize the dynamic motion of trucks being weighed. The lower the dynamic motion of the passing truck, the more accurate the WIM scale, regardless of the technology selected.

In addition to weight, WIM Systems are capable of classifying vehicles according to the FHWA classification scheme.

4.2.6.1 Layout and Components of WIM systems

WIM systems generally comprise the following basic components:

A mass sensor,
A vehicle classification and/or identification sensor,
A processor and data storage unit,
A user communication unit.

4.2.6.2 Vehicle Classification

Most WIM Systems have the ability to classify and/or identify the vehicle to which the weighed axle belongs. Classification is accomplished via the use of a variety of different vehicle detection sensors, placed adjacent to the actual mass sensor. Typical vehicle classification sensors are as follows:

Road tubes,
Piezoelectric cables,
Magnetometers,
Inductance loops.

These sensors can be used for either short-term or continuous classification counts (*41, 47*).

4.2.6.2.1 Road Tubes

Road tubes are the most frequently used portable classification sensors. Tubes used for classification purposes must be placed parallel to each other and perpendicular to the direction of travel. If the tubes are not perpendicular to the direction of travel, a single axle may generate more than one air pulse, resulting in an inaccurate count of axles. Both of the tubes must be the same length or the timing of the air pulse at the air switches will not be equal (*47*).

4.2.6.2.2 Piezoelectric Cables (BL and Ceramic)

Piezoelectric sensors are sensitive to temperature and thus do not perform well in very cold conditions. Similar to road tubes, the piezoelectric sensors are used to classify vehicles according to the FHWA classification scheme (*47*).

4.2.6.2.3 Inductance Loops and Magnetometers

Inductance loops and magnetometers classify by vehicle length. These two technologies are relatively inexpensive to purchase, and are easy and inexpensive to place. They are, however, designed to perform in low and moderate volume rural areas. In congested conditions, where vehicles are accelerating or decelerating while crossing the sensor or tailgating each other, these sensors are unable to measure the axle spacing correctly or distinguish between them (*47*).

4.2.6.3 Sensor Performance

All the different classification sensor technologies have the constant drawback of an inability to classify closely spaced vehicles. These technologies are thus unable to differentiate between multi-truck vehicles and closely spaced vehicles; hence, most states do not collect classification data on urban streets. Classification sensors used as permanent sensors have the advantage of eliminating the effects of impact loads. Permanent sensors, however, do have some disadvantages. The road must be closed, for example, when the sensors are installed, during maintenance work, and during recalibration (47).

Permanent sensors can fail because of fatigue or environmental effects such as water getting into the sensor or a nearby lighting strike that shorts out the sensor or its electronics. Failure of the pavement can cause premature failure of the sensor. Loops have an advantage over pressure sensors in that they are not in direct contact with axles; thus they are not subject to impact loading that leads to sensor failure. Sensor failure with loops is commonly due to freeze-thaw conditions that result in pavement movements sufficient to cut the wire placed in the pavement, and their accuracy tends to degrade under congested conditions.

4.2.6.4 Portable WIM Sensors

Capacitance mats and BL style piezoelectric sensors are commonly used in the United States for high-speed portable WIM data collection (*47*). Capacitance mats are manufactured from stainless steel, brass, aluminum, polyurethane, or rubber. The system typically consists of two or more conductors that carry equal but opposite charges. When a vehicle passes over the mat, the distance between the mat surfaces decreases and the capacitance increases. The data analysis and recording equipment measure the change, which is proportional to the axle weight.

These sensors are typically placed on the surface of the pavement and require only a few hours of lane closure. A portable WIM mounted on the surface of the pavement does create a bump, however, when axles pass over it. This bump adds to the dynamic forces, which affects the accuracy of the sensor. The bump also flexes the tire, absorbing horizontal forces from the impact with the bump. The tire flex force is then transmitted to the weight sensor causing additional bias and noise in the measurement process. Because of this, portable sensors need to be calibrated each time they are mounted. This limitation has resulted in states collecting short-term counts using either permanently installed sensors or low-speed portable WIM scales or portable static scales (*47)*.

4.2.6.5 Permanent WIM Sensors

4.2.6.5.1 Piezoelectric Sensors

All piezoelectric sensors operate on the same principle. When a mechanical force is applied to a piezoelectric device, it generates a voltage by causing electrical charges of opposite polarity to appear at the parallel faces of the piezoelectric material. The measured voltage is proportional to the force, or weight, of the wheel or axle and is transmitted by the sensor to electronics that measure and interpret the voltage signal. The piezoelectric effect generated by the sensor is dynamic. That is, the charge is generated only when the forces applied to the sensor are changing. As a result, piezoelectric sensor systems can only be used in applications where vehicles are moving at speeds not less than 10 mph; they are not reliable in slow-moving or stop-and-go traffic.

4.2.6.5.1.1 Piezoceramic Sensors

When used as permanent WIM scale sensors, the cable is most commonly placed in aluminum channels filled with epoxy resin or another substance. The channel is then placed so that the top of the sensor is flush with the road surface, in a slot cut into the pavement, less than 2 inches wide. Routine site installations can consist of two piezoceramic sensors plus an inductance loop, or one piezo sensor and two inductance loops. Each of these configurations allows for the computation of vehicle speed and, consequently, axle spacing, which in turn permits vehicle classification as well as axle weighing. Installations using two piezo sensors tend to provide better estimates of static axle weights because each sensor provides an independent measure of axle weight during a different time period associated with the vertical motion of the vehicle being weighed. Combining the two independent weight estimates generally improves the accuracy of the static weight estimate. Because the piezoceramic sensor is temperature sensitive, piezoceramic WIM systems must include various algorithms and/or additional sensor inputs that allow the WIM system to account for temperature changes when estimating weights.

4.2.6.5.1.2 Piezopolymer Sensors

The second common piezo technology uses a piezoelectric polymer surrounded by a flat brass casing. This sensor, commonly called the BL sensor, can be placed directly on the road for portable weighing but, like the piezoceramic cable, is commonly placed into an aluminum channel filled with epoxy resin when being used as a permanent WIM sensor. It is not a reliable sensor in slow or stop-and-go conditions, and additional steps are needed when processing sensor output to account for changes in sensitivity because of changing temperatures.

4.2.6.5.1.3 Piezoquartz Sensors

While it is more expensive per sensor than the other piezo style sensors, the quartz sensor has the distinct advantage of being insensitive to changes in temperature. It is therefore generally more accurate than other piezo sensors. However, because the sensor still relies on structural support from the pavement, if the pavement structure is sensitive to temperature, the sensor will show some change in response to a given axle load simply as a result of the change in pavement strength with changing environmental conditions. The sensor is not sensitive to changes in temperature or soil moisture if placed in a thick Portland cement concrete pavement. The site installation can consist of two lines (eight sensors) of piezoquartz sensors, two lines plus an inductance loop, or one line of piezo sensors and two inductance loops. Each of these configurations allows for the computation of vehicle speed and, consequently, axle spacing, which in turn permits vehicle classification as well as axle weighing. The installations using two piezo sensors tend to provide better estimates of static axle weights because each sensor provides an independent measure of axle weight during a different time period associated with the vertical motion of the vehicle being weighed. Combining the two independent weight estimates generally improves the accuracy of the static weight estimate.

4.2.6.5.2 Bending Plates

A bending plate WIM System utilizes plates with strain gauges bonded to the underside. As a vehicle passes over the bending plate, the system records the strain measured by the strain gauge and calculates dynamic load. Static load is estimated using dynamic load and calibration parameters. A typical bending plate site includes two inductance loops used to detect approaching vehicles, to differentiate between closely spaced vehicles, and to measure speed.

4.2.6.5.3 Load Cells

The most common load cell design uses two in-line scale platforms that operate independently and provide weight estimates for the right and left tires of each axle. The system records the weights measured by each scale and sums them to obtain the axle weight. Off-scale detectors are frequently integrated into the scale design to detect any vehicles off the weighing surface. In addition, at least one inductive loop and one axle sensor are usually included as part of the system design.

The inductive loop is placed upstream of the load cell to detect vehicles and alert the system of an approaching vehicle. The axle sensor is usually placed downstream of the load cell to determine axle spacing and vehicle speed. If a second inductive loop is used in place of the second axle sensor, it is placed downstream of the load cell to determine vehicle speed, which is needed to determine axle spacing. The deep-pit load-cell system is generally considered the most accurate of the available conventional high-speed WIM systems. It is generally insensitive to changes in temperature and can weigh vehicles at both low and high speeds. It is, however, the most expensive WIM system to purchase and install.

4.2.7 Factors that Affect Operational Capabilities of Sensors

4.2.7.1 Environmental

4.2.7.1.1 Temperature

Some sensors are affected by temperatures. While some vendors have developed algorithms to account for temperature sensitivity, these sensors are at a disadvantage when placed in an environment that quickly changes temperature. Sensors that rely on the structural strength of pavement will not perform consistently in asphalt pavement whose structural strength is affected by temperature changes.

4.2.7.1.2 Moisture

Moisture is also a common cause of equipment failure because of intrusion into either the sensor itself or the communication lines connecting the sensor to the data collection electronics.

4.2.7.2 Pavement Condition

Vehicle dynamics play a more significant role in the force applied by any axle at any point on the pavement surface than the type of sensor technology used to collect weight data. Poor pavement condition increases the dynamic motion of vehicles, which in turn increases the load impact on the sensor. Poor pavement condition also tends to decrease the bond between pavement and sensors, which affects the performance of the sensors. Pavement deformation that affects the pavement profile decreases the transition from the pavement surface to the WIM sensor surface, which causes impact loads and increased vehicle dynamics, both of which decrease data accuracy. In these cases the sensors are actually working correctly; they are just operating in an environment that prevents them from counting axles accurately.

Failure of pavement around a sensor can cause the effect of stray signals in sensors, a very common phenomenon with piezoelectric cable when concrete slab joints fail and rock against each other, causing ghost axles. Stray signals lead to misclassification of vehicles. Good condition pavement reduces vehicle dynamics and makes the bond between sensors and pavement more likely to last. A common cause of sensor failure is the failure of sensor/pavement bonds, which is often traced to poor pavement condition. The draft long-term pavement performance (LTPP) program specification sets a minimum pavement strength using a falling weight deflectometer (FWD) test. The pavement deflection must be between 0.012 and 0.018 inches, and the area of the basin must be 27 square inches or greater when a 9000 pound load is applied. The Draft LTPP Standard notes that the pavement must be designed to operate near these strength levels throughout the year, even during periods when the pavement structure is weakened by high moisture content or thaw.

Initial site selection and installation are keys to achieving long sensor life. Placing a sensor in pavement that is in poor condition is likely to result in poor sensor performance and short sensor life, regardless of the technology chosen. Similarly, haphazard sensor installation (poorly cleaned or dried pavement cuts) can also lead to early sensor failure.

4.2.7.3 Location of Sensor Relative to Pavement Surface

It is reported that the most accurate WIM systems have sensors that are mounted flush with the existing road surface (*47*). Sensors that are mounted on top of the pavement surface create a bump that affects vehicle dynamics and hence the accuracy of data. Sensors placed inside the pavement structure are affected by pavement strength, which varies due to environmental conditions.

4.2.7.4 Scale Width

The width of the scale can also influence the accuracy of weight measurements. A larger sensor ensures a longer contact between the tire and sensor, and a longer time of measurement compared to narrow sensors. The entire tire is not solely supported by narrow sensors at any point in time, which decreases the sensitivity of the sensor and makes weighing accuracy more sensitive to environmental changes in pavement strength (*47*). The narrow-sensor design has an advantage when it comes to the time and cost required for installation. The combination of these effects is that the sensor can sense a variety of different forces, and this ability results in a larger error when estimating static weights than with some other devices.

4.2.7.5 Geometric Design

The site should be selected so as to minimize the longitudinal and transverse effects on vehicle behavior (*41, 47)*. The ASTM standards set guidelines for horizontal curvature, the longitudinal gradient, the cross (lateral) slope, and the width of the paved roadway lane. Table 8 summarizes these standards for each type of WIM System.

TABLE 8 ASTM Standard (E 1318-94) Geometric Design Requirements

Characteristics	Type I	Type II	Type III	Type IV
Horizontal Curvature	Radius>1740m (5704 ft) 46m (150 ft) before/after	Radius>1740m (5704 ft) 46m (150 ft) before/after	Radius>1740m (5704 ft) 46m (150 ft) before/after	Radius>1740m (5704 ft) 46m (150 ft) before/after
Roadway Grade	≤ 2% 46m (150 ft) before/after	≤ 2% 46m (150 ft) before/after	≤ 2% 46m (150 ft) before/after	≤ 1% 91m (300 ft) before/after
Lateral Cross Slope	≤ 2% 46m (150 ft) before/after	≤ 2% 46m (150 ft) before/after	≤ 2% 46m (150 ft) before/after	≤ 1% 46m (150 ft) before/after
Lane Width	3-4.5m (9.8-14.8 ft) 46m (150 ft) before/after	3-4.5m (9.8-14.8 ft) 46m (150 ft) before/after	3-4.5m (9.8-14.8 ft) 46m (150 ft) before/after	3-4.5m (9.8-14.8 ft) 46m (150 ft) before/after

Source: Reference (*42*).

The ASTM guidelines state that for 150 feet before and after the sensor, placement should be maintained and leveled such that a 6 inch diameter circular plate 0.125 inches thick cannot be passed beneath a 20 foot long straight edge (*40*). The guidelines also state that a foundation be provided and maintained to accommodate sensors. ASTM specification E 1318 provides specific guidance on the pavement condition needed for accurate WIM system performance. The guidance stipulates a pavement that is:

Flat (no horizontal curves),
Smooth (no bumps or other surface conditions that create vehicle dynamics),
Strong (to reduce pavement flex under the WIM sensor),
In good condition (*6, 40, 47*).

Caltrans' successful practice requires that all WIM systems be installed in Portland cement concrete (PCC) pavement to provide roadway stability, durability and smoothness throughout the expected equipment life. Caltrans states that if WIM is to be placed on a roadway that is asphalt concrete (AC), the AC pavement must be replaced with PCC pavement for a minimum distance of 50 feet before and 25 feet after the sensor (*43*).

4.2.7.6 Traffic Conditions

WIM systems should be in an area of free flow traffic with good sight distance. The traffic condition should be such that stop-and-go traffic is minimized, slow-moving traffic is minimized, lane changing is minimized, and passing on two-lane sections is minimized (*41, 47*).

4.2.8 Sensor Installation

Poor installation is another common cause of sensor failure. Poor cleaning or drying of pavement cuts results in a weak bond that allows moisture intrusion and further deterioration of the bond. Proper installation is a key element in ensuring the WIM system will function within specifications throughout the site design life (*43*). ASTM standard E1318-09 requires that weigh-in-motion equipment be installed and maintained in accordance with the recommendations of the system vendors (40).

The report *States' Successful Practices Weigh-in-Motion Handbook* mentions three states that have been successful with their WIM data collection. Their selection was based on information from the Long Term Pavement Performance Program (*42*). California (bending plate), Missouri (piezoelectric), and Oregon (load cell) have developed and maintained installation procedures beyond those specified in the vendor's specifications that has led to their success in WIM data collection.

4.2.8.1 California (Bending Plate)

In addition to the vendor's recommendations for installing WIM systems, California has developed and maintained its own procedure for installing WIM sensors, which has been successful for over ten years of using bending plates. The following practices are followed during installation:

Preparing the Road: In preparing the road, which is the initial step in sensor installation, Caltrans' successful practice requires that Portland cement concrete (PCC) pavement be placed 150 feet before and 75 feet after the sensor location; the pavement must also be ground. The grinding specification requires that the distance between the roadway surface and the bottom edge of a straight edge be no more than 0.01 feet. Asphalt concrete is replaced with PCC for a minimum distance of 50 feet prior to and 25 feet after the scale location.

Excavating the Pit: The pit area is marked on the pavement surface using a scale frame as a guide. The concrete must be wet during the cutting process. The pit is vacuumed and air dried after the debris has been removed. Caltrans ensures that the pit is clean and dry for epoxy to reach maximum adhesion.

Frame Installation: Supports are attached to the tip of the scale frame to level the frame with the road surface and to make removing the frame easier. Shoulder conduits are installed for cabling and drainage. Drainage conduits are lower than the cabling conduit and sloped a minimum of one percent to ensure water will flow away from the scales. Mortar dams are constructed around the inside of the scale frames to contain the epoxy under the frames. The pit area and the scale frames are cleaned of any excess epoxy by scraping off any material on the scale frames. A vacuum and an air compressor are used to finish the cleaning process.

Final Test: Resistance checks are performed on the lead-in-cables to check for damages and excitation.

4.2.8.2 Missouri (Piezoelectric)

Initial Test: Prior to installing the sensor in the roadway, an initial test of the sensor is made. This will ensure that the sensor is working properly so that time and money are not wasted installing a defective sensor.

Sensor Layout and Slot Cutting: Once the sensor locations are determined for the site, slotted aluminum templates for the sensors are placed on the roadway according to site layout plans. Florescent orange paint is then sprayed on the templates to mark where the pavement cuts will be made for the sensor slots. Once the cuts have been made, the slots need to be cleaned using a wire brush, a vacuum, and an air compressor (*42, 48*).

4.2.8.3 Oregon (Load Cell)

Initial Test: Prior to installing the scales, resistance checks are performed on the scale and lead-in cable to check for cable damage, excitation, and proper attachments.

Preparing the Road: The Oregon DOT attempts to follow ASTM standard E 1318-94 for pavement condition. In order to reduce any pavement effects, the Oregon DOT requires the pavement 60 feet before and 40 feet after the sensor location to be ground in accordance with the state's specification. Oregon also requires the ground pavement be milled 100 feet before and 60 feet after in accordance with state specifications. Similar to Caltrans, if a load cell is to be placed in asphalt concrete, the AC is replaced with PCC 60 feet and 70 feet before and after the scale location. The concrete is then ground to state specifications.

Installing the Load Cell Scale: The Oregon DOT contracts the WIM site preparation and equipment installation to a prime contractor, but an Oregon DOT inspector is on site to ensure that the state's specification are met.

4.2.9 WIM Sensor Calibration

Calibration of a WIM system is essential for obtaining accurate weight data. The ASTM Standard Specification E 1318-09 concerning highway WIM systems lists recommendations for the calibration procedure, which includes the acceptance and initial calibration processes (*40*).

Each WIM sensor must be calibrated for the specific site where the sensor is located to offset the dynamic effects of the pavement leading to the scale sensor. This means that a portable WIM system must be calibrated each time is it installed at a new location. The other step required to account for truck dynamics is to calibrate the WIM scale to the unique traffic characteristics of each data collection site.

4.2.9.1 Caltrans' Successful Practice: Calibration Procedure for Bending Plate Weigh-in-Motion

Caltrans has established a calibration procedure for bending plate WIM systems during their years of experience collecting WIM data (*42*). The procedure is divided into two parts, acceptance testing and fine tuning. The acceptance testing is done after installation and is completed before the system is brought on line. The fine tuning or recalibration is done throughout the design life of the site. According to Caltrans, the vendor performs the initial field calibration and the department performs the subsequent accuracy performance test.

In order to prepare the scale for the initial field calibration after installation, the calibration factors are adjusted until Class 9 vehicle steering-axle weights in the traffic stream average near 10,500 pounds. The loop spacing distance setting in the WIM system is also set by adjusting the distance until the Class 9 drive tandem axle spacing averages between 4.2 feet and 4.5 feet. This brings the scale close to proper calibration, and the scale can then be more finely calibrated using test trucks.

The test truck is driven over the WIM between 45 mph and 65 mph, a minimum of three times. The range of speeds for the test is that typical for trucks in traffic streams. The gross weight percentage is calculated for each run by dividing the difference between the actual and estimated weight by the actual weight. The result is then plotted on a "Gross Weight Percent Error by Vehicle" graph and analyzed to adjust the WIM weight factors. The test truck makes two additional runs at each speed after the weight factors have been adjusted. These runs are used to determine if the WIM system is operating at an accuracy level that meets Caltrans' functional requirements for weight, axle spacing, vehicle length, and vehicle speed.

4.2.9.2 Minnesota DOT's Successful Practice: Automatic System Recalibration Procedure

The Minnesota Department of Transportation (DOT) utilizes a computer program to automatically recalibrate their bending plate WIM systems (*49*). The recalibration program is based on the front axles of five-axle semis (FHWA Class 9). This program is stored on the hard drive of the roadside computer at each WIM site and can be turned on and off from an off-site computer using the utility commands. The recalibration process is used on each lane individually.

The initial calibration procedure used by the Minnesota DOT is a two-step process. The first step is to calibrate the system using a five-axle semi as a test truck. The second part of the process is to operate the system for a week collecting data. The distribution of the gross vehicle weight (GVW) of five-axle semis collected during this period is examined. The emphasis of the examination is the placement of peaks for loaded and unloaded vehicles. If the peaks occur at reasonable locations, i.e. 33,500 - 35,300 kilograms (kg) (74,000 - 78,000 pounds) for loaded vehicles and 12,700 - 13,600 kg (28,000 - 30,000 pounds) for unloaded vehicles, the system is considered calibrated.

The front axle weights (FAWs) collected during the second part of the process are used as the desired FAWs in the automatic recalibration process. The program collects FAWs for three GVW groups. The average recorded FAWs are compared to given desired FAWs for each GVW group. The system recalibrates if the percentage of the difference between the average recorded FAWs and the desired FAWs is greater than a set percentage in at least two of the three GVW groups. The program collects FAWs for a predetermined number of Class 9 vehicles and number of hours. The number of Class 9 vehicles and hours are set in the program by the operating agency.

4.2.10 Location of Pavement Sensors

Vehicle dynamics play a more significant role in the force applied by any axle at any point on the pavement surface than the type of sensor technology used to collect weight data. Some sensor types rely on the structural strength of pavement in which they are installed; when these sensors are placed in weak pavement, their accuracy is degraded. When the strength of pavement changes with moisture and temperature changes, the accuracy of these sensors is affected, and calibration drift occurs frequently. Consequently, where weight data are needed for thinner flexible pavement subject to changing strength characteristics, selection of WIM technology that separates the weight sensor from the pavement through the use of some type of frame is a good idea. However, the pavement must be thick enough to hold the frame. In situations where the pavement cannot adequately support the sensor, the location should be moved elsewhere to ensure accuracy. It is very important to consider the pavement's expected life when determining the life of a WIM site (*41, 42*).

WIM sites should also be locations where vehicles are traveling at fairly constant speeds (no acceleration or deceleration), are not changing lanes frequently and have good lane discipline (*47*).

4.2.11 Selection of WIM Equipment

In the selection of WIM equipment, it is reported that differences in devices are more significant than the sensor technology. In work carried out by the Federal Highway Administration, it is stated that “It is more important to select a well designed and highly reliable product than to narrow a selection to a particular technology.” One important thing to consider in sensor selection is the ability of the sensor to accurately classify when vehicles are not traveling at constant speed. A common drawback with the different sensors is their inability to classify closely spaced vehicles. These technologies are unable to differentiate between multi-axle truck and closely spaced vehicles (47).

4.2.12 Advantages and Disadvantages of Detector Technology

The advantages and disadvantages of the various detector technologies are summarized in Table 9 on the following pages.

TABLE 9 Advantages/Disadvantages of Detector Technologies

Technologies	Advantages	Disadvantages
Inductive loop	• Flexible design to satisfy large applications • Mature, well-understood technology • Equipment is less expensive when compared to non-intrusive detectors • Provides basic traffic parameters (volume, presence, occupancy, speed, headway and gap) • High frequency excitation models provide classification data • Operability in harsh environment	• Disruption of traffic for installation and repair • Failure associated with installation in poor road surfaces • Multiple detectors usually required to instrument a location • Resurfacing of roadways and utility repair can also create the need to reinstall • Subject to stresses of traffic and temperature • Routine maintenance requirement
Magnetometer (Two axis fluxgate magnetometer)	• Can be used where loops are not feasible • Less susceptible than loops to stress of traffic • Some models transmit data over wireless RF link • Less disruption to traffic flow than inductive loop	• Installation requires pavement cut • Installation and maintenance require lane closure • Some models have small detection zones • Induction magnetic detectors cannot detect stopped vehicles
Pneumatic road tube	• Quick installation for temporary data recording • Low power usage • Low cost • Simple to maintain	• Inaccurate axle counting when traffic volume is high • Temperature sensitivity of the air switch • Cut tubes resulting from vandalism and wear produced by vehicle tires
Infra red	• Active sensor transmits multiple beams for accurate measurement of vehicle position, speed, and class • Multizone passive sensors measure speed • Multiple lane operation	• Operation of active sensor may be affected by fog when visibility is less than 20 ft or blowing snow is present • Passive sensor may have reduced sensitivity to vehicles in its field of view in rain and fog
Microwave radar	• Generally insensitive to inclement weather	• Antenna beam width and transmitted waveform

	• Direct measurement of speed • Multiple lane operation	must be suitable for the application • Doppler sensors cannot detect stopped vehicles • Doppler microwave sensors have been found to perform poorly as volume counters
Ultrasonic	• Multiple lane operation available • Easy installation	• Some environmental conditions, such as temperature change and extreme air turbulence can affect performance. Temperature compensation is build into some models. • Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles traveling at moderate to high speeds.
Passive acoustic	• Passive detection • Insensitive to precipitation • Multiple lane operation available	• Cold temperatures have been reported to affect data accuracy • Specific models are not recommended with slow-moving vehicles in stop-and-go traffic
VIP	• Monitors multiple lanes and multiple zones/lanes • Easy to add and modify detection zones • Rich array of data available • Provides wide-area detection when information gathered at one camera • Location can be linked to another	• Inclement weather, shadows, vehicle projection into adjacent lanes, occlusion, day-to-night transition, vehicle/road contrast, and water, salt, grime, icicles, and cobwebs on the camera • Requires a certain camera mounting height for optimum presence detection and speed measurement

Source: References (*50, 51*)

4.2.13 Summary of WIM Technology

Several traditional weigh-in-motion technologies are used in North America including Piezoelectric Sensors, Bending Plates, Single Load Cells and Kistler Lineas Quartz WIM Sensors. Brief discussions follow.

4.2.13.1 Piezoelectric Sensors

This is most common WIM device. The sensor is embedded in the pavement and produces a charge that is equivalent to the deformation induced by the tire loads on the pavement's surface. It is common to install two inductive loops and two piezoelectric sensors in each monitored lane. A properly installed and calibrated Piezoelectric WIM system can provide gross vehicle weights that are within 15% of the actual vehicle weight for 95% of the measured trucks (*42, 47*).

4.2.13.2 Bending Plates

The bending scale consists of two steel platforms that are 0.6m x 2m (2 ft. x 6 ft.), adjacently placed to cover a 3.65m (12 ft.) lane. The plates are instrumented with strain gauges, which measure tire load induced plate strains. The measured strains are then analyzed to determine the tire load. A properly installed and calibrated bending plate WIM system can provide gross vehicle weights that are within 10% of the actual vehicle weight for 95% of the measured trucks (*42, 47*).

4.2.13.3 Single Load Cells

These devices consist of two 3m x 3m (6 ft. x 6 ft.) platforms placed side-by-side to cover a 3.65 m (12 ft.) monitored lane. A single hydraulic load cell is installed at the center of each platform to measure the tire load induced forces that are then transformed into tire loads. A properly installed and calibrated single load cell WIM system can provide gross vehicle weights that are within 6% of the actual vehicle weight for 95% of the measured trucks.

4.2.13.4 Kistler Lineas Quartz

The Kistler Lineas Quartz WIM Sensor consists of a light metal profile in the middle of which quartz disks are fitted under preload. When force is applied to the sensor surface, the quartz disks yield an electric charge proportional to the applied force through piezoelectric effect. This electric charge is converted by a charge amplifier into a proportional voltage, which can be then further processed as required.

The sensors can be installed in combination with other traffic detectors like induction loops, switching cables, etc. Kistler WIM sensors are easy to install both individually and in groups for comprehensive recording over a wide roadway. Typically, two 1.75 meter (68.9") long sensors are required to cover one typical lane width of approximately 12 feet.

4.2.14 WIM Technology Comparisons

Table 10 provides a comparison of the various WIM technologies.

The signal strength of piezoelectric cable is affected by pavement strength (*47*). Piezoelectric scale sensor technologies rely on the structural strength of the pavement in which they are supported. When these sensors are placed in weak pavement (i.e., pavement that flexes), the accuracy of these sensors tends to degrade. Similarly, when the strength of the pavement changes with environmental conditions (usually because of changing moisture content or temperature), sensor performance can be expected to change, and calibration drift frequently occurs which is typical of thin flexible pavements (*42, 47*).

Consequently, a WIM technology that separates the weight sensor from the pavement through the use of some frame may work accurately under ASTM specified site conditions where weight data are needed for thinner, flexible pavements subject to changing strength characteristics, a specific case in New Mexico. The State of New Mexico has a greater percentage of its pavement sections as flexible pavements whose strength may vary with varying temperatures. Hence, bending plates or single load cells should be considered for those specific conditions.

TABLE 10 Weigh-In-Motion Comparisons

Technology	Installation requirements	Length of traffic disruption during installation	Environmental concerns	Other issues
Bending plate	Moderate frame installation	Moderate		
Piezoelectric cable	Narrow slot	Short	Temperature	Accuracy is affected by pavement strength
Piezoquartz	Narrow slot	Short-moderate		
Hydraulic load cell	Deep pit	Long		

Source: Reference (*47*).

Table 11 describes technology issues relating to collection of classification data.

TABLE 11 Permanent Classification Sensors

Technology	Types of classification collected	Number of lanes of classification data collected by each sensor	Environmental concerns	Other concerns
Piezoelectric cable	Axle based (FHWA 13+)	1 per pair of sensor	Susceptible to snowplow damage	Temperature sensitive Doesn't work well in stop-and-go traffic
Piezopolymer film	Axle based (FHWA 13+)	1 per pair of sensor	Susceptible to snowplow damage	Temperature sensitive Doesn't work well in stop-and-go traffic
Fiber-optic cable	Axle based (FHWA 13+)	1 per pair of sensor	Susceptible to snowplow damage	Doesn't work well in stop-and-go traffic
Inductive Loop	Length based	1 per pair of sensor	Freeze/thaw can break loop	

Source: Reference (*47*).

4.2.15 Economic Analysis of WIM Sensors

Research by Taylor and Bergan (*44*) indicates that the accuracy level of WIM Systems is related to both initial cost and maintenance cost. The cost of the system includes the estimated initial cost per lane as well as the annual maintenance cost. Performance reports for the systems is given as a percent error on gross vehicle weight (GVW) estimation at highway speeds under ideal, ASTM site conditions. The estimated initial cost per lane includes both equipment and installation costs. The estimated average cost per lane is based on a 12-year life span and includes annual maintenance costs. The data are summarized in Table 12 on the following page. All costs are in 2009 dollars and should thus only be used on a relative basis.

TABLE 12 WIM Technology Comparison

WIM System	Piezoelectric Sensor/lane	Bending Plate/lane		Kistler Quartz/lane		Load Cell/lane
		Single Threshold	Double Threshold	Single Threshold	Double Threshold	
Accuracy (GVW) (95% confidence interval)	±15-20%	±8-10%	±6-8%	±10%	±8-10%	±4-6%
Service Life (years)	3	7	7	4	4	12
Equipment Cost	$2,324	$21,548	$37,548	$19,780	$39,560	$55,239
Installation Cost	$2,324	$17,238	$34,476	$14,669	$29,338	$24,310
Annual Maintenance Cost	$4,750	$1,867	$3,734	$3,304	$6,608	$1,867
Cost per year (over 12 year period)	$7,512	$8,331	$15,738	$11,916	$23,833	$8,496

Source: Reference (52).

The cost of the electronics, cabinet, power supply, telephone connection, and road preparation are assumed to be relatively constant, regardless of the technology used and are not included in these estimates (*53*). The initial installation includes the equipment supply, installation by a local contractor, installation supervision and calibration by a vendor representative and traffic control during installation and curing. Installation costs are dependent on site conditions and local market rates and may vary.

4.3 Current Data Collection Practices In Other States

4.3.1 Colorado

The Colorado Department of Transportation manages about 9,148 centerline miles of roadway, 2,200 miles of which are covered by portable short volume count sites and 106 permanent count sites (*45*). The 106 permanent count sites include 4 sites for volume-only counts, 85 volume and classification permanent sites and 17 WIM permanent sites. Traffic monitoring equipment in use is provided by various suppliers including Diamond, Metro Count Mitron, and Jamar.

Colorado uses the Centurion, ECM (wEICoMe) system for data polling from permanent sites. For monthly and year-end traffic data processing, the Colorado DOT uses a combination of customized and vendor specified software. Some of the data items estimated include AADT, DD, ADT, DHV, ESAL, AADT Single Trucks, and AADT Combination Trucks. Colorado has contracted some of its data collection activities to consultants.

As part of its quality assurance process, Colorado DOT does a ride-along inspection with the contractor that supports its traffic monitoring as they set out counters to check for accurate location and layout. The purpose of ride-along is to introduce the process and standards of the DOT to the contractor. In addition, the DOT does periodic field inspections of the equipment to ensure that the count is being taken in the correct location and that the equipment is set out correctly for the type of count taken at the location. The DOT does these inspections every other week as a minimum (*45*).

4.3.2 Minnesota

The Minnesota Department of Transportation manages about 29,100 centerline miles of roadway and has a total of 32,000 portable short volume count sites and 83 permanent count stations. The permanent count stations consist of 46 volume-only permanent count sites, 30 volume and classification count sites and 7 WIM count sites. IRD software (i-Analyze, Road Reporter, Trafman, Telecom-TT-link) is used for data polling from the permanent sites. Like Colorado and New Mexico, Minnesota also uses a combination of customized and vendor specified software in its monthly and year end data processing, including Peek, Wavetronix, IRD, and Time Mark. Minnesota also has employed non-intrusive traffic counting equipment provided by TIRTL, Infrared axle sensors, Wavetronix, and Radar RTMS (*45*).

The state, supported by the FHWA, has conducted numerous surveys into non-intrusive technologies and equipment for data collection (30,35*, 36)*. These reports indicate that different equipment operating with the same technology produce different count results and, to provide the most accurate traffic count, sensors should be mounted at the correct height, distance from the edge of roadway, and at the correct angle. Additional information on the Minnesota experience with non-intrusive methods of data collection will be provided in a subsequent section of this report.

4.3.3 Virginia

The Virginia Department of Transportation traffic monitoring program includes more than 100,000 centerline miles of roadway. There are a total of 322 permanent count stations on these roadways including 140 on the Interstate system. Some 250 permanent count stations are on the National Highway System, including seven which have weigh-in-motion capability. VDOT traffic monitoring also includes 17,000 traffic links on higher functionally classified roads or collectors where traffic counts are taken on a 3-year cycle by individual jurisdictions. Traffic count data is stored in an Oracle database (*26).*

VDOT has encountered some challenges in its traffic monitoring program such as premature failure of sensors due to grout problems leading to the loss of valuable data. They also found problems with volume counts in high-volume urban locations due to technology limitations.

VDOT, however, has had some success stories as a result of the standard practices they follow:

1. Inductance Loops:

- VDOT, when installing inductance loops, uses a grout that breaks rather than pulls out to ensure that loops are at a 4-in depth. This practice ensures that the majority of the loops survive milling operations.

- It is known that the failure point is often due to the splice utilized when installing loops. To prevent this, Virginia's monitoring system has a "no splice" policy for installed loops.

- VDOT uses an encased wire that provides added protection to the inductance loops.

2. Coverage Counts:

- Virginia uses a "tailgating logic" feature that allows it to look at two vehicles traveling closely together and record them as two separated vehicles if the axle configurations do not match those within the classification tree for a truck. This allows for a good quality classification in urban areas and during peak hour conditions.

3. WIM Site Selection:

- Traffic monitoring personnel coordinate with pavement engineers around the state to collect their recommendations for new paving jobs with smooth pavement. A road profile van collects data from those locations and those that meet the 95% confidence level showing that smoothness will not be an issue for WIM data collection are used for new site installations (26).

4.3.4 Maryland

The State Highway Authority (SHA) of the Maryland DOT transferred its traffic data collection to its highway information services division (HISD). The HISD currently has 79 ATRs, with 69 currently online, providing data throughout Maryland. There are also over 3,700 short term (48-hour) program count locations. HISD also coordinates approximately 1,200 counts annually as needed. In order to ensure good quality data, the HISD has privatized data collection by using multiple consultant contracts. These consultants use innovative products such as Road Ramp and TIRTL, to collect classification data on high-speed roadways (26).

4.3.5 California

The California Department of Transportation (Caltrans) has great experience and excellence in the collection of traffic data, and in its quality assurance and use. Basically, they collect traffic volume counts and weigh-in-motion data. They do not need automatic classification systems because they operate a network with 106 weigh-in-motion stations that collect classification and weight data continuously.

Currently, the California Department of Transportation is operating 106 weigh-in-motion collection sites which are located at key locations across California. Several of these sites are under construction, and further expansion of WIM systems is planned for the coming years (*78*).

This extensive WIM network provides 24-hour traffic information including: individual axle weights, gross vehicle weight, weight violations, axle spacing, overall length, vehicle classification, and vehicle speed. Caltrans finds the collected data essential for the following uses: pavement studies, highway monitoring, capacity studies, accident rate calculations, and analysis of truck transport practices (*78*).

The weigh-in-motion equipment used by Caltrans is provided by either PAT or IRD (International Road Dynamics). Both companies recently consolidated under the IRD brand name, but PAT components are still available from IRD. There are only a handful of other WIM component manufacturers and WIM system integrators worldwide, including Massload, Mettler Toledo, and some European companies. The California Department of Transportation subjects its WIM installation projects to public bidding, but IRD/PAT is the only manufacturer bidding on new installations to the Caltrans specification (*78*).

The weigh-in-motion systems used by the California Department of Transportation are either bending plates installed on frames embedded in concrete or piezo sensors epoxied into the pavement. Another alternative system is the load cell, but Caltrans does not use it due to the long installation times that require extended traffic lane closures. Inductive loops are placed before and after the WIM sensor to measure vehicle speed and overall length. Caltrans does not use portable WIM systems. The Caltrans experience with portable systems reveals shortcomings concerning accuracy and service life due to the high and heavy truck volumes on California highways (*78*).

A smooth pavement surface is key for accurate weight readings. This helps dissipate any stored energy in the form of vertical displacement resident in the vehicle suspension while driving over the WIM sensors. Caltrans specifies 150 feet of approach and 50 feet of departure concrete ground to a +/- 3mm tolerance in 12 feet. Proper calibration is also a critical factor in quality of WIM data. Therefore, WIM systems must be calibrated to +/- 5% accuracy with a test vehicle of known static weight driven at various highway speeds over the WIM instrumentation. Routine maintenance and calibration are extremely important. Smooth pavement and proper calibration ensure quality and consistency in weight data (*78*).

The WIM field systems gather and store data 24/7/365 automatically in roadside cabinets. Data collection is via telemetry using an office file server and PC. WIM data downloads are both automated and manually performed according to a preset schedule. Data collected must be screened and sorted on a historical and operational basis to validate its quality before archiving or distributing. Data that exceeds control limits needs further investigation into possible field site problems (*78*).

Routine maintenance and calibration of WIM systems is vital for consistent and accurate archive data. Experienced personnel with adequate equipment and diligence are required to maintain the systems and fix trouble situations early. Electronic sensors can help expedite a proper and timely response to equipment or system health issues by sending some form of notification (*78*).

The CTWIM Suite is a collection of Windows-based applications developed by Caltrans. These applications are designed to aid the weigh-in-motion analyst in performing tasks associated with the on-site calibration, acceptance and/or accuracy validation of WIM systems as well as the day-to-day monitoring of calibration of WIM systems from the office utilizing downloaded traffic stream data (*78*).

For on-site calibration, one or more test trucks with known axle weights and axle spacings are used and statistical data is generated for comparison of WIM data versus actual static results to meet accuracy requirements. Graphs can also be generated to display WIM plots for individual axles, axle groups, or gross weights. Such graphs can be used by the analyst for deciding which system calibration parameter can be adjusted to produce the best estimate of static wheel weights for the most typical trucks in the traffic stream (*78*).

For analysis of the WIM system calibration accuracy, daily record data files (typically seven) are downloaded and imported into the program. Known operating characteristics of one or more specified truck classifications (typically Class 9) are then compared with traffic stream statistical summary data. Such summary data can be displayed in various distribution or graphic formats (*78*).

The information in this section was gathered from the Caltrans website: http://www.dot.ca.gov/. The CTWIM Suite is available for free download at the following link: http://www.dot.ca.gov/hq/traffops/trucks/datawim/install.htm.

4.3.6 Colorado State Survey

The Colorado Department of Transportation conducted an online survey of the 50 states relating to travel monitoring programs, operations and staffing. The responses revealed that DOT agency travel monitoring programs vary in management, organizational structure, staffing and operations (*45*).

One of the survey questions asked state DOTs to provide the number of full-time employees, including both internal and outsourced employees, needed to manage their respective travel monitoring program. 37% of the 46 respondents indicated a staff number between 6 and 10 are employed in data collection; for data dissemination, 71% indicated a staffing of between 1 and 5, and 67% required between 1 and 5 personnel for data processing.

The report also indicated that 55% of all DOT agencies required more than 11 staff members (both agency and outsourced) to manage their data collection operations. The number of staff needed for traffic monitoring seemed to be largely influenced by the number of centerline miles of roadway monitored.

4.4 Traffic Monitoring Guide (TMG)

The *Traffic Monitoring Guide* is a set of standards and practices outlined by the FHWA for traffic monitoring across the nation. The guide provides recommendations on how to conduct traffic collection but also allows states to structure their traffic collection practices to suit their various needs and conditions.

Some of the recommendations outlined in the guide are summarized as follows (*6*)**:**

1. Design of Short Term Counts

The TMG recommends that all short term counts be counted for 48 hours and data collected on an hourly basis. The following steps are outlined in the TMG in designing short term counts.

a. Divide the road into homogenous traffic volume segments; determine the count locations needed to cover the system over a maximum cycle of six years.

b. Determine the count locations required to meet the HPMS needs. This is a three-year cycle for volume counts for not only the National Highway System and Principal Arterials but for HPMS sample sections as well.

c. Determine the count locations and data collection needs of specific projects that will require data in the next year or two.

d. Schedule the counts to make use of available equipments and personnel.

The TMG does not dictate geographic data required for coverage counts; it is up to the state to decide. The spacing between coverage counts is also a function of a state's objectives and budget but should be such that it reflects the traffic volume on that segment of road. A rule of thumb for defining roadway segments is the traffic volume should differ by +/-10%. Counts missed as a result of equipment failure, bad weather, or some other reason should be made up during the year. The TMG also states as a general rule that counts less than 24 hours should be retaken.

2. Classification Counts

Classification counts provide the annual average truck travel. The TMG recommends that seasonal and day-of-week adjustment factors be computed for three to four classes of vehicles, namely:

- passenger vehicles
- single unit trucks
- single combination trucks (trucks or tractors with a single trailer)
- multi-trailer trucks

The TMG states as a rule that 25-30% of its volume counts be classified and that in cases where there are limited resources and staff, classification counts should be collected instead of volume counts. Data should be collected on sections/segments of roads that have significant variations in truck volume each year and on HPMS sections, where practical. Classification counts should be collected for all 13 FHWA classes. In situations where the 13 FHWA vehicle class scheme cannot be used, TMG recommends the use of three or four classes based on total vehicle length. Another recommendation from the guide is that states independently monitor and account for seasonal variation in truck traffic versus passenger car traffic.

3. Weight Data

The TMG recommends that each state group its roadway system into truck weight roadway groups and that weight data be collected for at least six sites in each factor group with at least one group being a continuous site. The remaining sites should be counted for no less than 24 hours to account for time-of-day differences in vehicle weights. The TMG also recommends a minimum of about twelve sites with two to four continuous sites for a small state with only two truck weight groups. For a larger state with diverse trucking characteristics, ten or more distinct truck weight groups and sixty or more WIM sites are needed with a corresponding increase in the number of continuously operating WIM locations.

4. Factors and the Factoring Process

The TMG states that the grouping of roadway section into factor groups can be done by either cluster analyses, the geographic/functional assignment of roads to groups, or same road factor application. Cluster analysis is the use of statistical tools to group roads with similar adjustment factors. Geographic assignment usually is based on the experience and knowledge of the traffic personnel monitoring the roadways. The Guide states that continuous count data should be plotted to determine outliers. The third process - same road factor application - assigns the factor from a single continuous counter to all the road segments within the influence of that counter site.

The TMG suggests that two different adjustment factors be developed for the total volume and truck volumes. Traffic should be characterized into local traffic or through traffic on roadways. Locally oriented truck traffic usually has heavy weekday or business day travel and through traffic usually has heavy weekend and night time truck volumes. Factors should be developed to best utilize available traffic data collection resources. The actual number of locations needed in a factor group is a function of variability of traffic patterns within that group and the precision required. Short counts taken should be adjusted with the present year's adjusted factors but in cases where the present factors are not available, TMG suggests the following temporary approaches may be used:

- applying last year's factors,
- computing an average of three previous year's factors,

- computing a monthly rolling average (for example, the temporary July 2008 factor would be computed as the factor for the 12 consecutive months from August 2007 through July 2008).

According to a study by Battelle, a number of different factoring techniques can reasonably result in the same levels of accuracy when short term counts are converted to estimates of annual average conditions. For example, estimates of annual average conditions obtained by combining day-of-week and seasonal factor into a single factor will provide similar estimates when these factors are applied separately. Individual day-of-week, that is a Monday factor, a Tuesday factor, will be more accurate to apply on roadway sections with varying daily traffic pattern than a single weekday factor. In cases where the traffic pattern is more stable, a single traffic weekday adjustment is simpler to maintain while being equally as accurate (*54*).

A good traffic monitoring program should collect at a minimum hourly volume by direction and lane. The purpose of this is for analyst who must look at operational characteristics of the roadway at different times of the day.

4.5 MN Pooled Fund Study – Phase 3 Results

The paper, "Evaluation of Non-Intrusive Technologies for Traffic Detection – Phase 3," (*46*) summarizes the latest results of a pooled fund study examining field tests for volume, speed, and classification data collection using several current non-intrusive sensor technologies by comparing their results to baseline data collected by either Piezo-Loop-Piezo (PLP) methods or by manual observation. The five sensors evaluated in phase 3 were as follows:

1. The Wavetronix SmartSensor HD, a side fire radar sensor,
2. GTT Canoga Microloops, magnetic sensors installed in a bored conduit under the roadway,
3. The PEEK AxleLight, a ground mounted laser that is reflected off vehicle tires and wheels,
4. The Infrared Traffic Logger (TIRTL), a side fire laser installed on both sides of the roadway, and
5. The Miovision system, a camera equipped with a video collection unit.

Results indicated the following:

1. Volumes collected by the SmartSensor under heavily congested conditions were most accurate for the lane closest to the sensor (12% undercount). Line of sight restrictions affected the accuracy in lanes 2 and 3 farther from the shoulder (20% and 23% undercount in lanes 2 and 3, respectively). Under free flow conditions, accuracy was typically within 2% in all lanes. Speeds were accurate to less than one mile per hour across all lanes under free flow conditions.
2. The Microloops had an overall volume accuracy of 2.5 percent although accuracy was affected by lane changes, leading to double counting. They experienced problems collecting speeds under low speed conditions although there were no issues with

blockage of lanes. Speed was also affected by borings that were not perpendicular to the roadway.

3. The Axlelight sensor was affected by vehicles being grouped together because of tailgating. Volume was undercounted by anywhere from 5 to 9%. Speeds were underreported by about 4%.
4. The TIRTL performed consistently in volume collection with a median overcount of about 2%. With slow speeds and multiple lanes, however, there was a possibility of occlusion (restrictions to the laser line-of-sight) caused by vehicles with large wheels. Speeds were consistently accurate under free-flow conditions, with an average error of only 0.7 mph high.
5. The Miovision system collected volumes with an accuracy of 2%. This system does not collect speed data but was determined to be very accurate in collecting intersection turning movement counts.
6. While all five systems had greatly improved capabilities for collecting classification data when compared to previous versions, the axle-based sensors sometimes had difficulty with truck classification caused by tailgating passenger vehicles. The length based sensors generally provided relatively accurate lengths.

CHAPTER 5: QUALITY CONTROL AND ANALYSIS PROCEDURES FOR WEIGH-IN-MOTION DATA

5.1 Introduction

The objective of this chapter is to check the quality and reliability of the weight data collected by NMDOT weigh-in-motion stations. As a first approach, only one of the WIM sites currently working throughout New Mexico was considered. The weight data collected during a whole year (part of 2008 and part of 2009) at the Cuba WIM station were analyzed. Then, several quality control procedures were applied by using a program created in Visual Basic (VBA) for this purpose (*55*).

First, eight rules are applied to check that the time and location of each vehicle are correct. After that, five rules check the consistency of the vehicle class, number of axles, number of axle spacings, gross vehicle weight, weight of each axle, and the maximum wheelbase for each truck recorded. Next, two more rules check that the axle weights and axle spacings are within acceptable ranges. Finally, the program calculates the gross vehicle weight and the front steering axle weight frequency distributions for each vehicle class (*56, 57, 58)*.

For the class 9 gross vehicle weight distribution, there is a check to see if there is a peak for unloaded vehicles within the range of 13,500 to 18,000 kg and another peak for loaded trucks within the range of 31,500 to 37,000 kg. Also, there is a check for the class 9 front steering axle weight distribution to determine whether the majority of axle weights fall in the range of 3,600 to 5,400 kg as shown from experience and as described in the *Traffic Monitoring Guide* (*6, 57*).

Based on the results obtained after performing these analyses, one can conclude if the data collected at the Cuba WIM site are accurate and reliable, and thus, can be used to develop MEPDG traffic inputs for New Mexico.

Additional steps will apply these procedures to all the WIM stations located in New Mexico to determine their accuracy and reliability.

5.1.1 Initial Weigh-in-Motion Data

Only one WIM site was considered for the preliminary analyses. Table 13 includes the location of the WIM site and the available years of WIM data. Table 14 shows the months of data collected during the last two years. The WIM data collected during 2009 was completed by adding the data collected during July, October, and November of 2008 since those months were missing. Therefore, a whole year of data was analyzed.

TABLE 13 WIM Site Location

WIM Site	ID	Road	Milepost	Years of Data
Cuba	102	US-550	71.05	2002-2009

TABLE 14 Data Collected During 2008 and 2009

2008	Jan	-	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	Jan	Feb	Mar	Apr	May	Jun	-	Aug	Sep	-	-	Dec
Considered	Jan 09	Feb 09	Mar 09	Apr 09	May 09	Jun 09	Jul 08	Aug 09	Sep 09	Oct 08	Nov 08	Dec 09

5.1.2 Quality Control Procedures

The data was analyzed by using a program created in VBA to perform the quality control. The program consists of several algorithms that apply the rules showed in Table 15 in order to check the quality of the WIM data.

The first eight rules check the location and time for each vehicle recorded at the WIM site. The next five rules check the consistency of the vehicle class, number of axles, number of axle spacings, gross vehicle weight, weight of each axle, and the maximum wheelbase for each truck. Then, two more rules check that the axle weights and axle spacings are within acceptable ranges. Finally, the program calculates the gross vehicle weight and the front steering axle weight frequency distributions for each vehicle class, so they can be subjected to visual interpretation (*56*, *57*, *58*).

From field experience and from references (*6*, *57*), it is known that the class 9 gross vehicle weight distribution should have a peak due to unloaded vehicles within the range of 13,500 to 18,000 kg and another peak due to loaded trucks within the range of 31,500 to 37,000 kg. Also, the class 9 front steering axle weight distribution should have the majority of axles within the range of 3,600 to 5,400 kg. These characteristics are checked by the program.

TABLE 15 Rules for Quality Control of WIM Data

Order	Rule	Rule Description
1	Year is Correct and Unique	If Year ≠ 09 Then Error
2	Month is Correct and Unique	If Month ≠ 01 Then Error (e.g., for January)
3	Day is Correct	If Day ≠ 1-31 Then Error
4	Hour is Correct	If Hour ≠ 0-23 Then Error
5	WIM Station ID is Correct	If Station Code ≠ 21020 Then Error
6	Direction is Correct	If Direction ≠ 1 or 5 Then Error
7	Lane Number is Correct	If Lane Number ≠ 1-4 Then Error
8	Vehicle Class is Correct	If Vehicle Class ≠ 4-13 Then Error
9	Number of Axles consistent with the Number of Axle Spacings	If Number of Axles ≠ Number of Axles Spaces + 1 Then Error
10	Number of Axles consistent with the Number of Axle Weights	If Number of Axles ≠ Number of Axle Weights Then Error
11	GVW consistent with the sum of axle weights	If Sum of Axle Weights ≠ Total Weight Then Error
12	Number of Axles consistent with the Vehicle Class	If Number of Axles ≠ range of axles for that vehicle class Then Error
13	Sum of Axle Spacings consistent with maximum wheelbase	If Sum of Axle Spaces > 29.93 m Then Error
14	Axle Weights within acceptable range	If 200 kg < Axle Weight < 20,003.4 kg Then Ok
15	Axle Spacings within acceptable range	If 0.6 m < Axle Spacing <15 m Then Ok
16	Visual review of the Gross Vehicle Weight (GVW) Frequency Distribution for each class to check consistency with the peaks for loaded and unloaded vehicles	
17	Visual interpretation of the Front Steering Axle Weight Frequency Distribution for each class to check whether the majority of axles fall within the proper range	

5.1.3 Results

An entire year of WIM data collected during 2008-09 at the Cuba WIM station was analyzed. A total of 352,649 trucks were recorded in that period. For 167 of them, the WIM scale could not measure the value of the axle weights and spacings.

All the data fulfilled the requirements described in rules 1 to 15. Moreover, the program calculated the frequency distribution by vehicle classes as shown in Figure 3, where it can be seen that classes 5 and 9 are the most important, accounting for almost 80% of the total number of trucks. Therefore, the gross vehicle weight and front steering axle weight frequency distributions for classes 5 and 9 will be obtained from the program and reviewed carefully.

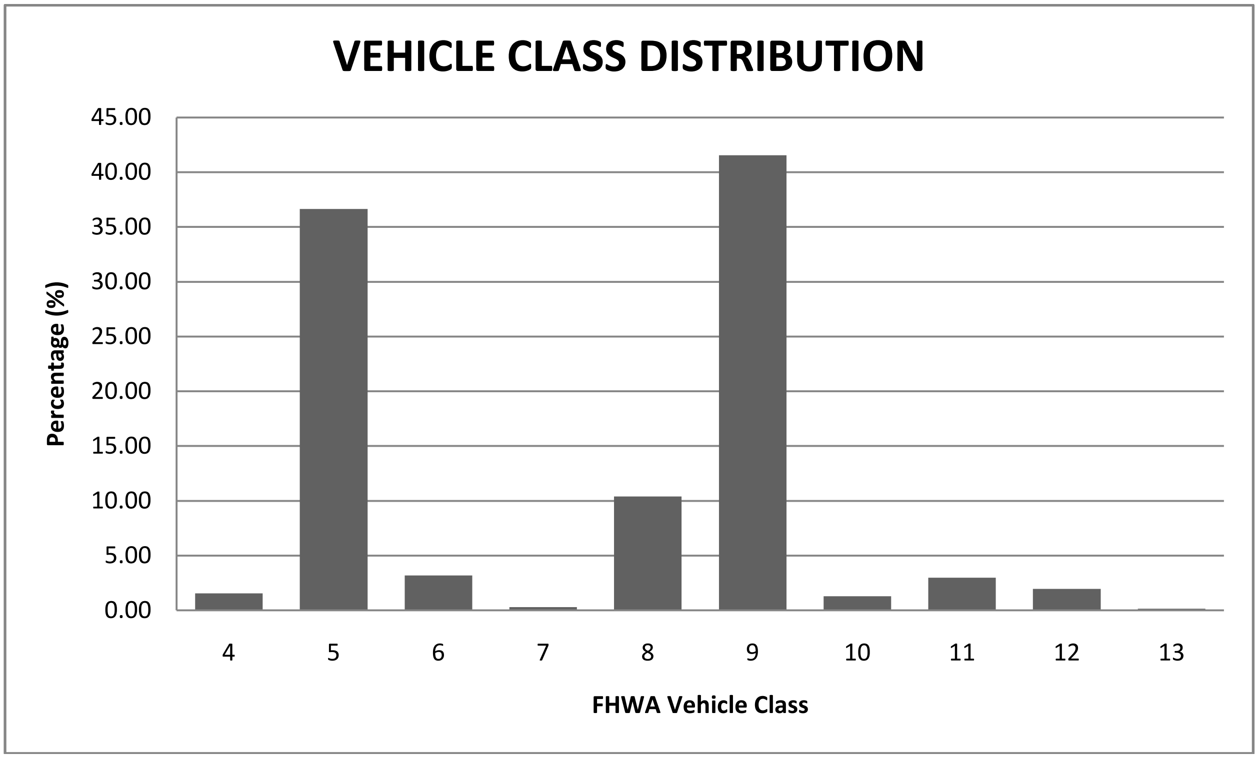


FIGURE 3 Frequency Distribution by Vehicle Class - Cuba

Figures 4 and 5 show the gross vehicle weight frequency distribution for classes 9 and 5, respectively. As can be seen in Figure 4, the gross vehicle weight frequency distribution for class 9 presents one peak due to unloaded vehicles between 13,500 and 18,000 kg and another peak due to loaded trucks between 31,500 and 37,000 kg. Similarly, Figure 5 shows that the gross vehicle weight frequency distribution for class 5 has one peak within the range of 2,000 to 6,000 kg.

Figures 6 and 7 show the front steering axle weight frequency distribution for classes 9 and 5, respectively. As shown, the majority of the front steering axle weights for class 9 trucks fall within the range of 3,600 to 5,400 kg. For class 5 vehicles, most of the front steering axle weights are between 1,200 and 2,800 kg.

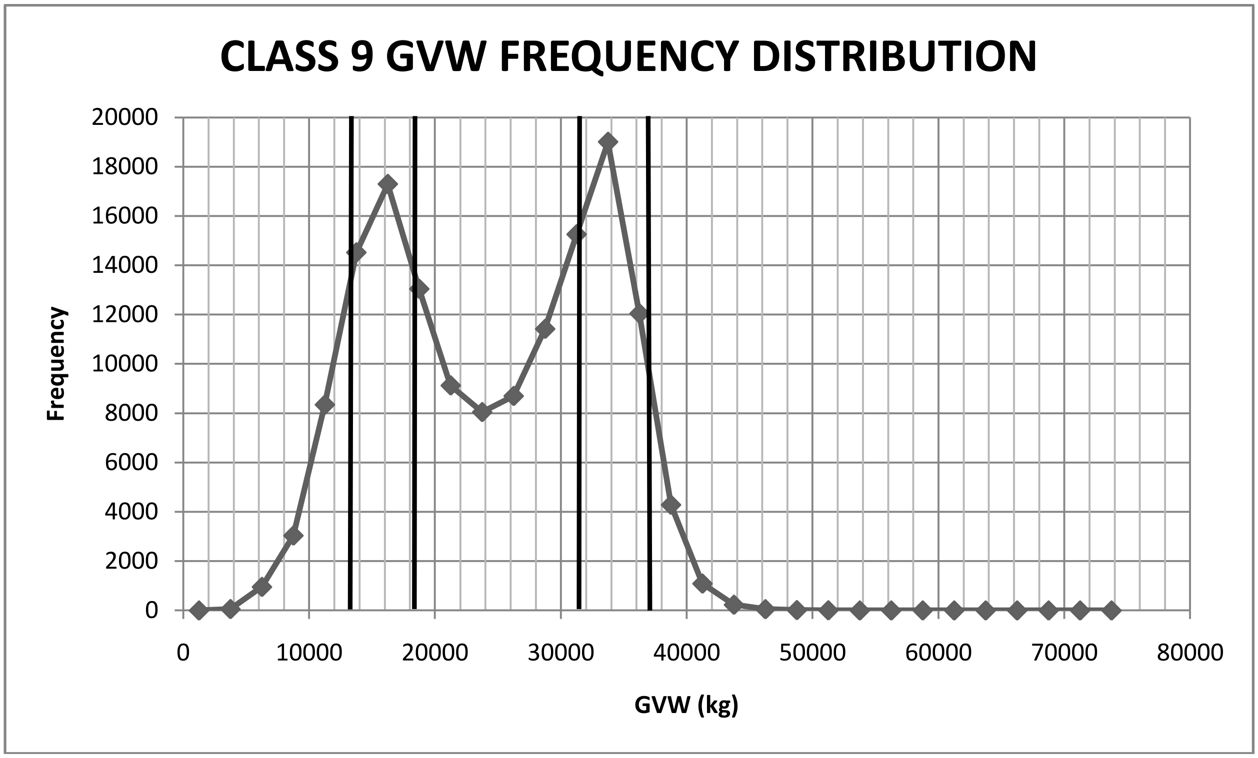


FIGURE 4 Gross Vehicle Weight Frequency Distribution for Class 9 Vehicles - Cuba

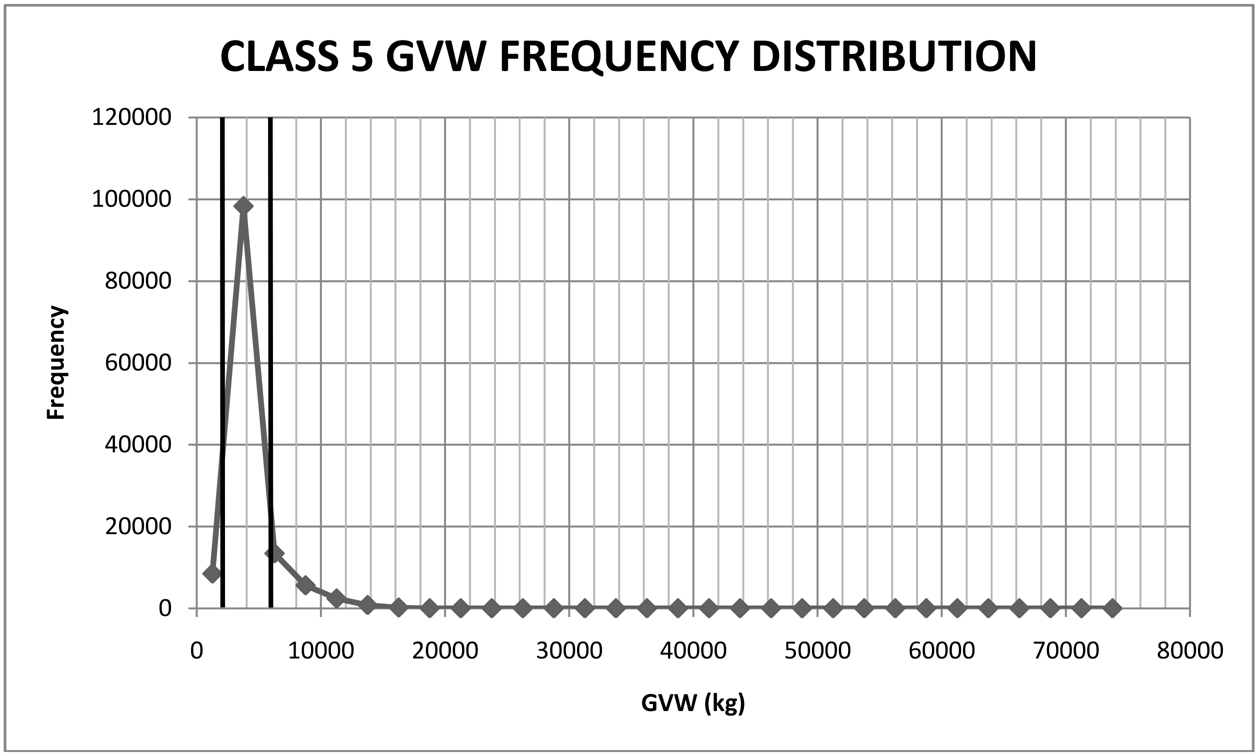


FIGURE 5 Gross Vehicle Weight Frequency Distribution for Class 5 Vehicles - Cuba

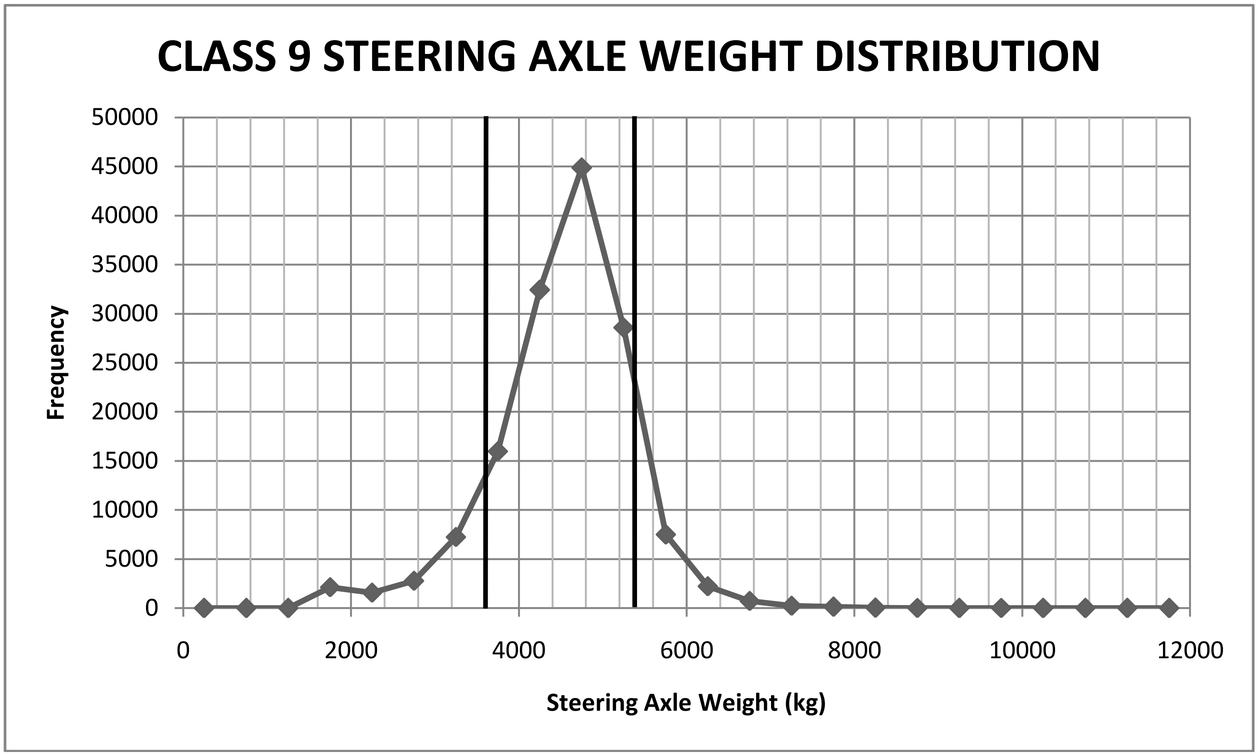


FIGURE 6 Front Steering Axle Weight Frequency Distribution for Class 9 Vehicles - Cuba

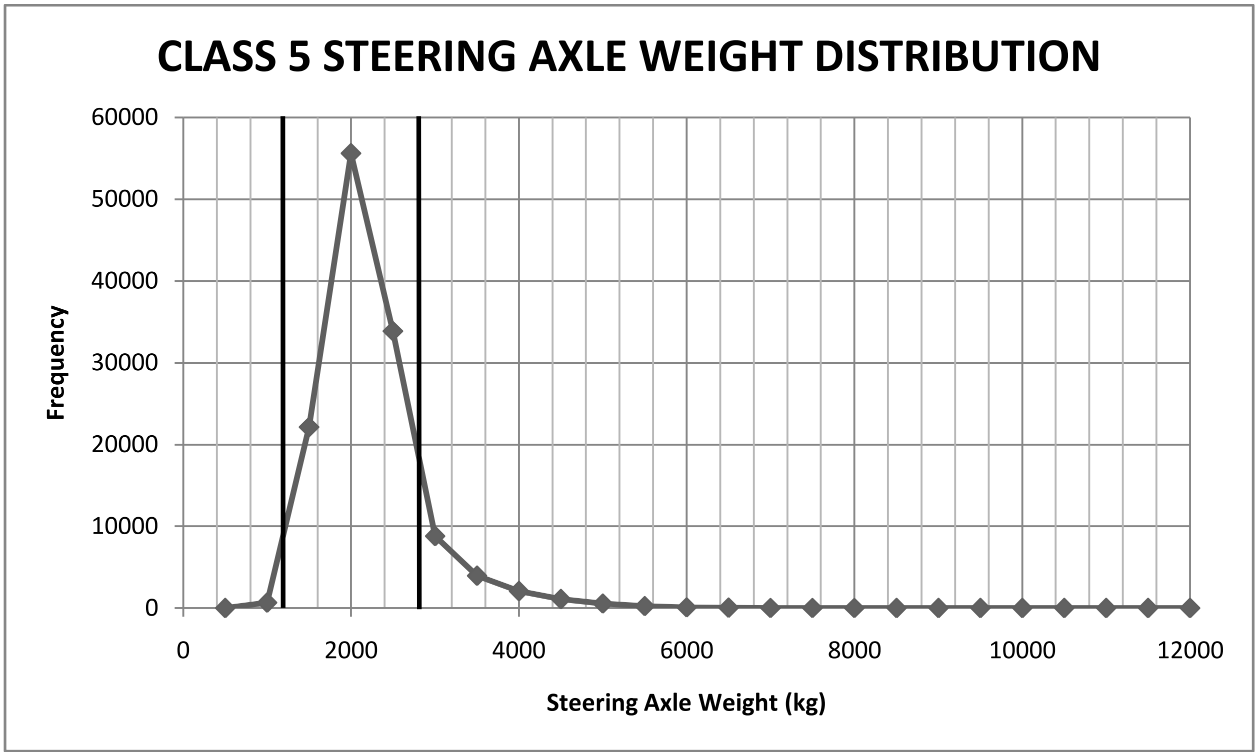


FIGURE 7 Front Steering Axle Weight Frequency Distribution for Class 5 Vehicles - Cuba

5.1.4 Conclusions

The results are consistent with the observations from field experience and with the recommendations given by the literature. Therefore, one can say that the Cuba WIM station collects accurate and reliable data, and thus it can be used as part of an effort to implement the MEPDG in New Mexico. Subsequent sections extend these analyses to other selected WIM sites to determine which additional WIM stations can contribute to the development of axle load spectra for New Mexico.

5.2 Extension of WIM QA/QC to Additional Sites

Three of the WIM sites currently operated by New Mexico Department of Transportation (NMDOT) use bending plate systems (IRD 1058), and the remaining use piezoelectric sensors (Mikros Raktel 8000).

This section of the report analyzes data collected at five selected WIM sites during the year 2009. The WIM sites considered are: Cuba, San Ysidro, and Bloomfield, (all bending plates) and Tucumcari and Tularosa (both piezo) and represent all three bending plate sites on US-550 as well as a rural Interstate site (Tucumcari) and a US numbered route (Tularosa). The same validation rules as previously described are employed.

5.2.1 Quality Control Rules and Algorithms

The set of previously described quality control rules was run on the five sites and less than 1% of the weight records were found to be invalid. Table 16 shows the total number of trucks recorded at each WIM site during 2009, and the corresponding number and percentage of erroneous data. The invalid records were removed, and the program calculated the previously mentioned frequency distributions.

TABLE 16 Number and Percentage of Invalid Records, 2009

WIM Site	Total Number of Trucks Weighed	Invalid Records	% of Invalid Records
CUBA	255,243	118	0.05
SAN YSIDRO	191,637	1,258	0.66
BLOOMFIELD	54,023	226	0.42
TUCUMCARI	965,503	548	0.06
TULAROSA	211,403	171	0.08

The vehicle class distribution of each WIM station is shown in Figure 8. In Cuba, San Ysidro, and Bloomfield (US-550) classes 5 and 9 comprise around 80% of the total traffic stream. A similar pattern is observed in Tularosa (US-70). But in Tucumcari (I-40) class 9 comprises almost 80% of the total heavy traffic. This indicates consistency of data since rural interstates usually are supposed to consist of larger trucks.

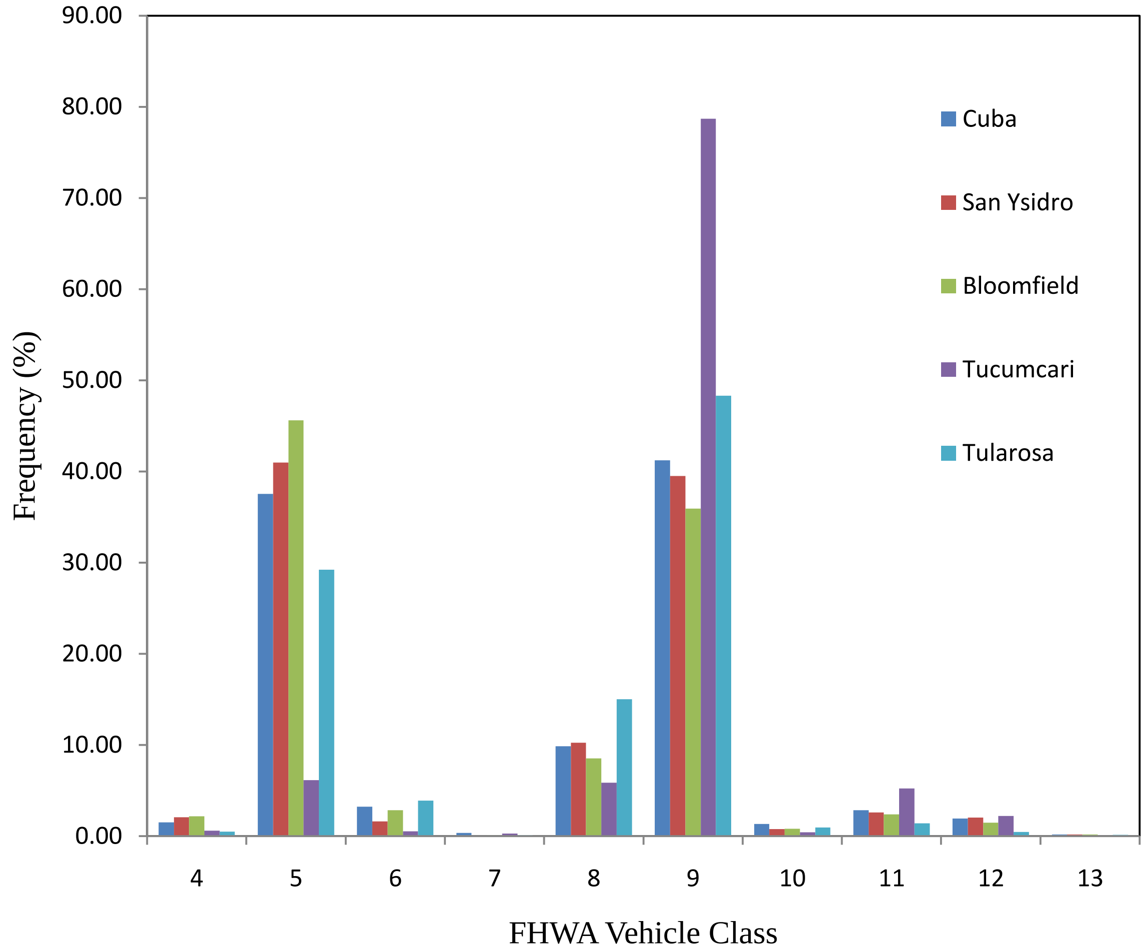


FIGURE 8 Vehicle Class Distribution

The directional distributions are shown in Figure 9 on the following page. The directional distribution factor is around 50% at all WIM sites, a trend to be expected on rural highways. This means that the weigh-in-motion equipment appears to be working correctly in both directions.

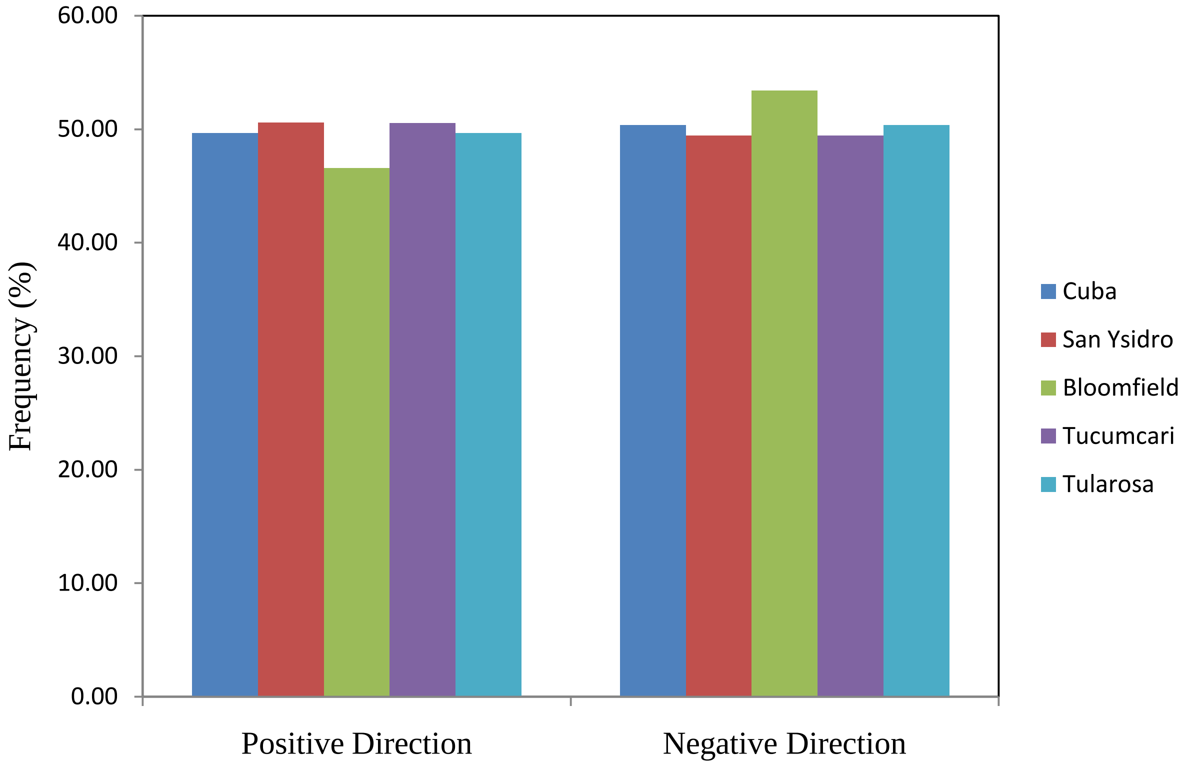


FIGURE 9 Directional Distribution

Similarly, Figure 10 shows the lane distribution at the selected WIM sites. The lane distribution factors are around 45% for the outer lanes and 5% for the inner lanes. This is a typical pattern on New Mexico rural highways. The interpretation is that the weigh-in-motion equipment worked properly in each lane during the year and the data are consistent.

The gross vehicle weight frequency distributions for classes 5 and 9 are plotted in Figure 11. These vehicle classes comprise almost 80% of the total heavy vehicle traffic stream. For class 9, the three bending plate systems (Cuba, San Ysidro, and Bloomfield) present a distribution with peaks for unloaded and loaded trucks in the middle of the ranges recommended by the Traffic Monitoring Guide. The two piezoelectric sites (Tucumcari and Tularosa) do not have a peak for unloaded trucks which indicates that these WIM sites are assigning high weights to every truck passing, probably due to malfunction of the system. In the class 5 gross vehicle weight frequency distribution, the three bending plates have their peaks in the middle of the range. The Tularosa distribution is totally out of range and Tucumcari presents too many frequencies over the range.

The front steering axle weight frequency distribution for class 5 and class 9 vehicles is shown in Figure 12. For the case of the three bending plates, most of the frequencies fall within the range recommended by the Traffic Monitoring Guide. The curves are totally out of the acceptable range in the case of piezoelectric systems (Tucumcari and Tularosa).

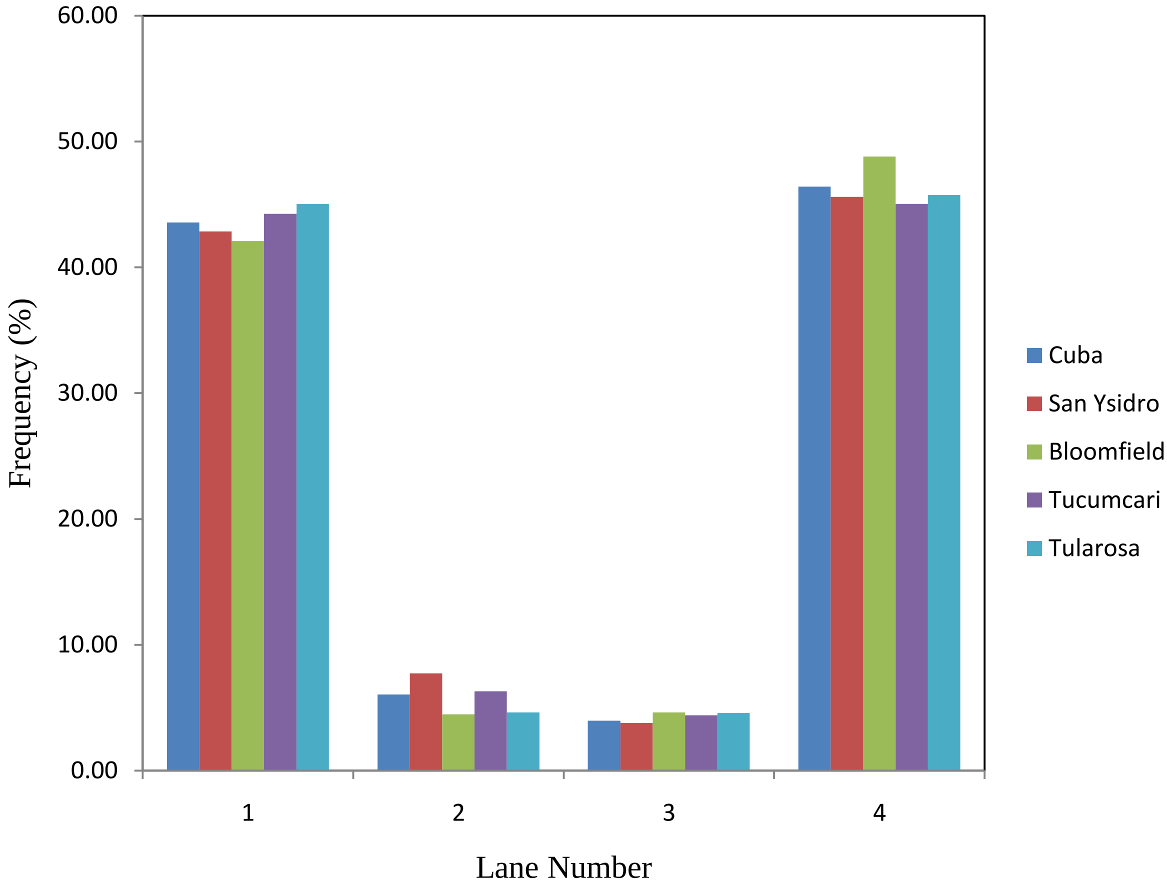
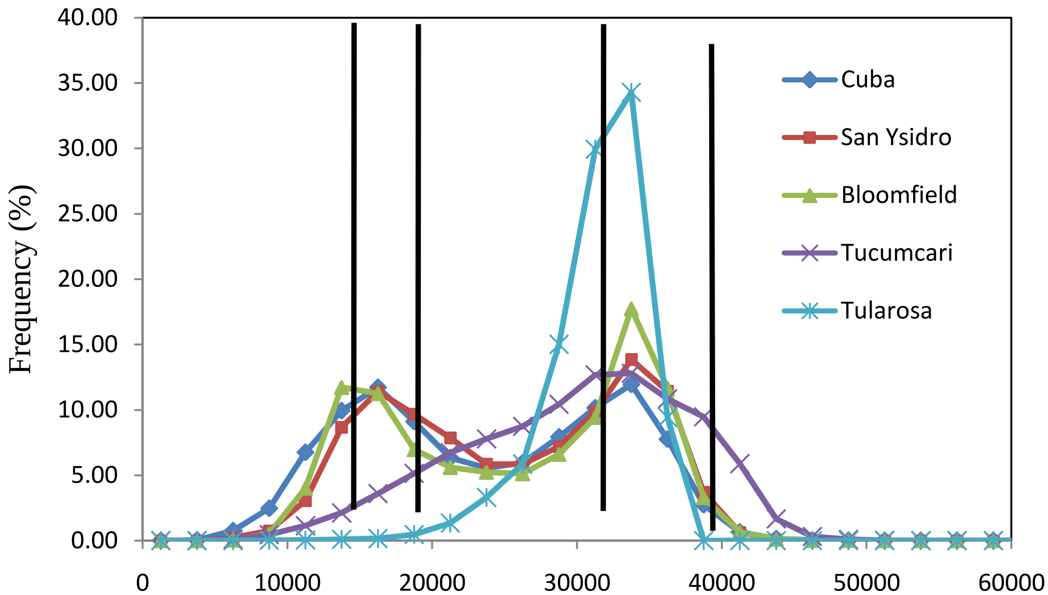
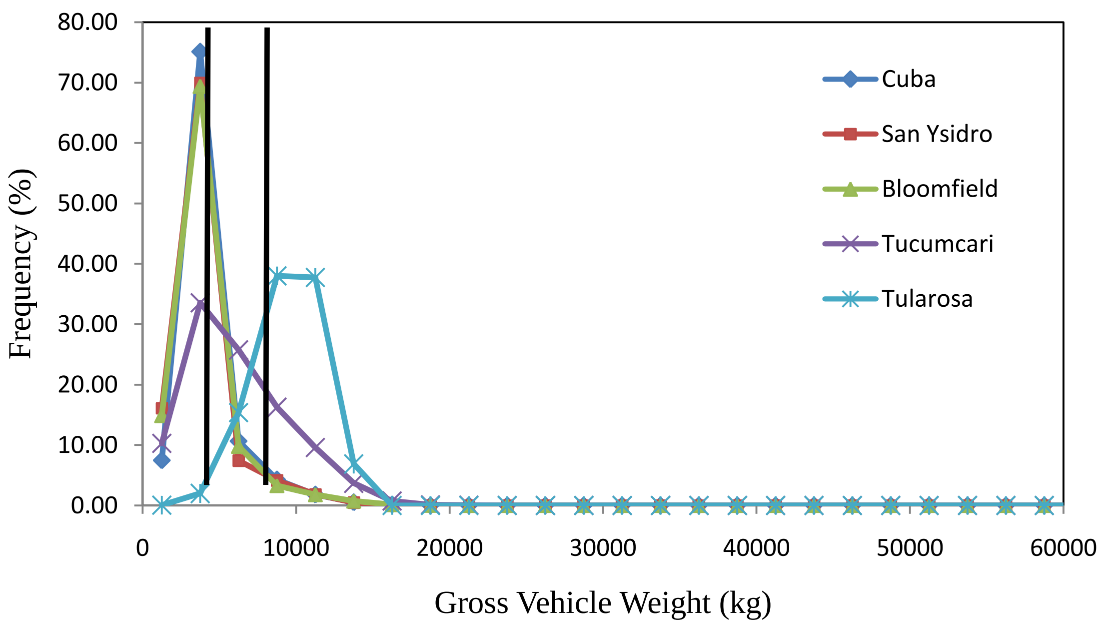


FIGURE 10 Lane Distribution

These results indicate that Tucumcari and Tularosa sites are not providing good weigh-in-motion data, perhaps due to the lack of calibration or the effect of surface condition and temperature on piezoelectric sensors. On the other hand, Cuba, San Ysidro, and Bloomfield are collecting acceptable WIM data. Among the bending plate systems, the data collected by the Cuba site is the most consistent.

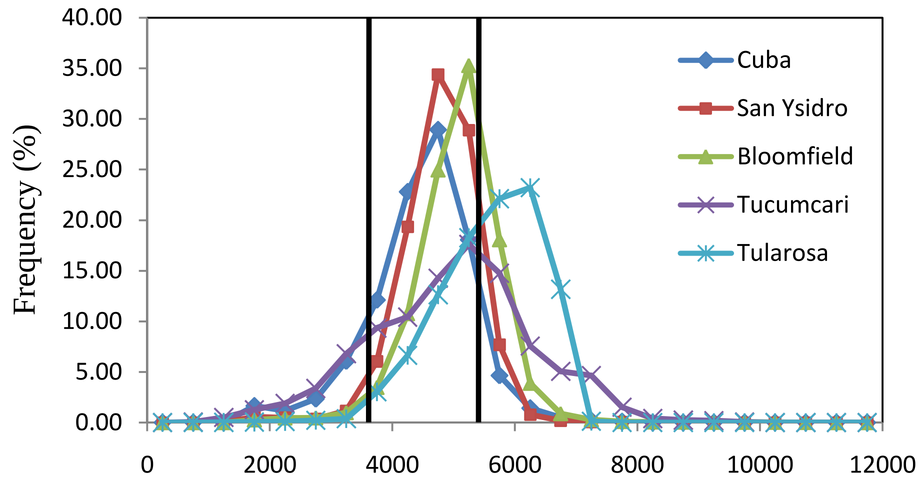


(a) Class 9

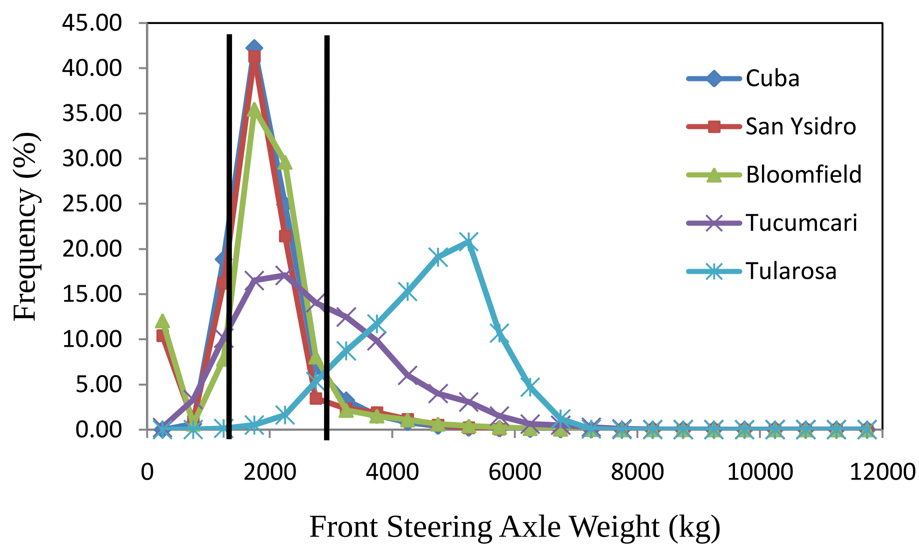


(b) Class 5

FIGURE 11 Gross Vehicle Weight Frequency Distribution



(a) Class 9



(b) Class 5

FIGURE 12 Steering Axle Weight Frequency Distribution

5.3 Development of Traffic Inputs for MEPDG

5.3.1 Traffic Data Required for Mechanistic-Empirical Pavement Design

In previous sections, a procedure to examine the quality of collected weigh-in-motion data was presented. The objective of this section is to define the traffic inputs required by the Mechanistic-Empirical Pavement Design Guide (MEPDG), and also present a series of subroutines that have been developed to obtain these traffic inputs from weigh-in-motion data. MEPDG adopts a hierarchical approach for the design inputs, defining three levels of traffic data input (Levels 1 through 3) on the basis of available data accuracy and reliability. Level 1 input correspond to historical site-specific traffic data; Level 2 is used when only regional or statewide traffic data are available; and Level 3 is defined for default national values or estimates based on local experience. If weigh-in-motion data collected at the road of interest is available, these scripts will allow for Level 1 pavement design *(59)*.

Traffic is one of the most important inputs required for the design of pavement structures. It allows us to know the magnitude and frequency of the loads applied during the pavement's design life. The previous versions of the AASHTO *Guide for Pavement Design* characterized traffic by defining the equivalent single axle load (ESAL). However, MEPDG uses a more complex approach, requiring a larger number of traffic inputs which are listed below *(58, 59)*:

- Base Year Truck Traffic Volume
    - Two-way Annual Average Daily Truck Traffic (AADTT)
    - Number of Lanes in Design Direction
    - Percent of Trucks in Design Direction
    - Percent of Trucks in Design Lane
    - Truck Operational Speed
- Truck Traffic Volume Adjustment Factors
    - Truck Class Distribution Factors
    - Monthly Distribution Factors
    - Hourly Distribution Factors
    - Traffic Growth Factors
- Axle Load Distribution Factors
- General Traffic Inputs
    - Mean Wheel Location
    - Traffic Wander Standard Deviation
    - Axle Configuration
    - Number of Axles by Axle Type per Truck Class
    - Wheelbase
    - Tire Dimensions and Inflation Pressures

From this long list of inputs, those corresponding to truck traffic volume, truck volume distributions, and axle load spectra can be obtained by processing weigh-in-motion data as will be shown in next sections. The remaining general traffic inputs do not vary significantly and their effects on the distress predicted is not important, therefore default values are used commonly for these inputs *(60, 61)*.

5.3.2 Development of Truck Volume Inputs and Truck Traffic Distributions

Weigh-in-motion systems continuously collect classification and weight data which are stored in C-files and W-files respectively. Classification data contains basically the following information: total number of vehicles that pass through the WIM site in every lane in every direction during every hour of the day, and the number of these vehicles by FHWA vehicle class. The format of the C-files is a standard recommended by the *Traffic Monitoring Guide*.

Two subroutines have been created to process the WIM classification data (*61*). The first one imports the C-files into Microsoft Excel and creates several tables to store the results. The second one processes all volume and classification data to calculate the required traffic inputs. The use of these subroutines is described step by step in a help file in Appendix 1. The outputs of these scripts are listed below:

- Average Daily Traffic (ADT)
- Average Daily Truck Traffic (ADTT)
- Percentage of Trucks
- Directional Distribution
- Lane Distribution
- Vehicle Class Distribution
- Truck Class Distribution
- Monthly Distribution by Vehicle Class
- Vehicle Hourly Distribution
- Truck Hourly Distribution

These outputs are in the form of tables which can be easily plotted using Microsoft Excel tools.

The subroutines may then be applied to classification data collected during the entire year. The 2010 data at the Tularosa WIM site (US-70, MP 231.65) is presented below to illustrate the usefulness of the routines.

Table 17 contains the annual average daily traffic (AADT), the annual average daily truck traffic (AADTT), and the percentage of heavy vehicles while Figure 13 shows the directional distribution with positive and negative directions corresponding to east and west, respectively. Figure 14 shows the lane distribution, where lanes 1 and 4 are the outside lanes and 2 and 3 are the inside lanes. Figure 15 plots the truck class distribution; FHWA classes 5 and 9 are dominant, as expected, and Figure 16 shows the total vehicle monthly distribution which indicates that July and August have slightly higher percentages than the average. Finally, Figure 17 shows the truck hourly distribution.

TABLE 17 Two-way Daily Traffic Volume - Tularosa

Two-way Daily Traffic Volume	
ADT	6677
ADTT	1021
Percentage of Trucks	15.30

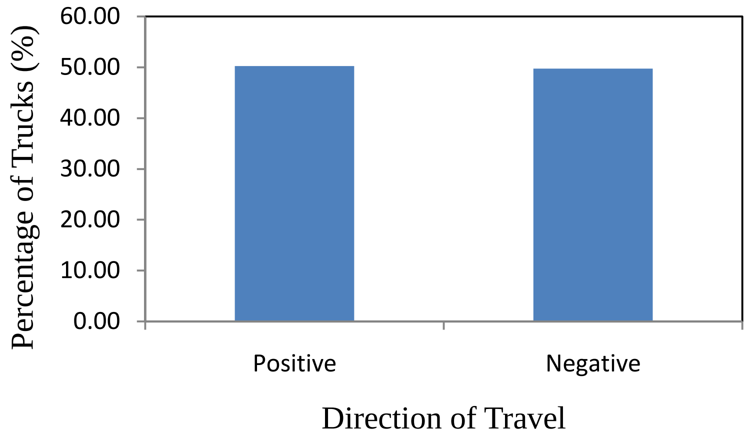


FIGURE 13 Directional Distribution - Tularosa

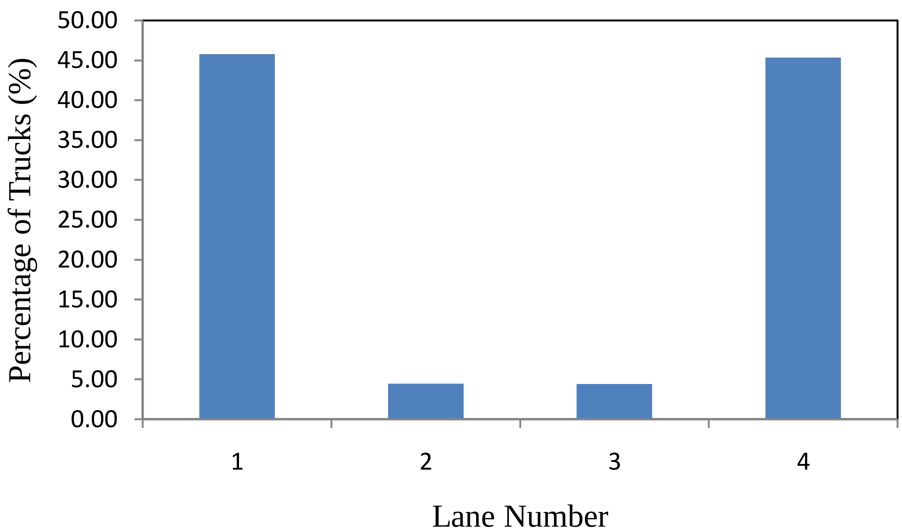


FIGURE 14 Lane Distribution - Tularosa

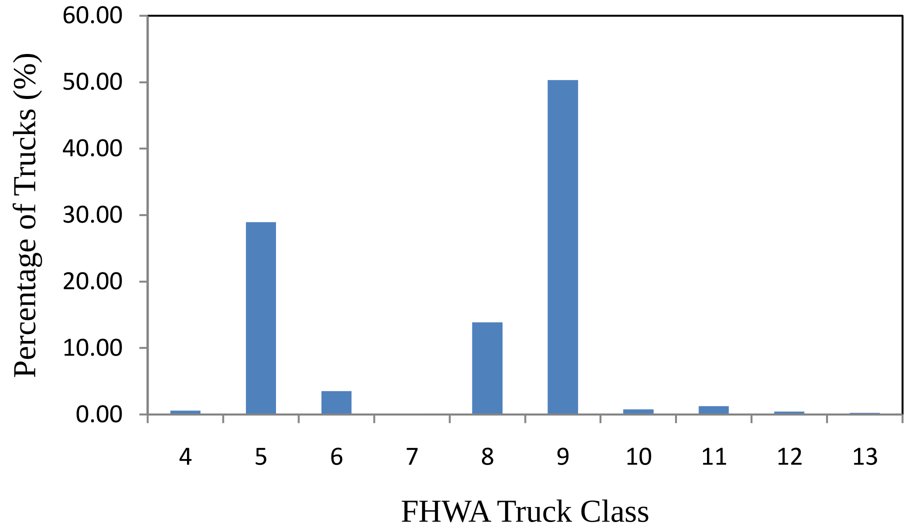


FIGURE 15 Truck Class Distribution - Tularosa

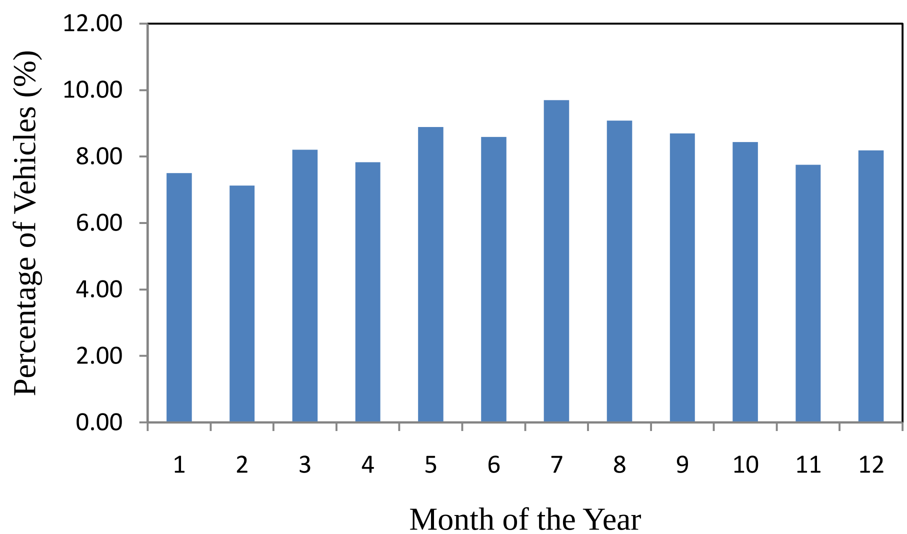


FIGURE 16 Vehicle Monthly Distribution - Tularosa

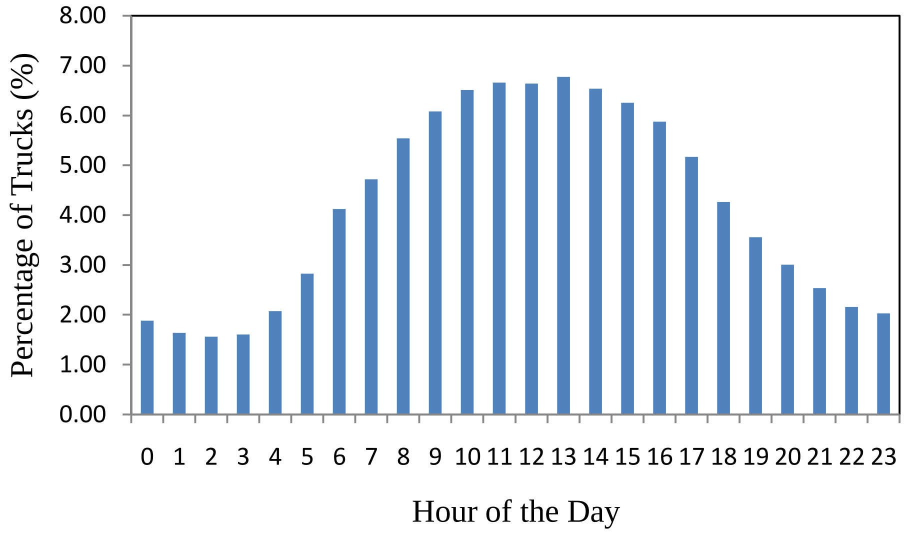


FIGURE 17 Truck Hourly Distribution - Tularosa

5.3.3 Development of Axle Load Spectra

One of the most important traffic inputs required in the MEPDG is the axle load spectra which can only be obtained from weigh-in-motion data. Therefore, it is critical for state highway agencies to collect and process high quality WIM data. Moreover, axle load spectra have been proven to have a strong influence on pavement performance (*62*).

As previously stated, weigh-in-motion (WIM) systems collect classification and weight data which are stored in C-files and W-files, respectively. For the weight data, for each truck passing, the equipment records a tabulation of the vehicle type (FHWA class 4 through 13) and the number, spacing, and weight of axles. The dynamic weight measurement obtained by the different technologies for WIM systems, such as load cell, bending plate, and piezo sensor, are not the same as the actual static weight, since there is an inherent error associated with each technology. Each system thus has a particular accuracy and reliability (*63*).

The axle load spectra can be defined as the percentage of the total axle applications within each load interval for a specific axle type (single, tandem, tridem, and quad) and vehicle class (classes 4 through 13). The following equation can be used to compute the axle load distribution factors (*59*):

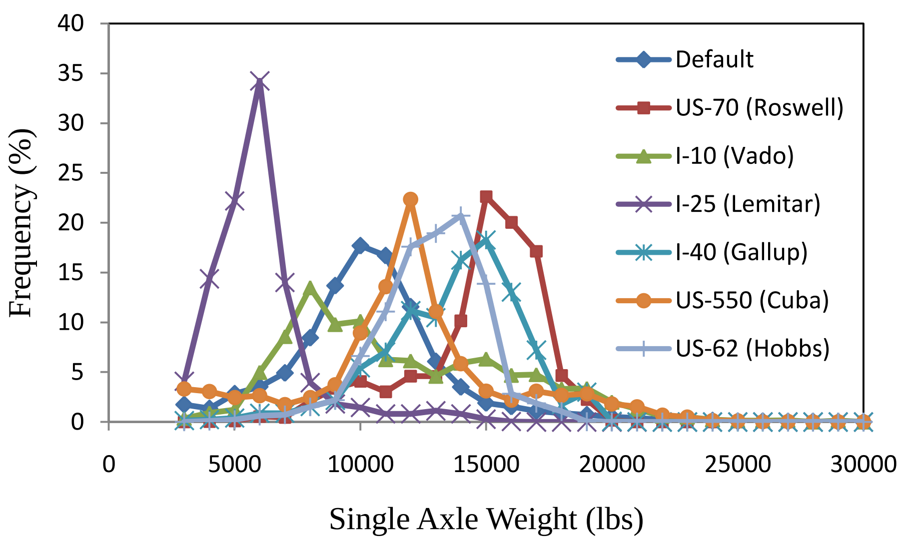
$$ALDF_{ijk} = \frac{No.\ of\ axles\ for\ class\ i,\ \ month\ j,\ \ and\ load\ range\ k}{Total\ No.\ of\ axles\ for\ class\ i\ and\ month\ j} \times 100$$

The computation of axle load spectra is a process external to the MEPDG. TrafLoad v1.0.8, created under NCHRP Project 1-39, is software for the processing and analysis of weigh-in-motion data. This program, however, could not be used because the software is inconsistent and has compatibility issues with the WIM data collected in New Mexico; this is similar to many other cases reported in the literature (*64*, *65*).

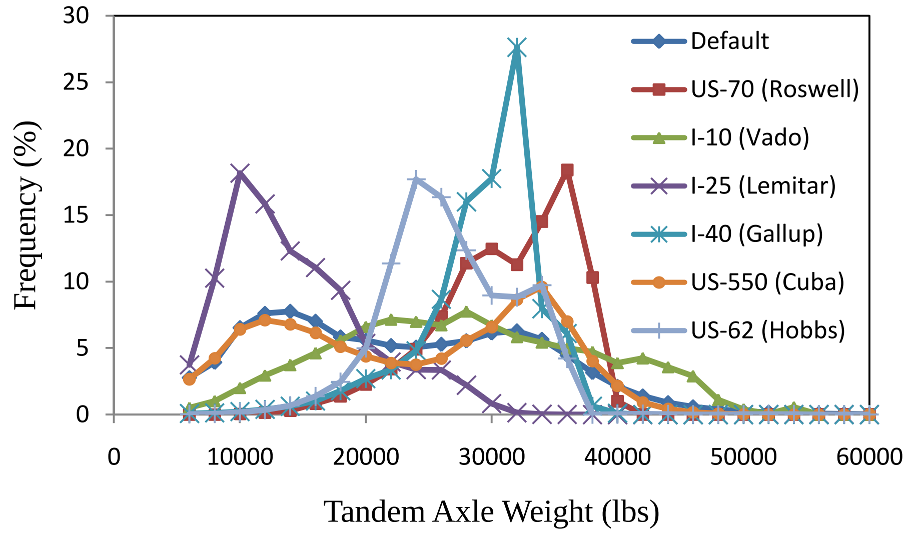
As a result, a set of subroutines has been implemented in Visual Basic to process New Mexico's weigh-in-motion data and to compute the corresponding axle load spectra. This algorithm is based on the spacing between axles and the weight of each axle. A limiting spacing value is defined such that when there are two, three, or four consecutive axles separated by a distance smaller than the limiting spacing value, these axles are considered as tandem, tridem, or quad, respectively. A single axle is separated from the surrounding axles by a distance greater than the limiting spacing. This algorithm has been previously shown to reproduce correctly the axle configuration of most of the trucks currently being operated on New Mexico roads.

The aforementioned subroutines have been used to obtain the axle load spectra at the additional New Mexico WIM sites not previously discussed for single, tandem, tridem, and quad axles. The site-specific axle load spectra for New Mexico weigh-in-motion sites versus the MEPDG default is plotted in Figure 18 below and on the following page. The figure shows that site-specific axle load spectra can be different from one location to another and different from the MEPDG default values as well. This is because differences in the economic and industrial development of one region compared to another result in different regional and seasonal truck loading characteristics which lead to different axle load spectra. Site-specific axle load spectra are usually different from the MEPDG default; very large differences, however, are uncommon, and are often due to weight measurement errors. Since the axle load spectra is a very sensitive input, site-specific values must be accurately determined.

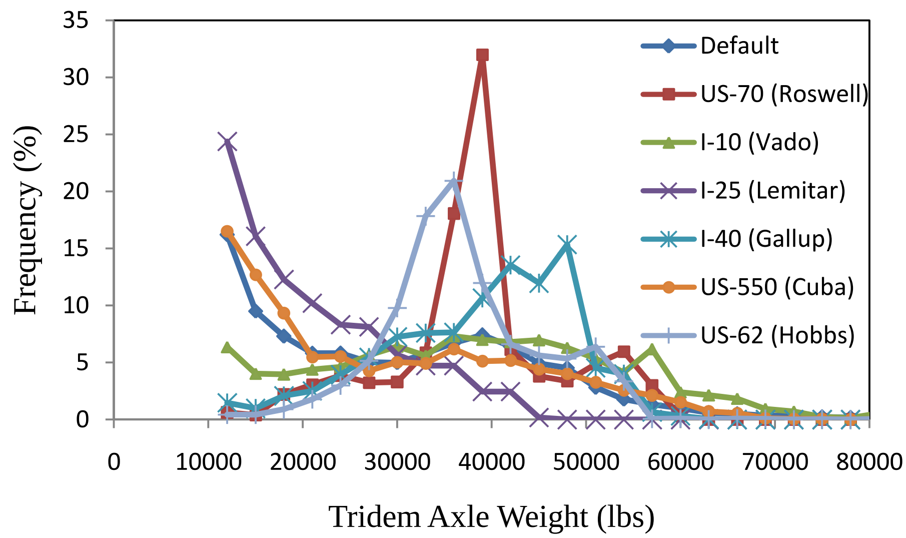
The use of this set of subroutines is described and explained step by step in Appendix 2 of this report.



(a) Single Axle Load Spectra



(b)Tandem Axle Load Spectra



(c) Tridem Axle Load Spectra

FIGURE 18 Axle Load Spectra for Selected New Mexico WIM Sites

5.3.4 PrepME Software for the Mechanistic-Empirical Pavement Design Guide (MEPDG)

PrepME is a software application developed by Kelvin Wang and Kevin Hall at the University of Arkansas to support the implementation of MEPDG in the Arkansas State Highway and Transportation Department (AHTD). The details and technical description of this software application are contained in the final report of the research project AHTD TRC-0702 "*Database Support for the New Mechanistic-Empirical Pavement Design Guide (MEPDG)*" *(79)*.

The objectives of this research project were: identify all the data and inputs required by MEPDG; locate possible sources of data; design a database to support MEPDG and manage all the available data; and most importantly, develop external software (PrepME) for preparation of MEPDG input files.

The first step in the use of PrepME software is to import all raw data, including traffic and climate data. The hourly climate data are obtained from the climate files available on the MEPDG website (www.trb.org/mepdg/climatic_state.htm); the water table depth data are obtained from USGS online databases; and the traffic weigh-in-motion data are provided by AHTD. When the importing process has been completed, a geo-referenced Google map utility shows the geographical locations of weather stations, water table depth testing points, weigh-in-motion stations, and the surrounding area.

The next step is to check the quality of the weigh-in-motion data; the application performs several quality control checks based on the Traffic Monitoring Guide separately for classification and weight data. In addition, the gross vehicle weight distribution, the average front axle weight distribution, the average drive tandem axle weight distribution, and the axle load spectra are determined. According to the results obtained from the quality control checks, the weigh-in-motion data is classified into three possible states: "accepted" when all the data from a station are good; "partial accepted" when some months of data are not good and are removed, but the remaining data can still represent twelve months of the year; and "not accepted" when all the data are not good or the remaining data are insufficient to represent the whole year. Not accepted data indicates that the WIM system is not properly calibrated.

Next, the climate and traffic data that can be used in MEPDG are interpolated at the project location being necessary to provide the GPS coordinates, the AADTT, the number of lanes, the operational speed, and the truck traffic classification (TTC) system. The interpolated climate and traffic files are generated and can be directly imported in MEPDG. Currently, a capability to retrieve the most significant input material parameters such as dynamic modulus for asphalt concrete and resilient modulus for unbound and subgrade materials based on the testing results from previous research projects is being developed. Material parameter input files will be generated in a format compatible with MEPDG.

The future work on this project will be to introduce traffic loading grouping and clustering, improving and making more flexible the quality control procedures, and making the application accessible to other state DOTs. The researchers have applied PrepME to NMDOT weigh-in-motion data, but the application is unable to import the raw data; perhaps there is a compatibility issue. If NMDOT elects to use the standard traffic monitoring data formats recommended by the

Traffic Monitoring Guide, PrepME will be a potential and very useful application for quality control of WIM data and implementation of MEPDG.

5.4 Truck Classification Schemes

After analyzing the classification data collected at New Mexico WIM sites, it was found that some FHWA classes (4, 6, 7, 10, and 13) have very small contributions to the truck traffic stream observed on New Mexico's roads. Classes 5, 8, 9, 11, and 12 comprise more than 90% of the total truck traffic stream. Therefore, a reduced classification scheme of three categories for use in the classification data collection program instead of the 10 bin FHWA scheme is recommended.

This new classification scheme should have a first category formed by the combination of FHWA classes 4, 5, 6, and 7; the second category should aggregate classes 8, 9, and 10; and finally the third category should combine FHWA classes 11, 12, and 13. Those classes presenting very low and highly variable volumes are eliminated, and thus, the factoring of short duration classification counts is simplified and stabilized.

The rules shown in Table 18 are suggested for converting from the FHWA classification scheme to New Mexico specific scheme and vice-versa. These conversion proportions must be updated periodically by performing specific studies.

TABLE 18 Conversion Rules between Classification Schemes

FHWA Scheme	Suggested Scheme	Percentage of the Total Truck Traffic Stream							
		I-10		I-40		I-25		US-named Routes	
Class 4	Category 1	1.25	11.28	0.54	20.78	1.19	26.93	1.39	43.05
Class 5		8.42		18.79		23.17		37.21	
Class 6		1.51		0.54		2.22		4.21	
Class 7		0.11		0.92		0.35		0.23	
Class 8	Category 2	6.94	75.04	5.26	69.54	16.94	65.78	10.96	53.65
Class 9		66.79		63.94		48.00		41.75	
Class 10		1.32		0.34		0.83		0.94	
Class 11	Category 3	4.88	13.68	3.79	9.68	5.50	7.30	2.01	3.30
Class 12		2.63		2.21		1.70		1.13	
Class 13		6.17		3.68		0.09		0.16	
Total		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

5.5 Truck Weight Roadway Groups

The *Traffic Monitoring Guide* recommends classifying the state roadway system into truck weight roadway groups so all roads within a particular group experience similar truck loading patterns in terms of individual vehicle weights. The determination of these truck weight roadway groups has to be performed accurately once consistent and reliable WIM data is available as a result of the implementation of this research project.

Nonetheless, a first approach can be performed based on the available WIM data. Also, the understanding of the freight movement function of each road, the type of goods being carried, and the truck traffic classification data are necessary for accomplishing this task.

Interstates 10 and 40 can constitute the first truck weight group since these two roads contain the higher percentages of the heaviest FHWA classes. They both have a large amount of through-trucks that carry freight between California and Texas - two very large industrial states.

Interstate 25 is the only road in the next group. This highway presents lighter truck traffic than the previous group but still heavier than the remaining US-named routes. Since I-25 connects Albuquerque, Las Cruces, and Santa Fe with Colorado and other states, this road has a significant movement of freight.

The third truck weight roadway group includes US-550, US-70, US-62, and US-54 which are farm-to-market roads and also have considerable freight movement at a statewide level. The remaining US-named routes currently have no WIM sites installed, but they have lower and more local truck traffic and therefore could make up the fourth and last truck weight roadway group.

The *Traffic Monitoring Guide* recommends using a minimum of six WIM sites for each truck weight group. Therefore, if the state of New Mexico has four different truck weight groups, a minimum of 24 WIM sites are required. At least one of the WIM sites within each group should operate continuously throughout the year. The remaining locations must be monitored for no less than one week.

CHAPTER 6: WEB-BASED DATA MANAGEMENT, REPORTING AND TRAINING

6.1 Introduction

Traffic monitoring programs are very essential in tracking, measuring, and managing the performance of the transportation system network. Through traffic monitoring programs, the transportation engineer is aware of the usage of the system and its performance measures and can thus make appropriate decisions in controlling the system. The traffic monitoring program is funded by the taxpayer and therefore the taxpayer becomes the automatic owner of the traffic data collected; hence there should be a medium through which data can be made available to the general public.

There are many uses to which traffic data is put; some examples are highway design and planning, in estimating the benefits of highway improvements, in locating service areas, estimating roadway revenue, and in research work such as methods of improving highway usage/efficiency. Traffic data needs for the above-mentioned traffic data uses are basically AADT, AADTT, peak hour traffic, turning movement counts, hourly volume adjustment factors, vehicle miles of travel (VMT), real-time volumes for emergency operation centers, directional factors, and directional hourly volumes. These data should be made easily accessible to the general public. With improvements in information technology and the need for on-the-fly data, the recent way of reporting traffic data is through the internet.

As part of this project, the researchers have been tasked to make recommendations for web-based traffic data management and reporting. In order to make appropriate recommendations for a web-based data management and reporting system, a review was conducted of states with existing web-based data reporting systems to determine the data reported and the format in which it is reported. The following sections discuss selected states and their web-based traffic data reporting systems.

6.2 California Department of Transportation

The traffic data branch of the California Department of Transportation (Caltrans) is responsible for collection and dissemination of traffic counts. As such, it has developed a link through which users can access the most recent traffic volumes, truck volumes, hourly volumes and seasonal traffic volumes. Historical data is also available for traffic data users.
Caltrans only collects data on its state highway system and thus data provided on this website are only for that system. Data on locally maintained roads are collected by engineers in their respective jurisdictions; Caltrans customers are directed to contact the appropriate jurisdictions for any such data.

The screen shot in Figure 19 on the following page is the online link developed by the Caltrans traffic data branch for public access.

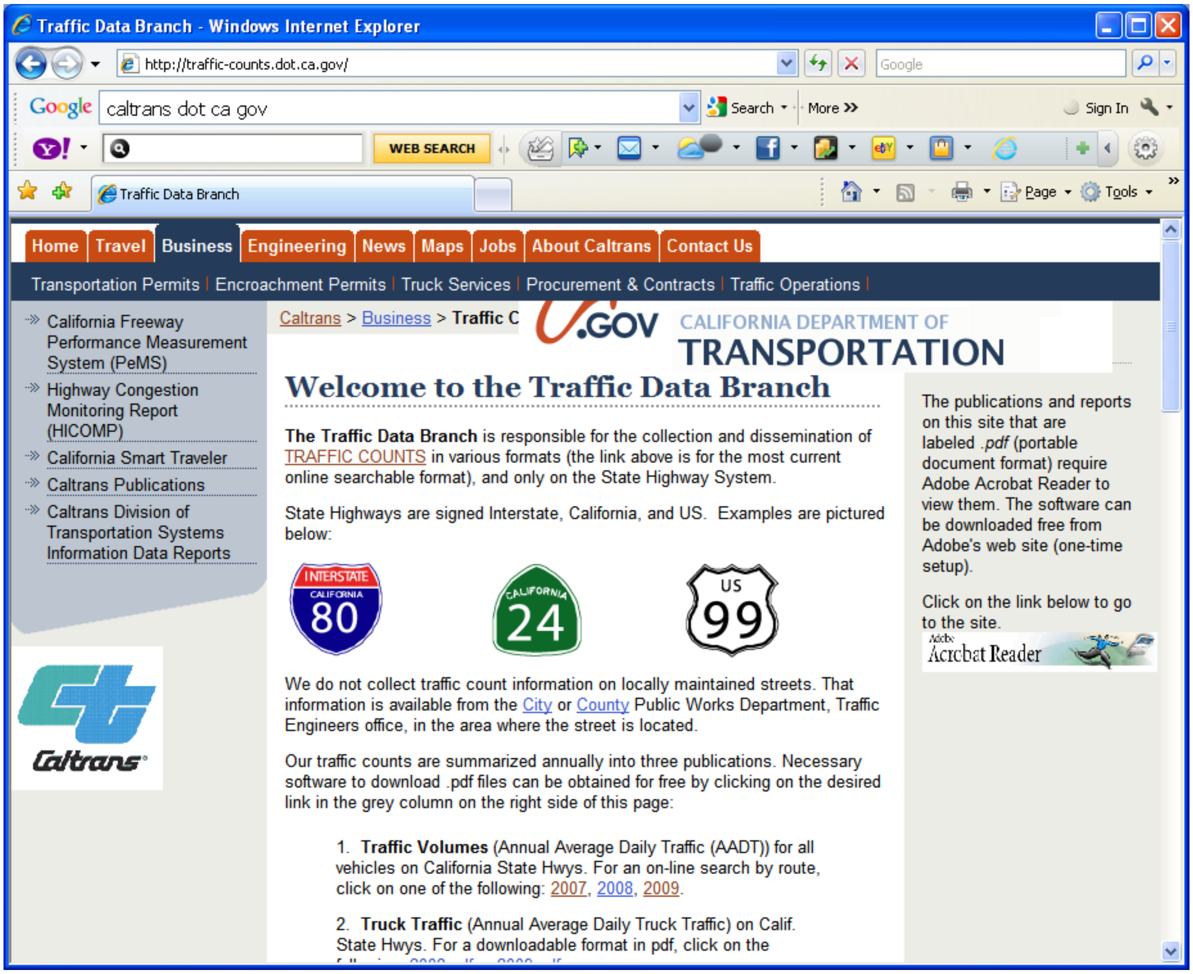


FIGURE 19 Caltrans Web-Based Data Reporting System

Source: Reference (*66*).

This site provides traffic data users with annual data collected on the state highway system in three publications: traffic volume AADT, truck volume AADT, and ramp volumes. These data are made available and can be downloaded in either .pdf or Excel format. Data is also available as a Word document for users with accessibility problems.

6.2.1 Traffic Volume AADT

The traffic volume AADT is available for each district, county, and route and can be downloaded and used for further analyses. There is associated metadata with each annual data file. For a particular year, users are provided with a link where they can search for traffic volume data by route.

6.2.2 Truck Volume Data

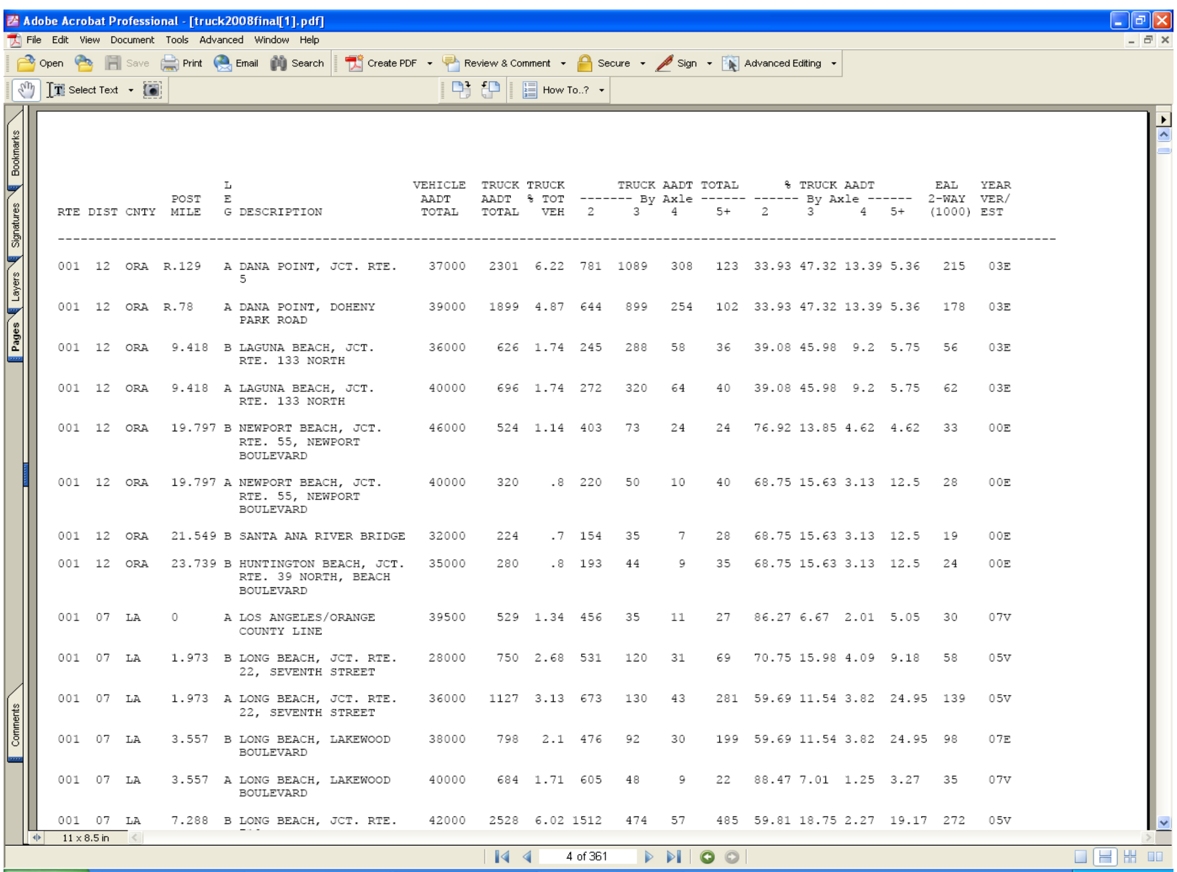
Annual truck volume data is also provided in .pdf or Excel format for each district, county, and route. Truck volume is provided as total truck AADT, total truck percent of volume, volume by vehicle classification, and percent by vehicle class. Figure 20 is an example of an AADT data file provided in .pdf format.

6.2.3 Ramp Volumes

Ramp volumes are available as trend data for those years for which data is available.

6.2.4 Other Data

In addition to the traffic volume AADT, truck volume AADT and ramp volumes provided on the website, peak hour volume is also available for download in .pdf format. Data provided include percentage of morning and afternoon/evening peak periods as a percentage of Annual Average Daily Traffic and is available by direction. An example is shown in Figure 21 on the following page.


Adobe Acrobat Professional - [truck2008final[1].pdf]

RTE	DIST	CNTY	POST MILE	LEG	DESCRIPTION	VEHICLE AADT TOTAL	TRUCK AADT TOTAL	TRUCK % TOT VEH	TRUCK AADT TOTAL By Axle 2	3	4	5+	% TRUCK AADT By Axle 2	3	4	5+	EAL 2-WAY (1000)	YEAR VER/ EST
001	12	ORA	R.129	A	DANA POINT, JCT. RTE. 5	37000	2301	6.22	781	1089	308	123	33.93	47.32	13.39	5.36	215	03E
001	12	ORA	R.78	A	DANA POINT, DOHENY PARK ROAD	39000	1899	4.87	644	899	254	102	33.93	47.32	13.39	5.36	178	03E
001	12	ORA	9.418	B	LAGUNA BEACH, JCT. RTE. 133 NORTH	36000	626	1.74	245	288	58	36	39.08	45.98	9.2	5.75	56	03E
001	12	ORA	9.418	A	LAGUNA BEACH, JCT. RTE. 133 NORTH	40000	696	1.74	272	320	64	40	39.08	45.98	9.2	5.75	62	03E
001	12	ORA	19.797	B	NEWPORT BEACH, JCT. RTE. 55, NEWPORT BOULEVARD	46000	524	1.14	403	73	24	24	76.92	13.85	4.62	4.62	33	00E
001	12	ORA	19.797	A	NEWPORT BEACH, JCT. RTE. 55, NEWPORT BOULEVARD	40000	320	.8	220	50	10	40	68.75	15.63	3.13	12.5	28	00E
001	12	ORA	21.549	B	SANTA ANA RIVER BRIDGE	32000	224	.7	154	35	7	28	68.75	15.63	3.13	12.5	19	00E
001	12	ORA	23.739	B	HUNTINGTON BEACH, JCT. RTE. 39 NORTH, BEACH BOULEVARD	35000	280	.8	193	44	9	35	68.75	15.63	3.13	12.5	24	00E
001	07	LA	0	A	LOS ANGELES/ORANGE COUNTY LINE	39500	529	1.34	456	35	11	27	86.27	6.67	2.01	5.05	30	07V
001	07	LA	1.973	B	LONG BEACH, JCT. RTE. 22, SEVENTH STREET	28000	750	2.68	531	120	31	69	70.75	15.98	4.09	9.18	58	05V
001	07	LA	1.973	A	LONG BEACH, JCT. RTE. 22, SEVENTH STREET	36000	1127	3.13	673	130	43	281	59.69	11.54	3.82	24.95	139	05V
001	07	LA	3.557	B	LONG BEACH, LAKEWOOD BOULEVARD	38000	798	2.1	476	92	30	199	59.69	11.54	3.82	24.95	98	07E
001	07	LA	3.557	A	LONG BEACH, LAKEWOOD BOULEVARD	40000	684	1.71	605	48	9	22	88.47	7.01	1.25	3.27	35	07V
001	07	LA	7.288	B	LONG BEACH, JCT. RTE.	42000	2528	6.02	1512	474	57	485	59.81	18.75	2.27	19.17	272	05V

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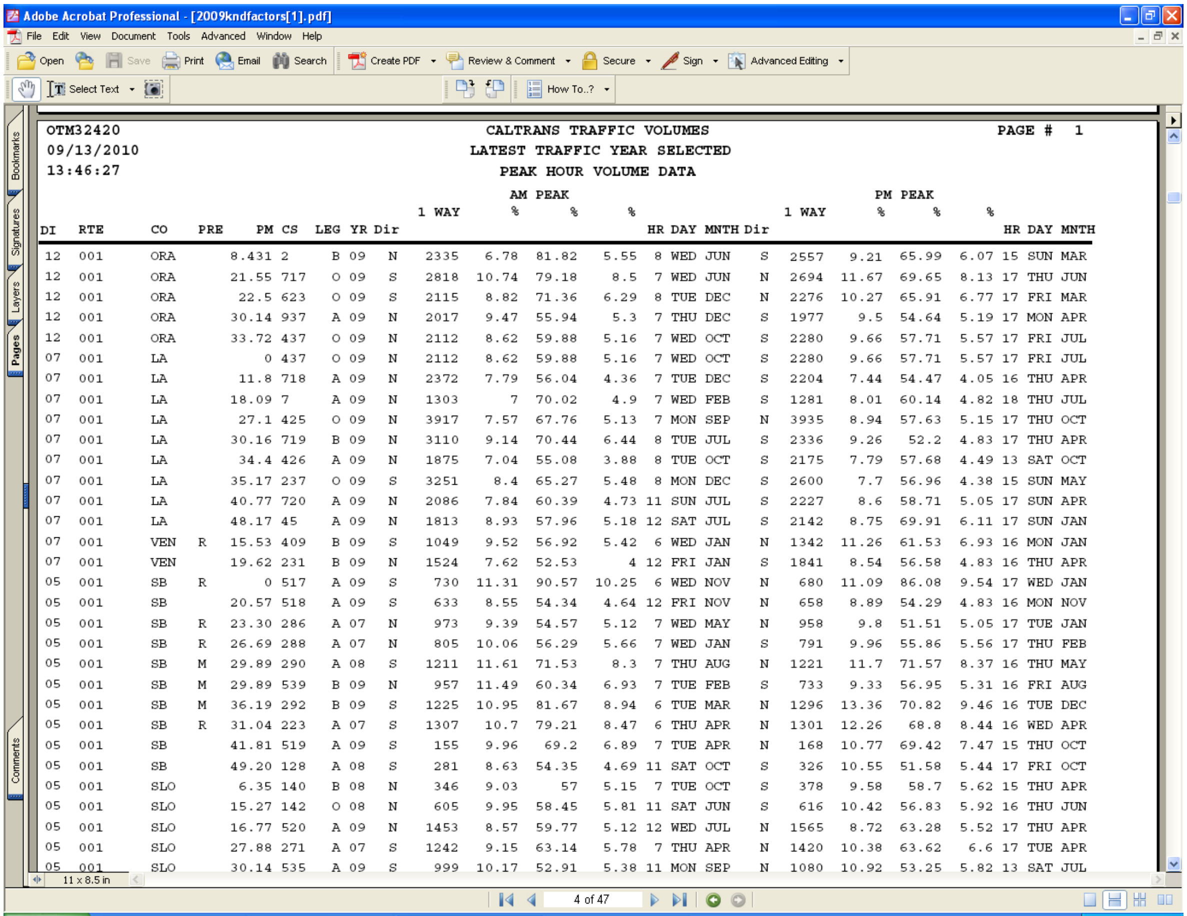
FIGURE 20 Traffic Volume AADT Report with Truck Volume AADT - CA

Source: Reference (*66*).



OTM32420 CALTRANS TRAFFIC VOLUMES PAGE # 1
09/13/2010 LATEST TRAFFIC YEAR SELECTED
13:46:27 PEAK HOUR VOLUME DATA

									AM PEAK								PM PEAK						
									1 WAY	%	%	%					1 WAY	%	%	%			
DI	RTE	CO	PRE	PM	CS	LEG	YR	Dir					HR	DAY	MNTH	Dir					HR	DAY	MNTH
12	001	ORA		8.431	2	B	09	N	2335	6.78	81.82	5.55	8	WED	JUN	S	2557	9.21	65.99	6.07	15	SUN	MAR
12	001	ORA		21.55	717	O	09	S	2818	10.74	79.18	8.5	7	WED	JUN	N	2694	11.67	69.65	8.13	17	THU	JUN
12	001	ORA		22.5	623	O	09	S	2115	8.82	71.36	6.29	8	TUE	DEC	N	2276	10.27	65.91	6.77	17	FRI	MAR
12	001	ORA		30.14	937	A	09	N	2017	9.47	55.94	5.3	7	THU	DEC	S	1977	9.5	54.64	5.19	17	MON	APR
12	001	ORA		33.72	437	O	09	N	2112	8.62	59.88	5.16	7	WED	OCT	S	2280	9.66	57.71	5.57	17	FRI	JUL
07	001	LA		0	437	O	09	N	2112	8.62	59.88	5.16	7	WED	OCT	S	2280	9.66	57.71	5.57	17	FRI	JUL
07	001	LA		11.8	718	A	09	N	2372	7.79	56.04	4.36	7	TUE	DEC	S	2204	7.44	54.47	4.05	16	THU	APR
07	001	LA		18.09	7	A	09	N	1303	7	70.02	4.9	7	WED	FEB	S	1281	8.01	60.14	4.82	18	THU	JUL
07	001	LA		27.1	425	O	09	N	3917	7.57	67.76	5.13	7	MON	SEP	N	3935	8.94	57.63	5.15	17	THU	OCT
07	001	LA		30.16	719	B	09	N	3110	9.14	70.44	6.44	8	TUE	JUL	S	2336	9.26	52.2	4.83	17	THU	APR
07	001	LA		34.4	426	A	09	N	1875	7.04	55.08	3.88	8	TUE	OCT	S	2175	7.79	57.68	4.49	13	SAT	OCT
07	001	LA		35.17	237	O	09	S	3251	8.4	65.27	5.48	8	MON	DEC	S	2600	7.7	56.96	4.38	15	SUN	MAY
07	001	LA		40.77	720	A	09	N	2086	7.84	60.39	4.73	11	SUN	JUL	S	2227	8.6	58.71	5.05	17	SUN	APR
07	001	LA		48.17	45	A	09	N	1813	8.93	57.96	5.18	12	SAT	JUL	S	2142	8.75	69.91	6.11	17	SUN	JAN
07	001	VEN	R	15.53	409	B	09	S	1049	9.52	56.92	5.42	6	WED	JAN	N	1342	11.26	61.53	6.93	16	MON	JAN
07	001	VEN		19.62	231	B	09	N	1524	7.62	52.53	4	12	FRI	JAN	S	1841	8.54	56.58	4.83	16	THU	APR
05	001	SB	R	0	517	A	09	S	730	11.31	90.57	10.25	6	WED	NOV	N	680	11.09	86.08	9.54	17	WED	JAN
05	001	SB		20.57	518	A	09	S	633	8.55	54.34	4.64	12	FRI	NOV	N	658	8.89	54.29	4.83	16	MON	NOV
05	001	SB	R	23.30	286	A	07	N	973	9.39	54.57	5.12	7	WED	MAY	N	958	9.8	51.51	5.05	17	TUE	JAN
05	001	SB	R	26.69	288	A	07	N	805	10.06	56.29	5.66	7	WED	JAN	S	791	9.96	55.86	5.56	17	THU	FEB
05	001	SB	M	29.89	290	A	08	S	1211	11.61	71.53	8.3	7	THU	AUG	N	1221	11.7	71.57	8.37	16	THU	MAY
05	001	SB	M	29.89	539	B	09	N	957	11.49	60.34	6.93	7	TUE	FEB	S	733	9.33	56.95	5.31	16	FRI	AUG
05	001	SB	M	36.19	292	B	09	S	1225	10.95	81.67	8.94	6	TUE	MAR	N	1296	13.36	70.82	9.46	16	TUE	DEC
05	001	SB	R	31.04	223	A	07	S	1307	10.7	79.21	8.47	6	THU	APR	N	1301	12.26	68.8	8.44	16	WED	APR
05	001	SB		41.81	519	A	09	S	155	9.96	69.2	6.89	7	TUE	APR	N	168	10.77	69.42	7.47	15	THU	OCT
05	001	SB		49.20	128	A	08	S	281	8.63	54.35	4.69	11	SAT	OCT	S	326	10.55	51.58	5.44	17	FRI	OCT
05	001	SLO		6.35	140	B	08	N	346	9.03	57	5.15	7	TUE	OCT	S	378	9.58	58.7	5.62	15	THU	APR
05	001	SLO		15.27	142	O	08	N	605	9.95	58.45	5.81	11	SAT	JUN	S	616	10.42	56.83	5.92	16	THU	JUN
05	001	SLO		16.77	520	A	09	N	1453	8.57	59.77	5.12	12	WED	JUL	N	1565	8.72	63.28	5.52	17	THU	APR
05	001	SLO		27.88	271	A	07	S	1242	9.15	63.14	5.78	7	THU	APR	N	1420	10.38	63.62	6.6	17	TUE	APR
05	001	SLO		30.14	535	A	09	S	999	10.17	52.91	5.38	11	MON	SEP	N	1080	10.92	53.25	5.82	13	SAT	JUL

FIGURE 21 Peak Hour Volume Data Report – CA

Source: Reference (*66*).

Also available on the website is the monthly Vehicle Miles of Travel (VMT) report. The vehicle miles of travel is calculated based on a sample of 20 traffic monitoring sites comprising various roadway types. Data is reported such that when a user clicks on a month of interest for a particular year, a link is opened where the user has access to data pertaining to total vehicle miles travelled for that month and the change in miles travelled with respect to the previous month, charts illustrating percentage change in miles driven over a three year period, and computations of monthly trends.

Historical monthly VMT is also available for the state highway systems in .pdf and Excel format for several years. In addition to the general state-wide VMT monthly data, Vehicle Miles of Travel are also provided for each county in .pdf and Excel format.

6.3 Maryland State Highway Administration (MDSHA)

In order to make traffic data available to customers, MDSHA has developed a website where traffic data users have access to information on traffic trends for all ATR stations. Users can download hourly, monthly and seasonal fluctuations in traffic volumes at the individual ATR sites. Also available is traffic volume by count type which may include turning movement counts, and vehicle occupancy, by day of the week, county and route. Data on vehicle classification by functional class is also available for downloads on the site.

MDSHA has also developed an interactive GIS mapping application where live traffic conditions are reported to the general public. Some of the information provided includes incident reports, weather related closures, live traffic cameras, speed sensor data, and current dynamic signs (*67, 68, 69*).

6.4 Pennsylvania Department of Transportation

PennDOT has developed an interactive web application called the Internet Traffic Monitoring System (iTMS), through which traffic data is made available to the general public. Through this interactive system, the user can select a county, route, intersection or any area of interest and a map is generated for it. When a user clicks on any of the links in the generated map, the AADT for a specific direction, truck volumes and other information are displayed. Highway links displayed on the map are color-coded based on traffic volume, thus, each highway link depicts a range of traffic volumes but clicking on a specific location gives the actual traffic volume at that site. The figure on the following page shows the PennDOT web-based interface for data reporting. In addition to the data described above, video images at camera sites are also displayed when such sites are selected.

The PennDOT website also provides users with expansion factors and other highway statistics including mileage and travel by system, functional class, county and district; these are available in both .pdf and Excel format (*71, 72, 73).*

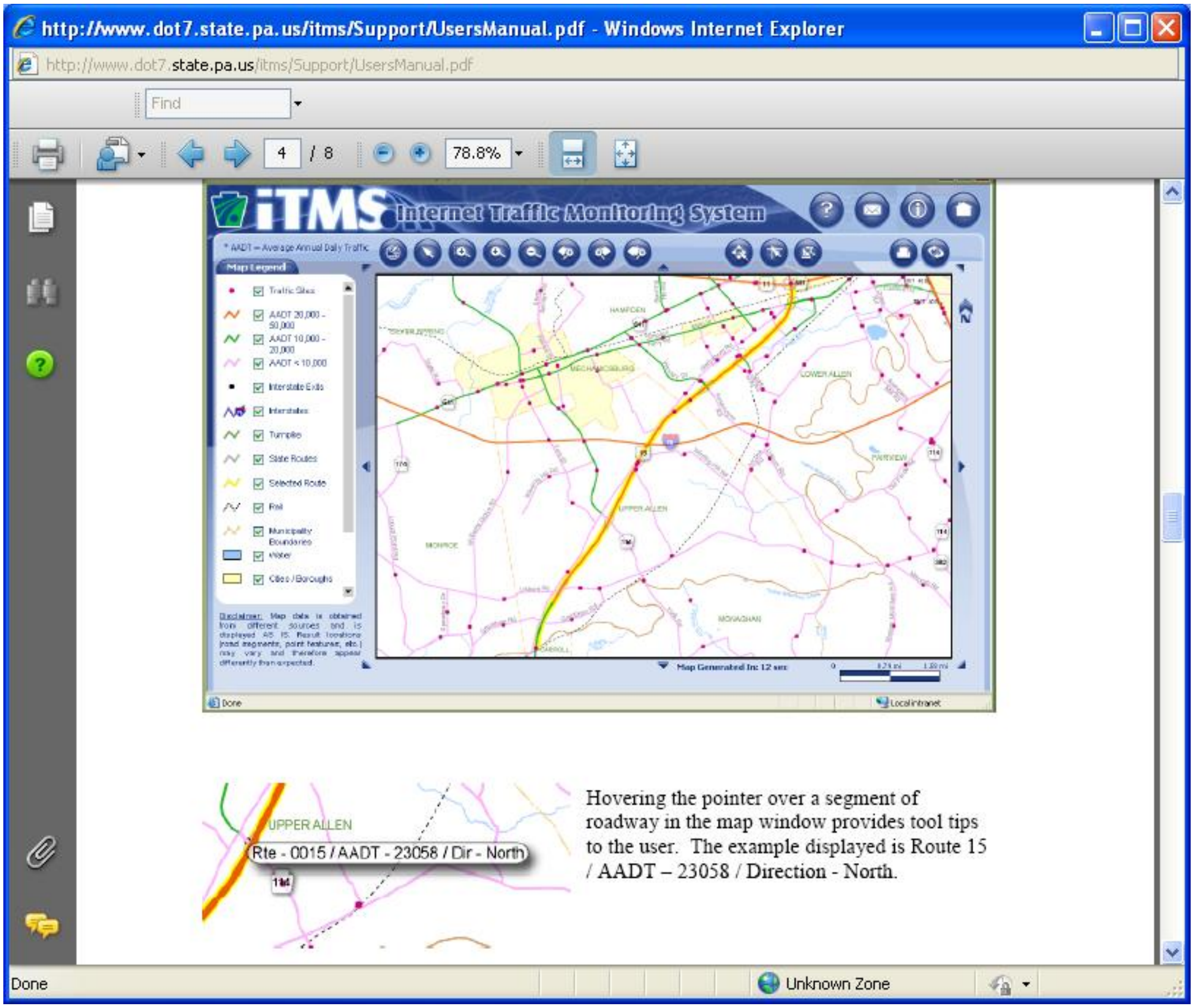


FIGURE 22 PennDOT Web Page

Source: Reference (*70*).

6.5 Virginia Department of Transportation

VDOT has also developed a website where AADT, vehicle classification, and VMT data by functional class are provided for all jurisdictions in both .pdf and Excel format. In addition, VDOT provides an interactive GIS-based map with several data layers of weigh stations, traffic conditions, park-and-ride locations, airports, and other information relevant to general public.

Like PennDOT, Virginia has also developed what they call the Virginia Road Alerts which is a web-based mapping system that provides information on incident reports, current lane closures and traffic cameras providing live video. VDOT's Archived Data Management System (ADMS) also provides real-time directional volume, speed, occupancy, and vehicle classification on freeways in both Northern Virginia and Hampton Roads. With this application, traffic data is provided at a minimum of 1-minute aggregation. Users can create temporal and spatial plots of traffic data on the website and incident data can be queried by type or duration. Other features, such as weather downloads, mobility measures of effectiveness, and HOV monitoring and evaluation are also included on the ADMS website (*74, 75*).

6.6 Florida Department of Transportation

The FDOT has developed a website where real-time count information is provided but activated only during emergencies such as hurricanes and tornadoes.

Similar to PennDOT, FDOT's website also features an interactive map which provides traffic count site locations with historical traffic count data and truck volumes. Highway links are color-coded based on traffic volumes. The website also provides a GIS-based map which provides users with AADT, truck AADT, portable count sites, weigh-in- motion sites and other related information with associated metadata *(76*).

6.7 Illinois Department of Transportation

IDOT has developed a website where AADT data is available for the state primary system. Traffic flow maps with color-coded links based on traffic volume are provided and an interactive GIS-based map is available (*77*).

6.8 Traffic Data Collection Training Programs

Human resources are a very important component of traffic monitoring programs as they are used as data collectors, inspectors, office support, and site/maintenance support. Data collection personnel must be trained to be able to detect discrepancies in the data being collected and the training should be such that the data collection personnel are able to detect the source of the error whether it is as a result of equipment malfunction, or count electronics, or from any other source. Training of personnel on the intricacies of the equipment is an essential part of ensuring quality data. When faulty data is collected, faulty data will be reported and all subsequent analyses will be inaccurate resulting in jeopardizing the whole essence of the data collection program. In addition, training of personnel is essential to the transportation program in order to keep pace with changing techniques and evaluate new procedures and developments.

To be able to make a recommendation regarding a training program for data collection personnel, a review was conducted of other states' traffic monitoring programs to ascertain their training programs. The following paragraphs discuss what selected states are doing in terms of training their data collection personnel.

6.8.1 Illinois Department of Transportation

The Illinois Department of Transportation, as part of their traffic monitoring program, has included a form of training for its district traffic staff.

IDOT has a central office equipment staff which manages all data equipment; the staff, all of whom are certified instructors for HILTI Powder Actuated Tools, provides training and certification to all district personnel in the proper operation of HILTI tools used by the department for setting counters. The equipment repair staff also provides training for IDOT district traffic staff to enable them to maintain data collection equipment. The training covers routine troubleshooting, maintenance, and light repairs. Training is also occasionally provided on programming, operation, installation, traffic equipment software, downloading procedures, and managing the data collected.

The equipment repair staff keeps their technical skills up to date by attending technical traffic meetings with other states, WIM conferences, biennial NATMEC conferences, industry and electronic workshops, and other vendor training.

In addition, the department annually holds a meeting with district traffic data collection personnel to identify problems, coordinate activities, and advance new technologies to ensure traffic data collection activities efficiently meet the department's needs. During this meeting the department distributes and discusses the annual "Traffic Data Collection Instructions" which details the roadway systems to be counted and any additional special emphasis for that year. If necessary, at that time additional training is conducted on software, equipment use, or installation procedures.

IDOT staff continues to monitor the changes in FHWA traffic requirements and "Best Practices" by other states by attending FHWA sponsored conferences on HPMS and other traffic monitoring activities (*77*).

6.8.2 Texas Department of Transportation

The Texas Department of Transportation, in its request for proposals for statewide traffic data services, requires data technicians to be qualified by the vendor. Qualified technicians are described as any individual deemed suitable by the vendor to perform data collection according to TxDOT specifications and prescribed procedures. Texas also requires vendors to test all technicians to determine if they possess the skills and abilities needed to perform the required work (80).

Some of the key requirements and tasks stated in the request for proposals for a technician include:

- The technician shall be trained and qualified by the vendor prior to beginning work.
- The technician shall wear required safety attire at all times while working outside the vehicle in the highway right-of-way.
- Technicians shall have a high school diploma, or GED equivalent.

Technician tasks should include:

- The technician shall synchronize the traffic counting equipment with the official time.

- Technicians shall observe the traffic counting equipment prior to leaving the count site per ASTM E1957, after setup is complete.

- Technicians shall update maps if actual conditions in the field differ from the TxDOT provided map. This includes, but is not limited to, on ramps and off ramps.

The training program in Texas, which may have applicability for New Mexico, addresses the following requirements and considerations:

6.8.2.1 Quantity of Training

The training program should continue a level of data collection staff training which will maintain the integrity of professional career development and the improvement of technological skills. The training should be such as will include, but not be limited to workshops, classes, and conferences. In addition, annual in-state Traffic Count Technician Training for District personnel may be included. It is recommended that data collection personnel attend training sessions organized by vendors and other conferences such as NATMEC, TMG Training, and GIS Conferences.

6.8.2.2 Interoperability

The training should foster relationships between the various data collection agencies. Training for Highway District Office Planning, MPO and other agency personnel in procedures, regulations, technical issues, etc., may also be included as necessary to provide for improved coordination and efficiency within and between the Statewide and Metropolitan planning efforts. This is very important when data collection efforts are to be coordinated among various data collection agencies. The training program should be such as will encourage employees to develop positive relationships and a sharing attitude with agencies that need data and those serving as resources.

6.8.2.3 Quality of Training

The quality of training may be enhanced by utilizing instructors from the various data collection agencies and from vendors. The training program should be geared toward technician familiarity with the equipment and troubleshooting techniques which may include training on the right type of equipment and ways of immediately identifying problems.

6.8.2.4 Resource Utilization

The training program should cover topics such as the methods available to make use of the resources available from all data collection agencies which will eventually lead to a better educational environment.

6.8.2.5 Current Trends

There should a staff member assigned training coordinator responsibilities who will research issues and techniques in data collection.

6.8.2.6 Tracking, Compliance and Information Management

The training program should include information services which will monitor the training and certification of data collection personnel. Also with a web-based interface, training schedules may be available online for easy access.

In addition, the training program should ensure the following:

- Collection personnel are trained on the importance of the traffic monitoring program. They should understand the purpose, interpretation and significance of the data they are collecting.

- Training should include the characteristics of the traffic monitoring sites such as daily variations in traffic volume and truck volume. The purpose of this is for the personnel to be able to quickly identify out-of-range data.

- A training program should make provisions for vendors to provide initial training on new equipment installation, equipment functioning, and calibration and maintenance issues.

- Training should cover topics on safety procedures and first aid techniques.

- Review training should be held annually to cover topics such as new protocols and guidelines.

6.8.2.7 Key Qualifications of Data Collection Personnel

Minimum qualifications for new data collection personnel, which already exist for current staff, should include the following:

- Data collection personnel should be computer literate.

- Data collection personnel should have as a minimum a high school diploma.

- Personnel should have a minimum of two weeks training on traffic data collection prior to starting data collection.

- Personnel should know how to drive and should possess a valid driver's license.

6.9 NHI Training Course

The National Highway Institute (NHI) offers a two day training course entitled "Application of the FHWA *Traffic Monitoring Guide*," geared toward state transportation and planning personnel working in traffic counting, vehicle classification and truck weight data programs. In addition to an overview of the TMG procedures and a discussion between producers and users of traffic data, specific topics include the use of automated procedures for data collection and analysis, a discussion of the AASHTO guidelines for traffic data collection, and the federal requirements for traffic monitoring.

Although costly ($400 per participant), the course might prove helpful to provide initial training to a supervisor who could then share with others involved in data collection and analysis in the State.

This course was held in Albuquerque in 2008; any new personnel involved in traffic monitoring should attend a subsequent offering.

CHAPTER 7: CONCLUSIONS, RECOMMENDATIONS AND IMPLEMENTATION

7.1 Introduction

This final chapter of the report summarizes the activities undertaken by the researchers regarding the main tasks of the project: a survey of traffic data collection professionals in the state to both identify current problems and describe possible opportunities and a summary of both the technical literature and the best data collection and analysis practices employed at the national level. Several conclusions associated with both data collection and analysis are presented and recommendations for improving the processes are given.

The chapter also briefly describes an implementation plan suggested by the researchers, including recommendation of a web-based application for the archiving and dissemination of traffic data (more detail is provided in a separate document), a plan for department training to improve data collection skills, and the development (in a separate submittal) of a multi-media presentation.

7.2 Survey of Current State Problems/Opportunities

New Mexico's involvement with issues associated with traffic monitoring dates to the late 1980s when the then NMSH&TD uncovered significant quality and reliability problems in its data collection and analysis processes. Rather than conducting a recount when missing or suspicious data readings were observed, for example, staff often used "engineering judgment" to replace the missing or questionable values. This revelation led to a national effort, in many ways spearheaded by New Mexico, to standardize data collection processes and improve data quality.

Since that time, the state has continued to make progress in its traffic monitoring activities and, in most instances, its documents appear to be in compliance with both Federal requirements and the several published national guidelines and standards. That is not to say, however, that areas of concern have not been identified through interactions with traffic data specialists in the state. Like many public enterprises nationwide, the department's traffic monitoring program is in need of additional funding to acquire both additional staff to oversee program activities and to conduct additional counts as well as to purchase additional and upgraded equipment. Funding is particularly important for the weigh-in-motion program not only to purchase up-to-date equipment, but also to more frequently perform equipment calibration, whether by department staff, contractors, or both.

The traffic data needs associated with new pavement design procedures as well as the possibility of additional data requirements related to the speed and vehicle occupancy data, also point to the importance of collecting timely and accurate data.

Interviews with department staff and others also pointed out the need to address additional data requirements. District personnel, in particular, expressed a need to collect, and, equally importantly, store, intersection turning movement counts and other manually collected data. Archiving of these data, which are typically collected as part of a traffic impact study, are also critical for other engineering applications.

7.3 Summary of the Literature and National Best Practices

New Mexico primarily uses inductive loops and piezoelectric sensors for its volume and speed counts. Loops have been identified in the literature as the most common method of volume data collection at permanent sites and have also been reported as the most accurate sensor for volume counts. As a result, they have been used for the establishment of baseline data in many national studies. Loop placement is essential, however, with loops installed at a suitable depth with a grout that breaks rather than one that pulls out in order to hold in place during milling. Some piezo-based sensors are sensitive to temperature.

Because of safety and other concerns relating to loop installation and maintenance, however, loops may not be suitable at many high volume, high speed areas or at those locations with limited sight distance. As a result, recent research has focused on the suitability of non-intrusive sensors to collect both count and speed data, particularly in urban areas.

A review of the different non-intrusive technologies reveals that equipment based on microwave has the advantage of being insensitive to inclement weather, has direct measurement of speeds and can have multiple lane operation. The disadvantage reported is, in some cases, an inability to detect stopped vehicles and poor performance at intersection locations. Research conducted into evaluating non-intrusive sensors for their reliability in traffic data monitoring reported the accuracy for equipment based on microwave technology ranged between 2%-13.8% for volume counts and from between 1%-7.9% for speed data. Sensor to sensor variation within a given technology is more prominent.

For reliable traffic counts using non-intrusive methods, it is essential that equipment be installed at the manufacturer’s recommended height, angle and distance from the edge of the roadway. It is thus critical that the manufacturer install the equipment. An onsite inspection performed with the vendor to ensure equipment is installed properly and at the correct locations is essential. This practice should also be followed by any other agencies providing the NMDOT with data.

National reviews of WIM performance and reliability indicate that load cells are the most accurate and also the most initially expensive weigh scale reported by all vendors and traffic data collection agencies. As indicated in the literature, the more accurate the weight data the more expensive the initial cost. Less initially costly alternatives that have performed adequately include bending plate scales and kistler lineas quartz. Life-cycle costs of these alternatives compare favorably with the less accurate piezoelectric alternatives. All technologies require lane closure for installation and maintenance. Pavement strength and sensor location and placement are also critical.

Since New Mexico is shifting from the old AASHTO method of pavement design to the MEPDG, it will be most appropriate to invest in a sensor that will give relatively reliable data under suitable conditions and proper installation practices.

7.4 Recommendations

7.4.1 Introduction

Based on input from the professional community in New Mexico as well as a thorough review of both the technical literature and national best practices, the following recommendations can be made:

7.4.2 Volume Counts

1. The TMG states that traffic data be collected at an hourly rate as a minimum by direction and lane for traffic analysis requiring operational characteristics of the roadway at the different times of the day. A review of summary data from the NMDOT ATR sites reveals that traffic counts are combined for both directions per lane. This combined volume may not provide the distribution needed by forecasters and roadway designers. It is recommended that data be separated into direction per lane to provide data for operational analysis purposes.

2. Continue to follow AASHTO's method for calculating AADT from ATR sites as recommended in the TMG. This procedure provides a consistent method for computing AADT even when a significant portion of a month's data is missing without losing the effects of seasonal and day-of-week effects. AASHTO's recommended procedure for computing AADT is as follows:

   Compute the average day-of-week volumes by month,

   Average day-of-week volumes to create annual day-of-week volumes,

   Average seven volumes to compute AADT.

3. Make more effective use of existing equipment for conducting coverage counts. Since the department apparently has approximately 30 portable counters that are not being used due to staff shortages, the options are:

   a. Bring on additional staff (3 field personnel and 2 office staff for count program),

   b. Hire contract personnel to perform the data collection (several states have indicated using SPR funds for this activity),

   c. Hire university students to collect additional short-term counts (much like the pavement evaluation program previously funded by the department).

4. Investigate the use of non-intrusive methods, particularly microwave radar and infra-red technologies, to collect data in certain high-risk, (high traffic, high speed) areas. Specifically, the Infra-Red Traffic Logger (TIRTL) and the Wavetronix SmartSensor have performed well in recent national studies. Coordinate with the NMDOT ITS Bureau

for sensor locations and data collection capabilities at its Traffic Management Center in Albuquerque.

5. Develop a standard protocol for collecting and archiving intersection turning movement counts, traditionally collected by NMDOT districts or by consultants. Video technology, such as the Miovision system, is available to do this, although even a standard procedure for using Jamar or other manual counters would be helpful. Coordinate activities at the districts with a central repository, perhaps in TIMS with a manual backup at the General Office.

6. Quality control for volume and classification data may be improved through selective use of video data, such as the system mentioned in 5 above. These procedures should be considered to verify the data collected at both permanent and short term count locations. The pause, rewind and replay capabilities of the video will allow accurate count and classification information to be obtained. Keep in mind, however, that while improved quality control may be achieved at the operational level, quality assurance is achieved only through the efforts of the entire agency – from data collection to analysis to storage to reporting.

7. The department should develop a plan for collecting and archiving vehicle occupancy data as required by 23CFR 500.204. Issues regarding collection, use and archiving of speed data should also be investigated.

7.4.3 Weigh-In-Motion

1. The WIM network should be expanded by 21 new sites; locations are described in the Implementation Plan.

2. Three new WIM technicians should be hired.

3. If available funding exists, load cell technology should be installed at the new WIM sites. If cost and lane closure issues become paramount, lower cost options such as bending plate scales and kistler lineas quartz should be considered. Level and straight segments with pavement in good condition should be chosen for the locations of the new sites.

4. The current 12 piezoelectric sensor locations should be replaced by the above technologies as they become obsolete.

5. Calibration must be performed twice a year at all WIM sites in order to ensure reliable and consistent data. Both contractor and NMDOT personnel should perform the calibration following ASTM Standard E1318-09. Successful calibration should be archived; videotaping of both calibration and installation activities should be considered.

6. WIM data should be retrieved daily, or, at the very least, collected on a weekly basis. Routine quality control should be applied to the data and any anomalies should be flagged and investigated by a field technician.

7. Classification and weight data must be stored in C-files and W-files, respectively, according to the standard data formats recommended in Section 6 of the *Traffic Monitoring Guide*. This will allow compatibility with the applications for analysis of the WIM data and the development of traffic inputs for MEPDG.

8. The Pavement Design Division and the WIM Data Collection Unit should work coordinately to make possible the successful implementation of MEPDG. The subroutines developed as part of this project should be applied to reliable WIM data for obtaining traffic inputs required for MEPDG.

9. PrepME, developed at the University of Arkansas, can be used for WIM data quality control and MEPDG traffic input files if it becomes compatible with NMDOT weigh-in-motion data.

10. The NMDOT should investigate interacting with the New Mexico Department of Public Safety (NMDPS) which is responsible for commercial vehicle enforcement operations in the state. NMDPS maintains the state's ports-of-entry and operates the Smart Roadside program employing imaging systems for automatic USDOT number and license plate recognition.

7.4.4 Web-Based Data Management System

Based on the review of other states' website reporting systems, an NMDOT website for data reporting should consist of the following:

7.4.4.1 Reporting Module

The website should feature a reporting module with traffic reports provided in .pdf, Excel, or, in some cases, Word format. The module should contain the following:

- AADT for both overall traffic and truck volume. The truck volume should be reported as a percentage of the total traffic volume and should be further broken down by percent in various vehicle classifications.

- Traffic trend reports, including information on hourly, monthly and seasonal fluctuations in traffic for individual sites.

- Volume counts by type (for example, turning movement counts, vehicle occupancy, etc.), day of week, county, and route.

- Vehicle classification by functional class and annual highway mileage.

- Vehicle Miles of Travel including information on travel by vehicle classification and functional class.

- Information on expansion factors, and growth factors should also be provided.

In addition to .pdf and Word formats, charts should also be provided, especially for trend data. With graphics, users can easily visualize the trends. The example below (*67*) shows a figure from the Maryland Department of Transportation's reporting module.

7.4.4.2 GIS-based Module

The website should feature an interactive GIS-based module will allow users to request counts by day of week, time of day, and by location, county, district, route and functional classification. GIS-based maps should consist of several layers including non-traffic information such as the location of weigh stations and park-and-ride lots, as well as other information that may be deemed necessary for the user.

Highway links provided on the map should be color-coded based on traffic volume. Information on ADT, truck volumes and other relevant information should be displayed when the links are clicked. Applying GIS in traffic data monitoring can also be useful for scheduling traffic counts. To optimize count schedules, count locations can be mapped and grouped by geography, roadway route, and by time of year.

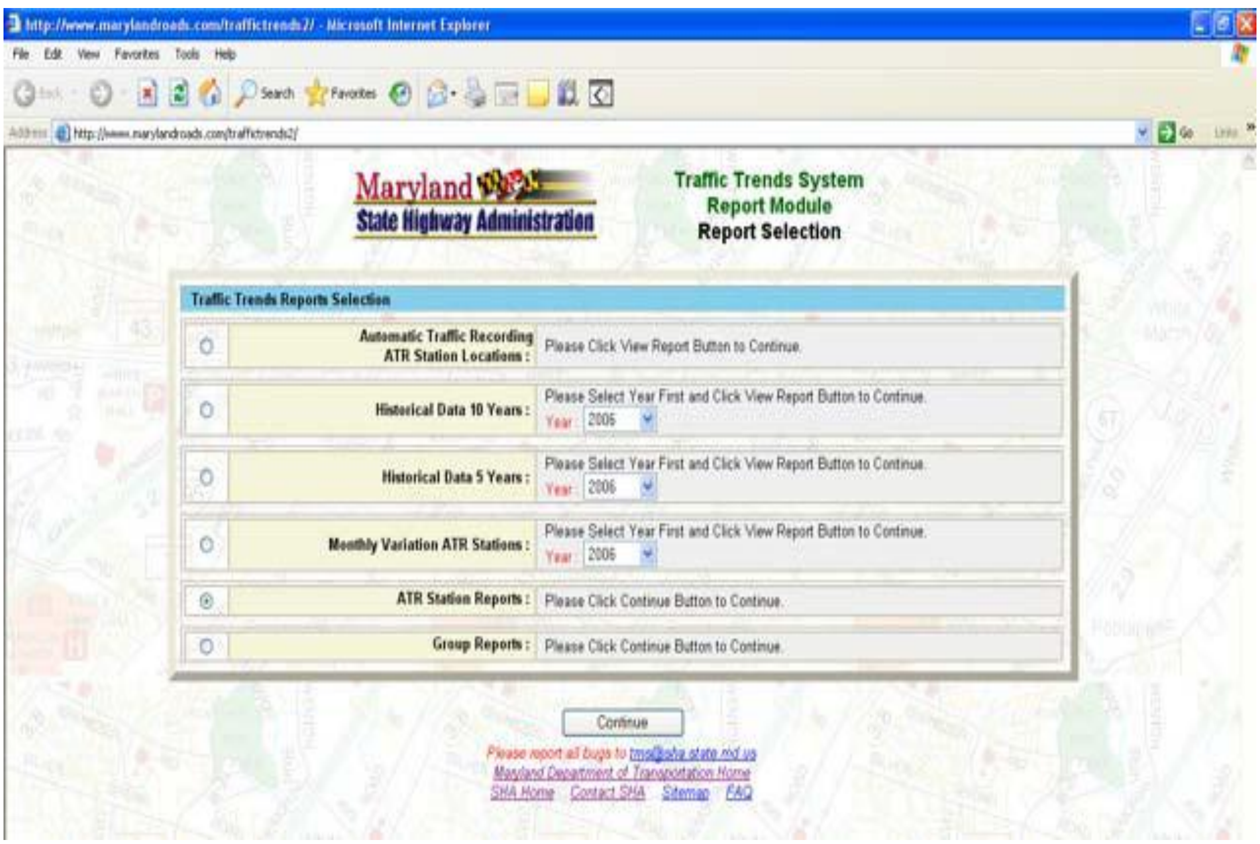


FIGURE 23 Traffic Trends System Report Module (MDSHA)

7.4.5 Staffing

The NMDOT currently has seven staff involved in data collection; more people are needed. An online survey carried out by the Colorado Department of Transportation indicated that many states have at least ten positions devoted to traffic data collection activities.

To maintain timely and reliable traffic monitoring procedures, it is recommended that the NMDOT increase its current data collection staff to at least ten. The staffing situation in the WIM data collection unit is the most critical; it consists of only one office analyst and one field technician. With more sites and significantly more calibrations to perform, the size of this staff should increase by three positions.

If contractor staff are to be employed, it is suggested that they may be best utilized for conducting short-term (coverage) counts throughout the state.

7.4.6 Training

Training for staff involved in traffic data collection, analysis and storage is essential in order to be familiar with current techniques and requirements as well as to be able to evaluate changes in both technology and policy. The following recommendations can be made regarding training:

1. Plans should be made for selected department staff to attend the NATMEC 2012 Conference, sponsored by the Transportation Research Board, on "Improving Traffic Data Collection Analysis, and Use" to be held June 4-7, 2012 in Dallas, TX. The "International Conference on Weigh-in-Motion (ICWIM)" will be held in conjunction with NATMEC. Limited travel support is available for state, MPO, and local government participants.

2. The department should consider enrolling appropriate staff in the National Highway Institute (NHI) two-day course entitled "Application of the FHWA *Traffic Monitoring Guide*. If sufficient enrollment is guaranteed, perhaps with the addition of MPO and others involved in traffic monitoring, the course could be held in-house. While this course was held in Albuquerque in 2008, new/reassigned staff will benefit from attendance.

3. Annual training of all department staff should be held to discuss problems, coordinate programs, and evaluate new technologies. Any new employees should receive additional training at this time. Training facilities such as the NMDOT-supported Associated Contractors of New Mexico (ACNM) location in Albuquerque, could be utilized and a formal certification program similar to the existing Traffic Technician Certification Program (TTCP) could be established.

7.5 Implementation Plan

Increased funding is necessary for any of the above recommendations to be implemented. Funds will be necessary to hire additional staff, purchase new and upgraded equipment and support any contractor data collection activities. Appropriate department personnel involved in the traffic monitoring process must approach senior management with an enhancement plan for the program, including a timeline and the anticipated cost for implementation. A detailed implementation plan, including estimated costs, is contained in a separate document.

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71. Pennsylvania Department of Transportation: www.dot7.state.pa.us/itms/default.asp.

72. Pennsylvania Department of Transportation: http://www.dot.state.pa.us/Internet/Bureaus/pdPlanRes.nsf/infoBPRHighwayStats2010Rpt.

73. Pennsylvania Department of Transportation: Planning and Research Bureau: www.dot.state.pa.us/Internet/Bureaus/pdPlanRes.nsf/PlanningAndResearchHomepage.

74. Virginia Department of Transportation: AADT and VMT Reports, current and historical: www.virginiadot.org/info/ct-TrafficCounts.asp.

75. Virginia Department of Transportation, GIS Map with a Traffic Data Layer: www.virginiadot.org/projects/prOTIM.asp.

76. Florida Department of Transportation: http://www.dot.state.fl.us/planning/statistics/trafficdata/.

77. Illinois Traffic Monitoring Program, Office of Planning and Programming, November 2004.

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79. Wang, K. and Hall, K., "Database Support for the New Mechanistic-Empirical Pavement Design Guide (MEPDG)," Research Project TRC-0702, Arkansas State Highway and Transportation Department (AHTD), Little Rock, Arkansas, 2009.

80. General Services Division, Texas Department of Transportation, TxDOT 968-85-74, October, 2010.

APPENDIX 1: SURVEY FORMS AND CONTACT LIST

A(1)
Statewide Traffic Data

Interview with: ____________________ **Date: __________**

Organization: _____________________

1. Do you or your office collect traffic data?

2. If so, what types of data do you collect?

   a. Why do you collect these data?

   b. How are the data processed?

   c. Who is the data reported to?

3. Has your office prepared a document(s) describing traffic data collection, policies, or practices?

4. Do you use documents on traffic data collection, policies, or practices that were prepared by others either inside or outside the department?

5. Do you or others in your office use traffic data?

6. If so, what types of data do you use? For what purposes do you use the data?

7. How do you access the data you need? What is the format and how is it stored?

8. Based on your experience and considering the data you use and/or collect, how would you characterize their:

Completeness

Reliability

Accuracy

Timeliness

9. Do you have additional current or projected data needs that are not currently being met?

Please return to Jim Brogan, Department of Civil Engineering, UNM, Albuquerque, NM 87131, (505) 277-1314 (voice), (505) 277-1988 (FAX), jbrogan@unm.edu.

A(2)
Statewide Traffic Data
Contacts for Tasks 1 and 2

Abbo, Tony	NMDOT D3	505-841-2761	Interviewed 8/19
Abeyta, Antonio	NMDOT	505-827-5543	Interviewed 8/17
Barricklow, Paul	Lee Engr.	505-338-0988	Form Received 9/29
DiRuggiero, John	NMDOT-ITS	john.diruggiero	Form given 9/22 – CALL
Garcia, Ruben	NMDOT D5	505-476-4223	Covered by Mobarek
Gardner, Mark	Fugro	?	Form Received 9/29
Hinojas, Maria	NMDOT D1	575-544-6544	Form Received 9/23
Julian, Brad	NMDOT	505-827-3263	Interviewed 8/19
Kahn, Leroy	NMDOT	?	Database Maint.
Laranaga, Billy	NMDOT	505-827-5380	Interviewed 8/17
Mann, Jeff	NMDOT	505-827-3245	Rafi Interview 8/26
McClenenan, Josh	NMDOT	?	Interviewed 8/17
McCoy, Robert	NMDOT	505-827-5648	Rafi to Call
Mobarek, Richard	NMDOT D5	?	Interviewed 8/19
Oliver-Wright, Pat	NMDOT	505-827-5562	Interviewed 8/17
Pena, Elizer	NMDOT	505-827-5529	Form Received 9/23
Perea, Nancy	NMDOT	505-841-2729	Interviewed 8/19
Remkes, Charles	NMDOT-ITS	Charles.remkes	Form Received 9/29
Romero, Adam	NMDOT D4	454-3600	Interviewed 8/19
Romero, Ron	NMDOT D6	285-3220	Invited 8/19 – CALL
Smith, Earl	NMDOT D2	575-637-7229	Form sent 9/23 – CALL
Von Stein, Steve	FHWA	505-820-2028	Form Received 9/30
Steffin, Paul	PB	505-878-6554	Form Received 9/28
Webster, Eric	MRCOG	505-724-3602	Form Received 9/23
Wilkinson, L. J.	TRADAS	?	Form Received 9/28
Wrage, Eric	BHI	505-823-1000	Form Received, 9/24
Castle, Stuart	NMDOH/EMS	?	Form Received 9/22
Escudero, Edward	NMDOT	505-827-5463	Form Received 9/22
Roybal, Robert	WH Pacific	505-247-0294	Form Received 9/28

A(3)
SURVEY IN TRAFFIC MONITORING AND COLLECTION OF DATA

This appendix contains the answers to the survey in regarding traffic monitoring and collection of data that was addressed to the technical panel during the last quarter. A table including the answers of the four responses received is presented, including conclusions. The results are then compared to results from Reference (*25*). The questions addressed to both groups were as follows:

KEY ISSUES

1. What problems in traffic monitoring and collection of data are you facing?
    a. Are there problems with politics?
    b. Is there lack of funds?
    c. Is there lack of personnel?
    d. Is there a problem with the training of staff?
    e. Are there problems with the equipment (sensors failing, ...)?
    f. Does WIM program meet MEPDG needs?
    g. Do you partner with MPOs to collect traffic data?
    h. Do you have any web-based traffic monitoring system where people can access to traffic data of state roads?
    i. Do you outsource or procure part of the traffic data collection duty?
    j. Other problems?
    k.

USING TRAFFIC DATA

2. List the main users of your traffic data product.
    a. Divisions of NMDOT (Planning, Design, Materials, Environmental, Districts, ...)?
    b. FHWA?
    c. Metropolitan Planning Organizations (MPOs)?
    d. Other state government agencies (police, tourism, ...)?
    e. County, city, and town governments?
    f. Consultants and engineering firms?
    g. Developers and realtors?
    h. Citizens?

3. Do their application support NMDOT's main goals? Which users? How?
    a. Better and most efficient design of roads?
    b. Funding allocation?
    c. Safety (fatality rates, seatbelt use rates, ...)?
    d. Congestion management?

4. Which particular data requires improvement in amount and quality (volume, classification, weight, ...)?

COLLECTION INVENTORY

5. How many volume count sites do you have?
    a. Continuous?

6. How many coverage count sites do you have?
    a. How are they distributed according to the duration?
    b. How are they distributed according to the frequency?
    c. How are they distributed according to the functional roadway classification?

7. How many classification sites do you have?

8. How many weigh-in-motion sites do you have?
    a. Do other agencies operate WIM sites? Do you share data with them?

9. Do you have any other continuous traffic monitoring sites?

10. What other traffic data do you collect?
    a. Turning movements?
    b. Speed, delay, travel time?
    c. Vehicle occupancy?
    d. Level of service?
    e. Other data?

TRAFFIC DATA COLLECTION

11. Does NMDOT have contracts with consultants for traffic data collection?
    a. For collecting which traffic data?

12. Does NMDOT share and use traffic data from MPOs and other agencies?
    a. Which agencies or organizations?

13. How do you market your traffic data and satisfy your customers?
    a. Traffic data available on website?
    b. Internet traffic monitoring system online?
    c. Do you market traffic data products to the public and within NMDOT?
    d. Do you make publications with traffic data available to purchase?
    e. Is there any traffic database for internal users?
    f. Do you make traffic data available as a GIS layer?

14. What new traffic data initiatives are you working on?
    a. Are you testing nonintrusive traffic monitoring devices?
    b. Radar detection system?
    c. Laser detection system?
    d. Acoustic detection system?
    e. Video detection system?

f. Infrared detection system?
g. Microwave detection system?
h. Are you expanding your continuous traffic data collection effort?

15. What technologies do you use to collect classification data?
    a. Inductive loops?

16. What technologies do you use to collect weight data?
    a. Piezo sensors?
    b. Bending plates?
    c. Load cells?

17. Do you use in-house or outsourced software to process your traffic data?
    a. Which software did you develop? For what purpose?
    b. Did you have consultants to develop any software? For what purpose?
    c. Did you purchase any software? For what purpose? Do you use their support?

18. What equipment maintenance and calibration procedures do you have in place?
    a. Do you use in-house staff or manufacturer technical support or both to meet maintenance and calibration needs?
    b. Do you have a maintenance and calibration contract with the manufacturer?
    c. Do you schedule regular calibration for each equipment? Quarterly? Semiannually?
    d. Do you keep record of the historical calibration of each WIM site?
    e. Do you follow the ASTM standard E1318-92 for calibration of WIM systems?
    f. Which test truck do you use for calibration? Who provides it, you or contractor?
    g. How many passes does the reference truck make during calibration?
    h. At which different speeds?
    i. What is the specified tolerance for calibration test (difference between measured and actual GVW)? ± 15%?
    j. What is the maximum number of measures allowed to exceed the tolerance? 15%?
    k. For the classification system of the WIM site, do you compare the classification recorded with a manual classification? For how long, 15 min?
    l. What is the allowed tolerance for successful calibration of the classifier? ± 5%?
    m. How often do you check air leaks in road tube counters? Twice a year?

19. How often do you download and review traffic data from continuous monitoring sites? Daily?Weekly?

20. Do you apply automated quality control checks to all collected traffic data?

21. Do you investigate in more depth flagged data?

22. If the problem cannot be solved, do you send a technician to the site?

23. Do you assign a quality code to all data?

24. Are the collected traffic data compared to historical archived data? How often?

25. When a large difference or variation is noticed, do you make an investigation?

26. Is the installation of sensors videotaped and photographed to report proper installation procedures?

27. Do you use loop logic in WIM sites to predict piezo failure?

STAFFING AND ORGANIZATIONAL

28. In which area/division of NMDOT is traffic monitoring and collection located?
    a. Planning? Traffic? Research? Other?

29. Do you operate your traffic data collection program from a centralized or decentralized location? What do you think would be best?

30. How many people make up the traffic monitoring section?
    a. Office analysts versus field technicians?
    b. Do they work together as a team in a centralized location?
    c. Do you have any part time field technician and data analyst?
    d. Do you fund any positions assigned to the districts to collect data for NMDOT?

31. Do you outsource any of your data collection-analysis tasks?
    a. Which kind of data? And which analyses?

32. Is funding the problem that keeps you from maintaining a good traffic monitoring program? If so, please explain.
33. Is upper management aware of the importance of collecting good quality traffic data?
    a. Do they realize that quality of data affects all projects and products generated by NMDOT?

The results of the survey in New Mexico are shown in the following table which contains the answers of the four responses received.

TABLE A(1) New Mexico Responses to Reference (25) Questions

QUESTION #	RESPONSE #1	RESPONSE #2	RESPONSE #3	RESPONSE #4
1	Meet HPMS, TMS/H, TMG, and AASHTO	Money	-	-
1.a	Don't know	Yes	Yes	No
1.b	Yes	Yes	Always	Always
1.c	Yes	Yes	Yes, in collection and IT	Yes, in all divisions
1.d	Probably	Yes	Training is available	Yes
1.e	Definitely	Yes	Yes, lack of calibration	No in ITS
1.f	Need Axle Load Spectra and more extensive	No	Not enough WIM sites	-
1.g	Yes	Not for WIM	Yes	Yes
1.h	No	No	Only static annual reports	Yes
1.i	-	No	One MPO	Yes
1.j	-	-	Funding	Disparities between geospatial layers and naming conventions
2	-	NMDOT, TIMS	Everyone below	-
2.a	Planning, Pavement	Yes	-	Available to everyone
2.b	HPMS, TMS/H	Yes	-	Yes
2.c	-	No	-	Yes
2.d	Motor Transportation Division	No	-	Motor Transportation Division
2.e	-	No	-	No
2.f	-	No	-	No
2.g	-	No	-	No
2.h	-	No	-	No
3	-	No	Yes MPO collects data for NMDOT	Yes
3.a	-	-	-	-
3.b	Yes	-	-	-
3.c	-	-	-	-
3.d	-	-	-	Yes
4	-	-	All types in	Volume, speed

			amount	and occupancy
5	-	17	15064	40
5.a	-	17	120	Yes
6	-	-	15064	-
6.a	-	-	48 hours short term counts	-
6.b	-	-	-	-
6.c	-	-	-	-
7	-	None	37 permanent, 1142 short term	-
8	14	17	17	-
8.a	-	No	No	No
9	Yes, ATRs	No	No	No
10	-	-	-	Volume, speed and occupancy
10.a	-	-	No	No
10.b	-	-	No	Yes
10.c	-	-	No	Yes
10.d	-	-	No	Yes
10.e	-	-	-	No
11	-	-	No, but one MPO does	Yes
11.a	-	-	Short term	-
12	Yes	-	Yes	Yes
12.a	MPOs	-	MPOs	MRCOG
13	-	-	-	-
13.a	-	No	Annual Reports	Yes
13.b	-	No	No	No
13.c	-	No	No	No
13.d	-	No	No	No
13.e	-	No	Stored in TIMS	Yes, via web
13.f	-	-	Yes	No
14	-	None	-	No
14.a	-	No	-	No
14.b	-	No	-	No
14.c	-	No	-	No
14.d	-	No	-	No
14.e	-	No	-	No
14.f	-	No	-	No
14.g	-	No	Yes	Yes
14.h	-	No	Not much	Yes
15	-	-	-	-
15.a	Yes	Yes	Yes	-
16	-	-	-	-
16.a	Yes, other than	Yes	Yes	-

	US-550			
16.b	Yes, at US-550	Yes	Yes	-
16.c	No	No	No	-
17	Tradas	In-house	Yes	Outsourced
17.a	-	-	Tradas	Didn't develop
17.b	-	-	Chaparral created Tradas	COTS, My Sequal
17.c	-	-	Yes, purchase Tradas	No
18	-	Once a year, US-550 twice a year	-	Internal staff, contractor
18.a	-	Both	-	Both
18.b	-	Yes	-	No
18.c	No	Annually and semiannually	-	As needed
18.d	-	Yes	-	-
18.e	-	Yes	-	-
18.f	-	Class 9 loaded between 75-80 k	-	-
18.g	-	10 good passes in a row	-	-
18.h	-	Speed limit, in US-550 50, 60, 70	-	-
18.i	-	15%, 10% in US-550	-	-
18.j	-	15%	-	-
18.k	-	-	-	-
18.l	-	+/- 10%	-	-
18.m	-	-	-	-
19	-	Weekly	Daily	Collected in real time, updated every minute
20	-	No	Yes	Scrubbed for outliers
21	-	Yes	Yes	Data Manager
22	-	Yes	Yes	Yes
23	-	No	No	No
24	-	-	Yes, per count	No in ITS
25	-	Yes	Purged and recounted	An informal one
26	-	No	No	No
27	-	No	-	-
28	-	Planning	-	-
28.a	Planning Division	-	Planning	Planning

29	-	Centralized	Centralized	Central web-based server
30	-	2 in WIM	-	-
30.a	-	2 in WIM field and office	3 to 7	-
30.b	-	Yes	Yes	-
30.c	-	No	No	-
30.d	-	No	No	-
31	-	Installation of sites and repair	No	Yes
31.a	-	-	-	Speeds, travel times and congestion maps
32	-	Funding is every 2 years not possible annually	Not enough money	Funding and resources, but ITS works fine
33	-	-	-	-
33.a	-	-	Upper Management is aware	-

Conclusions

- The main concerns of NMDOT in traffic monitoring and collection of data are:
  - The lack of funds for maintenance and calibration,
  - Not enough staff,
  - The staff needs more training,
  - In some cases, equipment is obsolete and inappropriate.
- Goals to achieve:
  - Weigh-in-motion program must meet the MEPDG requirements,
  - Web-based traffic monitoring system accessible to the general public.
- Main users of NMDOT traffic data are:
  - Divisions of NMDOT: Planning, Design, Materials, Environmental,
  - FHWA, HPMS, and TMS/H,
  - Metropolitan Planning Organizations (MPOs),
  - Other state government agencies such as Motor Transportation Division.
- Applications should support NMDOT's main goals through better and most efficient design of roads, increase in safety and decrease in fatality rates, better congestion management and fairer funding allocation.
- Classification and weigh-in-motion data being collected require significant improvements in both quality and amount.

- NMDOT has 120 continuous volume count sites, 15064 short-term volume count sites, 37 permanent classification sites, 1142 short-term classification sites, and 14 weigh-in-motion sites.

- NMDOT does not collect other data such as turning movements, delay, vehicle occupancy, and level of service.

- NMDOT does not contract with external consultants for traffic data collection.

- NMDOT shares their traffic data with MPOs and also use traffic data from MPOs.

- NMDOT makes only traffic volume data available in reports and GIS layers on a website.

- NMDOT does not market their traffic data products to the general public.

- NMDOT is not testing new technologies for traffic monitoring such as radar detection, laser detection, acoustic detection, video detection, infrared detection, and microwave detection.

- NMDOT uses inductive loops to collect classification data, and piezo sensors and bending plates to collect weigh-in-motion data.

- NMDOT purchased Tradas software that was developed by Chaparral Systems for processing volume counts.
- NMDOT uses both in-house staff and manufacturer technical support for maintenance and calibration of WIM sites. Equipment on US-550 is calibrated semiannually, and other equipment annually. The staff keeps records of the historical calibration. ASTM standard E1318-92 for calibration of WIM systems is followed. During calibration, a class 9 truck loaded between 75,000 and 80,000 lbs. has to make 10 good passes in a row at the posted speed limit and also at 50, 60, and 70 mph. The tolerance specified in the calibration test (difference between measured and actual GVW) is 10% for US-550 and 15% for other sites. The maximum number of measures allowed to exceed the tolerance is 15%.

- Quality control checks are applied to volume data, but not to weigh-in-motion data. Similarly, the collected data is compared to the historical archives for volume but not for weight. If there is a problem, a technician is sent to the site. Quality codes are not assigned.

- The installation of sensors is not videotaped or photographed to ensure that a proper procedure was used.

- WIM systems do not use loop logic to predict failure of piezo sensors.

- Traffic monitoring and collection of data are located in the Planning Division of NMDOT, operating from a centralized location. For monitoring and collection of volume data there are from 3 to 7 people, and for weigh-in-motion data there are 2 people. There is no part-time field technician and data analyst, nor positions assigned to the districts.

- Installation and repair of WIM sites is outsourced, also collection of speeds, travel times and congestion maps.

- Lack of funding is the main problem for having a good traffic monitoring program.

- Upper management realizes that quality of data affects all projects and products generated by NMDOT.

These conclusions can be compared to the results obtained from the DOTs of Delaware, District of Columbia, Maryland, Pennsylvania, and Virginia and reported in Reference (*26*):

KEY ISSUES

- What burning issues are you facing?

The main problems related to traffic monitoring that departments of transportation are dealing with are: politics, lack of funds, lack of personnel, training of staff, the need of axle sensors with longer life (constantly replacing failing piezo sensors), and the incorporation of ITS data into traffic monitoring programs.

- Do you have any successes that you could share with others?

These DOTs were very satisfied with the following achievements:

  - Partnering with our MPOs to collect traffic data.
  - The creation of Internet Traffic Monitoring Systems (iTMS) which allow anyone with internet access to look up traffic counts on state-owned roads and local roads.
  - Web-based systems (iTDUS) for planning partners to process traffic counts.
  - Statewide Traffic Count Services contract which allows PennDOT and planning partners to procure traffic counting services from vendors.

USING TRAFFIC DATA

- List the main users of your traffic data products

  - Several Divisions of the Department of Transportation
    - Planning
    - Design
    - Environmental

    - Materials
    - Data quality control
    - The districts in the field
  - Other state government agencies (state police, tourism, etc.)
  - Federal Highway Administration (FHWA)
  - Metropolitan Planning Organizations (MPOs)
  - County, city, and town governments
  - Consultants, engineering and consulting firms
  - Developers, realtors, business owners, and entrepreneurs
  - Private citizens

- How do their applications support the department's main goals?

  - The Bureau of Design uses traffic data for design of new roads and redesign of existing roads.
  - The Bureau of Maintenance and Operations uses traffic data in its maintenance funds allocation formula.
  - The Bureau of Highway Safety and Traffic Engineering uses traffic data to calculate the state's fatality rate, seatbelt use rate, and roadway capacity.
  - Traffic data is required for submission of the state's yearly HPMS to FHWA.
  - FHWA uses the traffic data reported in HPMS for the National Highway System maintenance, and surface transportation program funding formulas.
  - Pavement management
  - Congestion management

- What improvements do primary users want to see in the amount or quality of the data they receive?

  - More data, higher quality, consistency, timeliness, and continuity.
  - More vehicle weight and classification data.

COLLECTION INVENTORY

- How many continuous traffic monitoring sites do you have?

Pennsylvania, Maryland, and Delaware have around 80 continuous traffic monitoring sites. Virginia has significantly more, 318 stations. The District of Columbia has fewer than 20.

- How many coverage count sites do you have?

Delaware has 800. The District of Columbia has 1,800. Maryland has 3,737 on a 3-year cycle, and Pennsylvania operates 32,500. The Virginia Department of Transportation operates the following coverage count sites:

  - 17,000 48-h counts on the higher functionally classified roadways collected on a 3-year cycle (about 5,600 annually)
  - 11,270 24-h counts on the local road network collected on a 3-year cycle (mostly urban samples and unpaved roads)

- 75,750 24-h counts on the local road network collected on a 6-year cycle
- 2,500, 24-h counts on the local road network collected on a 12-year cycle

- How many vehicle classification sites do you have?

Delaware has 23. The District of Columbia has 3 WIM sites. Maryland has 17 ATRs and 1,640 portable vehicle classification sites. Pennsylvania has 5.
The Virginia Department of Transportation collects classification data as follows:

- 300 of continuous-count locations provide vehicle classification data.
- 6,200 of 3-year cycle 48-h counts provide vehicle classification data.

- How many WIM sites do you have?

Delaware has 23. Maryland has 6 but only one is currently collecting data. Pennsylvania has 13. Virginia has 6 and a data sharing agreement with the state Department of Motor Vehicles, therefore they use the information collected from their three stations.

- What other traffic data do you collect?

  - Speed
  - Turning movements
  - Delay
  - Travel time
  - Vehicle occupancy counts
  - Level of service
  - Pedestrians
  - License plate surveys

COLLECTING TRAFFIC DATA

- Does your state use consultants for traffic data collection?

In Delaware, the vendor provides coverage counts, and they have a consultant for special project counts such as turning movements or intersection counts. Both Maryland and the District of Columbia have active contracts to collect traffic data. Pennsylvania and Virginia use three consultants for their continuous and short-term traffic programs.

- Do you share and use traffic data from/with each other—state and MPO?

The District of Columbia and Pennsylvania share traffic data with other agencies. Delaware and Virginia share their data with all requesting organizations, but they do not use data from other agencies due to coordination, format, and quality. Maryland has a good working relationship with the BMC which gets traffic count data from the website or by special request with the Traffic Engineers. BMC is allowed to load validated traffic counts on Maryland's DOT website.

- How do you market your traffic data and satisfy your customers?

Delaware and District of Columbia make traffic data available on their websites. Maryland has a Traffic Monitoring System internet website at: www.marylandroads.com/SHAServices/mapsBrochures/maps/OPPE/trafficvolumemaps/tms.asp.

Pennsylvania has iTMS, a traffic data website that shows current information for every site. Their Transportation Planning Division is considering marketing their products and services to other areas within PennDOT and the public.

The Virginia Department of Transportation follows the following practices:

- Publications with traffic estimates and reports are made available via the Internet and also can be purchased in hard copy.
- Raw traffic count data are made available within the department via the Intranet.
- Direct read-only access to an Oracle database is provided to "power user" internal customers.
- Traffic data is made available as a layer on department GIS applications.
- Each time a jurisdiction is to be counted those responsible for the roadways are notified of the data collection effort through a letter. The letter provides a contact name/number, and they are offered the traffic data that will result from the counts.
- Many customers are provided with standard export sets of selected raw traffic data. MPOs and city–county government agencies being the primary customers for large datasets. A few consultants also receive large data sets; usually when working for such agencies. Many consultants receive small data exports for localized projects.
- Staff members attend meetings and serve on committees to explain what data is available and bring customer desires back to the group.
- A recent success was the effort to redesign the WIM program to meet the needs of the Mechanistic–Empirical Pavement Design program.

- What new traffic data initiatives are you working on?

Maryland is testing nonintrusive side-fire radar detectors at three sites (all sites are adjacent to an ATR station) to verify the ease of installation, accuracy of the traffic volumes and classification counts of the detector units. Installation and testing will be performed at the three sites for a period of 6 weeks without any need to close any travel lanes at any time.

Pennsylvania's division is working in a website (iTDUS) for the purpose of enabling their traffic counting partners and vendors to process traffic counts and submit it and upload it to PennDOT mainframe. They are also testing some nonintrusive data collection devices.

Virginia is expanding their continuous data collection effort on the Interstate. They are also testing a piezo sensor with a deeper installation; the attempt here is to improve longevity of the sensor. They want to test laser technology for vehicle classification as well.

- What technologies are used to collect vehicle classification data?

Delaware uses piezo systems. They are looking into the possibility of using the Groundhog Permanent Traffic Analyzer technology at selected sites or selected times. The problem of this technology is that it does not collect weight data but is easy to install.

The District of Columbia plans to make use of different technologies for 30 new permanent count stations such as inductive loops with piezoelectric sensors, microwave detection system, acoustic detection system, video detection system, and infrared detection system.

In Maryland, a number of ATRs are loop-piezo-loop. The WIM sites are piezo-loop-piezo-loop. Their consultants utilize road tubes, nonintrusive TIRTL devices, and manual classifying.

In Virginia, they use the following technologies:

- Continuous count stations use two loops and one piezoelectric sensor installed in each lane (ADR 3000+ with loop logic).
- WIM sites use two Quartz piezo sensors and one loop installed in each lane along with an ADR 3000+.
- Road tubes and ADR 1000 are installed with tailgating feature. The tailgating feature allows two cars traveling together to be classified as two cars and not combined into one Class-8 vehicle as many counters will do. Road tubes are setup in each lane separately (independent arrays), to provide a quality data product.
- Length-based classification data from nonintrusive technologies has not passed their data validation checks and is not used.

- Do you use in-house–outsourced, client–mainframe software to process your count data? What procedures were required to obtain software?

Delaware uses Chaparral’s TRADAS software to process their count data and they use their staff for support functions and for developing the annual Traffic Summary Book.

The District of Columbia uses Microsoft Excel software to process count data.

Maryland uses a web-based application with an Oracle backend to process and load the count data. The application was created by consultants for Maryland which owns and maintains the software.

Pennsylvania uses an in-house mainframe to upload and store traffic counts that have been processed through the iTDUS website.

Virginia has been using in-house developed software since the late 1990s. Their software consists of three main client applications that read and write all traffic data to one central Oracle database. The first application is a Microsoft Access database that serves as the main user interface. Very simplistically it provides the ability to manage/report/query the database. This database “front-end” utilizes linked tables with Visual Basic (VB) code and stored oracle procedures to build reports/queries and to execute various processes. It is maintained/updated by in-house staff.

The second application is a more typical Microsoft Windows user interface. It is written in VB and is maintained/updated by in-house staff. It is used primarily to load Binary or ASCII text files into a database and then to review and assign data quality codes to the data. These first two applications are used by only those responsible for managing VDOT traffic data. The third application is a website available to everyone on the VDOT computer network. It is used by their internal customers (planners/engineers) to query our data without having to put in a special request to one of the staff. It was developed in-house and maintained by IT support.

- How do you collect traffic data on high-volume roadways? How do you derive vehicle classification on high-volume–multilane roadways?

Delaware uses permanent ATRs for all roads, with the exception of I-95 where the counters have not been working for some time. The count data from I-95 comes from toll counts at the Delaware–Maryland border and from the Delaware River Bridge Authority toll counts at the Delaware Memorial Bridge.

The District of Columbia has 3 WIM stations and 14 RTMS sites on freeways which are high-volume roadways. They have traffic volume data with 13 classes from the 3 WIM station, and four classes from the RMTS sites.

Maryland has a number of ATRs which use embedded loops and piezo on high-volume roadways. Their consultants also collect short-term data utilizing road tubes, the Road Ramp System, and the nonintrusive TIRTL device. The data is collected by lane and by hour following the FHWA 13-bin class scheme.

In Pennsylvania, if a portable road tube count cannot be set safely, they use short-term in pavement (STIP) sites that collect volume and classification on the high-volume roadways along with some permanent sites. If there is no either a STIP or permanent site located there, they would schedule an 8-h manual classification count.

Virginia uses nonintrusive technology (side-fire radar) in a portable application for all short term counts on the interstate system. These data are collected as volume counts only at this time; however, they have had success collecting speed data as well as volume in testing done using the new Wavetronix HD sensor. They use this same nonintrusive technology off the interstate on some very difficult high-volume locations. They use road tubes and independent arrays at other high-volume locations. Technicians setup equipment during nonpeak times. Basically, high volume locations are set up with independent arrays, which employ blockers and other methods to separate the inputs from each other by lane.

- What equipment maintenance and calibration procedures do you have in place?

Delaware and District of Columbia use both in-house staff and manufacturer technical support to meet maintenance and calibration needs.

Maryland has an ATR maintenance contract in place and they require a regular schedule of quarterly site visits for each piece of equipment. Preventative maintenance should decrease the severity of failures and the length of downtime, thereby providing greater assurance of quality data collection. An in-depth maintenance record for each ATR is created and kept for review. These records are categorized and summarized to identify trends.

Pennsylvania has a very effective maintenance and calibration plan: For WIM and AVC sites, they currently have a maintenance contract in place which includes two calibrations to be conducted in the spring and fall of each year. Calibrations are accomplished by utilizing a modified version of the ASTM Standard E1318-92: Standard Specification for Highway Weigh-In-Motion Systems—Type II WIM Systems. The modifications dictate that, as a minimum, one five-axle single-trailer truck of known static weight and axle spacing will be utilized as the reference value for testing. The contractor provides the truck for calibration. The contractor makes all necessary arrangements for conducting a complete WIM calibration at each of the sites. The contractor notifies the department of the calibration dates. The contractor will calibrate the WIM system utilizing the referenced vehicle and the modified ASTM E 1318-92.

For Kistler or Bending Plate sites the reference vehicle will make a total of nine passes consisting of three passes over the WIM system at three different speeds. A record will be made of the gross vehicle weight (GVW), axle spacing, and speed for each pass. For polymer piezo sites the reference vehicle will make a total of nine passes over the WIM system at the posted speed. A record will be made of the GVW, axle spacing, and speed for each pass. Utilizing the recorded GVWs, the percent difference between actual and measured weights of each pass is calculated. Upon the completion of all passes, the percent of the total number of observed values exceeding the known vehicle weight is calculated. This will show the percent of calculated differences that exceeded the specified tolerance value (±15% of GVW). If the total number of calculated difference is greater than 15%, the WIM system is declared inaccurate and a report that it failed the acceptance test is submitted.

To successfully accomplish the accuracy test for vehicle classification the contractor must follow the procedure listed below:

- A manual vehicle classification will be performed on each lane of the site for the period of 15 min.
- The observer will make an entry for each observed vehicle and the corresponding vehicle recorded on the classifier.
- Upon completion of the manual classification period a separate analysis will be completed for each lane at the site.
- The indicated % error of the machine should be within ±5%. If the values fall outside of this range, the contractor must effect adjustments according to the machine's manufacturer.

For ATR sites, there is currently a QA program in place. The program includes:

- At least once every 3 years: a QA test at each site involving a classification count using manufactured calibrated portable counters (set for a minimum of 24 hours (midnight to midnight) and also a 2-hour manual count taken during counter set time. The percent error of the tests should be within ± 2%. If the values fall outside of this range, an investigation is undertaken and corrections made.

- If a new counter is placed at a site, a 2- to 3-hour manual count is taken within 1 year to verify counter accuracy to within ± 2%.
- Also in addition to field testing, data is compared to historical archived data on a monthly basis and large differences/variations are investigated.

Virginia states that the key to the maintenance effort is a strong data review program. Continuous count stations are downloaded and reviewed daily. All data (continuous and short term) go through an automated review against a series of data quality checks completed during the upload process. A second review, this one manual, occurs where the automated review messages are analyzed and a quality code is assigned to all data.

Data that are flagged during the review process are researched in more depth. Data issues that cannot be resolved will result in a technician being dispatched to perform a service call to a location in the case of continuous data or a recount in the case of short-term data. Sensor installations are videotaped and photographed to document that proper installation procedures were used. All new in-road sensor installations are checked during acceptance testing. Sensor readings are taken.

Validation checks are conducted by comparing counter data with a manual count. VDOT uses a loop logic, or 21 bin, classification table which aids in predicting piezo failure. The loop logic allows the shorter and lighter vehicles, which will begin to have missed axle hits first, to be classified as class 2 or 3 vehicles based on length. Vehicles with missed axles using the loop logic function to classify correctly are binned separately (class 16 thru 19) from those with two-axle hits. As the class 16 thru 19 vehicles grow in number, operators know that maintenance will be required soon.

When piezo performance deteriorates to the point that heavier/longer vehicles begin to miss axles, they are binned in a class 20 category. At this point the piezo sensor is failing and data is downgraded based on established program criteria. Sensor readings are collected at sites flagged for service calls. Annual checks and sensor readings are collected at locations that were not otherwise visited during the year as time allows.

For road tube counters, air switch readings are taken twice a year to ensure equipment is in working condition. Road tubes are checked for air leaks prior to each use. Short-term count contractors are required to perform a videotaped verification test of their equipment and set-up procedures in all types of traffic conditions. Videotaped traffic data are compared to submitted machine data. For short-term counts, VDOT inspection staff review contract set-up work and record findings. Manual verifications of traffic counts are conducted. Calibration of WIM equipment is performed following the ASTM standards semiannually.

STAFFING AND ORGANIZATIONAL

- In what area/division of the DOT is traffic monitoring located?

In Delaware, it is in the Planning division.

In Maryland, it is located in the Office of Planning and Preliminary Engineering.

In Pennsylvania, in the Bureau of Planning and Research (Transportation Planning Division) under the Office of Planning.

In Virginia, in the Traffic Engineering Division.

- Do you operate your data collection program from a centralized or decentralized location?

In Delaware from a decentralized location, and they say that is the crux of many of their problems.

Maryland's data collection program is operated from a centralized location in Baltimore.
Pennsylvania and Virginia also operate their data collection program from a centralized location.

- How many people make up the traffic monitoring section? Office versus field?

In Delaware, there are four people; two office people and two field people in different locations and different sections.

Maryland's Traffic Monitoring Section is made up of five office personnel and two field technicians.

The Pennsylvania Department of Transportation has seven people in the office and three in the field. In the office, the section is made up of one manager who is responsible for two transportation planning specialist supervisors who are responsible for three traffic analysts who are primarily responsible for assigning, processing, and tracking the yearly traffic count assignments and a fourth analyst who is a part time field person and data analyst with permanent site data. They have an additional transportation planning specialist who is responsible for permanent site data.

In the field, PennDOT has three people. The field operations section has one supervisor, one part-time field person housed in central office, and one full-time field person located in the western part of state whose main job is setting traffic counts.

In Virginia, fifteen full-time staff are assigned to this section. These are divided generally as eleven office and four field, although several office staff have significant field duties. The program funds another nine positions assigned to the districts who perform field data collection for VDOT. Serious consideration is being given to contracting this function. Contract staff of around 50 collect data and perform count station maintenance. Some of these 50 are office staff members who administer the program from the contract side, but the majority is field staff.

- Do you outsource any of your data collection–analysis processes?

In Delaware, they only outsource the coverage count portion of their program. No analysis is really done.

Maryland has been utilizing consultant contracts to collect traffic data, but they do their own traffic analysis.

Pennsylvania outsources roughly 3,300 traffic counts a year.

In Virginia, short-term counts on the higher functionally classified roadways (the 17,000 48-h 3-year cycle counts) are entirely contracted. Maintenance and installation of the continuous count station program is contracted. They do their own analyses.

- Do funding issues keep you from maintaining an acceptable traffic monitoring program? If so, please explain.
-

In Delaware, the traffic section that is responsible for the maintenance of the counters claim they do not have money in the budget to hire more maintenance people. In planning, no additional positions are allocated in the budget because senior management fails to recognize the importance of having good data.

In Maryland, funding issues have not been a problem for maintaining an acceptable traffic monitoring program. They recognize that they have been fortunate to have the support of upper management because they realize the importance of quality data as it affects all aspects of projects and products generated by the Maryland State Highway Agency.

APPENDIX 2: INSTRUCTIONS FOR USING THE MS EXCEL VISUAL BASIC APPLICATION FOR WIM DATA QC, CLASSIFICATION, AND AXLE LOAD SPECTRA

Two sets of subroutines have been developed in a Visual Basic Application for Microsoft Excel. The objective of the first subroutine is to apply quality control to the weigh-in-motion data collected; the second subroutine is intended to develop axle load spectra in a format compatible with the MEPDG (Mechanistic-Empirical Pavement Design Guide).

These scripts were created to operate with the new metric format for WIM data that the NMDOT (New Mexico Department of Transportation) recently began to use. Another subroutine was created to convert the previous US customary unit format to the new metric format.

In order to be able to run these scripts, a Visual Basic Application must be installed in MS Excel. This can be accomplished as follows:

- Open MS Excel, click the Office Button (upper-left corner), and click Excel Options.
- Click Add-Ins in the menu at the left, select Analysis ToolPak VBA in the main window, in the Manage scroll-down menu select Excel Add-ins, and then click Go.
- In the next window, check the Analysis ToolPak VBA box, and click OK.
- Finally, to visualize the Developer tab, go again to Excel Options, and in Popular, check the box Show Developer tab in the Ribbon.
- In the new Developer tab, click the Visual Basic button, and the programming environment will appear.

Instructions on how to apply the quality control procedures are given in the next section; the process to develop the axle load spectra are then explained.

Subroutines for Quality Control

These subroutines process the W-files which contain the weight data collected at WIM stations. The W-file to process must be imported previously into MS Excel as a text file. Then follow the steps below to import the weight data:

- Place the folder “QC-ALS Algorithms” in the desktop of your computer. This folder contains a subfolder called “1-Subroutines QC” containing the scripts required to perform the quality control procedure. The subfolder “2-Subroutines ALS” contains those subroutines that have to be run for development of axle load spectra. The subfolder “Templates” contains two excel files on which the output files will be created. The text file containing the WIM data must be placed within the subfolder “Inputs” and the results will be shown in two excel files that will be created inside the folder “Outputs”.
- Open Microsoft Excel, and go to the tab Developer and click Visual Basic to open the programming environment. In the Visual Basic window, go to the menu File, and click Import File, select the subroutine “1-QCWIMdataImport” inside the folder “1-Subroutines QC”, and click Import. The WIM data collected on US-550 (WIM sites:

Bloomfield, Cuba, and San Ysidro) have a slightly different format, therefore, use subroutine "1-QCWIMdataImportUS550" instead for these locations. In the small window at the left side, under Modules, double click the recently imported subroutine Module1 to access the code. Make the following changes inside the code:

- Enter the name of the input text file which contains the WIM data and the directory where it is located in lines 13 and 8 respectively.

- Enter the name of the template Excel file "QC template.xlsx" and the directory where it is placed in lines 42 and 37 respectively.

- Enter the name of the output Excel file that will be created and the directory where it will be located in lines 391 and 386 respectively.

- Finally run the code by clicking the green button in the upper menu.

A new Excel file with the imported WIM data and with the tables where the outputs will be stored is created inside the folder "Outputs." From now on we will work in this new Excel file, thus we can close the Excel file opened initially. In the new Excel file we need to insert the following inputs in those cells filled with yellow color (column BC):

- Number of Records: This is the number of the last row of WIM data imported in Excel.

- Year: Year of the data being processed.

- Month: Month of the data being processed.

- WIM Site Code: This is the code associated with the WIM site (155 for Bloomfield, 102 for Cuba, 103 for San Ysidro, 915 for San Antonio, 007 for Tesuque, 916 for Roswell, 919 for Tularosa, 202 for Hobbs, B20 for Tucumcari, B28 for Raton, 252 for Lemitar, 300 for Rincon, 074 for Vado, 004 for Hatchita, 111 for Gallup, and 919 for Tularosa).

- Positive Direction: One digit code (1 for N, 2 for NE, 3 for E, 4 for SE, 5 for S, 6 for SW, 7 for W, 8 for NW).

- Negative Direction: Opposite of Positive Direction.

- Lane Code: Code that represents the format used for numbering the lanes. This is 12 when the format is lane 1 and lane 2 for both positive and negative directions, and 1234 when the format is lanes 1 and 2 for positive direction and lanes 3 and 4 for negative direction.

Once these inputs have been provided, go to Visual Basic, and run the following subroutines in the given order:

1. WChecks: This subroutine performs fifteen QC checks that are shown below. The results of these QC checks, “OK” or “ERROR”, are shown in the spreadsheet in columns AM through BA. Use the Filter button to identify erroneous records, examine, and remove the rows containing bad data.

    - Check W1: This subroutine checks whether the year in every record is unique and correct, e.g. if Year ≠ 10 then “ERROR”.
    - Check W2: Checks whether the month is correct, e.g. if Month ≠ 06 then “ERROR”. If processing several months, allow for all these months using the logical function Or.
    - Check W3: Checks whether the day is correct, e.g. if Day ≠ 1 to 31 then “ERROR”.
    - Check W4: Checks whether the time is correct, e.g. if Hour ≠ 0 to 23 then “ERROR”.
    - Check W5: Checks whether the WIM site id is correct, e.g. if WIM Code ≠ 21020 then “ERROR”.
    - Check W6: Checks whether the direction is correct, e.g. if Direction ≠ 1 or 5 then “ERROR”.
    - Check W7: Checks whether the lane number is correct, e.g. if Lane Number ≠ 1 to 4 then “ERROR”.
    - Check W8: Checks whether the vehicle class is correct, e.g. if Vehicle Class ≠ 4 to 13 then “ERROR”.
    - Check W9: Checks whether the number of axles is consistent with the number of axle spaces, e.g. if Number of Axles ≠ Number of Axle Spaces + 1 then “ERROR”.
    - Check W10: Checks whether the number of axles is consistent with the number of axle weights, e.g. if Number of Axles ≠ Number of Axle Weights then “ERROR”.
    - Check W11: Checks whether the gross vehicle weight is consistent with the sum of axle weights, e.g. if Sum of Axle Weights ≠ GVW then “ERROR”.
    - Check W12: Checks whether the number of axles is consistent with the vehicle class, e.g. if Number of Axles ≠ Range of Axles for that Vehicle Class then “ERROR”.
    - Check W13: Checks whether the sum of axle spaces is consistent with the maximum length, e.g. if Sum of Axle Spaces > 35 m (115 ft) then “ERROR”.
    - Check W14: Checks whether the axle weights are within acceptable range, e.g. if Axle Weight ≠ 200 kg (440 lbs) to 15,000 kg (33,000 lbs) then “ERROR”.
    - Check W15: Checks whether the axle spaces are within acceptable range, e.g. if Axle Spacing ≠ 0.6 m (2 ft) to 15 m (50 ft) then “ERROR”.

2. ClassDirectionLane: This subroutine calculates the vehicle class distribution, the directional distribution, and the lane distribution, and normalizes the results over 100%. Remember before running these subroutines that the Number of Records now has to be updated since some erroneous data were deleted in the previous step.

3. GVW: This subroutine calculates the gross vehicle weight frequency distribution by vehicle class. The result is given in absolute values, and also normalized over 100 %.

4. FSA: This subroutine determines the front steering axle weight frequency distribution by vehicle class. The result is given in absolute values, and also normalized over 100 %.

These frequency distributions can be plotted conveniently using the tools available in Microsoft Excel.

In the last step of this process, the vehicle class, directional, and lane frequency distributions are subjected to engineering judgment. The gross vehicle weight and steering axle weight frequency distributions are subjected to the following criteria provided by the Traffic Monitoring Guide:

- The class 9 gross vehicle weight distribution must have a peak due to unloaded vehicles within the range of 13,500 kg (30,000 lbs) to 18,000 kg (40,000 lbs) and another peak due to loaded trucks within the range of 31,500 kg (70,000 lbs) to 37,000 kg (80,000 lbs).

- The class 9 front steering axle weight distribution must have the majority of axles within the range of 3,600 kg (8,000 lbs) to 5,400 kg (12,000 lbs).

Subroutines for Development of Axle Load Spectra

Once the fifteen QC checks have been applied, and after removing the erroneous data records, the weigh-in-motion data must pass several QC procedures where the frequency distributions are examined. If the WIM data is considered to have good quality according to the TMG (Traffic Monitoring Guide) criteria, then the second set of subroutines can be run to develop axle load spectra. The WIM data that have previously passed the QC procedures must be imported into Microsoft Excel where the subroutines for axle load spectra will be run. Follow these steps:

- Open Microsoft Excel, go to the tab Developer, and open Visual Basic. Import the subroutine “1-WIMdataImportALS” which is in the folder “2-Subroutines ALS”.

- In this script make the following changes:

    - Enter the name of the Excel file which is the output of the QC procedure and also the directory where it is located in lines 13 and 8 respectively.

    - Enter the name of the template Excel file “ALS template.xlsx” and the directory where it is placed in lines 63 and 58 respectively.

- Enter the name of the output Excel file that will be created and the directory where it will be saved in lines 927 and 922 respectively.

- Finally, run the code by clicking the green button in the upper menu.

This subroutine will create a new excel file containing the WIM data that passed the QC procedures and also several tables where the outputs of axle load spectra analyses will be stored later on. The following subroutines can be imported into the Visual Basic Developer of this new file and run in the order shown below. Before this can occur, however, the Number of Records must be input into column AL (the yellow colored cells).

2. AxleClass: This subroutine classifies every axle as single, tandem, tridem, or quad based on the spacing between the surrounding axles which determines the vehicle axle configuration. The subroutine also converts the axle weights that are recorded in kilograms to pounds since the MEPDG uses US customary units.

3. SingleALS1: This subroutine calculates the single axle load spectra in absolute values and then normalizes it over 100 %. It also arranges the single axle load spectra according to the format used in the MEPDG. Therefore, the table can be copied in Excel and directly pasted into the MEPDG.

4. SingleALS2: This subroutine calculates the single axle load spectra. There is a maximum limit of lines for a subroutine in Visual Basic, therefore, the script SingleALS had to be divided in two different subroutines.

5. TandemALS1: This subroutine determines the tandem axle load spectra in absolute values, normalized over 100 %, and in MEPDG format. Calculating the tandem axle load spectra requires many lines of code, and there is a maximum limit of lines for a subroutine in Visual Basic, therefore, the script TandemALS had to be divided in five different subroutines.

6. TandemALS2: This subroutine determines the tandem axle load spectra.

7. TandemALS3: This subroutine determines the tandem axle load spectra.

8. TandemALS4: This subroutine determines the tandem axle load spectra.

9. TandemALS5: This subroutine determines the tandem axle load spectra.

10. TridemALS1: This subroutine calculates the tridem axle load spectra in absolute values, normalized over 100 %, and in MEPDG format. TridemALS is divided into three subroutines for same reasons as TandemALS.

11. TridemALS2: This subroutine calculates the tridem axle load spectra.

12. TridemALS3: This subroutine calculates the tridem axle load spectra.

13. QuadALS: This subroutine calculates the quad axle load spectra in absolute values, normalized over 100 %, and in MEPDG format.

Subroutines for the Development of Truck Volume Inputs and Truck Traffic Distributions

In addition to weight data, weigh-in-motion sites collect volume and classification information which is stored in C-files. These data can provide very useful traffic information and distributions that are required by the MEPDG. Subroutines have been created in order to process the volume and classification data collected at WIM sites.

The way these scripts operate is similar to those presented previously. First of all, we have to import the C-file which is a text file into Microsoft Excel. For that, the subroutine named "1-ClassdataImport" contained in the folder "3-Subroutines Class" must be used. We need to open Microsoft Excel, go to Visual Basic Developer, and import the file "1-ClassdataImport". In order to be able to run the script without modifying the code, the input text C-file must be named "Classdata" and must be placed within the folder "Inputs". This subroutine will create a new Excel file within the folder "Outputs" under the name "ClassWIMdata" in which all the volume and classification data have been imported. It will also paste from "Class Template" the cell arrangement where the results will be stored.

During every run, the name of the input text file must be "Classdata". After the runs have been performed we can change the name of the input and output files. The first time we run the subroutine on a particular computer, the following lines of the subroutine "1-ClassdataImport" must be updated and the changes saved:

- Enter in line 11 the directory where the input text file is located.
- Enter in line 16 the directory and name of the input text file.
- Enter in line 48 the directory where the template file is located.
- Enter in line 53 the directory and name of the template file.
- Enter in line 358 the directory where the output Excel file will be saved.
- Enter in line 363 the directory and name of the output Excel file.

Before running the last subroutine, some inputs must be provided in column AB of the output Excel file. These inputs are the number of records, the codes for positive and negative direction, and the code for lanes. Next, the script named "2-ClassDistributions" within the folder "3-Subroutines Class," must be imported into the Visual Basic Developer of the output Excel file. When run, this subroutine will calculate and provide the following values and distributions:

- Annual Average Daily Traffic (AADT),
- Annual Average Daily Truck Traffic (AADTT),

- Percentage of Trucks,
- Directional Distribution,
- Lane Distribution,
- Vehicle Class Distribution,
- Truck Class Distribution,
- Monthly Distribution by Vehicle Class,
- Vehicle Hourly Distribution,
- Truck Hourly Distribution.