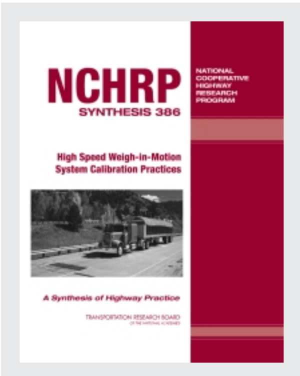


High-Speed Weigh-in-Motion System Calibration Practices

DETAILS

55 pages | | PAPERBACK
ISBN 978-0-309-09815-1 | DOI 10.17226/23062

AUTHORS

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 386

High Speed Weigh-in-Motion System Calibration Practices

A Synthesis of Highway Practice

CONSULTANTS
A.T. PAPAGIANNAKIS
University of Texas–San Antonio
R. QUINLEY
Sacramento, California
and
S.R. BRANDT
San Antonio, Texas

SUBJECT AREAS
Highway Operations, Capacity, and Traffic Control

Research Sponsored by the American Association of State Highway and Transportation Officials
in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD
WASHINGTON, D.C.
2008
www.TRB.org

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NOTE: The Transportation Research Board of the National Academies, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

NCHRP SYNTHESIS 386

Project 20-5 (Topic 38-10)
ISSN 0547-5570
ISBN 0-309-09815-1
Library of Congress Control No. 2008907267

COPYRIGHT PERMISSION

NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:
http://www.national-academies.org/trb/bookstore

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

TOPIC PANEL
MARK GARDNER, *Fugro Consultants, LP, Austin, TX*
ANNE-MARIE H. MCDONNELL, *Connecticut Department of Transportation*
STANLEY NORIKANE, *California Department of Transportation*
THOMAS PALMERLEE, *Transportation Research Board*
ZOLTAN RADO, *Pennsylvania State University*
RICHARD L. REEL, JR., *Florida Department of Transportation*
TONY RIVERA, *Nevada Department of Transportation*
DAVID JONES, *Federal Highway Administration* (Liaison)
MICHAEL MORAVEC, *Federal Highway Administration* (Liaison)

FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Jon Williams
Program Director
Transportation Research Board

Weigh-in-motion (WIM) is the process of weighing vehicle tires or axles at normal roadway speeds ranging up to 130 km/h (80 mph). WIM systems consist of sensors embedded onto the pavement surface and a data acquisition system equipped with software capable of processing sensor signals into weight, computing additional traffic data elements, and summarizing them into various database formats. There is an urgent need for ensuring WIM data accuracy. This is accomplished through routine WIM system calibration and periodic WIM data quality control. The way these tasks are carried out varies widely between agencies. This study synthesizes the state of the practice in high speed WIM system calibration. The study is likely to be of interest to those responsible for long-term pavement performance, pavement design, bridge design, monitoring highway usage, highway cost allocation, and enforcement of truck loads.

Two main tools were used in conducting this study—a thorough review of the European and North American literature on the subject and an on-line survey addressed to highway and load enforcement agencies administering WIM systems in the United States. The survey was supplemented by telephone interviews

A.T. Papagiannakis, R. Quinley, and S.R. Brandt collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

HIGH SPEED WEIGH-IN-MOTION SYSTEM CALIBRATION PRACTICES

SUMMARY

The scope of this synthesis captures the state of the practice in calibrating high speed weigh-in-motion (WIM) systems. "Practice" relates to the operational procedures used by state agencies to evaluate the in situ performance of WIM systems in terms of their load measuring accuracy, rather than the equipment-specific technical details used by WIM suppliers and installers for obtaining these measurements. "High speed" refers to WIM systems installed on the main driving lanes of highways and includes systems used for traffic data collection, enforcement screening, or a combination of both data collection and enforcement.

Two main tools were used in conducting this synthesis; a thorough review of the literature on the subject and an online questionnaire addressed to highway and load enforcement agencies administering WIM systems in the United States. The literature review covered the following topics:

- Current standards related to WIM system calibration,
- Historic WIM calibration practices in the United States,
- Current WIM calibration practices in the United States,
- WIM-related research in the United States,
- European WIM calibration practices, and
- European WIM-related research.

The literature review presented in detail the ASTM E1318-02 standard for test truck WIM calibration and the provisional AASHTO standard MP 14-05 for pavement smoothness requirements in the approach to WIM systems. In addition, emphasis was given to the European WIM specifications developed under the Cooperation in the Field of Scientific and Technical (COST) study 323 research. The main source of historic WIM calibration practices was the McCall and Vodrazka's *States' Successful Practices Weigh-in-Motion Handbook* published in 1997.

The source of current WIM calibration practices was documentation provided by agencies managing WIM systems and personal interviews with their personnel. These sources revealed several main differences between state practices and the ASTM E1318-02 standard, as follows:

- For on-site calibration, only one agency conformed to the standard's use of one Class 9 and one Class 5 truck. Most agencies use a single Class 9 truck.
- A requirement that test trucks are equipped with air suspension systems on non-steering axles is not enforced.
- Determination of calibration factors for specified speeds (for WIM systems utilizing this feature) is not performed.
- A requirement that subsets of the WIM measurements meet the accuracy tolerances, in addition to the entire dataset [i.e., this is a stringent requirement introduced for the post-installation validations of WIM systems under the Long Term Pavement Performance (LTPP) Specific Pavement Study pool fund study].

Overall, review of current state WIM calibration practices revealed the following:

- Agencies recognize that on-site test truck WIM calibration needs to be complemented by routine WIM data quality control (QC) to ensure long-term data quality. Software for this purpose has been developed by a number of state agencies as well as the LTPP program.
- Some agencies effectively use static load data of traffic stream vehicles as a means of calibrating their WIM systems.
- State WIM calibration practices change and institutional knowledge is lost as agency personnel retire and new managers with different levels of expertise and resources succeed them.

The on-line survey questionnaire was addressed to state agencies that manage WIM systems. These included departments of transportation (DOTs) and state weight and dimension enforcement agencies. The questions were organized into the following three main groups:

- WIM calibration using test trucks,
- WIM calibration using traffic stream trucks of known static weight, and
- WIM calibration monitoring using traffic stream data QC techniques.

In addition, background questions were included on the main type of WIM sensor technology used, and the general methodology used for initial calibration of these systems. At the end of the questionnaire, a number of WIM inventory questions were included. Questionnaires were distributed in web format to all DOTs and enforcement agencies that use WIM systems for screening. The actual number of questionnaires distributed was 53 (i.e., 50 states, District of Columbia, Puerto Rico, and one extra questionnaire used by Connecticut, which submitted separate responses for traffic data collection and research), with an additional 15 questionnaires distributed to enforcement agencies. Where necessary, the questionnaires were followed with telephone interviews to assist responders filling out the survey and to ask for any additional documentation available. The response rate to the questionnaire was 78% (for those distributed to DOTs) and 73% (for those distributed to enforcement agencies). The main findings of the questionnaire are provided in the following table. The agencies that responded to the questionnaire use one or more of the three calibration methods as summarized here.

Method	Traffic Data Only	Traffic Data and Enforcement	Enforcement Only
Test Truck Only	7	0	0
Traffic Trucks Only	2	0	6
Traffic Data QC Only	4	0	1
Test Truck and Traffic Trucks	3	0	0
Test Truck and Traffic Data QC	8	3	0
Traffic Trucks and Traffic Data QC	2	1	3
All Three Methods	4	3	1
Other	6	1	0
No Response	4	0	0

The majority of agencies perform test truck WIM calibrations on a routine basis at intervals ranging from 6 to 24 months, with most doing so every 12 months. Most agencies use a single Class 9 truck, whereas a small percentage uses two Class 9 trucks. Others use a Class 5, 6, 7, or 10 truck, either alone or with a Class 9 truck. Although a large majority of these agencies report considering pavement roughness, only about 25% does so objectively [i.e., 11.1% perform the straight edge/circular plate test described by ASTM E1318-02, 3.6% simulate this test using software that accepts the pavement profile as input, and 14.8% simply use the International Roughness Index (IRI)]. Even fewer agencies objectively consider the structural condition of the foundation of the sensors. Most agencies use fixed weigh scales for obtaining the static loads of test trucks, although more than 40% of agencies using WIM for both data collection and enforcement screening use portable scales. Most agencies perform the static measurements only once. About half of the WIM systems, regardless of application, perform test truck runs using the site median traffic speed, whereas the remainder uses either the posted speed limit or multiple speeds. The majority of agencies administering dual-use WIM systems use multiple test speeds. The majority of agencies using WIM traffic for data collection only conduct 10 test runs per vehicle speed, whereas agencies using WIM for either traffic data and enforcement or enforcement alone conduct three test runs per vehicle speed. Responders indicated that overall, 87% of agencies carry out calibration calculations on site. The method for computing calibration factors is equally split among agency software, vendor software, and short-hand calculations. For combined-use WIM systems, the majority of the agencies use short-hand calculations, whereas for enforcement-screening-only systems, about two-thirds of the agencies use vendor software. The main load data elements for which WIM errors are computed are the gross vehicle weight (GVW), the individual axle loads, and the tandem axle loads. The majority of agencies compute calibration factors by setting the mean GVW equal to zero, or by setting a combination of the mean GVW and the mean axle load errors equal to zero. Few agencies compute calibration factors by minimizing the least square errors between WIM and static axle loads through zero-intercept regression. Depending on the WIM application, up to 67% of the agencies report deriving speed-specific calibration factors, although a significant percentage of them reports inputting their average value in all speed bins after calibration.

Agencies that use traffic stream vehicles of known static weight for WIM calibration obtain static weights largely by permanent static scales at truck inspection stations. Only about one-third of agencies perform these calibrations on a routine basis at intervals ranging from 1 to 12 months. Most agencies do so only when there is an indication of calibration drift. There is roughly an equal division between the methods used for selecting the number of traffic stream vehicles used. Where a fixed number of vehicles is specified, it varies between 1 and 100, with an average number of 40 vehicles. Where a fixed time interval is used, it ranges between 1 and 168 hours, with the majority of agencies using data collected over a 1- to 4-hour period. The type of vehicles included in this sample varies; the majority of agencies using WIM for traffic data or traffic data and enforcement favor selecting vehicles in certain classes regardless of speed, whereas the majority of agencies using WIM for enforcement screening only use a random selection of truck classes. Axle spacing is measured mostly by manual means. The responses to the question as to where error calculations are performed varies; some agencies always do so at the site, whereas others do so at the office. Interestingly, enforcement agencies are more likely to perform the error and calibration computations at the site, which is explained by their ready access to static scale data. The actual method used for performing the calculations varies but most often vendor software is used. The most common traffic load elements for which errors are computed are GVW, individual axle loads, and tandem axle loads. The most commonly used approach for computing calibration factors for traffic data WIM systems is by setting the mean GVW to zero. For traffic data and enforcement and enforcement-only WIM systems, the most common calibration approach is to set the combined errors for GVW and individual axle loads to zero. About 16% of the agencies that operate traffic data WIM use regression for computing calibration factors. Most agencies do not compute multiple calibration factors corresponding to different traffic speeds.

Many agencies use traffic stream WIM data analysis techniques to monitor the calibration status of WIM systems. An indication by such monitoring that the calibration of a system is changing is used as a trigger for performing an on-site validation/re-calibration using one of the two methods described earlier. Some agencies however use this approach as the only WIM calibration method. The majority of agencies that operates dual-use WIM systems download data automatically, whereas the majority of agencies that manages enforcement screening WIM systems do so manually. The actual WIM data QC analysis frequency ranges from daily to monthly, or it is decided on the basis of personnel availability or perceived calibration need. It is performed by a combination of manual or automated means or a combination of the two. Typically, an initial series of data checks is made to determine any operational problems (e.g., vehicle errors, system errors, and unclassified vehicles). With few exceptions, almost all the agencies that responded believe that WIM data QC is capable of identifying system operational problems. The agencies were asked which traffic stream vehicle types are used and which of their characteristics are monitored in performing calibration monitoring. A large majority of agencies, regardless of WIM data application, focus their traffic stream WIM data analysis on Class 9 trucks or, more specifically, on 3S2 trucks. The most common load-related truck properties being monitored are the following:

- Steering axle load,
- Left-side/right-side wheel loads of the steering axle,
- GVW for empty versus loaded trucks, and
- GVW by vehicle speed.

Interestingly, the steering axle load standard deviation (SD) and the GVW SD are monitored mostly by agencies that manage enforcement screening WIM systems. The most common distance measure monitored is the axle spacing of the tractor tandem axles of 3S2 trucks and, less frequently, the total wheelbase versus the sum of the axle space data. Approximately 5% of the agencies that responded indicated that they take no further action when WIM data QC suggests calibration drift.

CHAPTER ONE

INTRODUCTION

Weigh-in-motion (WIM) is the process of weighing vehicle tires or axles at normal roadway speeds ranging up to 130 km/h (80 mph). WIM systems also are capable of measuring and calculating various other traffic data elements, such as axle spacing, vehicle classification, gross vehicle weight (GVW), and equivalent single-axle loads (ESALs). WIM systems consist of sensors embedded into the pavement surface and a data acquisition system equipped with software capable of processing sensor signals into weight, computing additional traffic data elements, and summarizing them into various database formats.

Since their inception, the performance of WIM systems in capturing truck weight data has been the focus of considerable investigation. There has been a multitude of reports documenting WIM system calibration methods and practices in the United States and internationally (*1–3*), whereas considerable research has taken place to improve these methods (*4*,*5*). Through this process, two standards of on-site calibration have emerged, one developed by ASTM (*6*) and the other developed by the European *Cooperation in the Field of Science and Technology* (*COST*) *323* study (*7*).

Recently, the deployment of WIM systems has proliferated through initiatives such as the Long Term Pavement Performance (LTPP) and the Commercial Vehicle Information Systems and Networks (CVISN) programs. Additionally, WIM data are being used extensively for other purposes, such as pavement design, bridge design, monitoring highway usage, and highway cost allocation. High-quality WIM data are essential to these applications. The new *Mechanistic-Empirical* (*ME*) *Pavement Design Guide* developed under NCHRP Study 1-37A, for example, requires WIM data for predicting performance in terms of the number of years it takes for pavement distresses to become critical. Poor-quality WIM data may lead to significant overestimation of this performance period and, hence, lead to premature functional failures. Similarly, high-quality WIM data are essential to research. On-going bridge design research under NCHRP Project 12-76, Protocols for Collecting and Using Traffic Data in Bridge Design, for example, relies on WIM data to revise design truck loading configurations for bridges. In addition, accurate WIM data are essential in establishing the level of pavement utilization in design-built projects, where premature pavement failures become the subject of litigation. These examples demonstrate the urgent need for ensuring WIM data accuracy. This is accomplished through routine WIM system calibration and periodic WIM data quality control (QC). The way these tasks are carried out varies widely among agencies. The goal of this study is to synthesize the state-of-the-practice in high-speed WIM system calibration. Practice relates to the operational procedures used by state agencies to evaluate the in situ performance of WIM systems in terms of their load measuring accuracy, rather than the equipment-specific technical details used by WIM suppliers and installers for obtaining these measurements.

OBJECTIVES

The objective of this synthesis is to assemble state-of-the-practice information on the methodologies used by state agencies in evaluating and calibrating high-speed WIM systems, as well as in monitoring WIM calibration over time. This objective was addressed through a thorough literature review and a survey questionnaire. The literature review covered U.S. and international sources on standards, practices, and recent research efforts on WIM calibration. The survey questionnaire was used as the main instrument for collecting state-of-the-art practice information from state agencies in the United States. It was addressed to the managers of the state agencies that administer WIM systems, including those used for data collection and/or load limit enforcement screening.

DEFINITIONS

The following definitions clarify some of the main terms used throughout this report and the survey questionnaire.

High speed—highway speeds of up to 130 km/h (80 mph) and, as such, includes permanently installed WIM systems on mainline and is used for continuous data collection or enforcement screening. Therefore, this excludes portable WIM systems used for temporary data collection and enforcement screening WIM systems installed on approach ramps to truck inspection stations.

WIM system refers to one controller, its computer and associated electronics, and all roadway sensors for all lanes for which traffic data are being processed by the controller and at least one lane is instrumented with weigh-in-motion sensors.

WIM site—a specific roadway location at which a WIM system has been or will be installed. Such a site includes all WIM in-road components, the WIM controller and its electronics, the power and communication facilities, all wiring, conduits, pull boxes, and cabinets necessary to make the WIM system functional, the pavement section in which the roadway components are installed, and the pavement approach and departure from the in-road sensors.

WIM lane—any lane that is instrumented with weigh-in-motion sensors.

MS-WIM or multi-sensor WIM system refers to WIM systems using multiple piezoelectric sensors.

Type I and Type II WIM—definitions given by ASTM E1318-02. Type I systems weigh the right- and left-hand side axles individually, whereas Type II systems weigh entire axles. ASTM E1318-02 accuracy tolerances are more stringent for Type I systems than for Type II systems. Type I systems are typically equipped with bending plates, load cell plates, or quartz piezoelectric sensors. Type II systems are typically equipped with 1.8-m (6-ft) or 3.6-m (12-ft) long ceramic or polymer piezoelectric sensors in various configurations. Piezoelectric (also referred to as piezo) sensor manufacturers typically rate their sensors as Class 1, which are designed for weighing, and Class 2, which are designed to act only for axle detection.

Site assessment encompasses on-site activities preceding either an on-site evaluation or calibration to document that a WIM system is operational, the sensors have no visible problems, and the pavement condition shows no apparent deterioration.

Evaluation/validation—on-site activities related to ascertaining compliance of WIM systems to error tolerances. This involves test trucks or samples of trucks from the traffic stream. It includes on-site testing for initial system acceptance, routine checks for calibration maintenance, and conformance to warranty requirements.

Calibration involves adjusting the system's calibration factors by setting the mean error measurements to zero. The data for determining such errors are typically obtained from test trucks or traffic stream trucks of known static weights.

Calibration factor—a user-defined value that is implemented by a WIM system to convert raw sensor output into weights.

Calibration factor speed point (also referred to as speed "bin")—a user-defined speed for which a weighing sensor's calibration factor can be entered. Certain WIM systems provide for three or more calibration factor speed points that allow the user to determine appropriate calibration factors over a range of vehicle speed that will best compensate for the effect of speed.

WIM calibration monitoring—data analysis that typically involves comparisons of representative traffic stream values to known load trends (e.g., the weight of steering axles of five-axle semi-trailers varies within a fairly narrow range and their gross vehicle weight exhibits a distinct double-peak pattern).

Autocalibration—a mechanism built into WIM software effecting automatic calibration adjustments when certain measurements fall outside prescribed limits.

Class 9 vehicles, under FHWA Scheme F, include all five-axle vehicles consisting of two units, one of which is a tractor or straight truck powered unit.

3S2 trucks are Class 9 vehicles consisting of three-axle tractors and two-axle semi-trailers.

Class 5 vehicle refers to the FHWA vehicle classification system and encompasses all two-axle, six-tired single-unit trucks.

CHAPTER TWO

LITERATURE REVIEW

A thorough review of the literature was undertaken. It was conducted utilizing the Transportation Research Information Services (TRIS), Research in Progress, and International Transport Research Documentation online databases. In addition, a multitude of papers from past proceedings of the North American Travel Monitoring Exhibition and Conference and the International Conference on WIM were reviewed. Finally, information on current practices was obtained from existing department of transportation (DOT) documentation and by telephone interviews of state DOT staff. The review, which focused on WIM calibration methods and practices, as well as research advancements that will allow these methods and practices to evolve, covers the following:

- Current standards related to WIM system calibration,
- Historic WIM calibration practices in the United States,
- Current WIM calibration practices in the United States,
- WIM-related research in the United States,
- European WIM calibration practices,
- European WIM-related research and,
- Discussion.

CURRENT STANDARDS RELATED TO WEIGH-IN-MOTION SYSTEM CALIBRATION

Weigh-in-Motion Calibration Standard (ASTM E1318-02)

The ASTM E1318-02 standard (*6*) describes test methods for evaluating and calibrating WIM systems using test vehicles of known static weights and dimensions. WIM system evaluation encompasses on-site activities for ascertaining compliance of WIM system measurements to error tolerances. Calibration involves determining "factors that will be subsequently applied within WIM system calculations to correlate the observed vehicle speed and tire-force signals with the corresponding tire-load and axle-spacing values for the static vehicle." Both evaluation and calibration require two test trucks of known static weights and dimensions making multiple runs over the WIM system sensors at prescribed speeds in each lane. This standard allows the user to modify WIM system performance requirements through the equipment procurement process.

The following four generic types of WIM systems are distinguished in the ASTM E1318-02 standard on the basis of operational and performance requirements:

- Type I has the ability to collect each axle's left and right load data at vehicle speeds ranging from 16 to 130 km/h (10 to 80 mph).
- Type II has the ability to collect individual axle load data at vehicle speeds ranging from 24 to 130 km/h (15 to 80 mph).
- Type III has a load enforcement screening or sorting function and operates at vehicle speeds from 16 to 130 km/h (10 to 80 mph). They are installed on the approaches to truck inspection stations, either on freeway lanes or ramps, to identify trucks that are likely to be over the legal load limits and need to be weighed statically. It is noted that before the E1318-00 version (i.e., E1318-94) the standard described the speed range of Type II systems from 24 to 80 km/h (15 to 50 mph), thus limiting their use to in-station ramp sorting.
- Type IV, which is intended for load enforcement at vehicle speeds up to 16 km/h (10 mph) is not yet used in the United States.

WIM accuracy is evaluated using a minimum of two test trucks, one each of FHWA Classes 5 and 9, performing several runs over the system at each of three vehicle speeds, (i.e., minimum and maximum operating speeds at a site and an intermediate speed). These test vehicles "shall have a suspension type (leaf spring, air, other) that is deemed by the user to be representative of most vehicles of their type operating at the site." The static axle loads of all these vehicles are established through static weighing using National Institute of Standards and Technology certified static scales (*31*). Axle spacings of the test trucks are to be measured at a resolution of 0.03 m (0.1 ft). Static weights should be measured a minimum of three times. Limits are set for the range in replicate axle weight measurements (e.g., static tandem-axle weight measurements must be within ±3% from the mean). The percent error in individual measurements, *e*, is defined with reference to the static measurements using the following equation:

$$e = \frac{\text{WIM} - \text{static}}{\text{static}} 100 \qquad (1)$$

where WIM and static are the measurements obtained with the WIM system and the static scale, respectively. Calibration consists of adjusting the WIM output to achieve a zero mean for the errors. The standard does not specify the actual measurement element(s) to be used for this computation. WIM accuracy is defined in terms of the probability that individual

TABLE 1
WIM SYSTEM ACCURACY TOLERANCES PER ASTM E1318-02 STANDARD (*6*)

Element	Tolerance for 95% Probability of Conformity				
	Type I	Type II	Type III	Type IV	
Wheel Load	±25%	—*	±20%	≥2300 kg**	±100 kg
				≥5,000 lb	±300 lb
Axle Load	±20%	±30%	±15%	≥5400 kg	±200 kg
				≥12,000 lb	±500 lb
Axle-Group Load	±15%	±20%	±10%	≥11300 kg	±500 kg
				≥25,000 lb	±1,200 lb
GVW	±10%	±15%	±6%	≥27200 kg	±1100 kg
				≥60,000 lb	±2,500 lb
Vehicle Speed	±2 km/h				
Axle Spacing	±0.15 m				

*Type II systems do not weigh individual wheels.

**Lighter masses and associated loads are of no interest in enforcement.

axle load measurement errors are within prescribed limits, as shown in Table 1. Each WIM type is to meet the specified load tolerances, provided that the pavement at the WIM site satisfies certain smoothness requirements. The latter establishes the essential obligation of the customer in supplying a site that will allow the manufacturer/vendor to install a system that can meet the prescribed tolerances. Smoothness is specified for a length of 60 m (200 ft) upstream from the WIM sensors and a length of 30 m (100 ft) downstream of them. For a new installation, smoothness is measured using a 6.1-m (20-ft) long straightedge and a 0.15 m (0.5 ft) diameter, 3-mm (0.001-ft) thick circular plate. The pavement passes the smoothness requirement (i.e., meets the on-site acceptance requirements) if the plate does not fit under the straightedge, when positioned along the pavement between the edges of the lane, as described in Table 2. Before calibration, the location and magnitude of pavement surface deviations from the smoothness requirement should be documented. After initial calibration, "alternative means of measuring the surface smoothness of the paved roadway . . . may be used to avoid closing the traffic lane. Data from suitable inertial profiling instruments analyzed by means of computer simulation of the 20-ft (6-m) straightedge and circular plate is suggested."

TABLE 2
PRESCRIBING STRAIGHTEDGE POSITIONING IN DEFINING WIM SITE SMOOTHNESS (*6*)

Lane Edge	Longitudinal Distance from Center of Sensors, m (ft)
Right	6, 9, 13, 18, 23, 28, 33, 38, 43, 48, 53, 58, 62
	(20, 30, 44, 60, 76, 92, 108, 124, 140, 156, 172, 188, 204)
Left	6, 11, 16, 21, 26, 30, 35, 40, 45, 50, 55, 60, 65
	(20, 36, 52, 68, 84, 100, 116, 132, 148, 164, 180, 196, 212)

The standard calls for calibration immediately following an initial WIM system installation and subsequent routine recalibrations at least annually. In addition, recalibration is recommended when

- A system is reinstalled;
- There are significant changes in system components, including software and their settings;
- There is significant change in site conditions; or
- There are significant changes in traffic data patterns.

It is noted that this standard does not prescribe pavement stiffness or pavement material type requirements, although it states that "[e]xperience has indicated that a portland cement concrete (also called rigid) pavement structure generally retains its surface smoothness over a longer period of time than a bituminous (also called flexible) pavement structure under heavy traffic at a WIM site."

A WIM installation is deemed acceptable if it yields measurement errors within the prescribed tolerances for the particular WIM type. However, "the user can require quality of performance only in proportion to the quality of the site conditions provided." In addition, all specified data-collection and data-processing features of a system should be demonstrated to function properly before it is accepted. A detailed outline of the main features of the ASTM E1318-02 standard, as applicable primarily to Type I and II WIM systems, is given in Appendix A.

When testing a new type of WIM system, its capabilities are ascertained through type approval testing. This requires testing in addition to that described previously, involving at least 51 traffic stream vehicles of known static weight and dimensions (i.e., this number is the result of selecting a given number of vehicles from each vehicle class). For these tests, pavement smoothness needs to be exceptional. This allows establishing the capabilities of a system in terms of the tolerance requirements listed in Table 1.

Smoothness of Pavements at Approaches to Weigh-In-Motion Scales (AASHTO MP 14-05)

AASHTO, in consultation with LTPP, currently is considering adopting a provisional standard known as MP 14-05 for quantifying the pavement smoothness requirements at a WIM site (*8*). This standard is based on simulating WIM measurements as the dynamic axle load estimates of a fleet of 3S2 trucks obtained from a two-degree of freedom (bounce and pitch) vehicle simulation model over a number of representative pavement profile sections (*9*,*29*). A variety of pavement smoothness indices were considered and evaluated on the basis of their correlation with the 95th percentile tandem axle WIM error computed according to Eq. 1. Two pavement smoothness indices were identified, referred to as the short-range index (SRI) and the long-range index (LRI). They are computed on two segments of the pavement profile, one from –2.8 m to +0.5 m (–9.16 to 1.64 ft) and the other from –25.8 m to +3.2 m (–84.6 to 10.49 ft), where the minus/plus signs signify locations upstream and downstream from the middle of the WIM sensor(s). Butterworth filters are applied to the pavement profile in these two segments to eliminate wavelengths outside the range of 1.6 m/cycle to 16.5 m/cycle (5.25 to 54.13 ft/cycle) and 1.1 m/cycle to 11.4 m/cycle (3.6 to 37.4 ft/cycle), respectively. The two resulting filtered profiles are summarized in terms of their average rectified (*AR*) velocity (m/km) using the following:

$$AR = \frac{1}{N_2 - N_1 + 1}\sum_{i=N_1}^{N_2} \left| F_i W_i \right| \qquad (2)$$

where F_i is the elevation at profile location i after Butterworth filtering, W_i is a weighing function (i.e., selected as equal to 1.0 for all locations), and N_1 and N_2 are the profile location limits identifying the profile range selected. The Butterworth filtering and the *AR* computations are performed in the distance domain using a state-transition algorithm.

In addition, a Peak SRI was defined to account for the potential localized roughness created by the installation of the WIM sensors themselves. The rationale is that this localized roughness needs to be considered, although it does not affect the overall SRI for the site. The Peak SRI is defined as the maximum SRI value for a distance ranging from –2.45 m to 1.5 m (–8 to 4.92 ft).

These algorithms were implemented into a nonproprietary software package available though the LTPP product delivery team. Thresholds for these three indices were established through a parametric study using the error tolerances for WIM Types I and II (Table 1) as a guideline. The results are given in Table 3 for Type I and II WIM systems. Sites with pavement roughness below the lower threshold are "very likely to produce an acceptable level of weighing error," whereas sites with pavement roughness above the upper threshold are "very likely to produce unacceptable levels of weighing error." It is recommended that a WIM site should be located on a pavement for which roughness is measured below the lower thresholds given in Table 3 over a length of at least 30 m (98.4 ft) upstream of the WIM sensors.

European Weigh-In-Motion Specification

Europeans developed WIM specifications as a result of a multi-year study that culminated in the European COST 323 report published in 2002 (*3*). A summary of the standard is given in Appendix I of the COST 323 report (*7*). It distinguishes six main WIM Classes, designated as A, B+, B, etc., based of the width of the confidence interval of error tolerated for each of the elements being measured, as shown in Table 4. Note that the designations A, B+, B, etc., are typically followed by the confidence interval width for the GVW measurements in parentheses [e.g., A(5), B+(7), and so on]. Additional classes, for example, E, can be distinguished by extrapolating the requirements for the main classes. The vehicle speed requirements in Table 4 are not mandatory, although it is recognized that speed is used as an input to the load computation algorithms for some sensor types.

The confidence level for the specified intervals depends on the type of reference loads and the methodology used for

TABLE 3
ROUGHNESS INDEX THRESHOLDS FOR WIM SITES (*8*)

		Lower Threshold m/km (in./mi)	Upper Threshold m/km (in./mi)
Type I WIM	LRI	0.5 (31.68)	2.1 (133.06)
	SRI	0.5 (31.68)	2.1 (133.06)
	Peak short range	0.75 (47.52)	2.9 (183.744)
Type II WIM	LRI	0.9 (57.02)	3.8 (240.77)
	SRI	1.25 (79.2)	5.7 (361.2)
	Peak short range	1.6 (101.38)	6.6 (418.18)

TABLE 4
WIM SYSTEM ACCURACY TOLERANCES AS PER COST 323 STANDARD (*7*)

	Accuracy Classes and Tolerances; Confidence Interval Width δ (%)						
Element	A(5)	B+(7)	B(10)	C(15)	D+(20)	D(25)	E
GVW	5	7	10	15	20	25	>25
Axle Group	7	10	13	18	23	28	>28
Single Axle	8	11	15	20	25	30	>30
Single Axle within a Group	10	14	20	25	30	35	>35
Speed	2	3	4	6	8	10	>10
Axle Spacing	2	3	4	6	8	10	>10
Vehicle Volume	1	1	1	3	4	5	>5

WIM system evaluation. Using trucks of known static weight allows defining four "repeatability levels" as follows:

- r1: One test truck passing several times over the WIM system at the same speed and carrying the same weight.
- r2: One test tuck passing several times over the WIM system at several speeds and loaded in several different ways.
- R1: A small sample of test trucks, ranging from 2 to 10, making several passes over the WIM system at several speeds and loaded in different ways.
- R2: A large sample (i.e., 10 to 200) of traffic stream trucks of known weight passing over the WIM system.

Furthermore, three domains of "environmental reproducibility" are distinguished, depending on the time period over which the test truck WIM system evaluations take place. The rationale is that the properties of the pavement layers, the smoothness, and the sensor constants may exhibit temporal variations. These three domains are as follows:

I: The test period is limited to a couple of hours within a day or spread over a couple of consecutive days.
II: The test period extends at least over a full week or several days spread over a month.
III: The test period extends over at least a year with actual test days distributed throughout this period.

Confidence levels are defined as a function of repeatability level, environmental reproducibility, and sample size, as shown in Table 5 for environmental reproducibility levels I, II, and III. As an example, to classify a WIM system as Type B+, the accuracy requirement in weighing individual axles should be within ±11% of their corresponding static values. If 20 axles were used for this evaluation that took place during a single day (i.e., environmental reproducibility of I) and involved a single truck making repetitive runs at a given speed (i.e., repeatability level r1), the probability of conformity should be 97.2% per Table 5; that is, only 2.8% of the errors can be outside the ±11% range.

The WIM site conditions necessary for achieving these tolerances are prescribed in terms of rutting, deflection (absolute and differential between left and right wheel paths), and smoothness [International Roughness Index (IRI) and Analyzer of Longitudinal Profile], a pavement smoothness scale not used in the United States]. Limits established in each of these conditions define three WIM site classes (excellent, good, and acceptable), as shown in Table 6. It should be noted that the deflection limits apply to asphalt concrete-surfaced pavements only. Table 7 shows the relationship between site condition and its sufficiency in meeting the accuracy requirements (e.g., a site classified as Type II is insufficient to produce Class A and B+ tolerances).

In addition to test trucks, the COST 323 standard provides for the use of alternative reference loads for evaluating and validating and calibrating WIM systems. These include the following:

- Stationary loads being applied to the sensors. This approach may be feasible for some WIM sites, but clearly does not take into account the pavement roughness-induced load excitation at a particular WIM site.
- Impact loads, such as those that can be applied with a falling weight deflectometer (FWD). As for stationary loads, applying such loads for evaluation or calibration may not be compatible with the data acquisition systems of some WIM systems.
- Test trucks instrumented to measure dynamic axle loads. This approach allows computing WIM errors with respect to the dynamic axle loads applied to the WIM sensor, as measured from the instrumentation on-board an instrumented vehicle. Instrumentation may consist of specially designed hub-mounted transducers or axles strain gauged in bending or shear. A number of research studies have made use of this technology for estimating "true" WIM accuracy (*10,11*).

The COST 323 standard recommends a number of alternative WIM calibration methods, depending on the repeatability

TABLE 5
CONFIDENCE LEVELS (%) FOR WIM EVALUATION

Test Conditions	Vehicle Sample Size					
	10	20	30	60	120	∞
Environmental Reproducibility I						
r1	95	97.2	97.9	98.4	98.7	99.2
r2	90	94.1	95.3	96.4	97.1	98.2
R1	85	90.8	92.5	94.2	95.2	97.0
R2	80	87.4	89.6	91.8	93.1	95.4
Environmental Reproducibility II						
r1	93.3	96.2	97	97.8	98.2	98.9
r2	87.5	92.5	93.9	95.3	96.1	97.5
R1	81.9	88.7	90.7	92.7	93.9	96.0
R2	76.6	84.9	87.4	90.0	91.5	94.3
Environmental Reproducibility III						
r1	91.4	95.0	96.0	97.0	97.6	98.5
r2	84.7	90.7	92.4	94.1	95.1	96.8
R1	78.6	86.4	88.7	91.1	92.5	95.0
R2	73.0	82.3	85.1	88.1	89.8	93.1

Source: Reference 7.

TABLE 6
WIM SITE CONDITION SPECIFICATIONS AS PER COST 323 STANDARD (*7*)

			WIM Site Classes		
			I Excellent	II Good	III Acceptable
Rut Depth mm (in.) using a 3 m (9.84 ft) straightedge			≤ 4 (0.157)	≤ 7 (0.256)	≤ 10 (0.394)
Deflection 10^{-2} mm (10^{-3} in.) under quasi-static load of 13 t (28.6 kips)	Semi-rigid pavement	Mean Max Diff. L-R	≤ 15 (5.9) ±3 (1.18)	≤ 20 (7.87) ±5 (1.97)	≤ 30 (11.8) ±10 (3.94)
	All-bitumen pavement	Mean Max Diff. L-R	≤ 20 (7.87) ±4 (1.57)	≤ 35 (13.78) ±8 (3.15)	≤ 50 (19.68) ±12 (4.72)
	Flexible pavement	Mean Max Diff. L-R	≤ 30 (11.8) ±7 (2.75)	≤ 50 (19.68) ±10 (3.94)	≤ 75 (29.52) ±15 (5.91)
Deflection 10^{-2} mm (10^{-3} in.) under dynamic load of 5 t (11.02 kips)	Semi-rigid pavement	Mean Max Diff. L-R	≤ 10 (3.93) ±2 (0.78)	≤ 15 (5.91) ±4 (1.57)	≤ 20 (7.87) ±7 (2.75)
	All-bitumen pavement	Mean Max Diff. L-R	≤ 15 (5.91) ±3 (1.18)	≤ 25 (9.84) ±6 (2.36)	≤ 35 (13.78) ±9 (3.54)
	Flexible pavement	Mean Max Diff. L-R	≤ 20 (7.87) ±5 (1.97)	≤ 35 (13.78) ±7 (2.75)	≤ 55 (21.65) ±10 (3.94)
Smoothness	IRI (m/km) (in/mi)		0–1.3 (0–82.4)	1.3–2.6 (82.4–164.7)	2.6–4.0 (164.7–253.4)
	APL (SW, MW, LW)		9–10	7–8	5–6

TABLE 7
WIM SITE CLASSIFICATION AND CORRESPONDING WIM CLASSES (*7*)

WIM Class	I Excellent	II Good	III Acceptable
A	+	–	–
B+	+	–	–
B	+	+	–
C	(+)	+	+
D+	(+)	(+)	+
D	(+)	(+)	+

– = insufficient; + = sufficient; (+) = more than sufficient.

levels identified earlier and the intended application of the traffic load data being collected. These are as follows:

1. Setting the mean error of the GVW of all the test vehicles passing over the sensors to zero (i.e., each pass is considered a sample). This method is recommended for r1 level calibrations.
2. Setting the ratio of the sum of WIM GVW measurements divided by the sum of the static GVW of all the test vehicles passing over the sensors to one (i.e., each pass is considered a sample). This method is recommended only for estimating aggregate traffic loading data (e.g., for economic impact analyses).
3. Finding the slope of the WIM GVW measurements versus the static GVW measurements by performing zero-intercept regression analysis (i.e., each pass is considered an observation). This method minimizes the sum of squares of the errors. It is recommended for r2 and R2 level calibrations.
4. Using the method described in 1 or 2 above, but developing calibration factors by truck class. This method is deemed applicable to R1 and R2 level calibrations.

Traffic Monitoring Guide

Appendix 5-A of the *Traffic Monitoring Guide* (*TMG*) (*12*) provides qualitative guidelines enhancing the procedures described by the ASTM E1318-02 WIM calibration standard. These include the following:

- Use of more than two test vehicles for the on-site evaluation,
- Testing of WIM performance at various speeds, and
- Testing performance under different environmental conditions (i.e., usually different temperatures).

These enhancements will improve WIM calibration depending on the following:

- The specific scale technology being used.
- The types of environmental conditions present at the WIM site.
- The type and structural capacity of the pavement, where the WIM sensors are installed.

It is argued that using more than a few test trucks for calibration limits the bias created from the use of a particular truck type. A common method for evaluating the extent of bias after calibration is to examine traffic stream summary weight data output by the scale and compare it with the known weights of trucks commonly found on the road.

The *TMG* also advocates WIM system calibration monitoring using traffic stream data QC principles. These consist of monitoring several traffic stream properties over time, including the following:

- Front axle weights (FAWs) of five-axle tractor semi-trailer trucks;
- GVW distribution of five-axle tractor semi-trailer trucks, following the technique developed by Dahlin (*13*);
- Spacing of tandem axles on five-axle tractor semi-trailer trucks; and
- Traffic volumes and distribution by classification.

1998 Long Term Pavement Performance Protocol

The LTPP protocol (*14*) describes a method for calibrating WIM systems located in the vicinity of truck inspection stations equipped with static weight scales. It is based on direct comparisons of WIM measurements to the static axle load of a large number of traffic stream trucks (i.e., at least 150) of known static weight. Where this is not possible, the LTPP protocol provides for WIM system calibration using test trucks. The recommended methods involve a number of refinements to the ASTM E1318-02 standard (*6*) as follows:

- One of the two test trucks must be a five-axle semi-trailer (i.e., 3S2) and, preferably, be equipped with an air suspension.
- The other test truck must have a different configuration or at least a different suspension type.
- Three- or four-axle single-unit trucks should not be used.
- The test trucks must have tires with conventional highway tread patterns.
- The 3S2 vehicle must have a GVW between 320 kN and 356 kN (72,000 lb and 80,000 lb).
- A minimum of 40 passes must be made (20 for each vehicle) at highway speeds.

This protocol also suggests monitoring WIM data calibration using the GVW distribution patterns of traffic stream vehicles. This consists of periodic comparisons of the frequency distribution of the GVW of 3S2 trucks to the frequency distribution established at a WIM site following test truck calibration. Significant differences between these frequency distribution patterns indicate a calibration drift. Figure 1 shows an example of such a drift indicated by the shifting to the right of the GVW peak weights of both empty and loaded trucks.

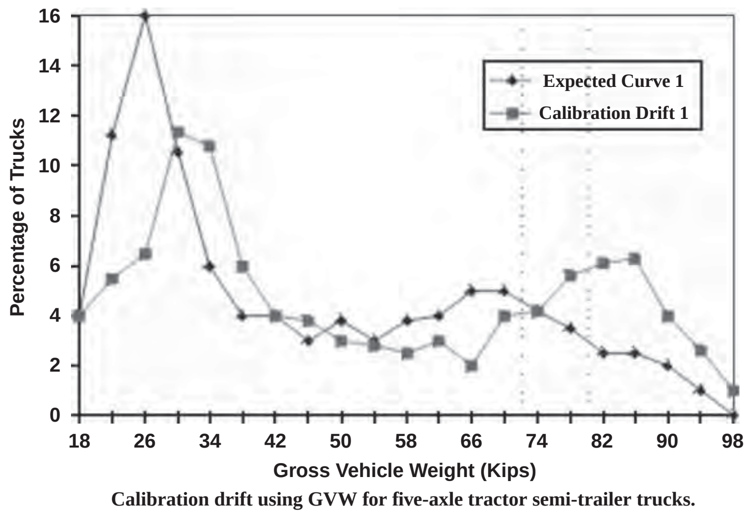


FIGURE 1 Example of GVW frequency distribution changing patterns (*14*).

HISTORIC WEIGH-IN-MOTION CALIBRATION PRACTICES IN THE UNITED STATES

Information for this section is derived from the *States' Successful Practices Weigh-in-Motion Handbook* (*15*) and reflects mid-1990s practices.

California Department of Transportation Practice

The California Department of Transportation (Caltrans) uses a variation of the ASTM E1318-02 standard for calibrating its WIM systems. The major departure from this standard is performing test truck passes at speed increments of 8 km/h (5 mph), plotting the resulting error in GVW measurements versus vehicle speed, and determining calibration factors for up to three distinct user defined vehicle speed "points." An example of such a plot is Figure 2, which shows a test truck's GVW WIM errors before calibration. Three speed points are selected, such as speeds of 72 km/h (45 mph), 88 km/h (55 mph), and 104 km/h (65 mph). Two straight lines are subjectively fitted, one providing best fit of the WIM errors between 72 km/h (45 mph) and 88 km/h (55 mph) and the other providing best fit of the WIM errors between 88 km/h (55 mph) and 104 km/h (65 mph).

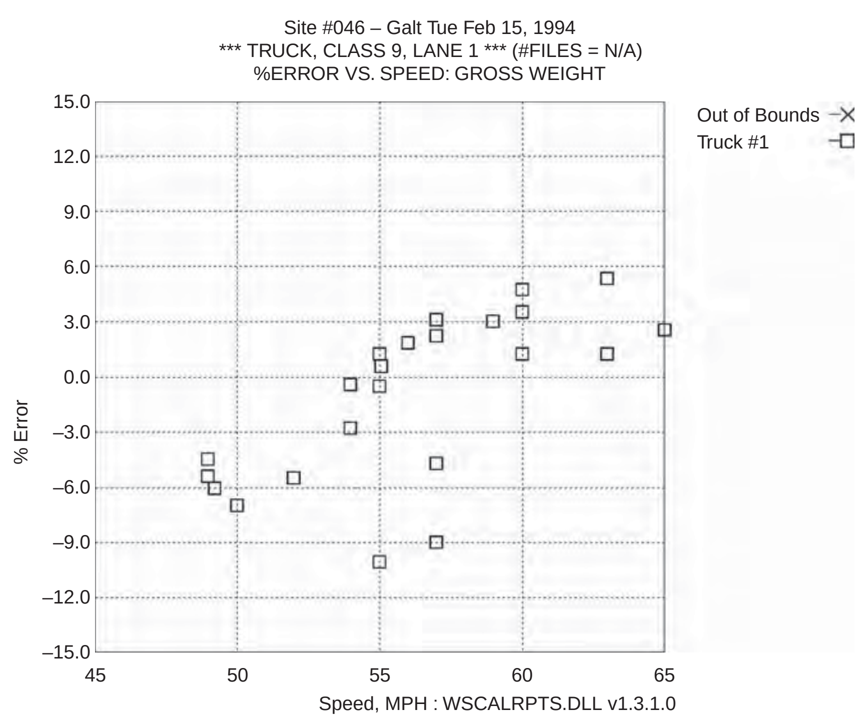


FIGURE 2 Example of GVW WIM measurement errors versus test speed.

The slope of these lines provides calibration factors for these two speed ranges. For the Figure 2 example, and given typical selected calibration factor speed points of 72 km/h (45 mph), 88 km/h (55 mph), and 104 km/h (65 mph), the resulting adjustment factors are as follows:

- Increase the calibration by 9% for the 72 km/h (45 mph) speed,
- No calibration adjustment for the 88 km/h (55 mph) speed, and
- Decrease the calibration factor by 6% for the 104 km/h (65 mph) speed.

For intermediate speeds in each speed range, WIM measurements are obtained through linear interpolation. After making these calibration factor adjustments, another set of test truck runs is performed to verify that the adjustments have resulted in GVW WIM errors closely concentrated around the 0% error axis. Caltrans field experience has shown that this approach results in lower traffic stream vehicle GVW WIM errors compared with a single calibration factor for all vehicle speeds.

Caltrans use a traffic data QC approach to monitor WIM system performance over time. The data QC approach involves four parts as follow:

1. Knowledge of site characteristics,
2. "Real time" review,
3. First level data review and,
4. Second level data review.

The first three steps ensure that a system is operating properly. The final step, second level data review, determines if calibration factor adjustments are needed and/or identifies equipment idiosyncrasies or subtle malfunctions not disclosed in the first level data review. Known operating characteristics of three traffic stream vehicle types can be used; namely, three-axle tractors with two-axle semi-trailers (i.e., 3S2s), three-axle single-unit trucks with two-axle full trailers, and two-axle tractors with one-axle semi-trailers and two-axle full trailers. This second level data review consists of the following two steps:

1. Evaluation of GVW data to obtain
   - Lane by lane comparisons and
   - Load frequency distribution patterns focusing on the location of the two peaks corresponding to loaded and empty trucks.
2. Evaluation of
   - Individual left and right weigh-pad output for both consistency and relative magnitude,
   - Effects of speed on the WIM weight output, and
   - Axle spacing and vehicle length accuracies.

Certain key statistical elements from each review are entered onto a log sheet that is used for the following:

- Documenting the effect of calibration factor changes on the WIM data for weight, axle spacings, and vehicle length;
- Establishing weight trends to determine seasonal variations and truck operating characteristic variations; and
- Determining whether or not calibration "drifts" over time.

This second level data review was initially performed using an off-the-shelf database program. Subsequently, a program was written in Basic to perform these functions. Finally, a much more comprehensive software program called the CTWIM Suite was developed in-house (*16*). It can be downloaded from www.dot.ca.gov/hq/traffops/trucks/datawim/install.htm. It accepts as input WIM data in ASCII, formatted according to Caltrans specifications. Although CTWIM was designed for WIM systems with dual weigh-pads (e.g., bending plates), it can be used for QC purposes with data from other types of WIM systems.

Minnesota Department of Transportation Practice

The Minnesota DOT used a test truck for initial WIM system calibration and autocalibration to maintain their calibration over time. The latter was used primarily for its bending plate systems, as described in *States' Successful Practices Weigh-in-Motion Handbook* (*15*). Initial calibration is carried out using a Class 9 test truck. Once concluded successfully, traffic stream data on Class 9 vehicles is monitored over a week-long period to verify that the GVW peaks occur at the following reasonable locations:

- Loaded peak between 329 and 347 kN (74 and 78 kips) and
- Unloaded peak between 125 and 133 kN (28 and 30 kips).

If these data are deemed satisfactory, they form the basis for the autocalibration, which is based on the FAWs of five-axle semi-trailer trucks (i.e., Class 9). Site-specific reference values for FAW weights are established for three distinct GVW groups of Class 9 vehicles. An example of such values is given in Table 8.

The autocalibration routine determines the differences between the average FAW WIM load for each GVW class and calculates adjustment factors. Weights are assigned to these adjustment factors as a function of the vehicle sample size used for computing them. These range from 0.2 for a single sample to 0.95 for 100 or more samples. An example of this weighing procedure is shown in Table 9 (i.e., the adjustment factor of +4.23% was computed by multiplying 4.7%, the deviation from reference, by 0.90, which is the weight factor that corresponds to a sample size of 59).

CURRENT WEIGH-IN-MOTION CALIBRATION PRACTICES IN THE UNITED STATES

The main source of information for this section is recent national and state documentation of WIM calibration procedures, as well as personal telephone interviews of a number of state DOTs that have lengthy experience in managing

TABLE 8
EXAMPLE OF AUTOCALIBRATION REFERENCE VALUES
FROM MINNESOTA DOT (*15*)

GVW kN (kips)	Reference FAW kN (kips)
<142 (32)	37.8 (8.5)
142–311 (32–70)	41.4 (9.3)
>311 kN (70)	46.3 (10.4)
Percent Deviation Allowed from Reference Weight	3.5%
Minimum Number of Monitoring Hours	48
Minimum Sample Size of Class 9 Vehicles	250

WIM systems. Its focus is on procedures that significantly differ from those of the ASTM E1318-02 standard.

Long Term Pavement Performance Specific Pavement Study Traffic Data Collection Pool Fund Study

The objective of this pool fund study is to determine the acceptability of the data being generated by existing WIM systems, to accelerate the installation or replacement of new systems, and to ensure the quality of the traffic data being produced for the LTPP experiments known as *Specific Pavement Study (SPS) 1, 2, 5, 6,* and *8* (*17*). The study is being carried out in two phases by two different contractors. The Phase I contractor is responsible for the evaluation of any existing or new systems installed by a state using its own procurement procedures, as well as newly installed systems under the pooled fund study. The Phase II contractor is responsible for the procurement, installation, and maintenance of the new pooled fund study systems. It is anticipated that ultimately this study will result in 9 existing and new state-installed WIM systems and 18 new Phase II contractor-installed systems.

The ASTM E1318-02 standard's functional performance requirements for Type I systems is being used for the purposes of this study. Certain other provisions of ASTM E1318-02 specifications are also used, enhanced by the provisions of the LTPP protocol as described earlier under the 1998 Long Term Pavement Performance Protocol (*14*). Additional refinements to these procedures were made by the TRB expert task group on LTPP traffic data collection and analysis. These refinements are as follows:

- A minimum of two test trucks are used, typically one 3S2 with a GVW between 338 and 356 kN (76,000 and 80,000 lb) and another 3S2 with a GVW between 267 and 285 kN (60,000 and 64,000 lb). The heaviest of the two trucks must have air suspensions for both tractor and trailer tandems.
- The ASTM E1318-2 tolerance requirements must be met not only by the entire dataset, but also by subsets of this dataset grouped by speed and ambient temperature.
- Static weighing of the test trucks is conducted before and after each set of test truck runs, and the axle weights and the GVWs are averaged.

Evaluation takes place in two stages. In the first stage, each test truck performs a minimum of 20 runs over the WIM system. If a change in calibration constants is deemed necessary, the Phase I contractor in conjunction with either the state agency or the Phase II contractor, determines the calibration factor adjustments. Regardless of whether calibration factor adjustments were made, a second stage of testing is undertaken involving another 20 runs of each of the two test trucks to verify the calibration of the WIM system. For WIM systems installed by the Phase II contractor, this contractor is responsible for the initial evaluation/calibration. If the performance standards are met, the system is deemed acceptable and it is turned over to the Phase I contractor for independent verification. If performance requirements are not met, the Phase II contractor is given the opportunity to make adjustments to the calibration factors and repeat the entire test truck evaluation process once again. If this new set of runs is unsuccessful, the Phase II contractor must make any sensor, hardware, or software replacement deemed necessary

TABLE 9
EXAMPLE OF MINNESOTA DOT'S WIM AUTOCALIBRATION CALCULATIONS (*16*)

GVW kN (kips)	Sample Size	Deviation from Reference	Adjustment Factor Weight	Adjustment Factor	Calibration Adjustment
<142 (32)	59	+4.7%	0.90	+4.23%	0.958
142–311 (32–70)	112	+4.3%	0.95	+4.09%	0.959
>311 kN (70)	79	+4.8%	0.90	+4.32%	0.957
Average Adjustment Factors	—	—	—		0.958

Source: Reference 16.

to correct the problem before performing a new performance evaluation.

Once a WIM system is installed through this process and is operational, its performance is monitored by the Phase II contractor using a two-level review process. The first level review consists of weekly reviews of the daily data files to check a system for proper operation and to determine the validity of the data. The second level review consists of a monthly data analysis of a sample (typically, a minimum of seven consecutive days) of 3S2 trucks in the traffic stream to monitor each system's maintenance of calibration and to identify any subtle operational problems. Several of the 3S2 truck properties are tracked and monitored, as shown in Table 10.

In addition to the 3S2 properties noted previously, the following properties are also included in the checks:

- GVW frequency distributions regardless of speed and
- GVW distributions by speed.

These properties are tracked and monitored by means of graphs and tabular distributions.

The noted properties for each month's check are compared with reference properties established from traffic stream data collected over a period of one week shortly after a successful evaluation/calibration of a system using test trucks as described earlier. For the monthly sampling to be used for calibration monitoring, it is important that the sampling consist of only data truly representative of the site's typical truck operating characteristics. Data from periods of time for which atypical conditions existed (road construction, holidays, extreme weather, etc.) should not be used. It is also noted that the calibration monitoring procedure described earlier is not an LTPP requirement. It is a procedure developed by the Phase II contractor to ensure the data quality required by the contract.

NCHRP Report 509

NCHRP Report 509: Equipment for Collecting Traffic Load Data (*18*) documents equipment and procedures for collecting traffic load data. It describes the on-site calibration approach using two test trucks standardized by ASTM E1318-02. Once calibration is verified, it is recommended that the traffic patterns established are used for monitoring WIM system calibration over time. This WIM data QC may involve the following data elements:

- Distribution of loaded and unloaded GVW peaks for the FHWA Class 9 trucks (or, potentially, other vehicle classes);
- Consistency of mean FAW for loaded Class 9 trucks;
- Consistency of percentage of weekday Class 9 trucks;
- Changes in the percentage of unclassified vehicles;
- Increases in equipment's counting errors;
- Consistency in load-relative magnitudes between right and left wheel path weighing sensors;

TABLE 10
EXAMPLE OF MONITORING TRAFFIC STREAM PROPERTIES OF A WIM SYSTEM (*17*)

SITE:	507- VIRGINIA SPS-1				CLASS 9 STATS						WIM LANE:	1 (SB #2)					
	PAT Bending Plates										AC Power, Tel Line						
YR				AVG	AX1 RT		AX1 LT		AXLE 1		GVW		%	AX SP	OAL	%	%
MO	DATES	DAYS	SAMPLE	SPEED	AVG	STD	AVG	STD	AVG	STD	AVG	STD	OVWT	2-3	+/-	INVAL	UNEQ DET
2006																	
12	19 - 20										INITIAL CALIBRATION						
2007																	
01	21 - 27	7	3,552	64.2	5.2	0.6	5.4	0.6	10.6	1.0	52.9	19.3	15.7	4.3	+1		
01/02	30 - 01				NO FACTOR CHANGES						POST VALIDATION						
02	04 - 10	7	3,691	64.6	5.2	0.6	5.4	0.6	10.5	1.0	52.6	19.3	15.5	4.3	+2		
02	16				REPLACE LOOP BOARD WITH MICROSENSE BOARD												
03	12 - 18	7	3,893	64.6	5.2	0.6	5.5	0.6	10.7	1.0	53.5	19.9	17.4	4.3		10.6	1.4
04	09 - 15	7	3,759	64.9	5.2	0.6	5.5	0.6	10.7	1.0	52.5	19.4	14.6	4.3		10.7	1.1
05	04 - 10	7	4,057	65.4	5.3	0.6	5.5	0.6	10.8	1.0	53.0	19.5	15.6	4.3	+2	12.0	1.4
06	04 - 10	7	4,061	65.1	5.4	0.6	5.5	0.6	10.9	1.0	52.8	19.4	16.3	4.3		16.2	1.6
07	16 - 22	7	3,987	64.9	5.3	0.5	5.6	0.6	10.9	1.0	53.3	19.6	17.1	4.3	+2	11.9	0.9
07	26				NO FACTOR CHANGES						POST VALIDATION						
08	13 - 19	7	3,820	64.9	5.4	0.6	5.5	0.6	10.9	1.0	53.6	19.5	18.5	4.3	+2	13.1	1.1
09	16 - 22	7	3,884	65.1	5.3	0.6	5.4	0.6	10.8	1.0	52.3	19.1	15.4	4.3	+2	12.3	1.4
10	14 - 20	7	3,766	64.6	5.3	0.6	5.4	0.6	10.7	1.0	53.0	18.9	15.9	4.3	+2	14.3	2.5
11	04 - 10	7	3,937	64.8	5.3	0.6	5.2	0.6	10.5	1.0	51.9	19.0	14.1	4.3	+2	16.7	4.6
12	10 - 16	7	3,942	64.7	5.3	0.6	5.2	0.6	10.5	1.0	52.2	18.8	13.9	4.28	+2	16.7	3.5

AX1 RT, AX1 LT = Right wheel path and left wheel path loads of Axle 1 (1,000 lb or kips), resp.

AXLE 1 = Axle load (1,000 lb or kips).

AX SP = Axle spacing (ft).

OAL = Over axle load limit (percent).

UNEQ DET = System error messages indicating right and left weigh sensors did not detect same number of axles.

- Consistency of tractor drive tandem axle spacings;
- Total number of vehicles within expected load ranges;
- Changes in time-of-day traffic patterns;
- Changes in hourly data volumes; and
- WIM system error diagnostic messages.

It is suggested that this WIM data QC process is essential and should not be replaced by autocalibration algorithms. The reason is that calibration drifting detected by data QC may be indicative of problems, such as pavement deterioration or sensor degradation, which cannot be rectified by simple calibration factor adjustments.

Long Term Pavement Performance Weigh-In-Motion Data Quality Control Software

This software was developed by LTPP (*19*). It implements a variety of traffic data QC tests, some of which relate to WIM data quality. This is conducted at two levels. The first level involves the raw Card-4 and Card-7 data obtained from the state WIM systems (i.e., they store individual vehicle classification and weight data, respectively). These QC tests involve comparisons of daily summaries of the following:

- Card-4 versus Card-7 data,
- Traffic count data for selected state vehicle classes, and
- GVW distribution data for selected state vehicle classes.

At the conclusion of this QC level, feedback is obtained from state DOTs to decide whether particular discrepancies in traffic patters can be justified by known changes in local traffic. Data that have passed the first QC review level are converted into the FHWA vehicle classification scheme (i.e., 13 classes) and entered into the second level of QC processing. The data elements analyzed at this QC level depend on the type of experiment that generated them (e.g., GPS; SPS 1, 2, 5, and 6; and SPS-pooled fund study). In general, it includes analysis of data summaries over a user-selected time interval that could be monthly or annually and cover multiple year periods. The data elements analyzed graphically include the following:

- Vehicle counts by vehicle class,
- Axle load distribution,
- GVW distribution,
- ESAL/vehicle, and
- Error statistics.

Clearly, these tests need to be performed by experienced users who must decide on the accuracy of the data on the basis of the software output graphs. Data that have successfully passed this QC process are labeled as "level E" and uploaded onto the Information Management System database.

Florida Department of Transportation Practice

The Florida DOT uses test trucks for WIM calibration. Before calibrating existing WIM systems, diagnostic checks are run to ensure that all the components for each WIM lane are operating properly. At least one Class 9 test truck with air tractor and trailer suspensions is used. Test truck runs are conducted at preselected speeds at which calibration factors are to be established. WIM errors versus speed are plotted to establish calibration factors for each of these preselected speeds. In addition, the calibration of speed and axle spacing measurements is adjusted, if necessary. During this process, communication with the test truck driver(s) is maintained by means of CB radio or cellular phone.

Following this step, the test truck(s) are run over the WIM system a minimum of two times at each of the calibration speeds as well as once at 8 km/h (5 mph) increments between the high and the low preselected calibration speeds. To isolate the effects of speed and temperature during the calibration session, test runs are performed in a sequence of low to high speed, which is repeated in the same order.

The WIM GVW percent error is plotted versus vehicle speed. This graph is analyzed to determine what adjustment needs to be made in the calibration factor for each preselected speed point to best reduce the overall GVW error to zero. If necessary, additional test truck runs are made to make final calibration factor adjustments. During initial calibration and verification, communications software is used to chronologically record the initial calibration factors, the WIM data elements for each test truck during each set of runs, any changes made to the calibration factors between test truck run sessions, the final calibration factors, etc.

The calibration of new WIM systems is slightly different than the one described previously. The main differences are as follow:

- No preliminary runs are made to adjust calibration factors.
- Test truck(s) runs a minimum of three times at each calibration factor speed point and three times at each 8 km/h (5 mph) increment between the high and low pre-selected speeds.
- The low to high speed incremental run sequence is performed three times.

If, for any reason, it is necessary to make adjustments to the calibration factors for either speed/axle spacing or weight, then the accuracy testing truck run procedure must be conducted again. Not only must the data item accuracies meet the functional performance requirements of ASTM E1318-02, but the percent GVW error plots must be evenly distributed around the zero error axis of the GVW versus vehicle speed plot. Following determination that the WIM system meets accuracy requirements, an analysis of the GVW versus speed graph is made and, if deemed appropriate, the calibration factors are again adjusted. This procedure is performed for each individual lane instrumented with WIM sensors.

California Department of Transportation Practice

Personal interviews with Caltrans personnel revealed that the methodology currently used for WIM calibration is essentially the same as the methodology followed by the Florida DOT.

Texas Department of Transportation Practice

The documentation submitted by the Texas DOT for calibrating WIM systems using test trucks was very comprehensive. The basic steps involved are as follows:

- A log file is initially created by the WIM system communication software to record all calibration events in chronological order.
- A number of test truck runs is made to first calibrate for speed/axle spacing measurements before commencing runs for weight calibration.
- The initial weight calibration factors are recorded for each speed.
- A minimum of three test truck passes is made each at 80, 96, and 112 km/h (50, 60, and 70 mph). Where necessary, the test runs at 80 and 96 km/h (50 and 60 mph) may be combined, and the runs at 112 km/h (70 mph) may be conducted at the speed limit.
- Calibration factors are computed for these distinct speeds using plots of GVW errors versus test speed.
- All test data are documented and a copy is left inside the WIM system cabinet.
- Finally, the log file is closed.

Indiana Department of Transportation Practice

The Indiana DOT uses a detailed WIM calibration procedure using test trucks. The main steps include the following:

- First, it is verified that the WIM system components are working correctly.
- The test truck drivers are briefed on the details of the test procedure to be used, including the sequence of speeds and lanes to be used as well as the signaling or cell phone/radio communication methods to be used.
- Initial test runs are intended to verify/adjust the speed/axle spacing calibration.
- Subsequently, the overall test truck wheelbase is verified/adjusted.
- Then, the WIM system weight calibration by speed range is performed as follows:
  - Initial calibration factors are set using a single pass of a test truck;
  - The test truck WIM data are inserted into a calibration spreadsheet;
  - If the GVW WIM measurements are accurate, but the FAW WIM measurements are not, the Dynamic Compensation Factor of the WIM system is adjusted (the Dynamic Compensation Factor is a front-axle-specific calibration factor adjustment);
  - The calibration process is concluded when both the GVW and the FAW WIM measurements collected for 10 consecutive test truck passes are within prescribed tolerances; and
  - Finally, the calibration factors are recorded and stored in a database.

Montana Department of Transportation Practice

The current Montana DOT WIM calibration practice applies to systems used for main-line weight enforcement screening for PrePass™ systems. WIM calibration is performed either quarterly to adjust calibration drift or as needed on the basis of the following weekly data:

- PrePass™ system rates at which vehicles are being stopped for static weighing;
- WIM data for performing QC (i.e., based on Class 9 vehicle GVW trends, changes in the number of unclassified vehicles, etc.); and
- PrePass™ static axle weight measurements.

For the latter, PrePass™ static axle load data are obtained for 25 Class 9 vehicles of each of the WIM lanes being monitored. These trucks exclude those that carry shifting cargo (e.g., liquid tankers and livestock haulers). WIM data are collected for the same trucks, which are identified manually on the WIM system printout to allow one-to-one comparison of static and WIM measurements. These reports are sent to the main office for analysis. To evaluate data and determine calibration factor adjustments, the following procedure is used for each WIM lane:

- The WIM data and the static weight data for each truck sampled are entered into a spreadsheet that calculates WIM error statistics. The tolerances are as follows:
  - Average GVW errors must be within 2% and
  - GVW error standard deviations must be lower than 6%.

If the WIM GVW errors are within tolerances, there is no need for calibration. Otherwise, the following steps are performed:

- A calibration factor correction is computed.
- The new calibration factor is averaged with the old calibration factor and the average is used to replace the old calibration factor by means of remote access (the reason for averaging is to effect small, rather than large, changes to system calibration).
- The new system calibration is verified using the same procedure and another sample of 15 Class 9 traffic stream vehicles.

Finally, if the WIM GVW error standard deviation is significantly higher than the specified tolerance, a visual inspection of the site is done to ascertain any roadway or sensor problems and, if deemed necessary, have these problems repaired.

New Jersey Department of Transportation Practice

The New Jersey DOT uses a single 3S2 test truck equipped with air suspension tandems for WIM system calibration. The test truck is driven on each WIM lane until a minimum of five passes of consistent single-axle and GVW WIM measurements are obtained. The average of the measurements of these five test runs is used as the basis of calibration. The calibration is validated by a minimum of another five consecutive passes of a test truck and the average axle and GVW WIM measurements are computed. The verification is satisfactory if the WIM average values are within 10% of the static weights for axles and within 5% of the GVW static weight. If these tolerances are not met, the process is repeated. If two iterations of this process prove unsuccessful, corrective action is taken (i.e., repair or replacement of pavement and/or sensors) before repeating the calibration procedure.

Utah Department of Transportation Practice

Utah has 15 permanent WIM sites, which consist of 9 piezoelectric systems (traffic data collection) and 6 load cell systems [Port of Entry (POE) applications]. POE sites utilize load cell systems, and the WIM vendor performs the calibrations biannually. The procedure used is to compare the static weights from the POE's static scale for particular trucks with their corresponding WIM measurements.

The traffic data collection sites use piezoelectric systems provided by two different vendors and calibrated by the Utah DOT. Currently, one vendor's systems use autocalibration, but the other vendor's systems do not (although the autocalibration feature is available). As such, two different calibration procedures are used for calibrating these systems. Both procedures use prescribed Class 9 steer axle weight targets. The major difference is that for one vendor's systems the calibration is automatically performed unattended by the systems, whereas for the other vendor's systems, a biweekly manual procedure of processing downloaded data, determining necessary factor adjustments based on steer axle weight criteria, and making the factor adjustments is used.

It was recommended that the procedures for systems utilizing autocalibration be continued. For the systems currently not using the available autocalibration feature, it was recommended that repairs to temperature sensors and any other needed modifications be made to the systems such that their autocalibration features may be utilized.

WEIGH-IN-MOTION-RELATED RESEARCH IN THE UNITED STATES

NCHRP Project 3-39(02)

On-Site Evaluation and Calibration of Weigh-in-Motion Systems, the final report for NCHRP Project 3-39(02) (*4*), deals with the on-site evaluation and calibration of WIM systems. It examines the feasibility of two methods, one using a combination of test trucks and vehicle simulation models, and the other using traffic stream vehicles of known static weight equipped with automatic vehicle identification (AVI) systems.

The first method utilized a modified version of the vehicle simulation model VESYM (*20*), referred to as VESYMF, to estimate the dynamic axle loads exerted by test trucks at three WIM sites, each equipped with pressure cells, bending plates, and traditional piezoelectric sensors. At each site, the pavement roughness profile was measured using an inertial profilometer (*30*). A field experiment was conducted at each of these sites involving three test vehicles, namely a two-axle single-unit truck, a three-axle single-unit truck, and a 3S2 truck. Each truck performed 10 replicate runs at each of four speeds (i.e., 50, 70, 90, and 110 km/h [31, 43, 56, and 68 mph]). The WIM measurements were plotted for each axle as a function of speed, as shown in Figure 3. For a given speed, it was observed that individual axles produce very precise WIM measurements as a result of their repeatable dynamics (i.e., average coefficients of variation of 3.8%, 5.7%, and 3.8%, respectively). Efforts to predict the magnitude of the dynamic load of individual axles over the WIM sensors using the vehicle simulation model were unsuccessful. Instead, the vehicle simulations were used for computing the distribution of axle load dynamics at the WIM site, given

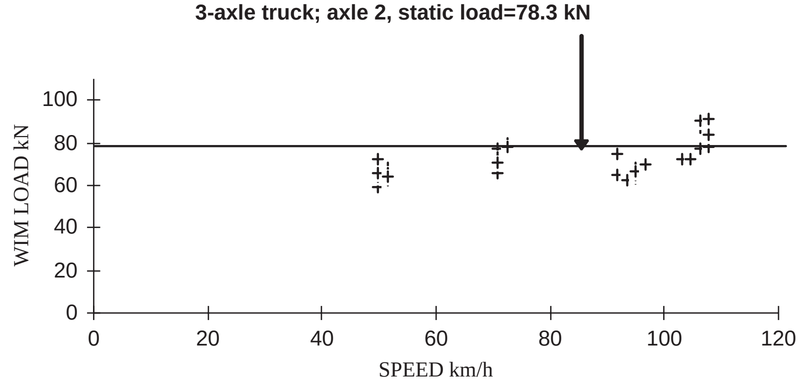


FIGURE 3 Example of pressure cell WIM measurements of an axle versus speed (*4*).

the pavement profile. This approach provides a rigorous connection between pavement smoothness and WIM errors.

This project also developed an automated method for comparing WIM with static axle loads of traffic stream vehicles equipped with AVI. This method is based on static load data obtained for particular vehicles at truck inspection stations, which are subsequently identified by the AVI as they travel over WIM systems. The method was field-tested using the fixed AVI facilities of the Heavy Vehicle Electronic License Plate program on the I-5 corridor in Washington State, Oregon, and California. Software was developed automating the WIM calibration calculations. This method was shown to be feasible in calibrating WIM systems, where fixed AVI facilities are available. It was also shown to be feasible using transportable AVI equipment developed for this purpose. This equipment was field-tested at two WIM sites on I-94 in Minnesota.

Multi-Sensor Weigh-In-Motion and Artificial Neural Networks

A number of studies have used multi-sensor WIM (MS-WIM) configurations and focused on the use of statistics for improving the resulting static load estimates (*21*). Recent work offers an alternative based on Artificial Neural Networks (ANN) (*22*). This approach involves measuring the WIM site pavement profile, using dynamic vehicle simulations (*20*) to model dynamic axle load and "train" the ANN algorithm to yield static axle loads. This approach was shown to significantly improve WIM accuracy, especially where pavement roughness was high. For example, WIM systems classified (see Table 4 for *COST 323* WIM class designations) as B(10) by simply averaging the WIM reading of each of the multiple sensors, were improved to B+(7) and in some cases to A(5) by applying the ANN algorithm on the output of the multiple piezoelectric sensors.

Indiana/Purdue Study on Weigh-In-Motion Data Quality Control

Indiana DOT and FHWA cosponsored a study to explore innovative WIM QC methods (*10*). The motivation of this study, in addition to maintaining long-term data quality, was to more effectively manage WIM systems across the network. Formal QC techniques were followed, including:

- Define,
- Measure,
- Analyze,
- Improve, and
- Control and Statistical Process Control.

The following procedure describes how these techniques were applied in conducting WIM data QC.

Two WIM system metrics are targeted, namely the axle spacing in drive tandem axles of Class 9 trucks and the difference between the left-hand-side and right-hand-side wheel loads of the steering axles of Class 9 trucks (referred to as "left-right residual"). Clearly, the latter is applicable only to Type I WIM systems.

The statistical properties of the first metric were established from manufacturer data of Class 9 trucks in the United States. These data suggest four common axle tandem spacings, namely 130, 132, 137, and 149 cm (4.25, 4.33, 4.50, and 4.58 ft). These spacings are the result of standard drive axle suspension designs; they have been fairly constant in the past and are anticipated to remain relatively unchanged in the future. It was concluded that 99% of the population of axle spacings falls in the interval between 130 and 140 cm (4.25 and 4.58 ft) and have a weighted average of 132 cm (4.33 ft). As a result, the accuracy of WIM systems in measuring vehicle speed can be tracked by the spacing of the tandem axle of Class 9 truck tractors.

The statistical properties of the second metric were established by extensive study of the configuration, mechanical arrangement, and dynamics of Class 9 truck tractors, as well as the result of the pavement cross-slope on the distribution of wheel loads between the left- and right-hand side. It was concluded that the latter differ less than 1% and hence can be used as a QC metric for WIM systems that separately measure left and right wheel loads (i.e., Type I systems).

The report presents the methodology used for downloading WIM data and analyzing them according to the QC methodology described previously. The data are downloaded into a relational database, such as Microsoft SQL. Cube files were created using the online analytical processing tools from the Microsoft SQL analysis server. These files can be viewed as pivot tables and pivot charts by means of a Microsoft Excel connection to the analysis server database and can also be created offline for distribution to users who do not have online access to the database. These analysis cube files allow simple summary reporting while affording detailed data mining capabilities.

The aforementioned analysis approach can be used to generate accuracy graphs for spacing/speed and left/right weight of Class 9 trucks. These data are used to identify WIM systems that are grossly off calibration and allow adjusting their calibration temporarily, until a proper calibration involving test trucks can be undertaken. The latter is warranted if the adjusted system generates stable data, which can be tracked through statistical process control charts (i.e., graphs indicating the allowable confidence intervals for the properties being measured).

Another innovation described in this study is the use of WIM systems as "virtual weigh stations," which allow enforcement officers to view real-time truck records by means of a wireless link. Vehicles to be stopped for static weighing can be flagged automatically or this decision can be made by the enforcement officers. Analysis determined that such virtual weigh stations are approximately 55 times more effective than static weigh stations alone in capturing overweight vehicles.

Utah Department of Transportation/Brigham Young University Study on Weigh-In-Motion Calibration

The Utah DOT sponsored a study on WIM calibration (*23*) intended to improve Utah's commercial motor vehicle data collection program. To accomplish these objectives several tasks were undertaken, including the following:

- Performance of a literature review to establish the state of the practice for commercial motor vehicle monitoring,
- Collection of WIM data for the state of Utah,
- Analysis of the WIM data collected,
- Development of a calibration methodology for use in the state, and
- Suggestions and conclusions based on this research.

The literature review focused on:

- WIM history,
- Basic WIM concepts,
- WIM technologies,
- Weight data collection standards and their calibration,
- Quality assurance methods,
- *TMG* weight data collection, and
- Discussion of the new AASHTO *Pavement Design Guide*.

The literature review conducted for this study was extensive and each of the above listed topics is discussed in some detail.

The report describes Utah's 15 permanent WIM sites, which consist of 9 piezoelectric systems (traffic data collection) and 6 load cell systems (POE applications), and discusses the methods used to perform analyses of the data collected from these sites. Each site's median and spread of the data, as well as the extent and nature of any departure from symmetry, were determined. The daily average steering axle weight for Class 9 vehicles was graphed for each site. Based on known static weight data, the average steering axle weight is expected to be approximately 49 kN (11,000 lb) with an acceptable site variance of ±20%. The drive tandem axle spacings for Class 9 vehicles were also found to be fairly constant, expected to average approximately 132 cm (4.33 ft), which provides a quality assurance measure for checking a WIM system's speed and axle spacing outputs. The acceptable ranges for drive tandem spacing are ±15 cm (0.5 ft). The percent of overweight trucks (Class 5 and above) for each site was found to be another viable data analysis metric.

A survey was conducted of 10 states with regard to system calibration procedures and methodologies. The report discusses the findings for each of the 10 states. The calibration and validation practices currently used in Utah were also reviewed. Recommended procedures were developed to bring Utah DOT practices in line with current WIM standards and practices of other states.

Currently, there is no validation procedure for the piezo systems. It was recommended that a verification process be implemented and that it include runs with a single test truck (predominate class at site, typically Class 9) to verify the systems' autocalibrations on, as a minimum, an annual basis. The recommended verification procedure included the following steps to be taken before making test truck runs:

- Evaluate the physical characteristics of the site, including pavement conditions 84 m (275 ft) before and 9 m (30 ft) after the WIM sensors.
- Check the WIM system's components for proper operation and check for proper software settings (weigh sensor and inductive loop thresholds, etc.).
- Use a radar gun to check speed calibration.

The test truck procedure, as well as the verification of conformance to performance requirements, is in general conformance to the ASTM E1318-02 standard for Type II systems, although there is some modification in the number of test truck runs and speeds.

Quality assurance methods are recommended to assess the data quality and, in turn, WIM system performance. Included in such assessment is the creation of the following graphs:

- Vehicle class histogram,
- Daily average Class 9 steering axle weight,
- Daily average Class 9 drive tandem axle spacing, and
- Class 9 GVW histogram.

The graphs are prepared on a quarterly basis.

EUROPEAN WEIGH-IN-MOTION CALIBRATION PRACTICES

The main source of information in this section is a recently completed report by the Commercial Motor Vehicle Size and Weight Enforcement scanning tour (*24*). It had two WIM related objectives, namely:

- Emerging WIM technologies capable of accuracies that will allow their direct use in enforcement applications and
- Novel uses or applications of WIM data to support pavement design, bridge/structural design, traffic engineering, transportation planning efforts, or ongoing performance monitoring and evaluation of vehicle size and weight enforcement programs.

The Commercial Motor Vehicle Size and Weight Enforcement scanning tour included six European countries (Belgium, France, Germany, the Netherlands, Slovenia, and Switzerland). It produced a critical review of contemporary European practices of WIM system utilization in enforcing commercial motor vehicle size and weight regulations. The majority of these systems use piezoelectric sensors. The basic WIM calibration standard used by these countries was developed by the *COST 323* study (*7*). The actual implementation of this standard, however, varies among countries. The highlights of the findings of this scanning tour are as follows:

- France operates in excess of 170 WIM stations and relies largely on autocalibration techniques to keep them calibrated.
- France and the Netherlands are developing MS-WIM systems capable of detecting axle weights at highway speeds with an accuracy rate that is sufficient for direct load enforcement. They anticipate that, with the appropriate administrative changes, this goal will be reached within the next 10 to 15 years.
- France has experimented with fiber-optic WIM sensors and has made progress in isolating the sensitivity of their output to steel in reinforced portland concrete pavements. Detailed documentation on the theoretical development and field performance of these sensors is provided in a *Weigh-in-Motion of Axles and Vehicles for Europe* (*WAVE*) report (*25*).
- The Netherlands has developed an instrumented vehicle that allows WIM calibration using a reference dynamic rather than static axle loads.
- Slovenia's WIM calibration is conducted by either test trucks or traffic stream vehicles of known axle weights following *COST 323* specifications. The pertinent documentation and WIM data are available online (see http://www.siwim.com/).
- Switzerland reports WIM system maintenance practices that involve annual inspections of sensors for wear and actual calibration according to the *COST 323* standard. Approximately 40 to 50 vehicles in excess of 3.5 metric tons are diverted from the local traffic stream to be statically weighed. They estimate that this requires approximately 15 staff for one to two days per year (e.g., approximately 120 to 240 person-hours).

A number of innovative enforcement screening methods are used involving digital photographic records of vehicles. These are as follows:

- WIM measurements and photographic records of vehicles that are likely overloaded are transmitted to mobile static weighing crews downstream (in Switzerland this is called WIM/VID).
- Records of WIM data and photographic records are analyzed to identify companies that habitually violate load limits. These companies are, in turn, contacted through the mail and given the opportunity to conform in the future.

EUROPEAN WEIGH-IN-MOTION-RELATED RESEARCH

Weigh-in-Motion for Axles and Vehicles for Europe (WAVE) has been one of the most significant European WIM-related research studies (*5*,*11*,*21*,*26*). The WAVE project had the following major objectives:

- Develop innovative methods for WIM system evaluation/calibration (*11*),
- Develop innovative WIM systems with multiple sensors (i.e., MS-WIM) (*21*), and
- Improve WIM data QC procedures (*26*).

The major innovation of the WAVE project in WIM system calibration was an instrumented three-axle single-unit truck developed by the Technical Research Center of Finland (VTT). Its instrumentation consisted of strain gauges and accelerometers installed on the vehicle axles to detect bending and vertical acceleration, respectively. The signals generated were combined into measurements of dynamic axle loads on board the vehicle. This type of instrumentation was used in the mid-1980s by the National Research Council of Canada (NRCC) on a five-axle semi-trailer truck (*32*). The VTT vehicle was used for testing WIM accuracy with respect to dynamic, rather than static, axle loads. This approach was successfully tested by Papagiannakis et al. using the NRCC instrumented truck (*27*). The main challenge with this approach was identifying the segment of the dynamic load measurements that corresponded to the location where an instrumented axle is over the WIM sensor. The importance of synchronizing test truck dynamic load measurements and WIM measurements is illustrated in Figure 4. This figure shows the size of a bending plate sensor; that is, about 0.3 m (1 ft) wide, superimposed on the dynamic load measurements from three passes of the drive axle of the VTT vehicle at 80 km/h (50 mph). This figure also demonstrates that dynamic axle loads under the same speed exhibit repeatability in space, which explains the resulting lower variation in errors for a given speed and axle.

The study also explores the idea of developing individual calibration factors by axle type and vehicle configuration. This instrumented vehicle was also driven over an array of 16 piezoelectric WIM sensors arranged in various spacings to examine whether these multiple sensors could improve static load predictions.

The development of MS-WIM (*21*) involved numerical simulations of the dynamic behavior of an idealized five-axle semi-trailer truck and of alternative arrangements of multiple sensor WIM installations. The simulation model for the five-axle semi-trailer truck was a theoretical two-dimensional model (i.e., pitch and bounce) that accepted the pavement profile as input. Similar models can be found in the U.S. literature (*20*). The dynamic axle load predictions

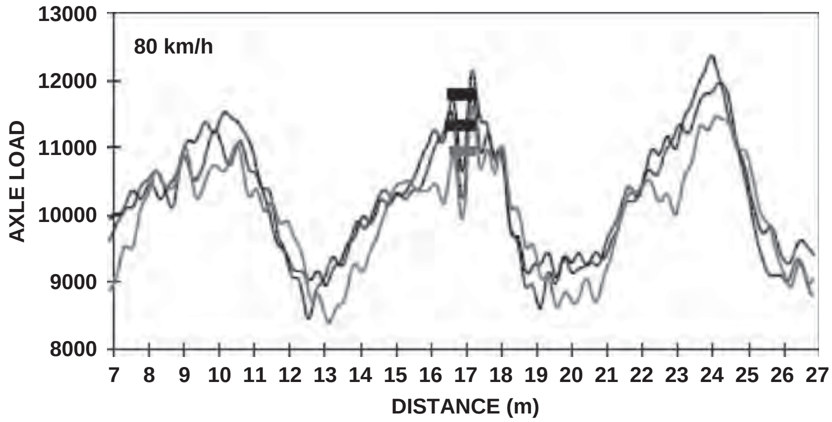


FIGURE 4 WIM evaluation using the VTT instrumented vehicle (*28*).

were simplified through several sinusoidal functions to describe the dominant dynamic load frequencies. This information was, in turn, used for estimating multi-sensor number and spacing to minimize the error between WIM and static axle loads. These results were finally field-validated using test trucks on several multi-sensor WIM installations.

The WAVE project also dealt with WIM data QC (*26*). The main objectives of this part of the study were to standardize WIM data QC and storage (i.e., the EU-WIM database), as well as to develop software that allows extraction of data by a variety of traffic data users. It is comprised of two parts, a "low level" dealing with the functionality of the sensors and electronics themselves and a "high level" dealing with the quality of data being output and their statistics. The low-level data QC consists of evaluating the following:

- Scale factor; that is, the maximum registered axle load (i.e., unusual or repeating values indicate that the sensor is malfunctioning or broken),
- Total traffic volume,
- Heavy vehicle traffic volume, and
- Status error messages, if any.

The high-level data QC is based on analysis of WIM data and their statistics using criteria such as the FAW and the GVW of certain truck classes. A computer program called MAR-TINE is used for these calculations.

DISCUSSION

The review of the national and international literature on WIM system calibration standards, practice, and related research reflects the significant effort expended in maintaining WIM traffic data quality. Conventionally, WIM errors are computed with reference to static load. As a result, errors are largely dependent on pavement roughness and the dynamic properties of the vehicles used for evaluating them (vehicle class, suspension type, and speed). Another issue is that the stiffness of the pavement supporting the WIM sensors influences their signal output. This is more pronounced in asphalt concretes that exhibit temperature-dependent stiffness. This problem is further compounded by the temperature sensitivity of some Type II WIM sensors. Error tolerances are set in the form of either

- Fixed confidence intervals, given a confidence level and a prerequisite pavement roughness (empirically established), as in the ASTM E1318-02 standard, or
- Variable confidence intervals, depending on the desired confidence level, available pavement roughness (IRI) and sample size, as in the *COST 323* standard.

In this light, the current U.S. WIM calibration standard, ASTM E1318-02, has the following limitations:

- It does not consider pavement roughness as it relates to dynamic axle loads and, hence, the magnitude of the resulting WIM errors. The proposed AASHTO provisional standard MP 14-05 addresses this limitation through estimates of the dynamic response of a simulated fleet of trucks. This approach is an improvement over the *COST 323* approach that sets empirical pavement roughness limits in terms of IRI, which is based on the relative displacement of the axle with respect to the frame of a passenger car.
- It does not consider pavement stiffness in supporting WIM sensors, which, as described earlier, is being considered by the *COST 323* WIM standard.
- It does not allow for a variable confidence level in establishing error tolerances (i.e., confidence intervals). The approach taken by the *COST 323* standard is more general, in as much as it provides for variable error tolerances as a function of the desired confidence level.
- It assumes that errors are normally distributed in establishing error tolerances. A Student-*t* distribution would be more appropriate for WIM errors, given the small

number of samples typically available during calibration. This is the approach used by the *COST 323* standard, whereby error tolerance is defined as a function of sample size.
- Finally, it does not include WIM data QC methods. The latter was not one of the objectives of the ASTM E1318-02 standard, but it may need to be standardized.

In addition to the main limitations described earlier, a number of enhancements may need to be considered in updating the national WIM calibration standard. These include data analysis by speed to quantify WIM system precision under replicate axle passes and to establish speed-specific calibration factors. Finally, a number of technological innovations may need to be considered for the future enhancement of WIM calibration, such as the use of instrumented test trucks and the use of traffic stream AVI-equipped trucks. Additional discussion on future research directions, which is based on the results of the survey questionnaire, is included in the following chapter.

CHAPTER THREE

SURVEY QUESTIONNAIRE

The general structure of the survey includes three main groups of questions dealing with on-site calibration using test trucks, calibration using traffic stream vehicles of known static weight, and calibration monitoring using properties of the traffic stream. The corresponding series of questions in Appendix B are 3.5, 3.6, and 3.7. The survey was structured in a way that allowed identifying the role of the agency responding; that is, either a DOT collecting traffic data, an enforcement agency performing load limit screening, or both. The questionnaire was input into a proprietary web-based format that allowed agencies to respond online. Statistics on the number of questionnaires distributed and the response rate are shown in Table 11. Of the agencies that responded to the questionnaire, 7 used WIM for both data collection and enforcement and had a common agency for managing these systems. The Connecticut DOT submitted two responses, one for traffic data collection and another for research. Table 12 shows a summary of agency responses by state.

Where necessary, questionnaire distribution was followed by telephone interviews to assist responders in filling out the survey and ask for any additional documentation available.

TABLE 11
SURVEY QUESTIONNAIRES CIRCULATED AND RESPONSES RECEIVED

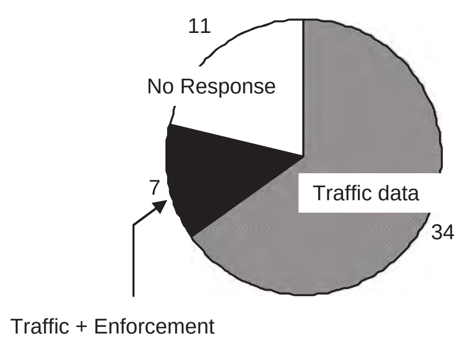
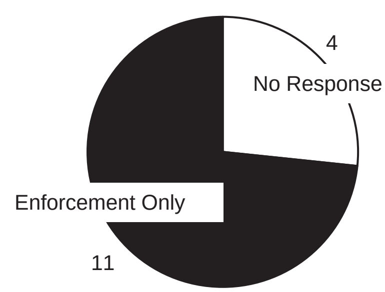
DOT Questionnaires Circulated = 53*	Enforcement Agencies Questionnaires Circulated = 15**
 *50 States + DC + Puerto Rico 1 extra for research by Connecticut	 **13 States do not use WIM in enforcement, 16 had no identifiable enforcement agency

TABLE 12
SUMMARY OF AGENCY SURVEY RESPONSE BY STATE

	Traffic Data	Enforcement
Alabama	□	□
Alaska	□	NA
Arizona	□	□
Arkansas	□	NA
California**	□	□
Colorado	□	□
Connecticut	□□	NR
Delaware	NR	NC
District of Columbia	NR	NA
Florida	□	NC
Georgia	□	NA
Hawaii	NR	NC
Idaho	□	□
Illinois	□	NA
Indiana	□	NR
Iowa	NR	NC
Kansas	□	NC
Kentucky	NR	NA
Louisiana	NA	□
Maine	NR	NC
Maryland	□	□
Massachusetts	□	NA
Michigan**	□	□
Minnesota	NR	NA
Mississippi	□	NA
Missouri	NR	NC
Montana	□	□
Nebraska	□	□
Nevada**	□	□
New Hampshire	□	NA
New Jersey	□	NA
New Mexico	□	NC
New York	□	NA
North Carolina	NR	□
North Dakota**	□	□
Ohio**	□	□
Oklahoma	□	NA
Oregon**	□	□
Pennsylvania	□	NA
Puerto Rico	□	NA
Rhode Island	□	NR
South Carolina	NR	NC
South Dakota	NR	NA
Tennessee	□	NC
Texas	□	NA
Utah	□	NC
Vermott**	□	□
Virgina	□	□
Washington	□	□
West Virginia	□	NC
Wisconsin	□	NC
Wyoming	□	NA

** = state submited one questionaire for both traffic and enforcement systems.
□ = agency responded.
NA = agency does not use WIM for this purpose.
NR = agency did not respond.
NC = no contact identified to fill survey.

CHAPTER FOUR

MAJOR SURVEY FINDINGS

DOTs replied as follows when asked how they cooperate with the enforcement agency in their state managing WIM systems:

- Six reported that they provide traffic WIM data to an enforcement unit for enforcement planning purposes.
- One stated that it collects data from WIM systems that are calibrated and maintained by the enforcement agency.
- Two stated that they install, calibrate, and maintain WIM systems for the enforcement screening at PrePass™ sites.
- One stated its repair crews occasionally perform work for the enforcement agency.
- One stated that it allows the enforcement agency wireless real-time access to WIM data during mobile enforcement operations.
- One stated that it provides contract plans review, evaluation/inspection services, post-warranty maintenance, and traffic data collection/analysis for the enforcement agency's WIM systems.
- One stated that it coordinates with the enforcement agency regarding WIM data quality and future site locations with high volumes of heavy trucks.

When asked how they cooperate with the DOT in their state managing WIM systems, enforcement agencies replied as follows:

- Seven reported that they make WIM data from their main line screening systems available to the DOT's traffic data unit.
- One stated that it provides static scale readings to the DOT's traffic data unit for testing WIM systems.

The overall findings of the survey are presented in Appendix D, which is presented in the online version only. The survey results were divided into three parts, to be made available electronically, as follows:

- Systems used for traffic data collection only,
- Systems used for both traffic data collection and enforcement screening, and
- Systems used for enforcement only.

The following tables offer a summary of the background findings of the survey. Table 13 suggests that most traffic data collection WIM systems are Type I, although the majority of the combined traffic data/enforcement screening sites are Type II systems. Interestingly, the majority of WIM systems used exclusively for enforcement screening are Type II systems. Table 14 suggests that autocalibration is used primarily for Type II systems used for both data collection and enforcement screening. Table 15 suggests that the majority of state agencies, regardless of application, perform in-house post-installation WIM system calibrations.

It should be noted, however, that not all agencies use test trucks in post-installation calibration. Two of the 25 agencies that reported conducting post-installation calibration use alternative methods. One agency uses FAW monitoring of traffic stream vehicles, whereas another relies on autocalibration. Table 16 shows the method used for performing routine WIM calibration. Note that some agencies use more than one method for calibration and/or monitoring the calibration over time. Under "Other," agencies provided clarifications on how one or more of the three listed methods were implemented (these are not shown in the table).

A summary of the actual number of agencies using particular WIM calibration methods is given in Table 17. It is noted that the majority of agencies that responded use more than one method for WIM calibration. Only five of the agencies reported using traffic data QC alone for this purpose.

The following sections present summaries of the survey findings organized in three parts, as follows:

- Test truck WIM calibration,
- Traffic stream truck WIM calibration, and
- WIM calibration through WIM data QC.

TEST TRUCK WEIGH-IN-MOTION CALIBRATION QUESTIONS

Under this questionnaire segment, agencies were asked questions about how they calibrate their most common WIM systems using test trucks. The number of agencies using test trucks for WIM calibration varies depending on their function, as follows:

- Twenty-two of the 34 agencies managing traffic data collection WIM systems use test trucks for WIM calibration. Six of these agencies reported that their most common WIM systems are Type I, whereas the remaining 16 reported that their most common systems are Type II.

TABLE 13
WHAT TYPES OF WIM SENSORS ARE USED?

WIM Sensors	Type I	Type II	Other
Traffic Data Only	56.3%	37.5%	6.3%
Both	33.3%	55.6%	11.1%
Enforcement Only	29.4%	58.8%	11.8%

Other = Type III, portable WIM sensors pit-embedded, single wheel path load cells.

TABLE 14
WHAT TYPE OF SENSORS IS AUTOCALIBRATION USED FOR?

Sensor	Type I	Type II	Other
Traffic Data Only	14.3%	75.0%	10.7%
Both	0.0%	100.0%	0.0%
Enforcement Only	50.0%	50.0%	0.0%

- Six of the seven agencies managing traffic data and enforcement screening WIM systems use test trucks for WIM calibration. Four of these agencies reported that their most common WIM systems are Type I, whereas one reported that its most common WIM systems are Type II.
- Two of the 11 agencies managing enforcement-only WIM systems use test trucks for WIM calibration. Their most common WIM system is Type I.

TABLE 15
IS POST-INSTALLATION CALIBRATION ALWAYS PERFORMED?

		Who Does it?	
	Yes	Agency	Vendor
Traffic Data Only	75.8%	51.5%	33%
Both	66.7%	66.7%	33.3%
Enforcement Only	90%	23%	77%

A summary of agency responses on the methodology used to calibrate WIM systems using test trucks is are shown in Table 18, which suggests that approximately half of the agencies perform test truck WIM calibrations in-house, and Table 19, which suggests that the majority of agencies does so on a routine basis. A contractor/manger differs from an on-call contractor. The former decides when on-site calibration is need, whereas the latter responds to an agency request to perform calibration. The frequency in routine calibrations ranges from 6 months to 24 months, with the majority performed at 12-month intervals, as shown in Table 20. In addition, some agencies do test truck calibrations in response to indications of calibration or for other reasons (e.g., changes in pavement or sensor condition).

Interestingly, although the majority of agencies using test trucks for WIM calibration reports considering pavement

TABLE 16
WHICH CALIBRATION METHOD IS USED?

	Test Trucks	Traffic Trucks	Traffic Data QC	Other
Traffic Data Only	66.7%	33.3%	57%	18%
Both	33%	22.2%	39%	5%
Enforcement Only	5.9%	58.9%	29.4%	5.9%

TABLE 17
WIM METHOD CALIBRATION METHOD SUMMARY

Calibration Method	Traffic Data Only	Both	Enforcement Only
Test Truck Only	7	0	0
Traffic Trucks Only	2	0	6
Traffic Data QC Only	4	0	1
Test Truck and Traffic Trucks	3	0	0
Test Truck and Traffic Data QC	8	3	0
Traffic Trucks and Traffic Data QC	2	1	3
All three methods	4	3	1
Other	6	1	0
No response	4	0	0

TABLE 18
WHO PERFORMS THE TEST TRUCK CALIBRATION?

	Agency	On-Call Contractor	Contractor/Manager	Agency and Contractor
Traffic Data Only	55%	9%	27%	9%
Both	80%	—	—	20%
Enforcement Only	50%	—	—	50%

TABLE 19
WHAT TRIGGERS CALIBRATION?

	Routine Schedule	Drift Indication	Other
Traffic Data Only	67%	26%	7.4%
Both	42.8%	28.6%	28.6%
Enforcement Only	50%	50%	—

TABLE 20
IF CALIBRATIONS ARE DONE ROUTINELY, HOW OFTEN?

	6 Months	12 Months	24 Months
Traffic Data Only	31.2%	67%	6.7%
Both	—	100%	—
Enforcement Only	—	100%	—

TABLE 21
IS SITE SMOOTHNESS CONSIDERED?

	Always	Only if Tolerance Not Met	Never
Traffic Data Only	59%	27.3%	13.6%
Both	100%	—	—
Enforcement Only	100%	—	—

roughness (Table 21), only about 25% does so objectively; 11.1% do the straightedge/circular plate test described by ASTM E1318-02, 3.6% simulate this test using software that accepts as input the pavement profile and 14.8% simply use the IRI (Table 22). Even fewer agencies consider the structural condition of the foundation of the sensors. Some do so indirectly by studying the shape of the sensor's raw signal and do so only when WIM measurements seem to be inaccurate (Table 23).

Tables 24 to 34 give details of the actual procedure used in test truck calibration and the calculations used for computing calibration factors. The majority of agencies use one or two test trucks (Table 24). The single truck chosen is typically a Class 9. Where two trucks are used, one is a Class 9 and the other is either a Class 5 or 7, with only one agency reporting using a Class 10 truck. Some agencies use two Class 9 trucks.

The majority of agencies specify an air suspension type for the test trucks (Table 25), but this is not always enforced. The majority of agencies uses fixed weigh scales for obtaining the static loads of test trucks, although more than 40% of agencies managing dual-use WIM use portable scales (Table 26). The majority of agencies weigh axle groups rather than individual axles (Table 27), which is probably the result of the configuration of enforcement static weigh scales. Most agencies perform the measurements only once (Table 27).

Table 28 lists the criteria used by agencies in selecting test truck speeds. About half of the WIM systems, regardless of application, are calibrated using test trucks running at the site median traffic speed. The remainder is divided between the posted speed limit and multiple speeds. The majority of agencies managing dual-use WIM systems use multiple test speeds. Instructions are issued to the drivers either by means of two-way radios or cell phones.

Although the majority of agencies using WIM traffic for data collection only conduct 10 test runs per vehicle speed, agencies using WIM for either traffic data/enforcement or enforcement alone conduct three test runs per vehicle speed (Table 29). The corresponding percentage of agencies not turning their autocalibration off during test truck calibration is 30% for those using WIM for data collection only, 20% for agencies using WIM for data collection and

TABLE 22
WHAT METHOD IS USED FOR QUANTIFYING SMOOTHNESS?

	Visual	Straight Edge/Circular Plate	Profile+ IRI	Profile+ LTPP Software	Other
Traffic Data Only	66.7%	11.1%	14.8%	3.6%	3.6%
Both	40%	30%	10%	10%	10%
Enforcement Only	100%	—	—	—	—

TABLE 23
DO YOU CONSIDER THE STRUCTURAL CONDITION AT THE SITE?

	Yes
Traffic Data Only	36%
Both	25%
Enforcement Only	0%

TABLE 24
HOW MANY TRUCKS ARE USED?

	1	2
Traffic Data Only	90%	10%
Both	100%	—
Enforcement Only	—	100%

enforcement, and 50% for agencies using WIM for enforcement only (Table 30). Responders indicated that overall, 87% of agencies carry out calibration calculations on site.

Table 31 shows that the calibration calculation method for traffic data WIM systems is equally split between agency software, vendor software, and short-hand calculations. Although for dual-use WIM systems, most agencies use short-hand calculations; for enforcement-only systems, about two-thirds of the agencies use vendor software to carry out the calculations.

The main load data elements for which WIM errors are computed are the GVW, individual axle loads, and tandem axle loads (Table 32). The majority of agencies computes calibration factors by setting the mean GVW equal to zero or by setting a combination of the mean GVW and the mean axle load errors equal to zero. Few agencies compute calibration factors by minimizing the least square error between WIM and static axle loads through zero-intercept regression (Table 33). Depending on the WIM application, up to 67% of the agencies report deriving speed-specific calibration factors, although a significant percentage of agencies input the average of these factors in all speed bins after calibration (Table 34).

TABLE 26
WHAT TYPE OF STATIC SCALES IS USED?

	Portable	Fixed	Other
Traffic Data Only	19%	81%	—
Both	42.9%	57%	14.3%
Enforcement Only	33%	67%	—

Other = Semi-portable.

TRAFFIC STREAM TRUCK WEIGH-IN-MOTION CALIBRATION QUESTIONS

Under this questionnaire segment, agencies were asked to respond to questions related to calibrating their most common WIM systems utilizing traffic stream trucks of known static weight. The total number of agencies using traffic stream trucks of known static weight varies as follows, depending on their function:

- Seven of the 34 agencies managing traffic data collection WIM systems use traffic stream trucks for WIM calibration. Four of these agencies use Type I systems, whereas the remaining three use Type II systems.
- Four of the seven agencies managing traffic data and enforcement screening WIM systems use traffic stream trucks for WIM calibration. All four of these agencies use Type I systems.
- Ten of the 11 agencies managing enforcement-only WIM systems use traffic stream trucks for WIM calibration. Nine of these agencies use Type I systems, whereas the remaining one uses Type II systems.

Responses on the means of weighing these traffic stream vehicles varied. Seventeen agencies use static scales (i.e., 15 use enforcement facilities and 2 use portable scales); three agencies answered "other," but evidently they use some known traffic stream weight, such as the FAW of certain vehicle classes, instead of actual weighing of vehicles statically; and one agency did not specify the actual weighing method.

Tables 35 to 48 describe agency responses related to the details of their WIM calibration procedures involving traffic stream trucks of known static weight. Most agencies conduct these types of calibration in-house, with the exception of enforcement agencies that involve a contractor (Table 35). The majority performs calibrations only when there is an indication

TABLE 25
ARE EACH TRUCK'S SUSPENSION TYPES SPECIFIED AND IF SO, WHAT TYPES? (Typically refers to a truck's tandem axle groups)

	Yes*	Site Rep.	Leaf Spring	Air
Traffic Data Only	81%	5.3%	10.5%	84.21%
Both	80%	—	—	100%
Enforcement Only	100%		50%	50%

*Specified but not always enforced.

TABLE 27
WHAT STATIC WEIGHT DATA ARE RECORDED AND HOW MANY TIMES ARE MEASURED?

	Axle Groups	Individual Axles	1	2	3
Traffic Data Only	51.6%	44.4%	87%	8.7%	4.3%
Both	57%	27%	—	40%	60%
Enforcement Only	50%	25%	50%	50%	—

TABLE 28
AT WHAT SPEEDS ARE THE TEST TRUCKS RUN?

	Median Speed at Site	Posted Speed	Multi-Speed Selected by Agency	Multi-Speed Selected by Driver
Traffic Data Only	40%	30%	25%	5%
Both	40%	—	60%	—
Enforcement Only	50%	—	—	50%

TABLE 29
MINIMUM NUMBER OF TEST RUNS BY SPEED

	2	3	5	6	7	8	10	20
Traffic Data Only	6.3%	12.5%	12.5%	6.3%	6.3%	6.3%	43.8%	6.3%
Both	25%	50%	—	—	—	—	—	25%
Enforcement Only	—	50%	—	—	—	—	—	50%

TABLE 30
IS AUTOCALIBRATION TURNED OFF DURING TRUCK TESTING?

	Yes	No	Do Not Know
Traffic Data Only	60%	30%	10%
Both	80%	20%	—
Enforcement Only	50%	50%	—

TABLE 31
HOW WIM ERRORS ARE COMPUTED ON-SITE

	Agency Software	Vendor Software	Calculator
Traffic Data Only	34.6%	30.1%	34.6%
Both	14.3%	28.6%	71.4%
Enforcement Only	33%	67%	—

TABLE 32
WHICH DATA ELEMENTS ARE ERRORS COMPUTED FOR?

	Total Length	Axle Spacing	GVW	Tandem Axle Loads	Individual Axle Loads	Speed
Traffic Data Only	24%	71%	100%	43%	71%	33%
Both	50%	50%	100%	33%	50%	50%
Enforcement Only	50%	100%	100%	50%	100%	50%

Note: Percentage reflects the number of agencies reporting to calculate WIM errors for the particular data element.

TABLE 33
WHAT FORMULA IS USED FOR COMPUTING CALIBRATION FACTORS?

	Mean Axle Error = 0	Mean GVW = 0	Combination of Previous Two	Slope WIM vs. Static	Auto-Computed*
Traffic Data Only	9.1%	40.9%	13.6%	4.6%	22.7%
Both	—	40%	20%	20%	20%
Enforcement Only	—	—	—	—	100%

*Responses to survey option Do not know (It is incorporated in an error comp utation spreadsheet)."

TABLE 34
DO YOU CALCULATE SEVERAL CALIBRATION FACTORS DEPENDING ON SPEED?

	No	Yes	Yes, But Average Is Input in Each Speed Bin
Traffic Data Only	50%	22.7%	27.2%
Both	33%	67%	—
Enforcement Only	100%	—	—

of calibration drift, which is evidently detected through WIM data QC (Table 36). About one-third of agencies perform these calibrations on a routine basis (interval ranges from 1 to 12 months as shown in Table 37).

There is roughly an equal division between the methods employed for selecting the number of traffic stream vehicles to use in performing WIM calibration (Table 38). Where a fixed number of vehicles is specified, it varies between 1–100, with an average of 40 being used (Table 39). Where a fixed time interval is used, it ranges between 1 and 168 hours, with the majority of agencies using data collected over a 1- to 4-hour period (Table 40). The type of vehicles included in this sample varies; the majority of agencies using WIM for traffic data or traffic data/enforcement favors selecting vehicles in certain classes regardless of speed, whereas the majority of agencies using WIM only for enforcement screening uses a random selection of vehicle classes (Table 41). Approximately 75% of the agencies use truck inspection station scales for obtaining static axle loads, whereas the remaining agencies use portable static scales.

Axle spacing is measured for the majority of these vehicles, mostly by manual means (Table 42). Table 43 lists the number of agencies that turn off the autocalibration system in their WIM systems. The responses to the question regarding where error calculations are performed vary; some agencies do so at the site always, whereas others do so at the office (Table 44). Interestingly, enforcement agencies are more likely to perform the error/calibration computations at the site, which is explained by their ready access to static data from static scales at truck inspection stations. The actual method for performing the calculations varies; most often, vendor software is used (Table 45). The most common load elements for which errors are computed are GVW, individual axle load, and tandem axle load (Table 46).

The most commonly used approach for computing calibration factors for traffic data WIM systems is by setting the mean GVW to zero. For traffic data/enforcement and enforcement-only WIM systems, the most common calibration approach is by setting the combined errors for GVW and individual axle loads to zero. About 16% of the agencies that operate traffic data WIM use regression for computing calibration factors (Table 47). Most agencies do not compute multiple calibration factors corresponding to different traffic speeds. Only about one-quarter of the agencies that responded indicated that they do compute and input speed-specific calibration factors (Table 48).

WEIGH-IN-MOTION CALIBRATION THROUGH WEIGH-IN-MOTION DATA QUALITY CONTROL QUESTIONS

The total number of agencies using traffic stream data QC for WIM calibration varies depending on the agency's function. The survey showed

- Twenty of the 34 agencies managing traffic data collection WIM systems,

TABLE 35
WHO PERFORMS THE TRAFFIC STREAM TRUCK CALIBRATION?

	Agency	On Call Contractor	Contractor/Manager	Agency and Contractor
Traffic Data Only	86%	—	14%	—
Both	100%	—	—	—
Enforcement Only	22%	11%	22%	44%

TABLE 36
WHAT TRIGGERS CALIBRATION?

	Routine Schedule	Drift Indication	Other
Traffic Data Only	33.3%	55.5%	11.1%
Both	50%	33.3%	16.7%
Enforcement Only	36.4%	57.1%	—

TABLE 40
IF A FIXED TIME INTERVAL IS USED, SPECIFY HOW LONG?

	1 h	4 h	168 h
Traffic Data Only		50%	50%
Both	N/A	N/A	N/A
Enforcement Only	100%	—	—

N/A = not available.

- Six of the 7 agencies managing traffic data and enforcement screening WIM systems, and
- Six of the 11 agencies managing enforcement-only WIM systems use traffic stream data QC for WIM calibration.

The remainder of this section and Tables 49 through 59 present a summary of agency responses on the methodology used.

Most DOTs perform their own WIM data QC-based calibration; however, approximately 37% of the agencies managing enforcement screening WIM use contractors for this purpose (Table 49). The majority of these agencies perform WIM data QC daily or weekly (Table 50).

Most DOTs (i.e., data collection and data collection/enforcement screening systems) download data automatically; however, most agencies that manage enforcement-only WIM systems do so manually (Table 51). The actual WIM data QC analysis frequency ranges from daily to monthly or, alternatively, it is decided on the basis of personnel availability or perceived calibration need (Table 52). It is performed by manual or automated means or a combination of the two (Table 53). Interestingly, the majority of agencies that manage traffic data WIM systems does so automatically, but the majority of agencies that either manage dual-use or enforcement-only WIM does so manually. Table 54 summarizes information on when the actual WIM data QC is performed; for example, the majority of agencies that manage traffic data collection WIM systems perform the QC analysis during data download.

Table 55 suggests that, with few exceptions, almost all of the agencies that responded believe that WIM data QC is capable of identifying system operational problems. The large majority of these agencies believe that WIM data QC detects errors in all of the following categories:

- Vehicle errors,
- System errors,

TABLE 37
IF CALIBRATIONS ARE DONE ROUTINELY, HOW OFTEN?

	1 Month	3 Months	6 Months	9 Months	12 Months
Traffic Data Only	33.3%	—	33.3%	—	33.3%
Both	25%	—	25%	25%	25%
Enforcement Only	—	33.3%	67%	—	—

TABLE 38
HOW DO YOU SELECT THE NUMBER OF TRAFFIC STREAM VEHICLES?

	Fixed Sample Size	Time Interval	Sample Within Time Interval	Other
Traffic Data Only	28.6%	28.6%	28.6%	14.3%
Both	50%	—	50%	—
Enforcement Only	44%	11.1%	22.2%	22.2%

TABLE 39
IF A FIXED NUMBER OF TRUCKS IS USED, SPECIFY HOW MANY?

	1	5	10	20	26	75	100
Traffic Data Only	33.3%	33.3%	—	33.3%	—	—	—
Both	—	—	—	50%	—	50%	—
Enforcement Only	—	—	25%	—	25%	—	50%

TABLE 41
WHAT CRITERIA ARE USED FOR SELECTING TRUCKS FROM THE TRAFFIC STREAM?

	None (Random Sample)	Class Only	Class and Speed	Other
Traffic Data Only	28.6%	57%	14.2%	—
Both	—	50%	25%	25%
Enforcement Only	55.5%	33.3%	11.1%	—

Other = vehicles screened as overweight.

TABLE 42
IS THE AXLE SPACING FOR THESE TRUCKS BEING MEASURED, AND IF SO HOW?

	Yes	Manually	Electronically
Traffic Data Only	42.8%	33.3%	66.7%
Both	75%*	100%	—
Enforcement Only	66%*	33.3%	66.7%

*Not for 100% of trucks.

TABLE 43
IF AVAILABLE, IS AUTOCALIBRATION TURNED OFF DURING THIS PROCESS?

	Yes	No	Do Not Know
Traffic Data Only	100%	—	—
Both	100%	—	—
Enforcement Only	56%	11%	33%

TABLE 44
ARE THE COMPUTATIONS PERFORMED ON-SITE?

	Always	Yes, Only for Additional Sampling	Never
Traffic Data Only	42.8%	28.6%	28.6%
Both	50%	—	50%
Enforcement Only	89%	11%	—

TABLE 45
HOW ARE WIM ERRORS COMPUTED ON-SITE?

	Agency Software	Vendor Software	Calculator
Traffic Data Only	22.2%	44.4%	33.3%
Both	33.3%	—	67%
Enforcement Only	15.4%	53.8%	30.7%

TABLE 46
WHICH DATA ELEMENTS ARE ERRORS COMPUTED FOR?

	Total Length	Axle Spacing	GVW	Tandem Axle Loads	Individual Axle Loads	Speed
Traffic Data Only	14%	29%	100%	14%	71%	14%
Both	25%	75%	100%	75%	100%	25%
Enforcement Only	22%	56%	100%	56%	78%	33%

Note: Percentage reflects the number of agencies reporting to calculate WIM errors for the particular data element.

TABLE 47
WHAT FORMULA IS USED FOR COMPUTING CALIBRATION FACTORS?

	Mean Axle Error = 0	Mean GVW = 0	Combination of Previous Two	Slope WIM vs. Static	Auto-computed*
Traffic Data Only	16.7%	50%	16.7%	16.7%	—
Both	25%	25%	50%	—	—
Enforcement Only	—	22.2%	44.4%	—	33.3%

*Responses to survey option “Do not know (It is incorporated in an error computation spreadsheet).”

TABLE 48
DO YOU CALCULATE SEVERAL CALIBRATION FACTORS DEPENDING ON SPEED?

	No	Yes	Yes, But Average is Input in Each Speed Bin
Traffic Data Only	57.1%	28.6%	14.3%
Both	75%	25%	—
Enforcement Only	62.5%	25%	12.5%

TABLE 49
WHO PERFORMS WIM DATA QC CALIBRATION?

	Agency	On Call Contactor	Contractor/Manager
Traffic Data Only	90%	—	10%
Both	100%	—	—
Enforcement Only	62.5%	25%	12.5%

TABLE 50
HOW OFTEN IS THE WIM DATA BEING DOWNLOADED?

	Daily	Weekly	Monthly	Other
Traffic Data Only	57.9%	31.6%	—	10.5%
Both	83.3%	—	16.7%	—
Enforcement Only	33.3%	33.3%	16.7%	16.7%

Other = Depends on traffic volumes or personnel availability (e.g., some do so bi-weekly).

TABLE 51
HOW IS THE WIM DATA BEING DOWNLOADED?

	Manually	Automatically	Combination
Traffic Data Only	31.6%	63.1%	5.3%
Both	16.7%	66.7%	16.7%
Enforcement Only	66.7%	33.3%	—

- Unclassified vehicles,
- Bad class counts, and
- Bad vehicle counts.

Unclassified vehicles and bad class counts were the operational problems checked most frequently for traffic data WIM systems. Vehicle errors, systems errors, and unclassified vehicles were the operational errors checked most frequently for dual-use WIM systems. Vehicle errors were the operational error checked by all the agencies operating enforcement screening only WIM systems. For calibration monitoring using traffic stream WIM data, most agencies, regardless of WIM data application, focus their analysis on Class 9 trucks or, more specifically, on only the 3S2 configuration (Table 56). Table 57 lists the traffic stream truck properties being monitored and the percentage of agencies by WIM data application using them. The most common load-related truck properties being monitored are the steering axle load average, the left-side/right-side wheel loads of the steering axle, the GVW for empty versus loaded trucks and the GVW by vehicle speed. Interestingly, the steering axle load SD and the GVW SD are monitored mostly by agencies that manage enforcement screening WIM systems. This is likely in response to the need for setting the appropriate load screening thresholds. Table 57 also shows that the most common distance measure being monitored is the axle spacing of the tractor tandem axles (for 3S2 trucks) and less frequently the total wheelbase versus the sum of the axle space data.

TABLE 52
HOW OFTEN IS WIM DATA QC BEING PERFORMED?

	Daily	Weekly	Monthly	Other
Traffic Data Only	21%	36.8%	26.3%	15.6%
Both	25%	25%	50%	—
Enforcement Only	33.3%	33.3%	16.7%	16.7%

Other = Depends on the traffic data element being analyzed (e.g., GVW distributions are checked monthly). Sometimes triggered by field observations or decided by field personnel.

TABLE 53
HOW IS THE WIM DATA ANALYSIS BEING PERFORMED?

	Manually	Automatically	Combination
Traffic Data Only	26.3%	47.3%	26.3%
Both	50%	16.7%	33.4%
Enforcement Only	50%	16.7%	33.4%

TABLE 54
WHEN IS THE WIM DATA ANALYSIS PERFORMED?

	At Time of Download	Separate Step
Traffic Data Only	67.7%	32.3%
Both	33%	67%
Enforcement Only	50%	50%

Table 58 summarizes the responses regarding agency actions when WIM data QC indicates calibration "drift." Only 5% of the agencies that use WIM for traffic data collection suggest that they take no action. The remaining agencies responded that they do take action in the form of an on-site calibration or by performing remote calibration adjustments. The latter are presumably based on the traffic stream data being monitored. A small percentage of these agencies use a combination of these approaches (i.e., attempt to deal with the problem remotely and, if unsuccessful, perform an on-site calibration). Table 59 suggests that most agencies keep records of the calibration adjustments they effect.

SUMMARY OF AGENCY OPINIONS

This section summarizes the results of particular survey questions related to the opinions of the responders on their WIM system operation and performance.

Figure 5 describes the responders' opinions of the WIM data quality being generated for traffic data purposes, Figure 6 provides similar information from responders at agencies that use WIM for both traffic data and enforcement purposes, and Figure 7 illustrates the responses from agencies that use WIM for enforcement purposes only.

Additional comments on the data quality of the Type I systems included the following:

- Bending plate systems no longer used owing to their requiring constant maintenance and their data being no better than that from Type II systems.
- Assumes data must be adequate, given that "FHWA is not complaining."
- WIM data are "not being used."

Additional comments on the data quality of the Type II systems include the following:

- Volume and classification data adequate, but weight data are borderline; and
- Accuracy is adequate for planning and pavement design purposes if proper data validation, maintenance procedures, and calibration schedules are followed.

Figure 8 summarizes the comments from 52 responders that encompass all WIM functions when asked what their WIM priorities would be if they were given additional resources. Additional comments provided in response to this question included the following:

- Need more personnel, both in field and office, but will not happen unless FHWA mandates that states must fully staff their traffic data collection programs.
- Average WIM GVW and loading data have not changed in 22 years; focus should be more on classification data to tell us how many trucks there are using routes.
- Eliminate WIM data collection.
- Would like to upgrade many of the Type II systems to Type I.
- Sites beginning to fail after 7 years.

Figure 9 summarizes the opinions of responders who only manage traffic data WIM systems, when asked what the main factors are that hinder WIM calibration. Other factors cited include that WIM systems are not a priority and that there are problems with the logistics of test truck calibration on Interstate highways. The following suggestions were offered for resolving the issues hindering WIM calibration:

TABLE 55
DOES QA IDENTIFY MOST OPERATIONAL PROBLEMS? IF SO, WHICH ONES?

	Yes	Vehicle Errors	System Errors	Unclassified Vehicles	Bad Class Counts	Bad Vehicle Counts
Traffic Data Only	84%	69%	69%	88%	88%	75%
Both	100%	83%	83%	83%	67%	67%
Enforcement Only	100%	100%	83%	83%	67%	50%

Note: Percentage reflects the number of agencies indicating that WIM data QA detects the particular problem.

TABLE 56
WHICH TRAFFIC STREAM VEHICLE TYPES ARE USED FOR CALIBRATION MONITORING?

	3S2 Only	All Class 9s	Other
Traffic Data Only	26.3%	73.7%	—
Both	16.7%	66.7%	16.7%
Enforcement Only	16.7%	66.7%	16.7%

TABLE 59
DO YOU KEEP RECORDS OF CALIBRATION FACTOR ADJUSTMENTS?

	Yes	No
Traffic Data Only	63.1%	36.9%
Both	100%	—
Enforcement Only	80%	20%

- Acquire resources (funding, qualified personnel, time);
- Perform more data analysis tuned to the characteristics of each WIM site and its traffic;
- Replace existing AC pavement with PCC pavement for WIM sensor installations;
- Use smoother and more wear-resistant pavements;
- Ensure roadway meets ASTM smoothness specifications before installing WIM;
- Employ more weight enforcement to lessen road deterioration;
- Install WIM system equipment properly;
- Set autocalibration parameters properly and monitor the operation;
- Develop new sensor materials not affected by temperature;
- Develop sensor technology not dependent on auto-calibration schemes but reasonably priced and easy to install;
- Develop better grouts for resealing piezoelectric sensors; and
- Utilize at least two calibration test trucks.

The following suggestions were offered by responders dealing with WIM traffic data in relation to the urgent technical needs question (where not otherwise noted the number of responders is one):

- Ensure controller/electronics reliability, reduction of power consumption, compactness (three responders);
  – Incorporate MIL-SPEC housing designs and
  – Increase data storage capacity for lower cost controllers.

TABLE 57
WHICH TRAFFIC STREAM VEHICLE PROPERTIES ARE ANALYZED FOR CALIBRATION MONITORING?

Data Element	Traffic Data Only	Both	Enforcement Only
Vehicle Length vs. Axle Spacing	42%	17%	33%
Other Axle Spacing Property	26%	33%	50%
Tractor Tandem Axle Spacing	53%	33%	83%
Steering Axle L/R Wheel Load Comparisons	5%	67%	33%
Steering Axle Load Average	95%	100%	67%
Steering Axle Load SD	32%	—	83%
GVW Empty vs. Loaded	47%	50%	17%
GVW Average by Speed	32%	50%	33%
Other GVW Property	26%	—	17%
GVW SD	32%	33%	100%

Note: Percentage reflects the number of agencies that monitor the listed data element.

TABLE 58
WHAT ACTION IS TAKEN IF QC INDICATES CALIBRATION “DRIFT”?

	On-Site Evaluation	Remote Calibration Adjustments	No Action	Other
Traffic Data Only	57.9%	21%	5.3%	15.8%
Both	16.7%	66.7%	—	16.7%
Enforcement Only	33.3%	50%	—	16.7%

Other = Depends on site (e.g., try remote adjustment first and if unsuccessful, perform on-site evaluation).

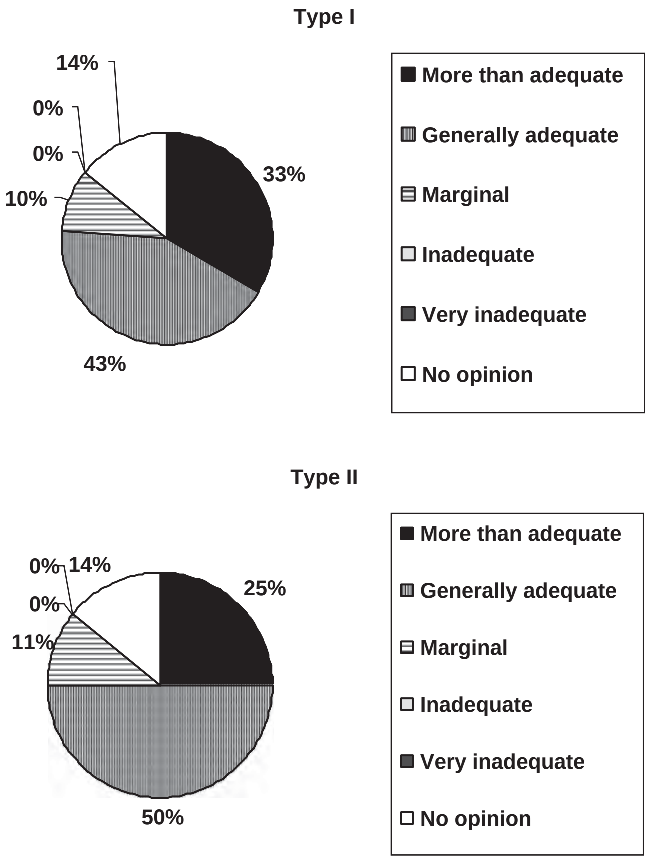


FIGURE 5 Rating WIM data quality; traffic data collection purposes.

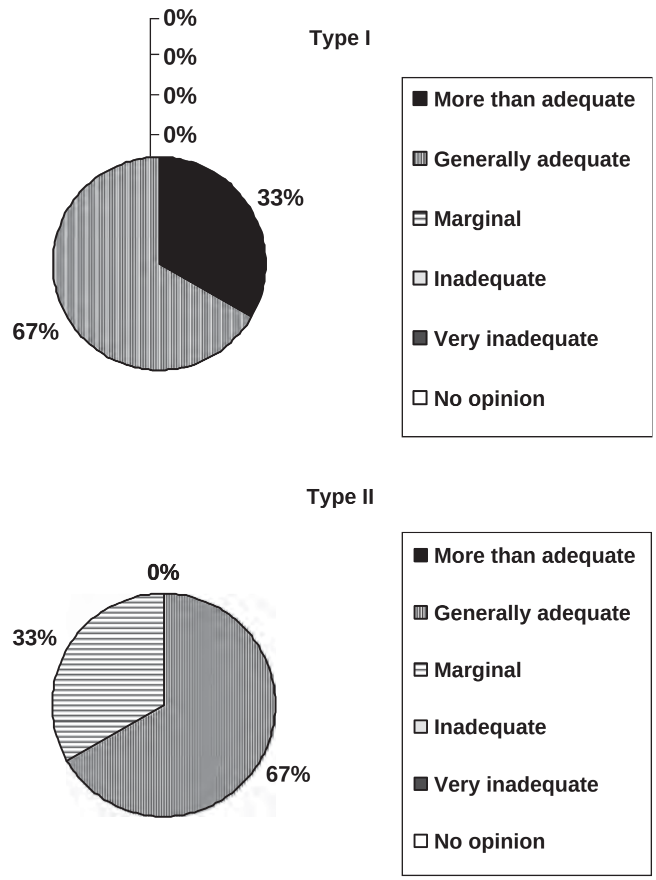


FIGURE 6 Rating WIM data quality; both traffic and enforcement purposes.

- Modernize and make more user friendly software for both on-site and office needs (two responders);
  - Have vendors perform software upgrades in response to customers' needs and
  - Update to Windows versions.
- Improve communication techniques for remote data retrieval (i.e., this should be done by vendors in response to customers' needs) (two responders).
- Extend sensor reliability and life (five responders);
  - Perform more metallurgy studies considering the large volume of truck traffic to evaluate optimum materials to be used,
  - Refine bending plate strain gauges in areas of adhesion and failure, and
  - Hold joint venture studies between states and vendors.
- Develop more accurate sensors (three responders).
- Develop accurate sensor that is less costly (two responders).
- Improve Type II sensors, and consider fiber optic sensors.
- Develop sensor that is consistent and easier to install.
- Use non-intrusive systems or methods to get out of the road.
- Compare accuracy differences between quartz piezoelectric and bending plate sensors;
  - Perform study of the two sensor types at the same location in a northern tier state and
  - Perform better autocalibration handling of pavement temperature (three responders).
- Develop better pavements in which to install sensors (two responders).
- Use better epoxy (three responders).
- Create understanding of how calibration test vehicles relate to the traffic stream.
- Create understanding of how pavement roughness relates to WIM accuracy.
- Calibrate without use of test trucks;
  - Field-test simulation programs.
- Attain knowledge of the accuracy needs of the different data user groups.
- Create effective database to retrieve, QC, and process the data (two responders).
- Use better methods to check data based upon actual vehicle configurations.
- Attain better understanding of the limitations of the data and educate the states on such limitations.
- Find best methods of sharing data among the states.

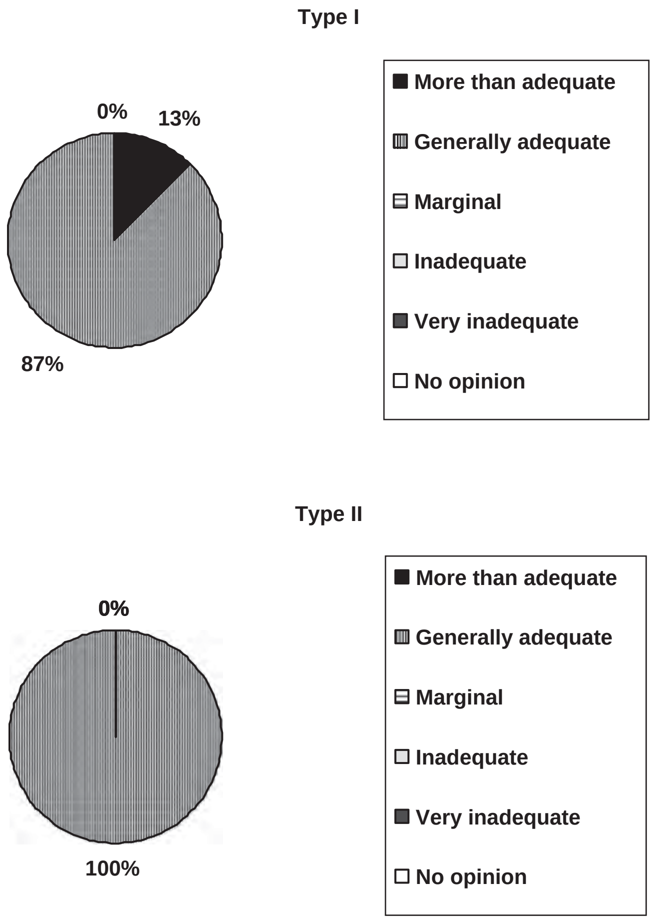


FIGURE 7 Rating WIM data quality; enforcement only purposes.

- Find best methods of sharing data among traffic data collection and enforcement entities to improve both operations.
- Identify and standardize best calibration practices, as performed by this study.
- Create diagnostic guidelines for calibration of WIM sites from centralized office location.

Interestingly, one of the responders commented “. . . if FHWA truly believes that this data is important, then they need to work with state legislatures to make sure that adequate staff is obtained, not only to collect and process data, but to aid in the advancement of data collection tools and methods.”

The following suggestions regarding urgent technical needs were offered by responders dealing with WIM systems used in enforcement:

- Use WIM as Virtual Weigh Stations to monitor known bypass routes.
- Remove obstacles in state procurement system, which is the biggest hindrance.
- Provide better installation and calibration guidelines (i.e., develop guidelines based on production grade data, not research data).
- Improve pavement smoothness quality.
- Create methods to repair or rehab pavement in which sensors have been installed, without effecting deterioration in WIM data quality.
- Lessen mix-ups on identification of prescreened vehicles.

Some additional comments offered included the following:

- Site maintenance is crucial in obtaining consistent WIM system performance, regardless of type.
- Running the entire program in-house gives a much more controlled and consistent product.
- Only do the absolute minimum WIM data collection.
- Piezo WIM data accuracy can be improved by the following method of modifying vendor’s autocalibration software.
  – Modify temperature binning to 40 bins with 2-degree increments in lieu of 30 bins with 5-degree increments and

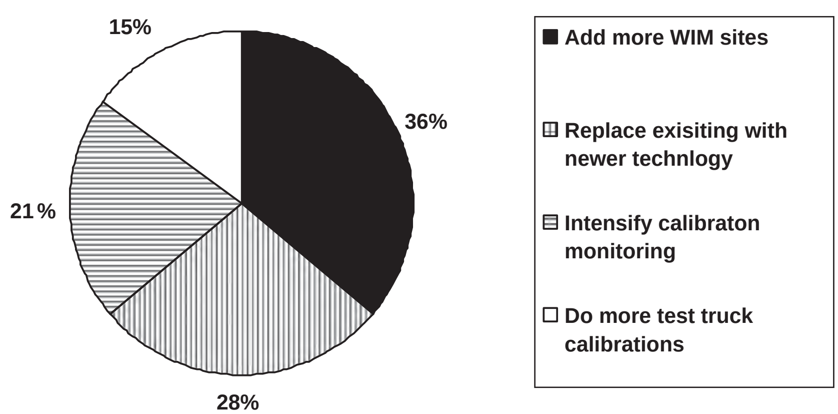


FIGURE 8 WIM related priorities, given additional resources.

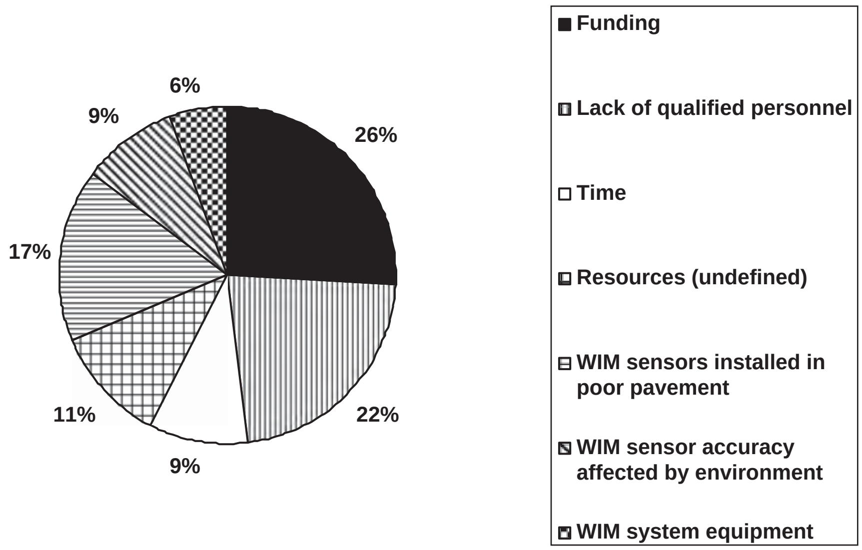


FIGURE 9 Factors hindering WIM calibration.

- – Modify weight limits of autocalibration vehicle type to exclude vehicles exhibiting partial weights.
- Percentage of WIM errors changes with temperature change (Type II systems).
- Autocalibration feature of vendor's piezoelectric WIM system is accurate.
- Accuracy of the WIM system is only as good as the quality of the pavement—the agency's road maintenance department needs to be a partner in the maintenance of a WIM site.
- Selection of WIM site location is important—data quality lessens when site is located where traffic is changing lanes.
- Although consideration has been given to the use of calibration test vehicles on several occasions, it has never appeared to be practical or cost-effective.

INVENTORY

The end of the survey questionnaire provided responding agencies with the opportunity to describe the type and number of WIM systems currently operational in their jurisdictions. These questions were optional and, as a result, not all agencies responded. The WIM system inventory for agencies that responded is provided in Appendix C (web version only).

CHAPTER FIVE

CONCLUSIONS

The agencies that responded to the questionnaire use one or more of the three calibration methods described; namely, by means of test trucks, traffic stream vehicles of known static weight, and weigh-in-motion (WIM) traffic data quality control (QC). A summary of the fraction of agencies that use particular WIM calibration methods is given by WIM application in Table 60.

Most agencies perform test truck WIM calibrations on a routine basis at intervals ranging from 6 to 24 months, with the majority of them doing so every 12 months. Most agencies use a single Class 9 test truck. Others use a Class 5, 6, 7, or 10 truck, either by itself or with a Class 9 truck. Although the majority of these agencies report considering pavement roughness, only about 25% does so objectively (i.e., 11.1% perform the straightedge/circular plate test described by ASTM E1318-02, 3.6% simulate this test using software that accepts the pavement profile as input, and 14.8% simply use the International Roughness Index). Even fewer agencies objectively consider the structural condition of the foundation of the sensors. Most agencies use fixed weigh scales for obtaining the static loads of test trucks; however, more than 40% of agencies using WIM for both data collection and enforcement screening use portable scales. Most agencies perform the static measurements only once. About half of the WIM systems, regardless of application, perform test truck runs using the site median traffic speed, whereas the remainder use either the posted speed limit or multiple speeds. The majority of agencies administering dual-use WIM systems use multiple test speeds. Most agencies using WIM for traffic data collection only conduct ten test runs per vehicle speed, but agencies using WIM for either traffic data/enforcement or enforcement alone conduct three test runs per vehicle speed. Responders indicated that overall 87% of agencies carry out calibration calculations on site. The method for computing calibration factors is equally split between agency software, vendor software, and short-hand calculations. For combined-use WIM systems, most agencies use short-hand calculations, but for enforcement-only screening systems, about two-thirds of the agencies use vendor software. The main load data elements for which WIM errors are computed are gross vehicle weight (GVW), the individual axle loads, and the tandem axle loads. Most agencies compute calibration factors by setting the mean GVW equal to zero, or by setting a combination of the mean GVW and the mean axle load errors equal to zero. Few agencies compute calibration factors by minimizing the least square errors between WIM and static axle loads through zero-intercept regression. Depending on the WIM application, up to 67% of the agencies reported deriving speed-specific calibration factors, although a significant percentage reported inputting their average value in all speed bins after calibration.

Agencies that use traffic stream vehicles of known static weight for WIM calibration obtain static weights largely by permanent static scales at truck inspection stations. Only about one-third of agencies perform these calibrations on a routine basis at intervals ranging from 1 to 12 months. The majority does so only when there is an indication of calibration drift. There is roughly an equal division between the methods used for selecting the number of traffic stream vehicles used. Where a fixed number of vehicles is specified, it varies between 1 and 100, with the majority of agencies using 50 vehicles. Where a fixed time interval is used, it ranges between 1 and 168 hours, with the majority of agencies using data collected over a period of from 1 to 4 hours. The type of vehicles included in this sample varies; most agencies using WIM for traffic data or traffic data/enforcement favor selecting vehicles in certain classes regardless of speed, but most agencies using WIM for enforcement-only screening use a random selection of vehicle classes. Axle spacing is measured mostly by manual means. The responses to the questions on where error calculations are performed vary; some agencies always do so at the site, others do so at the office. Interestingly, enforcement agencies are more likely to perform the error/calibration computations at the site, which is explained by their ready access to static scale data. The actual method for performing the calculations varies; however, most often vendor software is used. The most common traffic elements for which errors are computed are GVW, individual axle loads, and tandem axle loads. The most commonly used approach for computing calibration factors for traffic data WIM systems is by setting the mean GVW to zero. For traffic data/enforcement and enforcement only WIM systems, the most common calibration approach is by setting the combined errors for the GVW and individual axle loads to zero. About 16% of the agencies that operate traffic data WIM use regression for computing calibration factors. Most agencies do not compute multiple calibration factors corresponding to different traffic speeds.

Monitoring of the traffic stream WIM data is used by many agencies as a means of detecting WIM calibration status and,

TABLE 60
SUMMARY OF WIM CALIBRATION METHODOLOGY USED BY APPLICATION

Method	Traffic Data Only	Both	Enforcement Only
Test Truck Only	22/34 (65%)	7/34 (21%)	20 of 34 (59%)
Traffic Stream Trucks of Known Weight Only	6/7 (86%)	4/7 (57%)	6 of 7 (86%)
WIM Data QC Only	2/11 (18%)	10/11 (91%)	6 of 11 (55%)

as a result, is used as the trigger for more detailed on-site calibration by the other two on-site methods previously described. As shown in Table 60, some agencies use this approach as the only WIM calibration method. Agencies that operate dual-use WIM systems download data automatically, but most agencies that manage enforcement-only screening WIM systems do so manually. The actual WIM data QC analysis frequency ranges from daily to monthly, or it is decided on the basis of personnel availability or perceived calibration need. It is performed by manual or automated means, or a combination of the two. With few exceptions, almost all of the agencies that responded believe that WIM data QC are capable of identifying system operational problems (e.g., vehicle errors, system errors, and unclassified vehicles). Most agencies, regardless of WIM data application, focus their traffic stream WIM data analysis for the purpose of calibration monitoring on either Class 9 trucks or, more specifically, the 3S2 configuration. The most common load-related truck properties being monitored are the steering axle load, the left-side/right-side wheel loads of the steering axle, GVW for empty versus loaded trucks, and GVW by vehicle speed. Interestingly, the steering axle load standard deviation (SD) and the GVW SD are monitored primarily by agencies that manage enforcement-only screening WIM systems. The most common distance measure being monitored is the axle spacing of the tractor tandem axles of 3S2 trucks and, less frequently, the total wheelbase versus the sum of the axle space data. As shown in Table 58 in chapter four, which summarizes the responses of agencies regarding their actions when WIM data QC indicates calibration drift, approximately 5% of the agencies that use WIM for traffic data collection suggest that they take no action.

In concluding this synthesis, the following future research needs and suggestions are made:

- There is a need to field test the AASHTO MP 14-05 provisional standard to ensure that the pavement smoothness levels specified can reliably differentiate between suitable and unsuitable WIM sites.
- For Type I WIM systems, there is a need to test the effectiveness of the speed-specific calibration approach in reducing in-service traffic WIM errors in GVW and axle load measurements. This issue needs to be studied in terms of the vehicle class and suspension type of the test trucks and the dominant vehicle class and suspension type of the in-service truck traffic.
- There is a need for research to develop software standardizing the WIM system calibration process involving test trucks. This software, developed in coordination with WIM vendors, will facilitate and homogenize on-site WIM system calibration.
- Research is needed to establish simplified WIM data QC criteria for triggering test truck WIM calibration.
- Finally, it is suggested to study the potential for providing a system to train and certify WIM technicians. This could be organized along the lines of the AASHTO R18 accreditation process, which covers a variety of laboratory testing procedures.

REFERENCES

1. Cunagin, W.D., *NCHRP Synthesis of Highway Practice 124: Use of Weigh-in-Motion Systems for Data Collection and Enforcement,* Transportation Research Board, National Research Council, Washington, D.C., 1986, 34 pp.
2. Jacob, B., E.J. O'Brien, and W. Newton, *Assessment of the Accuracy and Classification of Weigh-in-Motion Systems, Part 2: European Specification,* Vol. 7, No. 2/3, Inderscience Enterprises Ltd., Geneva, Switzerland, 2000.
3. *COST 323: WIM Load* (*1993–1998*); *Weigh-in-Motion of Road Vehicles,* Final Report, Apr. 2002 [Online]. Available: http://cordis.europa.eu/cost-transport/src/cost-323.htm.
4. Papagiannakis, A.T., K. Senn, and H. Huang, *On-Site Evaluation and Calibration of Weigh-in-Motion Systems, Final Report for NCHRP Project 3-39*(*02*), Transportation Research Board, National Research Council, Washington, D.C., 1996.
5. *Weigh-in-Motion of Axles and Vehicles for Europe* (*WAVE*), General Report, Laboratoire Central des Ponts et Chaussees, Paris, Apr. 2001 [Online]. Available: http://wim.zag/si/wave.
6. *Standard Specification for Highway Weigh-in-Motion* (*WIM*) *Systems with User Requirements and Test Method, ASTM E1318-02,* American Society for Testing and Materials, West Conshohocken, Pa., 2002.
7. *COST 323; Weigh-In-Motion of Road Vehicles; Appendix 1,* European Specification Version 3.0, Aug. 1999.
8. *Smoothness of Pavement at the Approaches to WIM Scales, AASHTO Standard Specification MP 14-05,* American Association of State Highway and Transportation Officials, Washington, D.C., 2006.
9. Karamichas, S.M. and T.D. Gillespie, *Smoothness Criteria for WIM Scale Approaches,* Report UMTRI-2002-37, University of Michigan Transportation Research Institute, Ann Arbor, Sep. 2002.
10. Nichols, A.P. and D.M. Bullock, *Quality Control Procedures for WIM Data, Final Report,* FHWA/IN/JTRP-2004/12, Purdue University, West Lafayette, Ind., June 2004.
11. *Weigh-in-Motion of Axles and Vehicles for Europe* (*WAVE*), *Report Package 3.2, Calibration of WIM Systems,* Laboratoire Central des Ponts et Chaussees, Paris [Online]. Available: http://wim.zag/si/wave.
12. *Traffic Monitoring Guide,* Federal Highway Administration, Washington, D.C., 2001.
13. Dahlin, C., "Proposed Method for Calibrating Weigh-in-Motion Systems and for Monitoring That Calibration Over Time," *Transportation Research Record 1364,* Transportation Research Board, National Research Council, Washington, D.C., 1992, pp. 161–168.
14. Hallenbeck, M., *Long Term Pavement Performance Protocol for Calibrating Traffic Data Collection Equipment,* Federal Highway Administration, Washington, D.C., Apr. 1998, 16 pp.
15. McCall, W. and W.C. Vodrazka, Jr., *States' Successful Practices Weigh-in-Motion Handbook,* Iowa State University, Ames and Federal Highway Administration, Washington, D.C., Dec. 1997, 146 pp.
16. Quinley, R., "The CTWIM Suite," North American Travel Monitoring Exhibition and Conference 2002/3rd International Conference on WIM, Orlando, Fla., May 13–15, 2002.
17. Long-Term Pavement Performance (LTPP) Specific Pavement Study (SPS) Traffic Data Collection, FHWA Pool Fund TPF-5(004) awarded to IRD Inc., and MACTEC Inc. [Online]. Available: http://www.pooledfund.org/project details.asp?id=123&status=6 [accessed Nov. 17, 2008].
18. Hallenbeck, M. and H. Weinblatt, *NCHRP Report 509: Equipment for Collecting Traffic Load Data,* Transportation Research Board, National Research Council, Washington, D.C., 2004, 66 pp.
19. *Traffic Analysis Software, User's Guide,* Version 1.6.2, Long Term Pavement Performance, Federal Highway Administration, Washington, D.C., Apr. 2006.
20. Hedrick, J.K. and K. Yi, *VESYM User's Manual*, Vehicle Dynamics and Control Laboratory, Department of Mechanical Engineering, University of California, Berkeley, July 1989.
21. *Weigh-in-Motion of Axles and Vehicles for Europe* (*WAVE*), Report Package 1.1, Multiple Sensor WIM, Laboratoire Central des Ponts et Chaussees, Paris, May 2001 [Online]. Available: http://wim.zag/si/wave.
22. Gonzalez, A., A.T. Papagiannakis, and E. O'Brien, "Evaluation of an Artificial Neural Network Technique Applied to Multiple-Sensor Weigh-in-Motion Systems," In *Transportation Research Record 1855,* Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 151–159.
23. Schultz, G.G. and L.W. Seegmiller, *Utah's Commercial Motor Vehicle WIM Data Analysis and Calibration Method*, Report UT-06.10, Department of Civil and Environmental Engineering, Brigham Young University, Provo, Utah, June 2006.
24. *Commercial Motor Vehicle Size and Weight Enforcement,* International Technology Scanning Program, American Trade Initiatives, Washington, D.C., Aug. 2006.
25. *Weigh-in-Motion of Axles and Vehicles for Europe* (*WAVE*), Report Package 4, Optical WIM Systems, Technology for the Future, Laboratoire Central des Ponts et Chaussees, Paris, Oct. 2000 [Online]. Available: http://wim.zag/si/wave.
26. *Weigh-in-Motion of Axles and Vehicles for Europe* (*WAVE*), Report Package 2, A Quality Data Assurance System for the European WIM Database, Laboratoire

Central des Ponts et Chaussees, Paris [Online]. Available: http://wim.zag/si/wave.
27. Papagiannakis, A.T., W.A. Phang, J.H.F. Woodrooffe, A.T. Bergan, and R.C.G. Haas, "Accuracy of Weigh-in-Motion Scales and Piezoelectric Cables," *Transportation Research Board Record 1215*, Transportation Research Board, National Research Council, Washington, D.C., Jan. 1989, pp. 189–196.
28. *AASHTO Guidelines for Traffic Data Programs*, AASHTO, Joint Task Force on Traffic Monitoring Standards, Washington, D.C., 1992.
29. Karamichas, S.M. and T.D. Gillespie, *Advancement of Smoothness Criteria for WIM Scale Approaches*, University of Michigan Transportation Research Institute, Report UMTRI-2004-12, Ann Arbor, April 2004.
30. *Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference*, ASTM E-950-98, American Society for Testing and Materials, West Conshohocken, Pa., 2004.
31. U.S. Department of Commerce, *NIST Handbook 44: Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices*, National Institute of Standards and Technology, Washington, D.C., 1993.
32. Woodrooffe, J.H.F., P. LeBlanc, and K.R. LePiane, "Effect of Suspension Variations on the Dynamic Wheel Loads of a Heavy Articulated Vehicle," *Vehicle Weights and Dimensions Study*, Road and Transportation Association of Canada, Vol. 11, July 1986.

APPENDIX A

ASTM E 1318-02 Type I WIM System Specification Outline

EQUIPMENT

Sect 4. Classification

- ☐ System designed for use with local electrical power
    - ▫ 110V, ac, 60-Hz in North America
    - ▫ Optional- battery backup
    - ▫ Optional- system completely battery-powered
- ☐ Vendor supplied lightning protection for affected system components
- ☐ User selectable units of measurement
    - ▫ U.S.
    - ▫ S.I. units

4.1.1 Type I WIM System

- ☐ System covers one or more lanes
- ☐ Accommodates highway vehicles moving at speeds from 10 and 80 mph
- ☐ For each vehicle processed, system shall produce following required data items:

Required Data Items
• Wheel load *
• Axle load
• Axle-group load
• Gross-vehicle weight
• Speed *
• Center-to-center spacing between axles *
• Vehicle class (via axle arrangement)
• Site identification code *
• Lane and direction of travel *
• Date and time of passage *
• Sequential vehicle record number *
• Wheelbase (front-most to rear-most axle)
• Equivalent single-axle loads (ESALs)
• Violation code
* Data items temporarily stored on-site

- ☐ Data processed by on-site controller such that all required data items can be displayed in alphanumeric form for immediate review
    - ▫ May be accomplished by connecting a portable computer to on-site WIM controller
        - ✓ Vendor furnished and supported as part of WIM system equipment
- ☐ Required data items identified with "*" shall be temporarily stored on-site
    - ▫ Provision for user to define vehicles for which data to be stored:
        - ✓ All vehicles
        - ✓ Vehicles with a user defined threshold value for either:

- front-axle load
- front-wheel load

- Provision for user selection of option to have system generate axle load data using only left or right wheel weigh sensor(s)
- Provision for user entry of selected vehicle violation limits and tolerances:
  - Wheel loads
  - Axle loads
  - Axle-group (including bridge-formula grouping) loads
  - Gross-vehicle weights
  - Speed
- Provision for user to determine whether or not the system will prepare selected data items for display and recording
  - Use of feature shall not inhibit system's receiving and processing data
- System provides for rapid and efficient transfer of required data items identified above with "*" to files made available on a compatible host computer at a remote location
  - Host computer for specific site
    - User specifies either:
      - user furnished
      - vendor furnished
    - User specifies:
      - appropriate time schedule
      - data format
- Vendor furnish, document, and support software for use on host computer for processing the data items transferred from the on-site WIM system controller such that all required data elements can be displayed in alphanumeric form for immediate review and subsequent use by the host computer user; same software provided on the portable computer for use when it is connected directly to on-site controller
- On-site system controller options:
  - Option 1
    - Presentation of a hard-copy of all data items produced by the system
  - Option 2
    - Presentation of a hard-copy of all data items produced by the system and provide means for counting
    - Counting and recording vehicle counts
      - by hour
      - by lane
        - up to a maximum of ten lanes
        - including lanes without WIM sensors
  - Option 3
    - Recorded hourly by lane
      - vehicle count
      - vehicle classification (via axle arrangement)

- speed measurements

Sect 5. Performance Requirements

5.1 Accuracy

- WIM system to be capable of performing all required functions within the following accuracy:

Data Item	Tolerance for 95% Probability of Conformity
• Wheel Load	+/- 25%
• Axle-Load	+/- 20 %
• Axle-Group Load	+/- 15 %
• Gross-Vehicle Weight	+/- 10 %
• Speed	+/- 1 mph (2km/h)
• Axle-Spacing	+/- 0.5 ft (0.15 m)

- Required accuracy should be maintained for ambient air temperatures at the WIM site from -20 to 120°F (-28 to 50°C)
  - User shall specify at time of procurement the range of temperatures within which the WIM system must operate properly
- Vendor shall supply evidence that proposed system is capable of compliance
- After computation of these data items, no digit shall be retained less than:
  - 100 lb (50 kg) for load or weight
  - 1 mph (2 km/h) for speed
  - 0.1 ft (0.03 m) for axle spacing

5.2 Vehicle Class

- Vehicles shall be classified according to axle arrangement
- Vendor shall incorporate software within each system for using the available WIM-system axle-count and axle-spacing information for estimating FHWA Vehicle Types described in TMG
  - Axle-spacing values used for this process shall be associated with each vehicle classified via the software
  - The values shall be:
    - ✓ made readily available to the user
    - ✓ easily modifiable by means provided to the user
- FHWA Vehicle Type to be indicated by the 2-Digit Code as follows:

2-Digit Code	Brief Description
01	Motorcycles
02	Passenger Cars
03	Other Two-Axle, Four-Tire Single Unit Vehicles
04	Buses
05	Two-Axle, Six-Tire, Single Unit Trucks
06	Three-Axle, Single Unit Trucks
07	Four-or-More Axle Single Unit Trucks
08	Four-or-Less Axle Single Trailer Trucks
09	Five-Axle Single Trailer Trucks

10	Six-or-More Axle Single Trailer Trucks
11	Five-or-Less Axle Multi-Trailer Trucks
12	Six-Axle Multi-Trailer Trucks
13	Seven-or-More Axle Multi-Trailer Trucks

- ☐ In addition to the FHWA Vehicle Types 01 through 15, the system shall also provide:
  - ▫ A user-defined Vehicle Type Code 14 for application by the user
  - ▫ A Vehicle Type Code 15 shall be applied to any vehicle that the software fails to assign to one of the types described

5.3 Site Identification Code

- ☐ Provisions shall be made for entering, displaying, and recording a ten-character alphanumeric site identification number

5.4 Lane and Direction Code

- ☐ Each vehicle processed shall be assigned a lane and direction-of-traffic code
- ☐ Shall consist of a number beginning with 1 for the right-hand northbound or eastbound traffic lane and continuing until all lanes in that direction of travel have been numbered
- ☐ The next sequential number shall be assigned to the lanes in the opposite direction of travel beginning with the left-hand and continuing until all lanes have been numbered
- ☐ Provision shall be made for 12 numbers in the code

5.5 Date

- ☐ Date of passage shall be indicated numerically in each vehicle processed
- ☐ Date format(s) used by system shall be
  - ▫ Clearly documented
  - ▫ Defaulted to generally accepted format in the country of use
    - ✓ United States, typically MM/DD/YY
      - × MM is the month
      - × DD is the day
      - × YY is the year

5.6 Time

- ☐ Time of passage shall be indicated numerically in each vehicle processed in the format hh:mm:ss
  - ▫ hh the is hour beginning with 00 at midnight and continuing through 23
  - ▫ mm is the minute
  - ▫ ss is the second

5.7 Vehicle Record Number

- ☐ System shall provide sequential-numbering (user adjustable) for each recorded vehicular data set

5.8 Wheelbase

- ☐ System shall compute wheelbase as the sum of all axles spacings between centers of the front-most and the rear-most on the vehicle or combination that have tires in contact with the road surface at time of weighing
  - Value rounded before displaying or recording
    - ✓ Integer value in feet, or
    - ✓ Nearest 0.1 m

5.9 ESALS

- ☐ System shall compute Equivalent Single-Axle Loads (ESALs) using AASHTO axle load equivalency factors
  - For single, tandem, and triple axles
  - For flexible or rigid pavements
    - ✓ User selected
- ☐ System shall compute total ESALs for each vehicle or vehicle combination
  - Data prepared for display as part of each vehicle record
  - Displayed value rounded to two significant digits following decimal
  - Presented in following format:
    - ✓ FESAL = for flexible pavements
      - ✗ user adjustable parameters for serviceability and value for structural number
    - ✓ RESAL = for rigid pavements
      - ✗ user adjustable parameters for serviceability and value for thickness of slab
    - ✓ Refer to actual Standard Specification document for details on requirements pertaining to ESALs

5.10 Violations

- ☐ System shall determine vehicle violation(s) in accordance with all user-set parameters
- ☐ A 2-character violation code shall be used for each detected violation and shall be included in the displayed data (see following example):

Violation	Code
Wheel Load	WL
Axle Load	AL
Axle-Group Load	AG
Gross-Vehicle Weight	GV
Bridge-Formula Load	BF
Over Speed	OS
Under Speed	US

- ☐ Provision for user to define up to 15 violation codes
- ☐ Optional- user specified feature(s) calling attention to any data items in violation of user-set limits, such as flashing, underlining, bold facing, or audio

5.11 Acceleration

- ☐ Non-applicable to Type I system

5.12 User-Assignable Code

- ☐ Provision to allow manual entry of user-assignable three-digit code into any vehicular data set prior to recording

5.13 Tire-Force Sensor

- ☐ Magnitude of the signal to be the same (within tolerance) for a given applied tire force regardless of the lateral position of the tire(s) within the lane
    - ▫ 5.13.1 Vendor shall certify the testing and performance of every sensor prior to installation (refer to actual Standard Specification document for details on this requirement)

USER REQUIREMENTS and TYPE-APPROVAL TESTING

The Specifications include “Site Conditions” under 6.1 and “Type-Approval Test” under 7.2. The provisions of these sections are not included in this version of the checkoff list (other than the “Calculation” provisions of 7.2.7 referenced under 7.5 and 7.6).

Unless a user contemplating procurement of WIM system equipment has thorough knowledge of the performance of available equipment which may otherwise appear to meet procurement specifications, such user should fully evaluate the provisions of 6.1 and 7.2 for inclusion in the equipment procurement specifications. Attention is directed to 6.4.1, Implications of a Type-Approval Test, which notes that if a WIM equipment vendor does not provide evidence of previous type-approval testing, the user will not be assured of the capability of the system and shall either require conduct of a Type-approval Test (expenses to be negotiated) wherein the user shall provide appropriate site conditions (see 6.1), or reach an agreement with the vendor before the on-site acceptance test begins as to the specific, quantified tolerance values that will be acceptable if the site conditions provided by the user do not meet or exceed those given in 6.1.

CALIBRATION AND ON-SITE ACCEPTANCE TESTING

Sect 7 Test Methods for WIM System Performance

7.1.1 Apparatus for Weighing Static Vehicles

- ☐ All weighing apparatus shall be certified as meeting the applicable maintenance tolerance specified in *NIST Handbook 44* within 30 days prior to use
- ☐ When system required to meet accuracy requirements for wheel loads, the corresponding reference tire-load values shall be determined with either:
    - ▫ Wheel-load weighers
        - ✓ Required minimum number of wheel-load weighers is 2
        - ✓ Preferred minimum number of wheel-load weighers is 6
        - ✓ Must meet the respective tolerance specification of *NIST Handbook 44*
    - ▫ Axle-load scale or multi-platform vehicle scale that has approaches and aprons adjacent to the load-receiving platforms
        - ✓ Refer to actual Standard Specification document for details on requirements pertaining to wheel weighing

- When Type I system exempted from meeting accuracy requirement for wheel loads, reference tire-load values shall be obtained by using either:
    - Axle-load scale
    - Multi-platform vehicle scales
    - Portable axle-load weighers
    - A pair of wheel-load weighers
        - ✓ Must meet the respective tolerance specification of *NIST Handbook 44*

7.1.2 Use of Apparatus for Weighing Static Vehicles

- Tire-pavement contact surfaces of all tires on the vehicle being weighed shall be within 0.25 in. (6 mm) of a plane passing through the load-receiving surface(s) of the weighing device (s) when any tire-load measurement is made
    - Maximum slope of this plane from horizontal shall be 2 %
- When system required to meet accuracy requirements for wheel loads, wheel and axle load measured simultaneously using a pair of wheel-load weighers.
- When Type I system exempted from meeting accuracy requirements for wheel-loads:
    - Axle-load shall be determined by positioning each axle to be weighed either simultaneously or successively on either:
        - ✓ An axle-load scale(s)
        - ✓ A multi-platform vehicle scale
        - ✓ A portable axle-load weigher(s)
        - ✓ A pair(s) of wheel-load weighers
    - Axle-group load shall be determined by either:
        - ✓ Positioning all axles in the group simultaneously on the required number of weighing devices (preferred method)
        - ✓ Successively positioning each axle in the group on a pair of wheel-load weighers or on an axle-load weighing device
- Gross-vehicle weight shall be the total weight of the vehicle determined by single-draft weighing on a vehicle scale and/or the sum of all wheel loads or axle loads for the vehicle
- Refer to actual Standard Specification document for details on requirements pertaining to weighing

7.1.3 Procedure for Weighing and Measuring Test Vehicles to Obtain Reference Values

Two test vehicles (see 7.5.3) are used. The following procedure shall be applied for obtaining reference load, weight, and axle-spacing values for each of the static test vehicles:

- 7.1.3.1 Measure the center-to-center spacing between successive axles on each test vehicle and record these data to the nearest 0.1 ft (0.03 m) as axle spacing reference values
- 7.1.3.2 Weigh each test vehicle a minimum of three times, with brakes released, as described in 7.1.1 and 7.1.2 to measure tire loads for the wheel(s) on each end of every axle on the static vehicle

- Move the vehicle completely away from scale or weigher before beginning a new set of tire-load measurements
- Always approach weighing devices from the same direction for weighing
- Sum the applicable tire loads to determine wheel, axle, and tandem-axle loads as well as gross-vehicle weight each time the vehicle is weighed

☐ 7.1.3.3 For all wheel load, axle-load, tandem-axle-load, and gross-vehicle weight values that resulted from weighing each test vehicle three or more times, calculate:

- arithmetic mean
- difference, in percent, from the mean of each individual value used in calculating the respective mean

☐ 7.1.3.4 Compare percent differences from the mean to the following specified limits for each applicable load or weight value for each test vehicle:

- Gross-vehicle weight = +/- 2%
- Tandem-axle load = +/- 3%
- Axle load = +/- 4%
- Wheel load = +/- 5%

☐ 7.1.3.5 If any of the measured or calculated load or weight values exceed the specified range

- Correct deficiencies in the reference-value weighing process
- Weigh each test vehicle a minimum of three more times

☐ 7.1.3.6 Repeat 7.1.3.5 until the weighing process yields reference-value loads and weights that are within the specified range

☐ 7.1.3.7 For reference-value loads and weights against which to compare WIM-system estimates, use the calculated arithmetic mean value that resulted from successfully weighing each test vehicle three or more times for:

- Wheel load
- Axle-load
- Tandem-axle-load
- Gross-vehicle weight

7.5 Calibration Procedure

7.5.1 Scope

☐ Recommended for inclusion in every On-Site Acceptance Test (see 7.6)

☐ Shall be conducted by user with cooperation of vendor (or authorized rep)

☐ Requires that two loaded, pre-weighed and measured (see 7.1.3) test vehicles each make multiple runs over WIM-system sensors

- Each lane
- Specified speeds

7.5.3 Test Unit for Calibration Loading

☐ Test unit shall comprise two loaded, pre-weighed, and measured test vehicles that will make multiple runs over the WIM-system in each lane at prescribed speeds

- One Class 05
- One Class 09

- ▫ Suspension types deemed by user to be representative of most vehicles of their type operating at the site
  - ✓ Leaf spring
  - ✓ Air
  - ✓ Other
- ▫ Loaded to at least 90% of their respective registered gross-vehicle weight
  - ✓ Non-shifting load
  - ✓ Approximately-symmetric (side-to-side) load
- ▫ Excellent mechanical condition
- ▫ Special care to ensure that tires on test vehicles in excellent condition
  - ✓ Preferably dynamically balanced
  - ✓ Inflated to recommended pressures

- ☐ Reference-value weighing and measurement of the two test vehicles shall be in accordance with 7.1.3

7.5.4 Site Conditions

- ☐ Before initial calibration begins, the existing site conditions (see 6.1) in each lane instrumented with WIM sensors shall be described quantitatively and made a matter of permanent record
  - ▫ Estimates of the location and magnitude of each observed pavement surface deviation not meeting smoothness requirement
- ☐ Record time and approximate ambient air temperature
  - ▫ Beginning of the calibration process
  - ▫ During the calibration process
  - ▫ End of the calibration process

7.5.5 Procedure

The following steps are involved in the on-site calibration process for each instrumented lane:

- ☐ 7.5.5.1 Adjust all WIM-system settings to either
  - ▫ Vendor's recommendations
  - ▫ Best estimate of the proper setting based upon previous experience

- ☐ 7.5.5.2 Measure the speed of each test vehicle every time it passes over the WIM-system sensors using method acceptable to both user (or rep) and vendor
  - ▫ Calibrated radar speed meter
    - ✓ Calibrated by the method recommended by its vendor within 30 days prior to use
  - ▫ Wheelbase/time
  - ▫ Other
- ☐ 7.5.5.3 Using approved traffic control procedures and other reasonable safety precautions
  - ▫ Each test vehicle to make a series of three or more runs over the WIM-system sensors at the minimum and maximum speed specified by the user between 10 and 80 mph (16 and 130 km/h)
    - ✓ Maximum specified speed to be less than legal speed limit at site

  - ✓ These two speeds should differ by at least 20 mph (30 km/h)
  - ✓ These two speeds should be above and below the average speed of the vehicles operating at the site
- ▫ Each test truck to pass over the sensors three more times at an intermediate speed that is representative of the prevailing truck traffic at the site
- ▫ At each speed
  - ✓ One or more runs made with the test vehicle tires near the left-hand lane edge
  - ✓ One or more runs made with the test vehicle tires near the right-hand lane edge
  - ✓ All other runs made with the test vehicle approximately centered in the lane
- ▫ Record all data, and note the vehicle record number for every run of each test vehicle

☐ 7.5.5.4 Calculate
- ▫ the difference in the WIM-system estimate and the respective reference value, expressed in percent (see 7.2.7), for the two test vehicles for each:
  - ✓ Speed
  - ✓ Wheel-load
  - ✓ Axle-load
  - ✓ Tandem-axle load
  - ✓ Gross-vehicle-weight
  - ✓ Axle-spacing
- ▫ A mean value for the differences for each set of values (if applicable, at each speed set point)

☐ 7.5.5.5 Make necessary changes to the WIM-system settings that will adjust the mean value of the respective differences for each value to approximately zero (if applicable, at each speed set point)
- ▫ In accordance with vendor's recommendations

7.6 On-site Acceptance Test

7.6.1 Scope

- ☐ Provides means for determining whether or not an installed new or modified WIM system meets or exceeds specified functional and performance requirements
- ☐ Defines for the user and the vendor the test method that will be applied for evaluation
- ☐ Requires user to quantify and document site conditions that exist when test is conducted
- ☐ Uses two test vehicles for the test loading unit

7.6.3 Procedure

Test shall be conducted on-site by user (or rep), in cooperation with the vendor, immediately after a WIM system has been installed or modified. The following steps are required for each instrumented lane:

- ☐ 7.6.3.1 Calibrate WIM-system and install WIM-system settings
  - Calibrate and install WIM-system settings per 7.5
  - Use another calibration procedure as agreed upon in advance by both user and vendor
- ☐ 7.6.3.2 With settings agreed upon by both user and vendor installed on WIM system
  - Each of the two test trucks
    - ✓ Makes five or more runs over the sensors at an attempted speed approximately 5 mph (8 km/h) less than the maximum speed and makes five or more additional runs at an attempted speed approximately 5 mph (8 km/h) greater than the minimum speed
      - Maximum and minimum speeds those used during calibration
      - At each speed
        - One or more runs made with test vehicle tires near left-hand lane edge
        - One or more runs made with test vehicle tires near right-hand lane edge
        - Other runs made with test vehicle approximately centered in lane
  - Measure the speed of each test vehicle every time it passes over the WIM-system sensors using method acceptable to both user and vendor
    - ✓ Calibrated radar speed meter
      - Calibrated by the method recommended by its vendor within 30 days prior to use
      - Wheelbase/time
      - Other
  - Record all data, and note the vehicle record number for every run of each test vehicle

7.6.4 Calculation

- ☐ Calculate percent difference (error) of WIM data items (7.2.7) for 20 or more runs of the test vehicles
  - Five or more runs at two speeds by two vehicles
- ☐ Compare the functions and performance of the WIM system with all specification requirements, including speed and axle spacing
  - Section 4 for Type I functions
  - Section 5 for Type I performance tolerances

7.6.5 Interpretation of Test Results and Report

Declare that the WIM-system was dysfunctional or inaccurate if either:

- ☐ Any specified data-collection feature, data-processing feature, or option of the Type I system described in Section 4 is not demonstrated to function properly
- ☐ More than 5 % of calculated differences for any applicable data item resulting from all passes of the two test vehicles exceeded the Type I tolerance specified in Section 5.

APPENDIX B

Survey Questionnaire

NCHRP Synthesis 38-10 Survey of High Speed WIM System Calibration Practices

Background:

Since their inception, the performance of weigh-in-motion (WIM) systems in effectively capturing truck weight data has been the focus of considerable investigation. Recently, the deployment of WIM systems has proliferated through initiatives such as the LTPP and the Commercial Vehicle Information Systems and Networks (CVISN) programs. Proper calibration is essential in achieving adequate WIM system performance and ensuring the quality of obtained data. This is becoming paramount in meeting the functional demands of public agencies and the trucking industry alike.

Objective:

The purpose of this Synthesis is to assemble state-of-the-practice information on the actual methodologies State agencies use in evaluating and calibrating their high speed WIM systems as well as monitoring the calibration of these systems over time. The survey questionnaire that follows is intended to collect this information. It is addressed to the manager of State agencies in charge of WIM used either for data collection or enforcement. We expect that some states will submit two surveys one for WIM used in traffic data collection and one for WIM used in enforcement screening.

Definition of terms:

High Speed refers to highway speeds (i.e., up to 80 mph) and as such includes WIM systems installed on mainline and utilized for data collection or enforcement screening, (i.e., it excludes enforcement screening WIM systems installed on approach ramps to truck inspection stations).

WIM System refers to one controller, its computer and associated electronics, and **all roadway sensors** for all lanes for which traffic data is being processed by the controller and at least one lane is instrumented with weigh-in-motion sensors.

WIM Lane refers to any lane which is instrumented with weigh-in-motion sensors.

Type I and Type II WIM refer to the definitions given by ASTM E1318-02. Type I systems weigh individually the right and left-hand side axles, while Type II systems weigh whole axles. ASTM E1318-02 accuracy tolerances are more stringent for Type I than for Type II systems. Type I systems are typically equipped with bending plates, load cell plates or quartz sensors. Type II systems are typically equipped with 6´ or 12´piezoelectric sensors in various configurations.

Site Assessment encompasses on-site activities preceding either an on-site evaluation or calibration to ensure that the WIM system is operational, the sensors have no visible problems and the pavement shows no signs of significant distress.

Evaluation/Validation refers to the on-site activities related to ascertaining compliance of WIM systems to error tolerances. It involves test trucks or samples of trucks from the traffic stream. It includes on-site testing for initial system acceptance, routine checks for calibration maintenance, and conformance to warranty requirements.

Calibration involves adjusting the system's constant by setting the mean error measurements to zero. Calibration data is typically obtained from test trucks or traffic stream trucks of known static weights.

WIM Calibration Monitoring is a data analysis that typically involves comparisons of representative traffic stream values to known load trends, (e.g., the weight of steering axles of 5-axle semi-trailers varies within a fairly narrow range and their gross vehicle weight exhibits a distinct double-peak pattern).

Auto-calibration is a mechanism built into WIM software effecting automatic calibration adjustments when certain measurements fall outside prescribed limits.

INSTRUCTIONS: Fill in the survey starting below. In the questions you will be asked to type in or click on responses. Each time you click on the Next Page button your responses are automatically saved. You can change your responses by paging back using the Previous Page button and reentering a response. (NOTE: Do NOT use your web browser's back and forward arrow buttons.) You can exit the WebSurveyor website at any time and your responses will be saved, allowing you to return to it later. If you complete part of the survey and want someone else to complete another section, you can do so by forwarding the email with the link to them and they will be able to access your partially completed survey using the same UniqueID and password.

NOTE: Once you click on the Submit Survey button at the end the survey, you can no longer edit nor see your responses.

To avoid having difficulty paging forward and backward through he survey it is advisable that you clear your cache before you complete this survey. Your cache is the temporary internet files folder. In Windows Explorer go to Tools/Internet Options/General and then delete Temporary Internet files.

Estimated time to complete survey: 1 to 1.5 hours

Part 1: PRIMARY RESPONDENT'S INFORMATION

We assume that multiple parties will be contributing to this survey but only want the name and contact information for the primary state department/division/agency person responsible for completing this survey listed here.

Name:

Title:

Agency:

Unit/Department/Division:

Mailing Address including city, state and zip:

Phone (please include extension, if any):

e-mail:

Is there another unit(department/division/agency) in your State managing high speed WIM systems used for a different purpose (i.e. , data collection versus enforcement)?

- No
- Yes

If Yes, please provide a contact name and information (address, phone, email) for the other unit below. We will send them a separate survey to complete.

Please comment below on whether your unit cooperates with that other unit and how:

Part 2: DESCRIBE YOUR WIM PROGRAM

2.1 What are the WIM systems for which your unit is primarily responsible used for?

- Traffic Data Collection Only
- Enforcement Screening Only
- Traffic Data Collection and Enforcement Screening

2.2 Which types of WIM systems have been installed by/for your unit?

- [ ] Type I
- [ ] Type II
- [ ] Other (please specify)

If you selected other, please specify:

2.3 Is auto-calibration typically utilized by your systems during routine data collection?

- ( ) No - It is not used in our systems
- ( ) Yes

Additional comments:

If Yes, for which system types? Check all that apply.

- [ ] Not Applicable - Do not use auto-calibration.
- [ ] Type I
- [ ] Type II
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

Part 3: WIM SYSTEM CALIBRATION PRACTICES AND PROCEDURES

3.1 Is a post-installation system calibration always performed?

- Yes
- No (click on next page to skip to 3.4)

Additional comments:

3.2 Who performs this post-installation calibration? Check all that apply.

- In-House Staff
- WIM Vendor
- Other contractor
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.3 Is the post installation calibration procedure any different than the routine calibration?

- No
- Yes: highlight the major DIFFERENCES in comment field below

Additional comments:

3.4 Which methods do you use for the evaluation/calibration of high speed WIM systems throughout their lives? Check all that apply.

- ☐ On-site evaluation/calibration using test trucks
- ☐ On-site evaluation/recalibration using traffic stream vehicles of known weights
- ☐ Calibration monitoring through quality control analysis of traffic stream data
- ☐ Other (please specify)

If you selected other, please specify:

Additional comments:

3.5 WIM On-Site Evaluation/Calibration Procedures Using Test Trucks

NOTE: The majority of the questions under 3.5 relate to the general provisions of the ASTM Standard E1318-02 and the LTPP WIM System Calibration Protocol. They are intended to determine which parts of these standards your unit may be using.

Do you perform on-site evaluation/calibration using test trucks?

- ○ Yes
- ○ No (click on next page to skip to 3.6)

In the series of questions under 3.5 please describe the procedure you use for the MOST COMMON WIM type in your unit (department/division/agency).

What is the most common WIM type in your unit for which test trucks are used for calibration?

- Type I
- Type II
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.1 Who conducts these on-site evaluation/calibration activities using test trucks? Check all that apply.

- In-House Staff
- Outsourcing to an external on call contractor
- Outsourcing to an external contractor that manages evaluation/calibration activities

Additional Comments:

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions.

3.5.2 What is the criterion you use to initiate test-truck WIM calibration? Check all that apply.

- It is routinely scheduled
- It is carried out only when calibration monitoring using traffic stream vehicles of known weight or traffic data indicates a calibration drift.
- Other (specify in Comments)

If routinely scheduled, specify typical interval (months):

Additional comments:

3.5.3 Do you have procedures for conducting diagnostic tests to ensure proper operation of the WIM system prior to committing to a complete on-site evaluation and/or calibration?

- No
- Yes

If Yes, how are these diagnostic tests conducted? Check all that apply.

- Not Applicable - Do not conduct diagnostic tests
- From the office by performing system diagnostics and/or data analyses
- At the site by performing system diagnostics and real-time monitoring
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.4 Do you have procedures for inspecting the condition of the WIM sensors?

- No
- Yes

If Yes, on which of the following do you perform a visual inspection? Check all that apply.

- Not Applicable - Do not have procedures for sensor inspection.
- Physical damage to sensor
- Proper levelling of sensors with pavement surface

- [ ] Secure attachment of sensors to pavement surface and/or frame
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.5 When conducting test-truck WIM calibrations, do you consider the pavement smoothness at the WIM site?

- No - Not Considered
- Considered only when system fails to meet accuracy tolerances.
- Yes, always considered.

Additional comments:

In cases where the pavement smoothness is considered which methods are used? Check all that apply.

- [ ] Not Applicable - Pavement smoothness not considered.
- [ ] Visual Inspection
- [ ] An inertial profilometer to obtain IRI
- [ ] An inertial profilometer to simulate straight-edge/pack test
- [ ] Other profile-based method
- [ ] Physical straight-edge/pack test
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.6 In conducting WIM calibrations with test trucks, do you consider the structural condition (deflection) of the pavement supporting the WIM sensors?

- No
- Yes, please highlight method in Comments.

Additional comments:

3.5.7 How are test trucks procured? Check all that apply.

- Agency owned
- Rented from trucking firm by Agency
- Rented from trucking firm by WIM vendor or other contractor
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.8 How many test trucks are used by class or type?

FHWA Class or Type

Number

FHWA Class or Type

Number

FHWA Class or Type

Number

FHWA Class or Type

Number

Additional comments (If more than 4 types are used please indicate the type(s) and number(s) here):

3.5.9 Do you specify the suspension type of these test trucks?

- No
- Yes

Additional comments:

If Yes, which types are specified? Check all that apply.

- Not Applicable - Types not specified.
- Air
- Leaf Spring
- Representative of the suspension types at the WIM site
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.10 What is your test truck loading criteria?

- Loaded to 90% to 100% of their legal load limit
- Loaded to reflect the local truck population loadings at the WIM site
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.11 Please provide the following details on static weighing in conjunction with WIM calibration using test trucks.

Do you require that static scales be certified?

- No
- Yes

Additional comments:

Which types of static scales do you use? Check all that apply.

- Fixed
- Portable
- Other (please specify)

If you selected other, please specify:

Which static weights are obtained? Check all that apply.

- Individual wheel/wheel sets for left and right wheel path
- Individual axles
- Axle groups
- Other (please specify)

If you selected other, please specify:

How many times is each static weight measured?

Additional comments regarding static weight practices:

3.5.12 Are the axle spacings for each test truck measured?

- No

- Yes

Additional comments:

3.5.13 Are the test truck speeds measured as they cross the sensors?

- No
- Yes, at least for the first few passes
- Yes, for every pass

Additional comments:

3.5.14 How is test truck speed measured?

- Not Applicable - Test truck speeds are neither measured nor their WIM speeds verified.
- By using a calibrated radar speed meter.
- Speed itself not measured, but WIM speed is verified by comparing WIM axle spacings to the measured axle spacings.
- By another method. Please specify in comment field below.

Additional comments:

3.5.15 At what speeds do the test trucks run?

- Single speed set at posted speed limit
- Single speed set at median speed of truck traffic stream
- Multiple speeds selected randomly by the driver
- Multiple speeds selected by agency within a range (specify range in Comments)
- Other (specify in Comments)

Additional comments:

3.5.16 Is there a minimum number of test truck runs required at each speed?

- No
- Yes

If Yes, please specify the minimum number of runs:

Number of runs for each speed.

Additional comments:

3.5.17 Are the test truck drivers given specific instructions as to the desired lane and speed for each run?

- No
- No, but they are advised to alter lanes and speeds within the ranges specified above.
- Yes

Additional comments:

If Yes, by what means are the instructions given? Check all that apply.

- Not Applicable
- CB radios or cell phones
- Check-off lists
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.18 Is the system auto-calibration turned off during test truck runs?

- Not Applicable - Auto-calibration not available.
- No
- Yes
- Do Not Know

Additional comments:

3.5.19 How is the test truck data being recorded during WIM calibration testing?

- Manual real-time recording of test truck WIM record numbers and WIM measurements.
- Electronic (computer printout or file) real-time recording of test truck WIM record numbers and WIM measurements.
- Real-time test truck WIM record numbers recorded only, while WIM measurements are retrieved later from system's datafiles for off-site processing.
- Other (please specify)

If you selected other, please specify:

Additional comments:

If test truck data is manually recorded, what method is used?

- Not Applicable - Do not manually record.
- Pencil/Paper
- Direct Computer Keyboard Entry
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.20 When performing on-site calibration using test trucks are the WIM error computations performed on-site?

- Never
- Yes, always
- Yes, only if it is evident that additional sampling of traffic steam trucks may be needed.

Additional comments:

3.5.21 During on-site calibration using test trucks how are the WIM error computations carried out?

- Manually, with hand-held calculator
- Using a spreadsheet or other analysis program supplied by a vendor
- Using a spreadsheet or other analysis program developed by your Agency
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.22 During on-site calibration using test trucks what error formula is used?

- The percent difference between WIM measurement and the corresponding static value.
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.23 For which of the following measurements are WIM errors computed during on-site calibration using test trucks? Check all that apply.

- Speed
- Wheel load and/or axle load
- Tandem axle load
- Gross vehicle weight
- Axle spacing
- Overall vehicle length
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.24 Are test trucks ever run for the sole purpose of determining WIM system accuracy tolerance pass/fail (e.g. new site acceptance, warranty, etc.)?

- No, calibration (or recalibration) is always done in conjunction with accuracy validation
- Yes, but under a fail situation vendor/contractor may use test truck data to recalibrate system
- Yes, but under a fail situation vendor/contractor must recalibrate using own trucks
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.25 During on-site calibration using test trucks, what method is used to compute the calibration factors?

- By setting the mean of the axle load arithmetic errors to zero

- By setting the mean error of the GVW to zero
- By combining the two methods above
- By setting the slope of the WIM versus static axle load measurements to zero
- Do Not Know (It is incorporated in the error computation spreadsheet)
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.26 During on-site evaluation using test trucks do you compute calibration factors for two or more speed points?

- Yes, our systems provide for two or more speed point factor entries and we do compute factors for each by analyzing data by speed.
- No, although our systems provide for two or more speed point factor entries a single factor is computed and used for all speed points.
- No, our systems provide for only a single factor.
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.5.27 What remedial action is taken for WIM systems that fail to meet accuracy tolerances during test truck testing?

- System is summarily abandoned or removed
- A site evaluation is undertaken to ascertain roughness and structural condition, as described earlier under 3.5.5 and 3.5.6
- System remains in use, but the data is used only for specific purposes
- Other (please specify)

If you selected other, please specify:

Additional comments:

What is the use of the data being generated by WIM systems that fail to meet accuracy tolerances?

- ☐ Not Applicable- sites evaluated and/or abandoned or removed
- ☐ Count/Classification
- ☐ Applications requiring only low quality weight estimates
- ☐ Other (please specify)

If you selected other, please specify:

Additional comments:

3.6 WIM On-Site Evaluation/Calibration Using Traffic Stream Trucks of Known Weight

NOTE: In this section we are referring to on-site evaluation/ calibration by sampling trucks from the traffic stream for which you are able to obtain static weights.

Do you perform on-site evaluation/calibration using traffic stream trucks of known weights?

- ○ Yes
- ○ No (click on next page to skip to 3.7)

In the series of questions under 3.6 please describe the procedure you use for the MOST COMMON WIM type in your unit(department/division/agency).

What is the most common WIM type in your unit for which traffic stream trucks of known weight are used for calibration?

- ○ Type I
- ○ Type II

☐ Other (please specify)

If you selected other, please specify:

3.6.1 Who conducts these on-site evaluation/calibration activities using traffic stream trucks of known weight? Check all that apply.

☐ In-House Staff
☐ Outsourcing to an external on-call contractor
☐ Outsourcing to an external contractor that manages evaluation/calibration activities.

Additional Comments:

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions.

3.6.2 What is the criterion you use to initiate WIM calibration using traffic stream trucks of known weight? Check all that apply.

☐ It is routinely scheduled
☐ It is carried out only when calibration monitoring using traffic data indicates a calibration drift.
☐ Other (specify in Comments)

If routinely scheduled, specify typical interval (months):

Additional comments:

3.6.3 How do you select the number of traffic stream trucks of known weight to be included in the sample?

- ☐ A fixed number of trucks is selected.
- ☐ All the trucks in a given time interval are selected.
- ☐ Some of the trucks in a given time interval are selected.
- ☐ Other (specify in Comments)

If a fixed number of trucks are selected, specify the number.

If all of the trucks in a given time interval are selected, specify the time interval (in hours).

If some of the trucks in a given time interval are selected, specify the number and interval:

Number of Trucks

Time Interval (in hours)

Additional comments:

3.6.4 What are the criteria used for selecting the type of traffic stream trucks of known weight to include in the sample?

- ☐ No particular criteria, i.e. sample is random
- ☐ Selecting specific truck classes, regardless of speed. Specify classes in Comments.
- ☐ Selecting specific truck classes by speed. Specify classes and speeds in Comments.
- ☐ Other (please specify)

If you selected other, please specify:

Additional comments:

3.6.5 How is the static weight of these traffic stream trucks obtained?

- [ ] Using portable scales
- [ ] Utilizing a nearby static enforcement facility.
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

If using a weight enforcement facility, how is the static weight of the traffic stream trucks recorded?

- [ ] Not Applicable - Weight enforcement facility not used.
- [ ] Automatically
- [ ] Manually

Additional comments:

3.6.6 Do you measure the axle spacing for these traffic stream trucks?

- [ ] No
- [ ] Yes
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

If Yes, how do you measure the axle spacing?

- [ ] Not Applicable - Axle spacing not measured.

- Manually
- Electronically
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.6.7 Is the system auto-calibration turned off during traffic stream truck runs?

- Not Applicable - Auto-calibration not available.
- No
- Yes
- Do Not Know.

Additional comments:

3.6.8 How is the WIM data of the sampled traffic stream trucks of known weight recorded?

- Manual real-time recording of test truck WIM record numbers and WIM measurements.
- Electronic (printout or file) real-time recording of test truck WIM record numbers and WIM measurements.
- Real-time test truck WIM record numbers recording only, while WIM measurements are retrieved later from system's data files for off-site processing.
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.6.9 Are the on-site calibration using traffic stream trucks of known weight WIM error computations performed on-site?

- Never
- Yes, always
- Yes, only if it is evident that additional sampling of traffic stream trucks may be needed

Additional comments:

3.6.10 During on-site calibration using traffic stream trucks of known weight how are the WIM error computations carried out?

- Manually, with hand-held calculator
- Using a spreadsheet or other analysis program supplied by a vendor
- Using a spreadsheet or other analysis program developed by your Agency
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.6.11 For which of the following measurements are WIM errors computed? Check all that apply.

- Speed
- Wheel load and/or axle load
- Tandem axle load
- Gross vehicle weight
- Axle spacing
- Overall vehicle length
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.6.12 Are traffic stream trucks of known weight ever sampled for the sole purpose of determining WIM system accuracy tolerance pass/fail (e.g. new site acceptance, warranty, etc.)?

- [ ] No, calibration (or recalibration) is always done in conjunction with accuracy validation
- [ ] Yes, but when "fail" vendor/contractor may use test truck data to recalibrate system
- [ ] Yes, but when "fail" vendor/contractor must recalibrate using own trucks
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

3.6.13 During on-site calibration using traffic stream trucks of known weight, what method is used to compute the calibration factors?

- [ ] By setting the mean of the axle load arithmetic errors to zero
- [ ] By setting the mean error of the GVW to zero
- [ ] By combining the two methods above
- [ ] By setting the slope of the WIM versus static axle load measurements to zero
- [ ] Do Not Know (It is incorporated in the error computation spreadsheet)
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

3.6.14 During on-site calibration using traffic stream trucks of known weight do you compute calibration factors for two or more speed points?

- [ ] Yes, our systems provide for two or more speed point factor entries and we do compute factors for each by analyzing data by speed.

- No, although our systems provide for two or more speed point factor entries a single factor is computed and used for all speed points.
- No, our systems provide for only a single factor.
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.6.15 What remedial action is taken for WIM systems that fail to meet accuracy tolerances during traffic stream truck evaluation?

- System is summarily abandoned or removed
- A site evaluation is undertaken to ascertain roughness and structural condition, as described in 3.5.5 and 3.5.6
- On-site evaluation using test trucks is undertaken, as described in 3.5
- System remains in use, but the data is used only for specific purposes
- Other (please specify)

If you selected other, please specify:

Additional comments:

What is data from systems that remain in use but fail to meet accuracy tolerances used for?

- Not Applicable-Sites evaluated and/or abandoned or removed.
- Count/Classification
- Applications requiring only low quality weight estimates
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.7 WIM Calibration Monitoring Using Traffic Stream WIM Data

Do you use WIM calibration monitoring using traffic stream WIM data to monitor your WIM systems?

- Yes
- No (click on next page to skip to Part 4)

Additional comments:

3.7.1 Who conducts WIM calibration monitoring using traffic stream WIM data? Check all that apply.

- In-House Staff
- Outsourcing to an external on-call contractor
- Outsourcing to an external contractor that manages evaluation/calibration activities.

Additional comments:

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions.

3.7.2 Typically, how often are your systems' data files downloaded?

- Daily
- Weekly
- Monthly
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.7.3 How are your systems' data files downloaded?

- [ ] Manually - utilizing communications software or via the internet
- [ ] Automatically - utilizing proprietary auto-polling software
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

3.7.4 How often do you perform checks of the WIM data?

- [ ] Daily
- [ ] Weekly
- [ ] Monthly
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

3.7.5 How is your WIM data analysis performed?

- [ ] Manually, using judgment to detect departure of known traffic stream properties from their expected ranges
- [ ] Automatically, using software to perform these tests (e.g. commercial or in-house developed software)
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

If your data analysis is performed automatically using software, when is it carried out?

- Not Applicable - Not automatic
- As an integral part of the download
- As a separate step

Additional comments:

3.7.6 In your opinion, do the analyses of your WIM data identify most system operational problems and atypical traffic characteristics?

- No
- Yes

Additional comments:

If Yes, which types of system operational problems and/or atypical traffic characteristics are identified? Check all that apply.

- Not Applicable
- Missing or atypical vehicle counts by hour
- Atypical class counts and/or distributions
- Large number or percentage of unclassified vehicles
- Large number of system error flags (e.g. loop not triggered)
- Large number of vehicle record flags (e.g. possible axle or wheel weighing errors)
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.7.7 Which traffic stream vehicle types are utilized for calibration monitoring? Check all that apply.

- [ ] All FHWA Class 9's
- [ ] 3S2 Only
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

3.7.8 Which characteristics are monitored through WIM calibration monitoring using traffic stream WIM data? Check all that apply.

- [ ] GVW average by speed
- [ ] GVW standard deviations
- [ ] GVW graph and/or listing of empty vs. loaded distributions
- [ ] Other GVW property
- [ ] Steering axle weight average
- [ ] Steering axle weight standard deviations
- [ ] Steering axle left/right wheel weights
- [ ] Other steering axle property
- [ ] Tractor tandem axle spacing
- [ ] Other axle spacing property
- [ ] Overall vehicle lengths vs. overall axle spacing
- [ ] Other (please specify)

If you selected other, please specify:

Additional comments:

3.7.9 If the monitoring of traffic stream characteristics indicates a system is experiencing calibration "drift" what action is taken?

- No action is taken.
- Calibration factors are adjusted from the office by remote access
- On-site evaluation/calibration as described earlier is triggered
- Other (please specify)

If you selected other, please specify:

Additional comments:

3.7.10 If calibration factors are adjusted from the office, do you check the effect on the traffic characteristics described in 3.7.8? *Those characteristics included: (GVW Average, GVW Average by speed, Steering axle weight average, etc.).*

- Not Applicable - Calibration factors NOT adjusted from office
- No, Never
- Yes, Always
- Sometimes. Please note in Comments field when it is checked.

Additional comments:

3.7.11 Do you keep records of WIM calibration factor adjustments?

- No
- Yes

Additional comments:

If Yes, how are records kept?

- [ ] Not Applicable - Records not kept.
- [ ] Automatically through the WIM system software
- [ ] Manually

Additional comments:

Part 4: YOUR OPINION

4.1 In your opinion, are your Type I traffic data systems generating data of adequate quality to meet the requirements for the intended purposes?

- ○ Not Applicable - Not responsible for any Type I systems used for traffic data
- ○ More than adequate quality
- ○ Generally adequate quality
- ○ Of marginal or borderline quality
- ○ Inadequate quality
- ○ Very inadequate quality - please give main reasons in Comments.
- ○ No Opinion

Additional comments:

4.2 In your opinion, are your Type I main line enforcement screening and/or sorting systems effective?

- ○ Not applicable - Not responsible for any Type I systems used for enforcement screening and/or sorting
- ○ More than effective
- ○ Generally effective
- ○ Of marginal or borderline effectiveness
- ○ Ineffective
- ○ Very ineffective - Please give main reasons in Comments.
- ○ No opinion

Additional comments:

4.3 In your opinion, are your Type II traffic data systems generating data of adequate quality to meet the requirements for the intended purposes?

- Not Applicable - Not responsible for any Type II systems used for traffic data
- More than adequate quality
- Generally adequate quality
- Of marginal or borderline quality
- Inadequate quality
- Very inadequate quality - please give main reasons in Comments.
- No Opinion

Additional comments:

4.4 In your opinion, are your Type II main line enforcement screening and/or sorting systems effective?

- Not applicable - Not responsible for any Type II systems used for enforcement screening and/or sorting
- More than effective
- Generally effective
- Of marginal or borderline effectiveness
- Ineffective
- Very ineffective - Please give main reasons in Comments.
- No opinion

Additional comments:

4.5 In your opinion, given additional resources for high speed WIM traffic data collection and enforcement, which of the following would your unit consider? Check all that apply.

- Install additional WIM systems
- Install newer and better technology WIM systems to replace current ones

- [ ] Perform more intensive system diagnostics and calibration monitoring
- [ ] Perform more on-site system calibrations

Additional comments:

4.6 In your opinion, what is the main factor hindering proper WIM calibration and how could it be solved?

4.7 In your opinion, what are the most urgent WIM technical needs at present and what studies need to be conducted to address them?

Please provide any additional comments you may want to share about high speed WIM calibration.

Part 5: INVENTORY OF WIM SYSTEMS

This last part of the questionnaire is optional. It is an inventory of WIM systems in your state.

Do you want to complete it?

- ☐ Yes
- ☐ No (click next page to skip to end of survey)

INVENTORY OF TYPE I WIM SYSTEMS

5.1 Approximately how many Type I WIM systems are currently in use by your unit for the following purposes:

Please put in a "0" if you have no systems that fall into a category or you are not responsible for those systems.

Dual Use - A Single WIM System Used for Both Traffic Data Collection AND Enforcement Screening

Approximate number of **Type I WIM Systems** [ ]

Approximate Number of **Type I WIM Lanes** [ ]

Sensor Type(s) [ ]

Single Use - Traffic Data Collection ONLY

Approximate Number of **Type I WIM Systems** [ ]

Approximate Number of **Type I WIM Lanes** [ ]

Sensor Type(s) [ ]

Single Use - Enforcement Screening ONLY

Approximate Number of **Type I WIM Systems**

Approximate Number of **Type I WIM Lanes**

Sensor Type(s)

INVENTORY OF TYPE II WIM SYSTEMS

5.2 Approximately how many Type II WIM systems are currently in use by your unit for the following purposes:

Please put in a "0" if you have no systems that fall into a category or you are not responsible for those systems.

Dual Use - A Single WIM System Used for Both Traffic Data Collection AND Enforcement Screening

Approximate Number of **Type II WIM Systems**

Approximate Number of **Type II WIM Lanes**

Sensor Type(s)

Single Use - Traffic Data Collection ONLY

Approximate Number of **Type II WIM Systems**

Approximate Number of **Type II WIM Lanes**

Sensor Type(s)

Single Use - Enforcement Screening ONLY

Approximate Number of **Type II WIM Systems**

Approximate Number of **Type II WIM Lanes**

Sensor Type(s)

Thank you again for your time and effort in completing this survey.

APPENDIX C

WIM Inventory

	AK	AL	AR	AZ	CA	CO	CT	FL	ID	KS	LA	MA	MD	MI
		(T)					(T)		(E)					
TYPE I SYSTEMS														
Dual Use Systems	6	14	0	6	6	0		0	0	0	8	0	1	20
WIM Lanes		56		8	16						16		?	80
Sensor Type(s)	BP, LC	BP		LC	BP						LC,PZ		QZ	BP,QZ
Traffic Data Systems	0		0	11	101	0	5 (R)	7	18	2	0	0	0	13
WIM Lanes				22	412		?	22	40	3				52
Sensor Type(s)				BP, PZ	BP, QZ		QZ	BP	PZ	BP,PZ				BP,QZ
Enforcement Systems	0		0	0	28	13		0	2	0	0	0	0	0
WIM Lanes					60	15			2					
Sensor Type(s)					BP	LC			LC					
TYPE II SYSTEMS														
Dual Use Systems	0	0	0	2	0	0		0	0	0	0	0	0	24*
WIM Lanes				2										96*
Sensor Type(s)				PZ										PZ*
Traffic Data Systems	0		54	7	0	16		34	0	8	0	12	6	
WIM Lanes			174	7		62		90		17		30	6	
Sensor Type(s)			PZ	PZ		?		BP,QZ,PZ		PZ		PZ	PZ	
Enforcement Systems	0	0	0	0	0	11		0		0	0	0	0	0
WIM Lanes						11								
Sensor Type(s)						PZ								

(T) Traffic Unit declined to provide info
(E) Enforcement Unit declined to provide info
* Appears to be a duplication of "Dual Use" counts
(R) Research Unit info only
BP: Bending Plate
QZ: Quartz Piezo
LC: Load Cell
PZ: Conventional Piezo

	MS	MT	NC	ND	NE	NH	NJ	NM	NV	NY	OK	OR	PA	SC
					(T)									
TYPE I SYSTEMS														
Dual Use Systems	1	10	3	12		0	0	0	1	0	0	22	0	0
WIM Lanes	4	19	2	0					4			24		
Sensor Type(s)	BP	BP,QZ	?	QZ					BP,QZ			LC		
Traffic Data Systems	0	2	1	0		0	0	3	5	22	0	0	0	0
WIM Lanes		4	1					12	20	?				
Sensor Type(s)		PZ	?					?	BP,QZ	?				
Enforcement Systems	0	7	0	0		0	0	0	0	0	0	0	0	0
WIM Lanes		11												
Sensor Type(s)		BP,QZ												
TYPE II SYSTEMS														
Dual Use Systems	15	0	0	0		0	0	0	0	0	0	0	0	12
WIM Lanes	4													44
Sensor Type(s)	BP													PZ
Traffic Data Systems	0	24	0	0		4	65	13	0	0	20	0	8	0
WIM Lanes		66				18	260	48			76		9	
Sensor Type(s)		PZ				PZ	?	?			PZ		QZ	
Enforcement Systems	0	0	0	0	6	0	0	0	0	0	0	0	0	0
WIM Lanes					6									
Sensor Type(s)					?									

(T) Traffic Unit declined to provide info
(E) Enforcement Unit declined to provide info
(R) Research Unit info only
BP: Bending Plate
QZ: Quartz Piezo
LC: Load Cell
PZ: Conventional Piezo

	TN	TX	UT	VA	VT	WA	WI	WY
TYPE I SYSTEMS								
Dual Use Systems	0	0	3	3	0	11	0	0
WIM Lanes			3	10		11		
Sensor Type(s)			LC	QZ		LC		
Traffic Data Systems	0	12	0	4	0	1	1	0
WIM Lanes		48		10		2	4	
Sensor Type(s)		BP		BP,QZ		?	BP	
Enforcement Systems	0	0	0	14	0	0		0
WIM Lanes				14				
Sensor Type(s)				LC				
TYPE II SYSTEMS								
Dual Use Systems	0	0	0	0	17	11	0	0
WIM Lanes					46	11		
Sensor Type(s)					PZ	LC		
Traffic Data Systems	30	4	9	0	0	32	10	9
WIM Lanes	2	16	56			90	30	22
Sensor Type(s)	PZ	PZ	PZ			?	PZO	PZ
Enforcement Systems	0	0	0	0	0	0	0	0
WIM Lanes								
Sensor Type(s)								

(T) Traffic Unit declined to provide info
(R) Research Unit info only
BP: Bending Plate
LC: Load Cell
(E) Enforcement Unit declined to provide info
QZ: Quartz Piezo
PZ: Conventional Piezo

APPENDIX D

Aggregate Survey Results (All High-Speed WIM Applications)

Survey Results & Analysis

for

NCHRP Synthesis 38-10 Survey of High Speed WIM System Calibration Practices

Saturday, June 2, 2007

Powered by:

http://www.websurveyor.com/

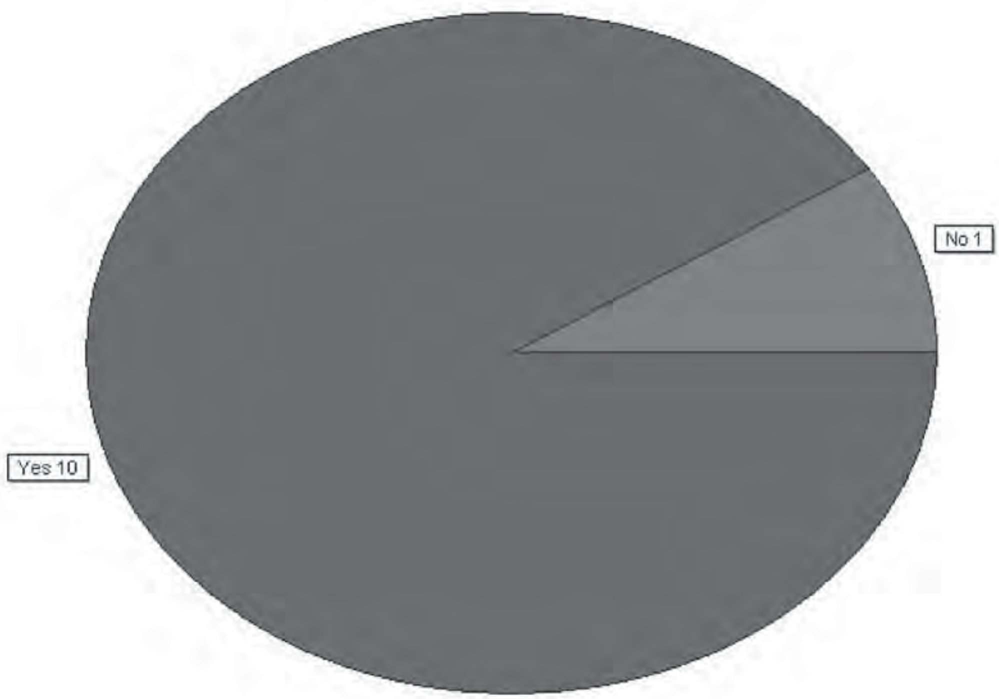
Executive Summary

This report contains a detailed statistical analysis of the results to the survey titled *NCHRP Synthesis 38-10 Survey of High Speed WIM System Calibration Practices*. The results analysis includes answers from all respondents who took the survey in the 76 day period from Friday, March 16, 2007 to Wednesday, May 30, 2007. 11 completed responses were received to the survey during this time.

Survey Results & Analysis

Survey: NCHRP Synthesis 38-10 Survey of High Speed WIM System Calibration Practices
Author: T. Papagiannakis and R. Quinley
Filter: (In question "13) 2.1 What are the WIM systems for which your unit is primaril..." the respondent selected "Enforcement Screening Only")
Responses Received: 11

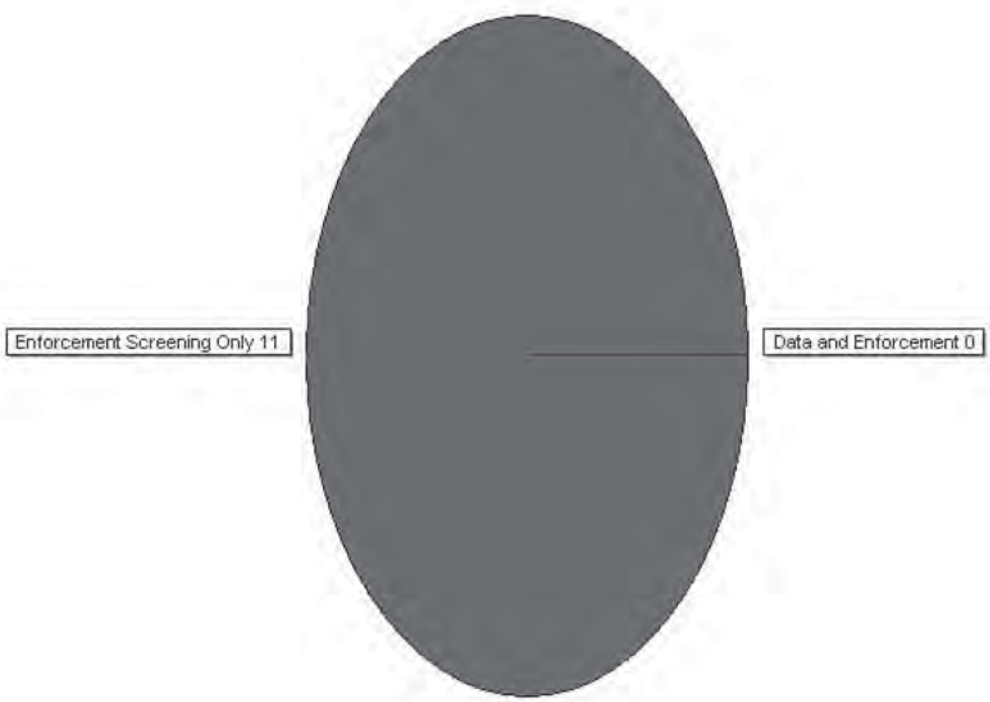
Is there another unit (department/division/agency) in your State managing high speed WIM systems used for a different purpose (i.e., data collection versus enforcement)?



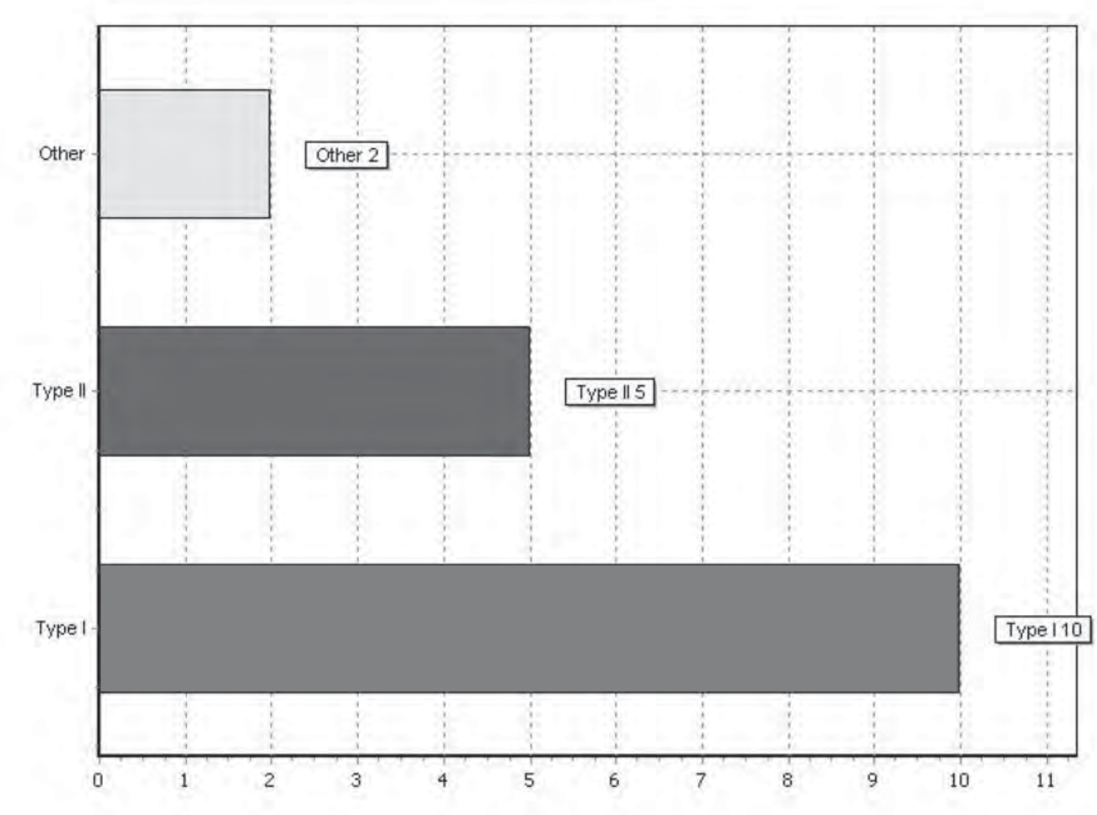
Please comment below on whether your unit cooperates with that other unit and how:

Not known
MT-Enforcement: Motor Carrier Services Division receives enformenent reports from Planning Division for all WIM systems statewide. Planning Division maintains all MDT piezo-based WIM systems, three of which are use for weigh station bypass. MCS Division maintains all Bender-plate WIM systems used for weigh station bypass.
CO-Enf: Sites for Enforcement and Data collection have been shared to compare new technologies as well as to fulfill other uses such as traffic monitoring for incident detection and public information
WA-Enf: Yes we cooperate together. Some of the CVISN WIM sites give data to the Transportation Data Collection information system.
NC-Enf: This unit provides us raw data for interpetation and use in enforcement operations.
AZ-Enf: Yes but cooperation has been very limited. They have had little to no interest so far in sharing info with us or from us.
ID-Enf: Work in partnership when need arises

2.1 What are the WIM systems for which your unit is primarily responsible used for?



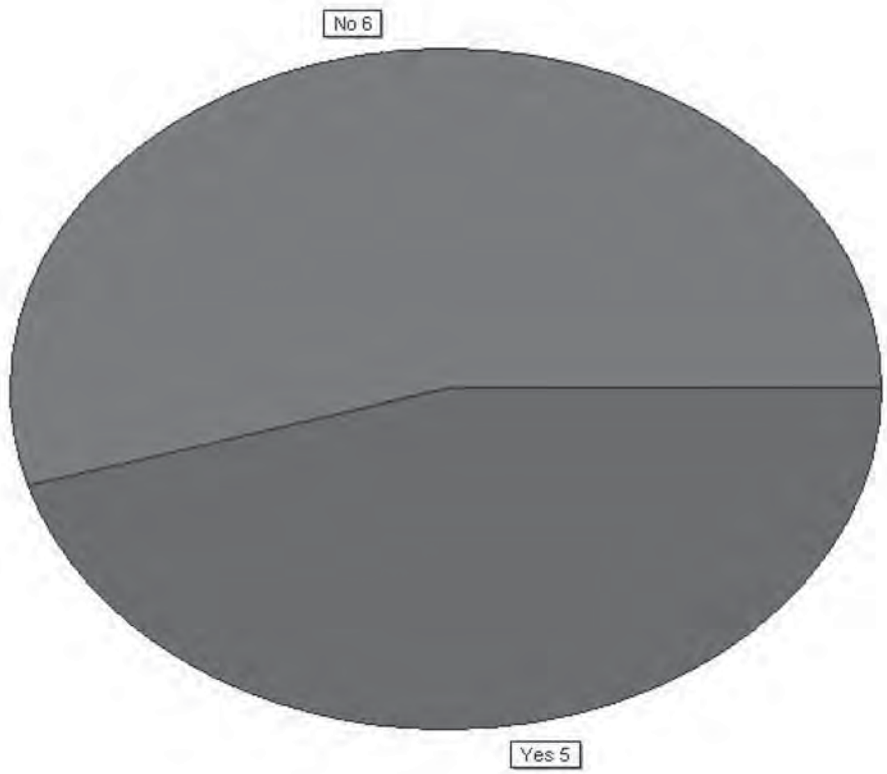
2.2 Which types of WIM systems have been installed by/for your unit?



Other Responses:

Type III

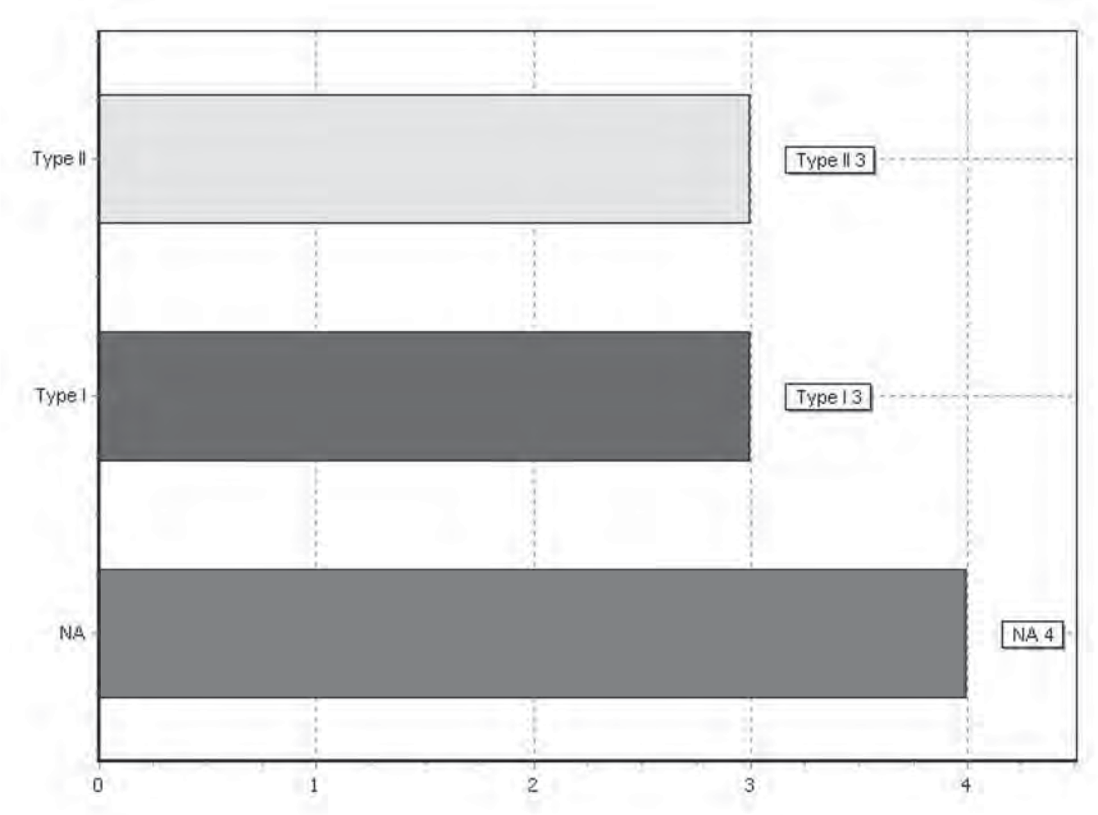
2.3 Is auto-calibration typically utilized by your systems during routine data collection?



Comment Responses:

MT-Enforcement: The bender-plates are not temperature sensitive.
AZ-Enf: Also annual calibration by service techs.

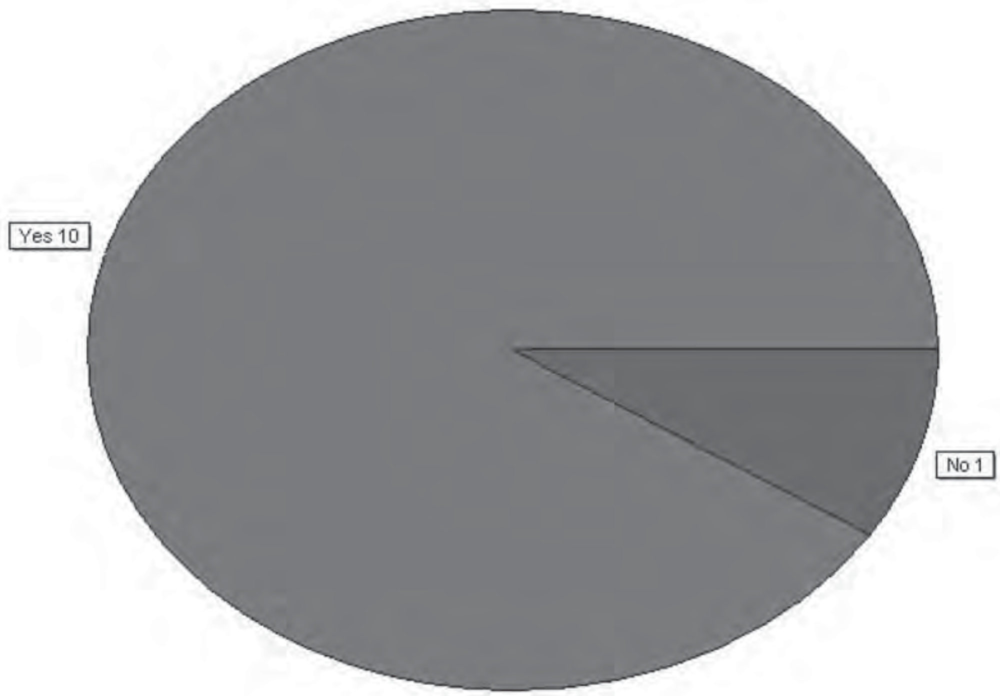
If Yes, for which system types? Check all that apply.



Other Responses:

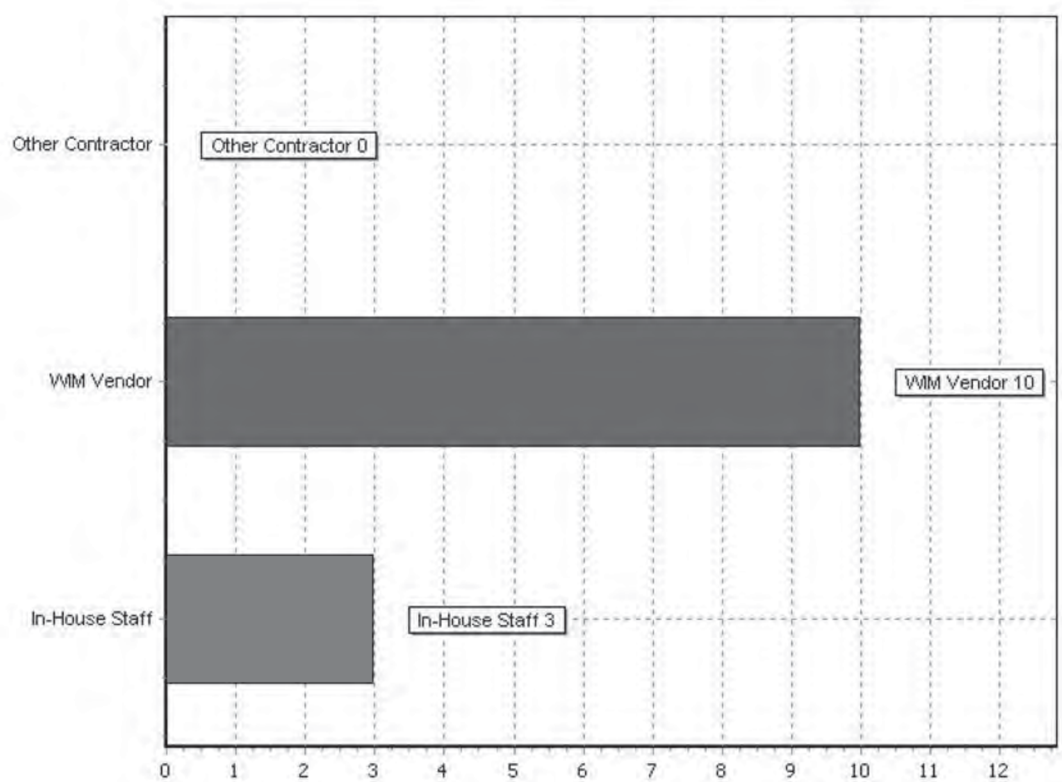
Comment Responses:

3.1 Is a post-installation system calibration always performed?



Comment Responses:

3.2 Who performs this post-installation calibration? Check all that apply.

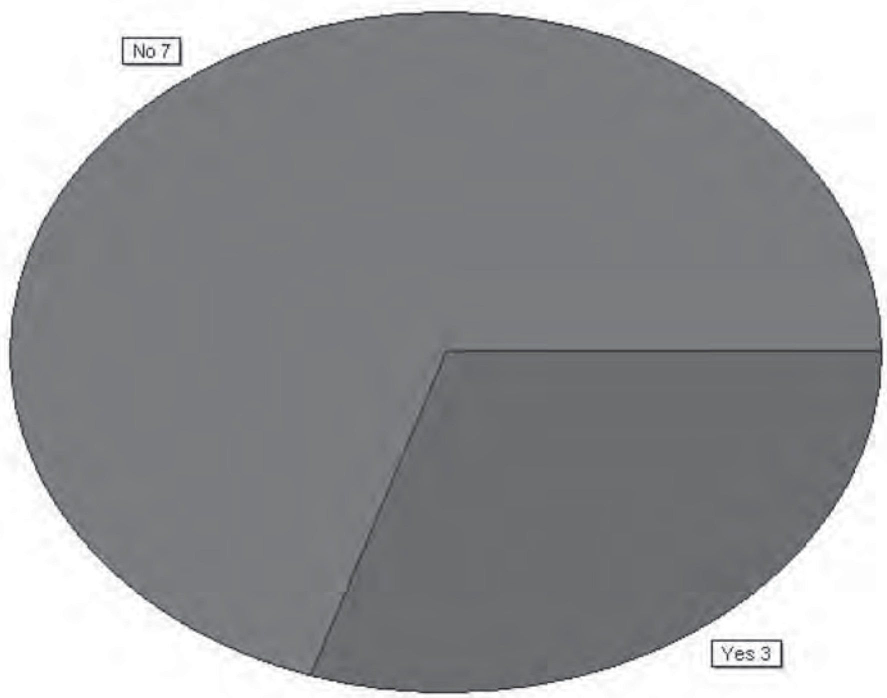


Other Responses:

Additional comments:

MT-Enforcement: Since the bender-plate systems used by MCS are for high-speed screening in conjuction with AVI (PrePass), in house and vendor staff collect WIM information from 26 type 9, non-liquid, not livestock loads per lane. A scale officers weighs each vehicles axle groups using the static platform scale and records the weights with corresponding WIM record. Using this information, calibration factors are determined and entered into the recorder. Another sample of WIM and corresponding static weight records are collected to verify calibration. This process continues until calibration is achieved and verified.
AZ-Enf: IRD installed and maintains all of our sites at this time.

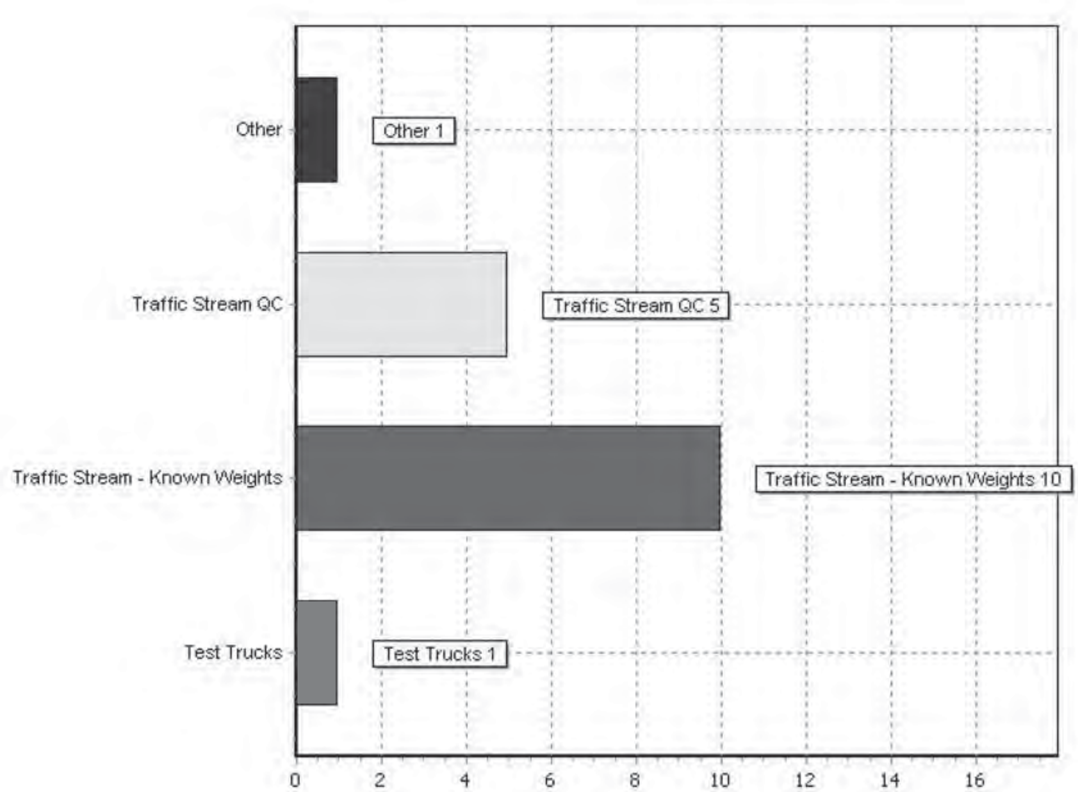
3.3 Is the post installation calibration procedure any different than the routine calibration?



Additional comments:

AL-Enf: We have known weight trucks with 2 different axle configurations and run them continuously over the WIM until calibrated
WA-Enforcement: We use a known truck, a calibration truck, with known weights and known axle distances during the post installation calibration versus n-trucks from the highway.
AZ-Enf: Only to the extent we test and retest it several times at the initial installation calibration acceptance stage.

3.4 Which methods do you use for the evaluation/calibration of high speed WIM systems throughout their lives? Check all that apply.

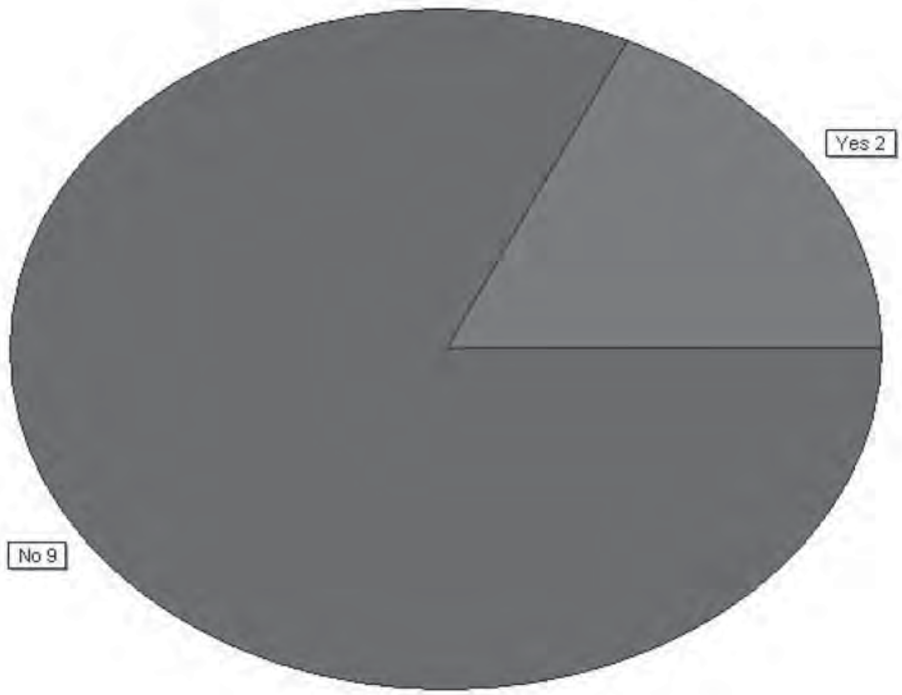


<u>Other Responses</u>:

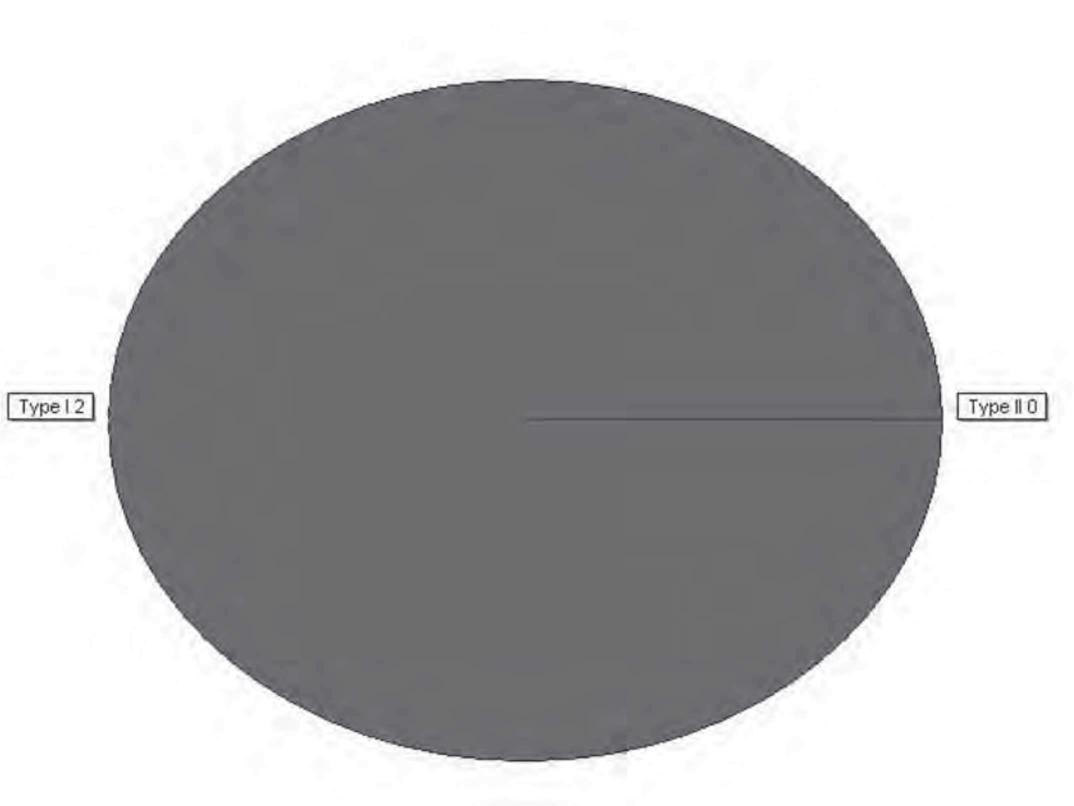
<u>Comment Responses</u>:

MD-Enf: PrePass tag comparison method (weights on static scales compared to weights on WIM)
MT-Enf: Using weight distribution graphs produced from data collected from each WIM recorder, MCS can observe loaded and unloaded peaks to montor system changes or drifts. We also monitor prepass data for pull ins.
CO-Enf: Port Operators track truck weights periodically and call when a pattern of either overweight or under weight vehicles appear
AZ-Enf: Annual test required. Also use self calabration and monitering of system on regular basis

3.5 WIM On-Site Evaluation/Calibration Procedures Using Test Trucks NOTE: The majority of the questions under 3.5 relate to the general provisions of the ASTM Standard E1318-02 and the LTPP WIM System Calibration Protocol. They are intended to determine which parts of these standards your unit may be using. Do you perform on-site evaluation/calibration using test trucks?



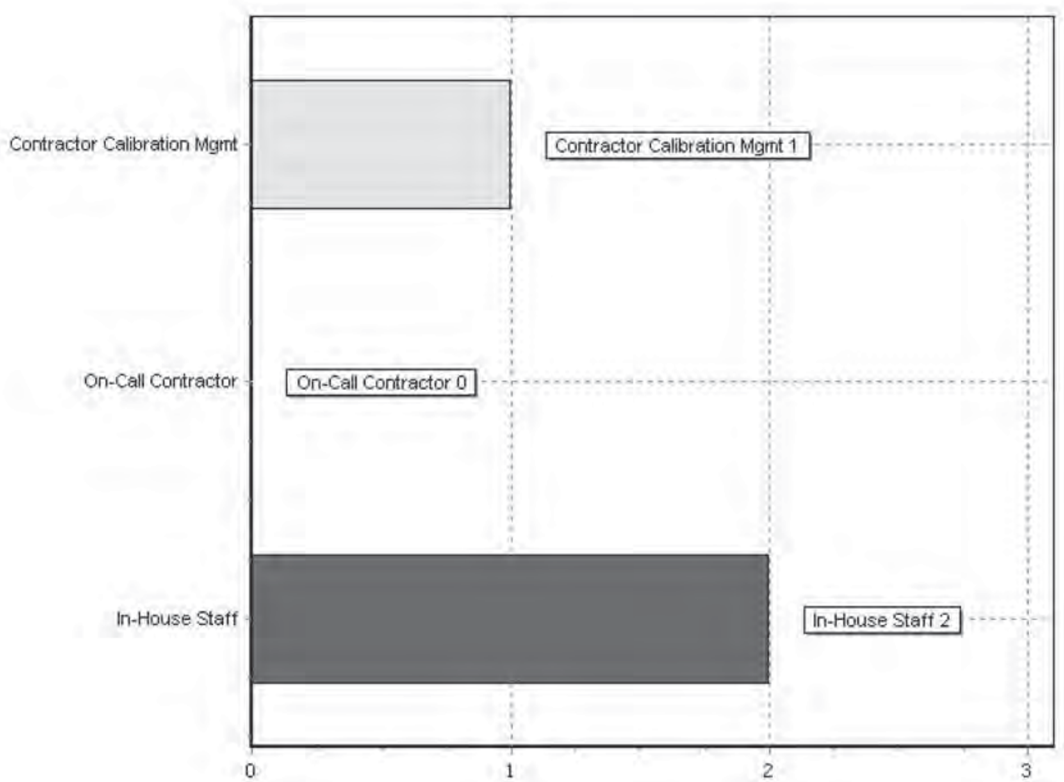
In the series of questions under 3.5 please describe the procedure you use for the MOST COMMON WIM type in your unit (department/division/agency). What is the most common WIM type in your unit for which test trucks are used for calibration?



Other Responses:

Comment Responses:

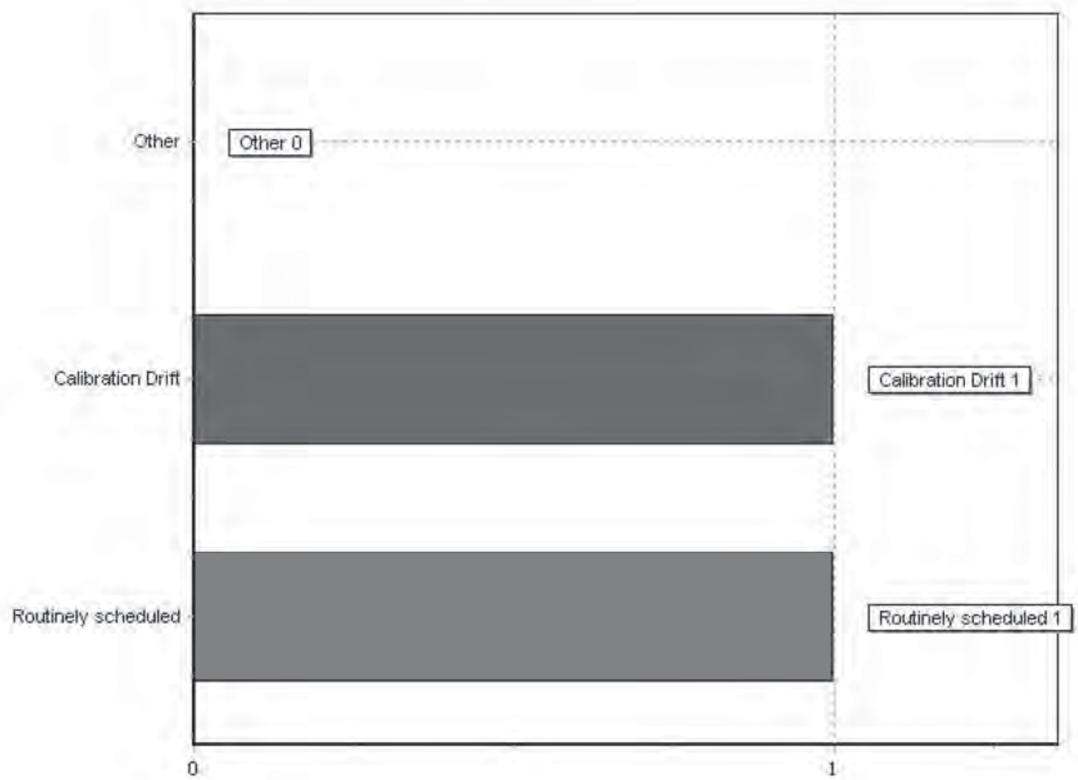
3.5.1 Who conducts these on-site evaluation/calibration activities using test trucks? Check all that apply.



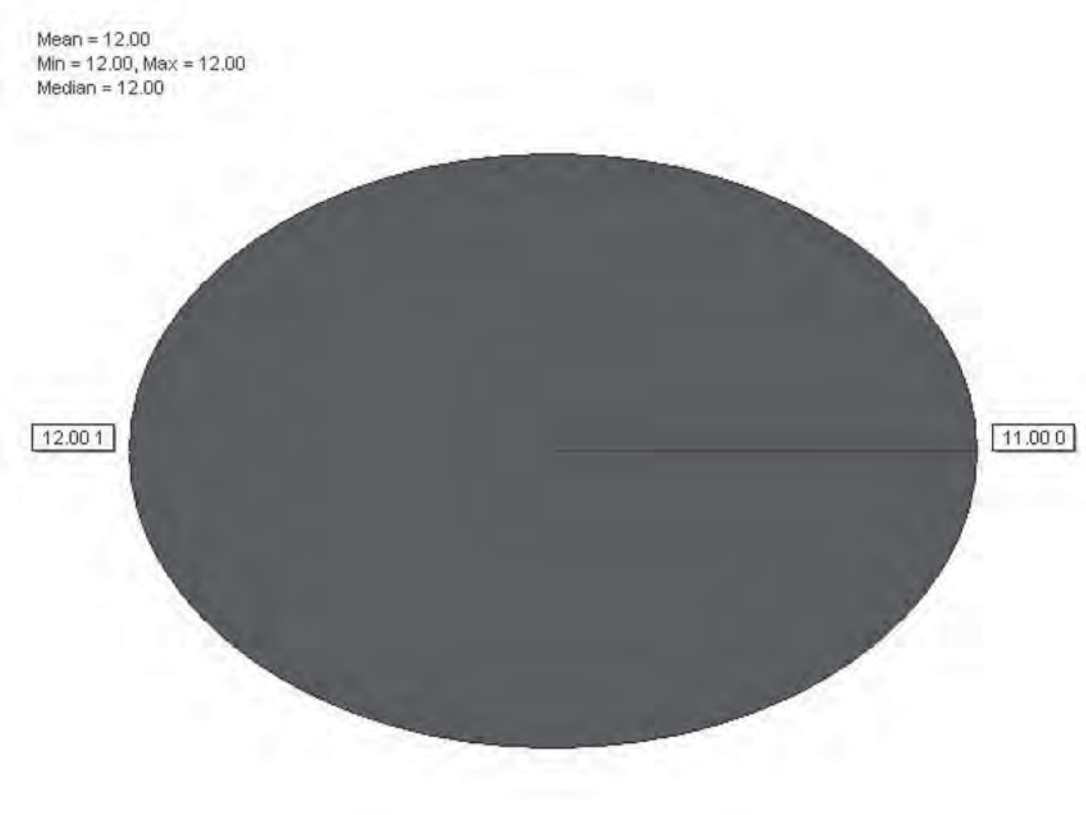
Additional Comments:

AZ-Enf: Use both. IRD is primary contractor.

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions. 3.5.2 What is the criterion you use to initiate test-truck WIM calibration? Check all that apply.



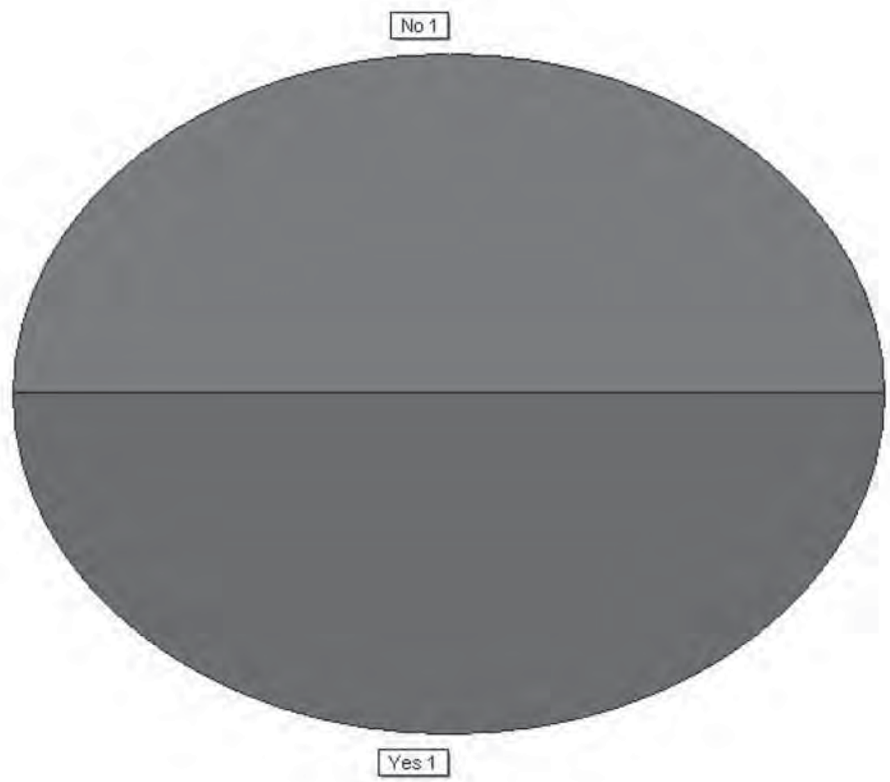
If routinely scheduled, specify typical interval (months):



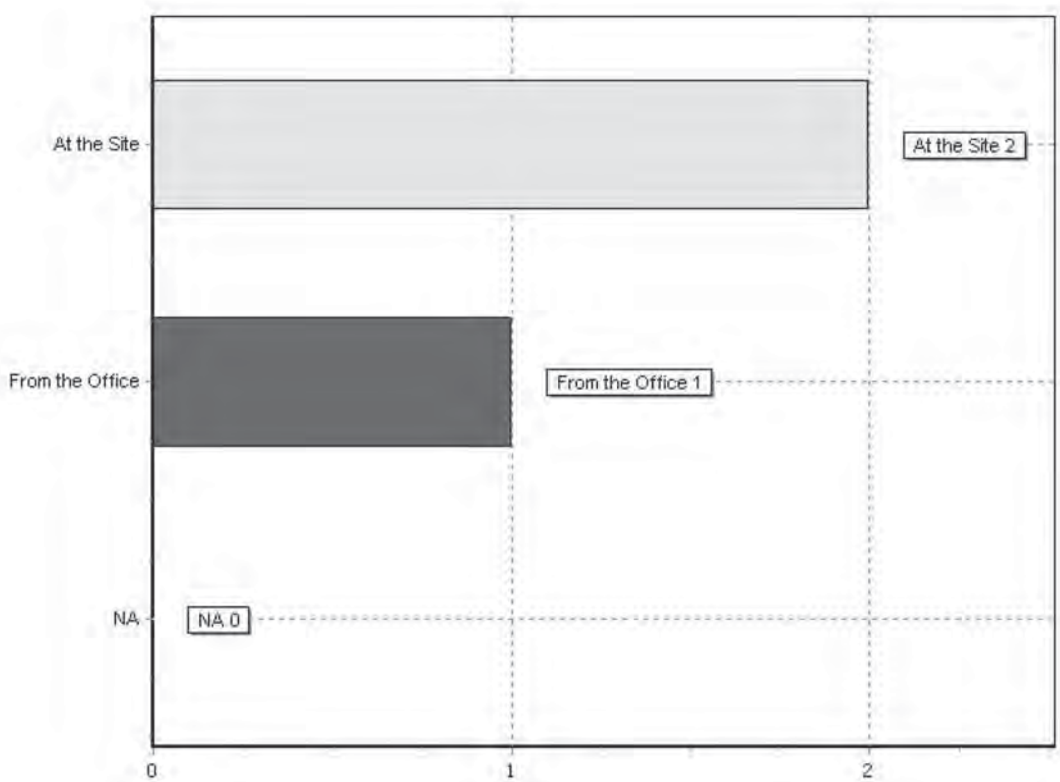
Additional comments:

AZ-Enf: Annual testing with constant on-line monitering by IRD for system review.

3.5.3 Do you have procedures for conducting diagnostic tests to ensure proper operation of the WIM system prior to committing to a complete on-site evaluation and/or calibration?



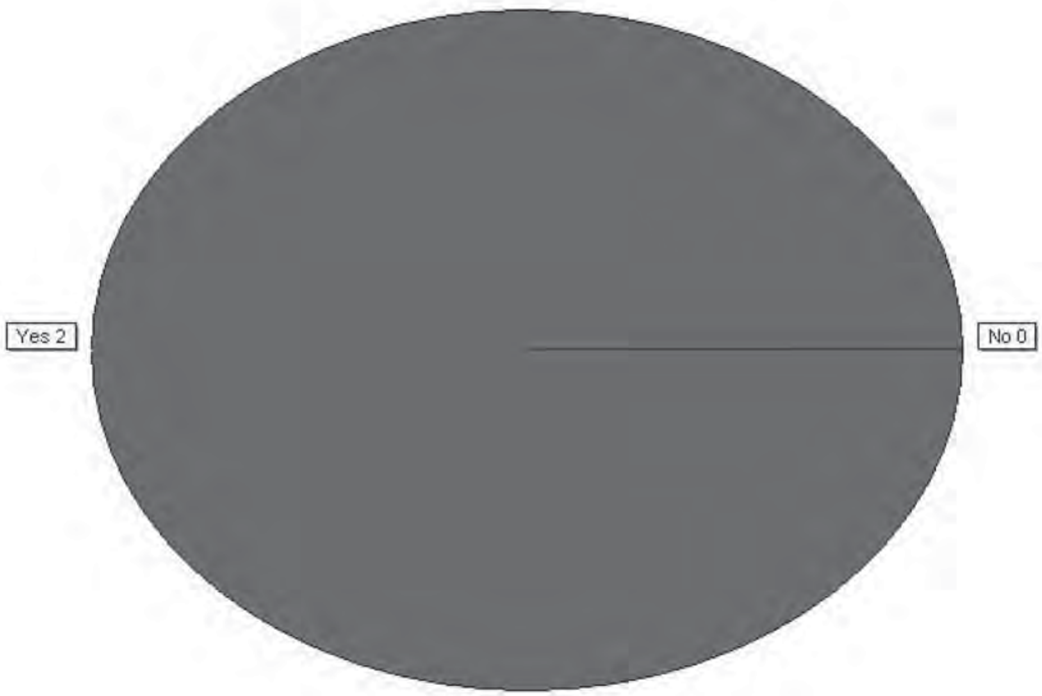
If Yes, how are these diagnostic tests conducted? Check all that apply.



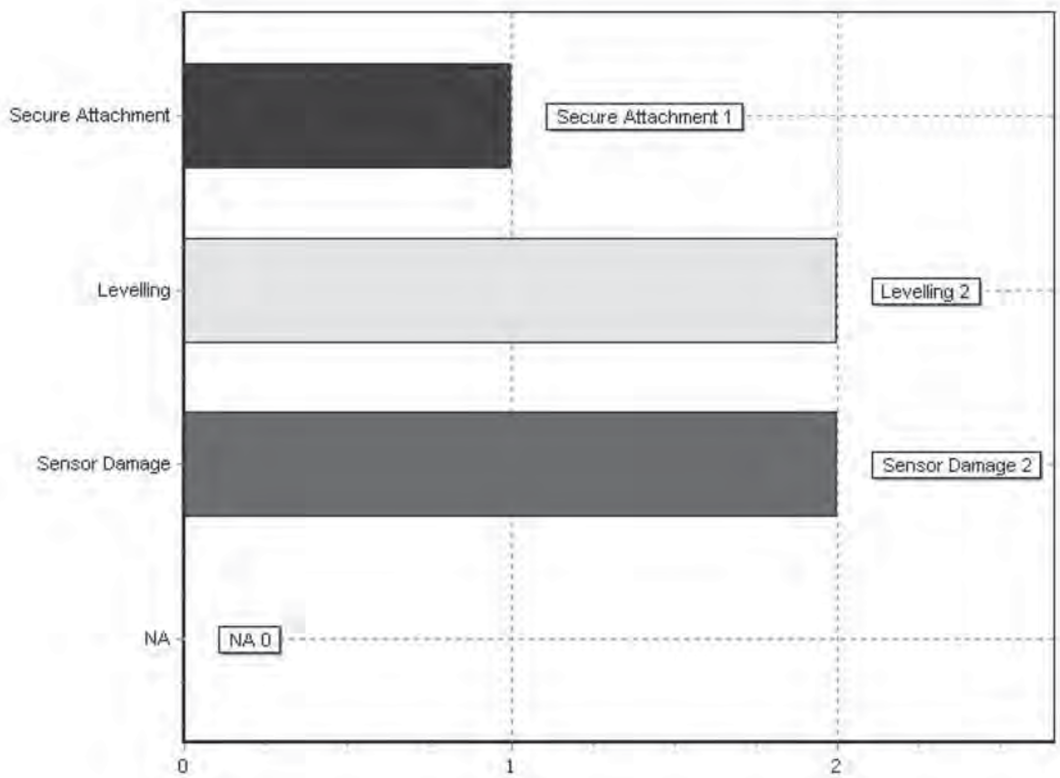
Other Responses:

Comment Responses:

3.5.4 Do you have procedures for inspecting the condition of the WIM sensors?



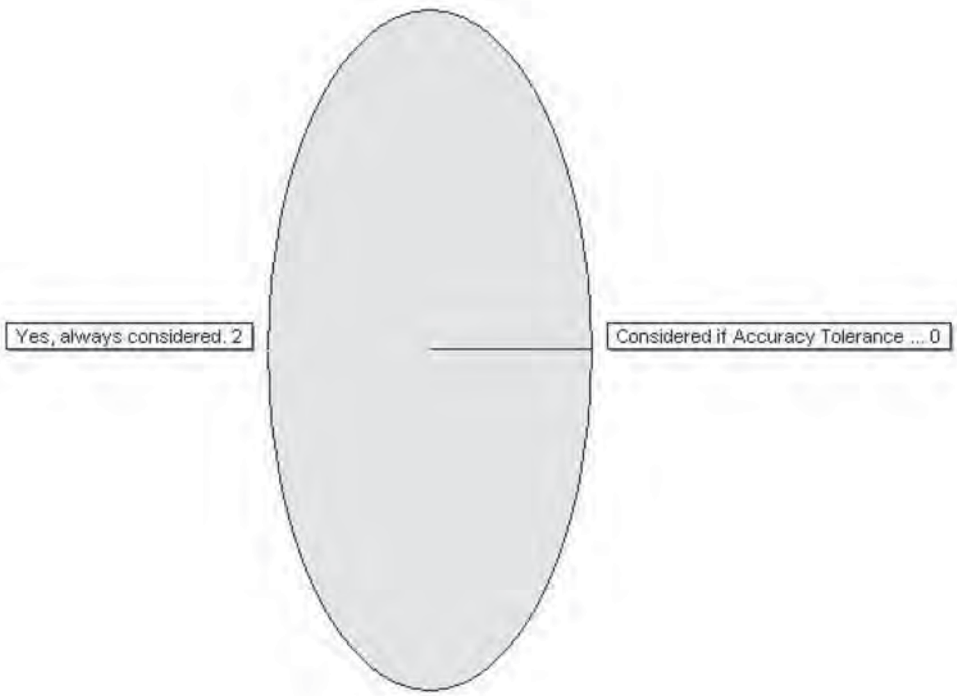
If Yes, on which of the following do you perform a visual inspection? Check all that apply.



Other Responses:

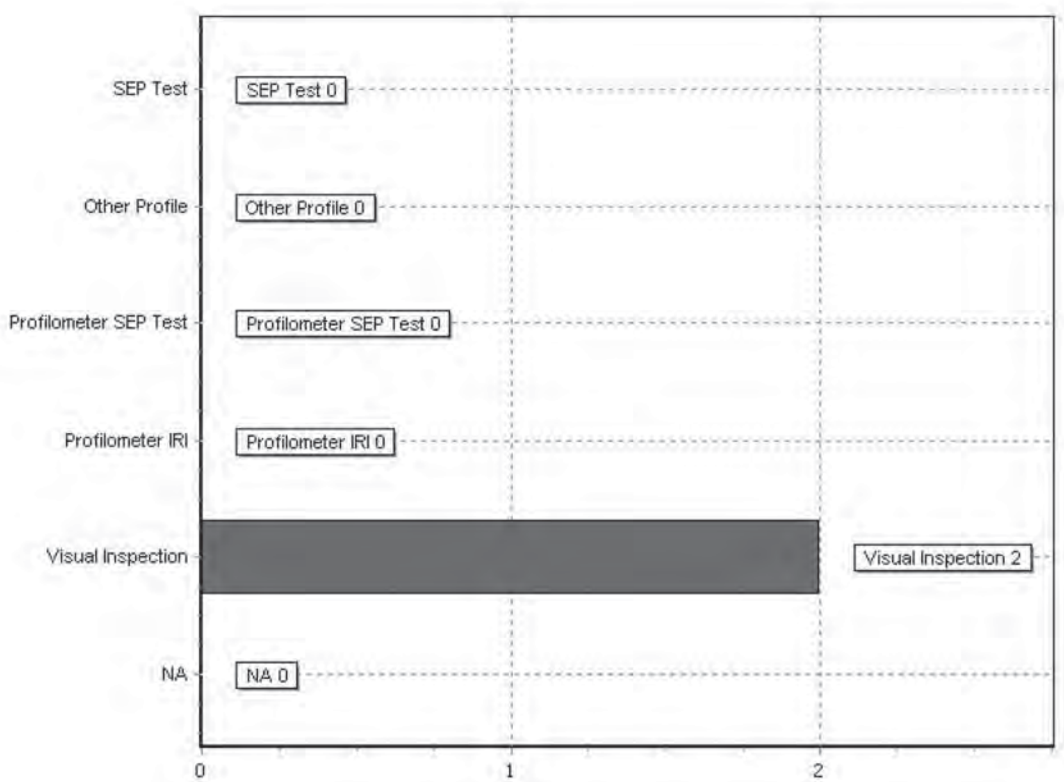
Comment Responses:

3.5.5 When conducting test-truck WIM calibrations, do you consider the pavement smoothness at the WIM site?



Comment Responses:

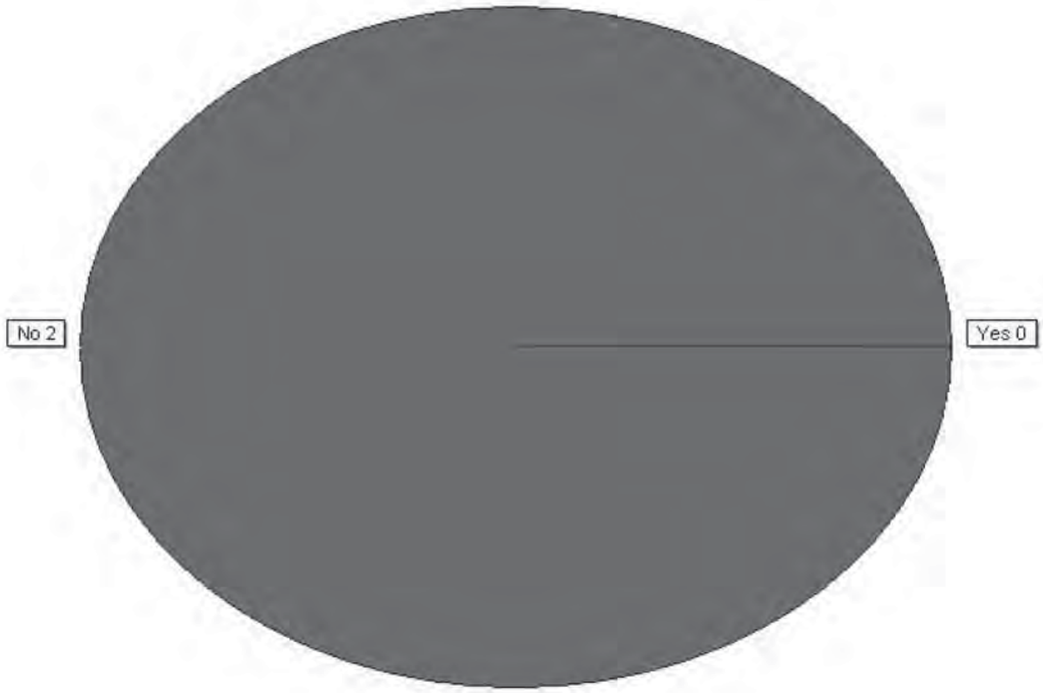
In cases where the pavement smoothness is considered which methods are used? Check all that apply.



<u>Other Responses</u>:

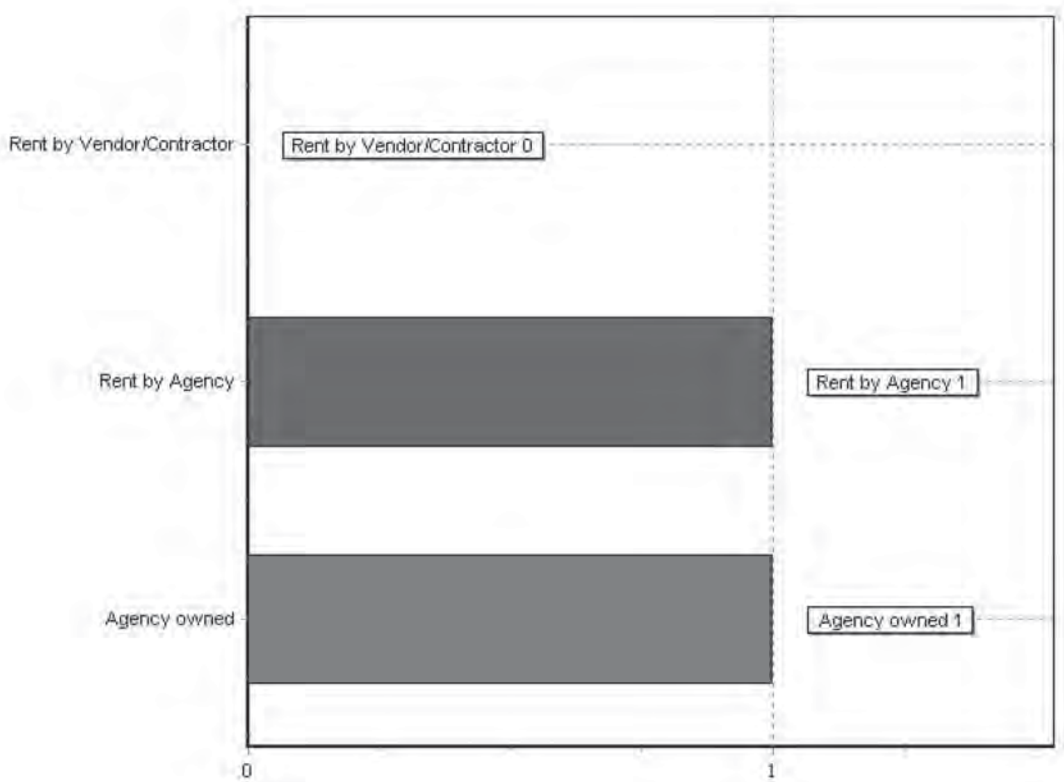
<u>Comment Responses</u>:

3.5.6 In conducting WIM calibrations with test trucks, do you consider the structural condition (deflection) of the pavement supporting the WIM sensors?



Comment Responses:

3.5.7 How are test trucks procured? Check all that apply.



Other Responses:

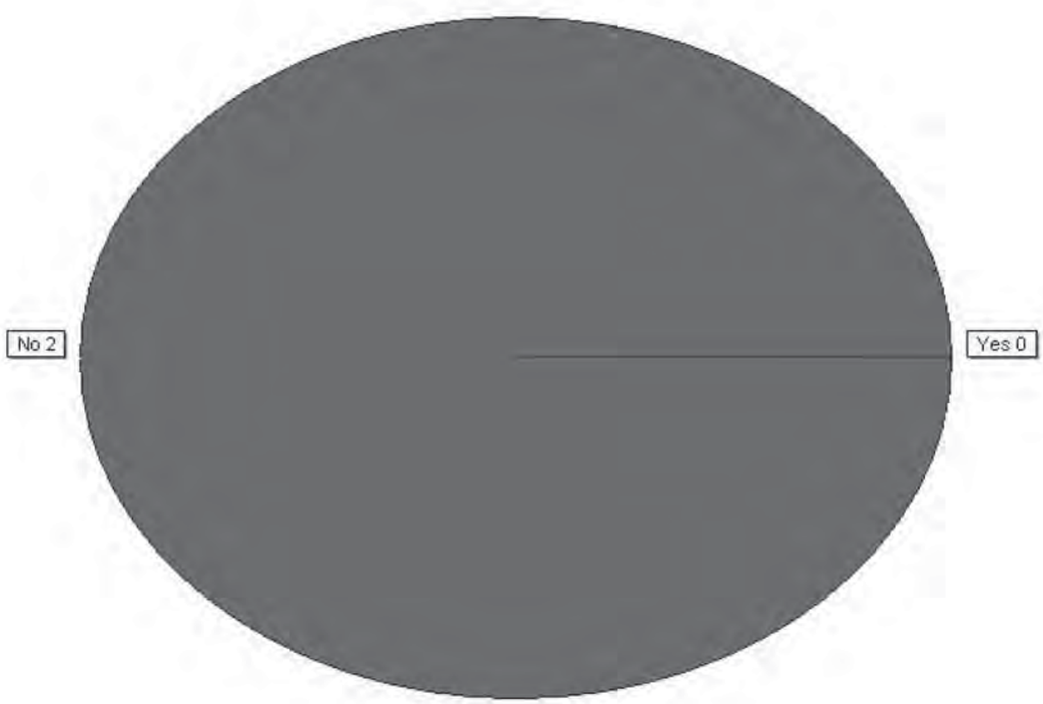
Comment Responses:

3.5.8 How many test trucks are used by class or type?

FHWA Class or Type	Number	FHWA Class or Type	Number	FHWA Class or Type	Number	FHWA Class or Type	Number	Additional comments (If more than 4 types are used please indicate the type(s) and number (s) here):
9	1							
9	1	7	1					

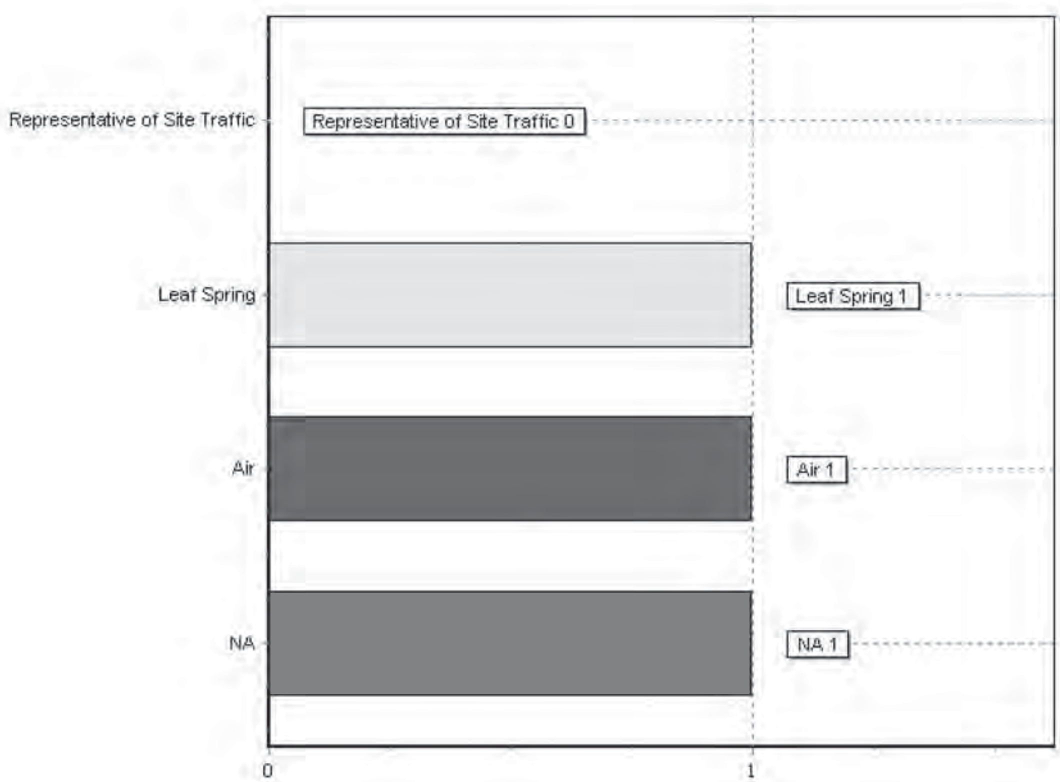
Additional comments (If more than 4 types are used please indicate the type(s) and number(s) here):(3.5.8 How many test trucks are used by class or type?)

3.5.9 Do you specify the suspension type of these test trucks?



Comment Responses:

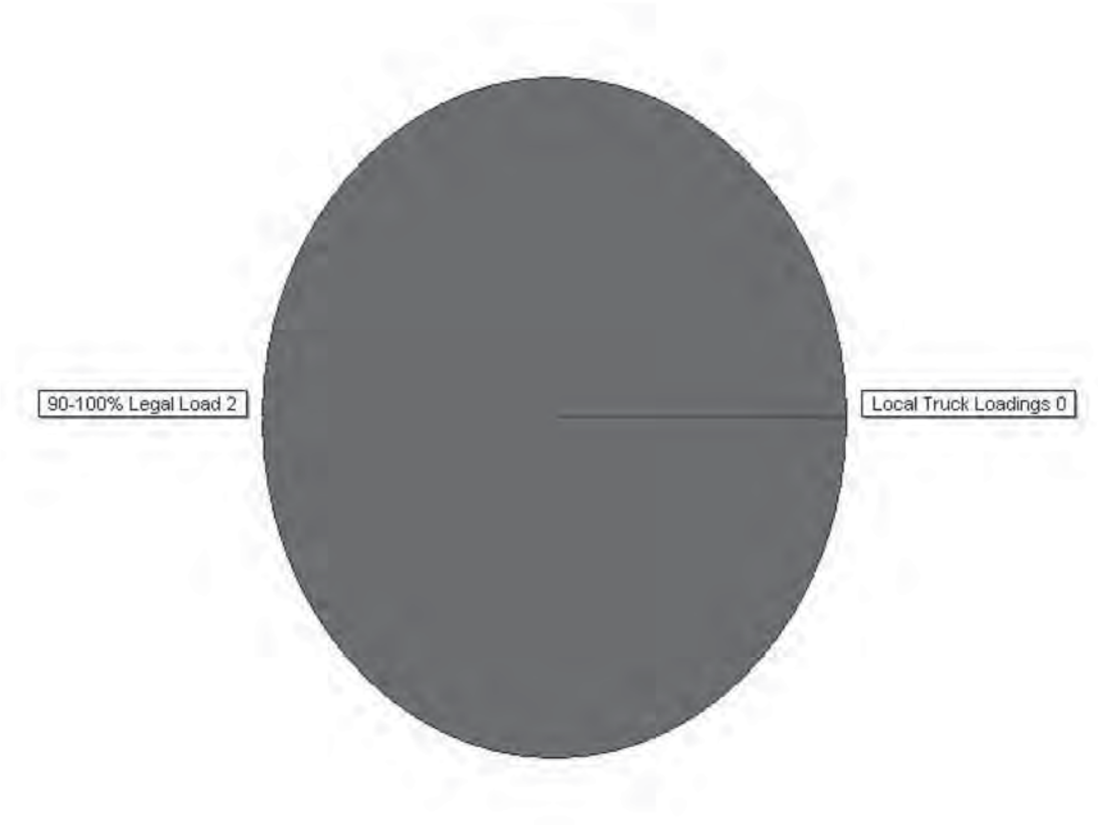
If Yes, which types are specified? Check all that apply.



Other Responses:

Comment Responses:

3.5.10 What is your test truck loading criteria?

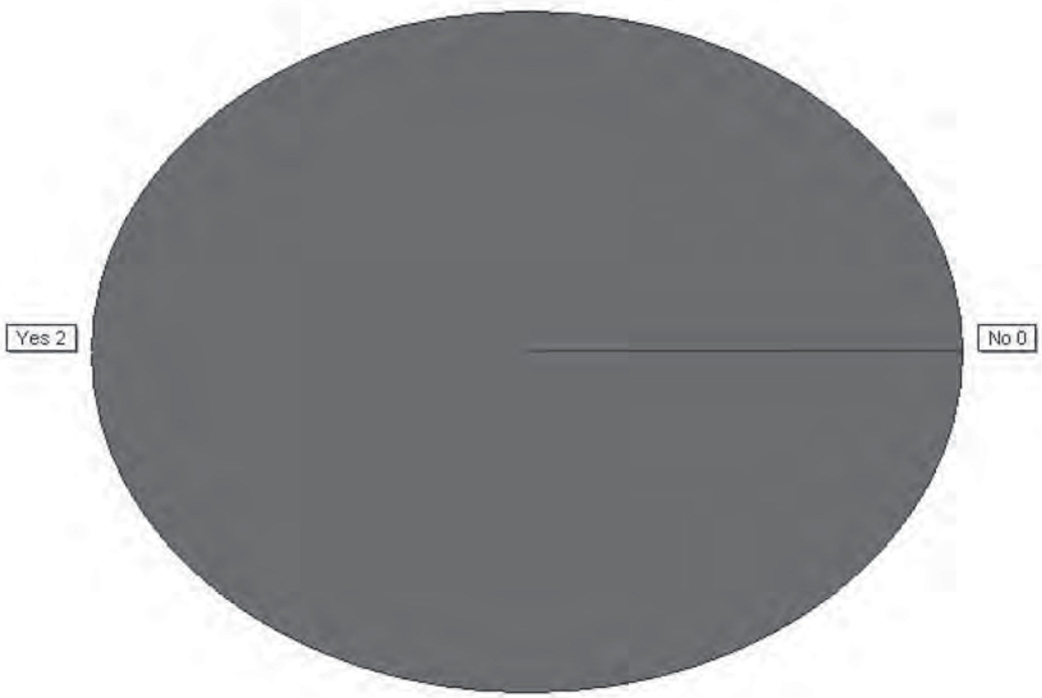


Other Responses:

WA-Enf: We vary the weight depending on the test performed

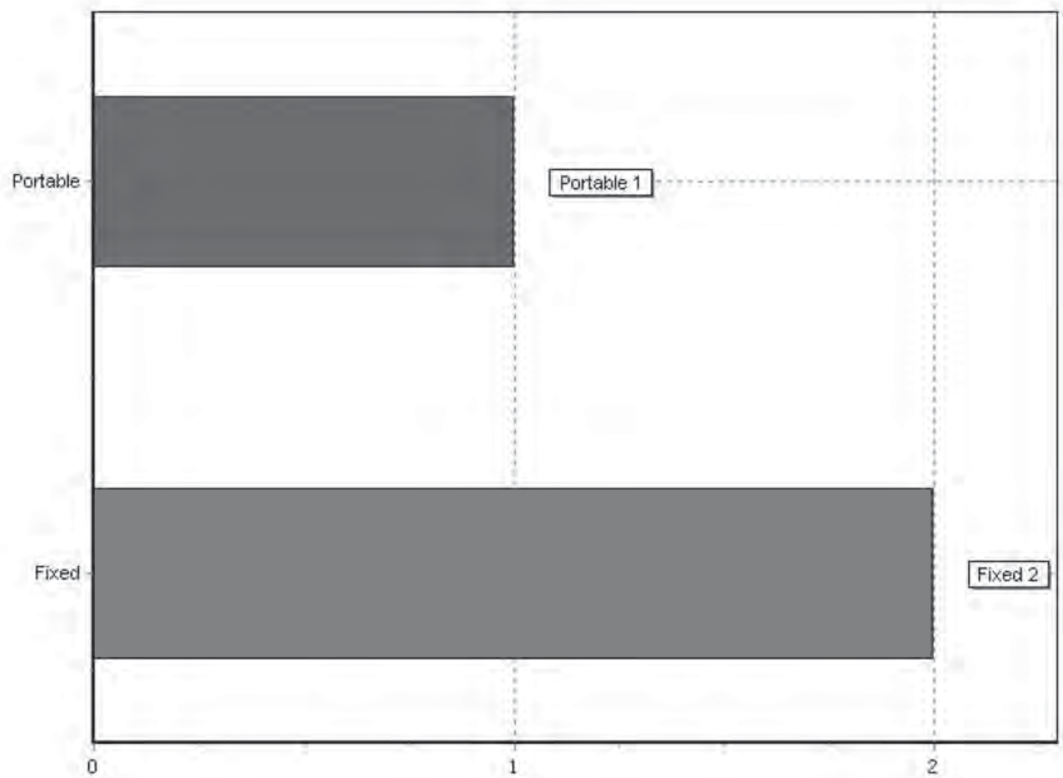
Comment Responses:

3.5.11 Please provide the following details on static weighing in conjunction with WIM calibration using test trucks. Do you require that static scales be certified?



Comment Responses:

Which types of static scales do you use? Check all that apply.

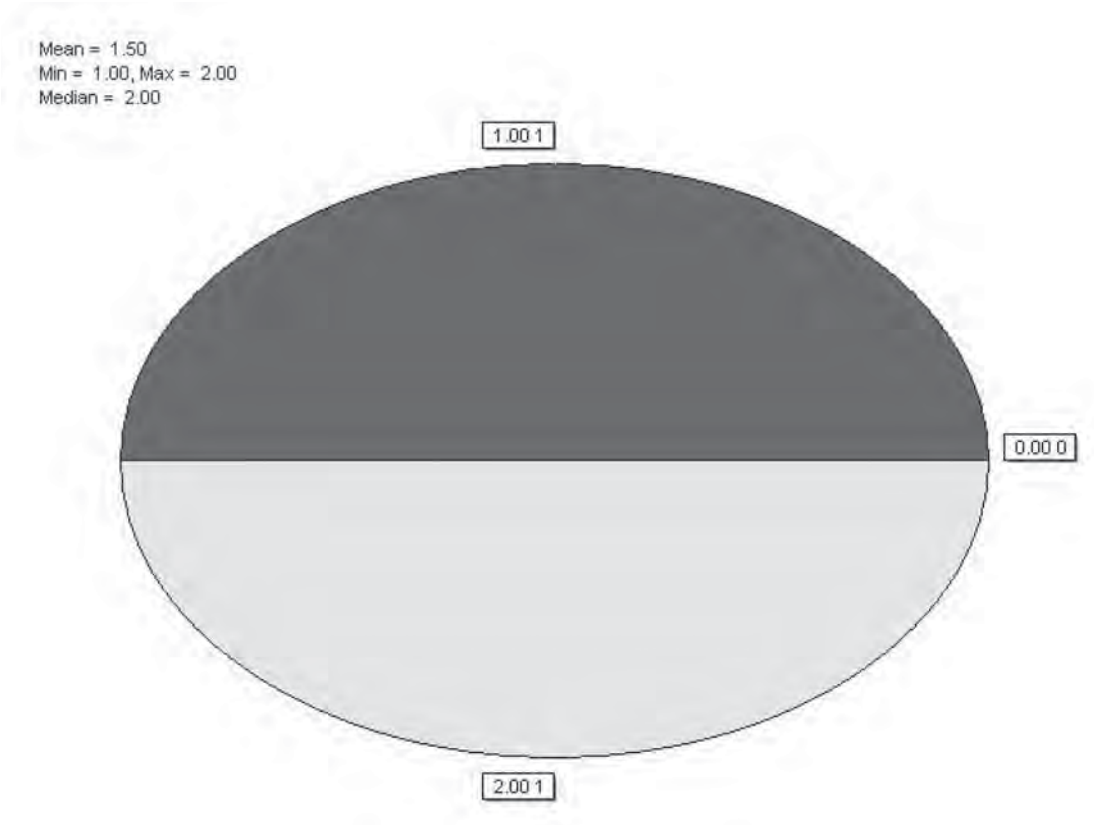


Other Responses:

Which static weights are obtained? Check all that apply.

Other Responses:

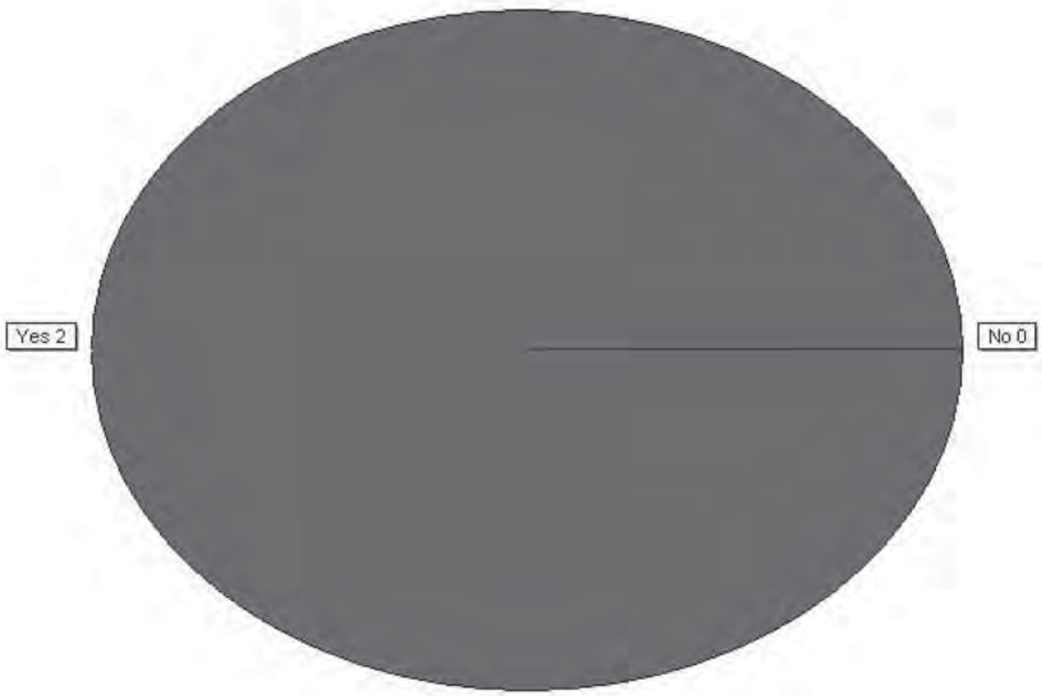
How many times is each static weight measured?



Additional comments regarding static weight practices:

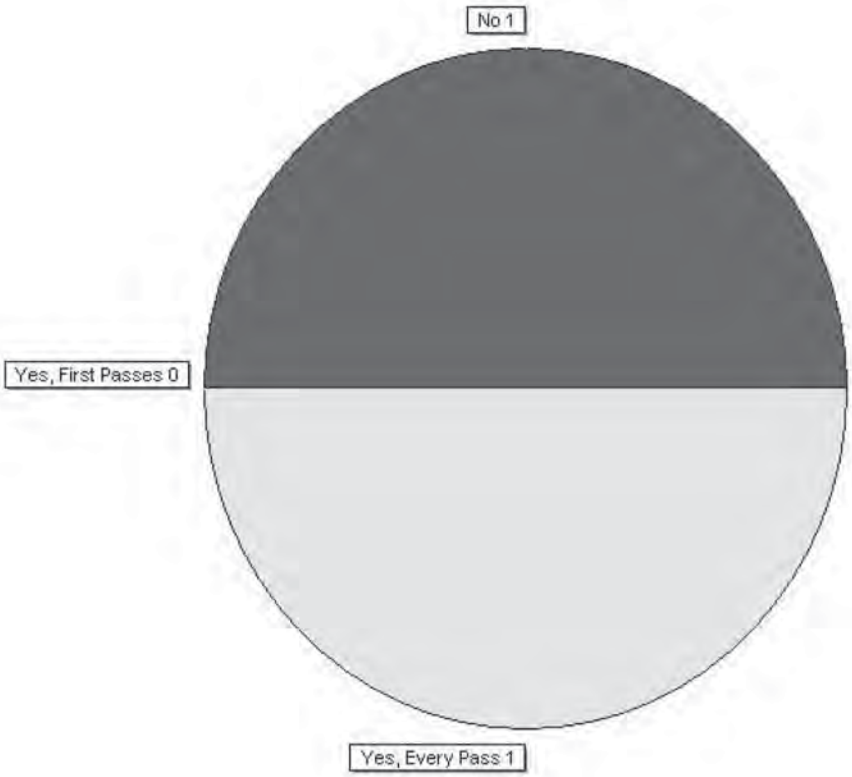
AZ-Enf: We check them twice to insure accuracy

3.5.12 Are the axle spacings for each test truck measured?



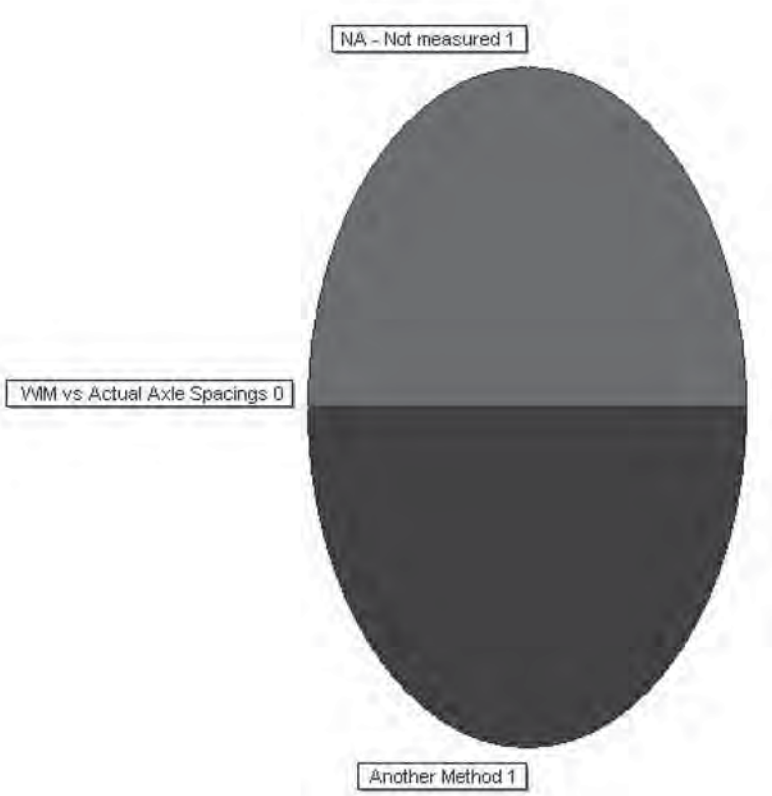
Comment Responses:

3.5.13 Are the test truck speeds measured as they cross the sensors?



Comment Responses:

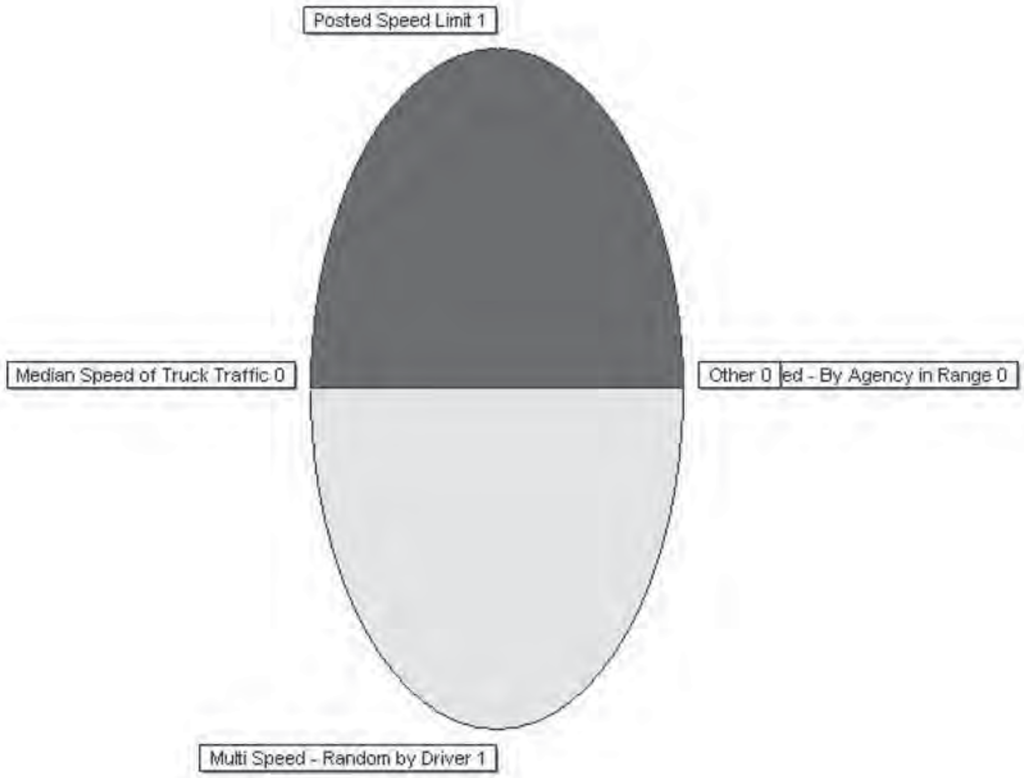
3.5.14 How is test truck speed measured?



Comment Responses:

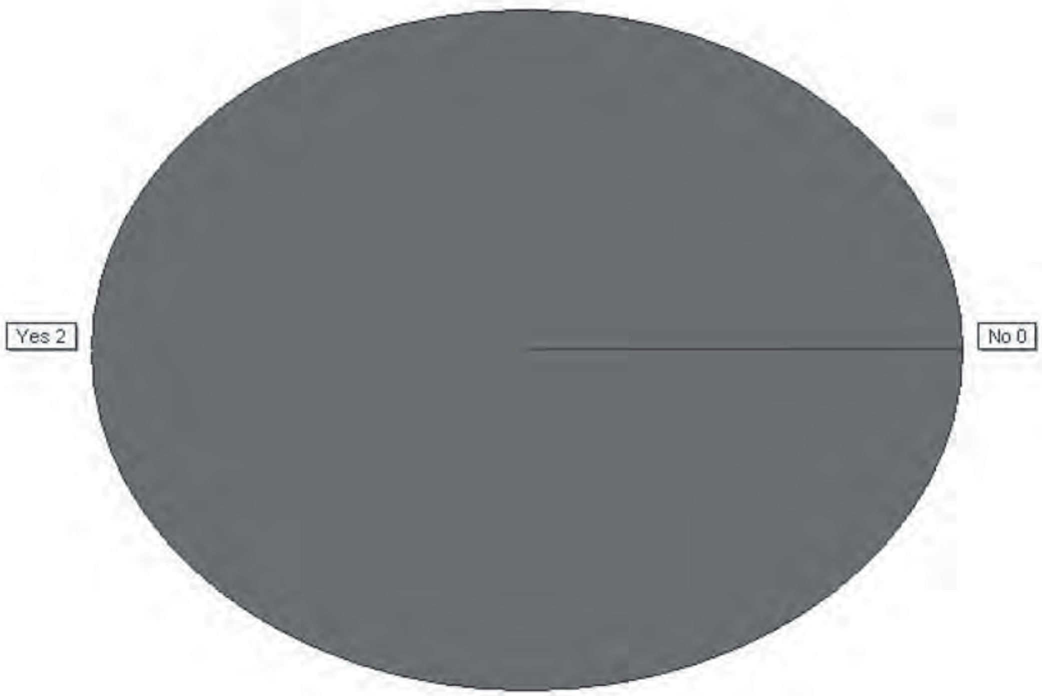
AZ-Enf: Careful operators of vehicles

3.5.15 At what speeds do the test trucks run?



Comment Responses:

3.5.16 Is there a minimum number of test truck runs required at each speed?

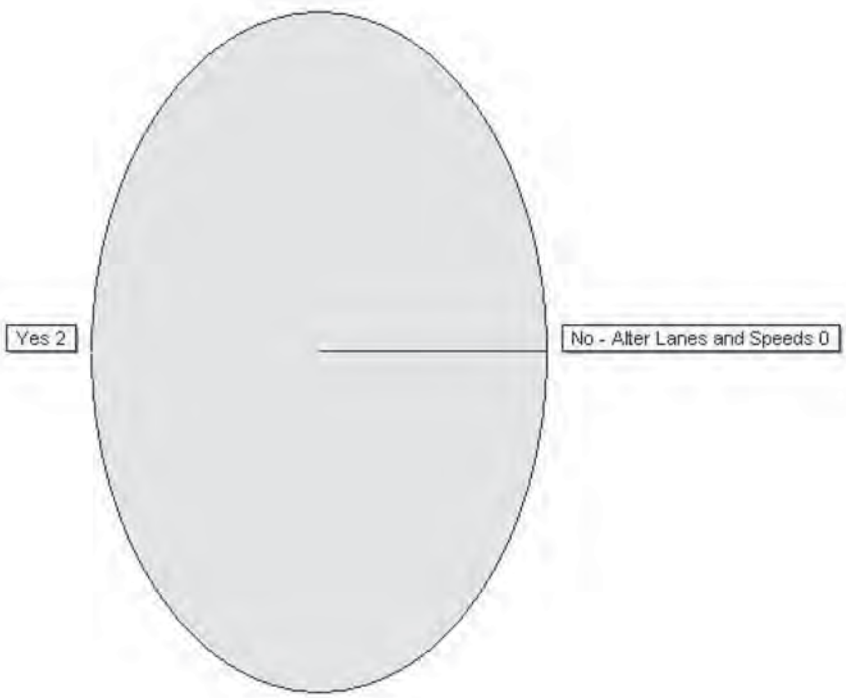


If Yes, please specify the minimum number of runs:

Number of runs for each speed.
20
3

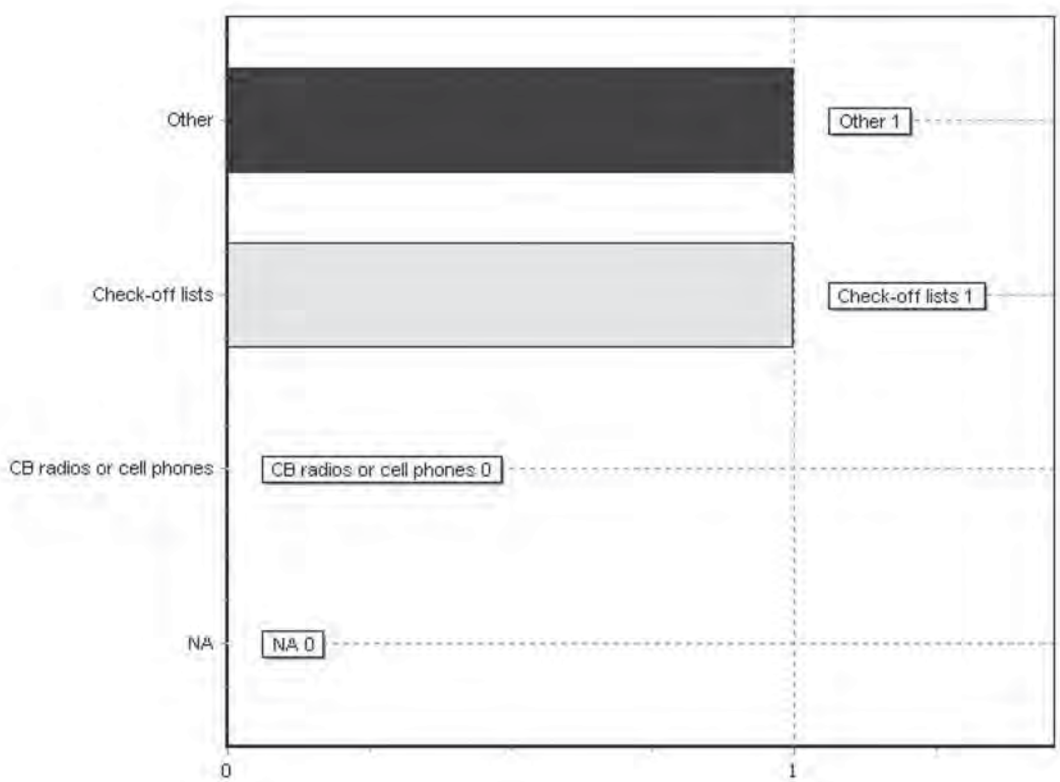
Additional comments:

3.5.17 Are the test truck drivers given specific instructions as to the desired lane and speed for each run?



Additional comments:

If Yes, by what means are the instructions given? Check all that apply.

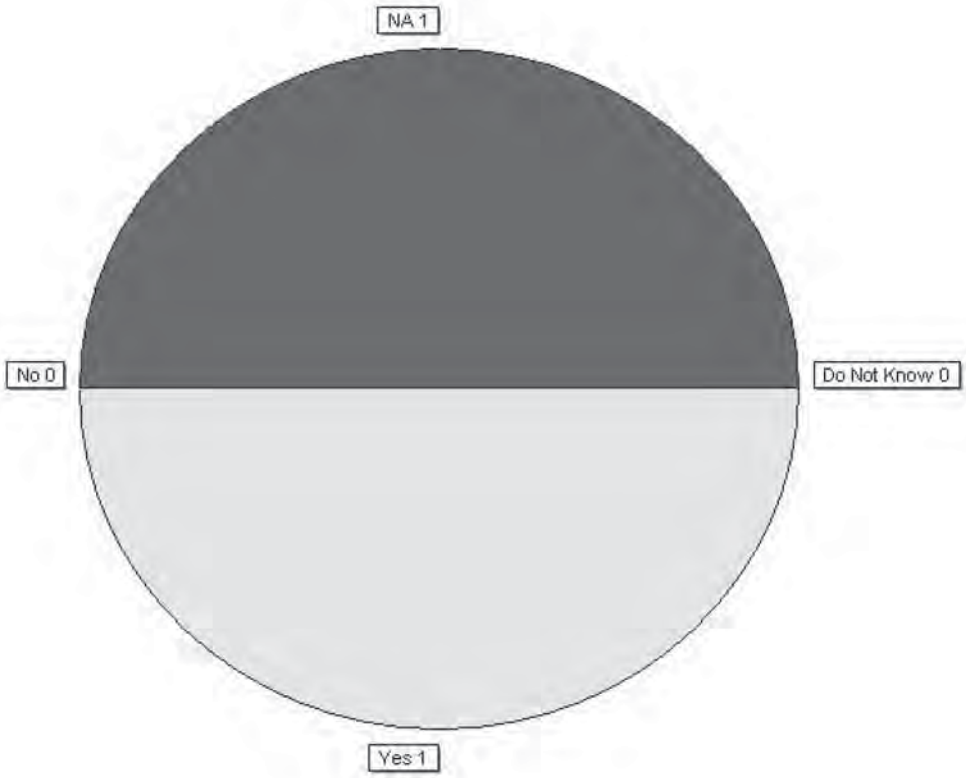


Other Responses:

AZ-Enf: Verbal instructions

Comment Responses:

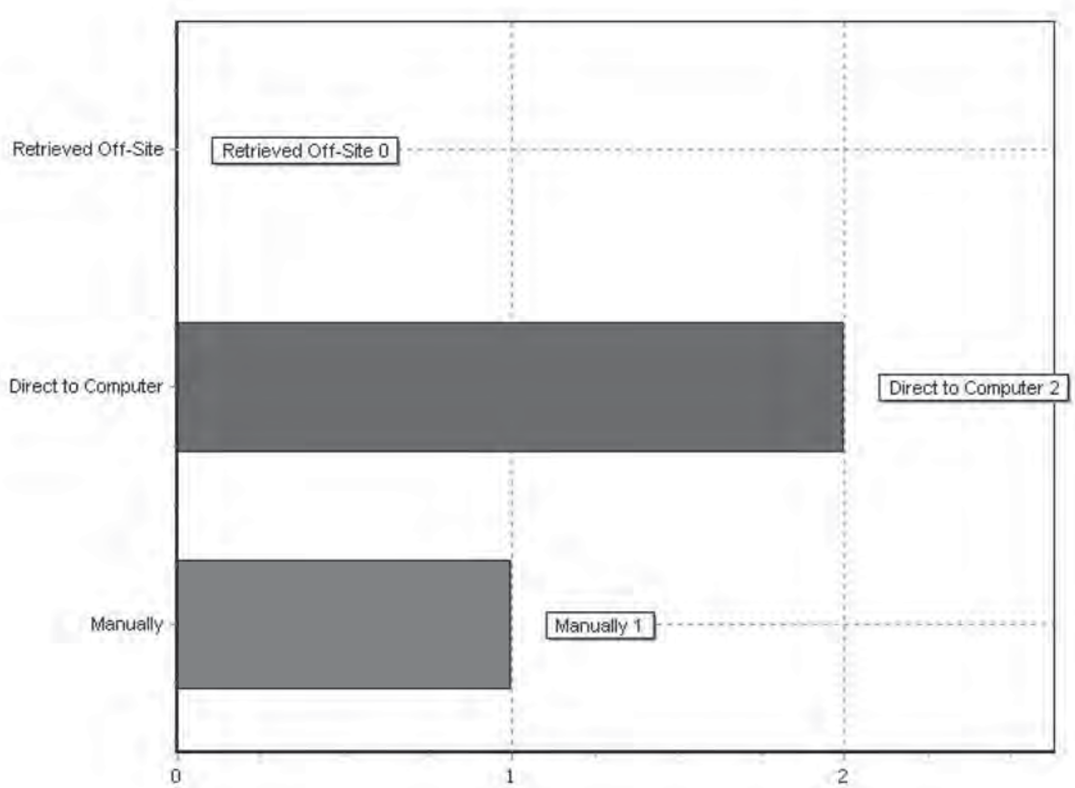
3.5.18 Is the system auto-calibration turned off during test truck runs?



Comment Responses:

AZ-Enf: We test once without.

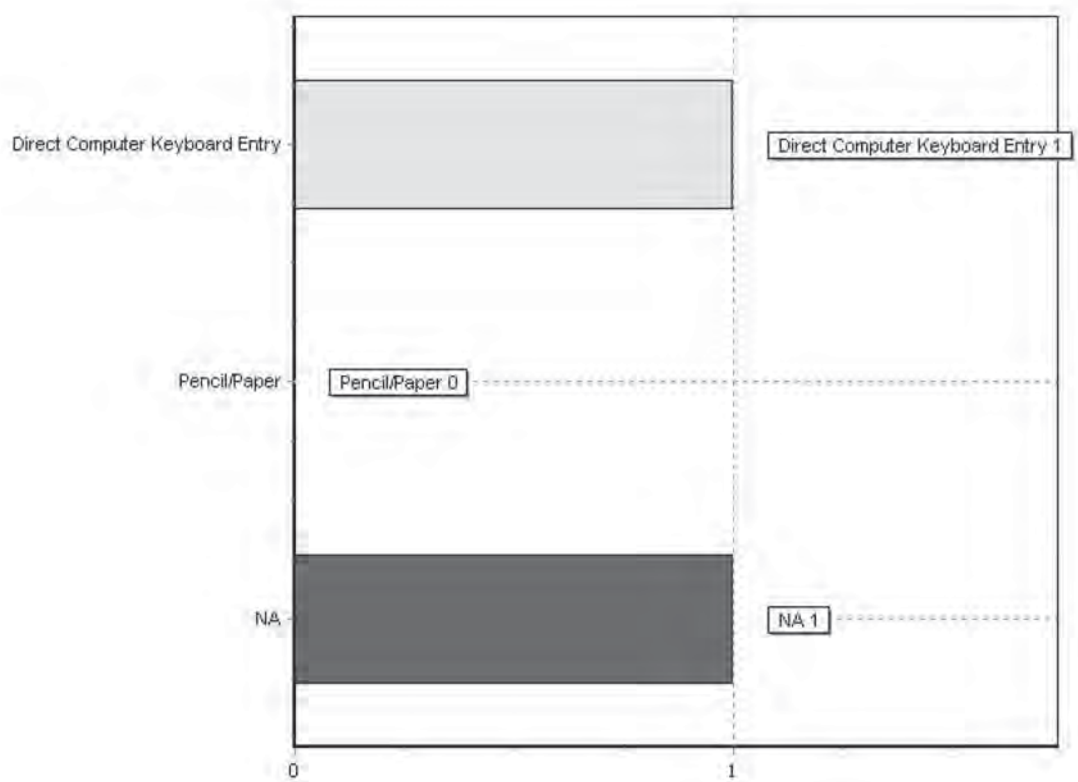
3.5.19 How is the test truck data being recorded during WIM calibration testing?



Other Responses:

Comment Responses:

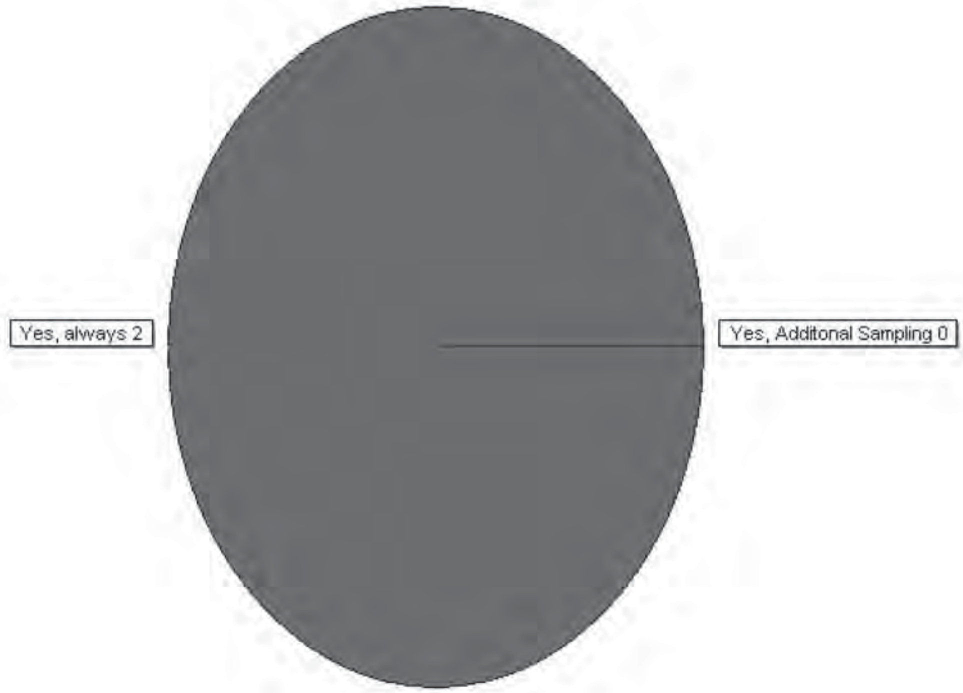
If test truck data is manually recorded, what method is used?



Other Responses:

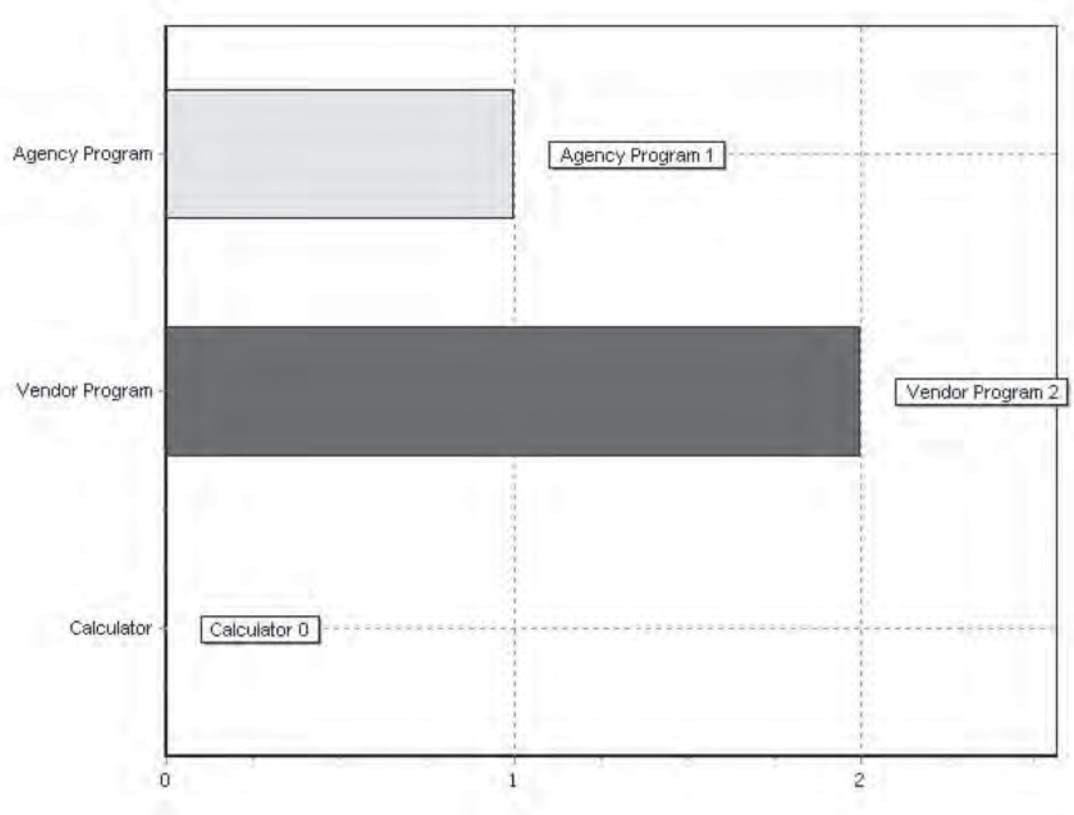
Comment Responses:

3.5.20 When performing on-site calibration using test trucks are the WIM error computations performed on-site?



Comment Responses:

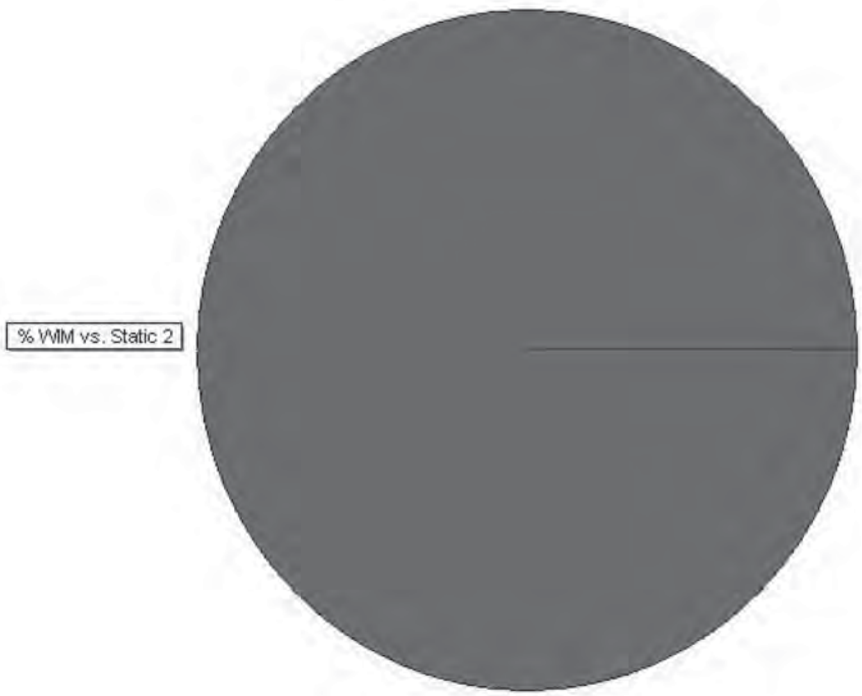
3.5.21 During on-site calibration using test trucks how are the WIM error computations carried out?



Other Responses:

Comment Responses:

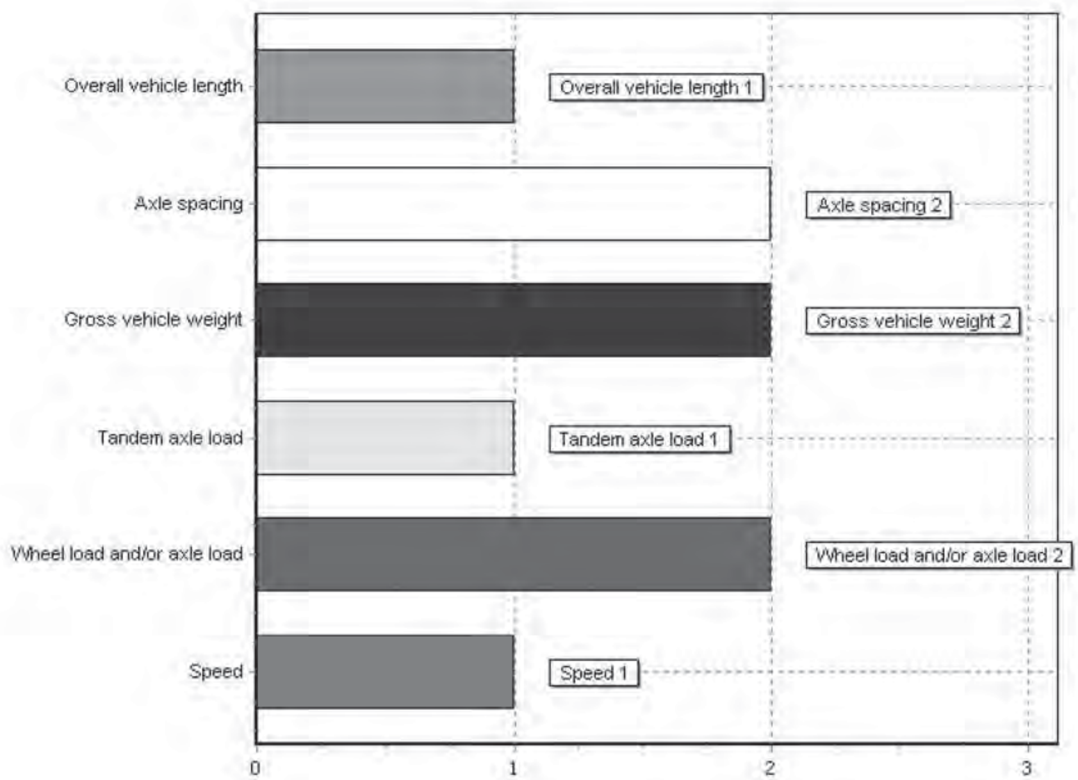
3.5.22 During on-site calibration using test trucks what error formula is used?



Other Responses:

Comment Responses:

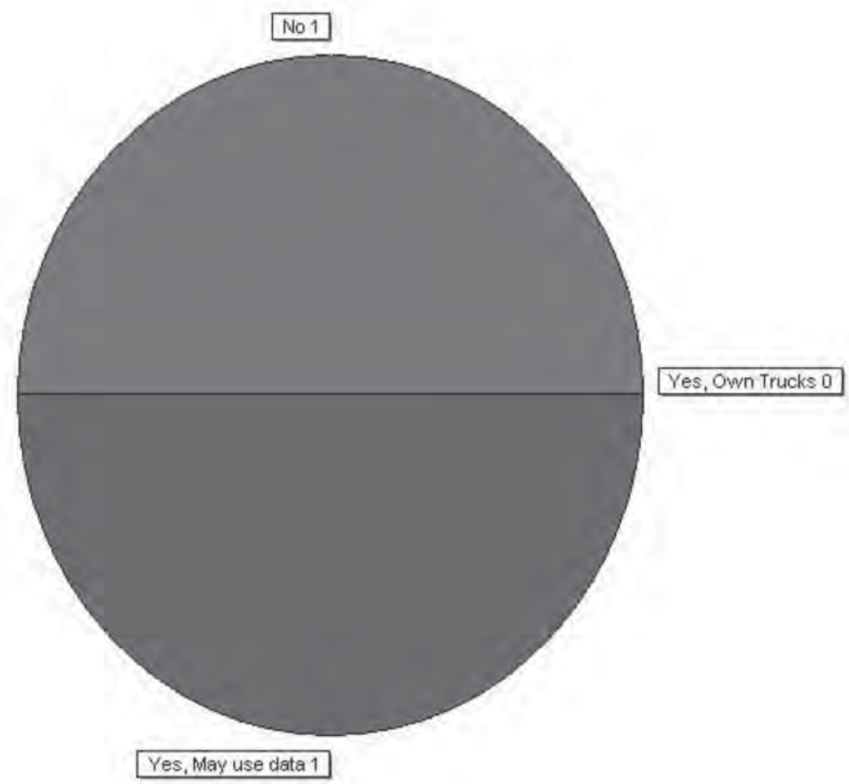
3.5.23 For which of the following measurements are WIM errors computed during on-site calibration using test trucks? Check all that apply.



Other Responses:

Comment Responses:

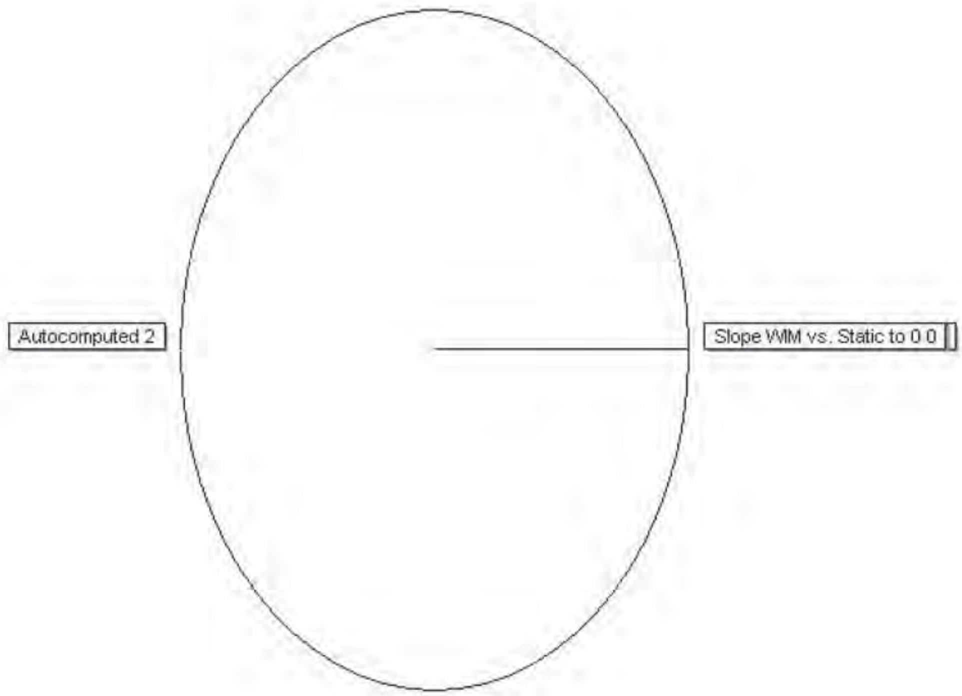
3.5.24 Are test trucks ever run for the sole purpose of determining WIM system accuracy tolerance pass/fail (e.g. new site acceptance, warranty, etc.)?



Other Responses:

Comment Responses:

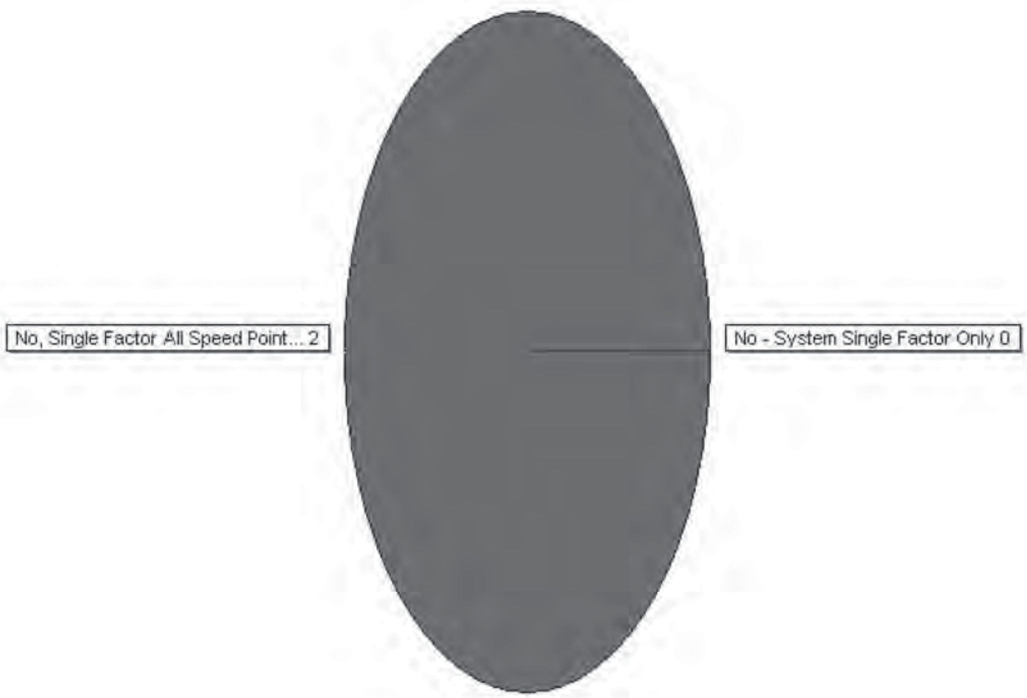
3.5.25 During on-site calibration using test trucks, what method is used to compute the calibration factors?



Other Responses:

Comment Responses:

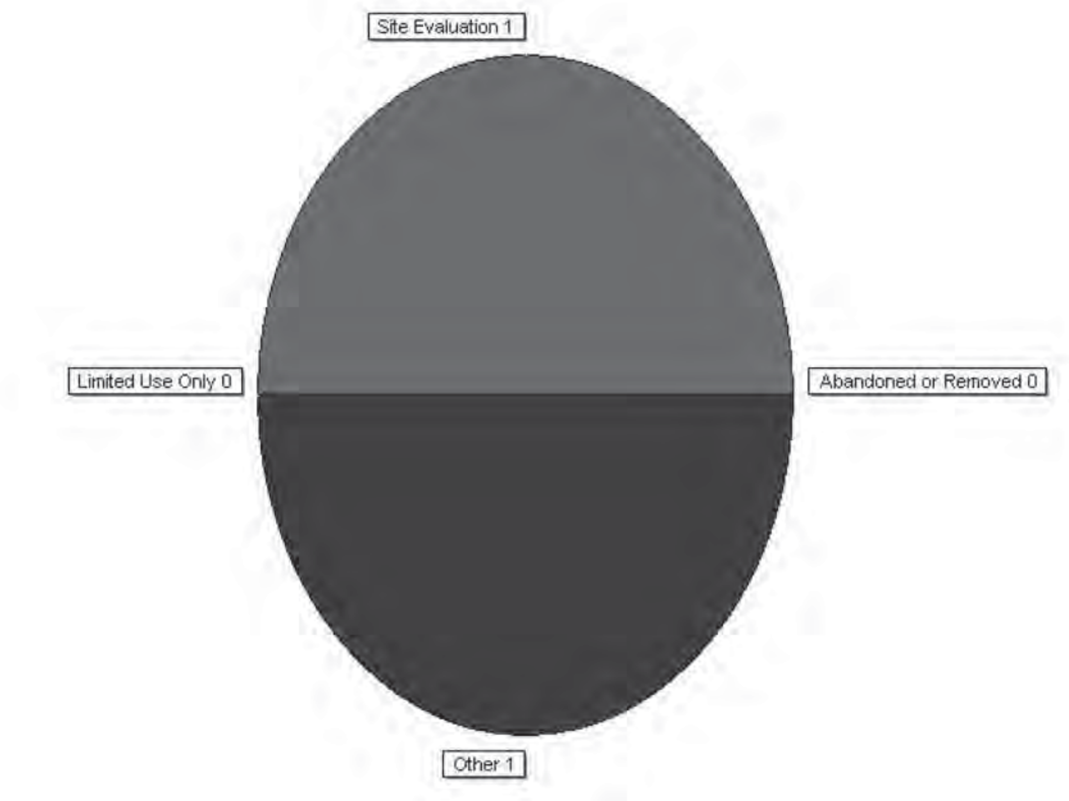
3.5.26 During on-site evaluation using test trucks do you compute calibration factors for two or more speed points?



Other Responses:

Comment Responses:

3.5.27 What remedial action is taken for WIM systems that fail to meet accuracy tolerances during test truck testing?



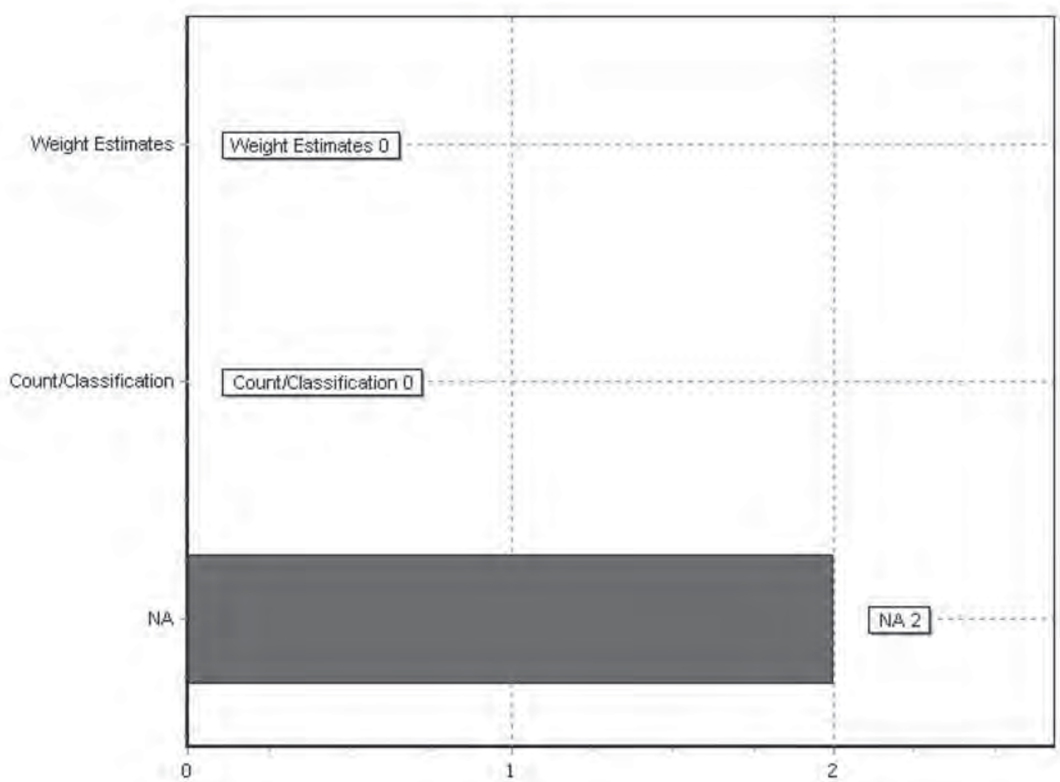
Other Responses:

AZ-Enf: Repair as needed

Comment Responses:

AZ-Enf: Problems identifed and resolved. What ever it takes.

What is the use of the data being generated by WIM systems that fail to meet accuracy tolerances?

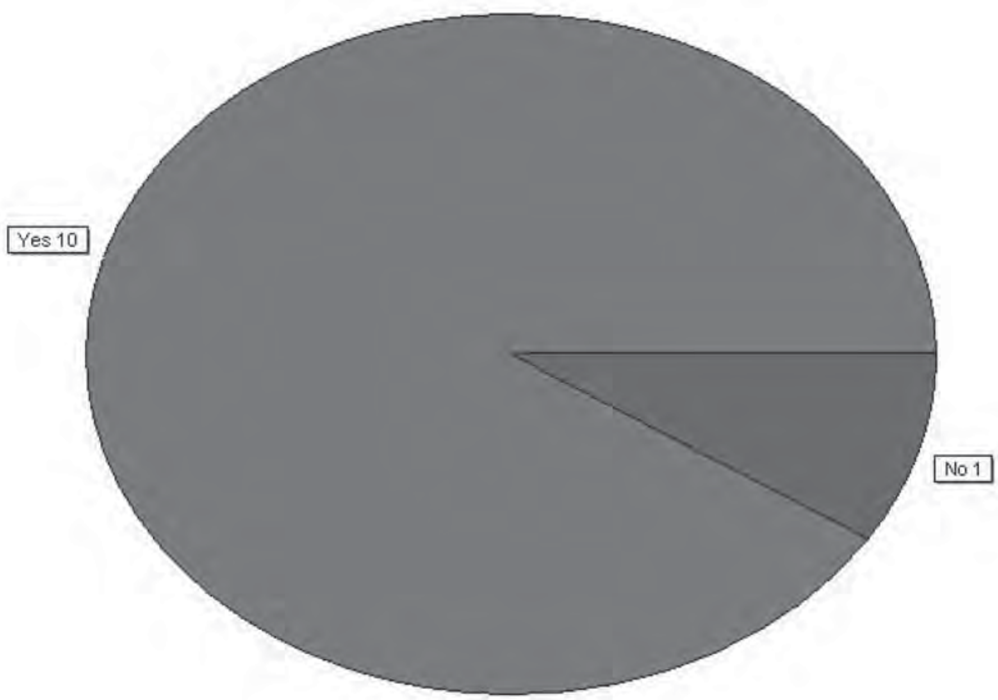


Other Responses:

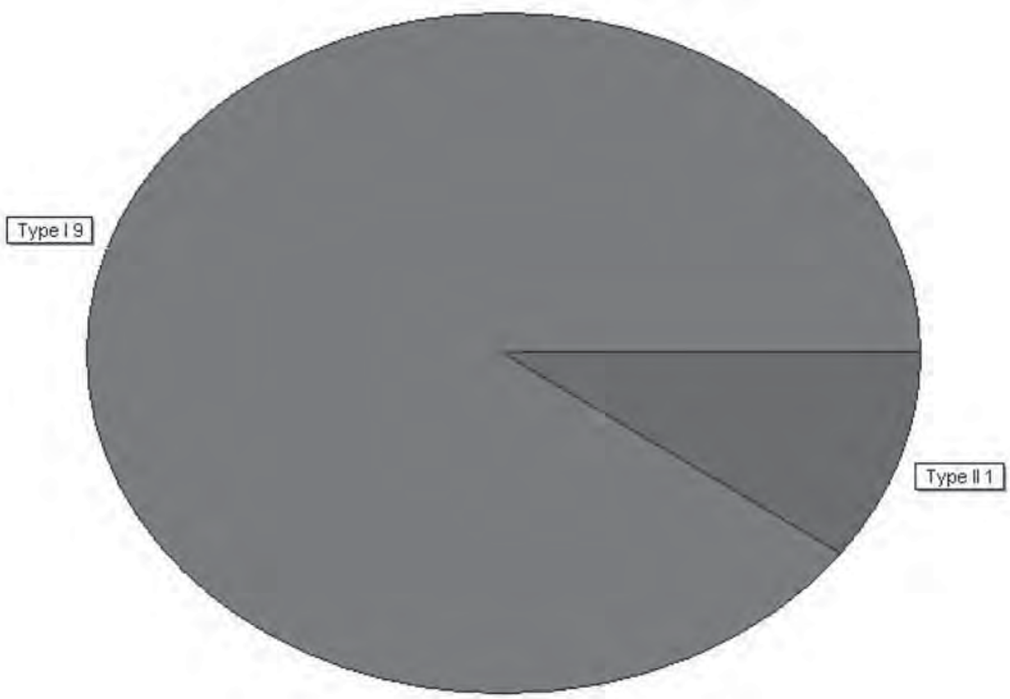
Comment Responses:

AZ-Enf: Repair as needed.

3.6 WIM On-Site Evaluation/Calibration Using Traffic Stream Trucks of Known Weight NOTE: In this section we are referring to on-site evaluation/calibration by sampling trucks from the traffic stream for which you are able to obtain static weights. Do you perform on-site evaluation/calibration using traffic stream trucks of known weights?

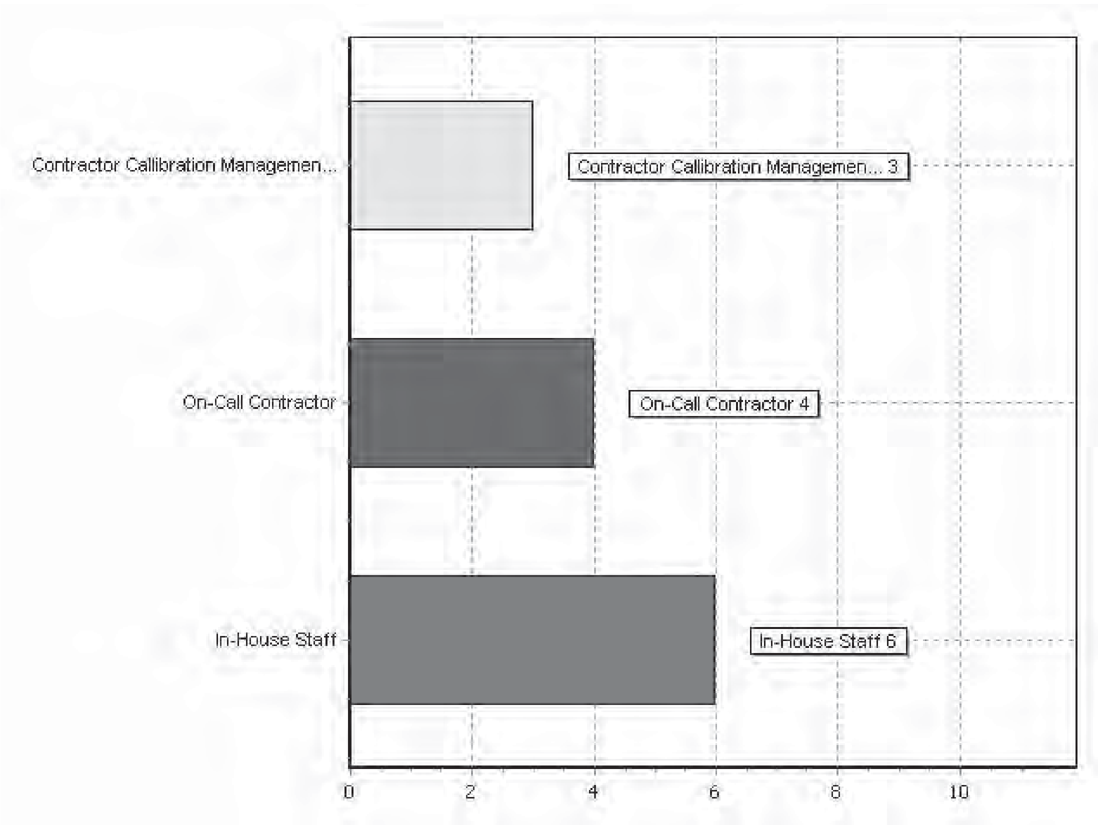


In the series of questions under 3.6 please describe the procedure you use for the MOST COMMON WIM type in your unit (department/division/agency). What is the most common WIM type in your unit for which traffic stream trucks of known weight are used for calibration?



Other Responses:

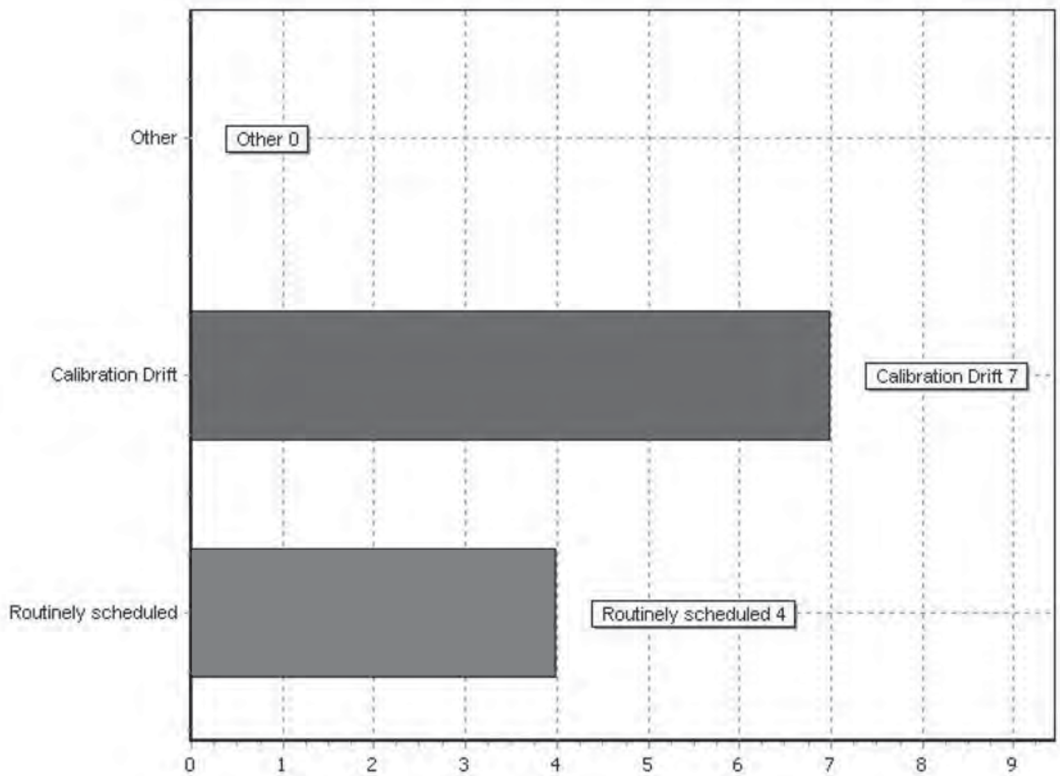
3.6.1 Who conducts these on-site evaluation/calibration activities using traffic stream trucks of known weight? Check all that apply.



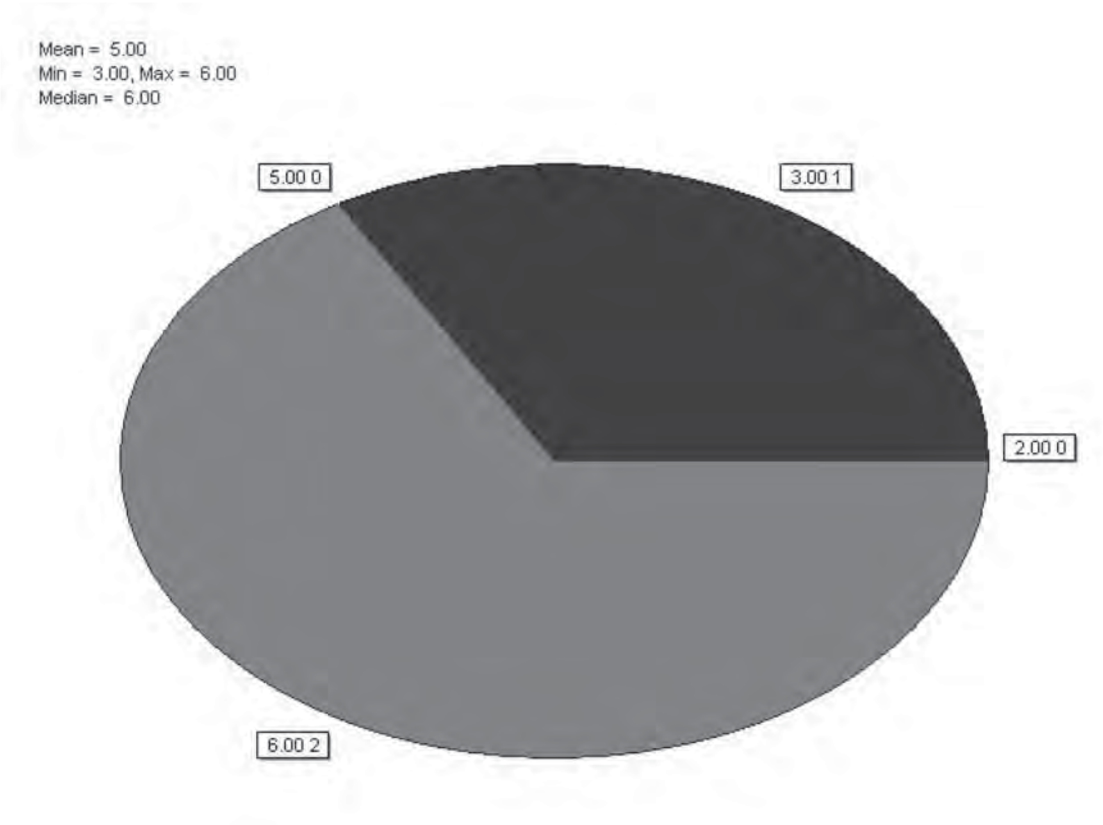
Additional Comments:

LA-Enforcement: WIM Vendor technician(IRD)
CO-Enf: Port Operators collect data when time permits.

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions. 3.6.2 What is the criterion you use to initiate WIM calibration using traffic stream trucks of known weight? Check all that apply.



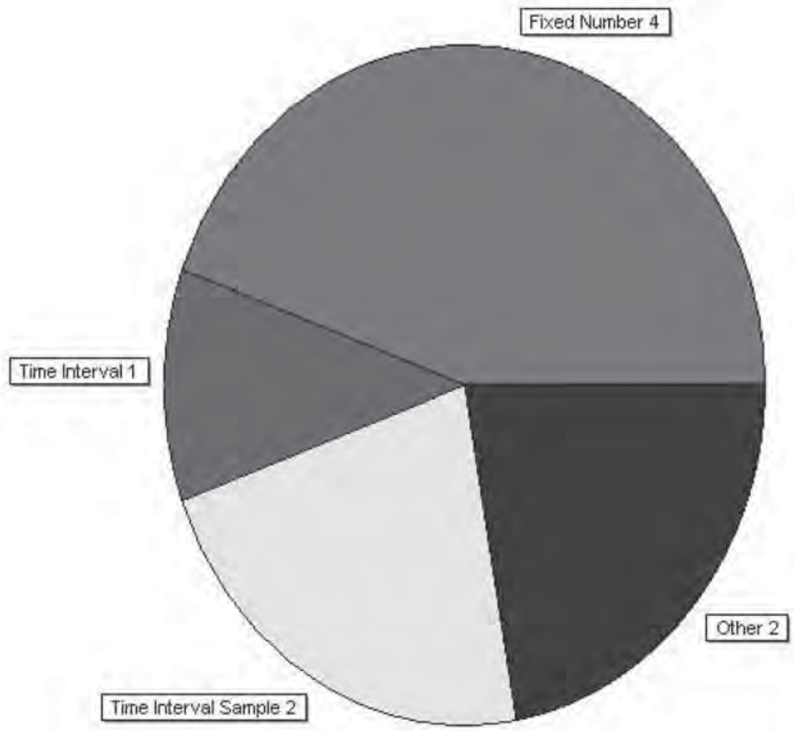
If routinely scheduled, specify typical interval (months):



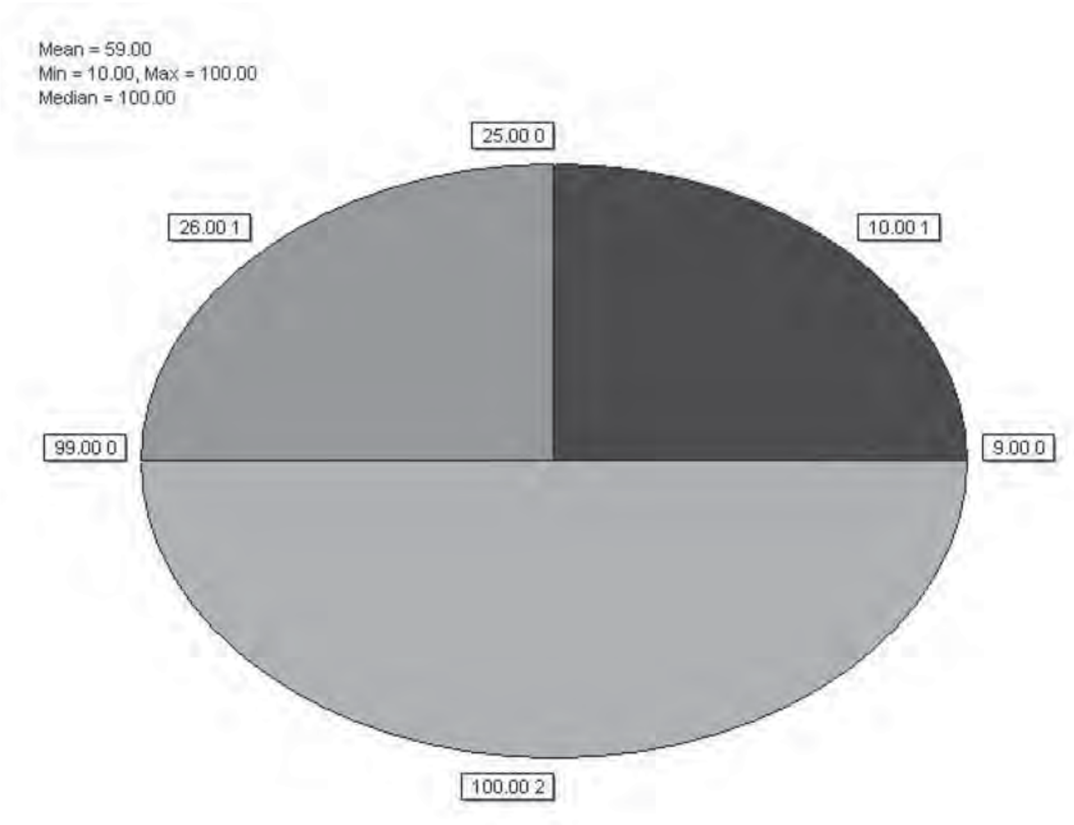
Additional comments:

CO-Enf: A check of the WIM system is done if the Static Scale has been serviced or calibrated. The WIM system is checked if it has been serviced to the static scale.
AZ-Enf: POE staff does this when something alerts them there may be a problem.

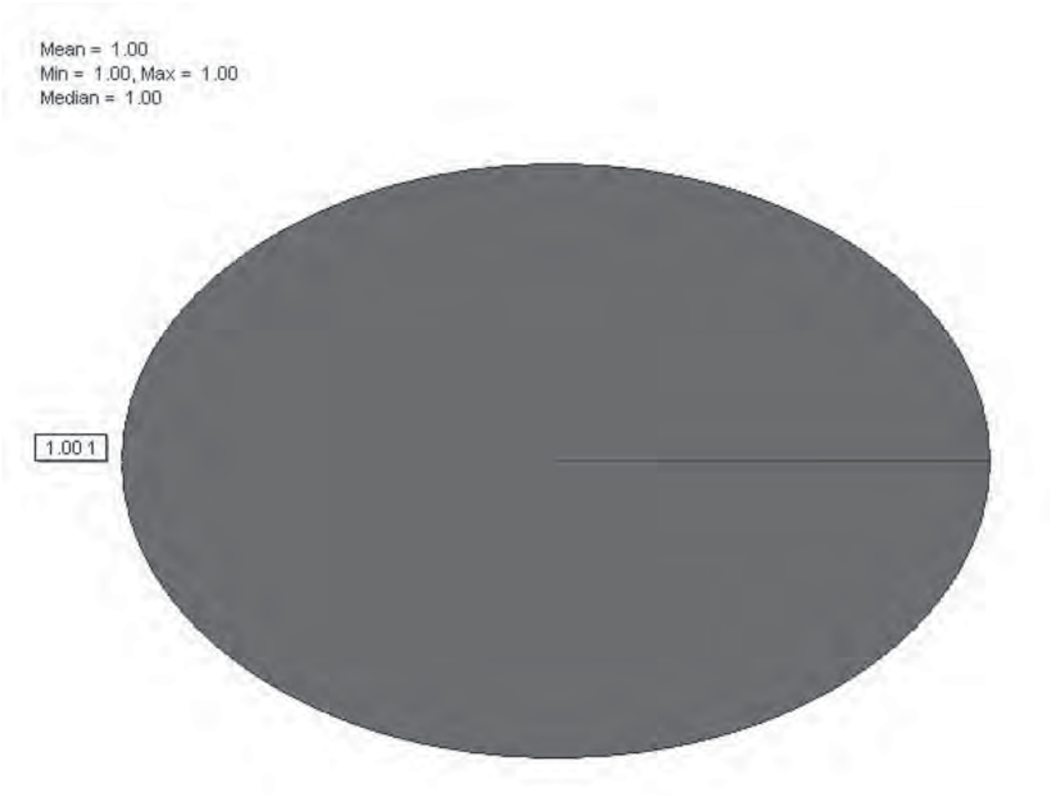
3.6.3 How do you select the number of traffic stream trucks of known weight to be included in the sample?



If a fixed number of trucks are selected, specify the number.



If all of the trucks in a given time interval are selected, specify the time interval (in hours).



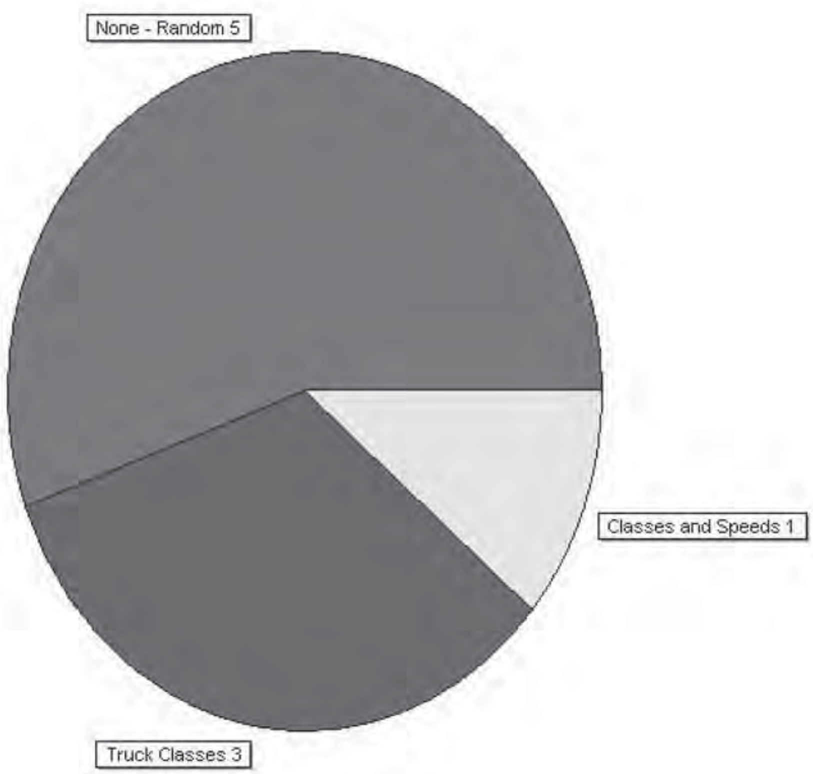
If some of the trucks in a given time interval are selected, specify the number and interval:

Number of Trucks	Time Interval (in hours)
10	1
10	

Additional comments:

See 3.6.1 for explanation
LA-Enforcement: This is determined by how busy the scale operators, amount of traffic volume, etc.
CO-Enf: Site specific due to varying truck volumes. 3 to 5 trucks are checked then an adjustment is made if needed. This continues until consistancy is found in the WIM system. Allowances are made for trucks that are not called in to be weighed or cannot be tracked because the truck pulled over prior to the scale.
AZ-Enf: Done until staff is satisfied system is operational and within standards. If not refered to IRD for correction.

3.6.4 What are the criteria used for selecting the type of traffic stream trucks of known weight to include in the sample?



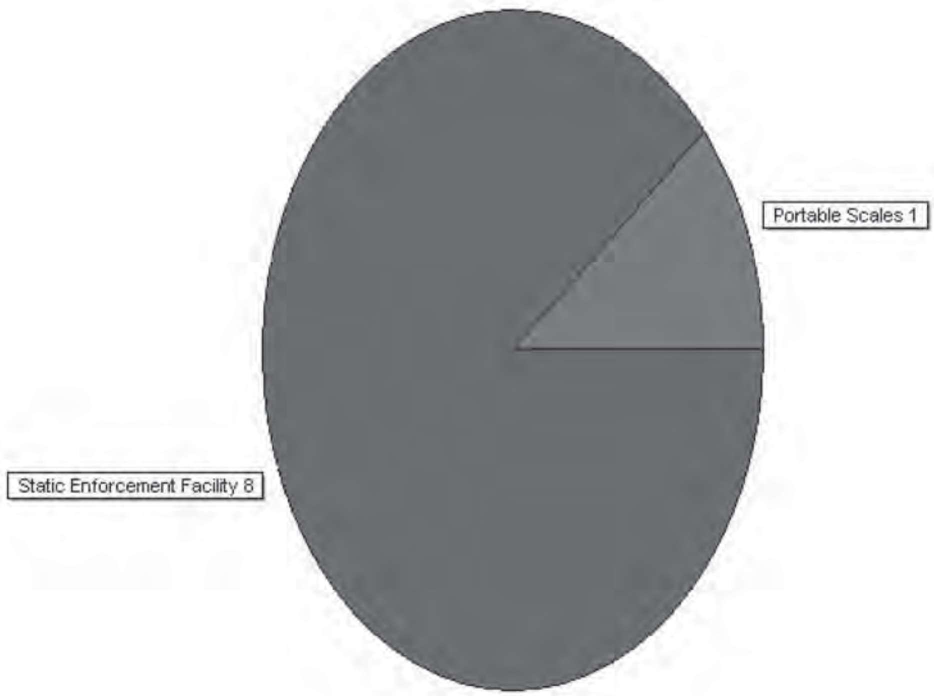
Other Responses:

Class 9

Comment Responses:

MT-Enf: Type 9 vehicles; non-liquid/non-livestock loads.
CO-Enf: Trucks under 56,000 gross are discouraged unless vary low volumes exist

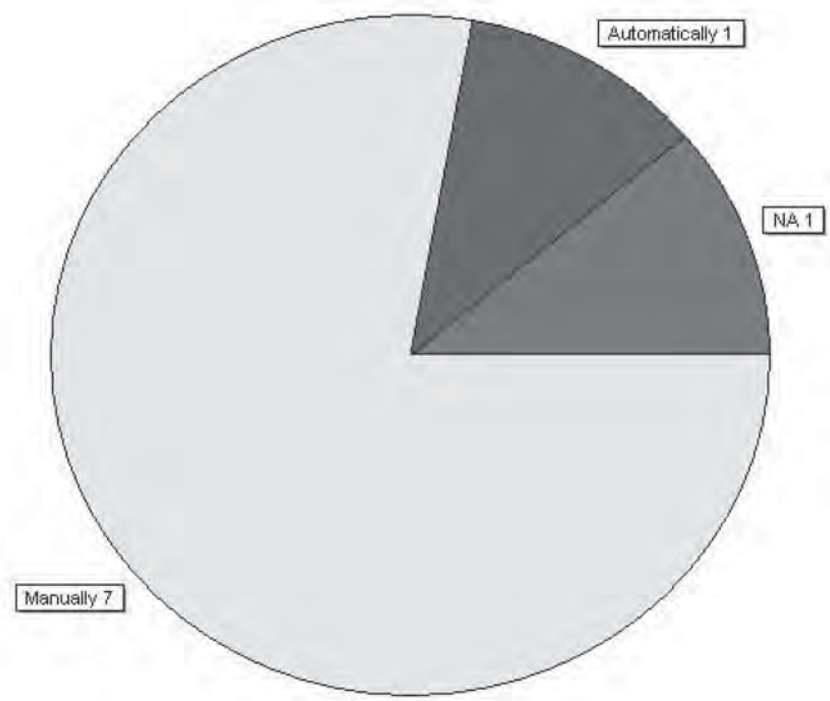
3.6.5 How is the static weight of these traffic stream trucks obtained?



Other Responses:

Comment Responses:

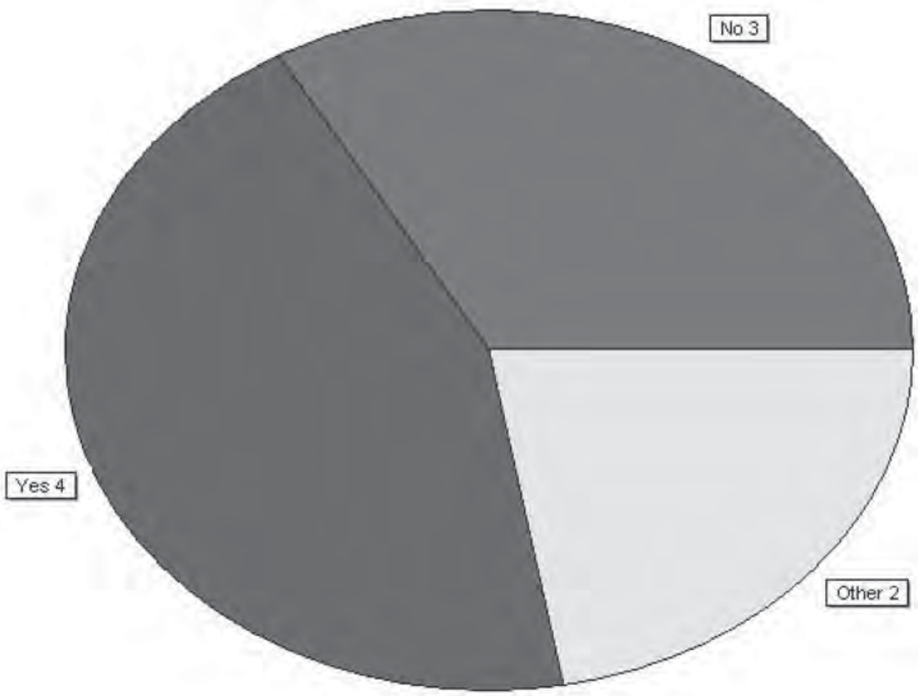
If using a weight enforcement facility, how is the static weight of the traffic stream trucks recorded?



Comment Responses:

MT-Enf: Using the PrePass system print-out reports for specific vehicles, the weigh station officer identifies the vehicle and records the axle group weights obtained from the static scale on the PrePass WIM printout.
COEnf: If operators are available computer printouts are done on WIM and Static Scale records.

3.6.6 Do you measure the axle spacing for these traffic stream trucks?



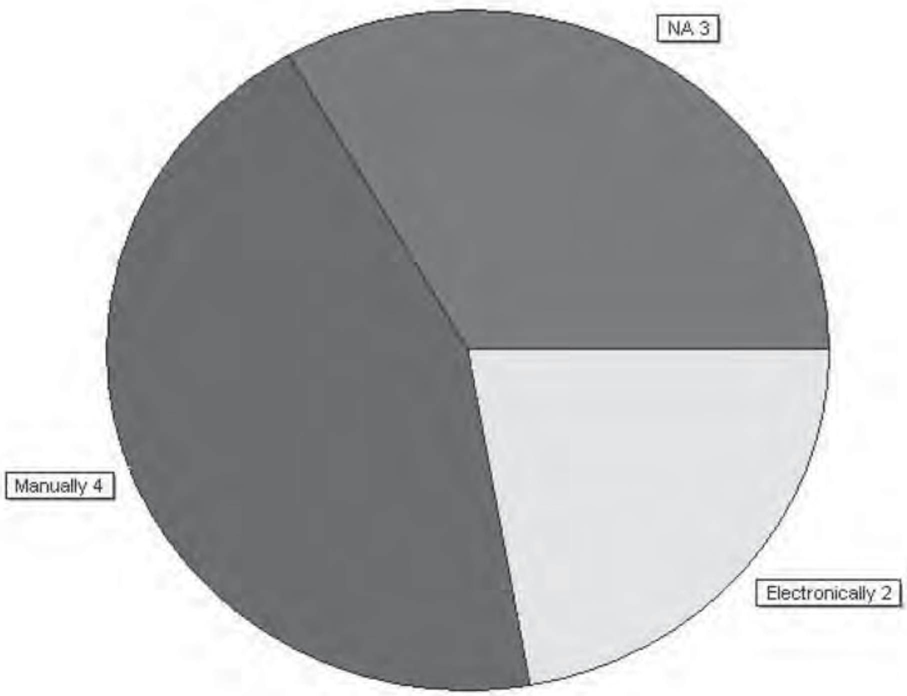
Other Responses:

VA-Enf: The first 20 vehicles
CO-Enf: Only if a Port Operator request or notices a problem.

Comment Responses:

Co-Enf: Unless an Port Operator has a specific problem with axle spacing the standard 4.5' between tandoms and 10.9' between split axles is used. I has been found that axle spacings are vary accurate and don't tend to drift.

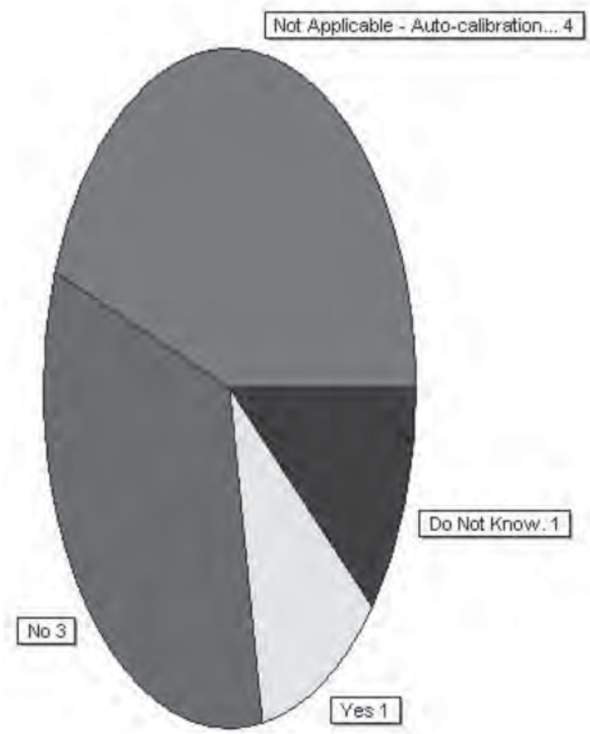
If Yes, how do you measure the axle spacing?



Other Responses:

Comment Responses:

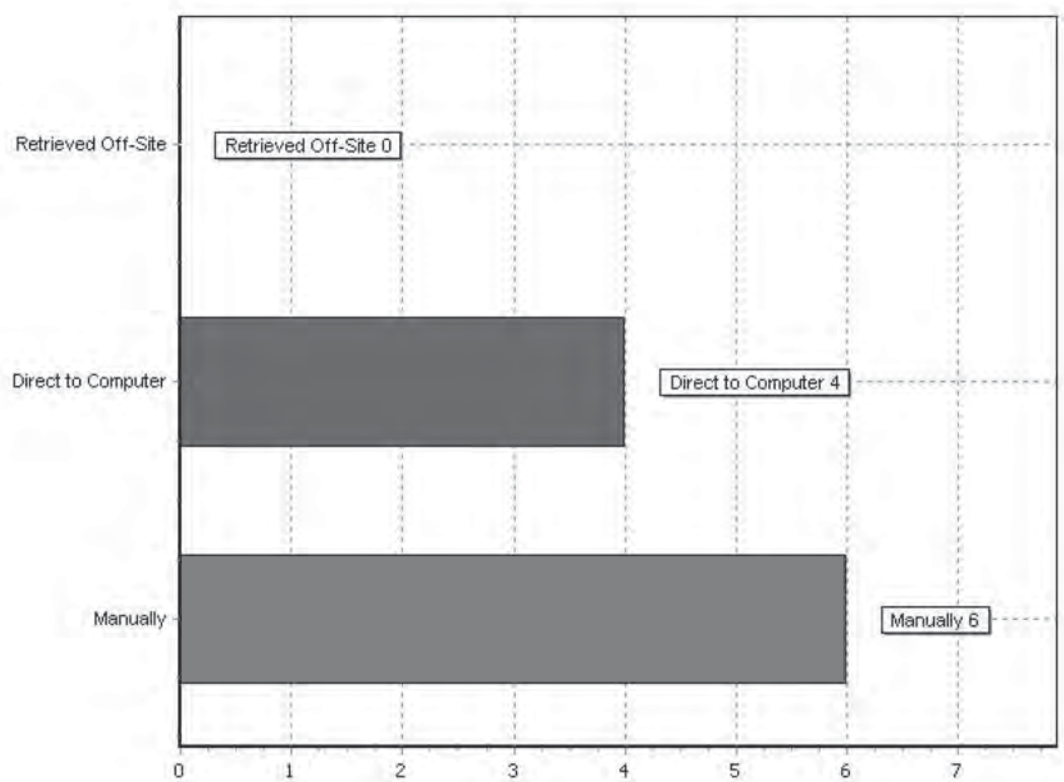
3.6.7 Is the system auto-calibration turned off during traffic stream truck runs?



Comment Responses:

Co-Enf: Auto-callibration is available but not used.

3.6.8 How is the WIM data of the sampled traffic stream trucks of known weight recorded?

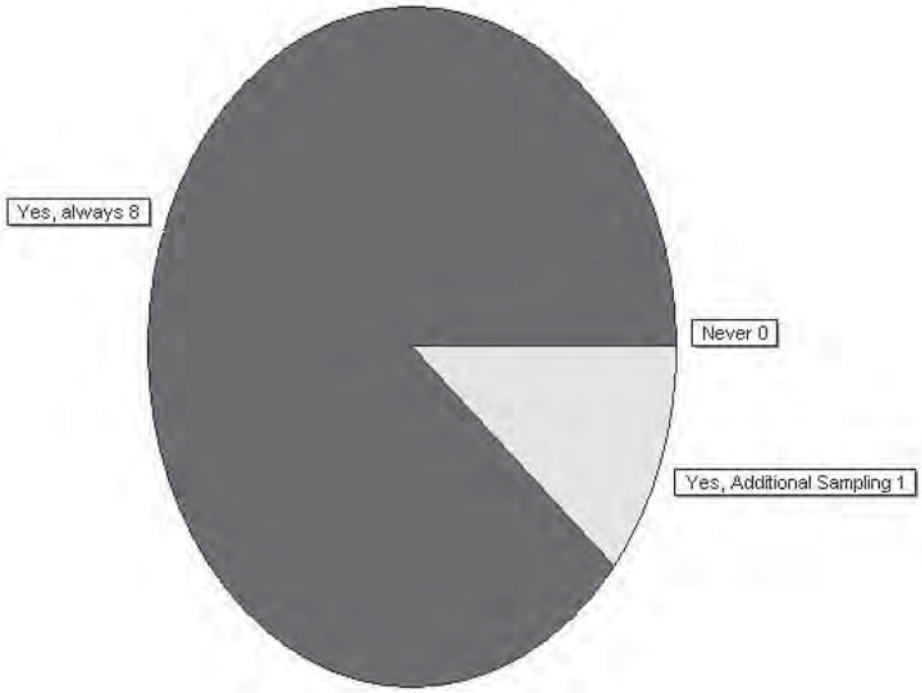


Other Responses:

Comment Responses:

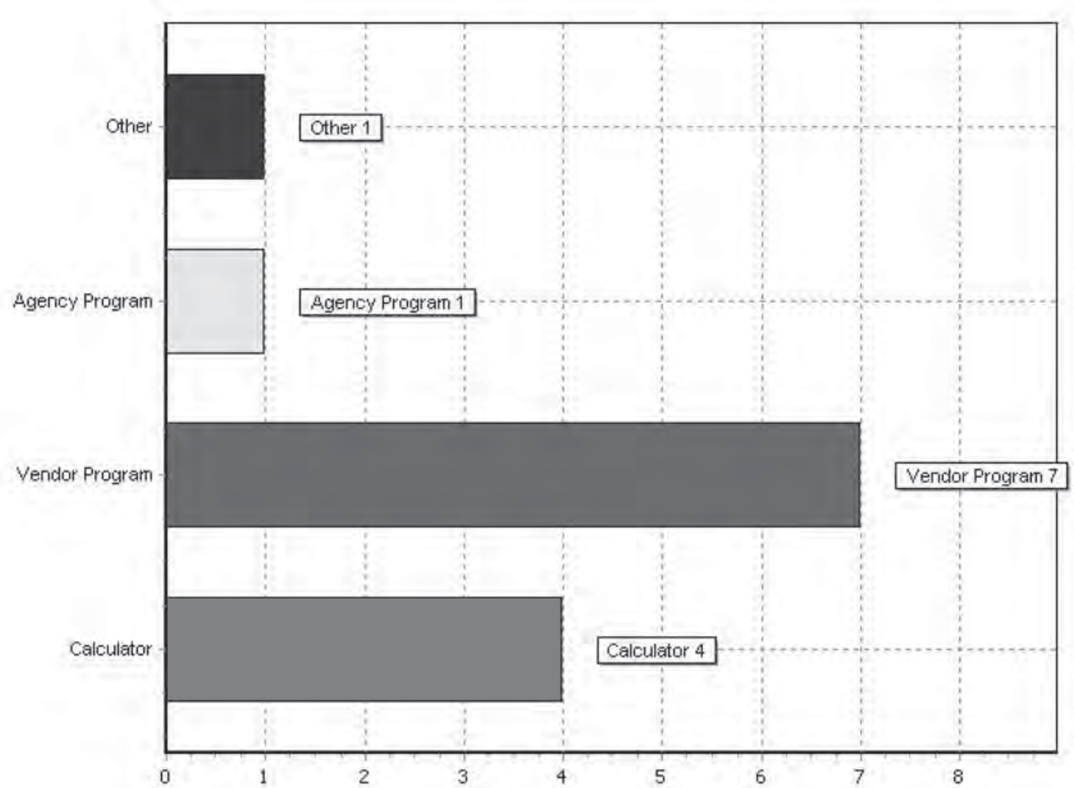
MT-Enf: PrePass system allows the printout of WIM information for all vehicles, transpondered or not.

3.6.9 Are the on-site calibration using traffic stream trucks of known weight WIM error computations performed on-site?



Comment Responses:

3.6.10 During on-site calibration using traffic stream trucks of known weight how are the WIM error computations carried out?

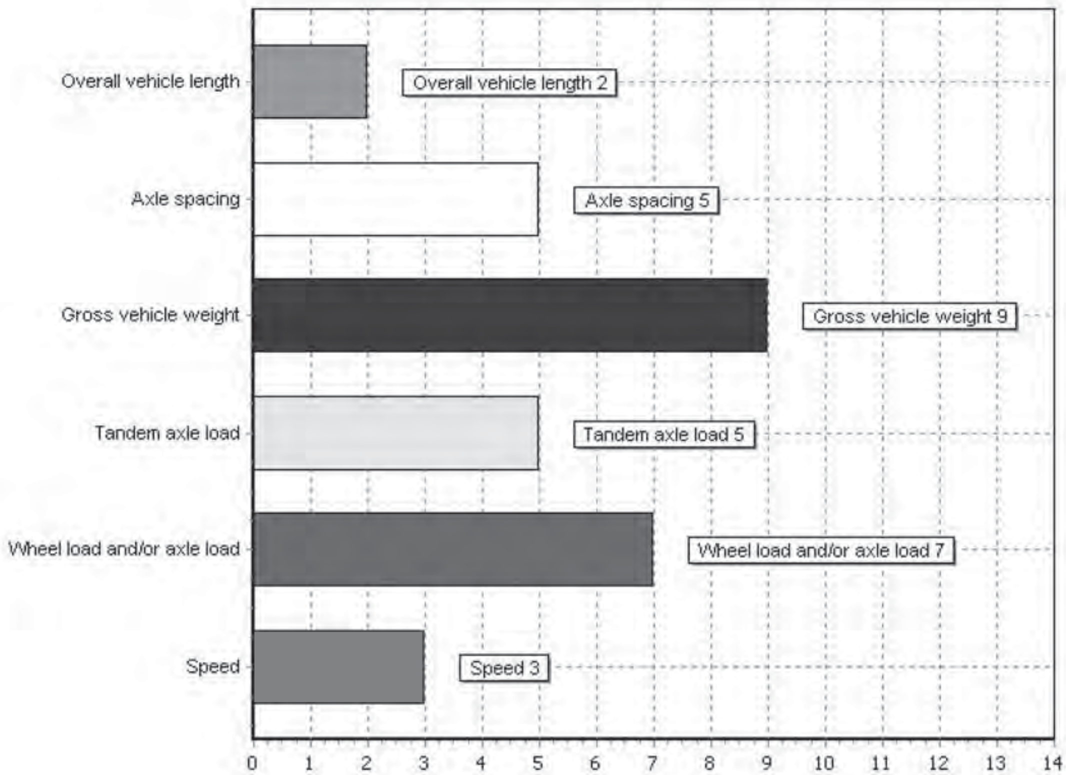


Other Responses:

CO-Enf: A spreadsheet has been used if requested by another agency for comparision

Comment Responses:

3.6.11 For which of the following measurements are WIM errors computed? Check all that apply.

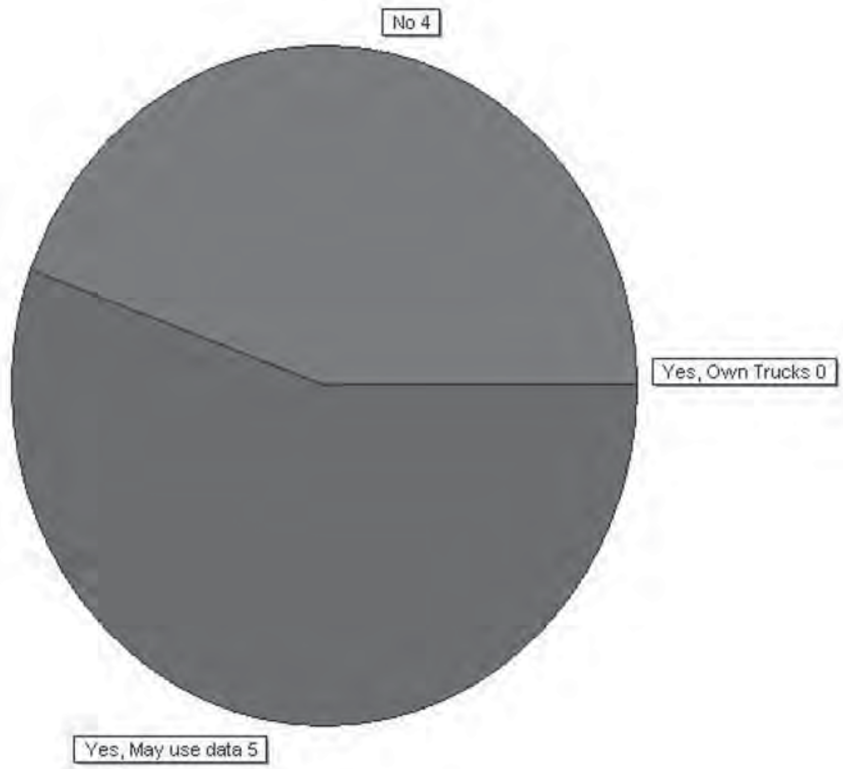


Other Responses:

Comment Responses:

Co-Enf: Axle Spacing, Speed, and Overall vehicle length are noted only.

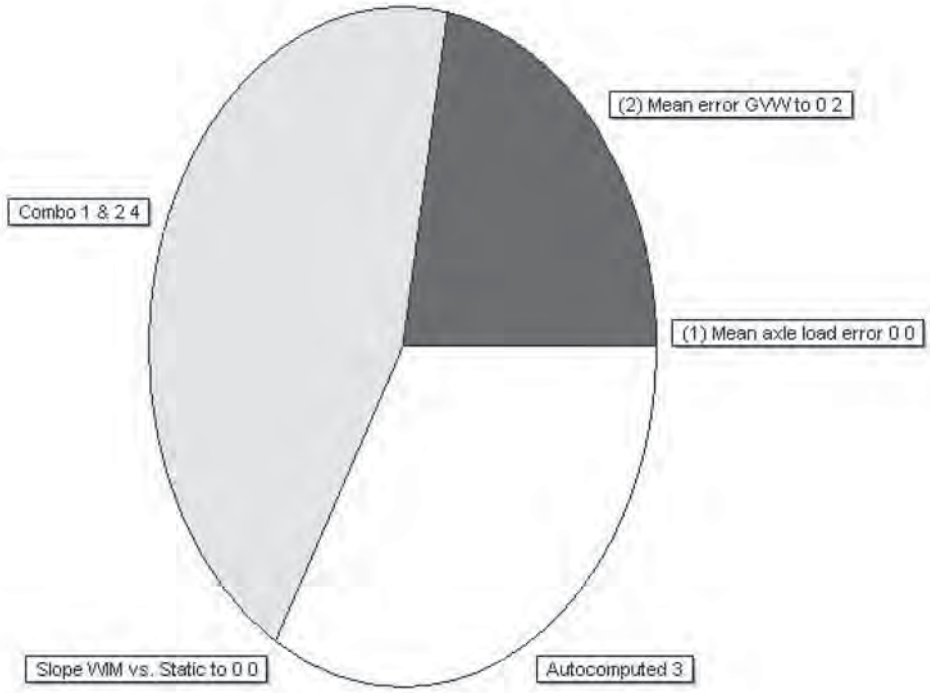
3.6.12 Are traffic stream trucks of known weight ever sampled for the sole purpose of determining WIM system accuracy tolerance pass/fail (e.g. new site acceptance, warranty, etc.)?



Other Responses:

Comment Responses:

3.6.13 During on-site calibration using traffic stream trucks of known weight, what method is used to compute the calibration factors?

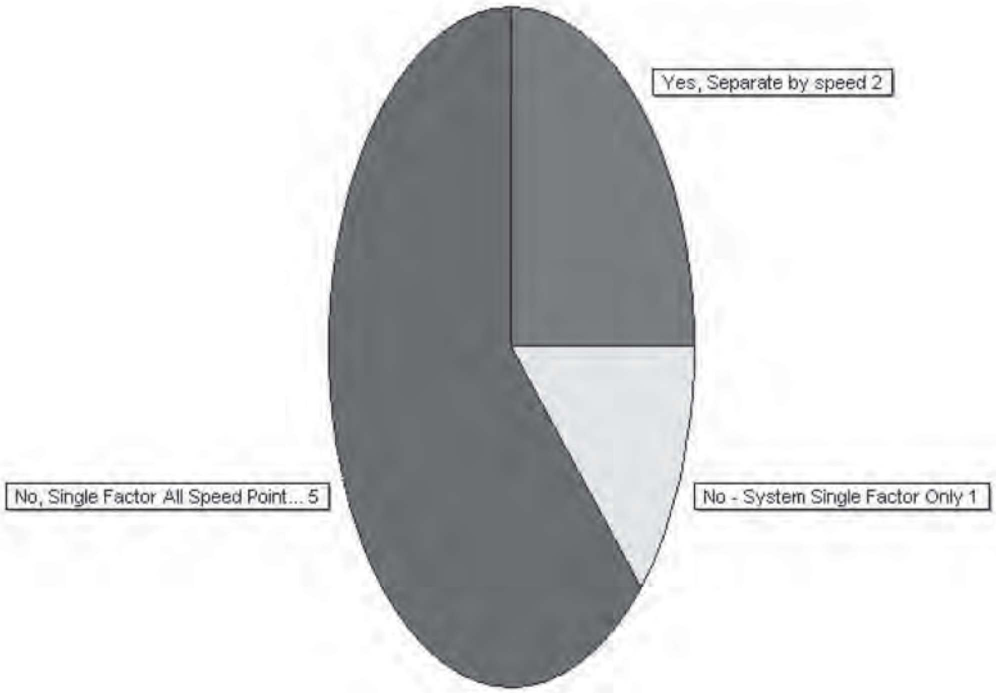


Other Responses:

Comment Responses:

Co-Enf: GVW is used first then Axle loads are compared to fine tune the system

3.6.14 During on-site calibration using traffic stream trucks of known weight do you compute calibration factors for two or more speed points?

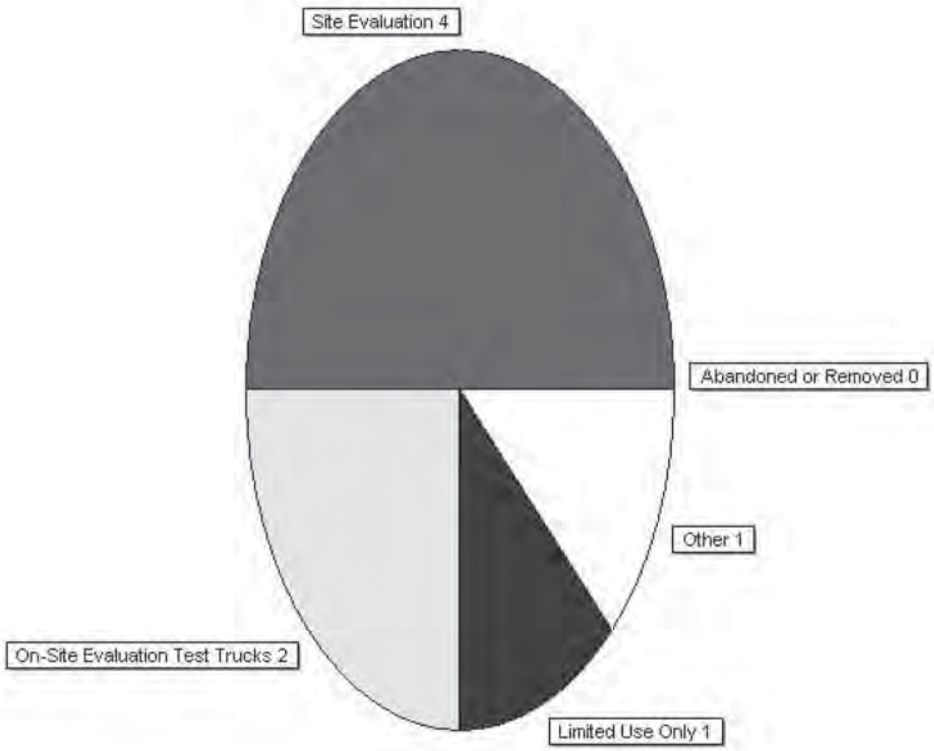


Other Responses:

Comment Responses:

MT-Enf: The majority of our traffic stream travels within one speed group.
Co-Enf: If problems arise Speed is checked and an adjustement is made. To date all calibration factors remain the same.

3.6.15 What remedial action is taken for WIM systems that fail to meet accuracy tolerances during traffic stream truck evaluation?

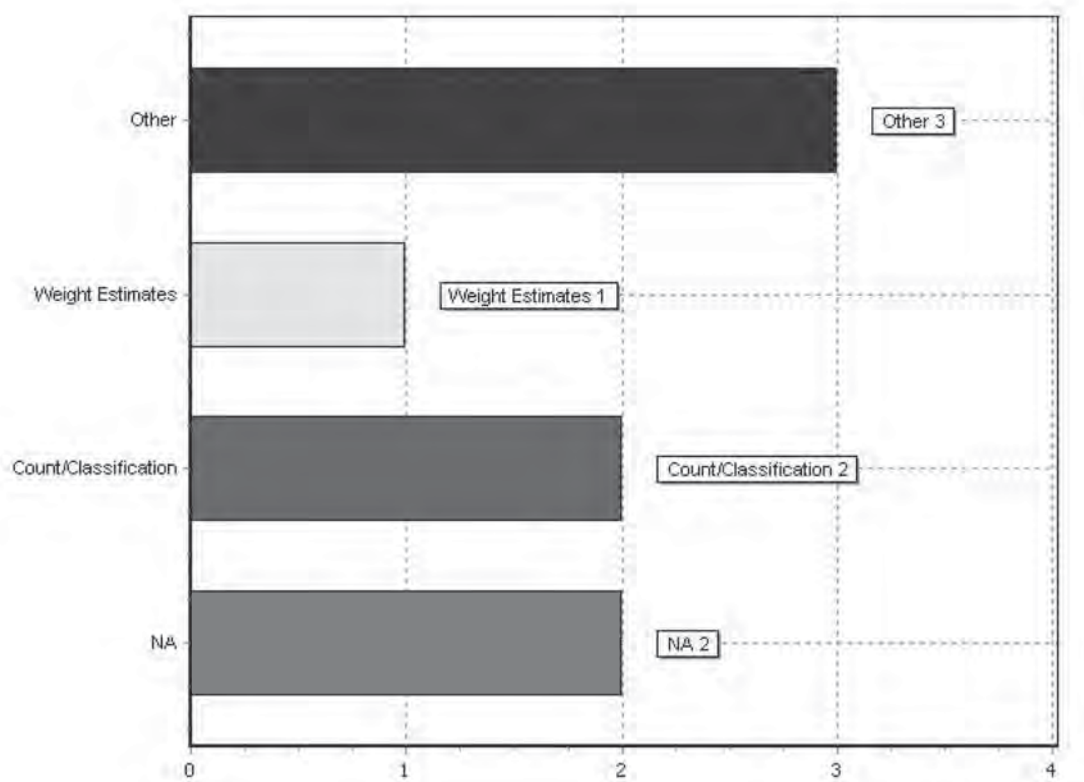


Other Responses:

AL-Enf: We schedule a re-calibration but continue to use system

Comment Responses:

What is data from systems that remain in use but fail to meet accuracy tolerances used for?

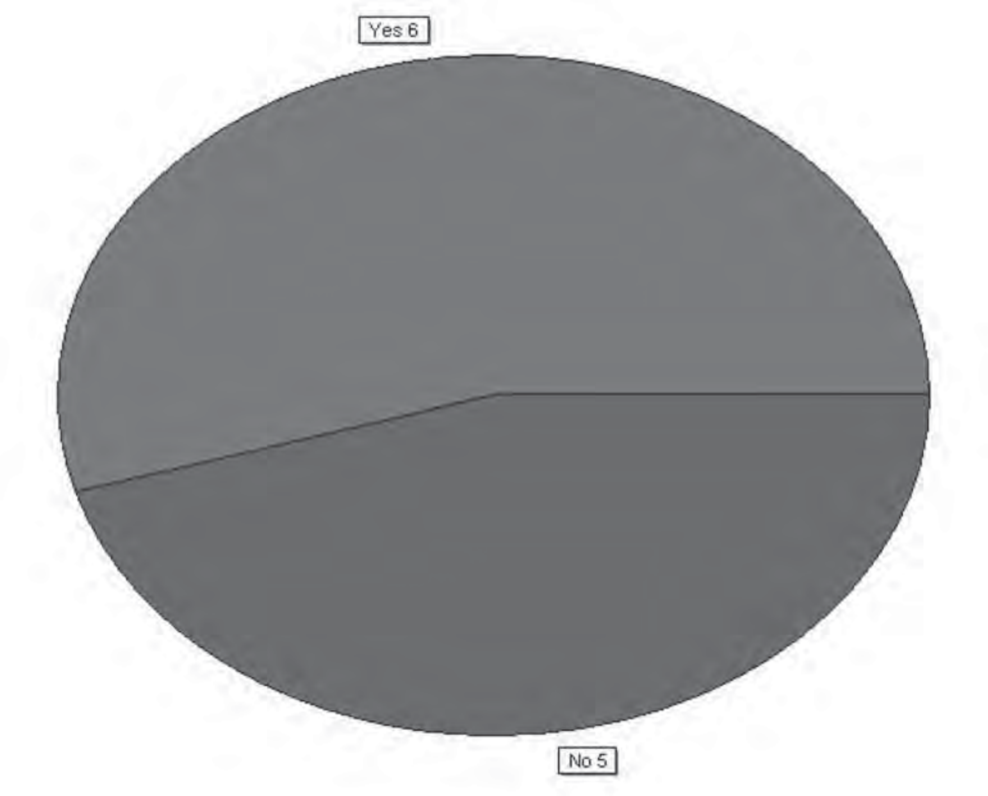


Other Responses:

Comment Responses:

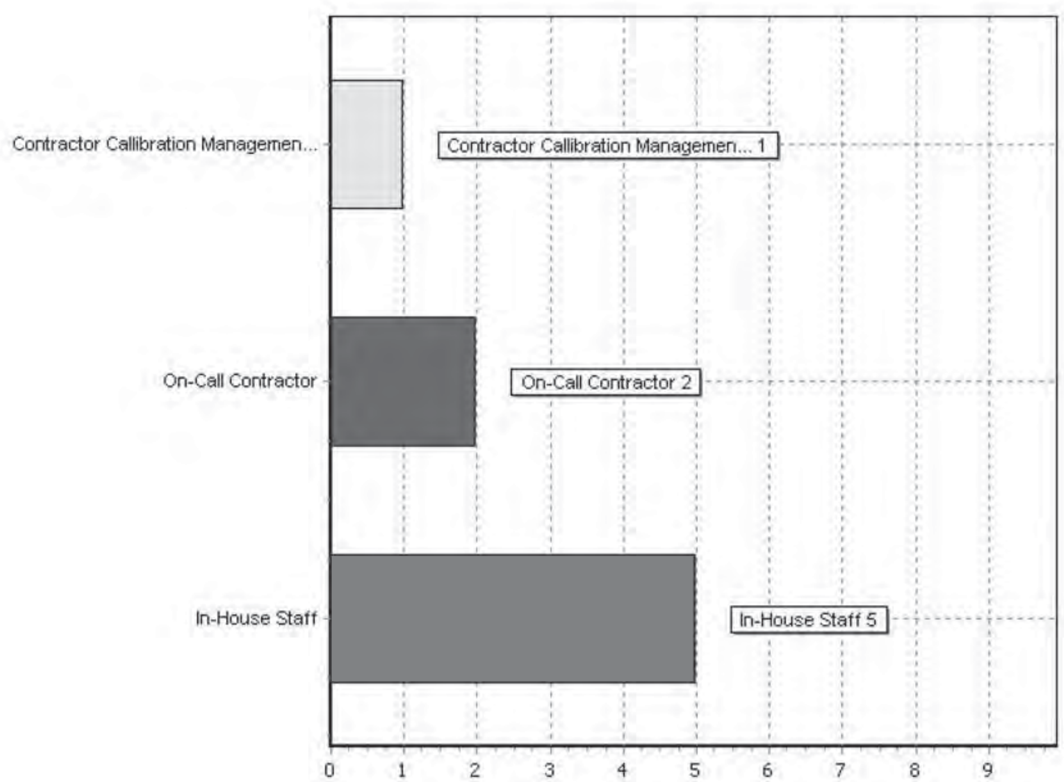
Each WIM system is evaluated, problem isolated and corrected. As system meet their life-cycle, the department will evaluate and if warranted, deploy new technology to improve operations.
AZ-Enf: Site repaired

3.7 WIM Calibration Monitoring Using Traffic Stream WIM Data Do you use WIM calibration monitoring using traffic stream WIM data to monitor your WIM systems?



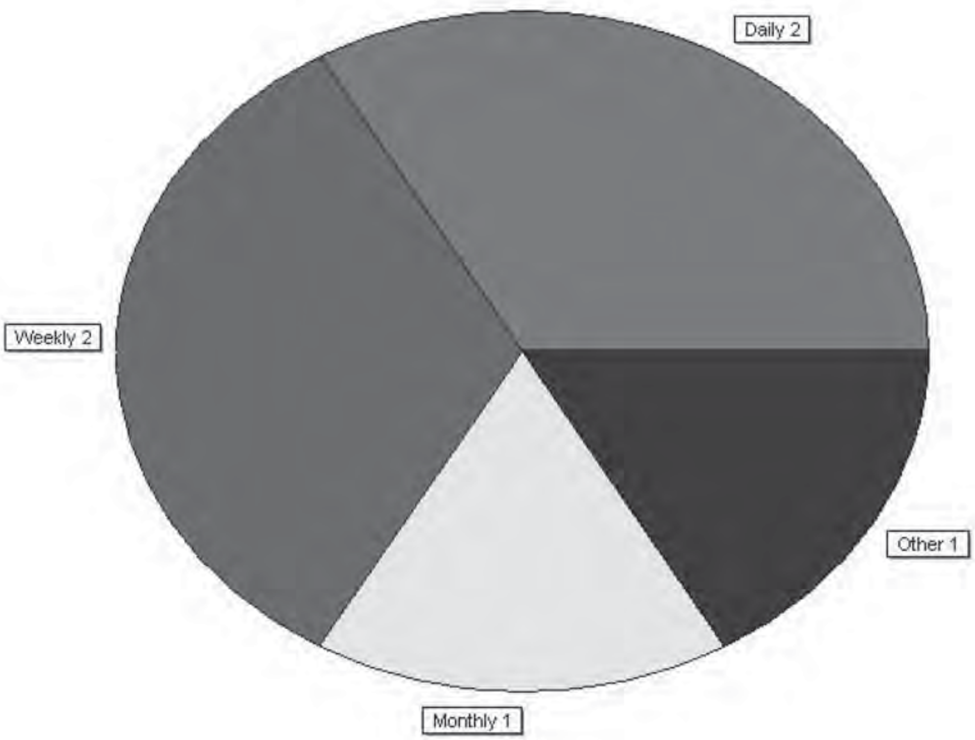
Comment Responses:

3.7.1 Who conducts WIM calibration monitoring using traffic stream WIM data? Check all that apply.



Additional comments:

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions. 3.7.2 Typically, how often are your systems' data files downloaded?

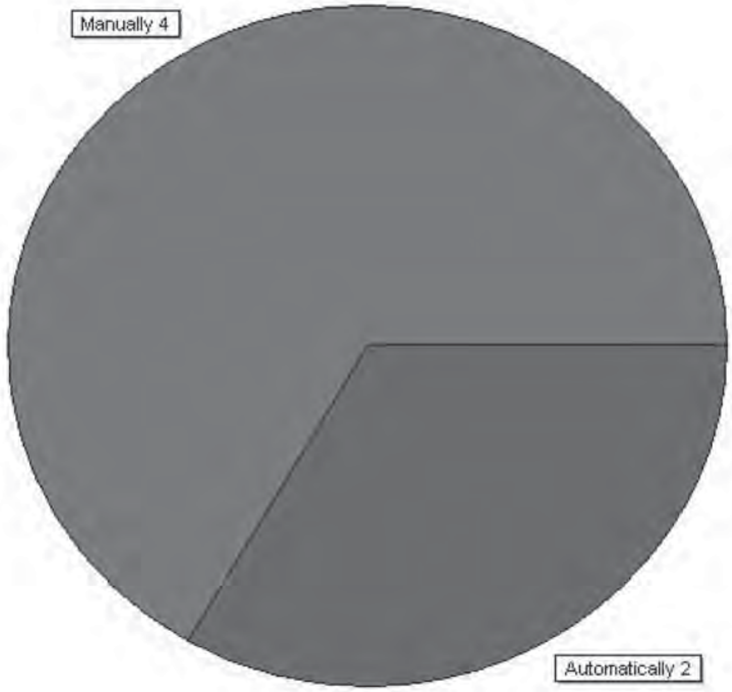


Other Responses:

AZ-Enf: Bi-weekly

Comment Responses:

3.7.3 How are your systems' data files downloaded?

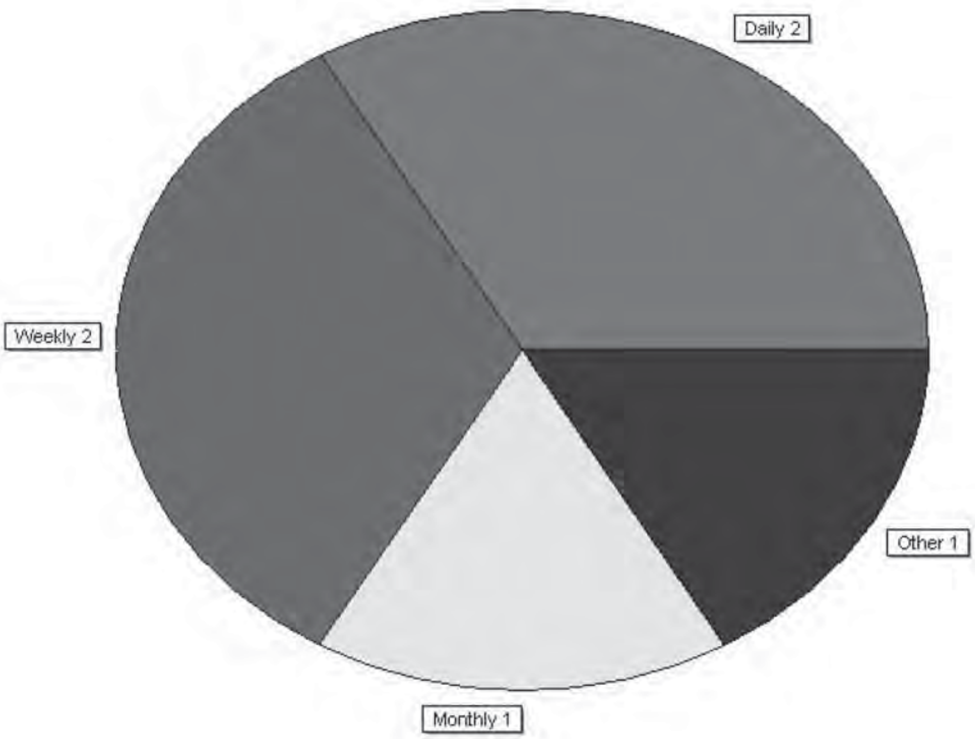


Other Responses:

Comment Responses:

MT-Enf: For bender--plate sites, manual polling is conducted; for quartz piezo sites, auto-polling proprietary software is used.

3.7.4 How often do you perform checks of the WIM data?

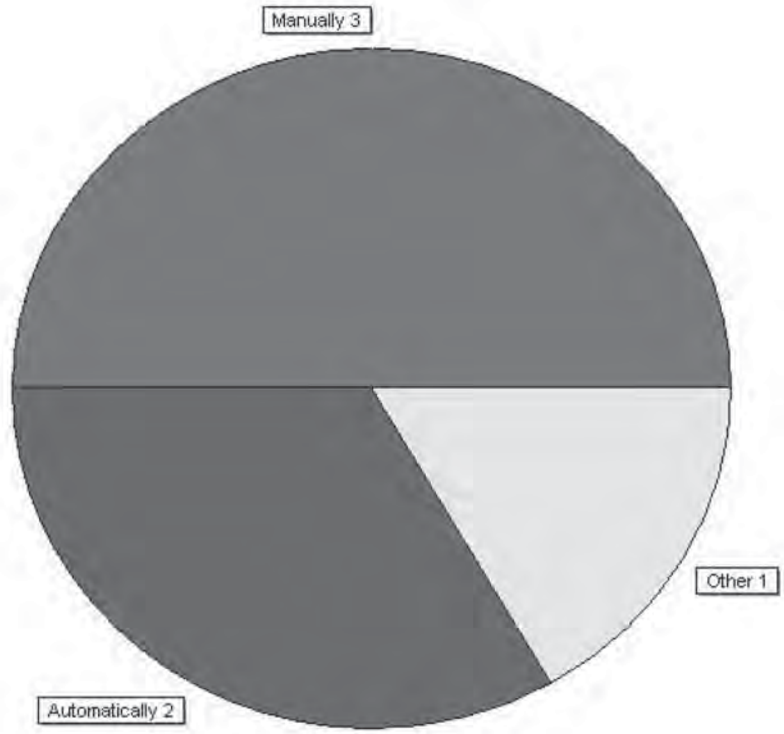


Other Responses:

Comment Responses:

MT-Enf: Reviewed when officers at weigh scale location notify HQ of weight differences between the WIM system and Static Scales.

3.7.5 How is your WIM data analysis performed?

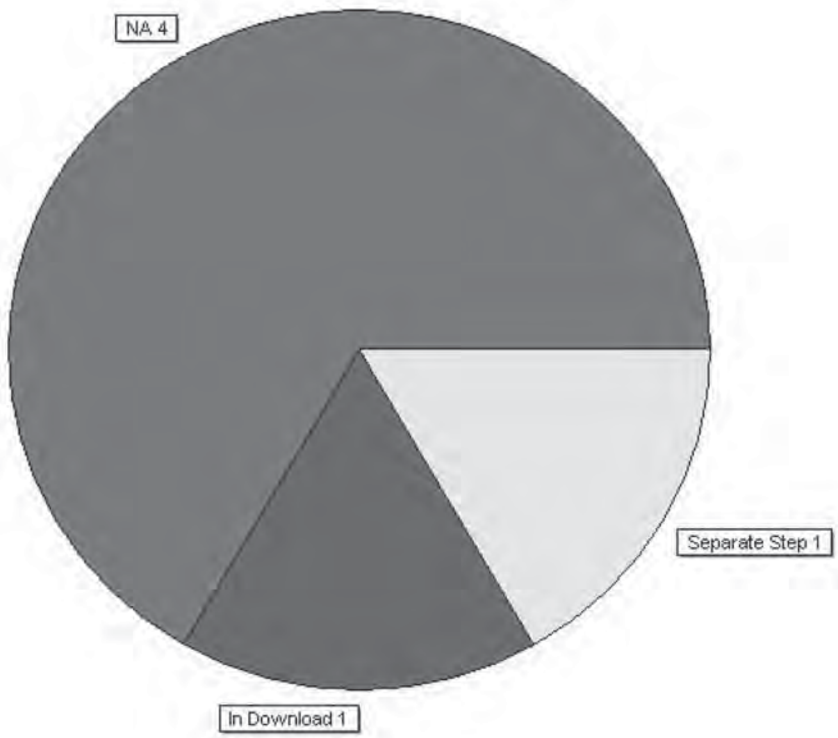


Other Responses:

Comment Responses:

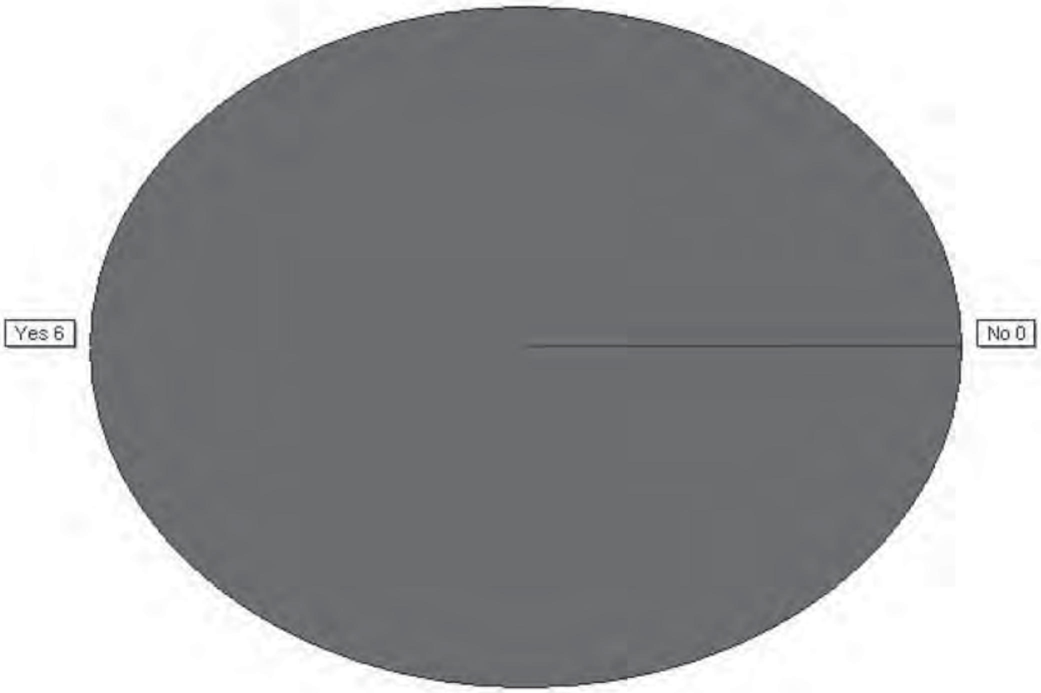
MT-Enf: Manual review of weigh distribution graphs looking at loaded and unloaded peaks. We also look at the Prepass information. (# of pullins and the reason for pullins)

If your data analysis is performed automatically using software, when is it carried out?



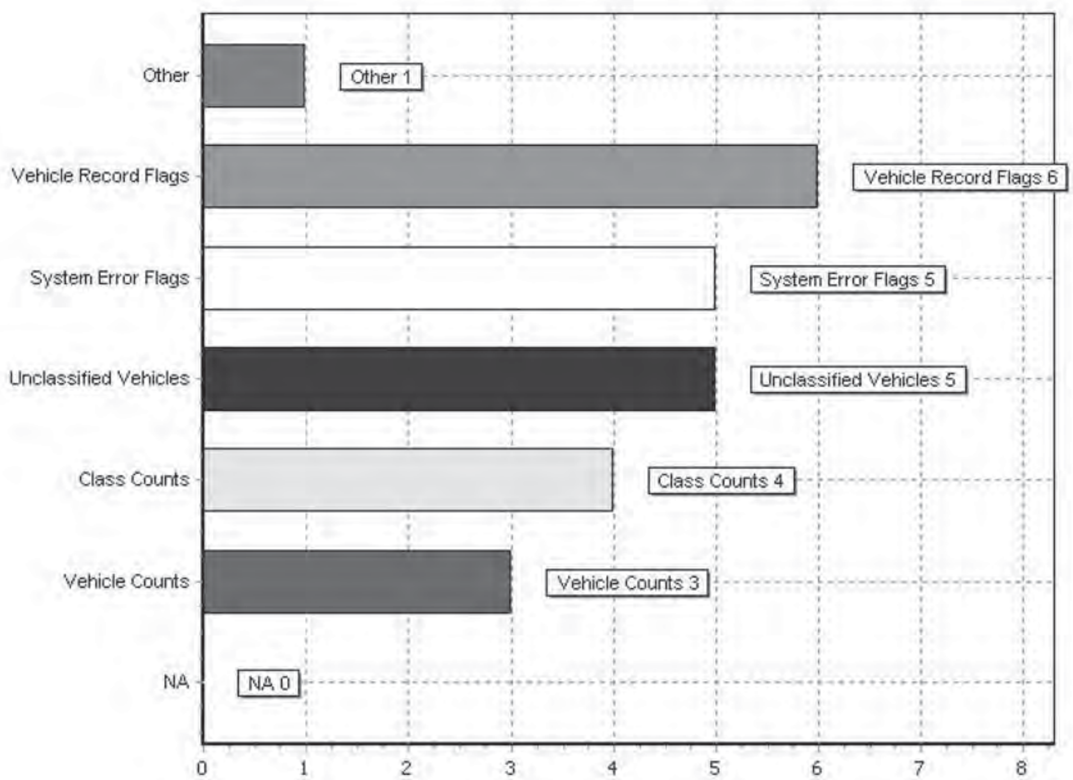
Comment Responses:

3.7.6 In your opinion, do the analyses of your WIM data identify most system operational problems and atypical traffic characteristics?



Comment Responses:

If Yes, which types of system operational problems and/or atypical traffic characteristics are identified? Check all that apply.

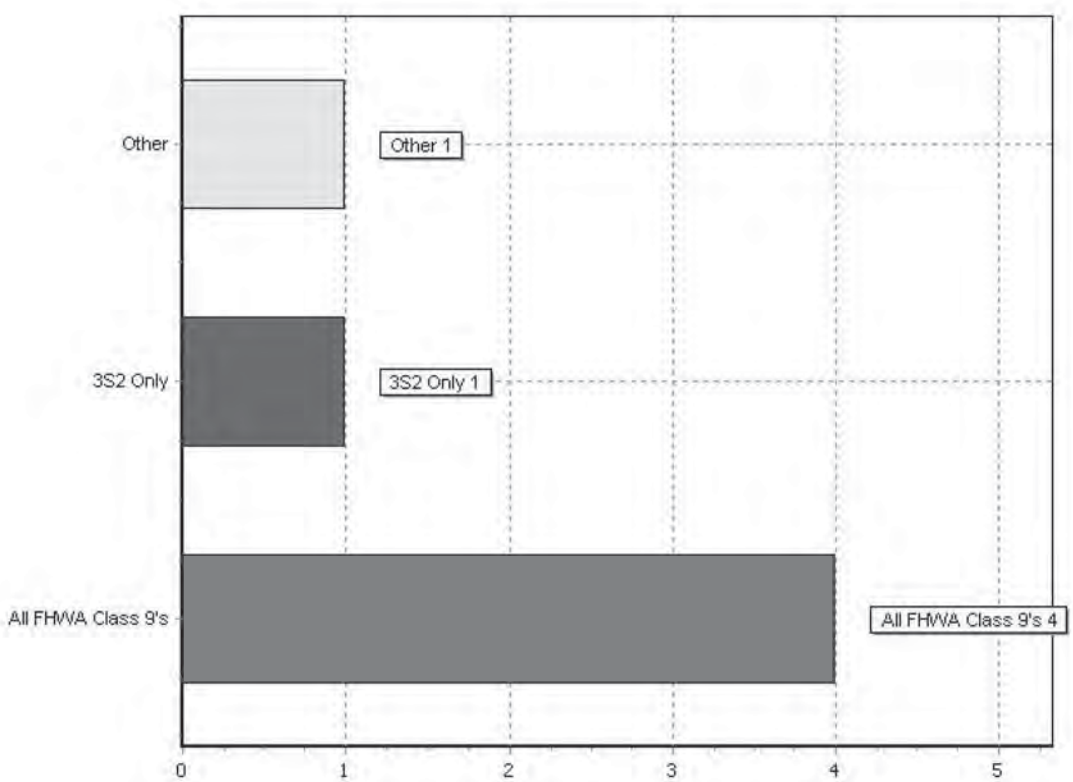


Other Responses:

speed of vehicles monitored

Comment Responses:

3.7.7 Which traffic stream vehicle types are utilized for calibration monitoring? Check all that apply.



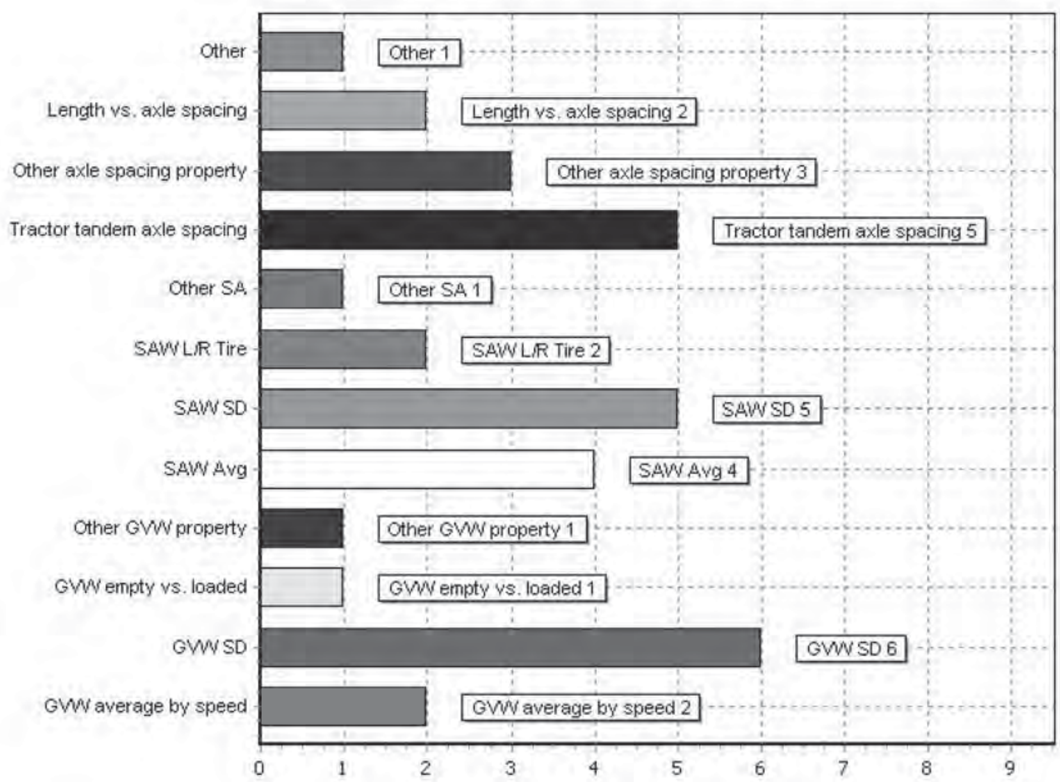
Other Responses:

AL-Enf: 2 axle vehicle, tridem 3 axle dump truck, 5 axle lowboy

Comment Responses:

MT-Enf: Non-liquid/non-livestock loads.

3.7.8 Which characteristics are monitored through WIM calibration monitoring using traffic stream WIM data? Check all that apply.

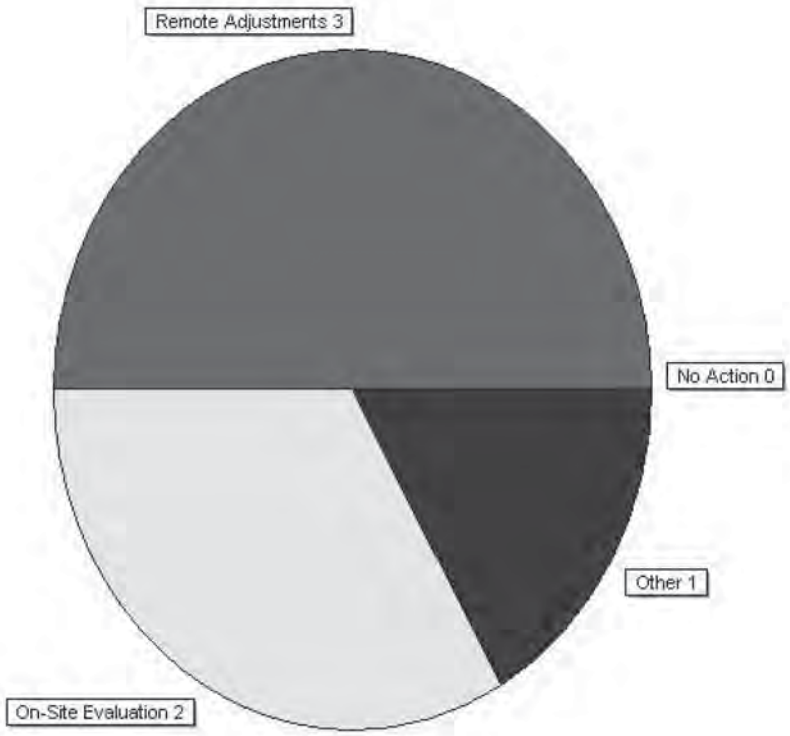


<u>Other Responses</u>:

AZ-Enf: Axle, Group, Bridge, and gross weights.

<u>Comment Responses</u>:

3.7.9 If the monitoring of traffic stream characteristics indicates a system is experiencing calibration "drift" what action is taken?

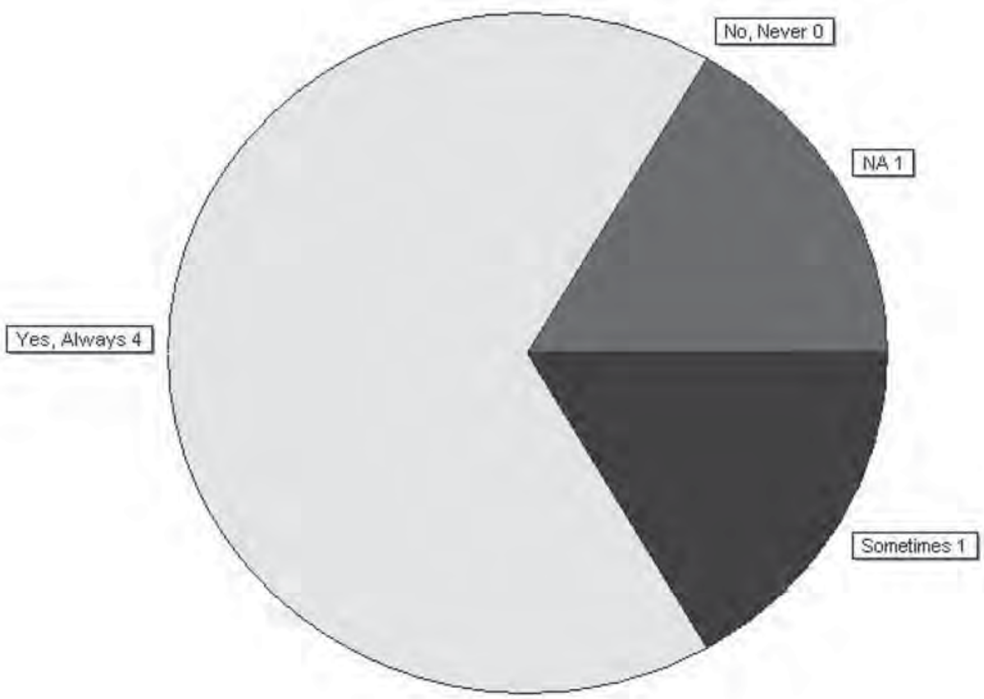


Other Responses:

Comment Responses:

MT-Enf: HQ notifies the Captain in charge of the weigh scale and officers collect the WIM and Static information; mail or fax information to HQ. If needed, factors are computed and entered into the recorder via telephone/modem communications.
AZ-Enf: On site if necessary to resolve issues.

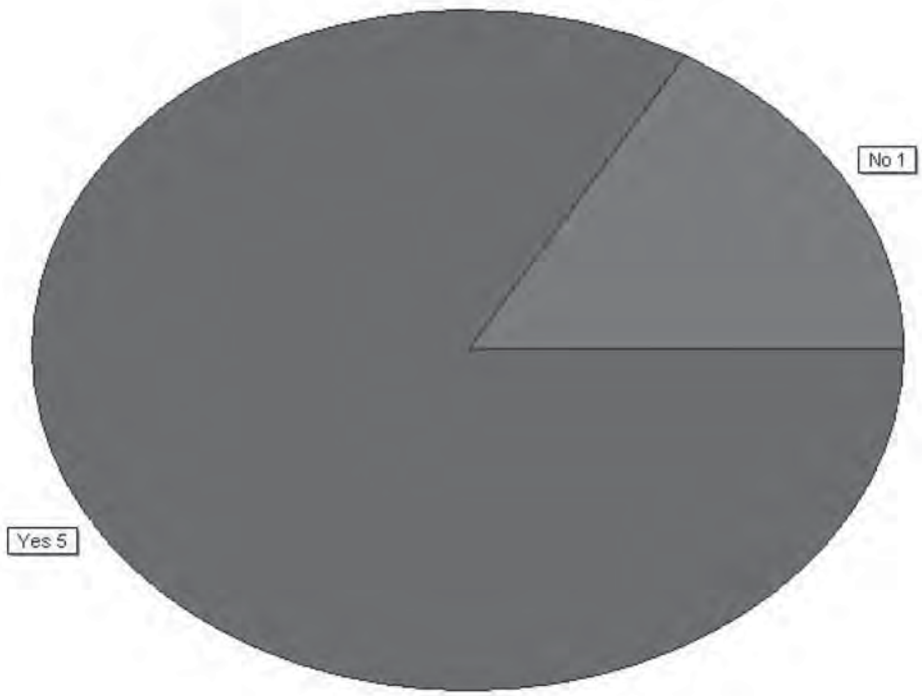
3.7.10 If calibration factors are adjusted from the office, do you check the effect on the traffic characteristics described in 3.7.8? Those characteristics included: (GVW Average, GVW Average by speed, Steering axle weight average, etc.). To view a complete list click on Previous Page below.



Comment Responses:

MT-Enf: Yes additional data is collected after each adjustment.

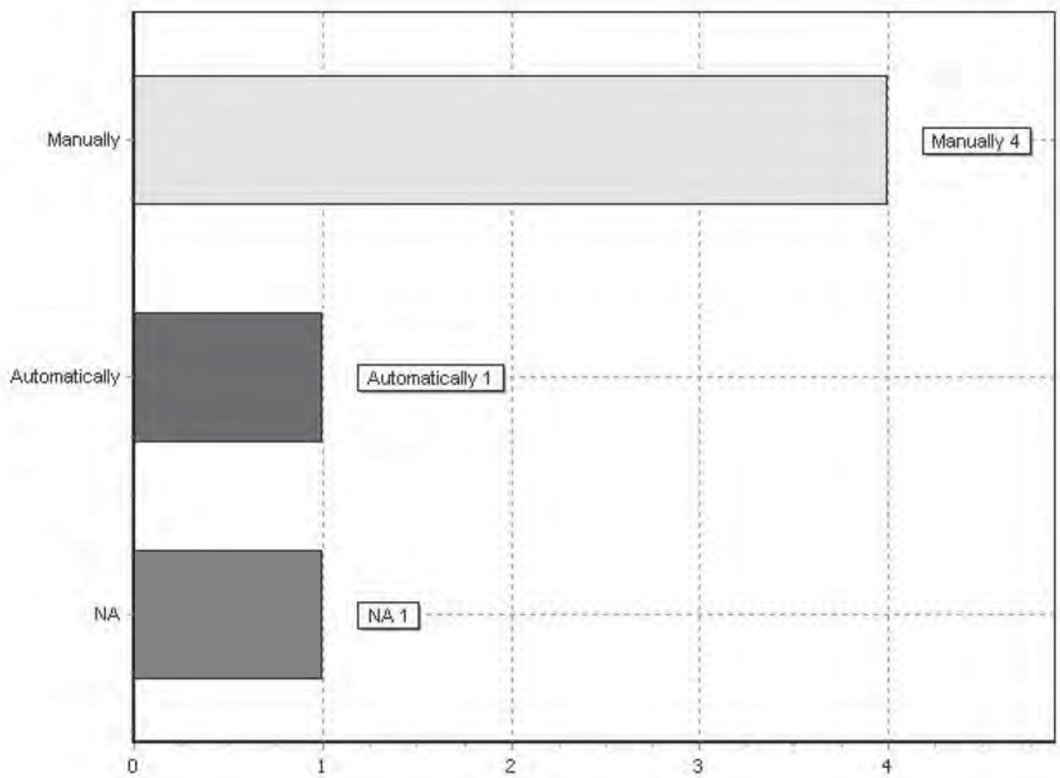
3.7.11 Do you keep records of WIM calibration factor adjustments?



Comment Responses:

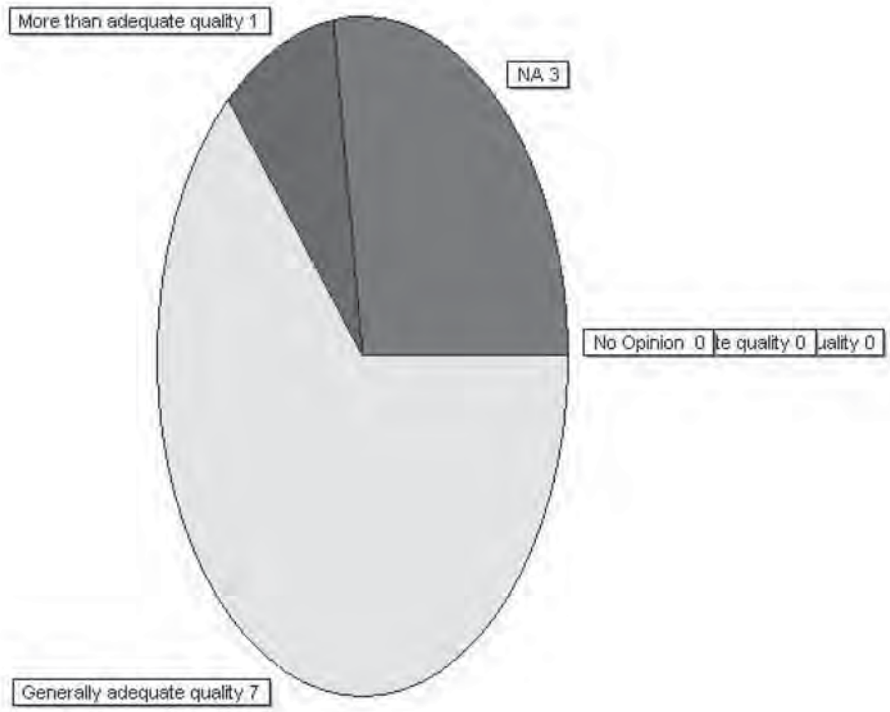
AZ-Enf: Contractor keeps info for future use.
ID-Enf: The contractor does

If Yes, how are records kept?



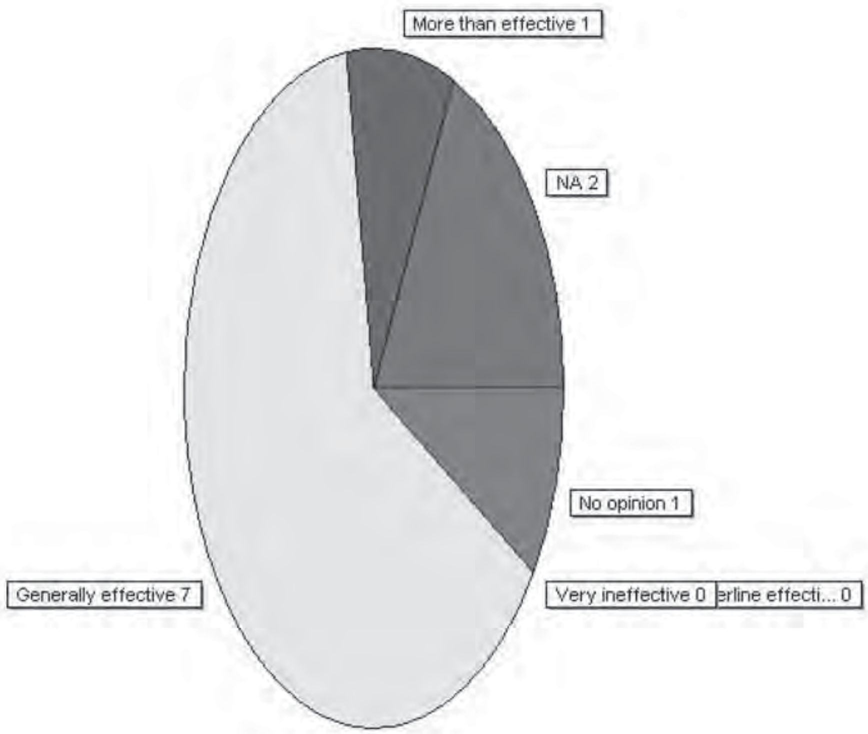
<u>Comment Responses</u>:

Part 4: YOUR OPINION 4.1 In your opinion, are your Type I traffic data systems generating data of adequate quality to meet the requirements for the intended purposes?



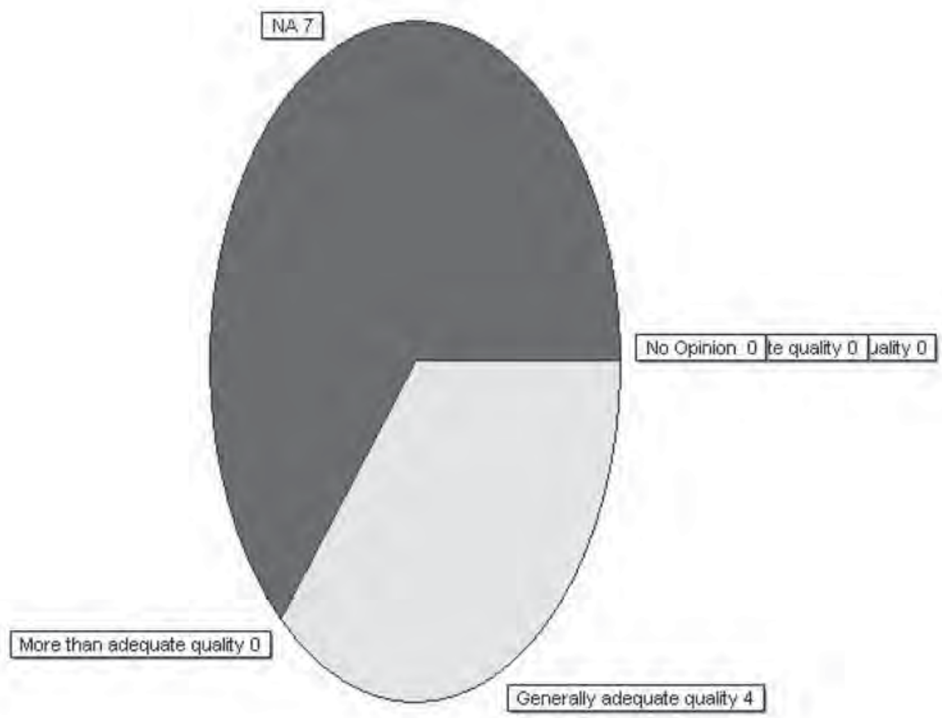
Additional comments:

4.2 In your opinion, are your Type I main line enforcement screening and/or sorting systems effective?



Additional comments:

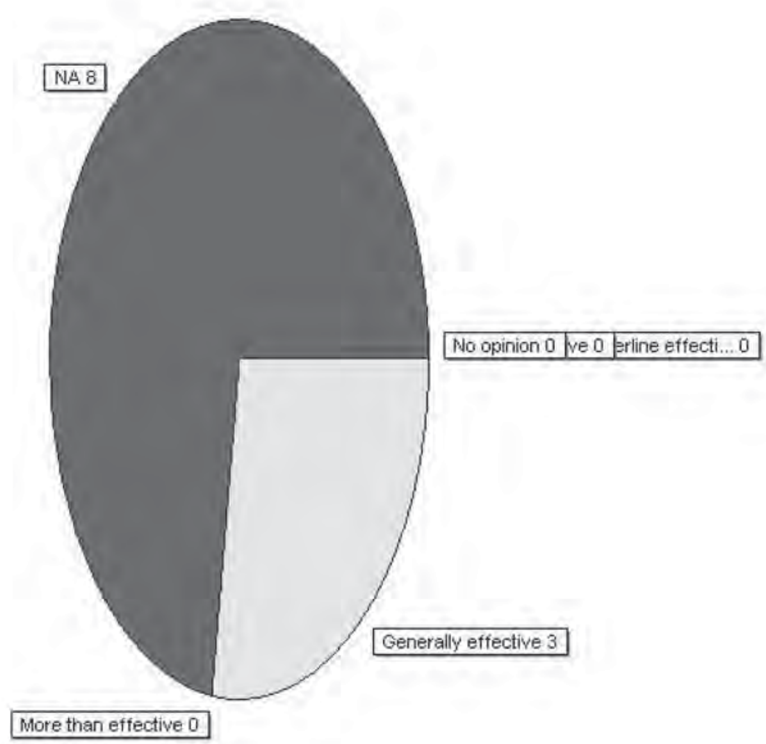
4.3 In your opinion, are your Type II traffic data systems generating data of adequate quality to meet the requirements for the intended purposes?



Additional comments:

MT-Enforcement: MCS uses bender-plate and piezo quartz screening WIM systems; both are Type 1.

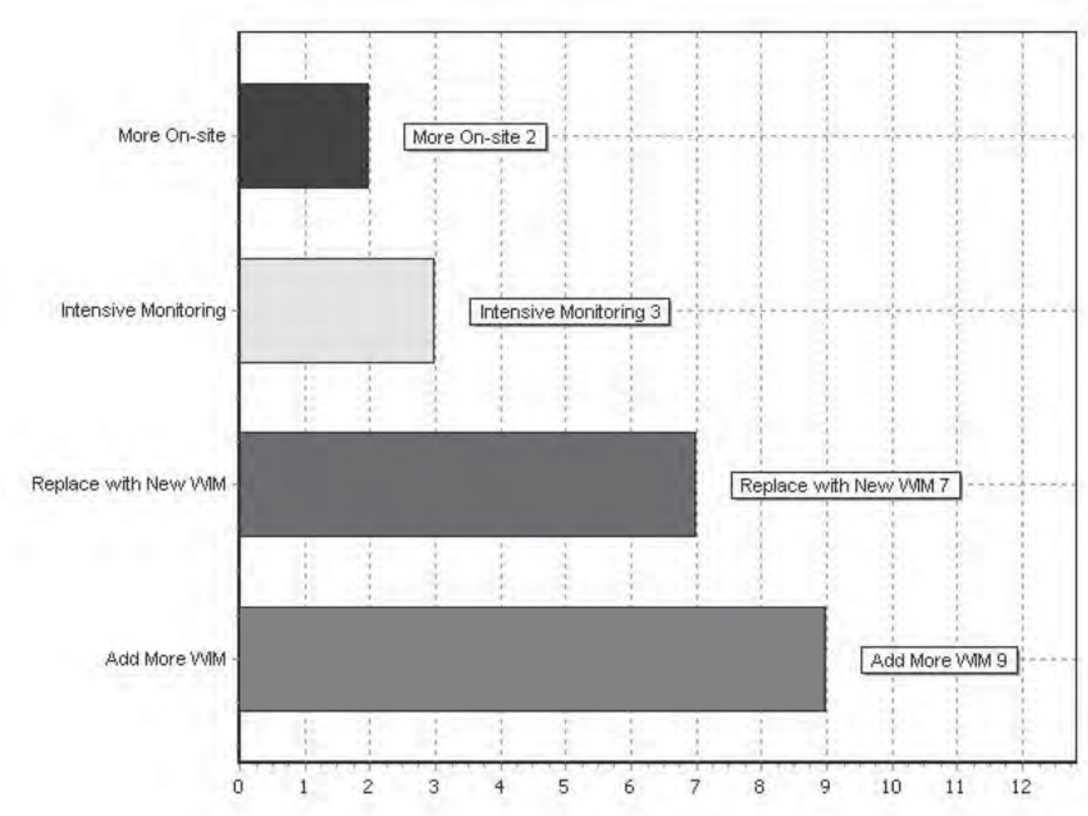
4.4 In your opinion, are your Type II main line enforcement screening and/or sorting systems effective?



Additional comments:

CO-Enf: The type II systems are for Axle Counts in the adjacent lane only, not used for weight enforcement

4.5 In your opinion, given additional resources for high speed WIM traffic data collection and enforcement, which of the following would your unit consider? Check all that apply.



Additional comments:

4.6 In your opinion, what is the main factor hindering proper WIM calibration and how could it be solved?

MD-Enforcement: Incompatible WIM systems with static scale systems (ie, one scale vendor's WIM does not work with another scale vendor's static scale). No reliable data available on WIM system deployed elsewhere by dominant scale vendor for our state.
VA-Enforcement: Resources and Time.
LA-Enforcement: It would be hard to get a more accurate figure without bringing the trucks in off the interstate at a slower and more controlled speed
AL-Enf: Roughness of the roadway, Humidity and Temperature
CO-Enf: WIM calibration is not a problem. Maintenance of the Sites on Busy highways is difficult. Servicing the systems must be done at night in most areas. Calibration can occur any time and does not disrupt the travelling public. Calibration can be done remotely if the Port Operators provide the data via fax or email.
NC-Enf: Manufacturer poor response time for repairs causes unnecessary down time.
AZ-Enforcement: Mostly funding to cover testing.
ID-Enf: Too many variables concerning the locations, vehicle types can lead to inaccurate calibrations and sorting.

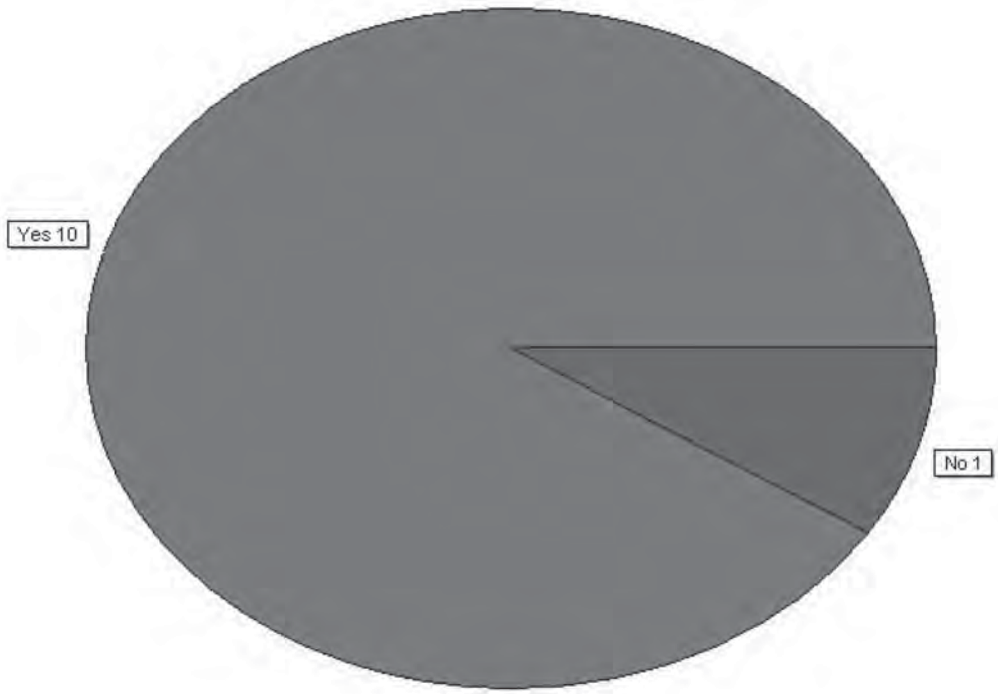
4.7 In your opinion, what are the most urgent WIM technical needs at present and what studies need to be conducted to address them?

MD-Enforcement: WIM deployment for Virtual Weigh Stations to monitor known bypass locations. Studies have been conducted to determine which areas/roads to target. The state procurement system is the biggest hindrance to deploy these in a timely fashion. Technical needs - better installation and calibration guidelines from research community based on production grade data, not research data.
MT-Enforcement: Montana State University, on behalf of MDT has studied bender-plate vs. conventional piezo systems at same location; findings indicate both systems provided similar accuracy. Recommend similar comparison study of quartz piezo and bender-plate systems in northern tier state.
VA-Enforcement: Quality of pavement smoothness.
LA-Enforcement: Cars Stealing the trucks signal showing the truck is running scale
AL-Enf: Keep up with technology in regards to accuracy and durability
CO-Enf: Many WIM systems out live the road surfaces. Many times road surfaces are repaired without thought given to the WIM system and therefore making the WIM system inaffective and sometimes useless. Proper installation combined with proper maintenance of both road surface and WIM system can provide many years of service. Colorado has scales still operational that were installed in 1991 thru 1994. The road surface has been replaced but the system is still operational.
NC-Enf: These units are used as a screening device and meets our present need.
AZ-Enforcement: Improve technology

Please provide any additional comments you may want to share about high speed WIM calibration.

CO-Enf: Many times a system is installed but the Road Maintenance department are not informed until they see something in the road. I feel the Road Maintenance department needs to be active in maintaining the system as the accuracy of the WIM system is only as good as the Road Surface leading up to the System. If the Road surface has been damaged or deteriorated then the WIM accuracy does the same.

Part 5: INVENTORY OF WIM SYSTEMS This last part of the questionnaire is optional. It is an inventory of WIM systems in your state. Do you want to complete it?


Yes 10
No 1

Dual Use - A Single WIM System Used for Both Traffic Data Collection AND Enforcement Screening

Approximate number of Type I WIM Systems	Approximate Number of Type I WIM Lanes	Sensor Type(s)
1		MD-Enf: Kistler Digital Quartz Sensor
7	13	MT-Enf: Bender Plate and Quartz Piezo
0	0	
8	16	LA-Enforcement: IRD SLC, Piezo
14	56	Bending plate
0	0	
11	11	WA-Enf: SLC
3	2	NC-Enf: IRD
0	0	
6	8	AZ-Enf: Electronic load cell
0	0	

Single Use - Traffic Data Collection ONLY

Approximate Number of Type I WIM Systems	Approximate Number of Type I WIM Lanes	Sensor Type(s)
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
1	1	NC-Enf: IRD
0	0	
0	0	
0	0	

Single Use - Enforcement Screening ONLY

Approximate Number of Type I WIM Systems	Approximate Number of Type I WIM Lanes	Sensor Type(s)
0	0	see dual use above
7	11	MT-Enf: Bender Plate and Quartz Piezo
14	14	VA-Enf: IRD single load cells
0	0	
0	0	

13	15	CO-Enf: Single Load Cells
11	11	WA: Enf: SLC
0	0	
0	0	
0	0	
2	2	ID-Enf: IRD load cell systems

Dual Use - A Single WIM System Used for Both Traffic Data Collection AND Enforcement Screening

Approximate Number of Type II WIM Systems	Approximate Number of Type II WIM Lanes	Sensor Type(s)
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	0
0	0	
0	0	
2	2	AZ-Enf: Peizo
0	0	

Single Use - Traffic Data Collection ONLY

Approximate Number of Type II WIM Systems	Approximate Number of Type II WIM Lanes	Sensor Type(s)
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	0
0	0	
0	0	
0	0	
0	0	

Single Use - Enforcement Screening ONLY

Approximate Number of Type II WIM Systems	Approximate Number of Type II WIM Lanes	Sensor Type(s)
0	0	
0	0	

0	0	
0	0	
0	0	
11	11	CO-Enf: Piezo Electric
0	0	0
0	0	
6	6	
0	0	
0	0	

Generated: 6/2/2007 3:58:48 PM

Survey Results & Analysis

for

NCHRP Synthesis 38-10 Survey of High Speed WIM System Calibration Practices

Saturday, June 2, 2007

Powered by:

http://www.websurveyor.com/

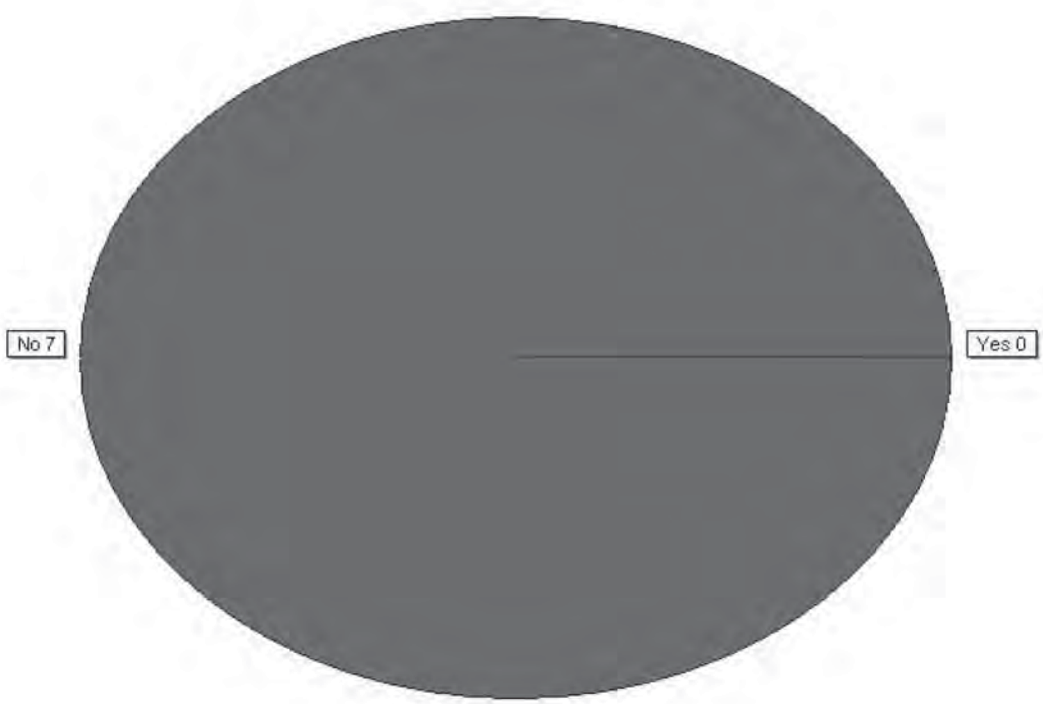
Executive Summary

This report contains a detailed statistical analysis of the results to the survey titled *NCHRP Synthesis 38-10 Survey of High Speed WIM System Calibration Practices*. The results analysis includes answers from all respondents who took the survey in the 76 day period from Friday, March 16, 2007 to Wednesday, May 30, 2007. 7 completed responses were received to the survey during this time.

Survey Results & Analysis

Survey: NCHRP Synthesis 38-10 Survey of High Speed WIM System Calibration Practices
Author: T. Papagiannakis and R. Quinley
Filter: (In question "13) 2.1 What are the WIM systems for which your unit is primaril..." the respondent selected "Data and Enforcement")
Responses Received: 7

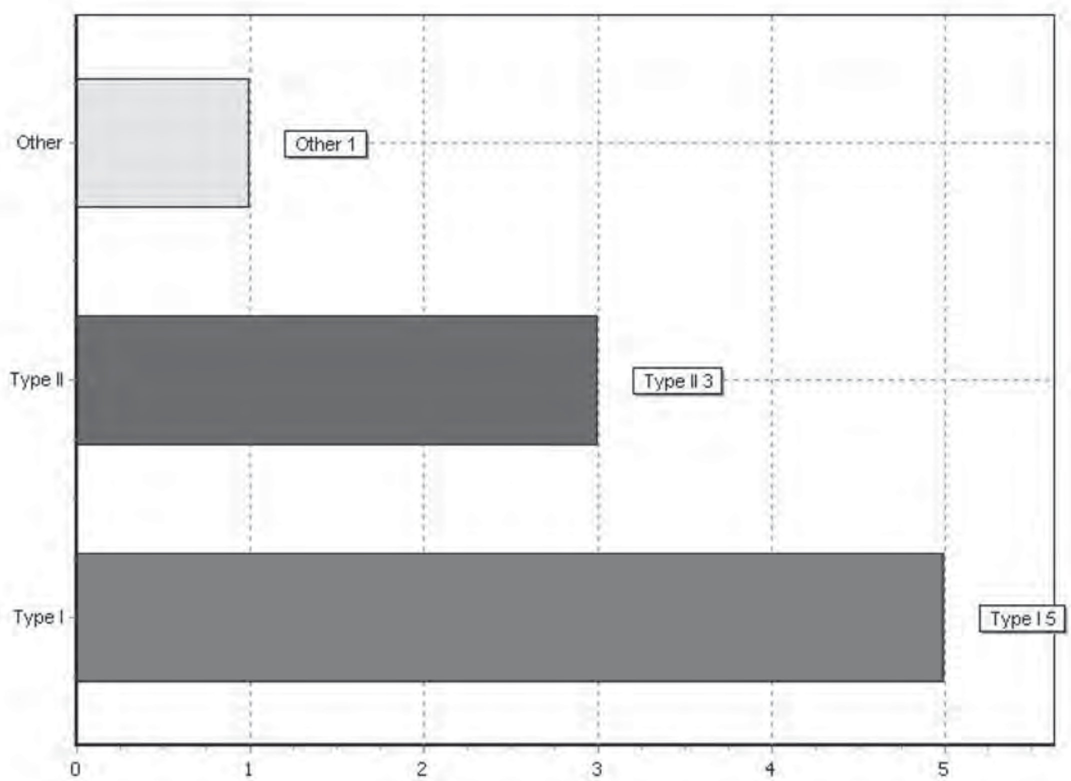
Is there another unit (department/division/agency) in your State managing high speed WIM systems used for a different purpose (i.e., data collection versus enforcement)?



Please comment below on whether your unit cooperates with that other unit and how:

OH: In regards to commercial vehicle enforcement, we have two locations on I-75 that are "Pre-Pass" sites. They provide WIM data for prescreening to our enforcement scales.
ND: Yes we cooperate with our Highway Patrol. The Planning and Programming Division supplies HP with data/graphs of overloaded trucks by site/hour of day/day of week as well as monthly and yearly summations

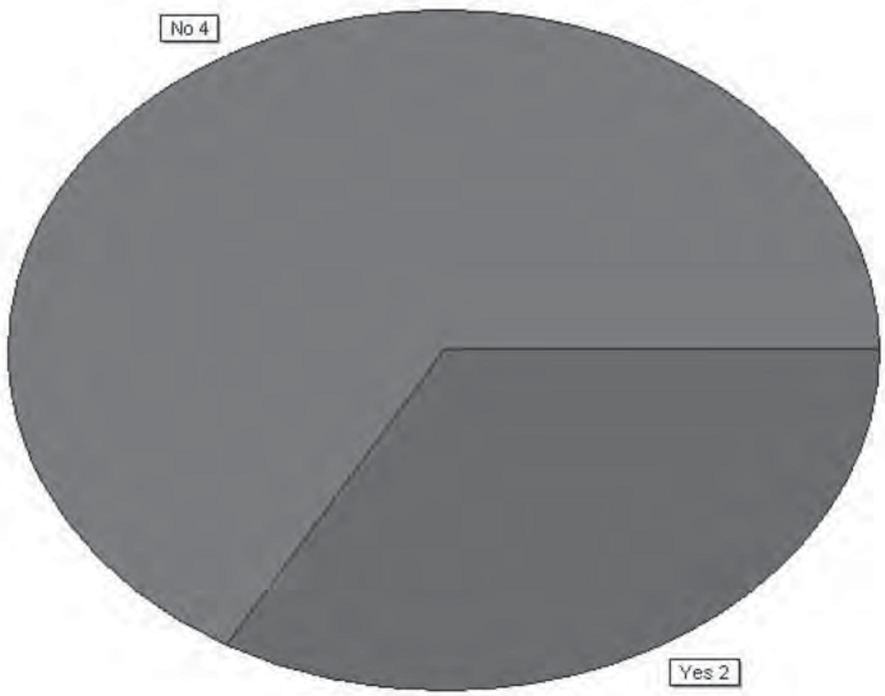
2.2 Which types of WIM systems have been installed by/for your unit?



Other Responses:

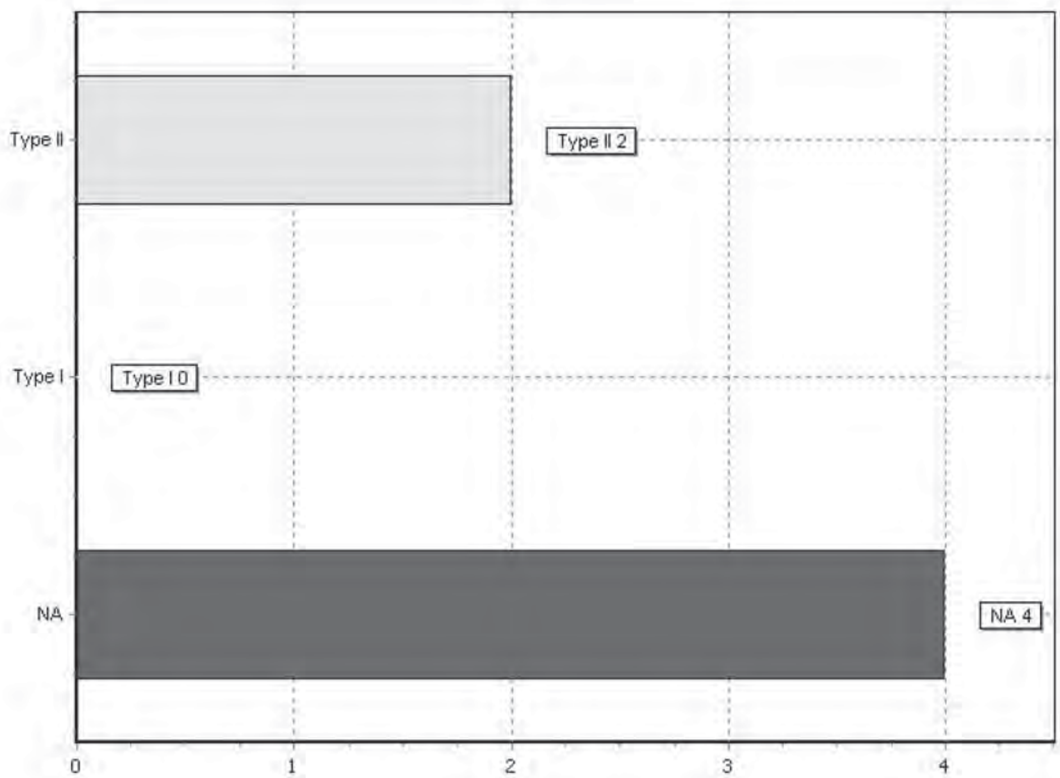
CA: We use piezo electric sensors at our WIM sites but only for classification.

2.3 Is auto-calibration typically utilized by your systems during routine data collection?



Comment Responses:

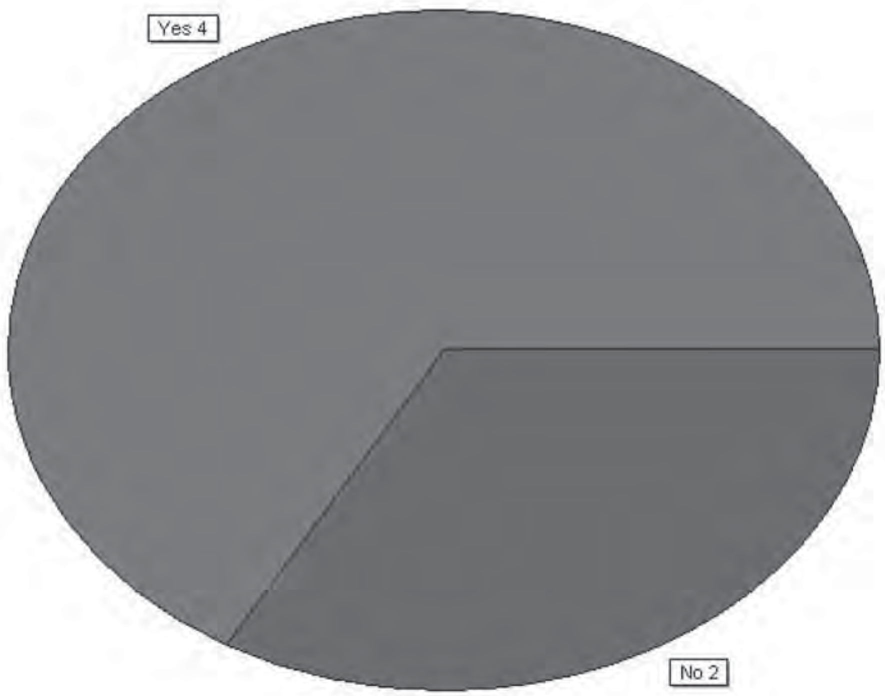
If Yes, for which system types? Check all that apply.



Other Responses:

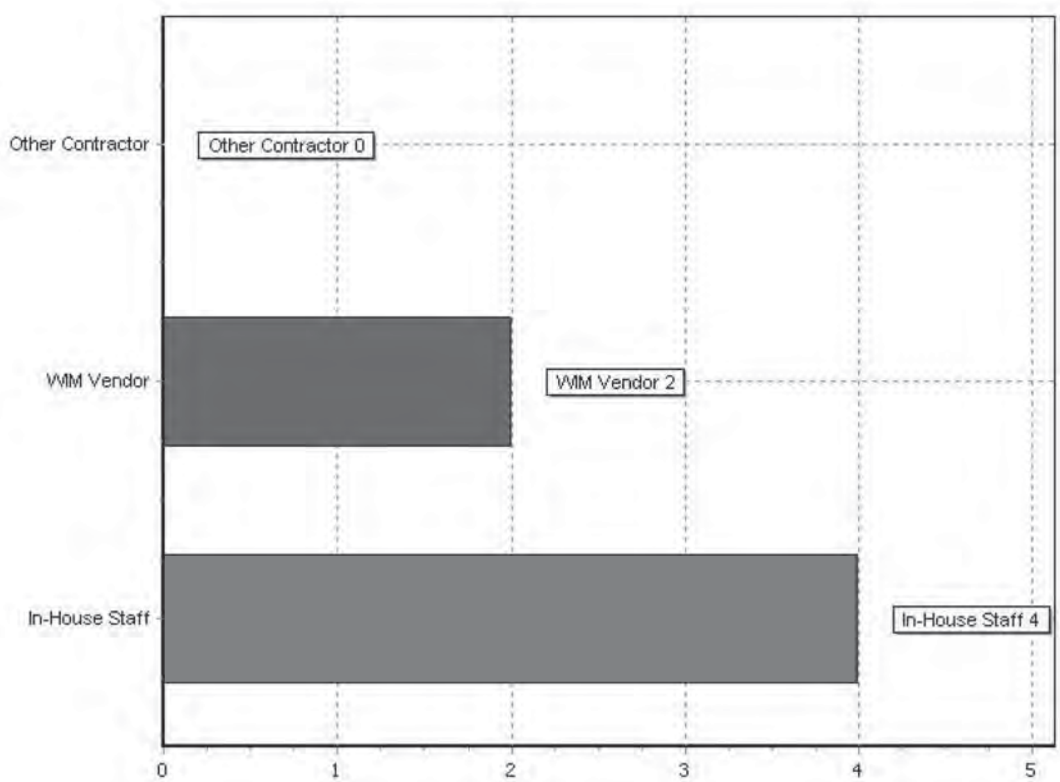
Comment Responses:

3.1 Is a post-installation system calibration always performed?



Comment Responses:

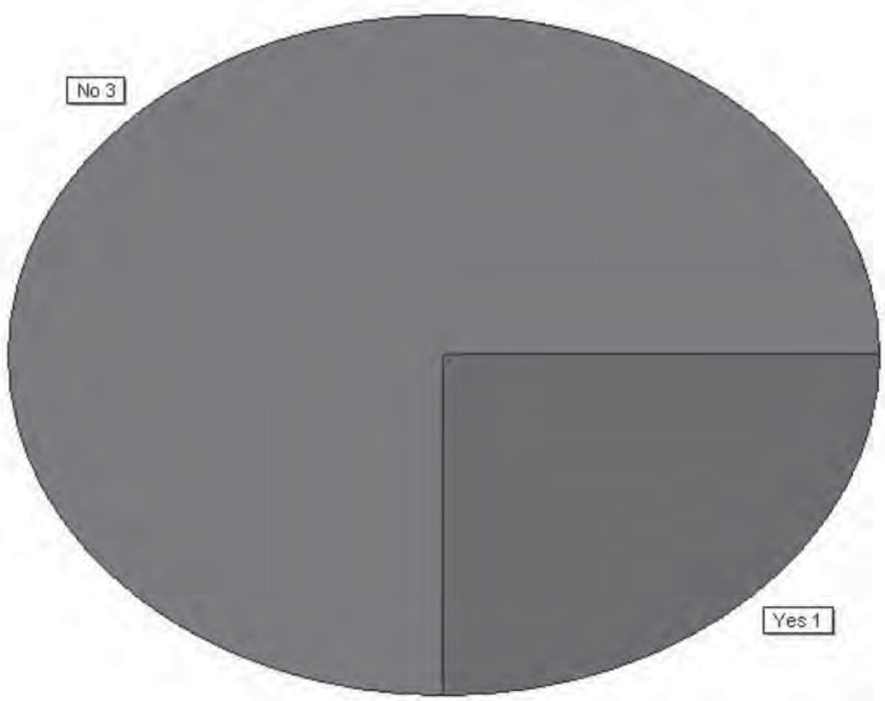
3.2 Who performs this post-installation calibration? Check all that apply.



Other Responses:

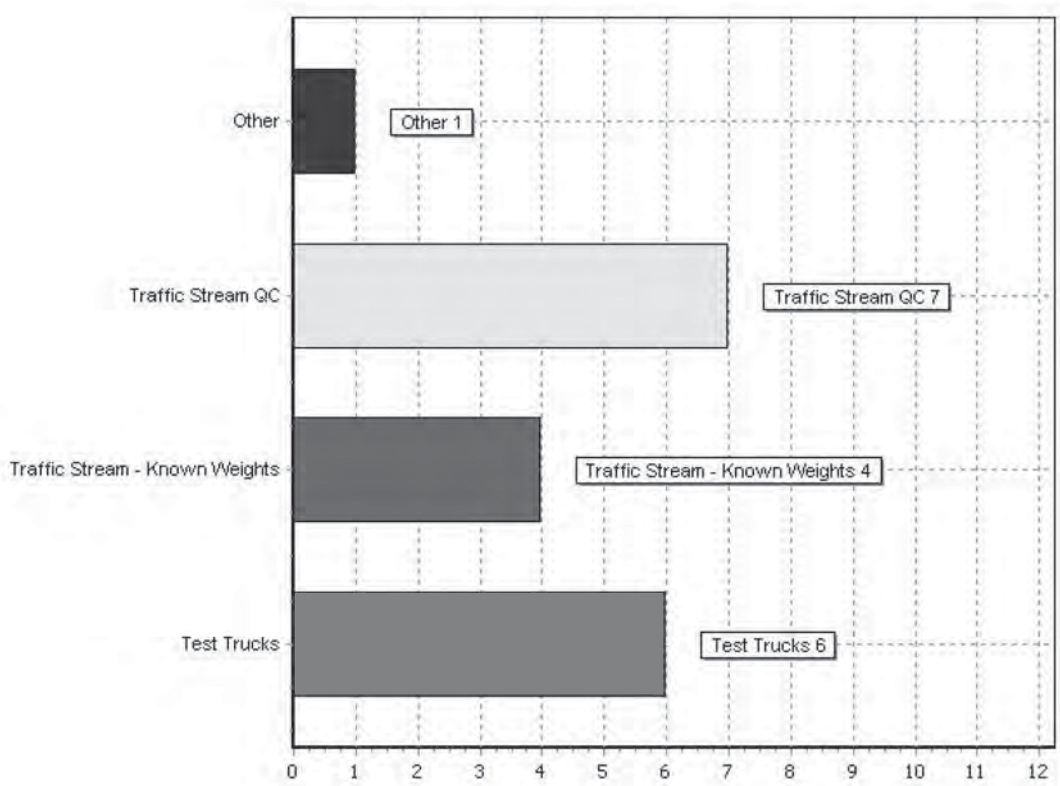
Additional comments:

3.3 Is the post installation calibration procedure any different than the routine calibration?



Additional comments:

3.4 Which methods do you use for the evaluation/calibration of high speed WIM systems throughout their lives? Check all that apply.



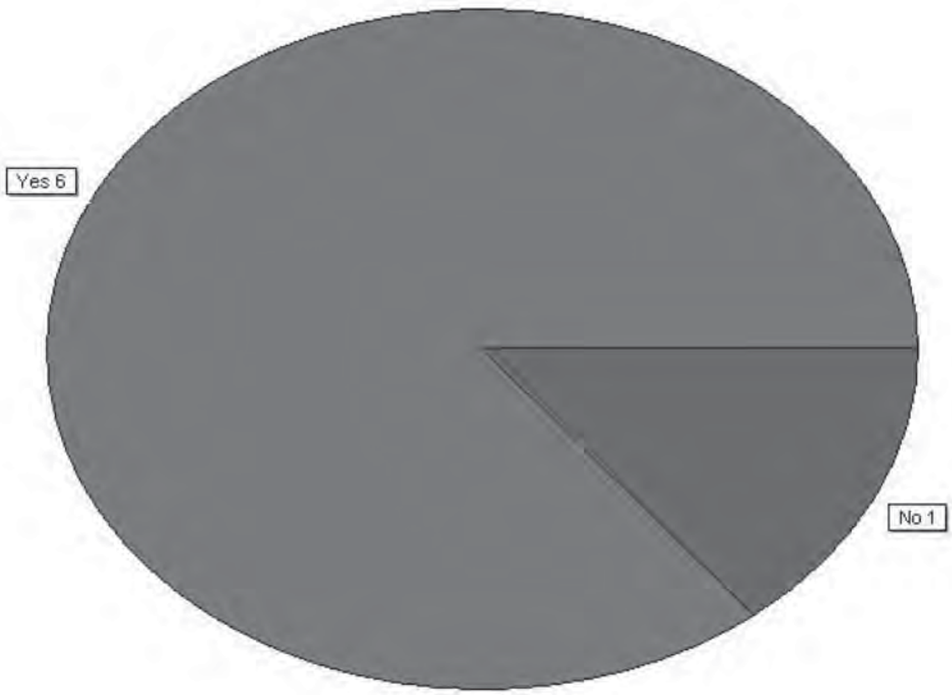
Other Responses:

ND: monitor front axle, drive tandem and GVW

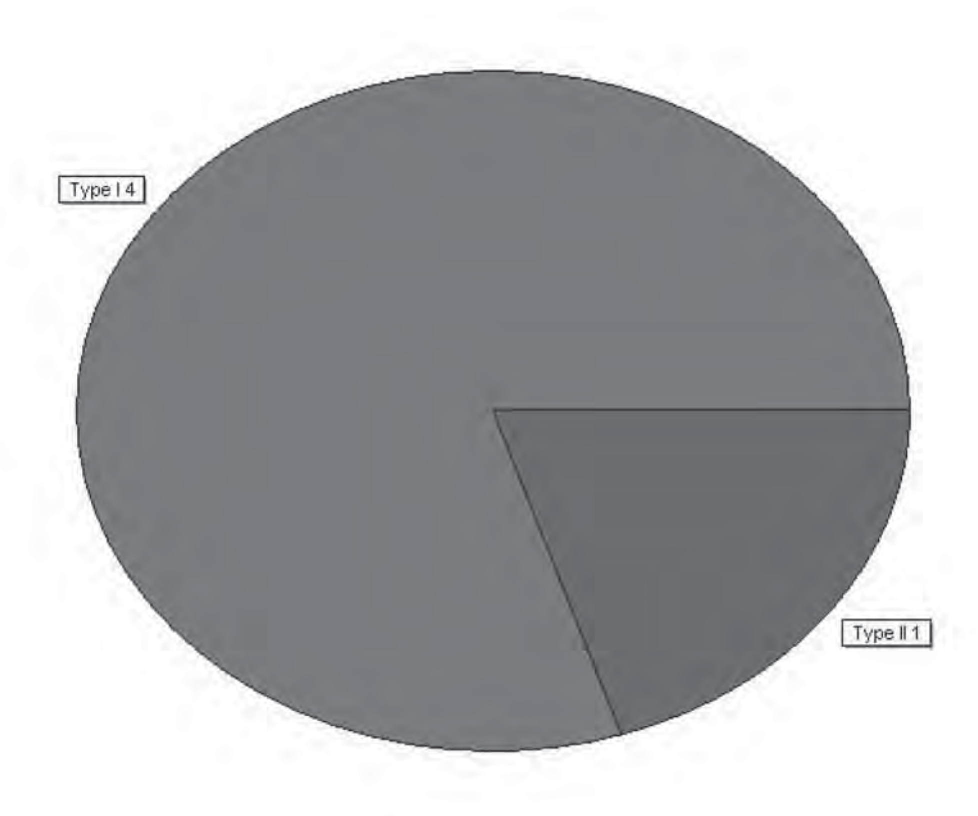
Comment Responses:

ND: also monitor temp sensor performance

3.5 WIM On-Site Evaluation/Calibration Procedures Using Test Trucks NOTE: The majority of the questions under 3.5 relate to the general provisions of the ASTM Standard E1318-02 and the LTPP WIM System Calibration Protocol. They are intended to determine which parts of these standards your unit may be using. Do you perform on-site evaluation/calibration using test trucks?



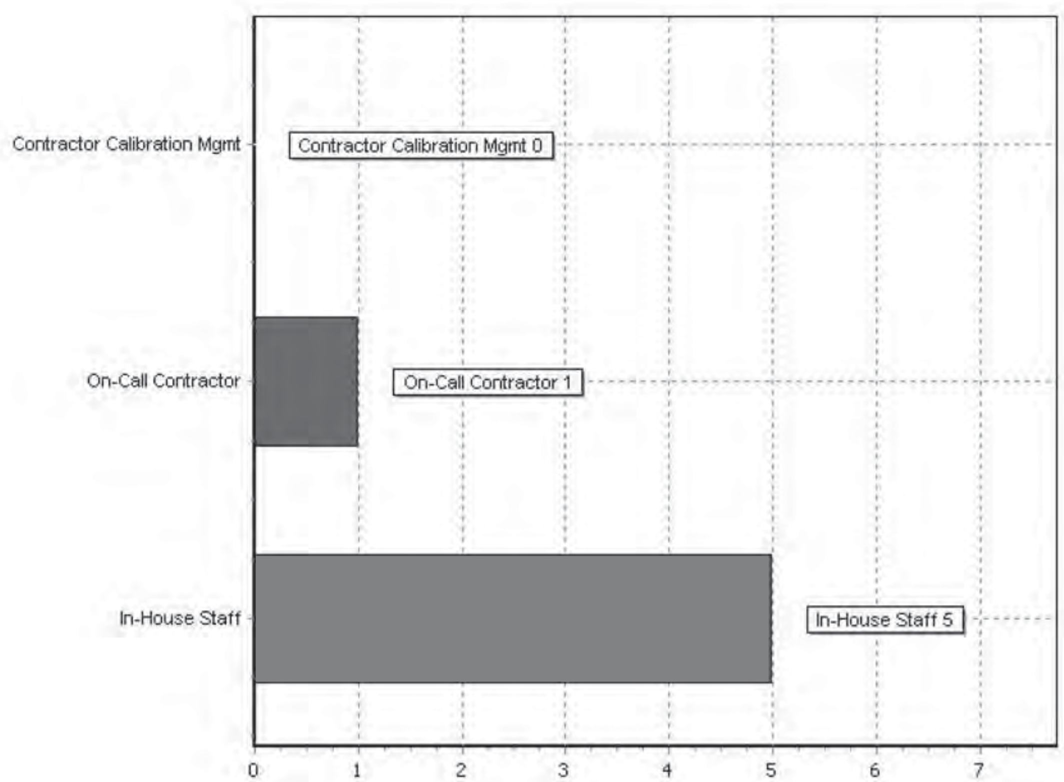
In the series of questions under 3.5 please describe the procedure you use for the MOST COMMON WIM type in your unit (department/division/agency). What is the most common WIM type in your unit for which test trucks are used for calibration?



Other Responses:

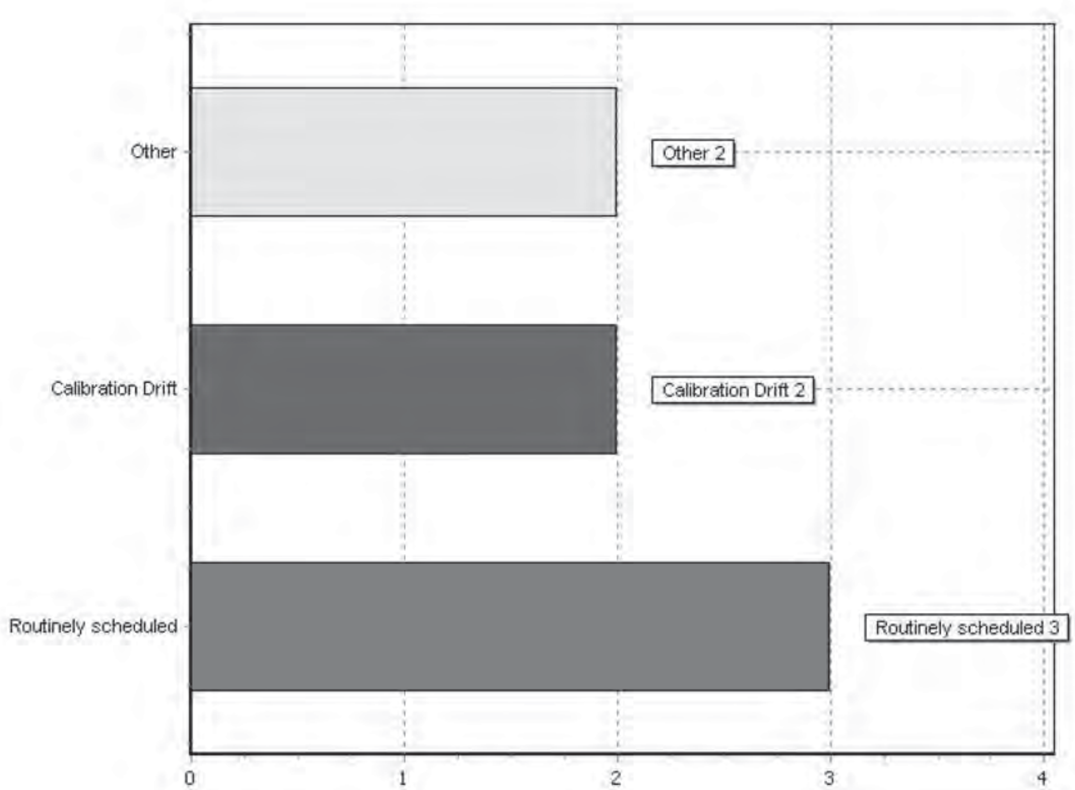
Comment Responses:

3.5.1 Who conducts these on-site evaluation/calibration activities using test trucks? Check all that apply.

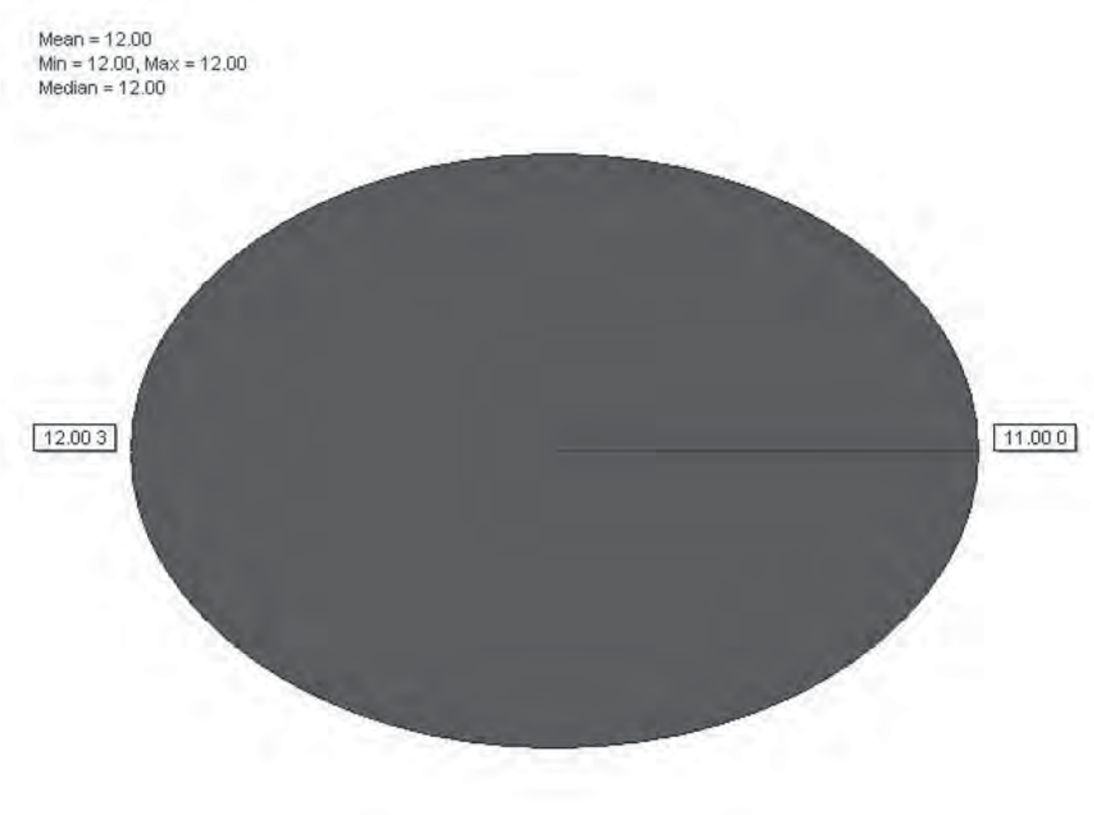


Additional Comments:

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions.3.5.2 What is the criterion you use to initiate test-truck WIM calibration? Check all that apply.



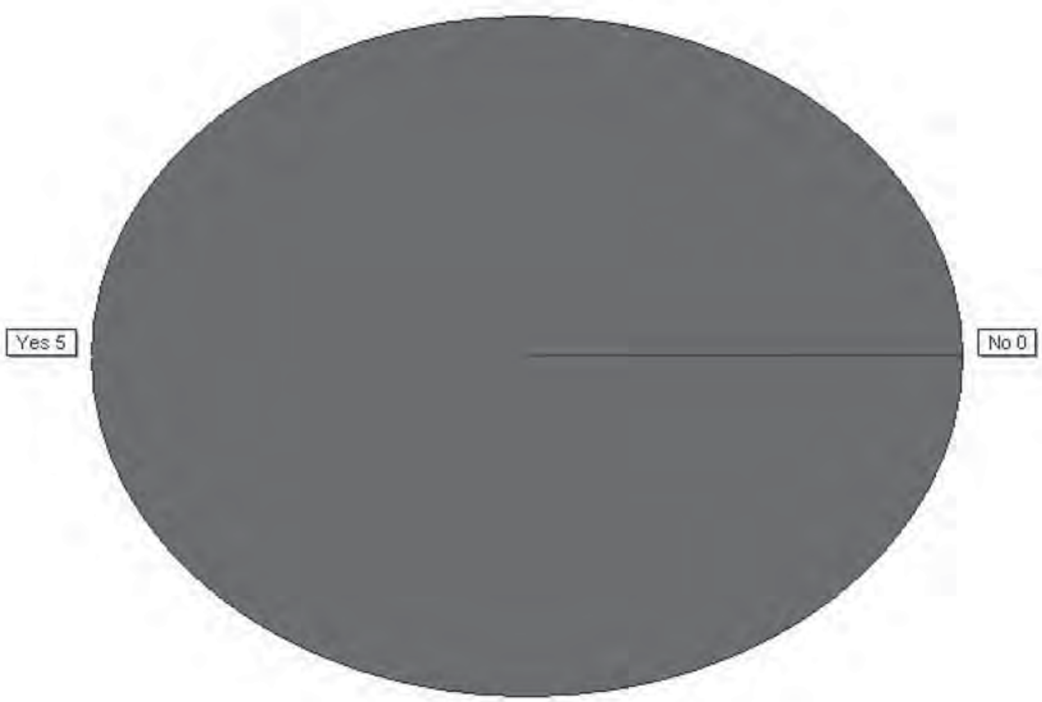
If routinely scheduled, specify typical interval (months):



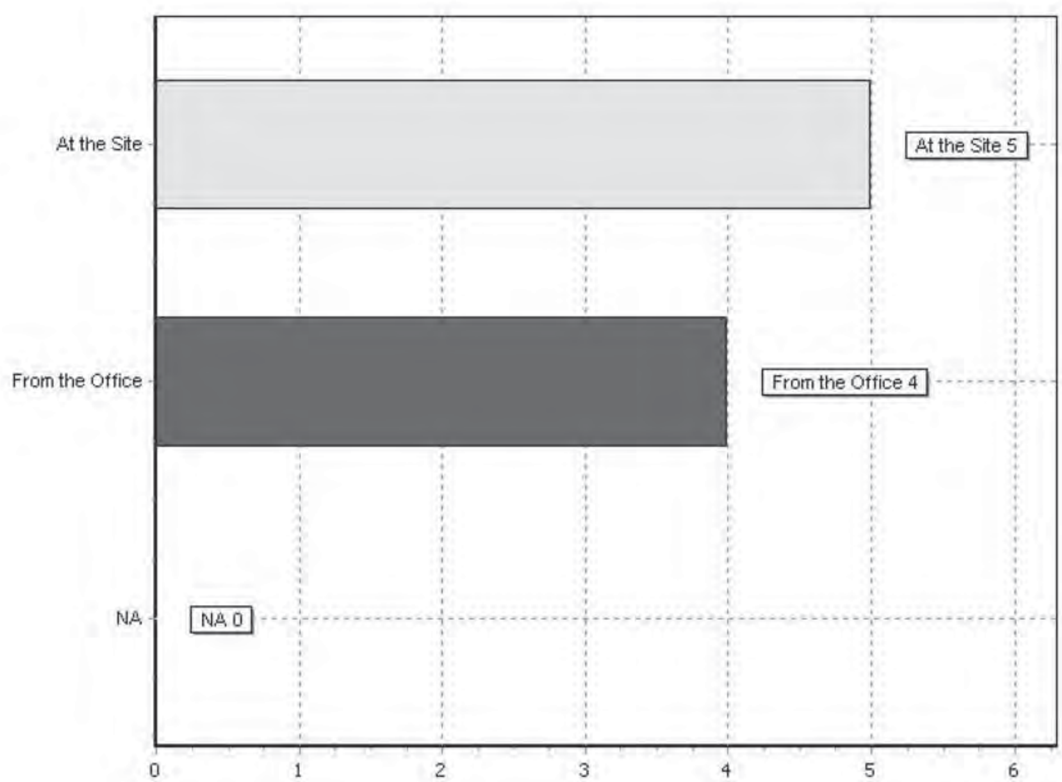
Additional comments:

MI: Sensor or equipment changes
VT: During Summer months on sites with solid installation in the road.

3.5.3 Do you have procedures for conducting diagnostic tests to ensure proper operation of the WIM system prior to committing to a complete on-site evaluation and/or calibration?



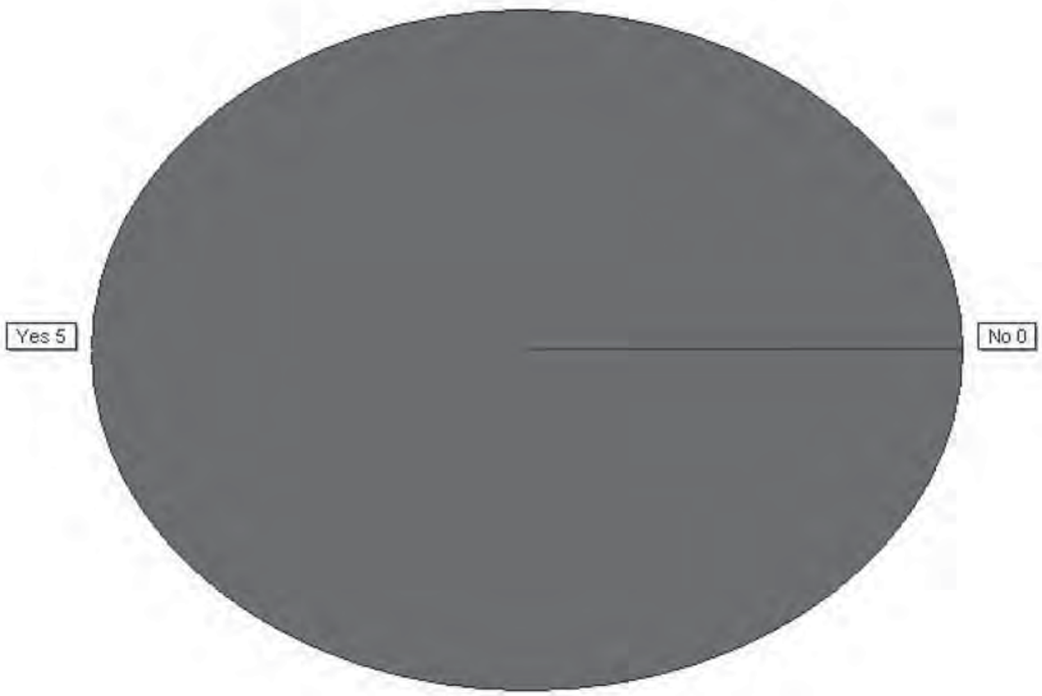
If Yes, how are these diagnostic tests conducted? Check all that apply.



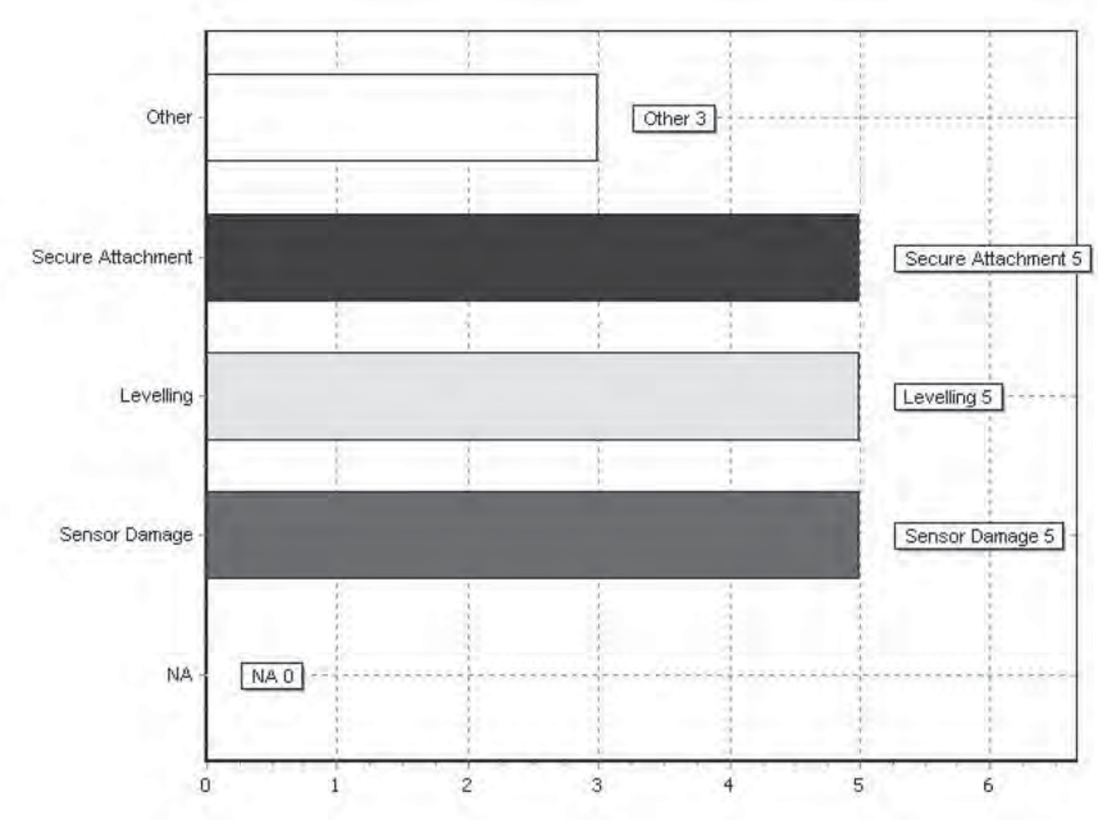
Other Responses:

Comment Responses:

3.5.4 Do you have procedures for inspecting the condition of the WIM sensors?



If Yes, on which of the following do you perform a visual inspection? Check all that apply.

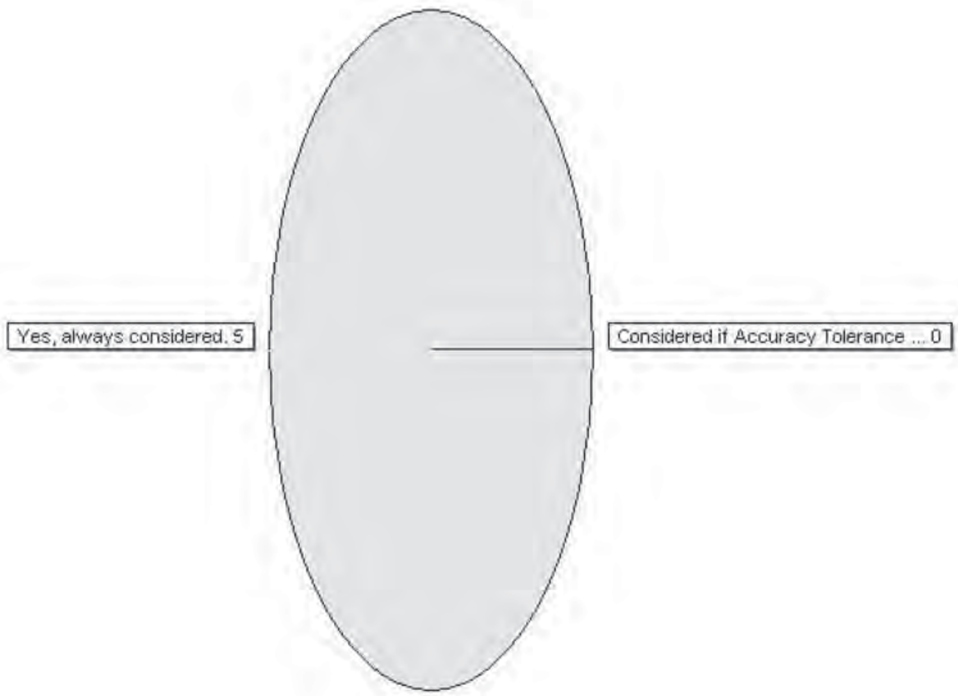


Other Responses:

NV: Electronic testing for capacitance and impedence
MI: Condition of surrounding pavement
VT: Oscilliscope testing

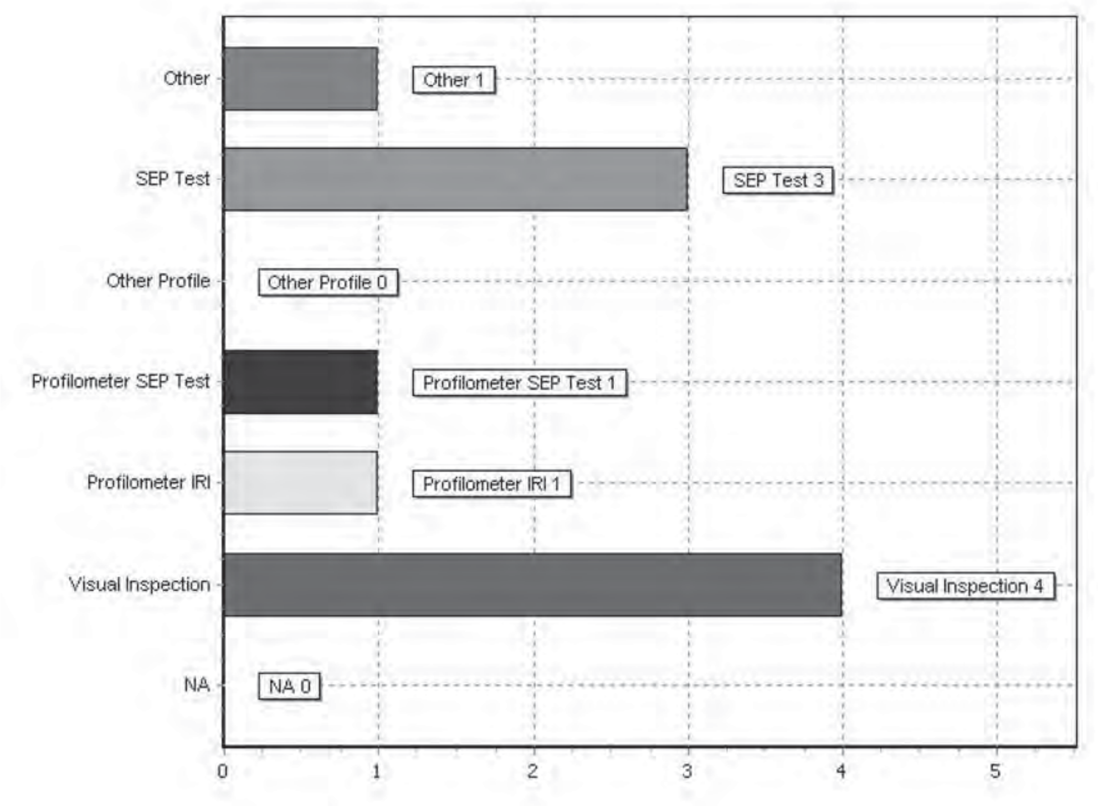
Comment Responses:

3.5.5 When conducting test-truck WIM calibrations, do you consider the pavement smoothness at the WIM site?



Comment Responses:

In cases where the pavement smoothness is considered which methods are used? Check all that apply.

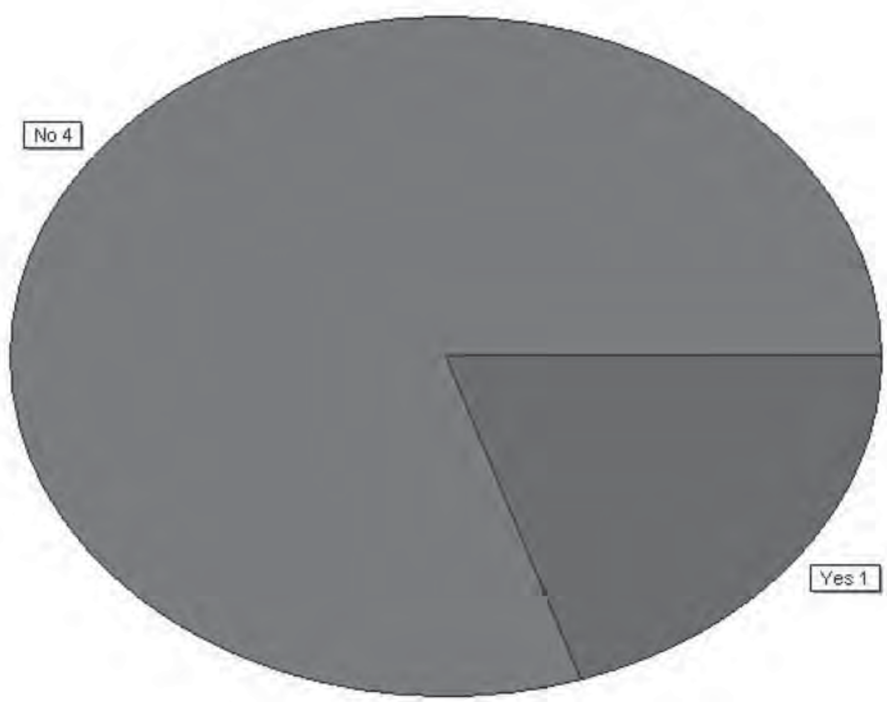


Other Responses:

MI: Watching for any truck bounce

Comment Responses:

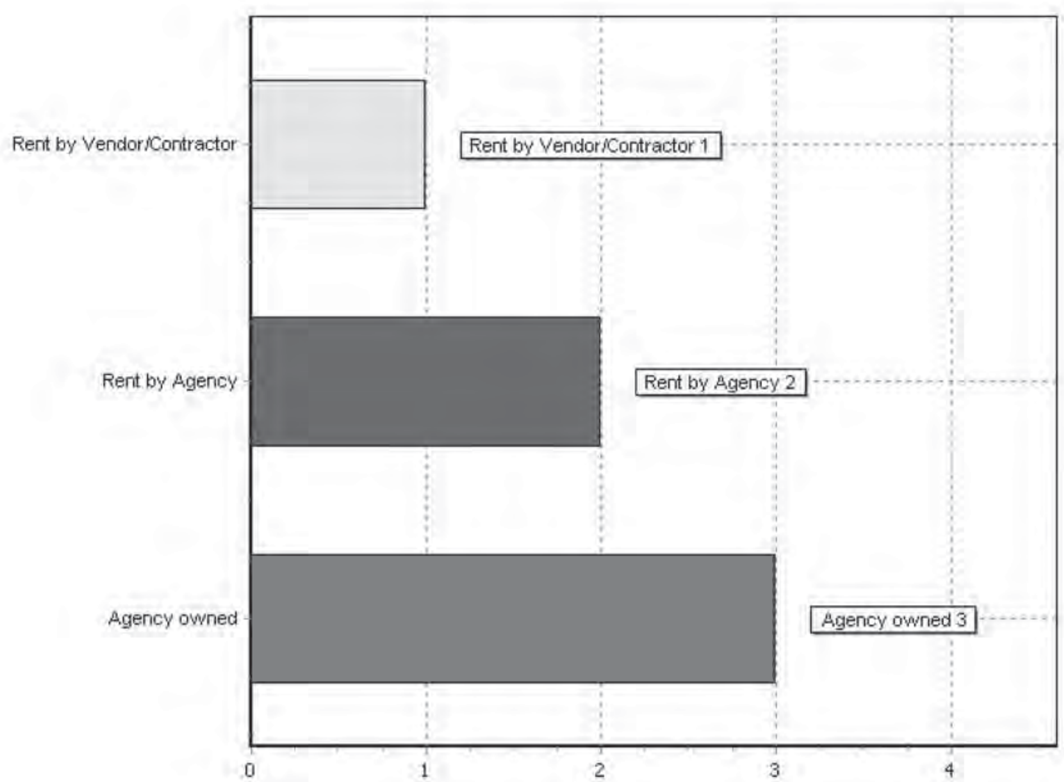
3.5.6 In conducting WIM calibrations with test trucks, do you consider the structural condition (deflection) of the pavement supporting the WIM sensors?



Comment Responses:

CA: Typically not since almost all of our sites are installed in PCC.
NV: Visual inspection

3.5.7 How are test trucks procured? Check all that apply.



Other Responses:

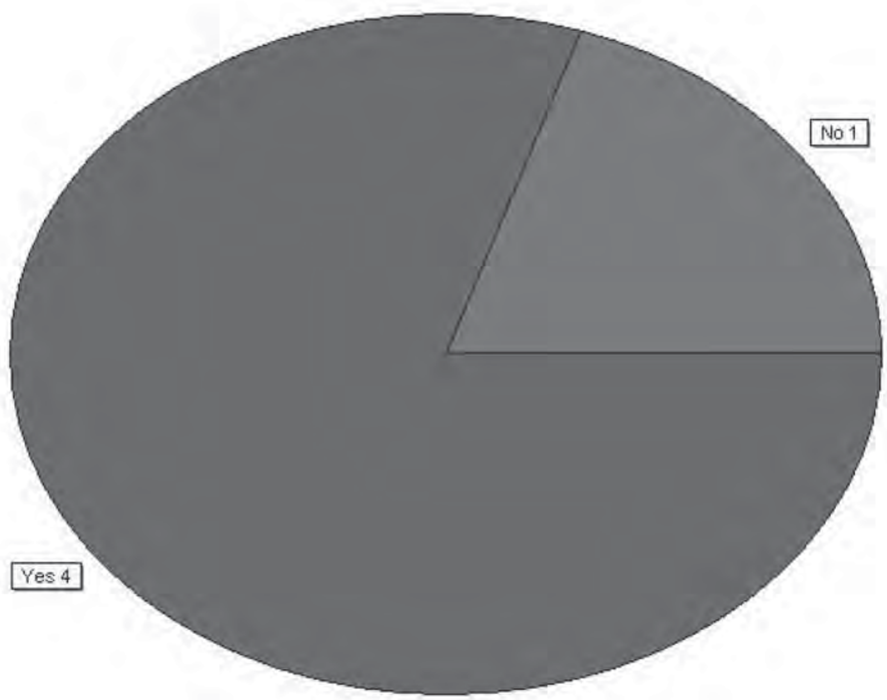
Comment Responses:

3.5.8 How many test trucks are used by class or type?

FHWA Class or Type	Number	FHWA Class or Type	Number	FHWA Class or Type	Number	FHWA Class or Type	Number	Additional comments (If more than 4 types are used please indicate the type(s) and number (s) here):
9	1							
type 9	1							
FHWA class 9	1							
9	1							
9	1							

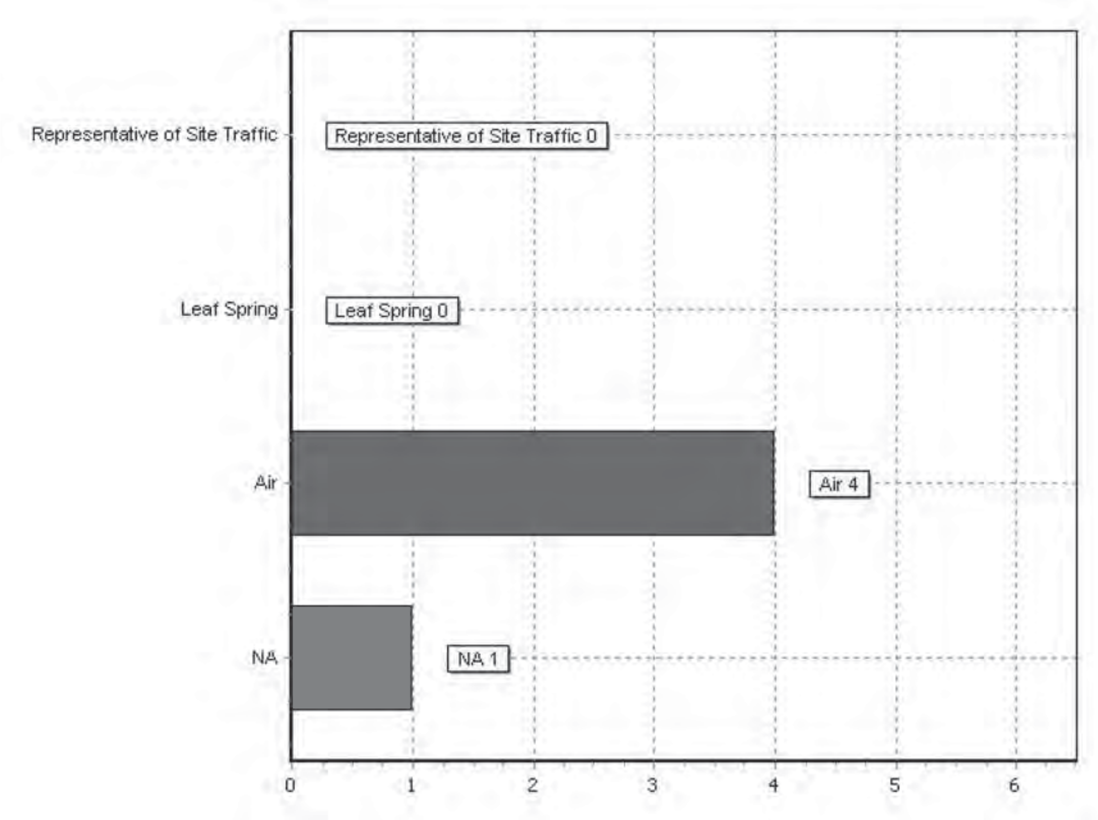
Additional comments (If more than 4 types are used please indicate the type(s) and number(s) here):(3.5.8 How many test trucks are used by class or type?)

3.5.9 Do you specify the suspension type of these test trucks?



Comment Responses:

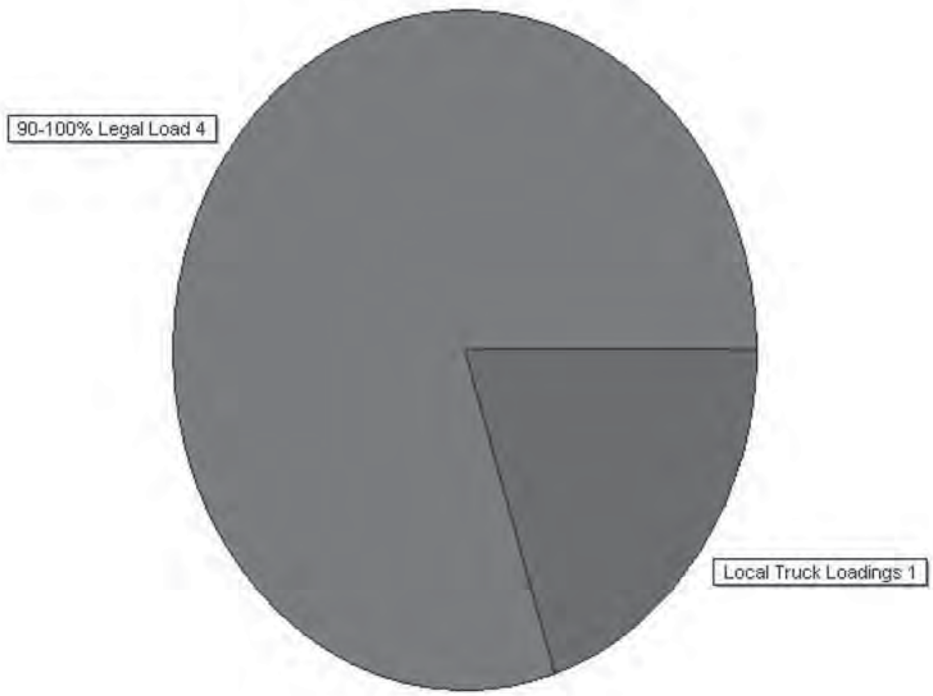
If Yes, which types are specified? Check all that apply.



Other Responses:

Comment Responses:

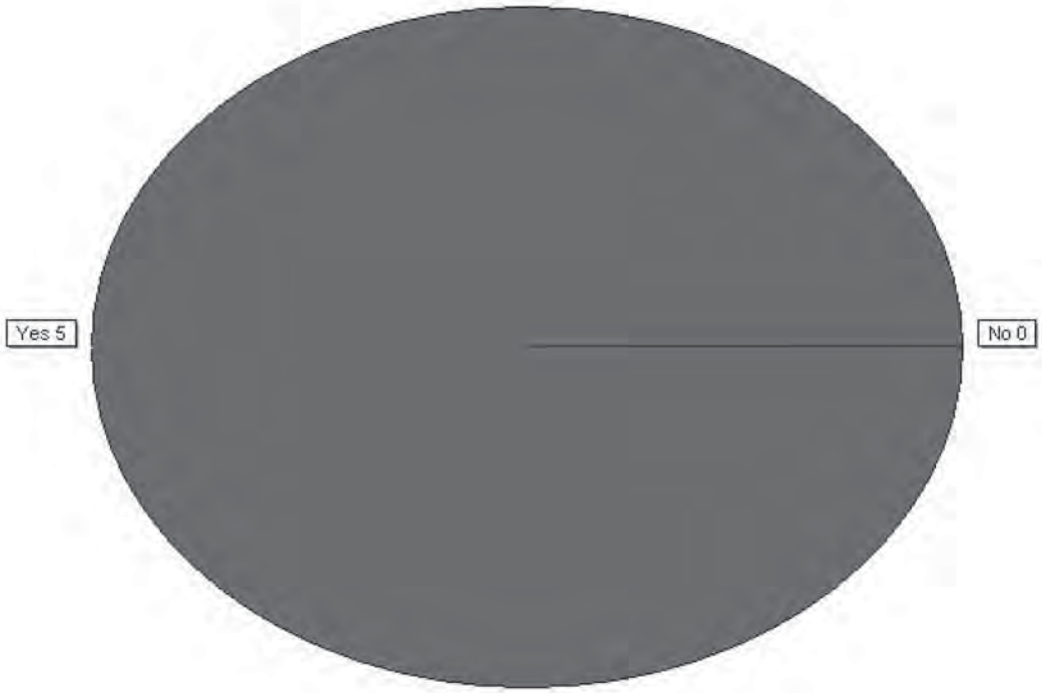
3.5.10 What is your test truck loading criteria?



Other Responses:

Comment Responses:

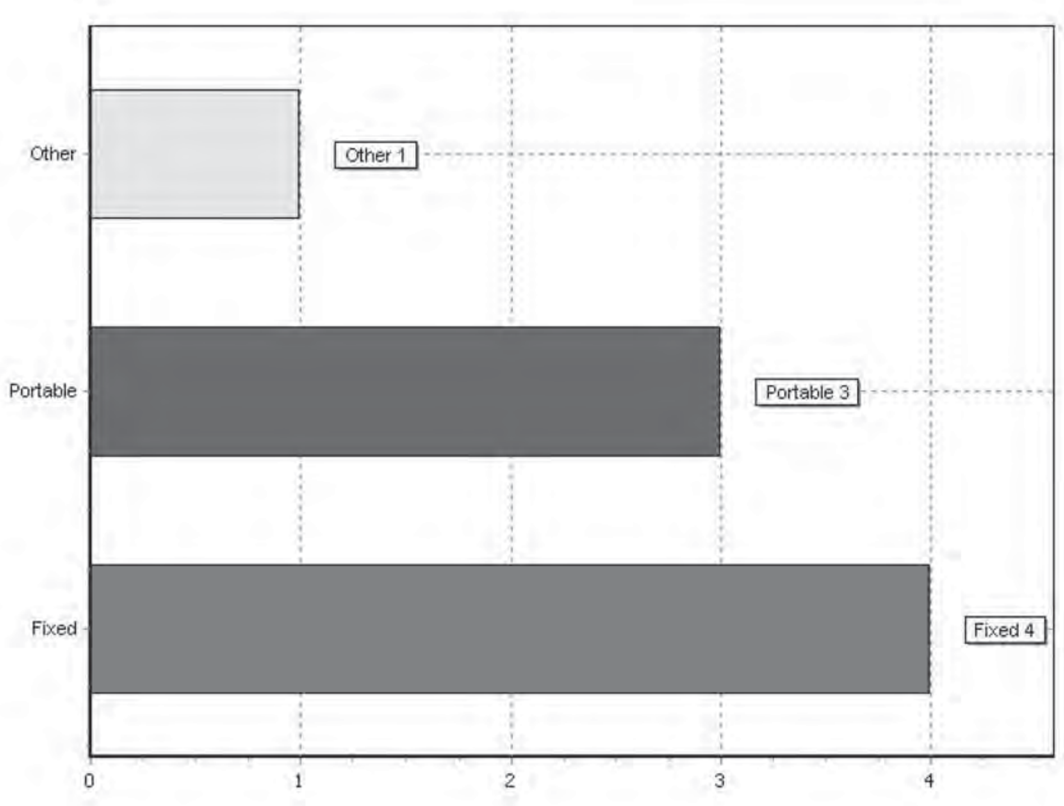
3.5.11 Please provide the following details on static weighing in conjunction with WIM calibration using test trucks. Do you require that static scales be certified?



Comment Responses:

ND: All permanent and portable static weigh stations/scales are certified

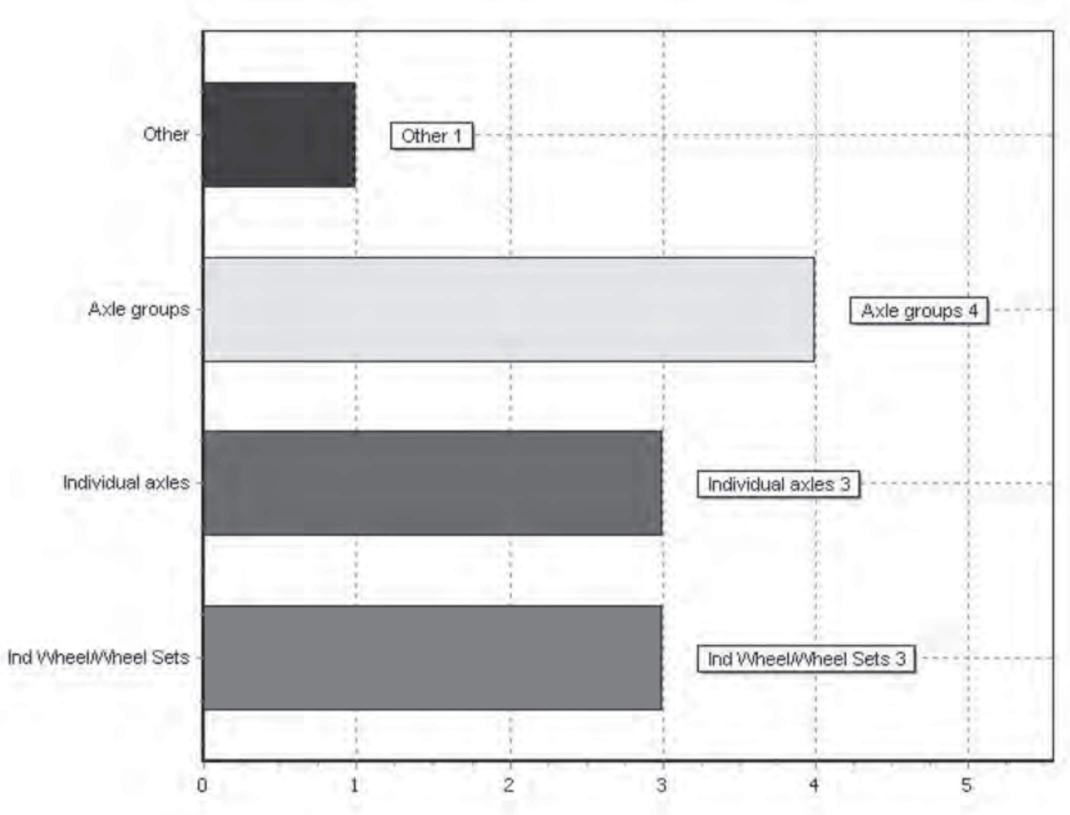
Which types of static scales do you use? Check all that apply.



Other Responses:

semi-portable platform scales

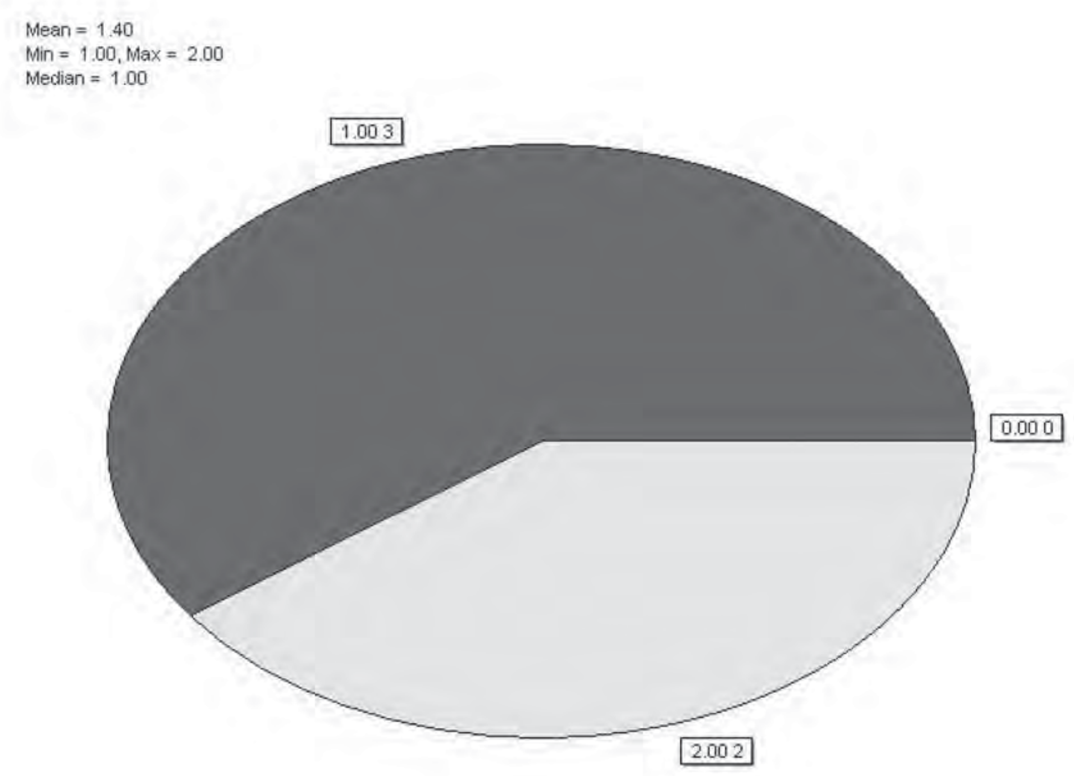
Which static weights are obtained? Check all that apply.



Other Responses:

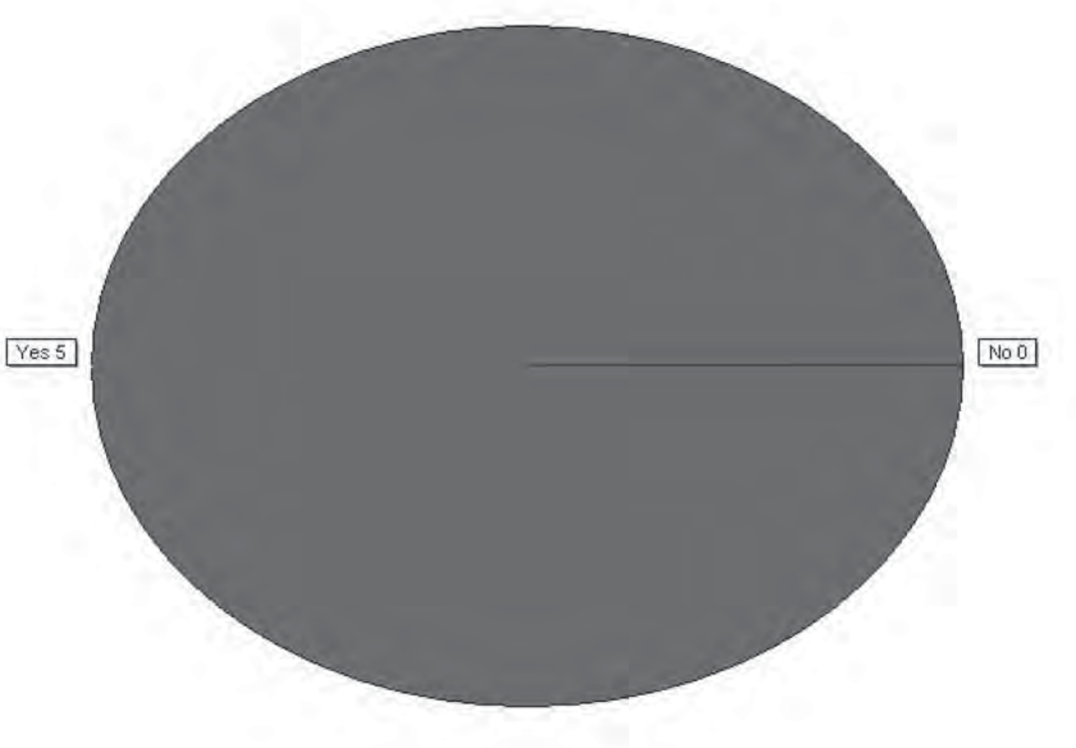
and GVW

How many times is each static weight measured?



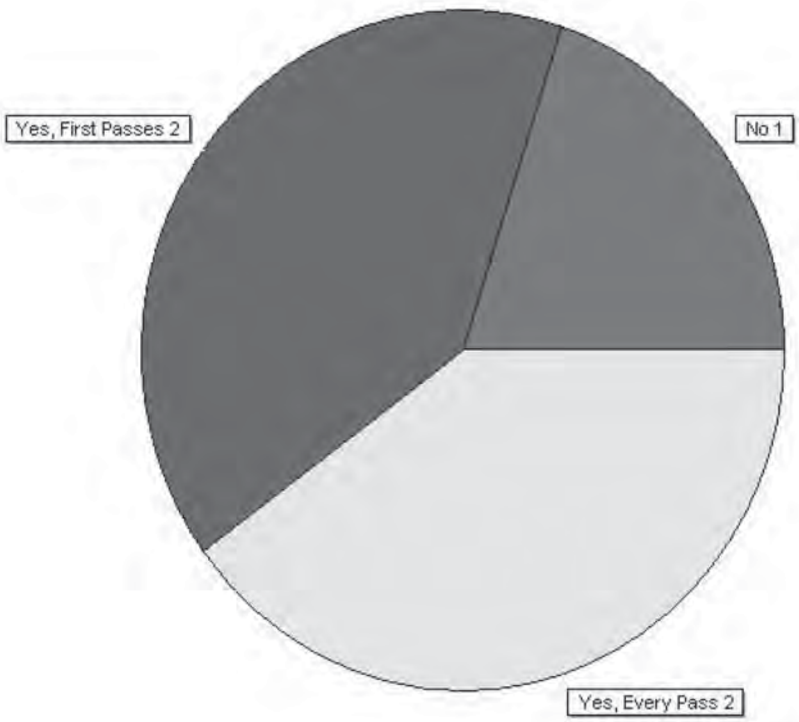
Additional comments regarding static weight practices:
ND: Once prior to each site calibration and upon refueling of truck
MI: We do 2 weights minimum. If there is any discrepancy between the 2 then we will do a 3rd and even a 4th. Some of the time our weights are done by the local Motor Carrier and then compared to the static permanent scales.

3.5.12 Are the axle spacings for each test truck measured?



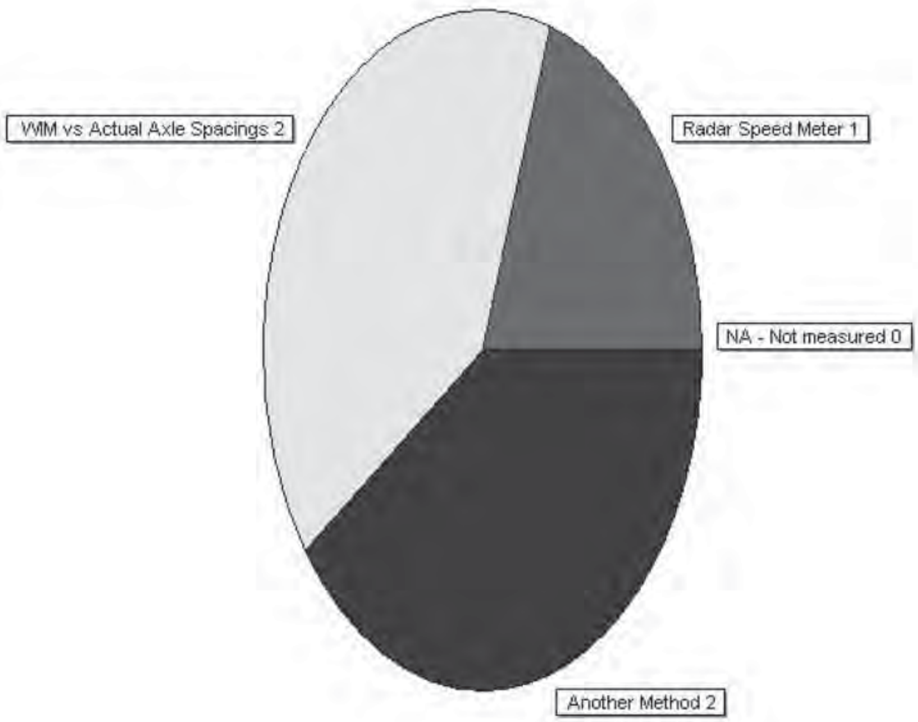
Comment Responses:

3.5.13 Are the test truck speeds measured as they cross the sensors?



Comment Responses:

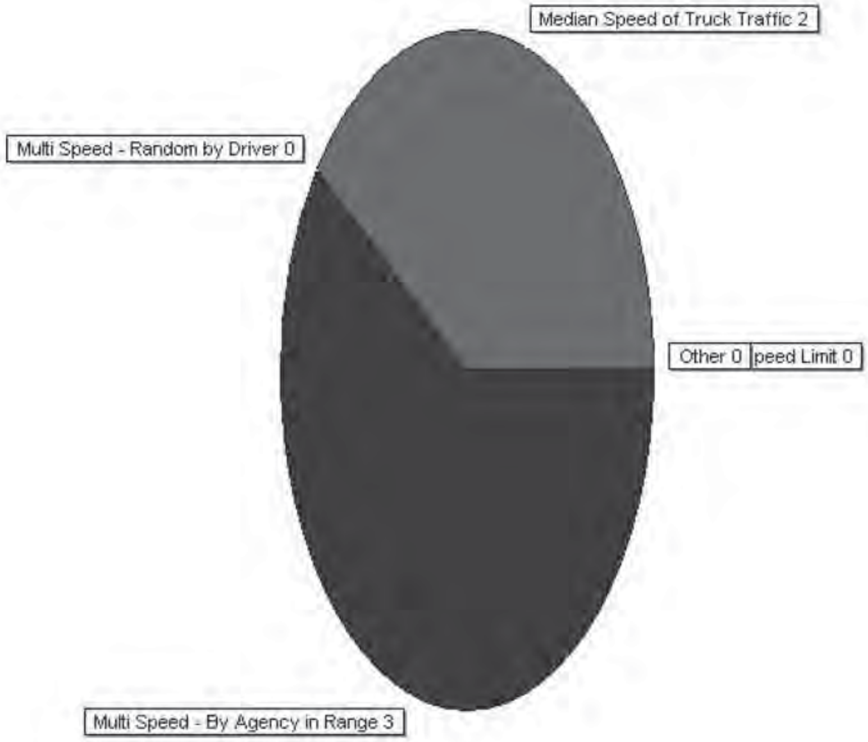
3.5.14 How is test truck speed measured?



Comment Responses:

MI: We use a laser speed gun and also by comparing WIM axle spacings to the measured axle spacings
VT: WIM readout

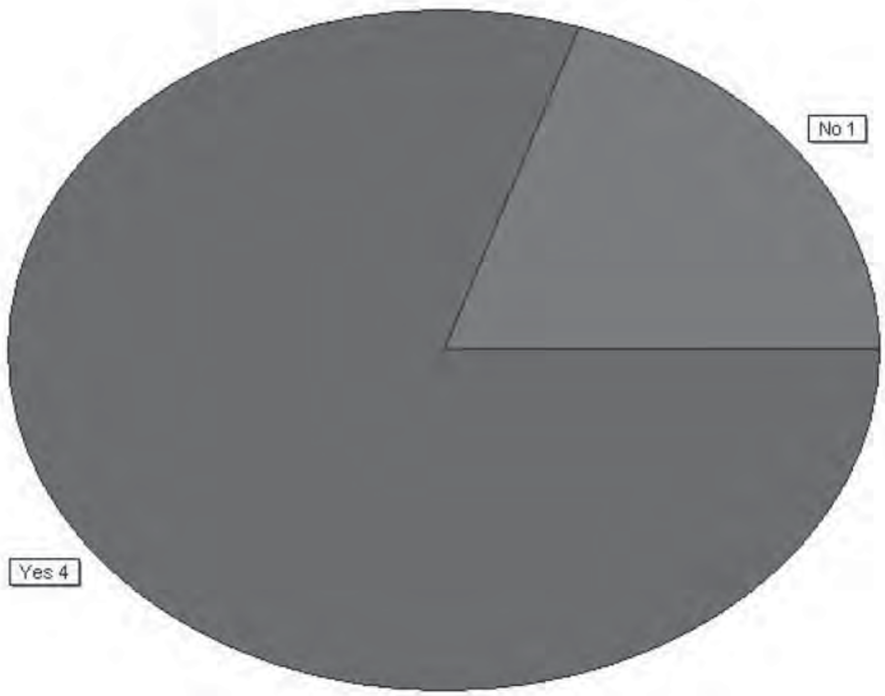
3.5.15 At what speeds do the test trucks run?



Comment Responses:

ND: posted speed limit, 5 or 10 mph above and below posted speed limit depending on type of roadway classification
MI: We run 3 speeds. The speed limit and 10 MPH above and below.

3.5.16 Is there a minimum number of test truck runs required at each speed?



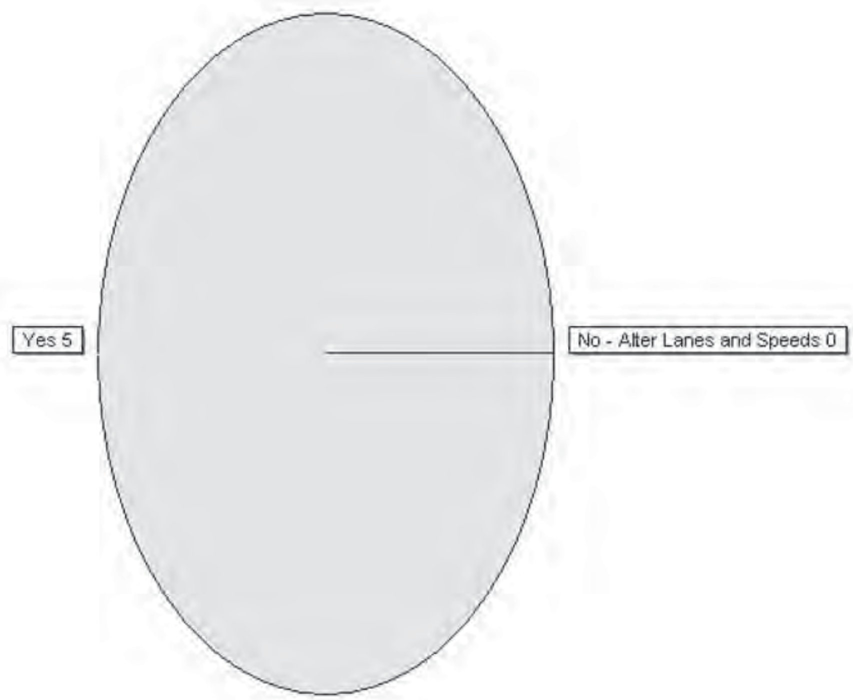
If Yes, please specify the minimum number of runs:

Number of runs for each speed.
2
20
3
3

Additional comments:

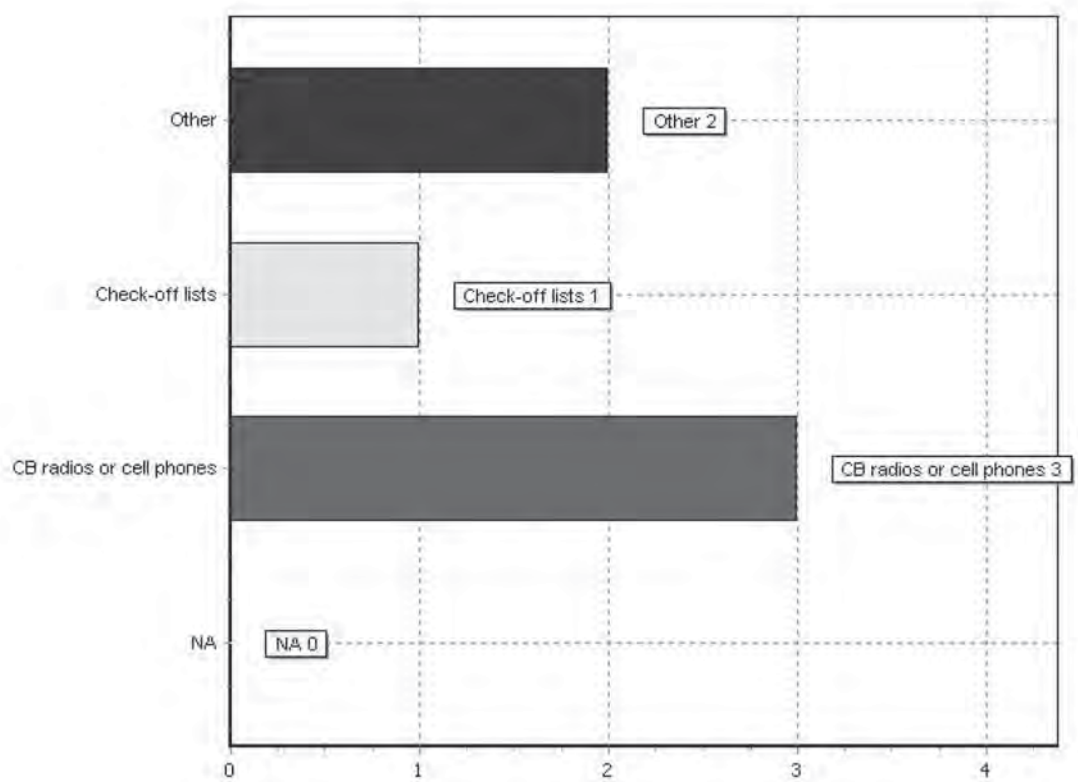
MI: 3 runs are done for an initial calibration then 3 runs minimum are done at each speed in the calibration stage and then also in the verification stage.

3.5.17 Are the test truck drivers given specific instructions as to the desired lane and speed for each run?



Additional comments:

If Yes, by what means are the instructionsgiven? Check all that apply.

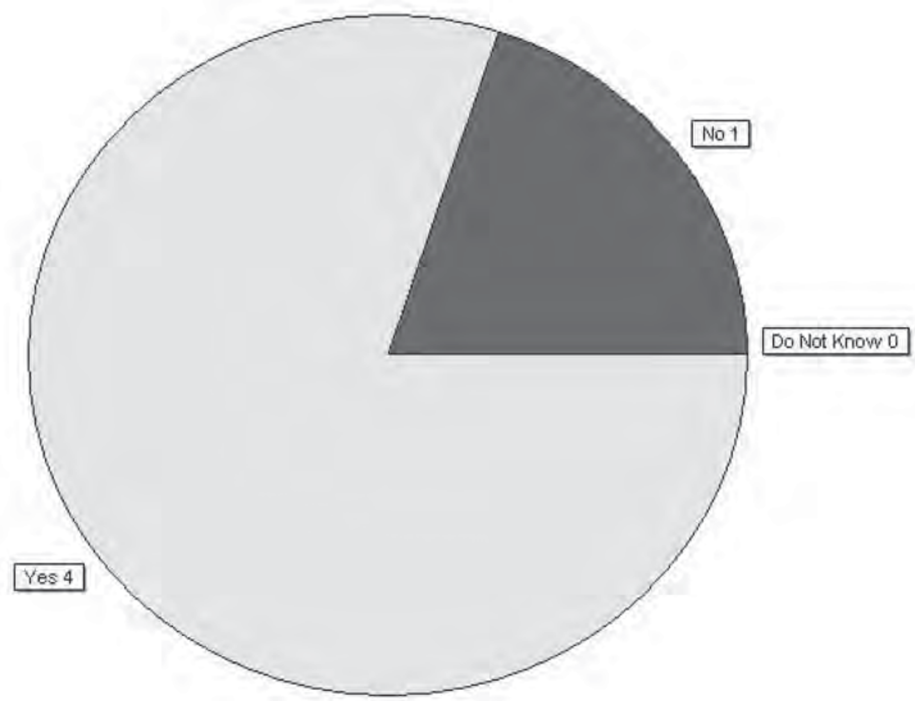


Other Responses:

ND: hand held 2-way radios or cell phone
VT: Verbal direction pre-test run

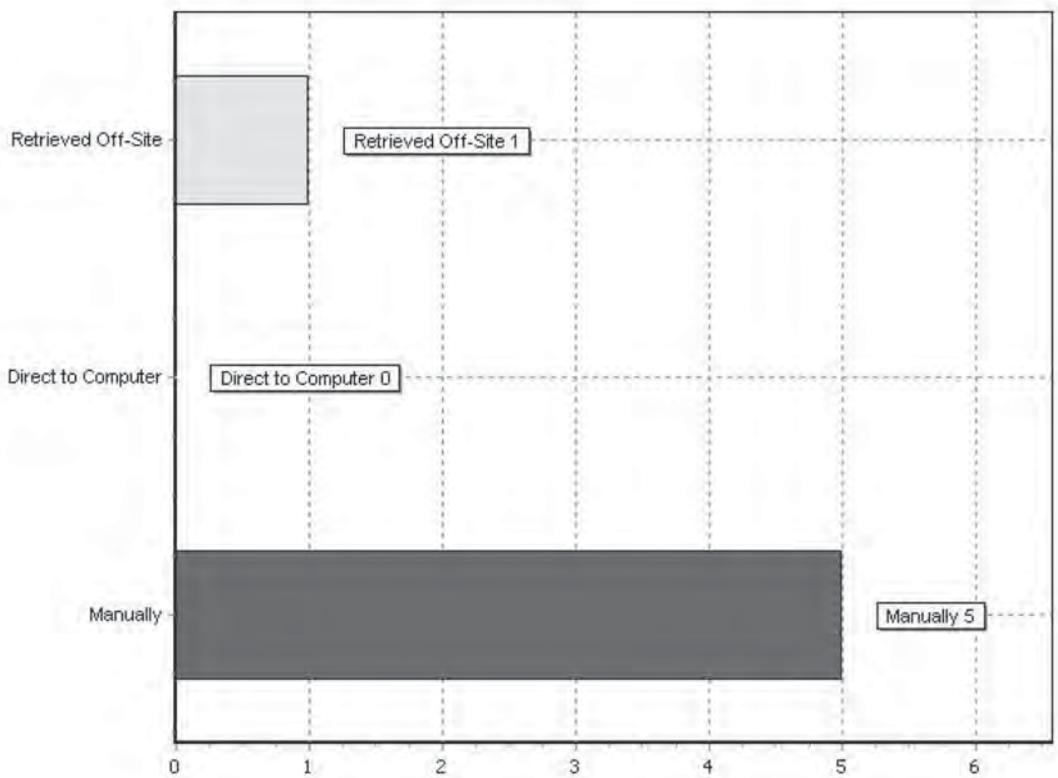
Comment Responses:

3.5.18 Is the system auto-calibration turned off during test truck runs?



Comment Responses:

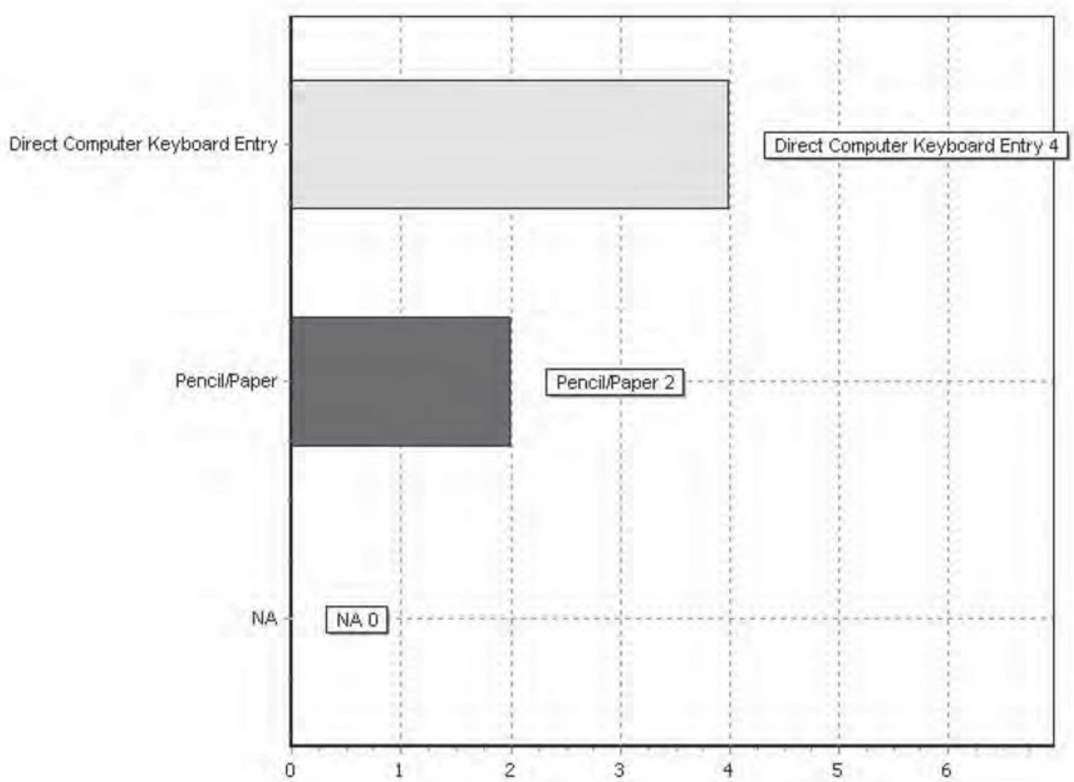
3.5.19 How is the test truck data being recorded during WIM calibration testing?



Other Responses:

Comment Responses:

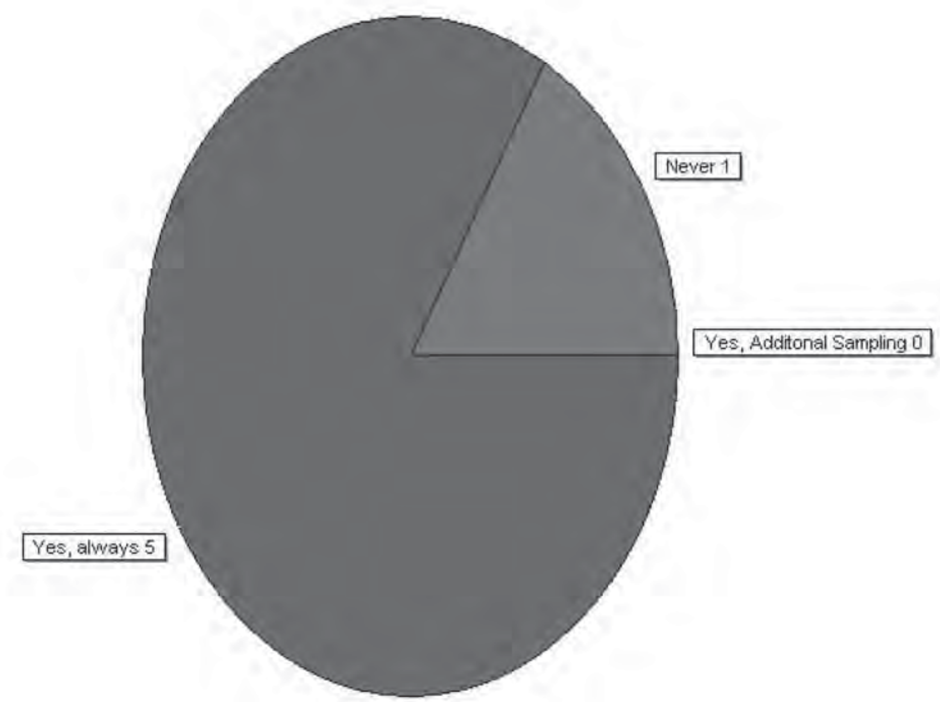
If test truck data is manually recorded, what method is used?



<u>Other Responses</u>:

<u>Comment Responses</u>:

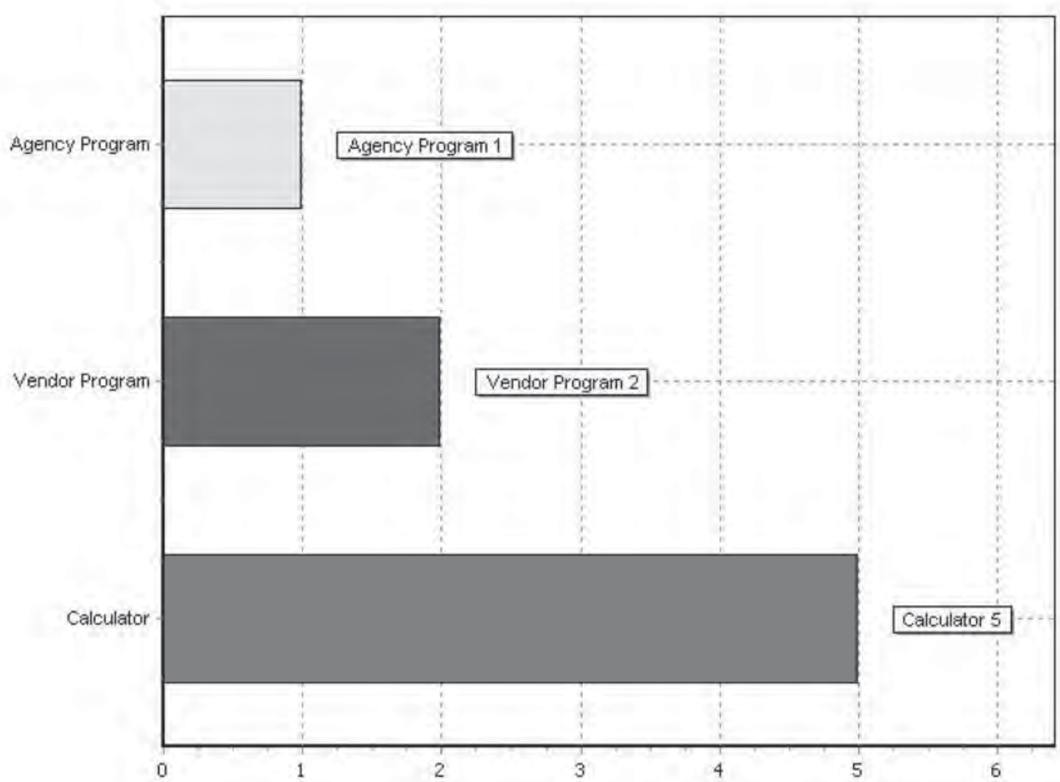
3.5.20 When performing on-site calibration using test trucks are the WIM error computations performed on-site?



Comment Responses:

Multiple WIM vendors are used, so the response is for the PEEK ADR units.

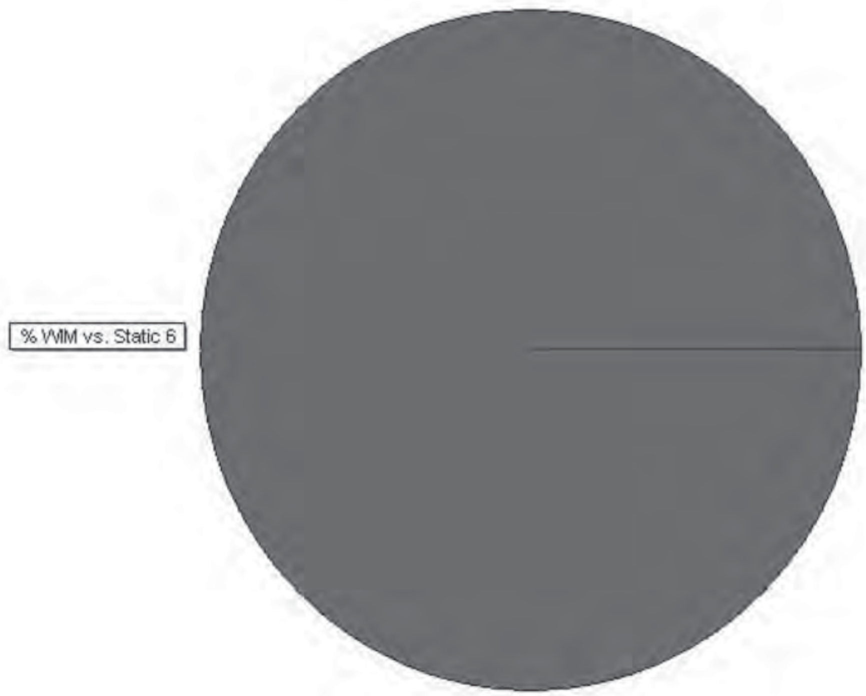
3.5.21 During on-site calibration using test trucks how are the WIM error computations carried out?



Other Responses:

Comment Responses:

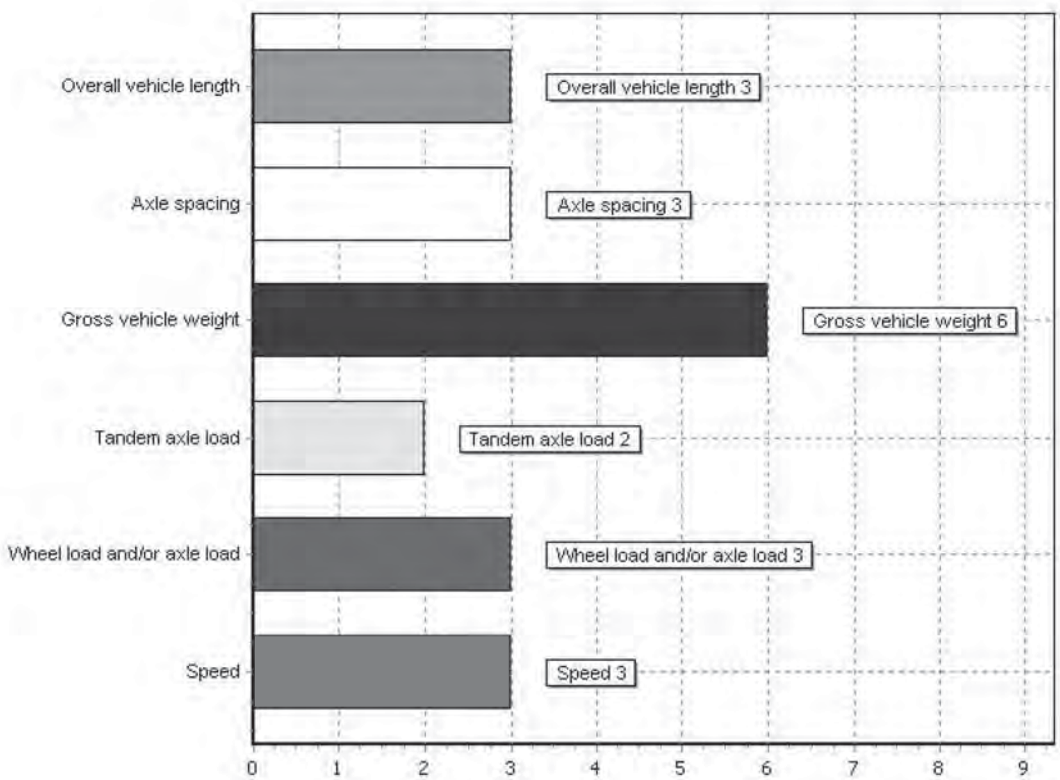
3.5.22 During on-site calibration using test trucks what error formula is used?



Other Responses:

Comment Responses:

3.5.23 For which of the following measurements are WIM errors computed during on-site calibration using test trucks? Check all that apply.

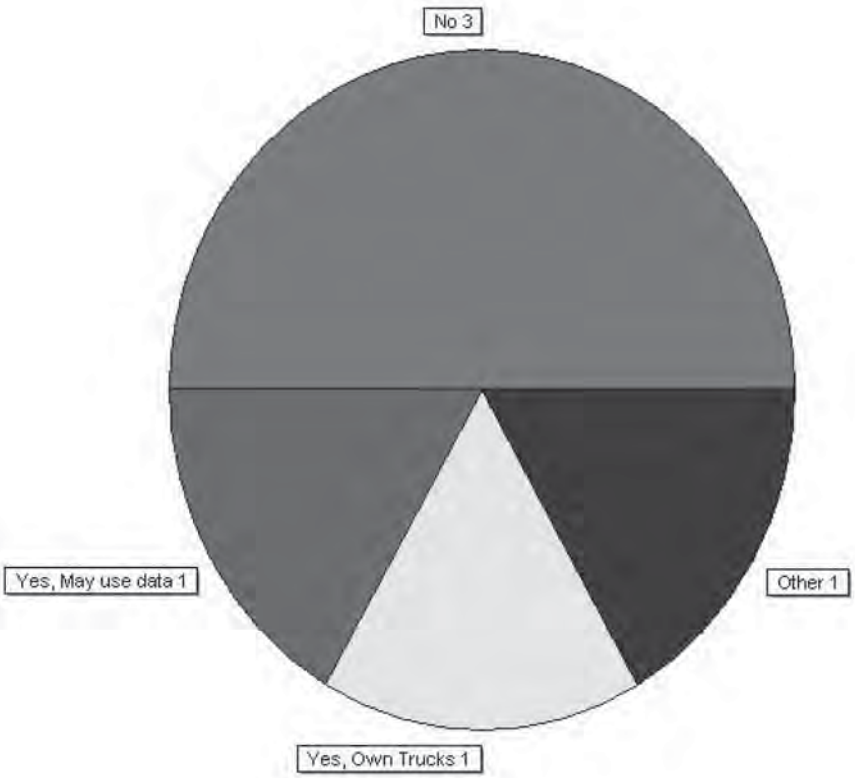


Other Responses:

speed, wheel load and /or axle load, tandem axle load, axle spacing, overall vehicle length are all monitored and compared to static measurements

Comment Responses:

3.5.24 Are test trucks ever run for the sole purpose of determining WIM system accuracy tolerance pass/fail (e.g. new site acceptance, warranty, etc.)?

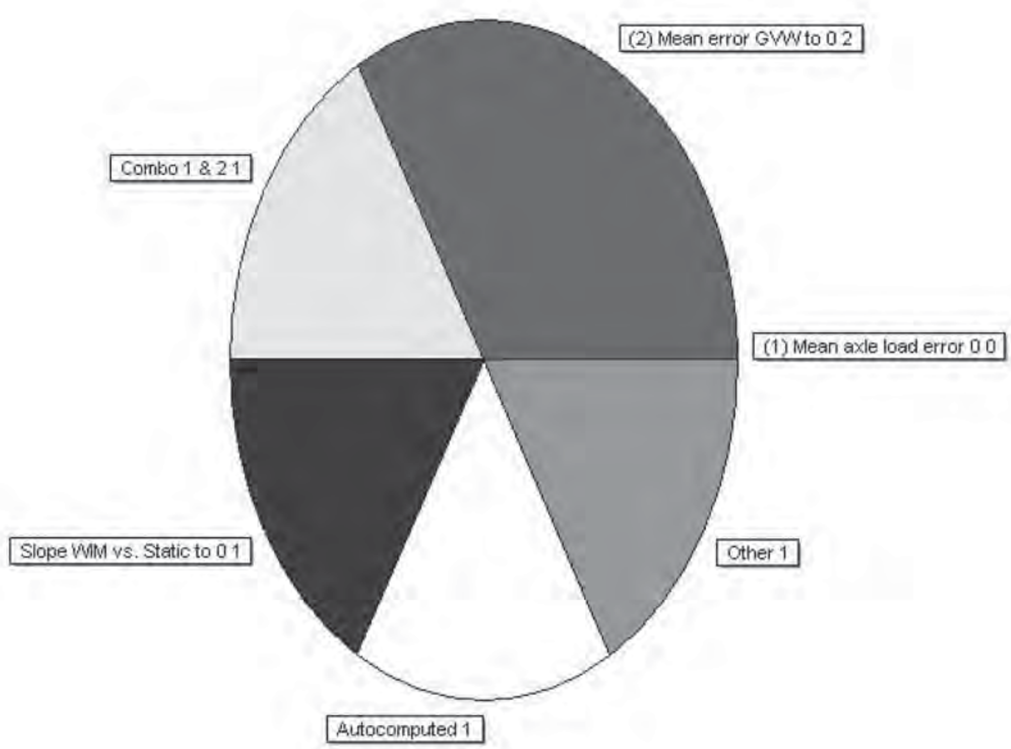


Other Responses:

LTPP method

Comment Responses:

3.5.25 During on-site calibration using test trucks, what method is used to compute the calibration factors?

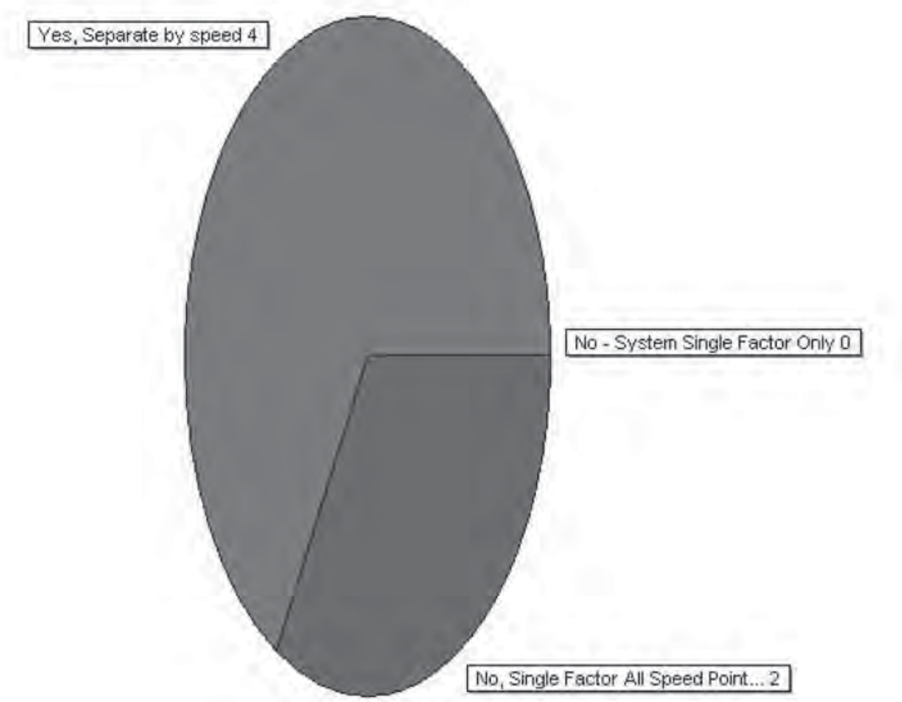


Other Responses:

VT: We use the same factor for each weight group

Comment Responses:

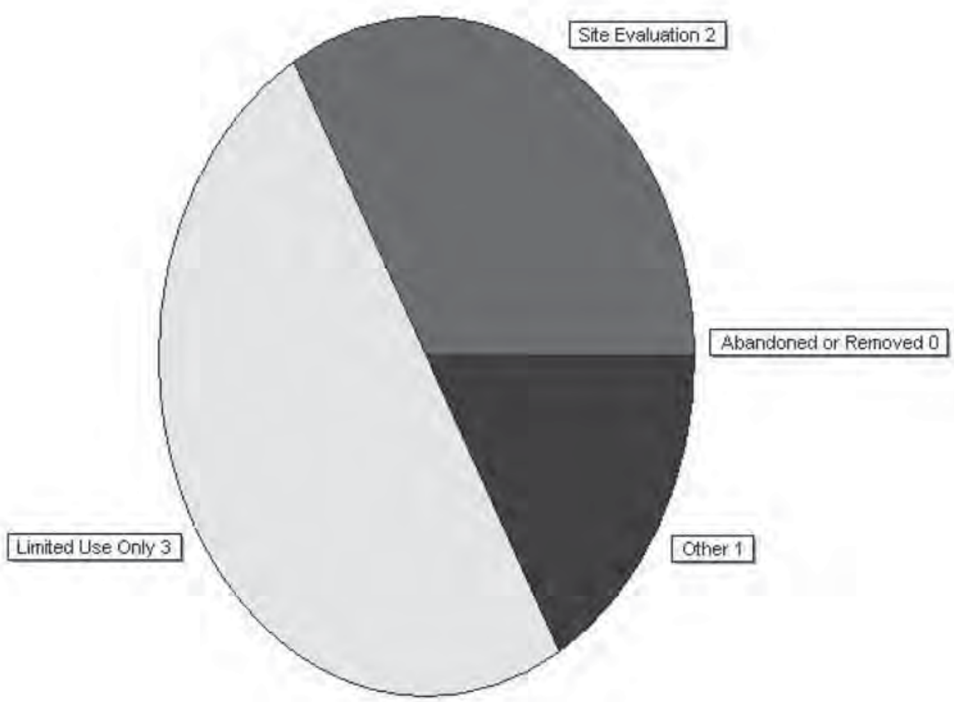
3.5.26 During on-site evaluation using test trucks do you compute calibration factors for two or more speed points?



Other Responses:

Comment Responses:

3.5.27 What remedial action is taken for WIM systems that fail to meet accuracy tolerances during test truck testing?

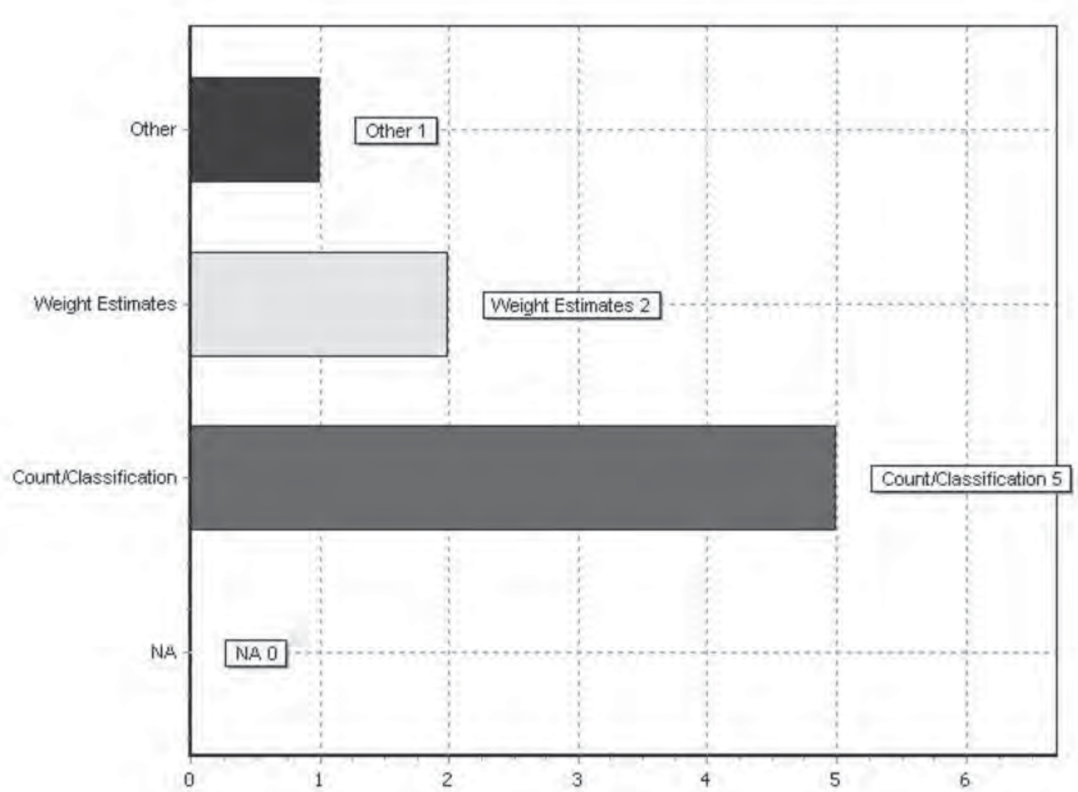


Other Responses:

NDDOT is early in its WIM program development and we have not had this situation occur to date

Comment Responses:

What is the use of the data being generated by WIM systems that fail to meet accuracy tolerances?

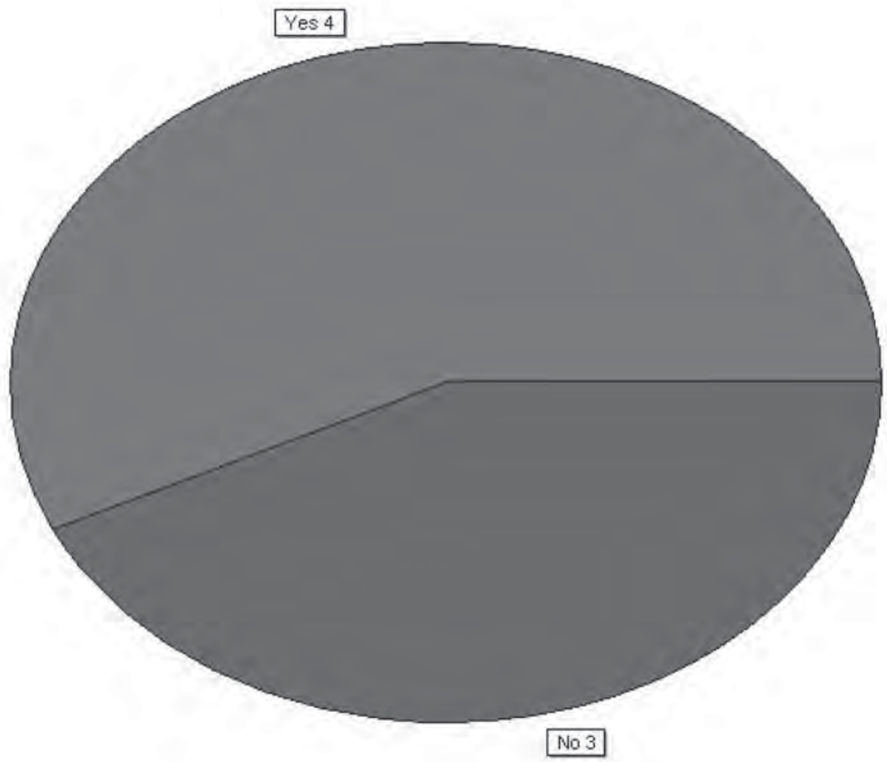


Other Responses:

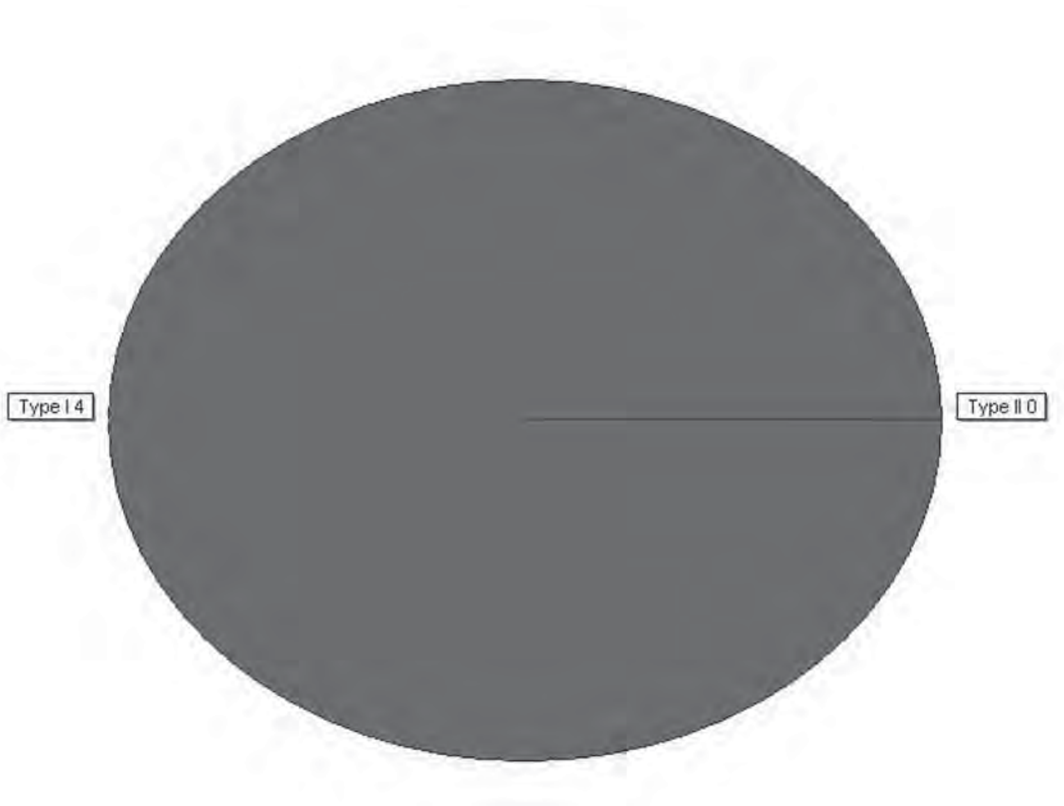
ND: Haven't had to make this determination yet

Comment Responses:

3.6 WIM On-Site Evaluation/Calibration Using Traffic Stream Trucks of Known Weight NOTE: In this section we are referring to on-site evaluation/calibration by sampling trucks from the traffic stream for which you are able to obtain static weights. Do you perform on-site evaluation/calibration using traffic stream trucks of known weights?

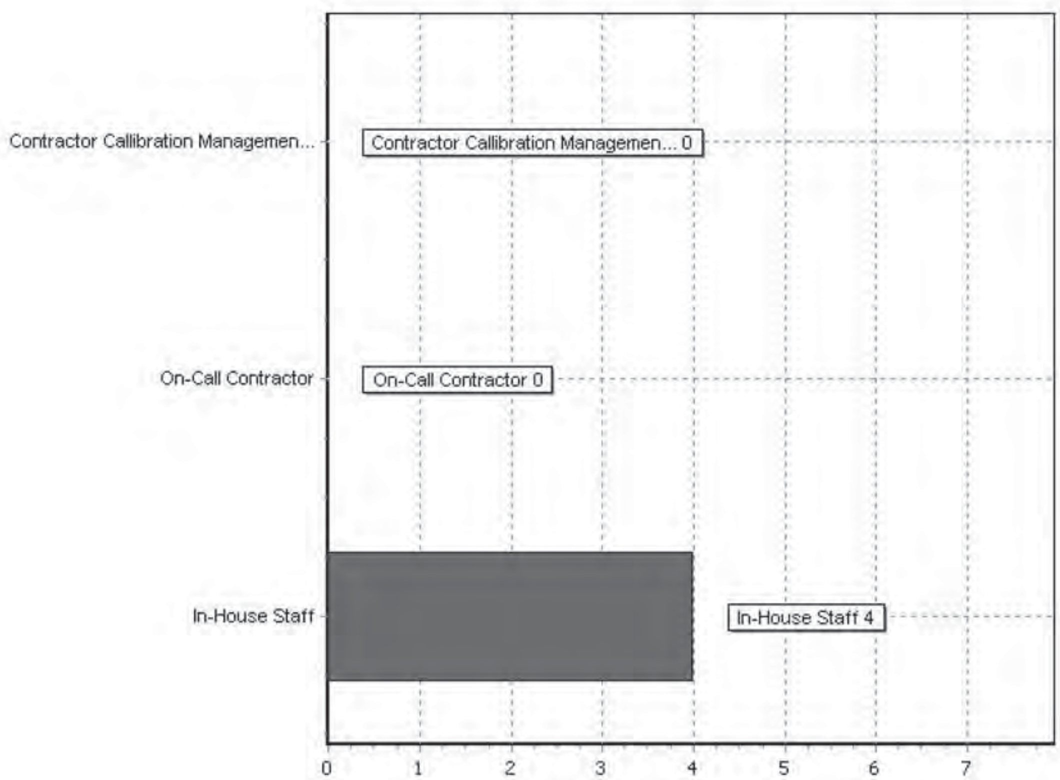


In the series of questions under 3.6 please describe the procedure you use for the MOST COMMON WIM type in your unit (department/division/agency). What is the most common WIM type in your unit for which traffic stream trucks of known weight are used for calibration?



Other Responses:

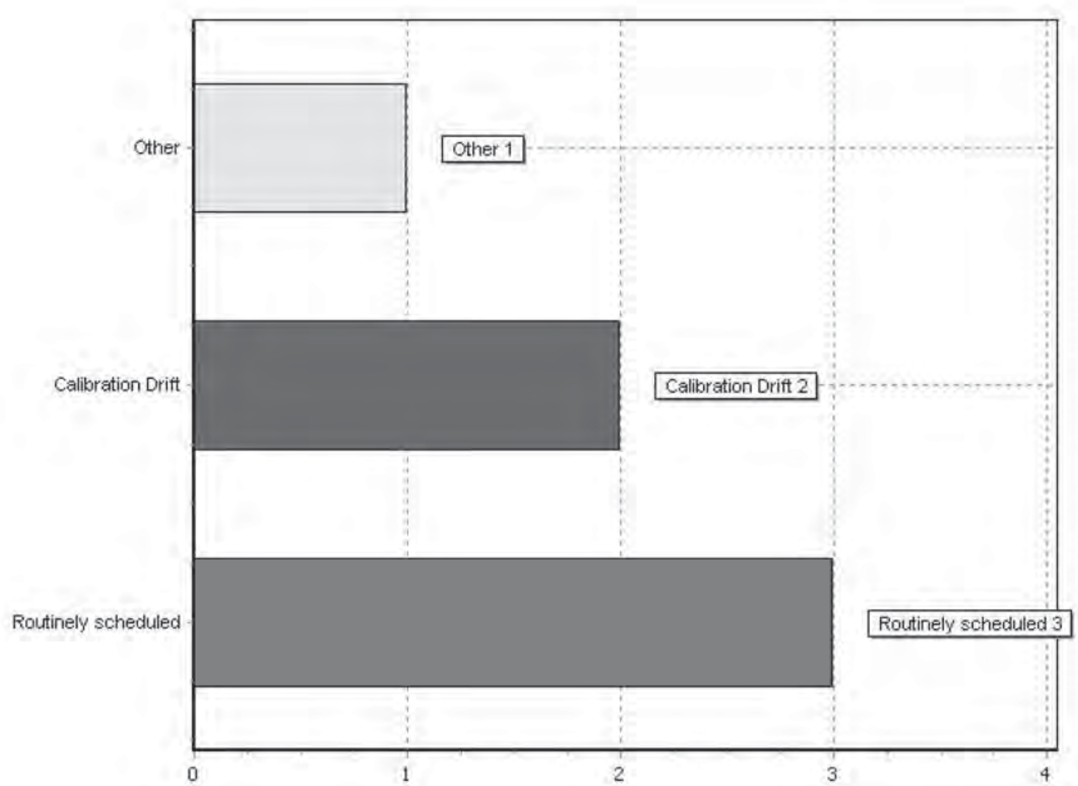
3.6.1 Who conducts these on-site evaluation/calibration activities using traffic stream trucks of known weight? Check all that apply.



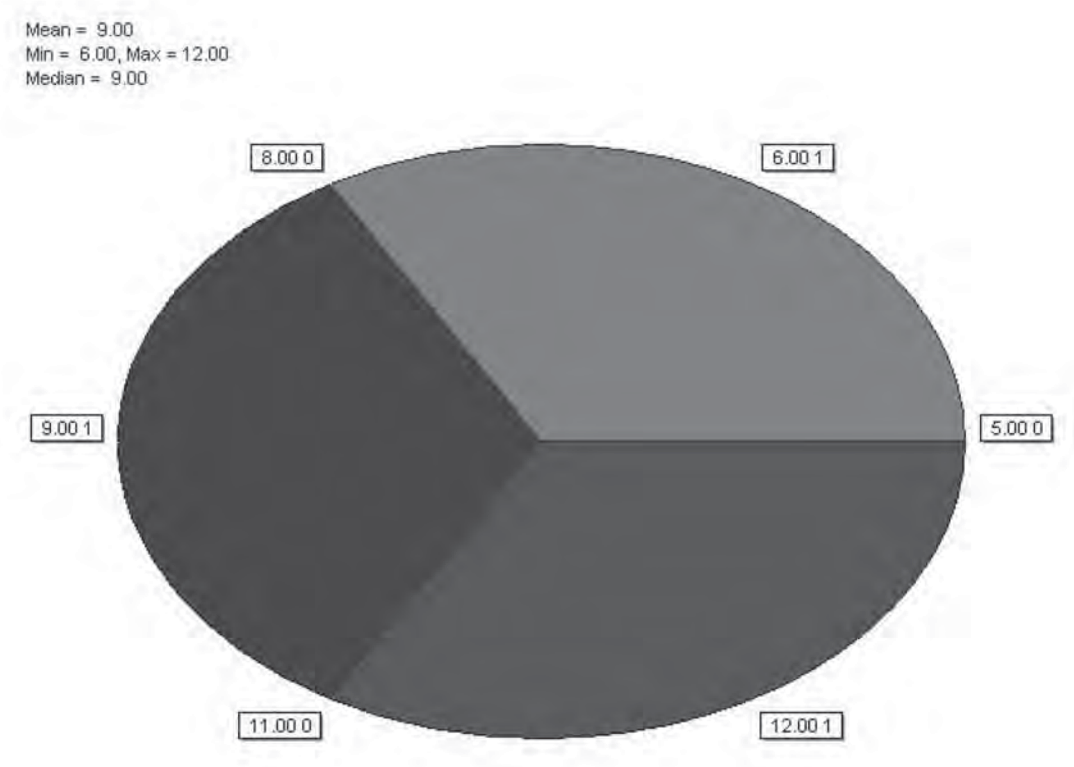
Additional Comments:

MI: We do this with the help of Motor Carrier. They stop and weight trucks from the traffic stream and we then use those numbers to calibrate. It's rare we use this system any more.

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions. 3.6.2 What is the criterion you use to initiate WIM calibration using traffic stream trucks of known weight? Check all that apply.



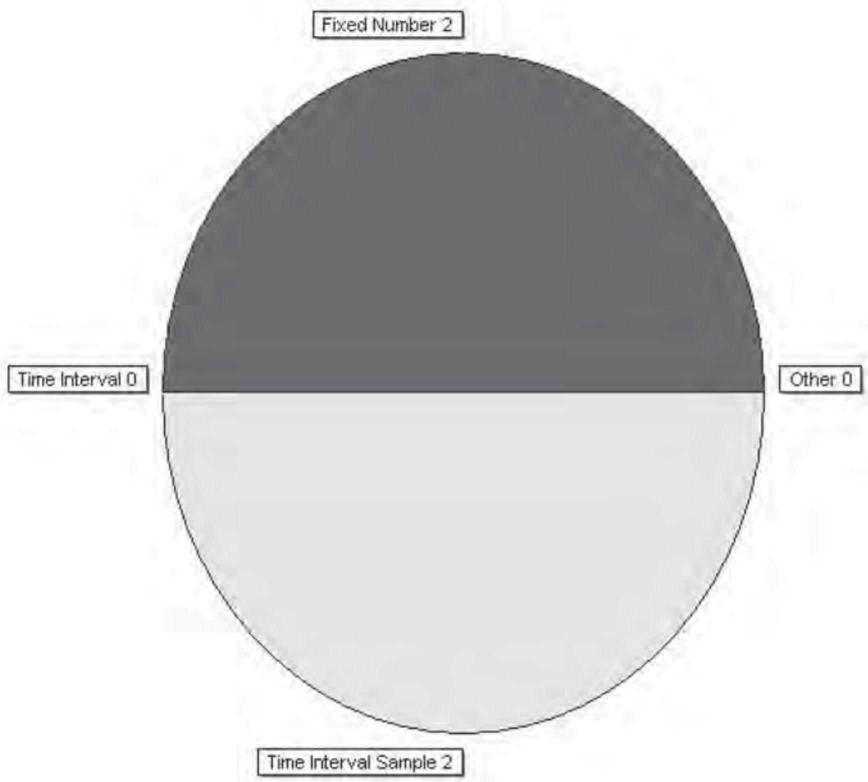
If routinely scheduled, specify typical interval (months):



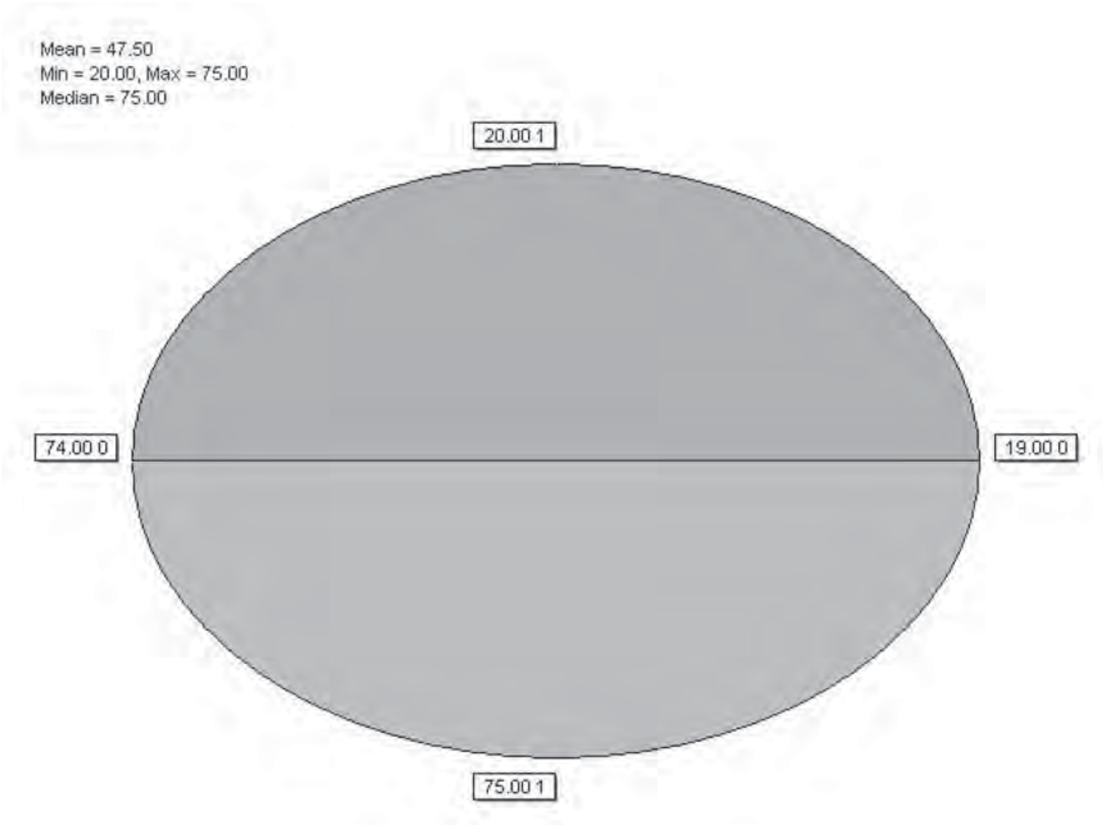
Additional comments:

CA: Typically 6 month intervals are optimal, but lack of time and personnel forces some delays.
NV: We schedule a verification of calibration factors on an annual basis. As we monitor the performance of the WIM system throughout the year a determination is made if the system has demonstrated calibration drift. If the system has not demonstrated any drift the calibration may be postponed until the following year. This determination is made with available resources in mind, which are always at a premium.
MI: This is done more at the wants/needs of Motor Carrier.

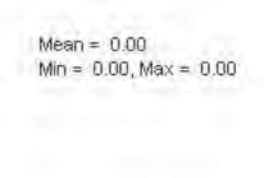
3.6.3 How do you select the number of traffic stream trucks of known weight to be included in the sample?



If a fixed number of trucks are selected, specify the number.



If all of the trucks in a given time interval are selected, specify the time interval (in hours).



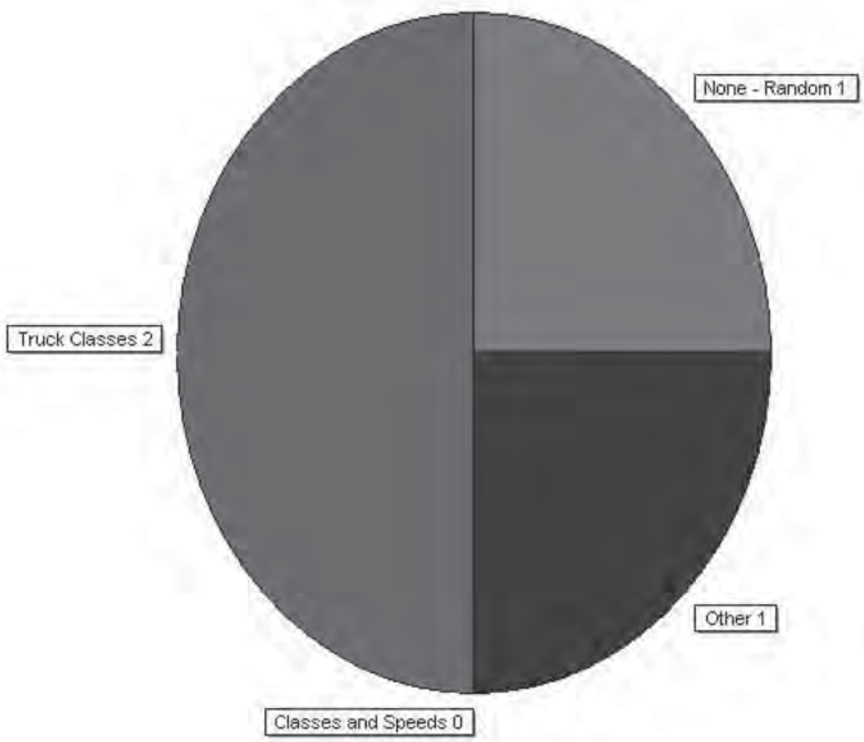
If some of the trucks in a given time interval are selected, specify the number and interval:

Number of Trucks	Time Interval (in hours)
20	

Additional comments:

MI: It varies with what Motor Carrier is able to weigh. Generally it will be at least 20 trucks
OR: Initial calibration uses a 50-truck sample. Follow-up calibration (6-month intervals) uses a 20-truck sample

3.6.4 What are the criteria used for selecting the type of traffic stream trucks of known weight to include in the sample?



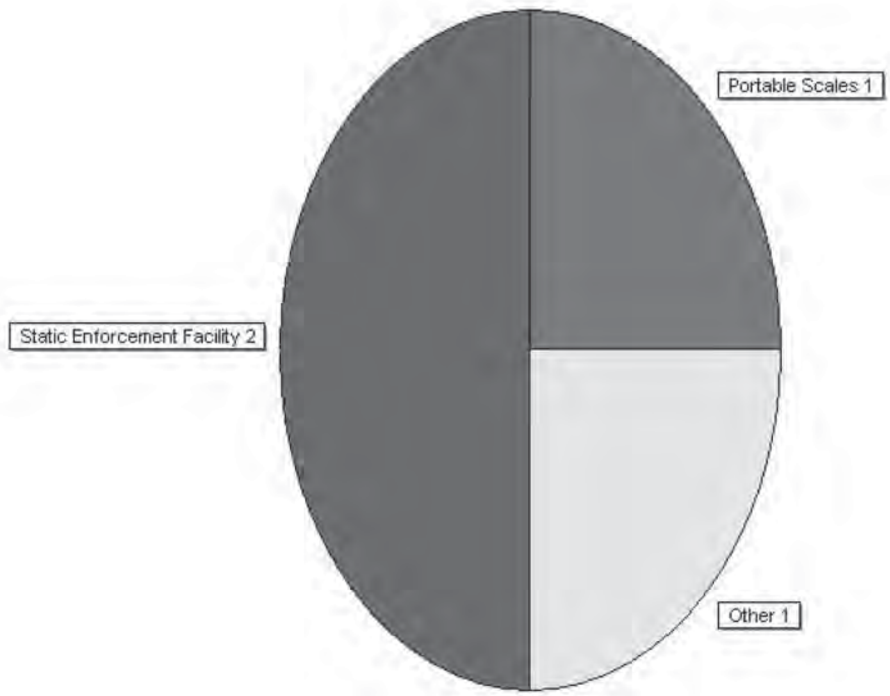
Other Responses:

MI: It's usually trucks that are suspected of being near or over weight. Or that might have some other sort of violation.

Comment Responses:

CA: Typically class 9 trucks.
NV: 332000 type 9.

3.6.5 How is the static weight of these traffic stream trucks obtained?

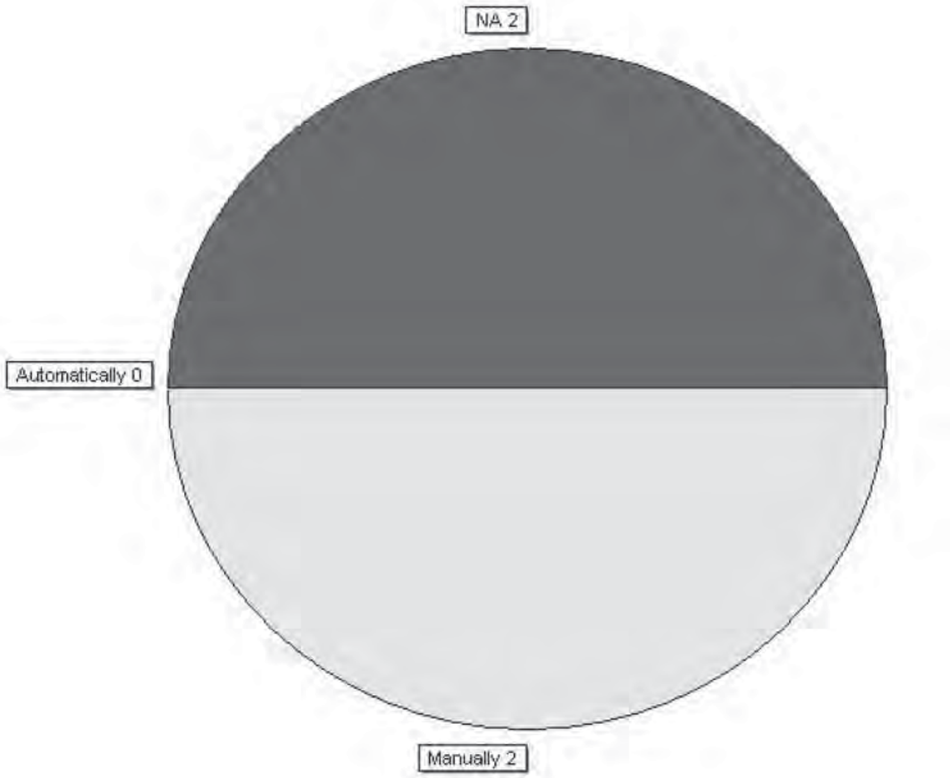


Other Responses:

CA: Most steering axles are of similar weight, we use established estimates as a baseline.

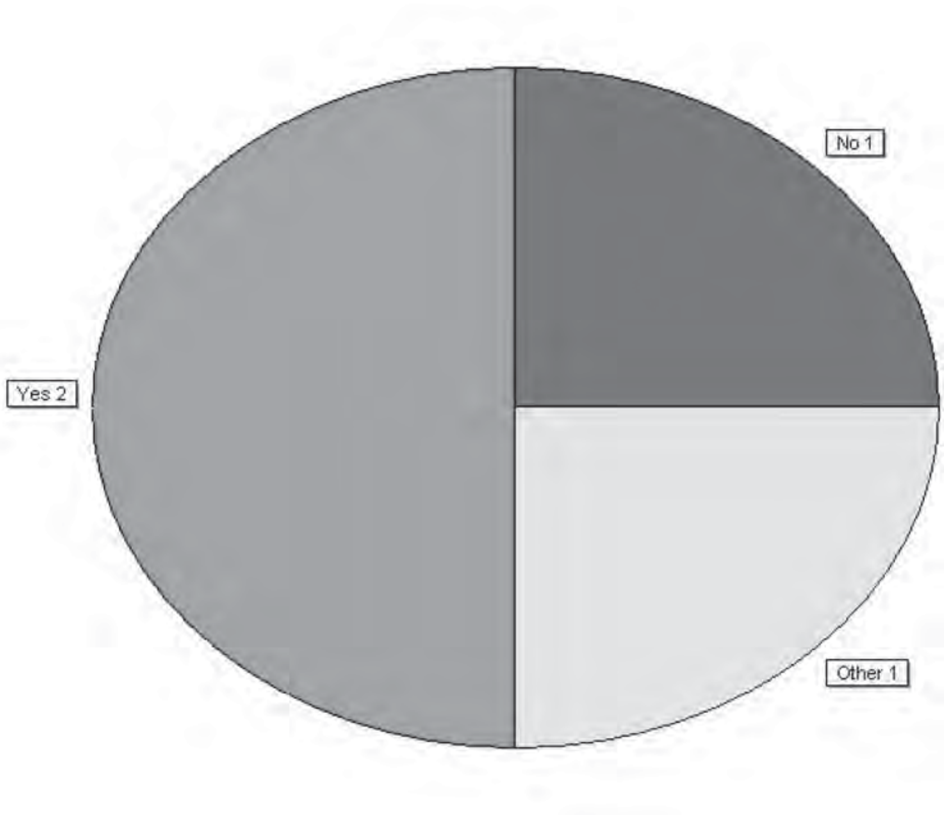
Comment Responses:

If using a weight enforcement facility, how is the static weight of the traffic stream trucks recorded?



Comment Responses:

3.6.6 Do you measure the axle spacing for these traffic stream trucks?

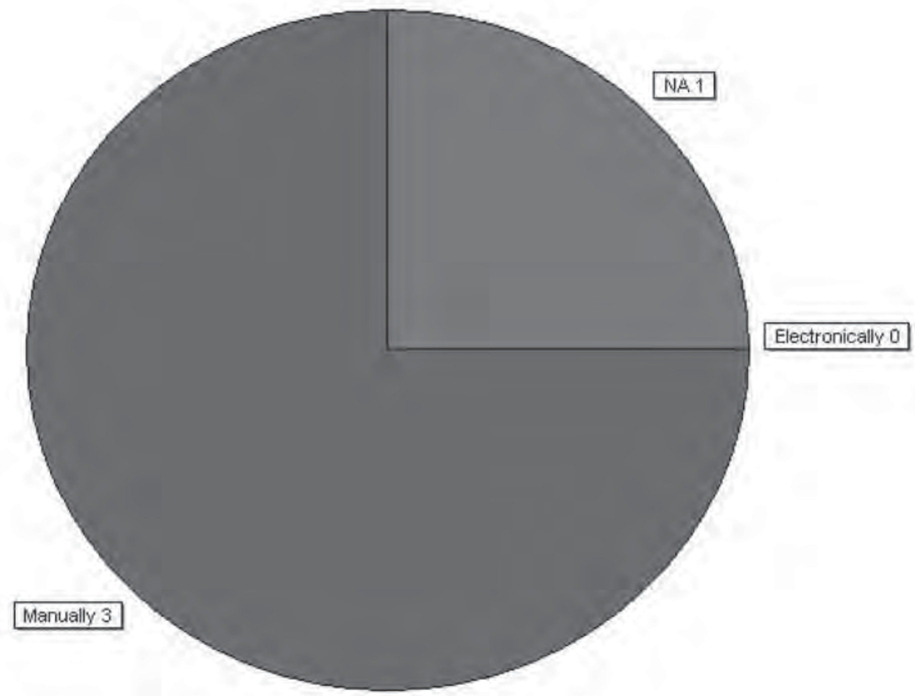


Other Responses:

NV: Only for ten percent of the sample

Comment Responses:

If Yes, how do you measure the axle spacing?

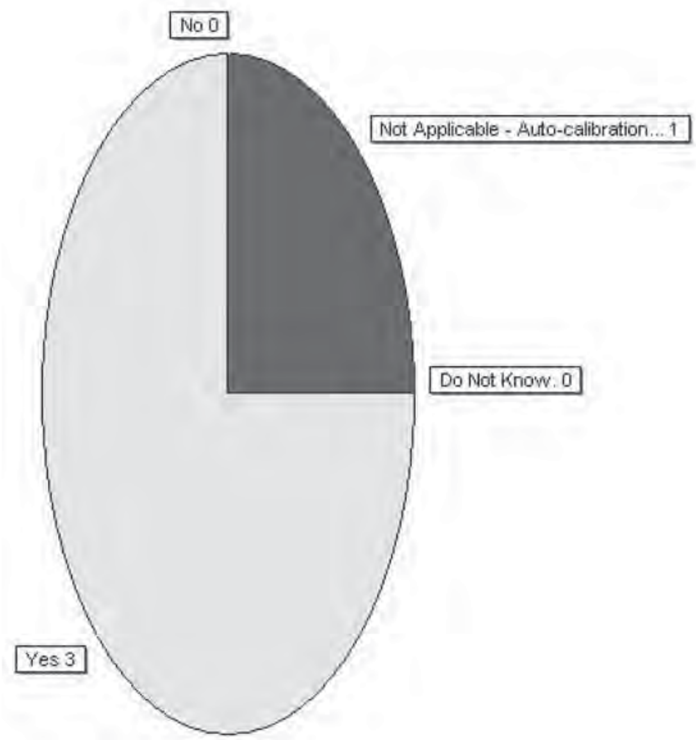


Other Responses:

Comment Responses:

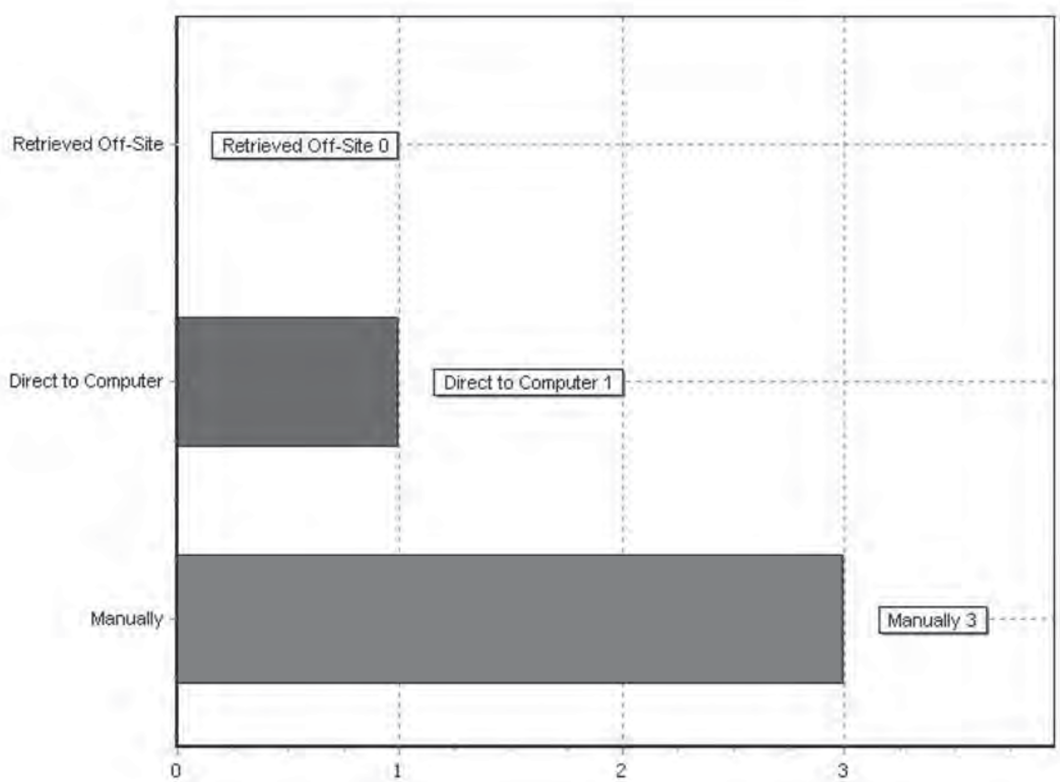
CA: Axle spacing between the #2 and #3 axle is typically 4.3-4.4 feet

3.6.7 Is the system auto-calibration turned off during traffic stream truck runs?



Comment Responses:

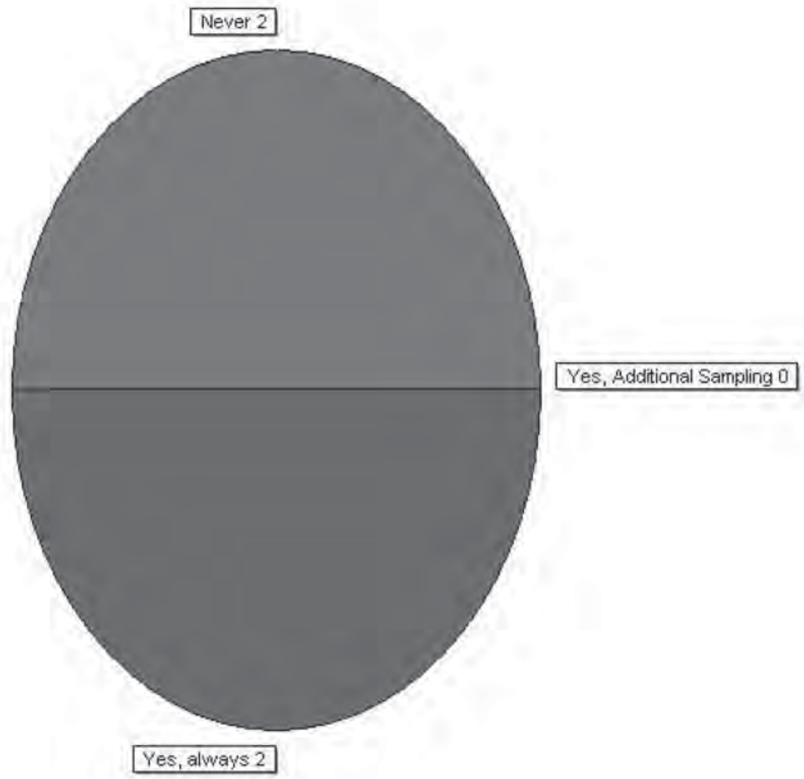
3.6.8 How is the WIM data of the sampled traffic stream trucks of known weight recorded?



Other Responses:

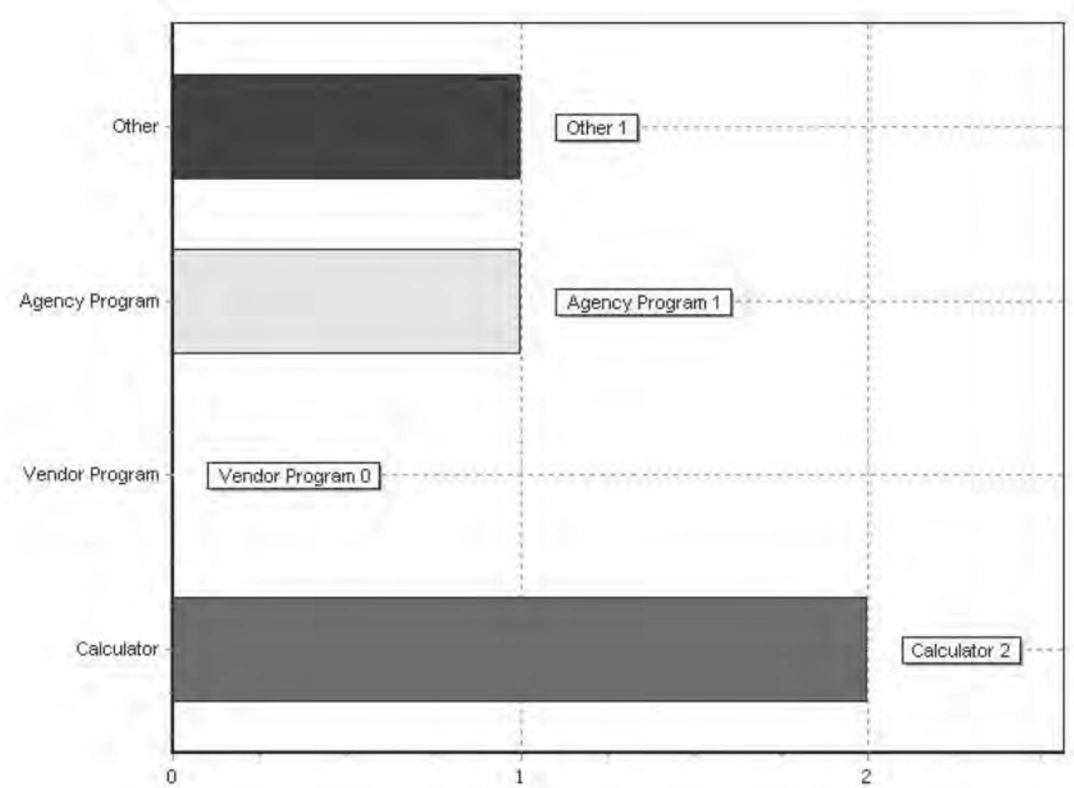
Comment Responses:

3.6.9 Are the on-site calibration using traffic stream trucks of known weight WIM error computations performed on-site?



Comment Responses:

3.6.10 During on-site calibration using traffic stream trucks of known weight how are the WIM error computations carried out?

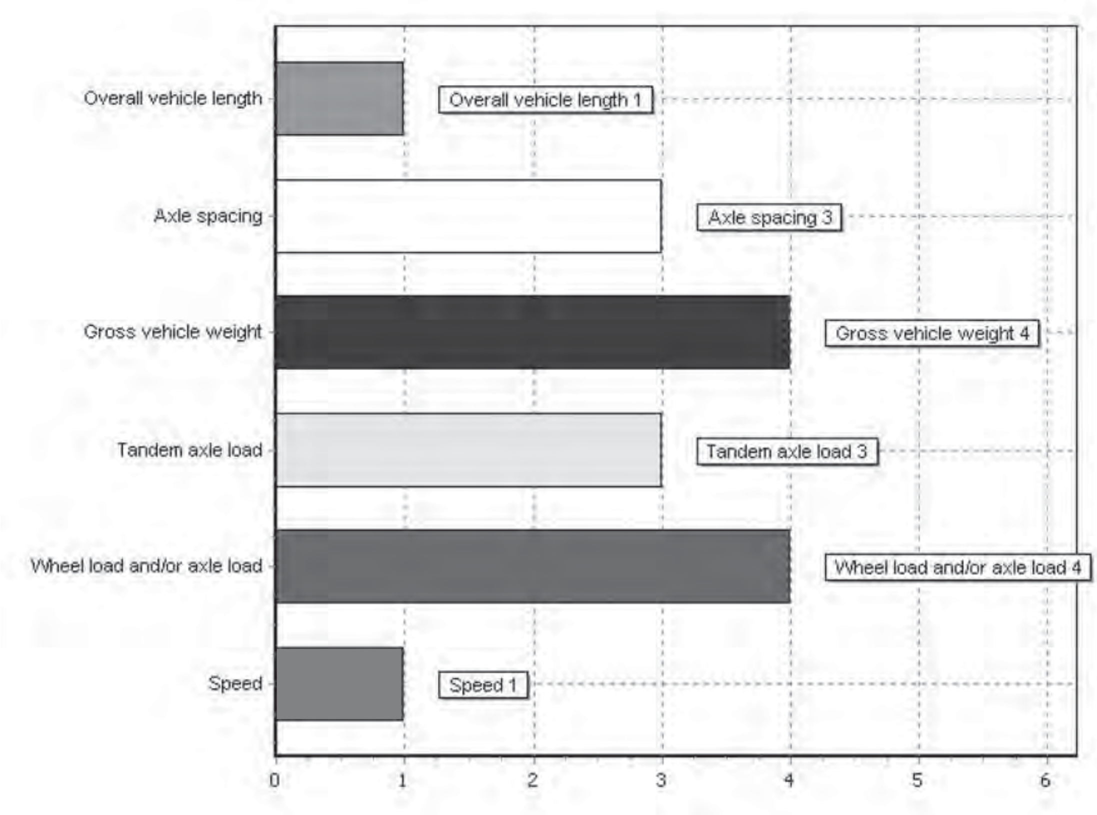


Other Responses:

Comment Responses:

CA: Traffic Stream data is calculated in the office.

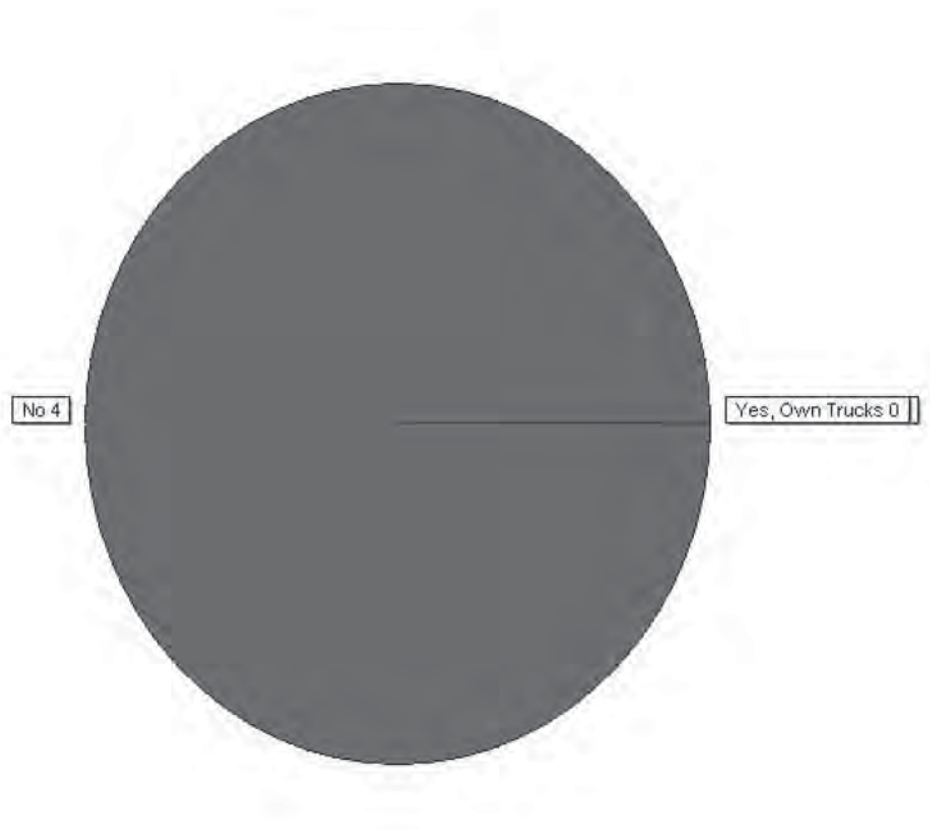
3.6.11 For which of the following measurements are WIM errors computed? Check all that apply.



Other Responses:

Comment Responses:

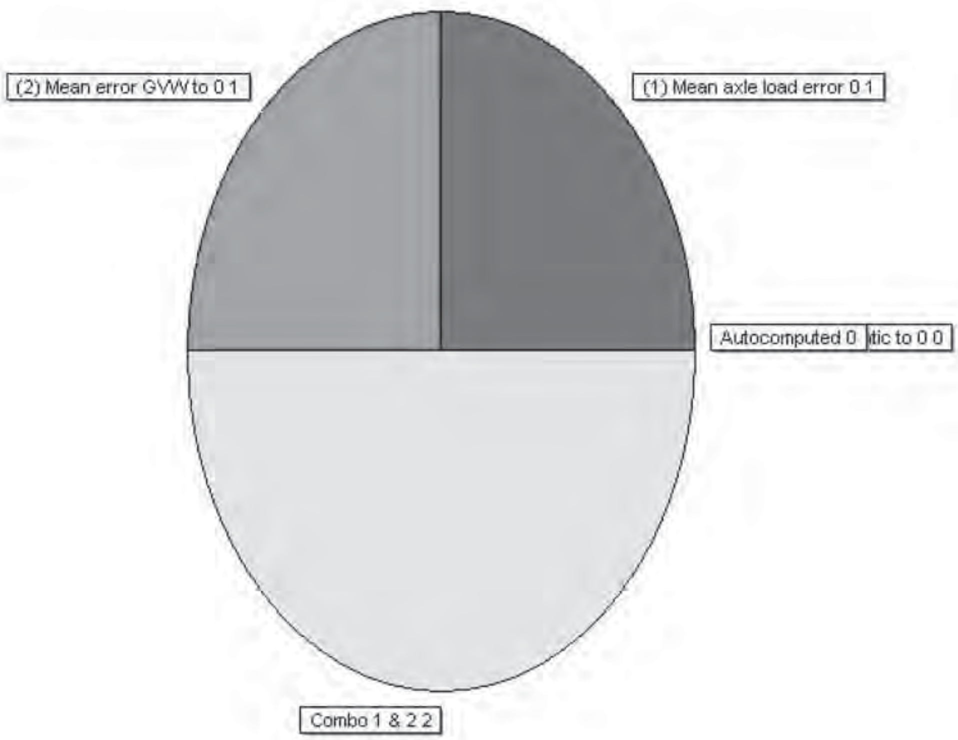
3.6.12 Are traffic stream trucks of known weight ever sampled for the sole purpose of determining WIM system accuracy tolerance pass/fail (e.g. new site acceptance, warranty, etc.)?



Other Responses:

Comment Responses:

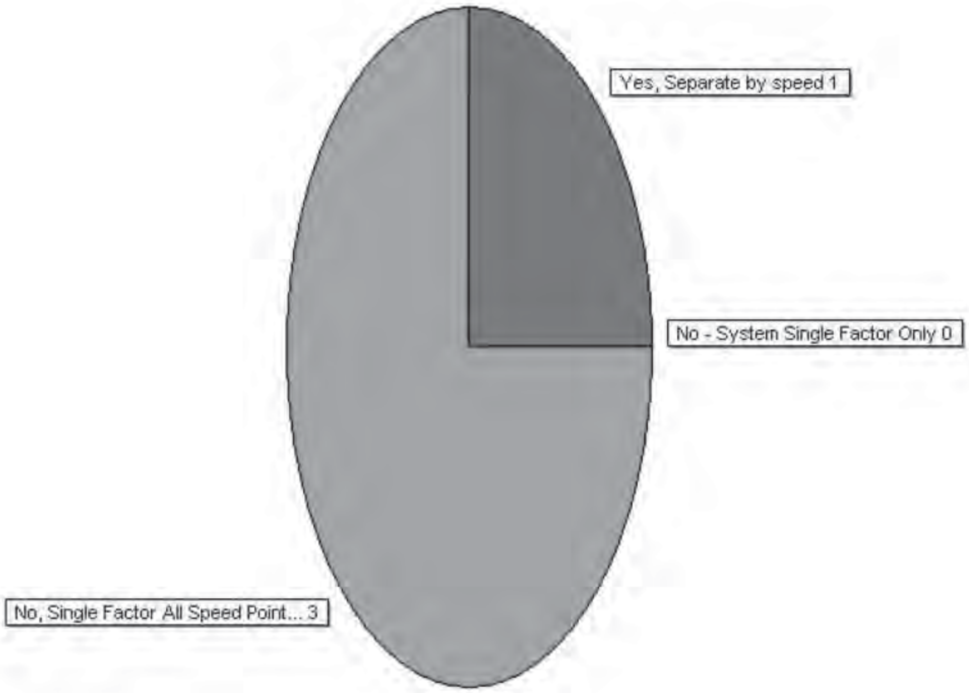
3.6.13 During on-site calibration using traffic stream trucks of known weight, what method is used to compute the calibration factors?



Other Responses:

Comment Responses:

3.6.14 During on-site calibration using traffic stream trucks of known weight do you compute calibration factors for two or more speed points?

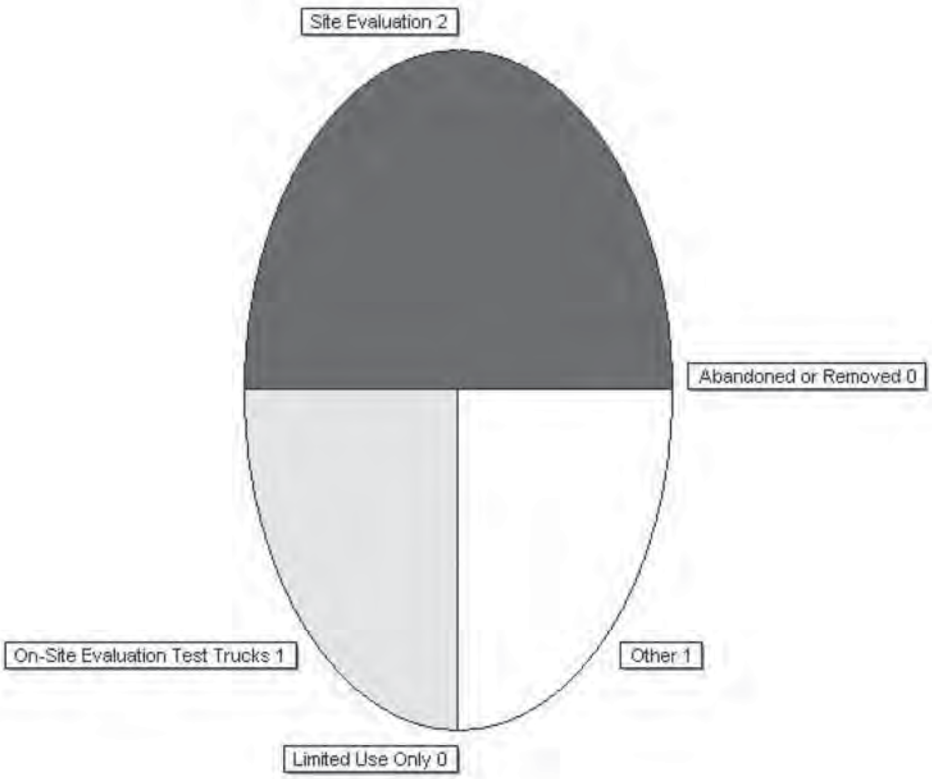


Other Responses:

CA: Traffic stream data is utilized in the office and calibration factors are adjusted from the office.

Comment Responses:

3.6.15 What remedial action is taken for WIM systems that fail to meet accuracy tolerances during traffic stream truck evaluation?

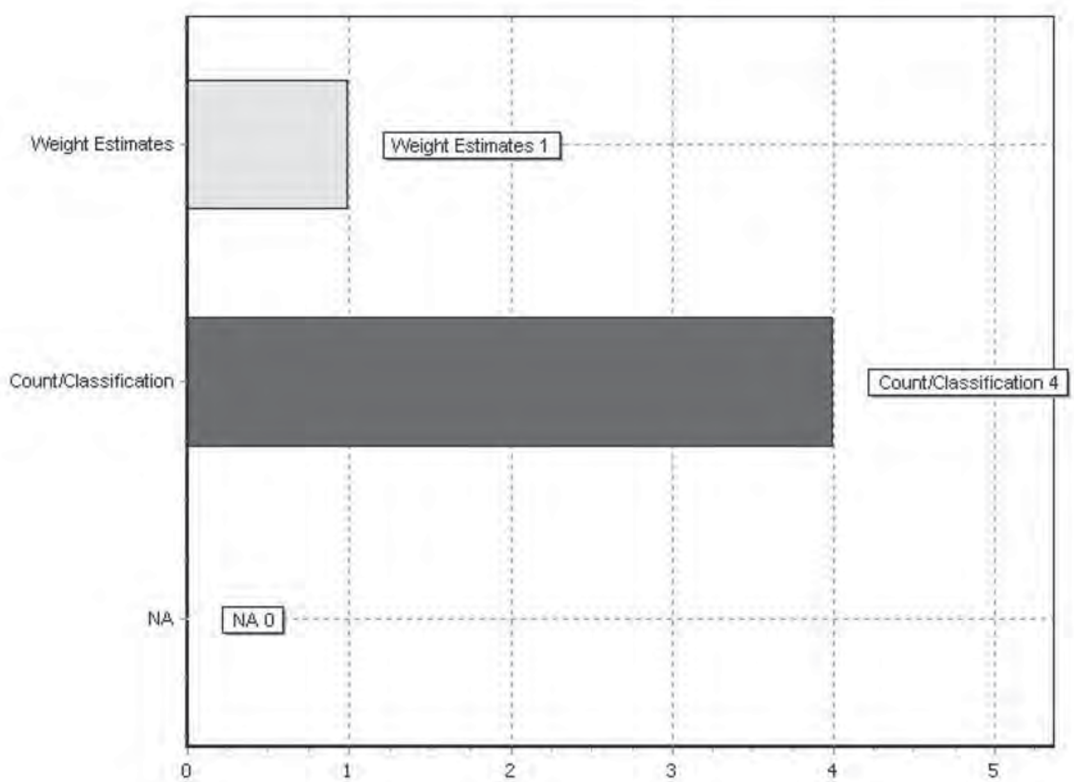


Other Responses:

OR: action is taken to correct the problem

Comment Responses:

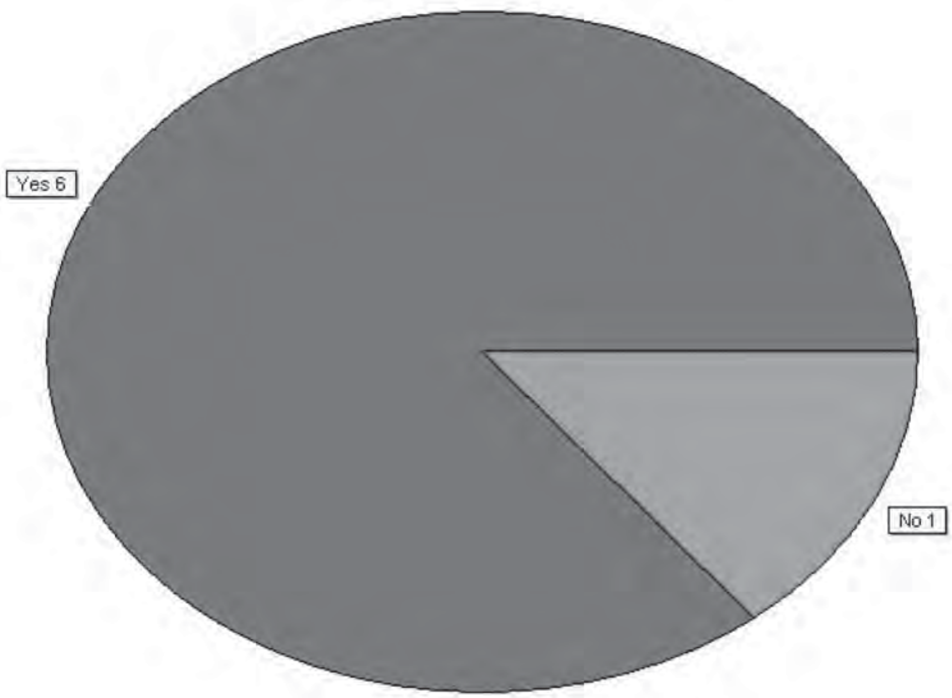
What is data from systems that remain in use but fail to meet accuracy tolerances used for?



<u>Other Responses</u>:

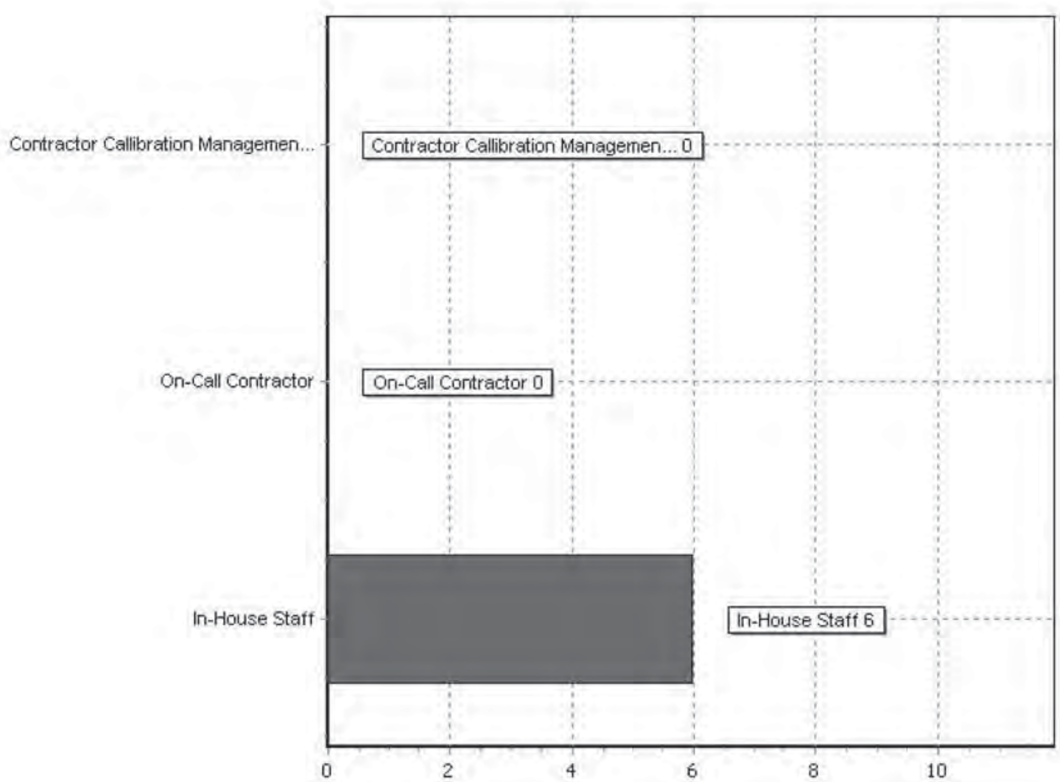
<u>Comment Responses</u>:

3.7 WIM Calibration Monitoring Using Traffic Stream WIM Data Do you use WIM calibration monitoring using traffic stream WIM data to monitor your WIM systems?



Comment Responses:

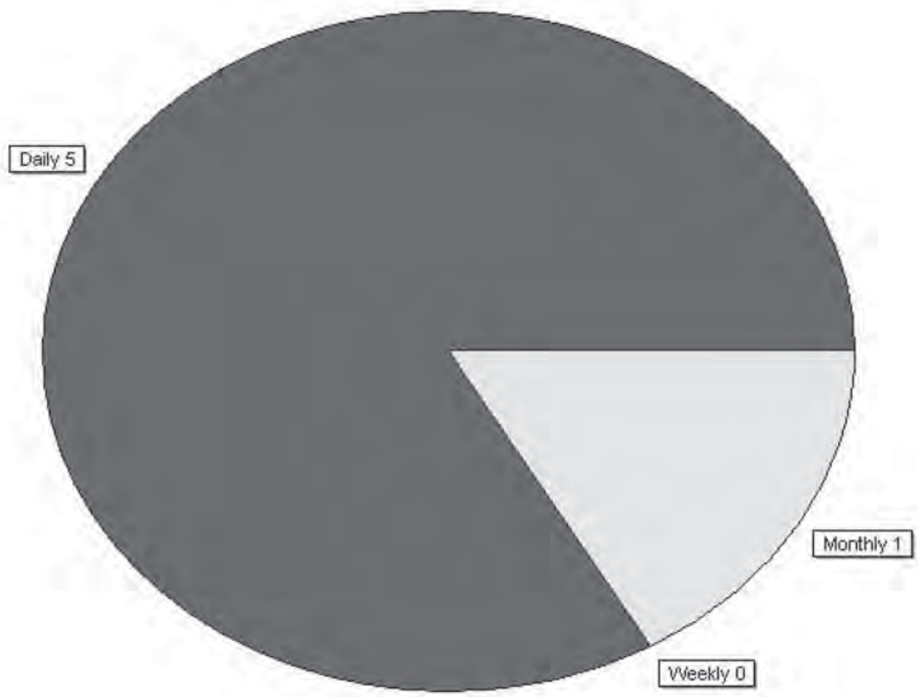
3.7.1 Who conducts WIM calibration monitoring using traffic stream WIM data? Check all that apply.



Additional comments:

OH: Generally check the weights of empty class 9 vehicles as compared to 35,000 lbs.

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions. 3.7.2 Typically, how often are your systems' data files downloaded?

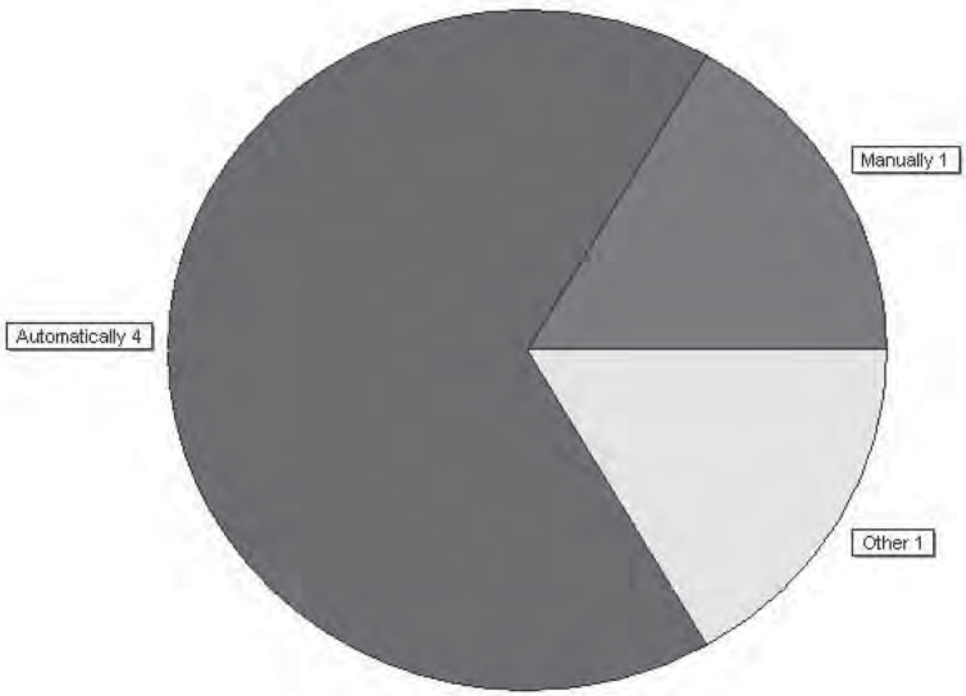


Other Responses:

Comment Responses:

California utilizes a validation server which downloads data daily from most sites. Other sites are downloaded weekly.

3.7.3 How are your systems' data files downloaded?



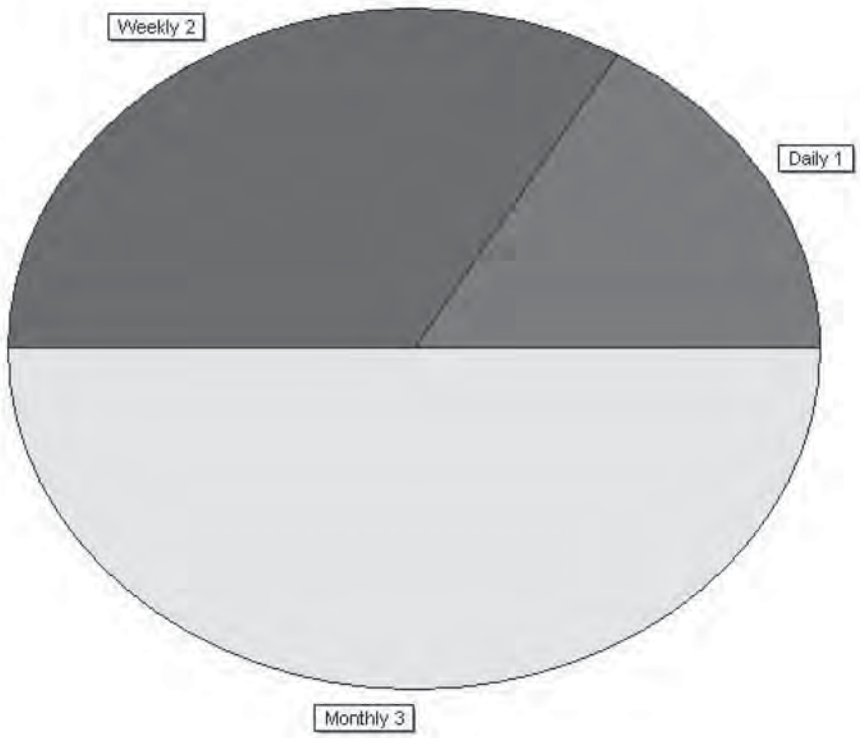
Other Responses:

CA: Combinations of auto downloads and manual, the bulk of our sites are downloaded automatically.

Comment Responses:

MI: Automatically - utilizing in house written auto-polling software

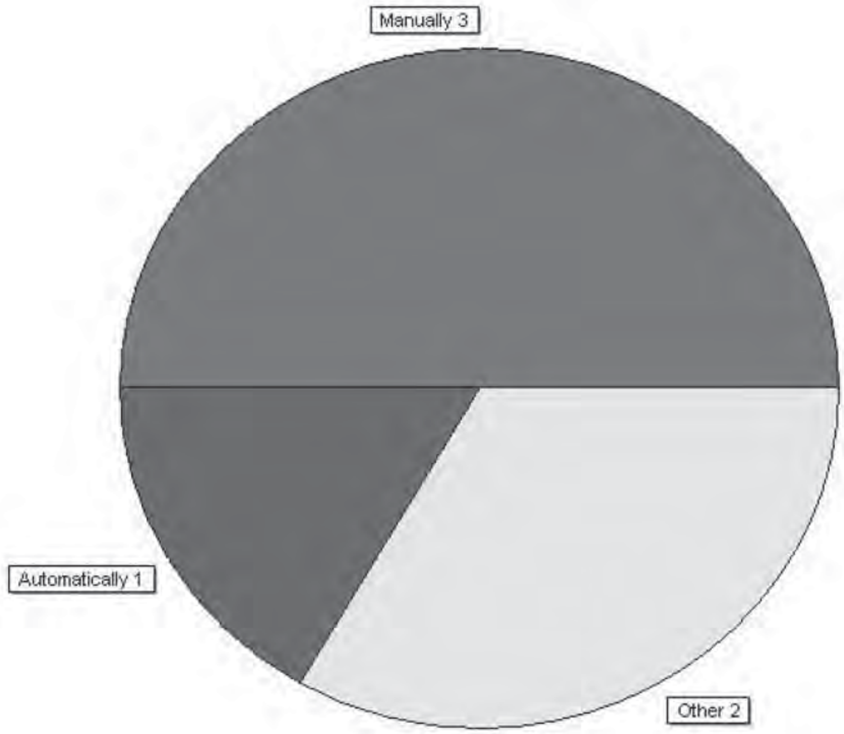
3.7.4 How often do you perform checks of the WIM data?



Other Responses:

Comment Responses:

3.7.5 How is your WIM data analysis performed?

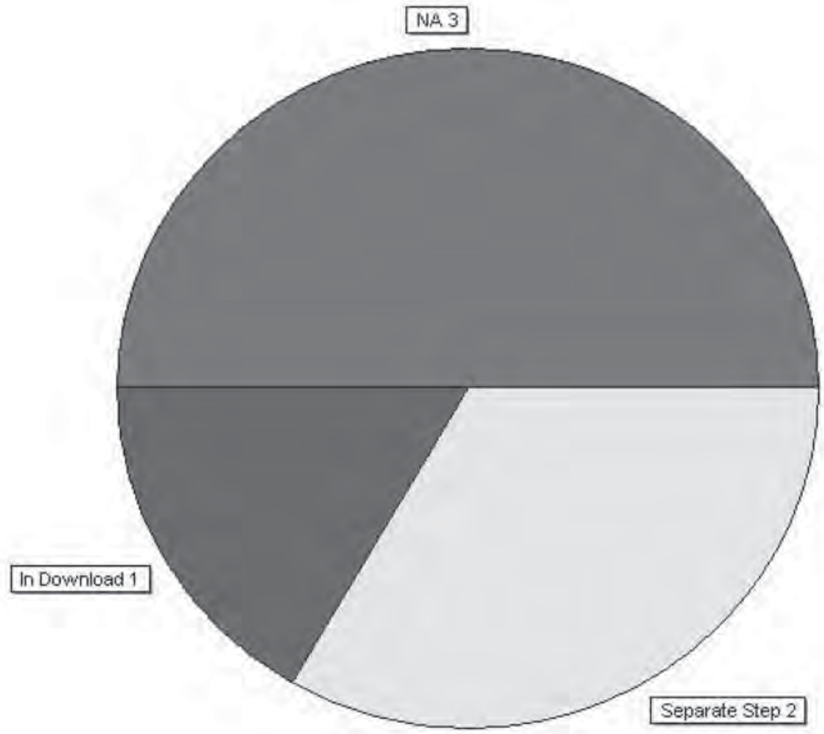


Other Responses:

CA: Some criteria of data analysis is automated, but others require user judgement. Site specific knowledge is needed at some sites.
manually, however in-house software has been created to assist in this task by compiling the data into graphs etc
MI: Both manualy and automaticaly

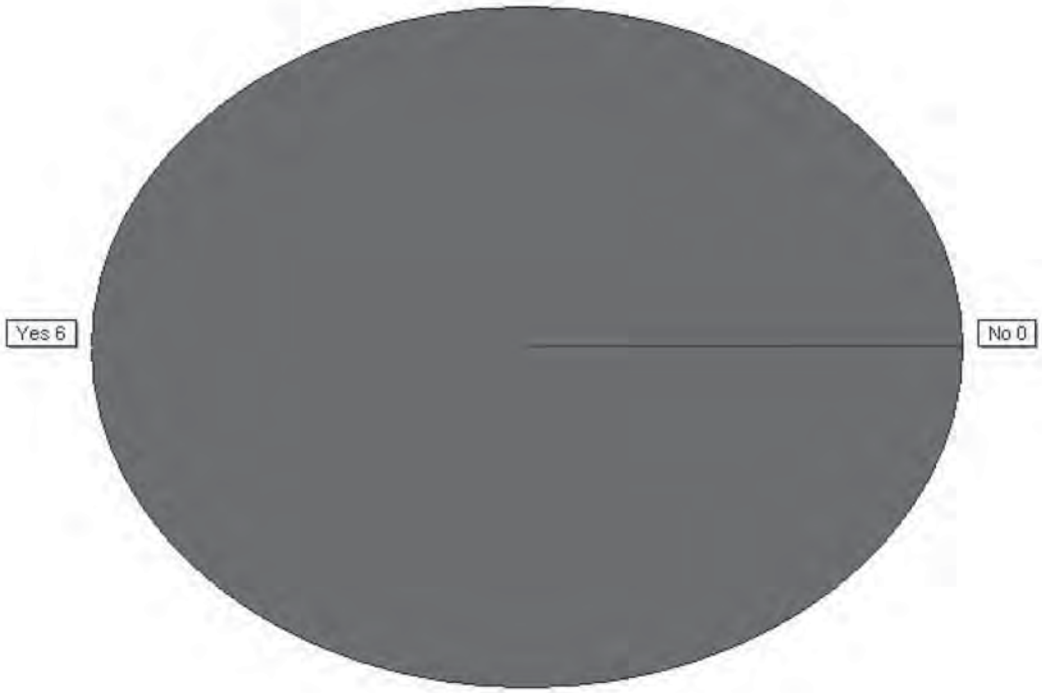
Comment Responses:

If your data analysis is performed automatically using software, when is it carried out?



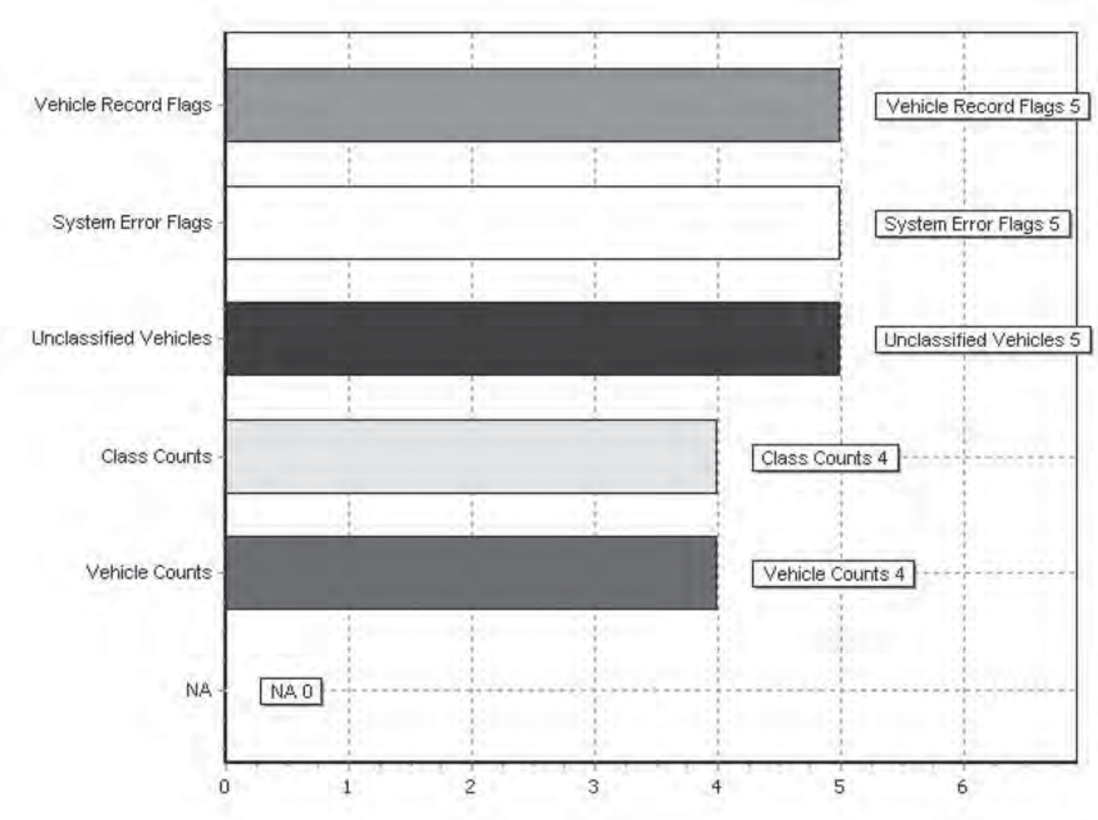
Comment Responses:

3.7.6 In your opinion, do the analyses of your WIM data identify most system operational problems and atypical traffic characteristics?



Comment Responses:

If Yes, which types of system operational problems and/or atypical traffic characteristics are identified? Check all that apply.

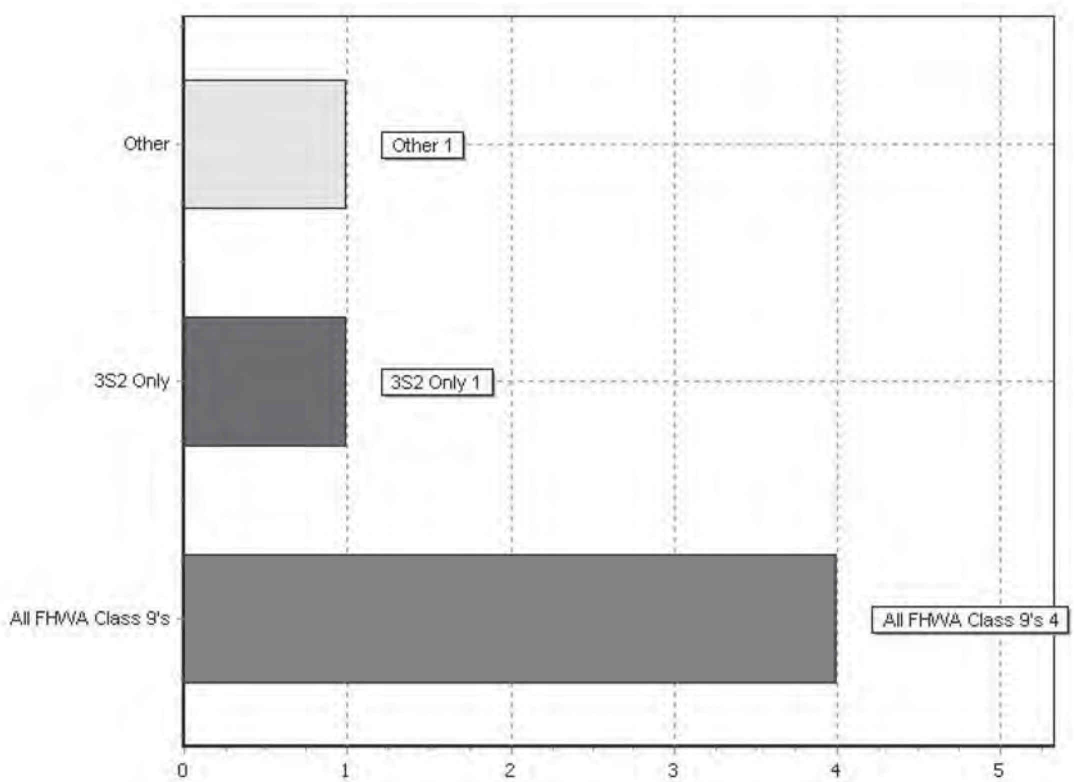


Other Responses:

some of these checks have not been developed yet but are currently being developed in-house

Comment Responses:

3.7.7 Which traffic stream vehicle types are utilized for calibration monitoring? Check all that apply.

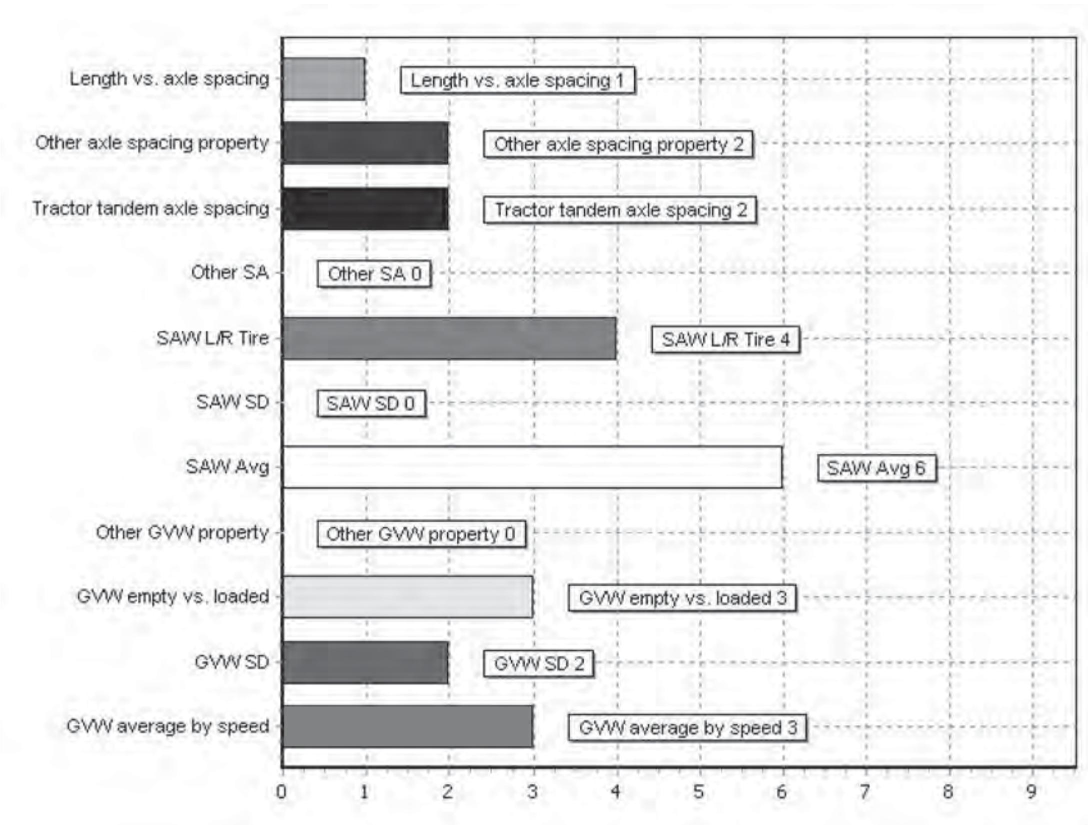


Other Responses:

MI: We use most vehicles to a certain degree to monitor the basic system but only class 9s for actual calibration

Comment Responses:

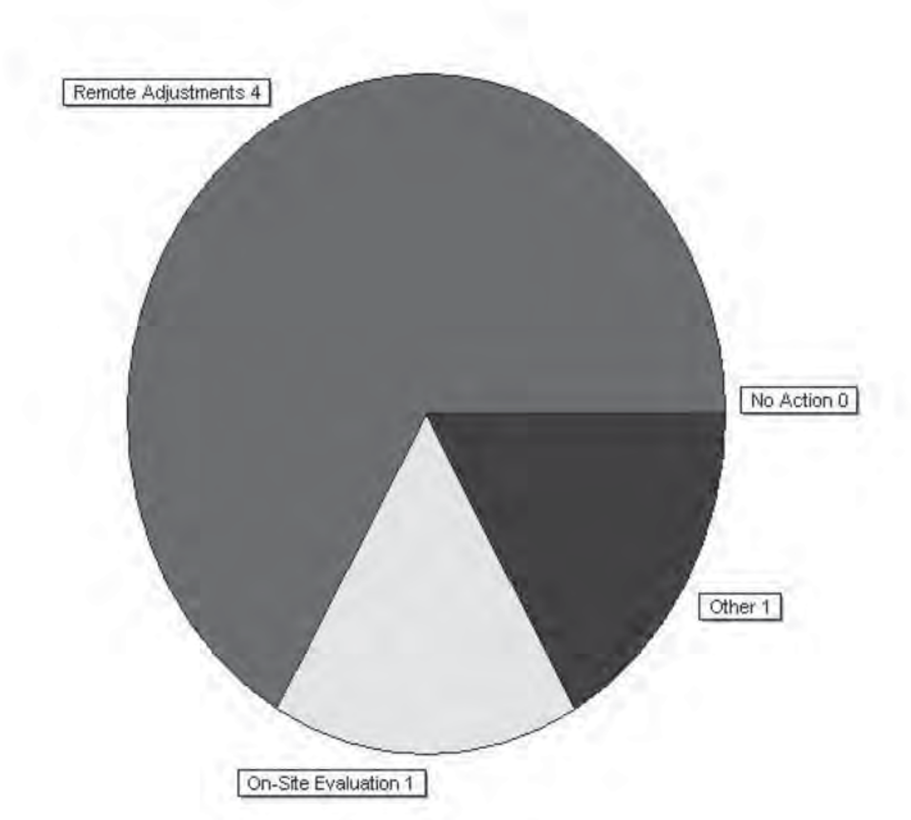
3.7.8 Which characteristics are monitored through WIM calibration monitoring using traffic stream WIM data? Check all that apply.



Other Responses:

Comment Responses:

3.7.9 If the monitoring of traffic stream characteristics indicates a system is experiencing calibration "drift" what action is taken?



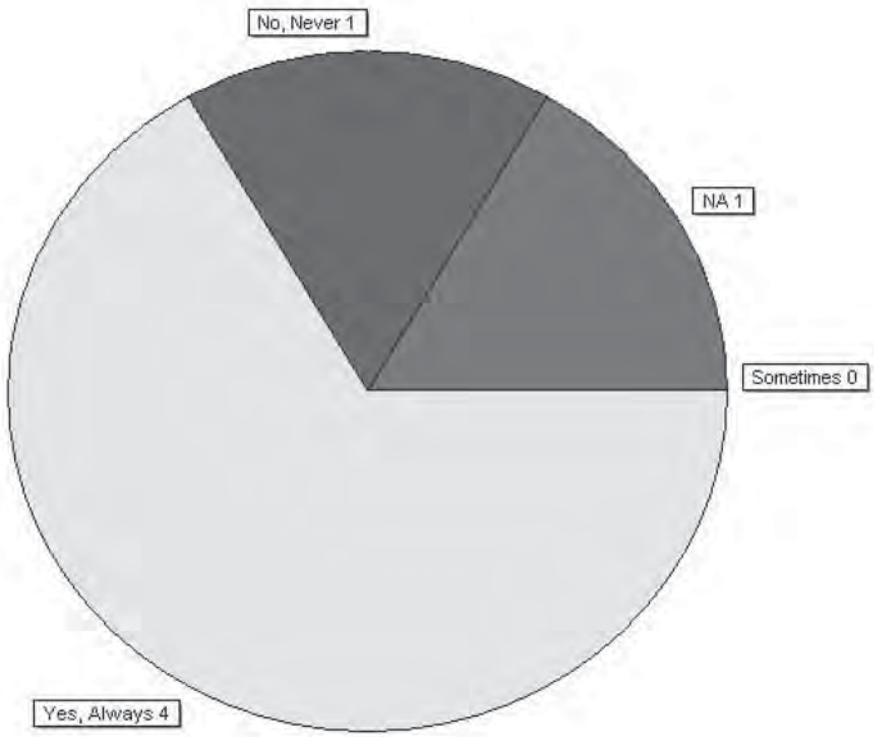
Other Responses:

MI: It's a judgement call. If it's a very minor drift we may adjust it from the office, but it would generally trigger the site for calibration.

Comment Responses:

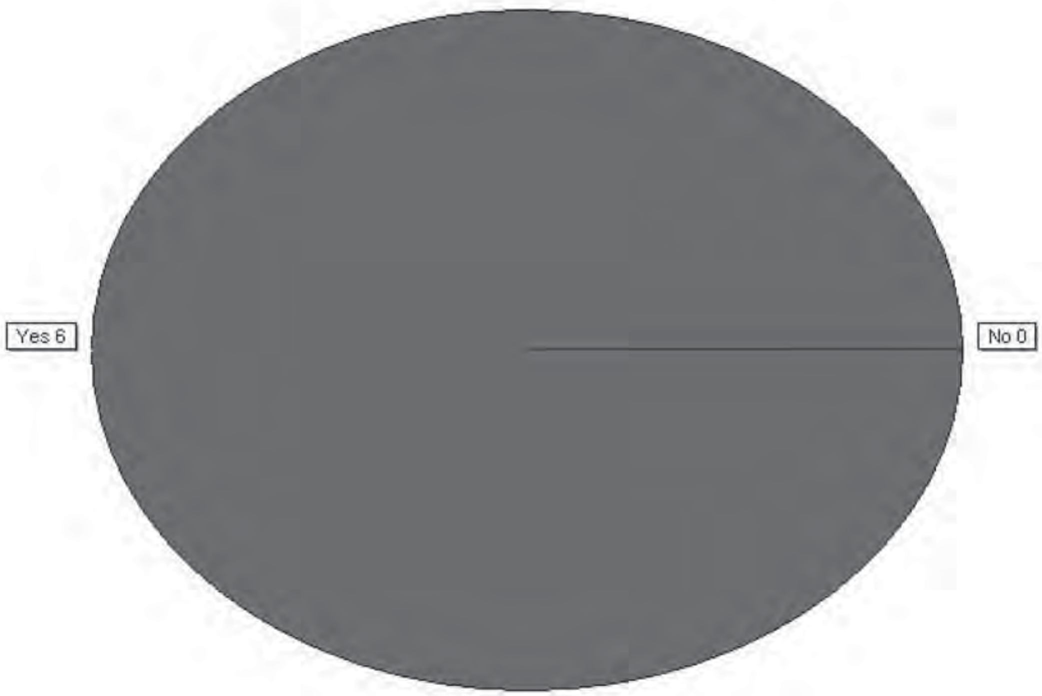
OH: Target weights are modified.

3.7.10 If calibration factors are adjusted from the office, do you check the effect on the traffic characteristics described in 3.7.8? Those characteristics included: (GVW Average, GVW Average by speed, Steering axle weight average, etc.). To view a complete list click on Previous Page below.



Comment Responses:

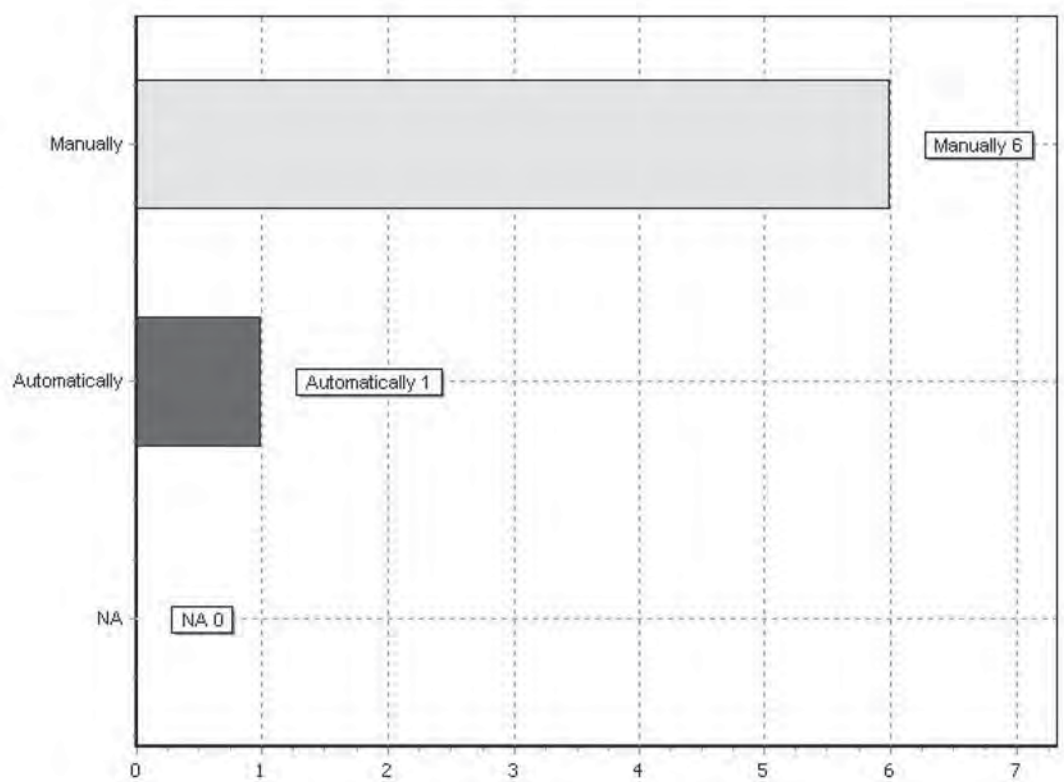
3.7.11 Do you keep records of WIM calibration factor adjustments?



Comment Responses:

OH: We do neglect to record the changes.

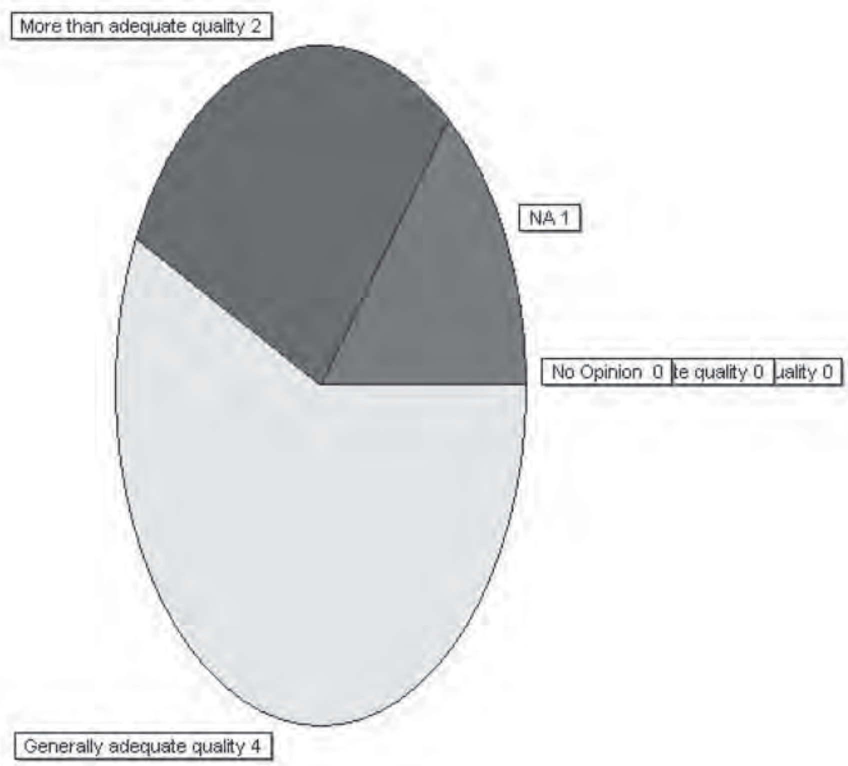
If Yes, how are records kept?



Comment Responses:

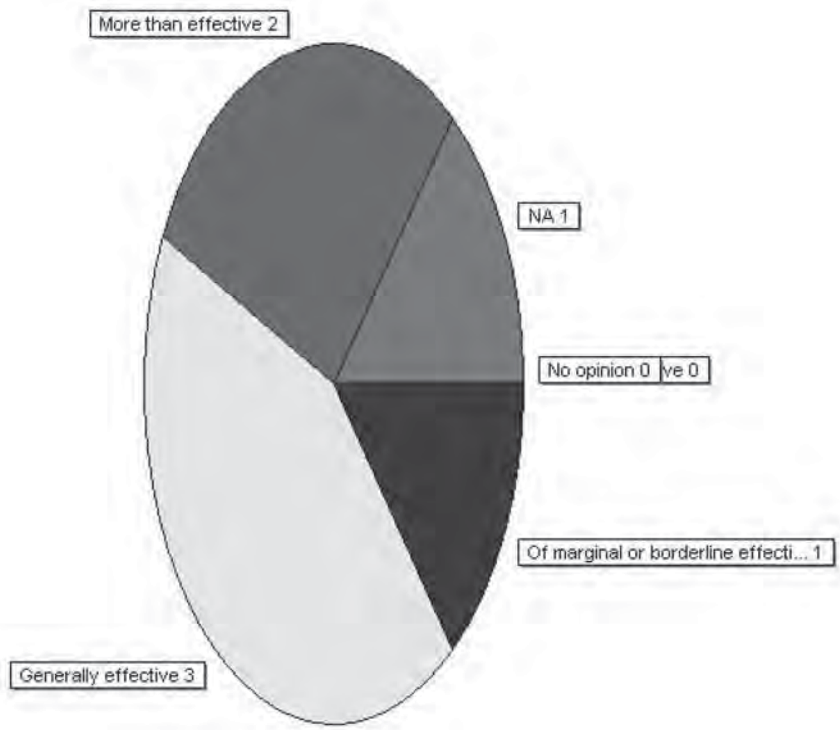
MI: We keep both a hard (paper) copy and an electronic copy.

Part 4: YOUR OPINION 4.1 In your opinion, are your Type I traffic data systems generating data of adequate quality to meet the requirements for the intended purposes?



Additional comments:

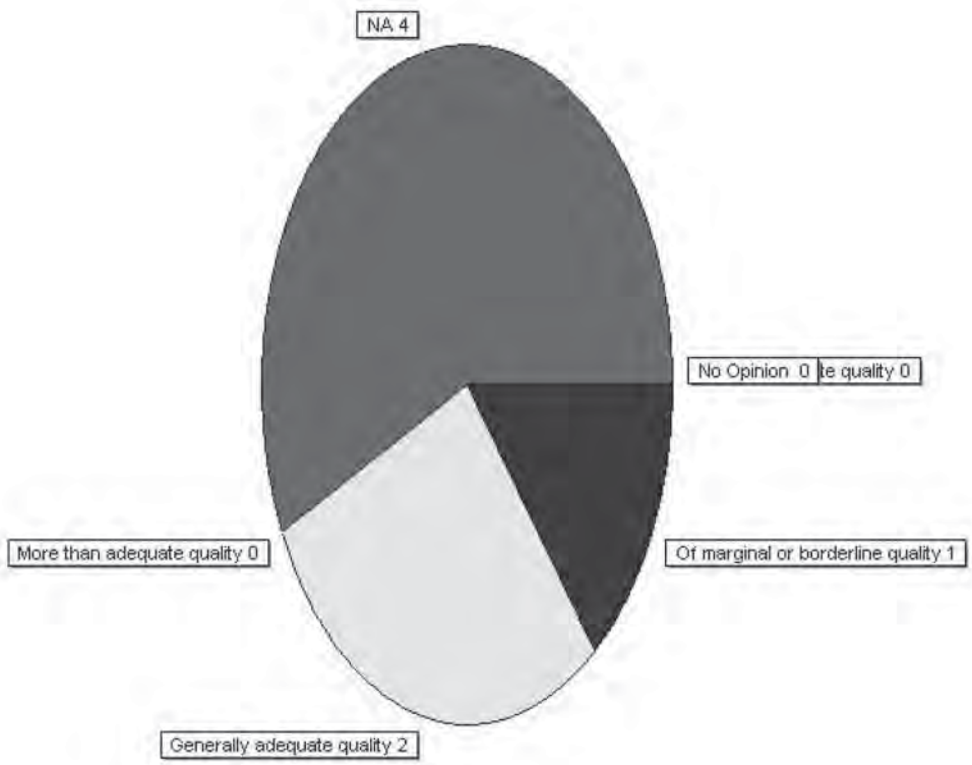
4.2 In your opinion, are your Type I main line enforcement screening and/or sorting systems effective?



Additional comments:

OH: If used in conjunction with enforcement, they are considered a very successful failure.

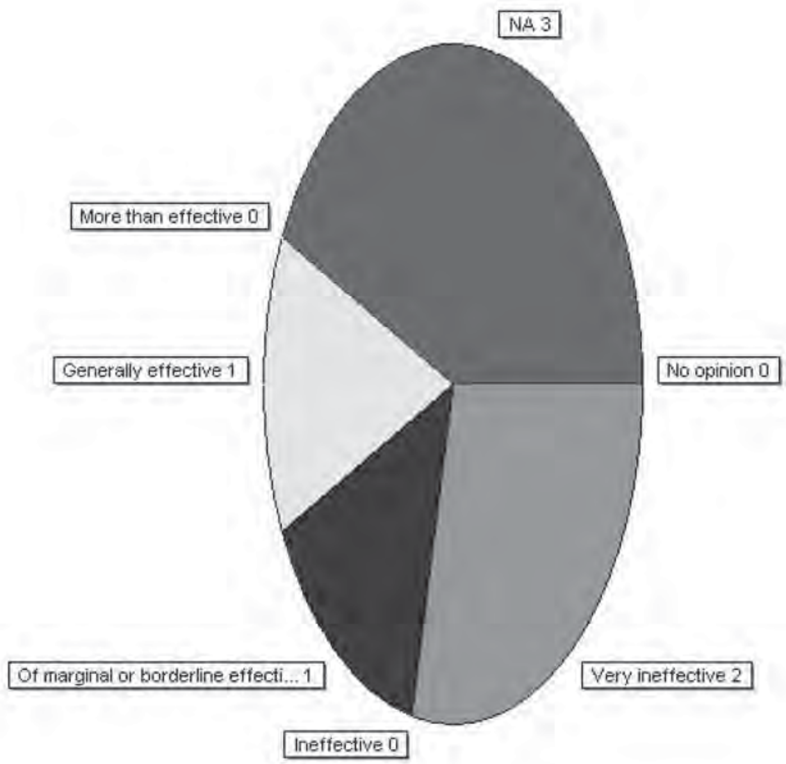
4.3 In your opinion, are your Type II traffic data systems generating data of adequate quality to meet the requirements for the intended purposes?



Additional comments:

California does not use Type II systems for weight.
No type II systems

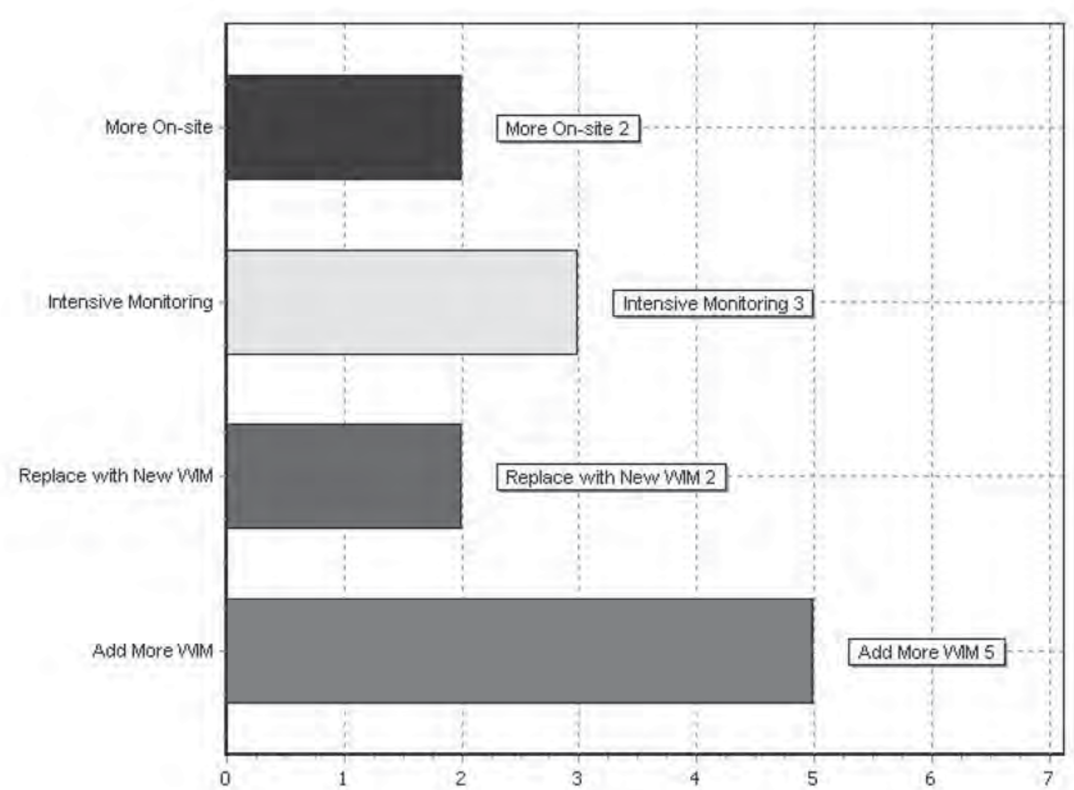
4.4 In your opinion, are your Type II main line enforcement screening and/or sorting systems effective?



Additional comments:

CA: There will be problems with using data from a Type II source, data of poor quality should not be considered for this use.
No type II systems
MI: We do not use any Type II systems for enforcement or sorting.

4.5 In your opinion, given additional resources for high speed WIM traffic data collection and enforcement, which of the following would your unit consider? Check all that apply.



Additional comments:

OH: Eliminate WIM data collection.
MI: We would like to upgrade many of our type II to type I

4.6 In your opinion, what is the main factor hindering proper WIM calibration and how could it be solved?

CA: Funding and lack of personnel is a major issue hindering proper WIM calibration. Field calibrations are very time consuming and expensive, funding increases are needed and qualified staff needs to be available.
NV: Acquiring the test vehicles which are very expensive. The only way to solve the problem is to identify additional funding.
ND: Manpower/time constraints/funding. NDDOT will try to keep calibration procedure in-house
MI: VERY time and resource consuming.
VT: Weather and pavement quality related issues.
OR: N/A

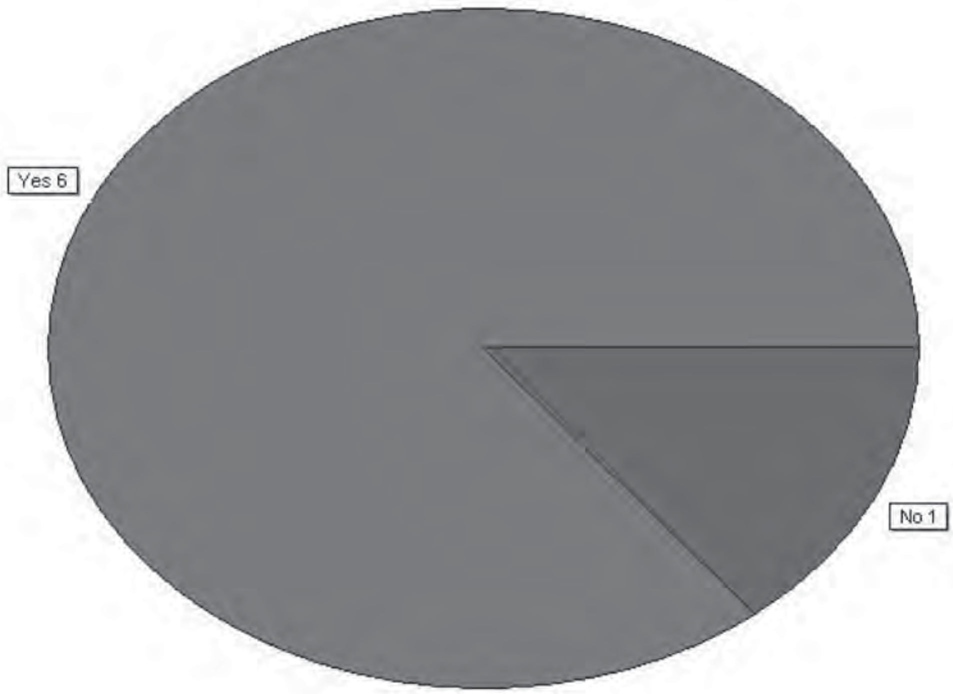
4.7 In your opinion, what are the most urgent WIM technical needs at present and what studies need to be conducted to address them?

CA: Controller stability and sensor life. WIM controllers are a very expensive item and the reliability of these units is somewhat variable. Concerns regarding their housing and components comes into question. Housing elements are subject to extreme temperatures and insects/rodents. Secure mil-spec housing designs should be incorporated. WIM sensors are prone to failure, partly due to the large volume of trucks. Knowing these forces, more metallugy studies may be needed to done to evaluate the optimum materials to be used. Sensor strain gauges in bending plates may need refinement in the areas of adhesion and failure.
NV: I would say this study is the most urgent techical need. Best calibration practices need to be identified and standardized.
ND: Obtaining more consistent, well calibrated high speed dynamic weights for Highway Patrol useage and design criteria uses. More technical manuals made available by the vendor
MI: Find an accurate sensor that is not so costly.
VT: Cost effective sensors that are consistent and easier to install.
OR: N/A

Please provide any additional comments you may want to share about high speed WIM calibration.

OH: Only do the absolute minimum WIM data collection.
OR: N/A

Part 5: INVENTORY OF WIM SYSTEMS This last part of the questionnaire is optional. It is an inventory of WIM systems in your state. Do you want to complete it?


Yes 6
No 1

Dual Use - A Single WIM System Used for Both Traffic Data Collection AND Enforcement Screening

Approximate number of Type I WIM Systems	Approximate Number of Type I WIM Lanes	Sensor Type(s)
6	16	CA: Bending Plates
1	4	NV: Quartz Kistler and bending plate
12	0	ND: Kistler Quartz Piezo
20	80	MI: Quartz Bending Plate
0	0	
22	24	OR: Single Load Cell

Single Use - Traffic Data Collection ONLY

Approximate Number of Type I WIM Systems	Approximate Number of Type I WIM Lanes	Sensor Type(s)
101	412	CA: Bending Plates on 100 and 1 Kistler
5	20	NV: Quartz Kistler and bending plate
0	0	
13	52	MI: Quartz Bending Plate
0	0	
0	0	

Single Use - Enforcement Screening ONLY

Approximate Number of Type I WIM Systems	Approximate Number of Type I WIM Lanes	Sensor Type(s)
28	60	CA: Bending Plates
0	0	
0	0	
0	0	
0	0	
0	0	

Dual Use - A Single WIM System Used for Both Traffic Data Collection AND Enforcement Screening

Approximate Number of Type II WIM Systems	Approximate Number of Type II WIM Lanes	Sensor Type(s)
0	0	
0	0	
0	0	
24	96	MI: Piezo
17	46	VT: Class 1 RoadTrax

		BL
0	0	

Single Use - Traffic Data Collection ONLY

Approximate Number of Type II WIM Systems	Approximate Number of Type II WIM Lanes	Sensor Type(s)
0	0	
0	0	
0	0	
24	96	MI: Piezo
0	0	
0	0	

Single Use - Enforcement Screening ONLY

Approximate Number of Type II WIM Systems	Approximate Number of Type II WIM Lanes	Sensor Type(s)
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	

Generated: 6/2/2007 4:02:16 PM

Survey Results
& Analysis

for

NCHRP Synthesis 38-10 Survey of High Speed WIM System Calibration Practices

TRB

Saturday, June 2, 2007

Powered by:

webSURVEYOR

http://www.websurveyor.com/

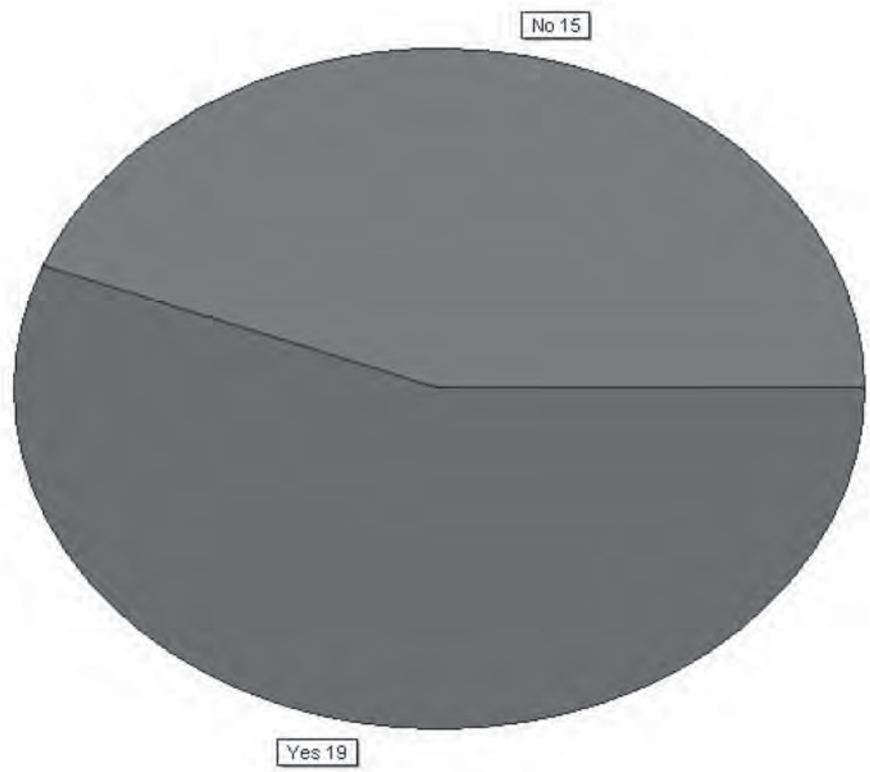
Executive Summary

This report contains a detailed statistical analysis of the results to the survey titled *NCHRP Synthesis 38-10 Survey of High Speed WIM System Calibration Practices*. The results analysis includes answers from all respondents who took the survey in the 76 day period from Friday, March 16, 2007 to Wednesday, May 30, 2007. 34 completed responses were received to the survey during this time.

Survey Results & Analysis

Survey: NCHRP Synthesis 38-10 Survey of High Speed WIM System Calibration Practices
Author: T. Papagiannakis and R. Quinley
Filter: (In question "13) 2.1 What are the WIM systems for which your unit is primaril..." the respondent selected "Data")
Responses Received: 34

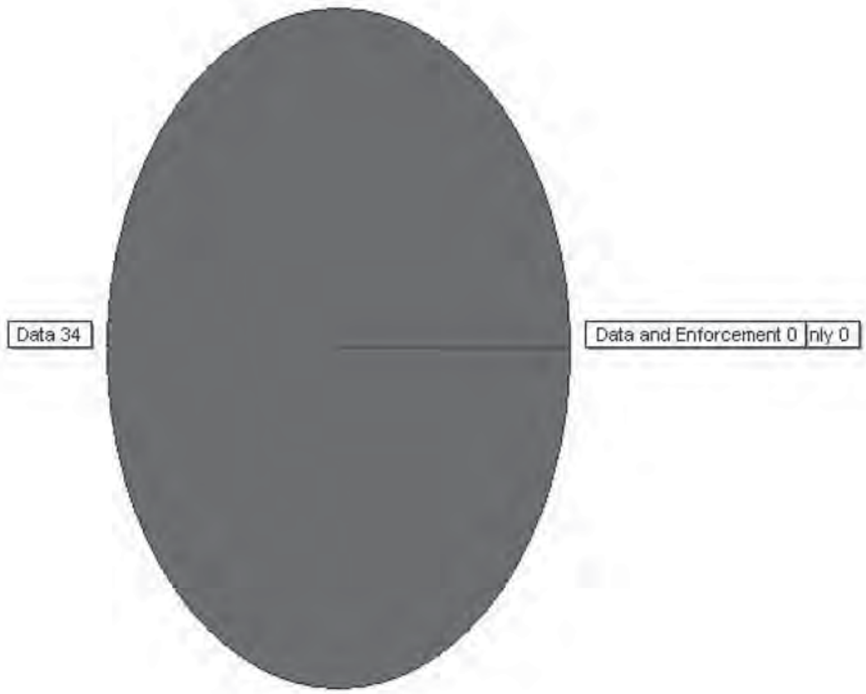
Is there another unit (department/division/agency) in your State managing high speed WIM systems used for a different purpose (i.e., data collection versus enforcement)?



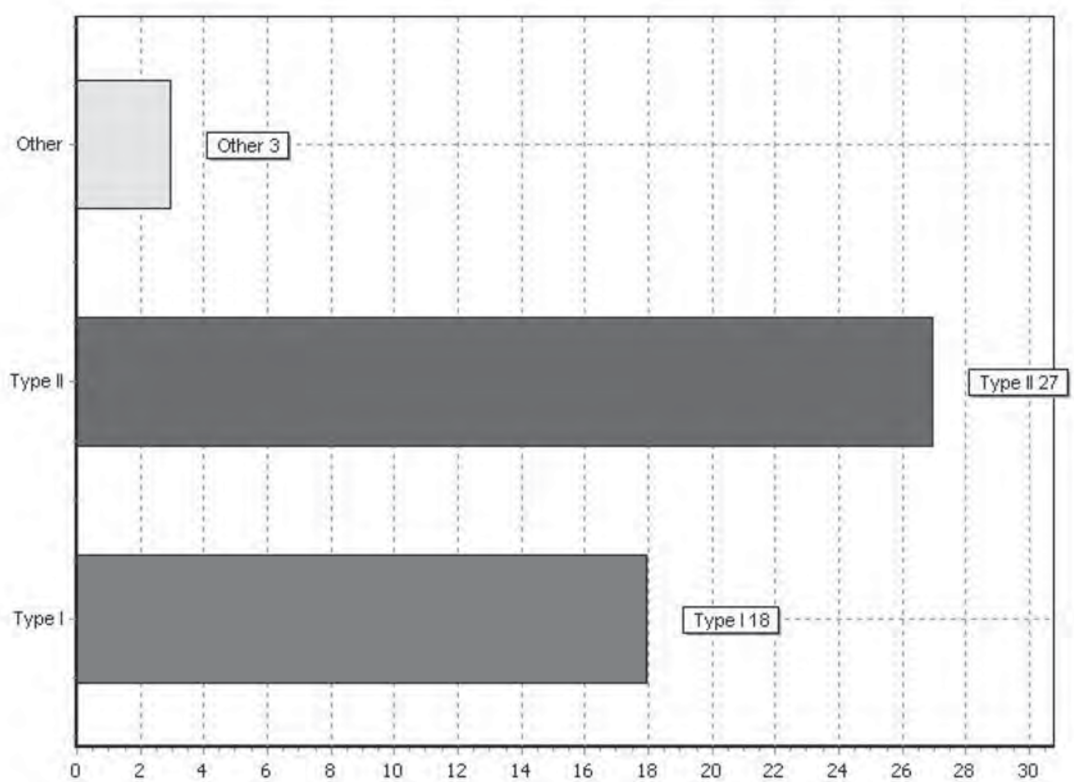
Please comment below on whether your unit cooperates with that other unit and how:

FL: Motor Carrier Compliance (our enforcement office) also has installed a number of WIM systems at their fixed scale locations. They use their WIM systems for pre-pass and screening. Motor Carrier puts their screening WIM data into an FTP site, and I download that data routinely. I consider the Motor Carrier WIM data to be biased, because overweight trucks can easily avoid the fixed weigh stations, but it has been interesting to compare their data to my own.
CT-R: We cooperate with these units as needed and as requested. We are responsible for LTPP data collection and research studies involving evaluation of WIM technologies.
MT-Traffic: My unit (Traffic Data Collection) installs, calibrates and maintains the Kistler sensor based WIM systems used for some of Motor Carrier Services Pre-Pass systems. In addition, we collect data from bender plate WIM systems that are calibrated and maintained by Motor Carrier Services. These bender plate WIM systems are used with some of Motor Carrier Systems' Pre-Pass sites. We also provide portable WIM data to Motor Carrier Services for enforcement purposes.
NE-Traffic WIM test vs static scales
NM-Traffic: Port of Entries have some high-speed WIMS
WA-Traffic: Our repair crew occasionally does work for the CVISN section.
NJ: We are currently at the planning stage of upgrading some of our WIM systems to be used for "Virtual Weigh Stations" . None of the sites have been upgraded to Virtual Weigh Station yet, so currently no WIM system is being used for enforcement.
VA-Traffic: The two agencies cooperate as follows: The DOT, which is responsible for traffic data collection, allows the DMV to wirelessly connect to some of their WIMs during mobile enforcement operations. The DMV, which is responsible for enforcement, shares the traffic data collected at their WIMs with the DOT.
NY: Passenger & Freight Safety Division is responsible for a pilot project that includes the installation of commericial vehicle electronic screening equipment. Included in this project is three types of WIM equipment; piezo electric (NYS standard), quartz piezos and load cells. The three types of WIM equipment will be evaluated as part of this project with additional commercial vehicle screening sites installed in subsequent years. The three types of WIM equipment will be installed in the east bound driving lane, however the remaining three lanes include our standard piezo electric, so this will be a fully functioning WIM site for NYSDOT. Our relationship with Passenger & Freight Safety includes reviewing all contract plans, site evaluation/inspection, maintenance of the site after the warranty period expires, and traffic data collection and analysis.
MS: Corespondence between planning and law enforcement occurs to discuss quality of WIM data and potential WIM sites in the future. New software is being purchased, Transmetric in which more coordination will occur. Law enforcement is primarily concerned with heavy trucks and axle spacings.
MA: tentative plans for future cooperation
AZ-LTPP: Internal consultations.
AL-Traffic: The data collected from the enforcement systems are stored on our file server. We generate 3-card and C-cards from these files for our use.
UT: I borrow and archive their data
CT-Traffic: We use research for portable calibration. They rent trucks for their LTTP calibration we take part in it.
Yes
AK: We provide truck weight data to Division of MSCVE Commerical Enforcement for secondary enforcement. MSCVE is going to deploy CVISN using the 3 of the planning WIM sites in the near future.
KS: We send them data summaries annually
ID-Traffic: Yes, we work together informally exchanging information on equipment and results.
NH: No Cooperation

2.1 What are the WIM systems for which your unit is primarily responsible used for?


Data 34
Data and Enforcement 0
nly 0

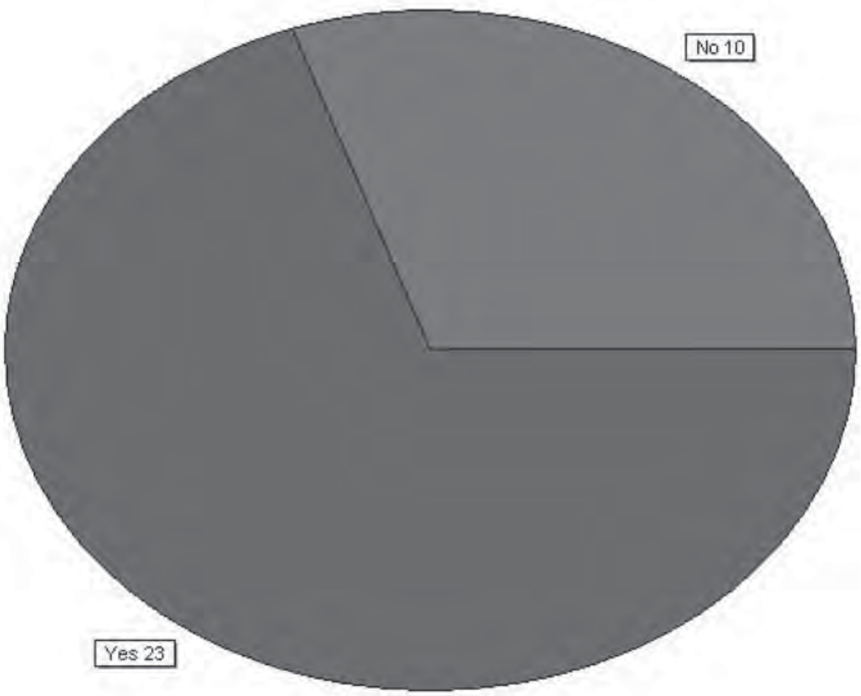
2.2 Which types of WIM systems have been installed by/for your unit?



Other Responses:

MT-Traffic: Portable WIM, which is set up in a Type I configuration, but only weighs the right-hand side of the vehicle.
MS: We have 15 operational Type II BL sites and 1 operational Type I Bending Plate Site.
UT: Type III
IN-Traffic: Single Load Cell, Piezo, DOS O/S
ID-Traffic: IRD and ECM permanent systems - channelized and BL sensors.

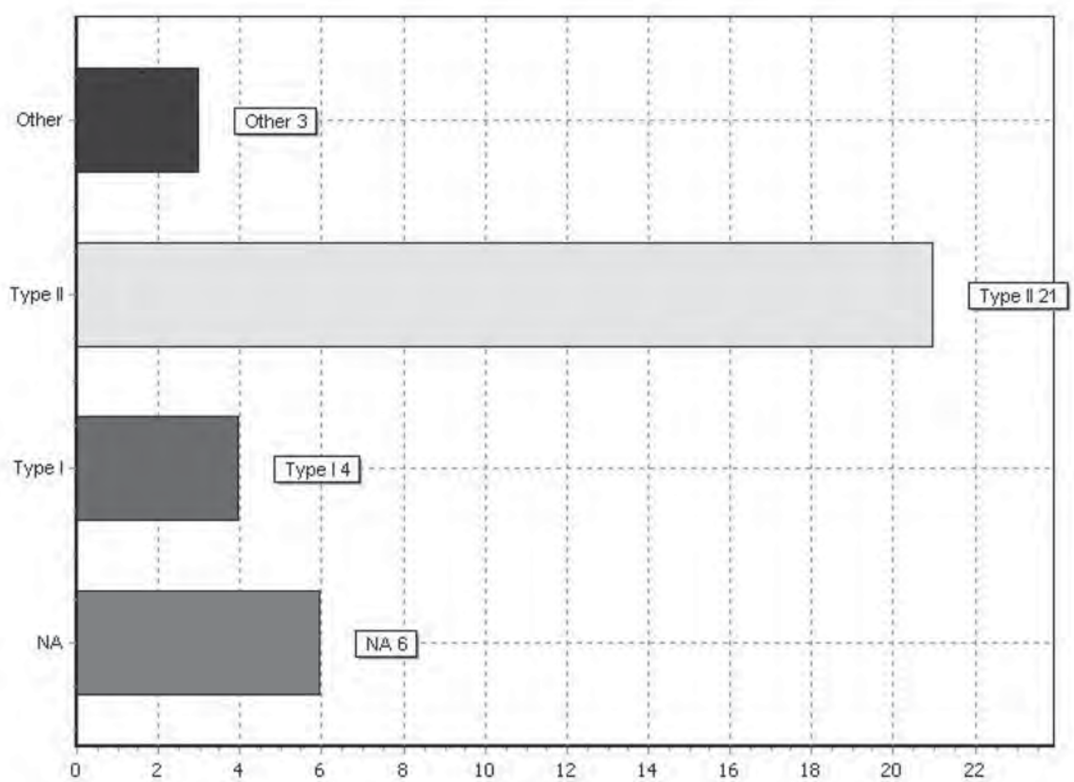
2.3 Is auto-calibration typically utilized by your systems during routine data collection?



Comment Responses:

MT-Traffic: Kistler-based Type I systems do not use auto-calibration.
MS: Our system has the capability of auto-calibrating, but this function is turned off.
UT: I do it manually weekly when able
TX: Thermocoax Sensors Only
Auto calibration is the ONLY calibration done.

If Yes, for which system types? Check all that apply.



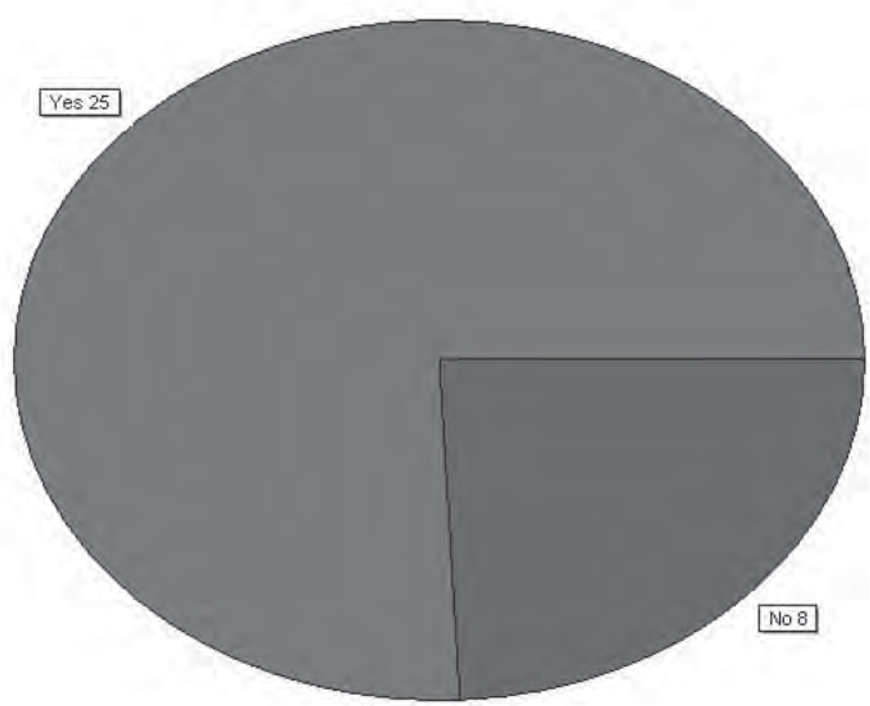
Other Responses:

CT-R: Earlier work on evaluating WIM used systems that needed autocalibration to function. For that reason we have installed quartz sensors at LTPP sites and do not use autocalibration.
MT-Traffic: Portable WIM uses auto-calibration.
IN-Traffic: Only for piezo sensors
ID-Traffic: Both IRD and ECM permanent systems use auto calibration.

Comment Responses:

MT-Traffic: Portable WIM data is collected only for Motor Carrier Sevices as an aid to enforcement.

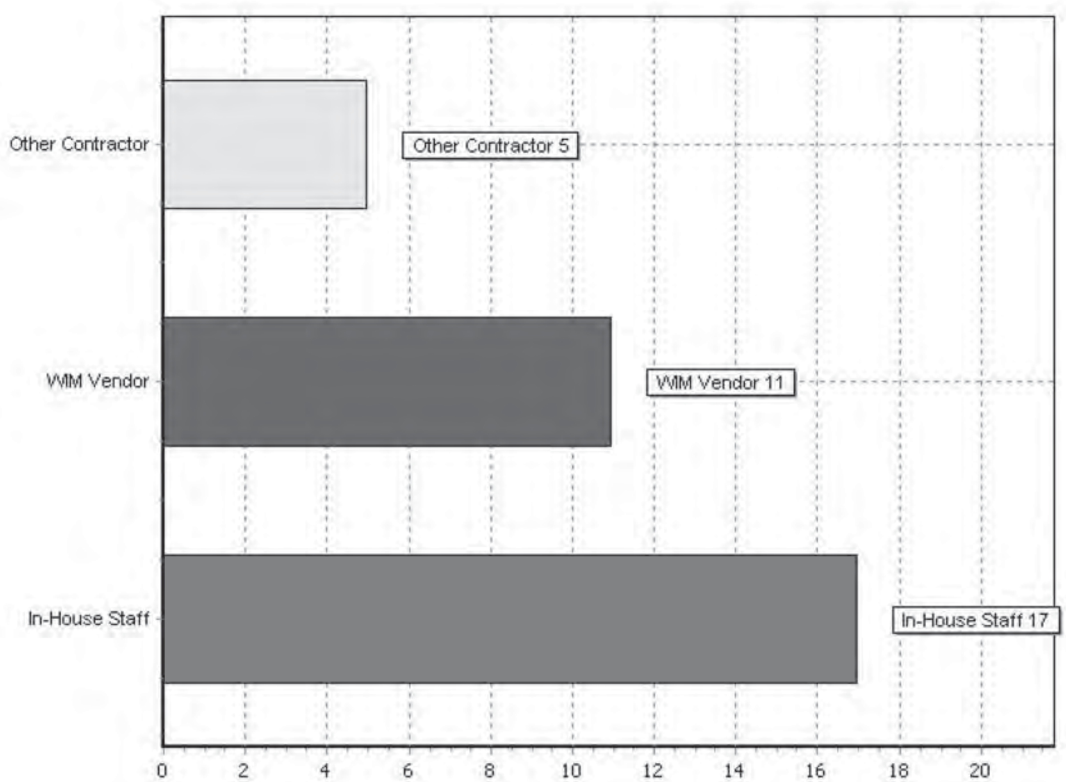
3.1 Is a post-installation system calibration always performed?



Comment Responses:

MT-Traffic: Post-installation calibration is performed on the Type II systems after they have seen at least 2 weeks of traffic with the default calibration factors in place.
NJ: 3 stage system calibration
AL-Traffic: We let the system autocal and make adjustments while on site. Then check the weights from the office for the next week or so.
ID-Traffic: Based on first axle weights from traffic stream -- NOT vehicle of known weight.

3.2 Who performs this post-installation calibration? Check all that apply.



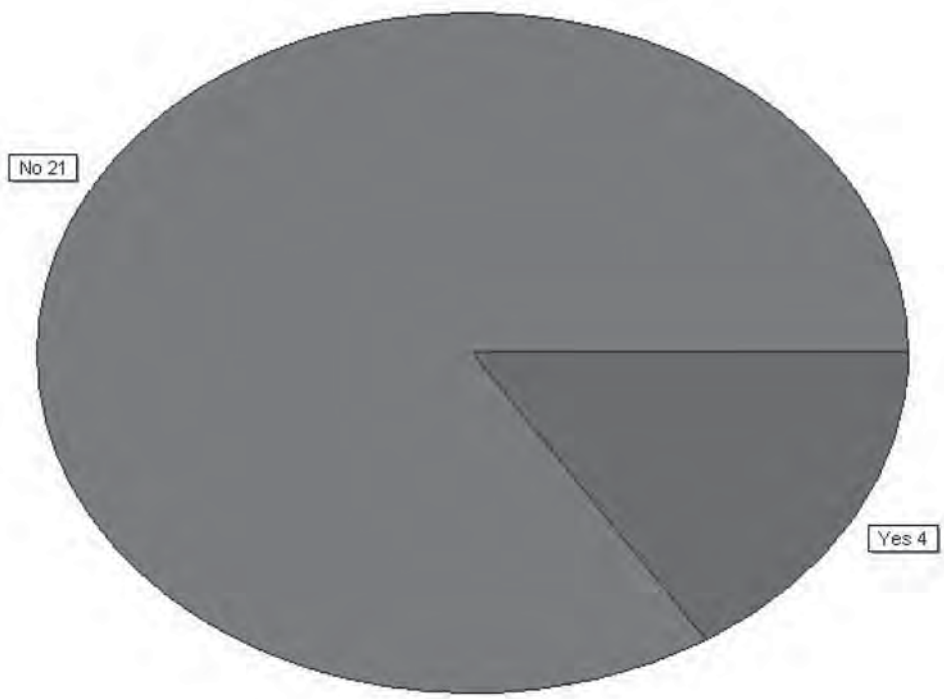
Other Responses:

CT-R: We traditionally have the WIM vendor conduct the initial calibration, but have an in-house staff person present for all aspects of the process.

Additional comments:

NJ: Vendor performs hardware testing and initial calibration. Then, two weeks of data is then analyzed in-house before final acceptance.
AK: IRD employs a subcontract to complete calibrate (2X year spring and fall) and maintenance in AK. The sub was previously employed by IRD.

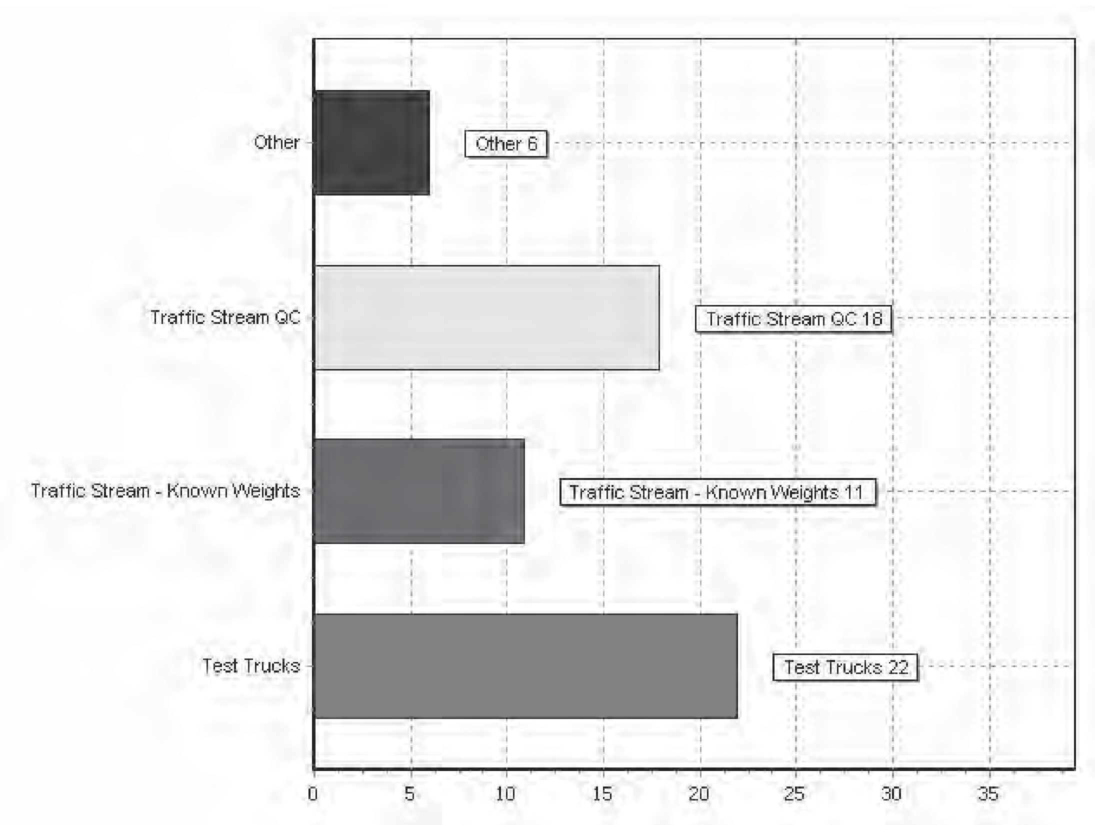
3.3 Is the post installation calibration procedure any different than the routine calibration?



Additional comments:

WA-Traffic: Using traffic stream instead of known weigh truck.
AK: Only a single class type is used...type9.
TX: Calibration of Speed and Axle Spacing, Vehicle Length, and Front Axle

3.4 Which methods do you use for the evaluation/calibration of high speed WIM systems throughout their lives? Check all that apply.



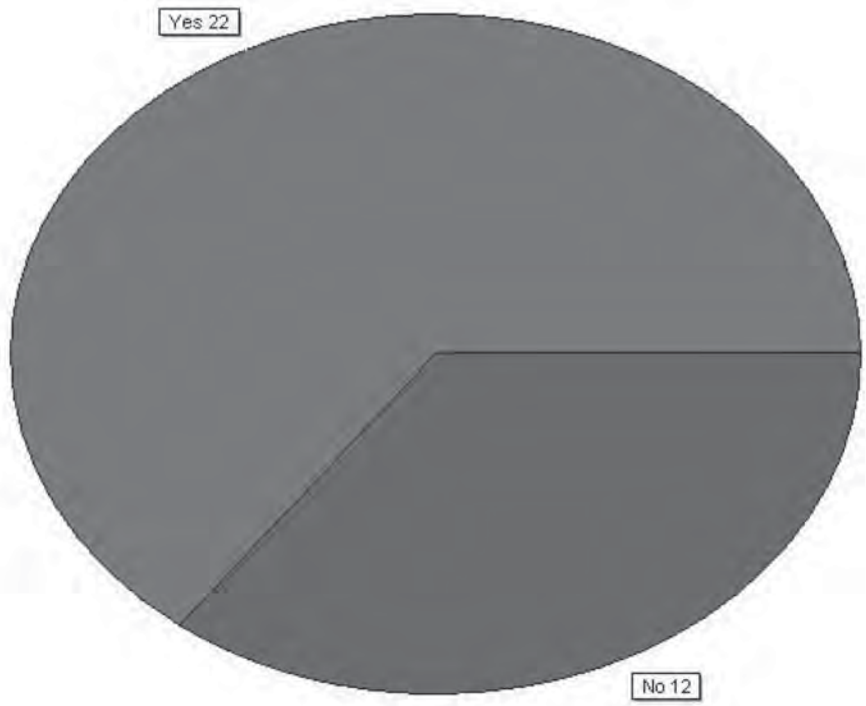
Other Responses:

CT-R: Have used all three and combinations of. Primary basis: multiple test trucks.
MA: Only using auto-calibration feature Peek Traffic ADR 2000.
AL-Traffic: We perodically check the steering axle weights of loaded class nine trucks
UT: Post collection calibration
TN: Counters self-calibrate with known number of trucks.
IL: IL none
NH: We only calibrate with trucks when new sensors are installed.

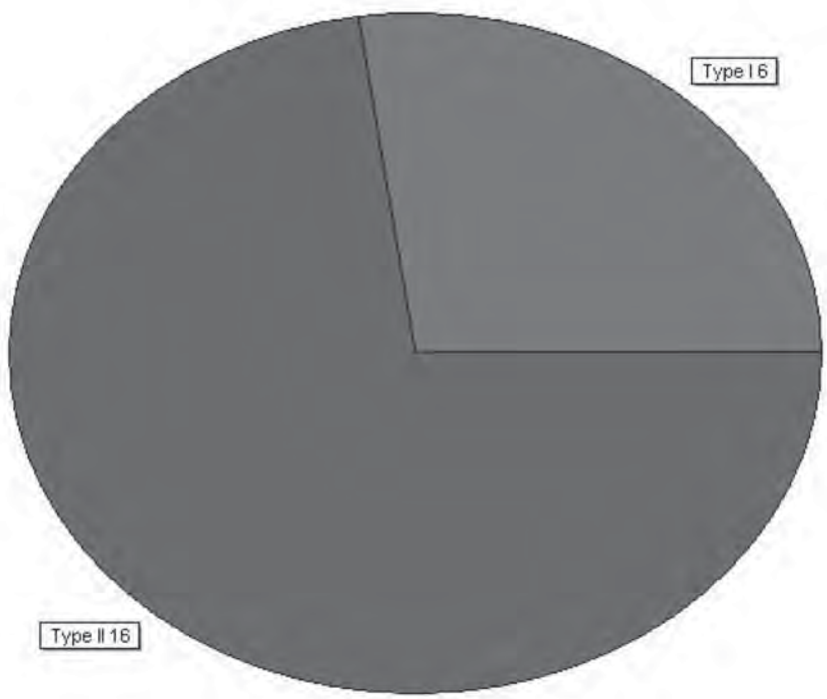
Comment Responses:

MT-Traffic: Known traffic stream evaluation is only conducted if the site is located near a scale house (such as a Pre-Pass WIM site). Currently, this is only on Type I systems (Kistler sensors)
NJ: Calibartion with test truck once every 2 years and adjusted as needed based on WIM Calibration Monitoring of 5-axle semi trailers.
AL-Traffic: Ideally the systems would be checked each year on site using a class 9 of known weight. But we currently lack the manpower to do this.
In NH we do not run calibration trucks on a regular basis over the lifetime of the sensors. Auto calibration is the only calibration done.

3.5 WIM On-Site Evaluation/Calibration Procedures Using Test Trucks NOTE: The majority of the questions under 3.5 relate to the general provisions of the ASTM Standard E1318-02 and the LTPP WIM System Calibration Protocol. They are intended to determine which parts of these standards your unit may be using. Do you perform on-site evaluation/calibration using test trucks?



In the series of questions under 3.5 please describe the procedure you use for the MOST COMMON WIM type in your unit (department/division/agency). What is the most common WIM type in your unit for which test trucks are used for calibration?



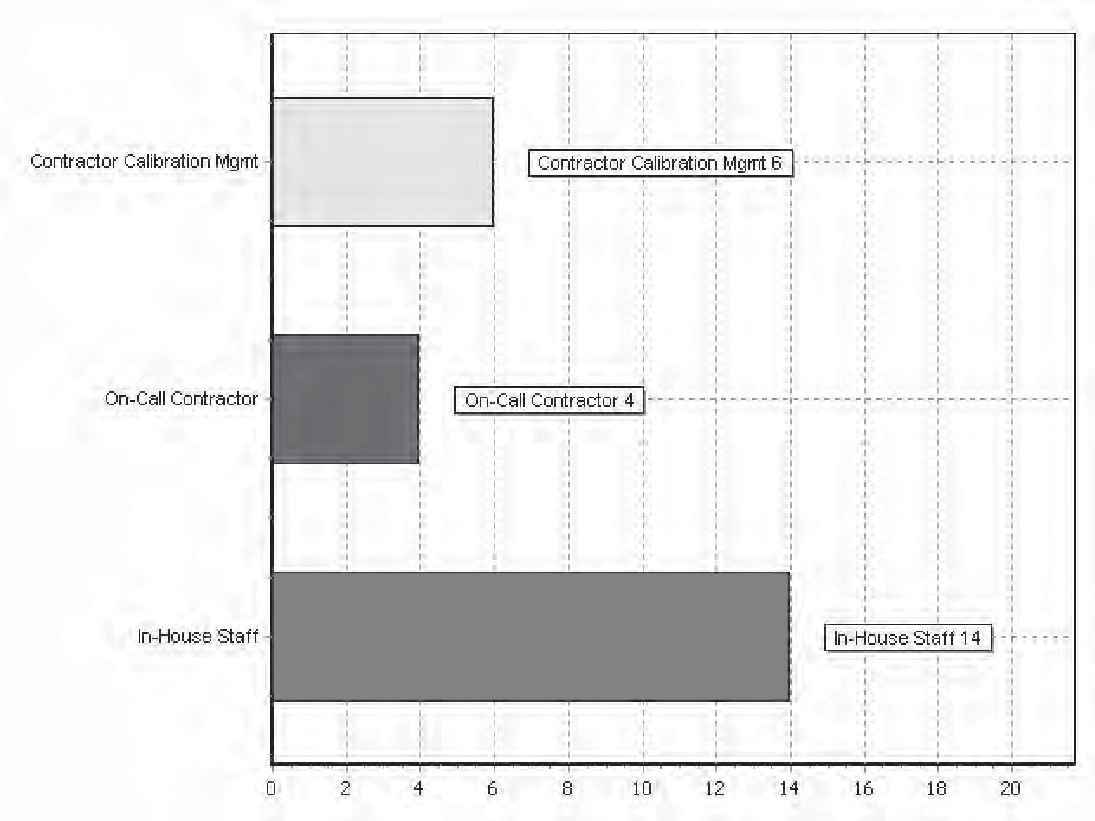
Other Responses:

IN-Traffic: Piezo, then SLC

Comment Responses:

NJ: We only used loaded 5-Axle Single Trailer Trucks for calibration
We have one type I bending plate site in which a test truck is utilized as well.
TX: We are trying to get away from Thermocoax sensors

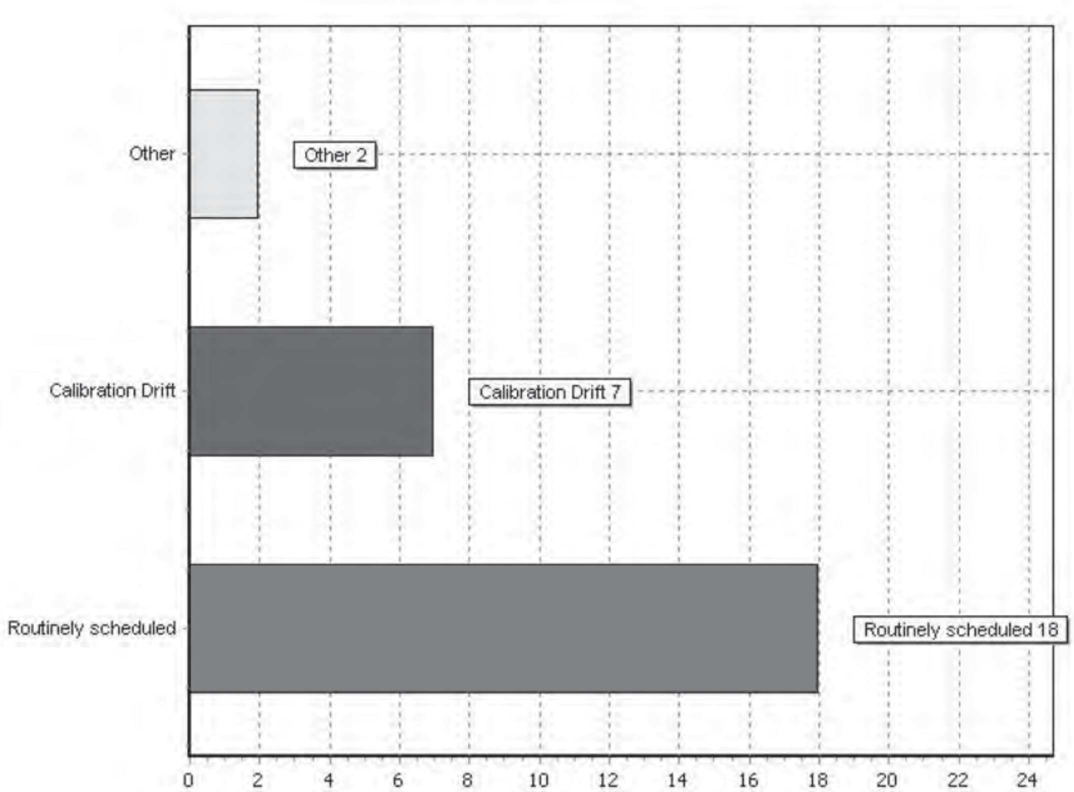
3.5.1 Who conducts these on-site evaluation/calibration activities using test trucks? Check all that apply.



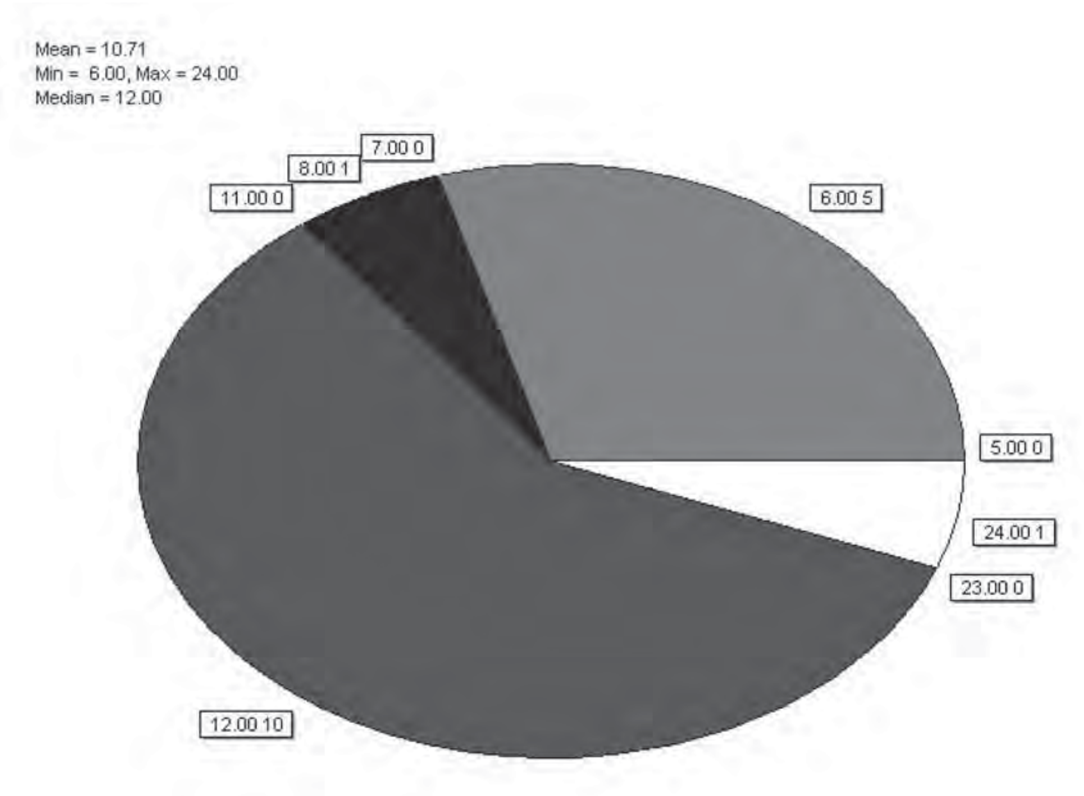
Additional Comments:

NJ: The initial calibration is done by contractor/vendor included in the installation and then by in-house staff every 2 years.
NY: Staff include those from Traffic Monitoring Section, NYSDOT Residency closest to the WIM site, and NYS Troopers to statically weigh the test vehicle.
AK: Contract with WIM vendor for maintenance and calibration. Will try to meet with contactor.

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions. 3.5.2 What is the criterion you use to initiate test-truck WIM calibration? Check all that apply.



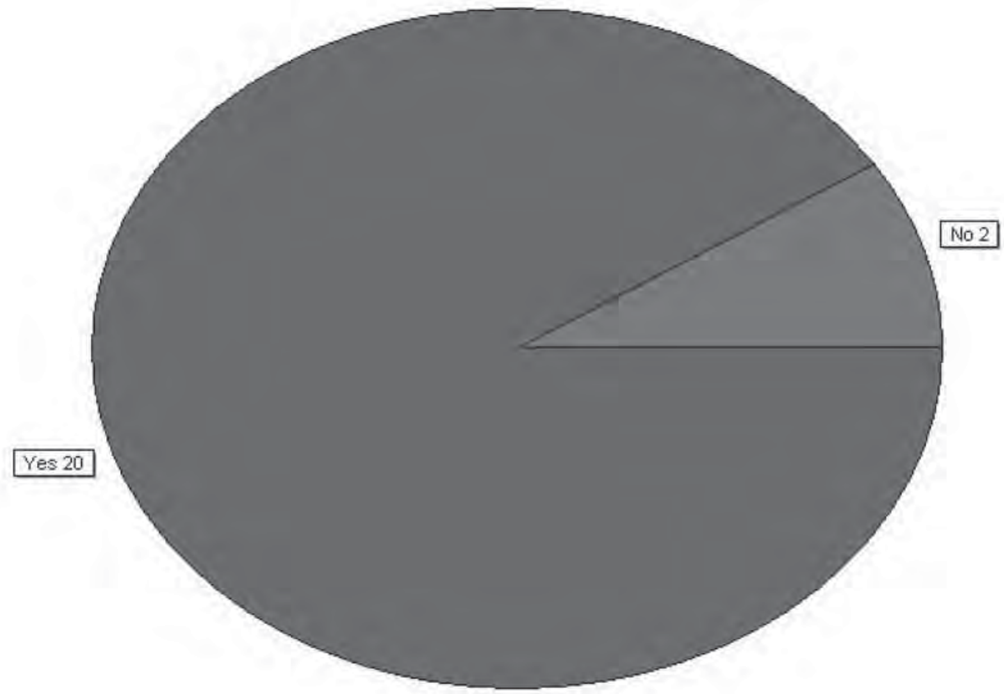
If routinely scheduled, specify typicalinterval (months):



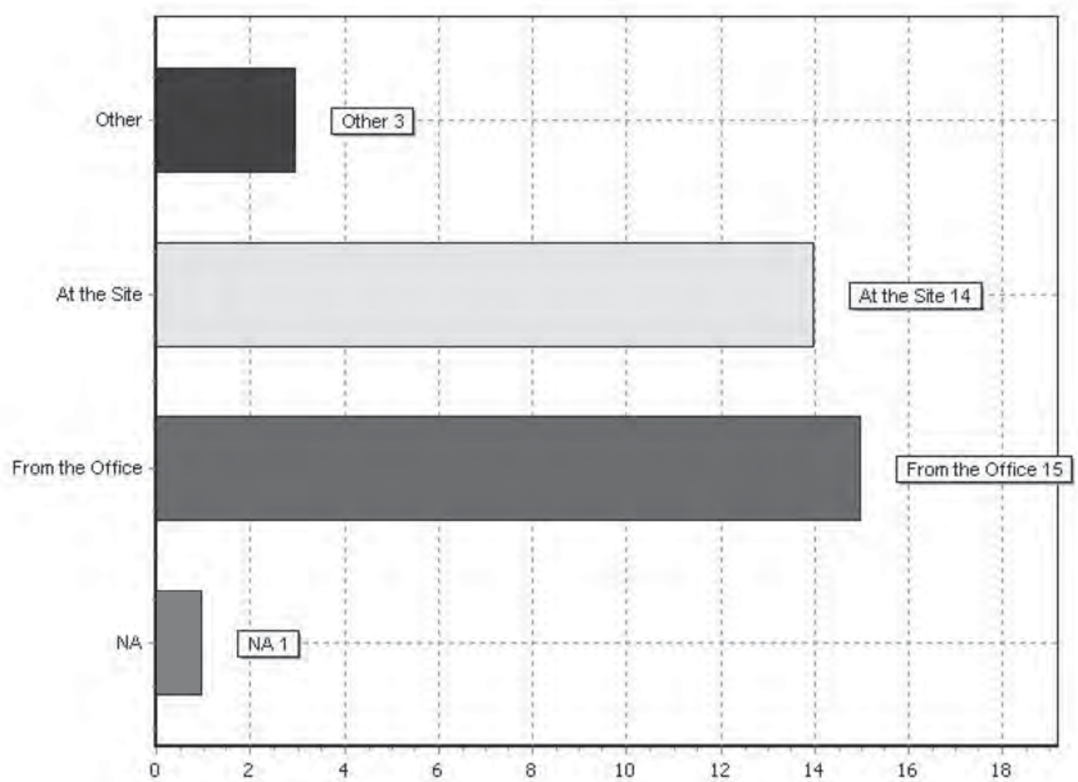
Additional comments:

FL: My WIM systems are calibrated whenever they are first installed; whenever any major component is replaced; and whenever the data indicates a drift in GVW distribution; the average steering axle weight of a large sample (more than 100) of class 9 trucks falls outside the range of 9000 - 12000 pounds; or the average drive axle spacing falls outside a 4.1 - 4.3 foot range. And two of my LTPP WIM sites are calibrated annually by FHWA as part of the pooled fund project.
MT-Traffic: We typically calibrate each site twice per year, once in the spring and once in the fall. Calibration in Montana is somewhat weather dependent. Data from each site is monitored and reviewed on a weekly basis for error trends or changes in traffic stream makeup (QA/QC checks) using reports generated by our traffic data processing software. Monthly calibration graphs are generated and evaulated for drift and truck weight characteristics as well. Additional calibration (outside of the scheduled calibration) may be performed on a system that has had sensorsor electronics replaced, or exhibits problems that requires the test truck for evaluation.
AR-Traffic: AHTD plans to begin routine calibration (bi-annual) of WIMs in late summer/fall of 2007.
NJ: We maintained over 60 WIM sites and tried to calibrate each site as often as as possible, when electronics are replaced or there is calibration drift.
VA-Traffic: This typically has been about twice per year
NY: All WIM sites are calibrated on an annual basis, except for sites such as I-495 in Queens that has traffic volumes that are too high to allow for a safe manual calibration of the system.
AK: 6 months is the ideal but not less than 5 months or greater than 7.
KS: scheduled annually, not always done
TX: 12 months for Bending plate and 6 months for coax

3.5.3 Do you have procedures for conducting diagnostic tests to ensure proper operation of the WIM system prior to committing to a complete on-site evaluation and/or calibration?


No 2
Yes 20

If Yes, how are these diagnostic tests conducted? Check all that apply.



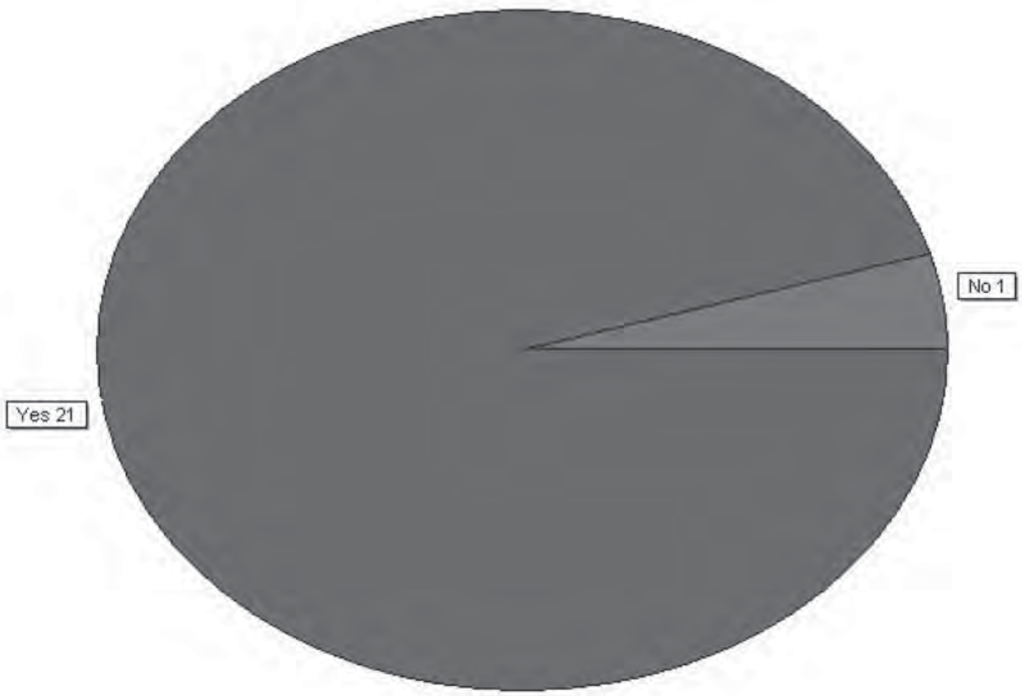
Other Responses:

CT-R: Check sensor output, check reasonableness of data.
PA: Vendor calls site to diagnose the counter
RI: real time viewing of traffic
AK: scope traces are evaluated,

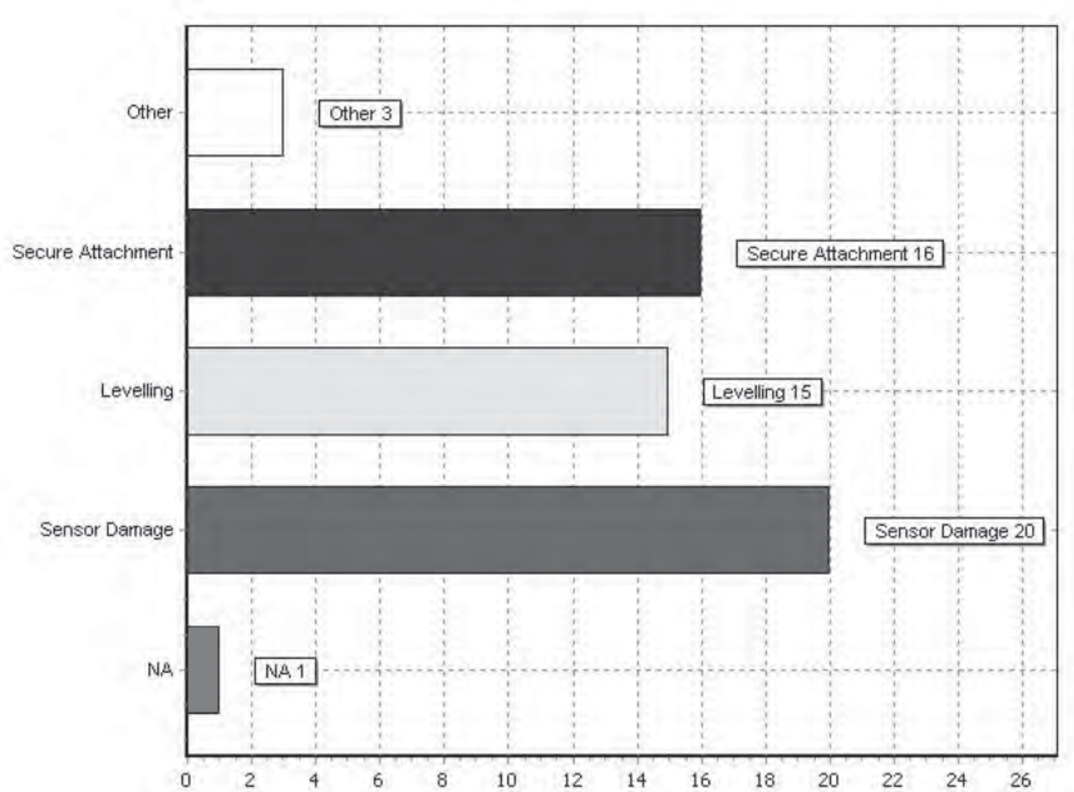
Comment Responses:

MT-Traffic: Sites to be calibrated need to be running "normally" a minimum of 2 weeks prior to calibration, or they get scheduled at a later time.
PA: Data can be analyzed from the office
AK:...an "as recieved" 5 pass test preceeds baseline tuning followed by the optimization tuning before the final 10 pass test.

3.5.4 Do you have procedures for inspecting the condition of the WIM sensors?



If Yes, on which of the following do you perform a visual inspection? Check all that apply.



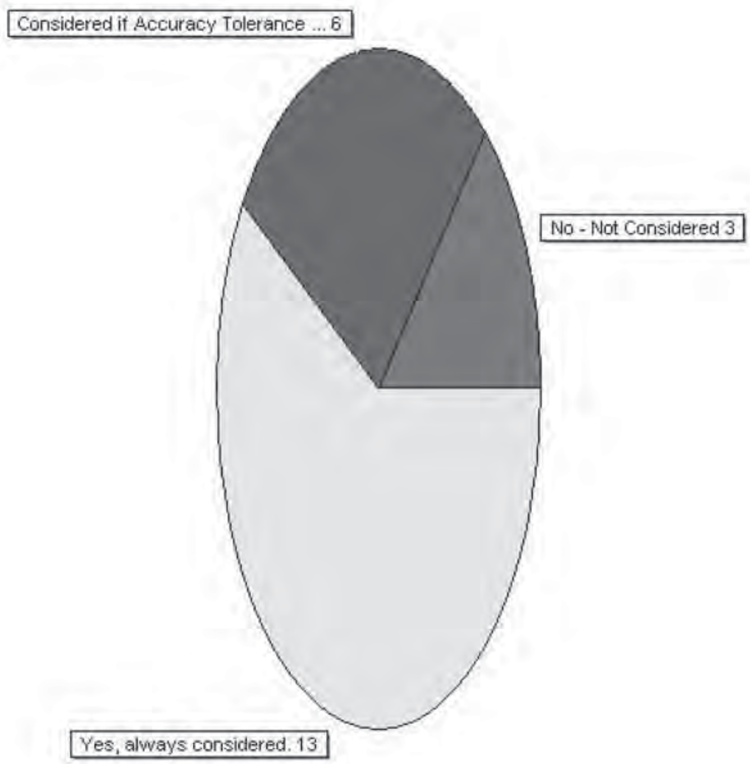
Other Responses:

CT-R: meter at cabinet for sensor output
NJ: Sensor connectors to the electronics
WY-Traffic: Oscilloscope Measurements
OK: Digitaly Measure Sensor's outputs

Comment Responses:

MT-Traf: Other checks are performed as well including inspection of pull boxes, conduit, and wiring along with the condition of the cabinet and solar panel (if applicable). We also inspect the roadway for visual signs of decay or topography changes.
NJ: Visual inspection of loops and sensors is performed every site visit
AK: twice annual mounting hardware checks are conducted.

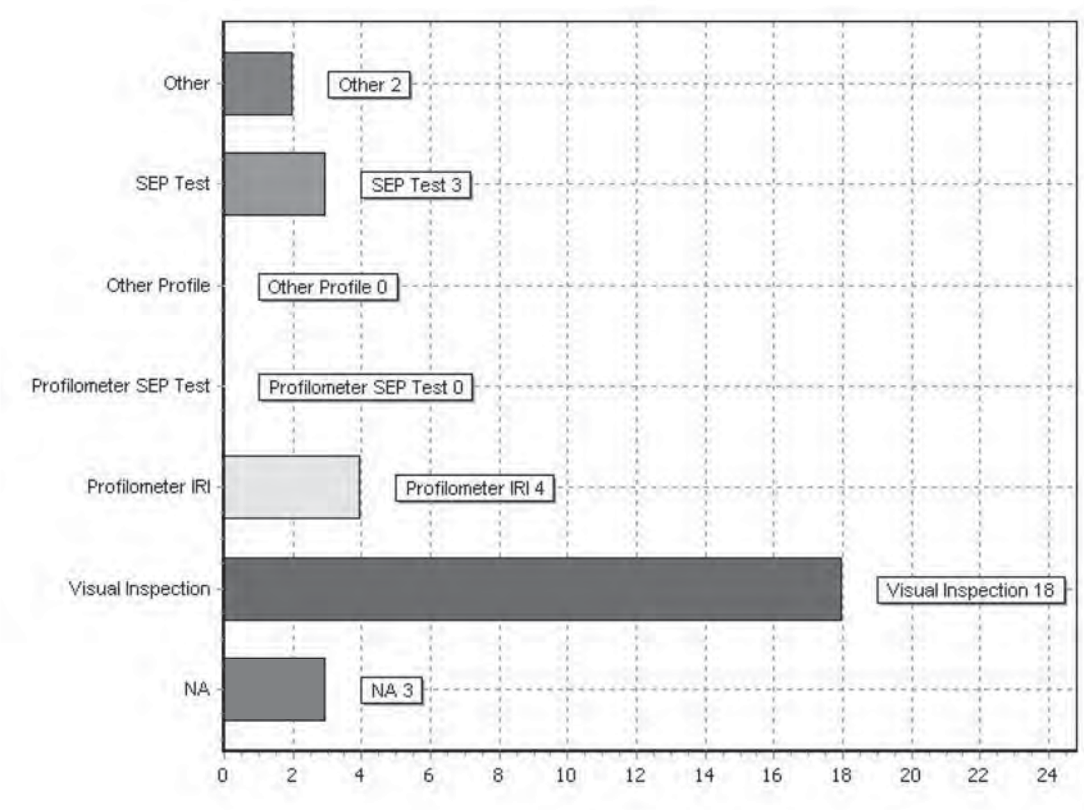
3.5.5 When conducting test-truck WIM calibrations, do you consider the pavement smoothness at the WIM site?



Comment Responses:

MT-Traffic: We make note of any visual damage and get a verbal report from the test truck driver as well.
AK: 330' concrete pads, that were correctly profiled upon installed are used at all sites...the long studded tire season here does cause degredation i.e. wheel rutting, common to asphalt elsewhere requires the addition of grout builup to maintain
KS: Most type-II were placed to fit SHRP sites
TX: I consider this critical

In cases where the pavement smoothness is considered which methods are used? Check all that apply.



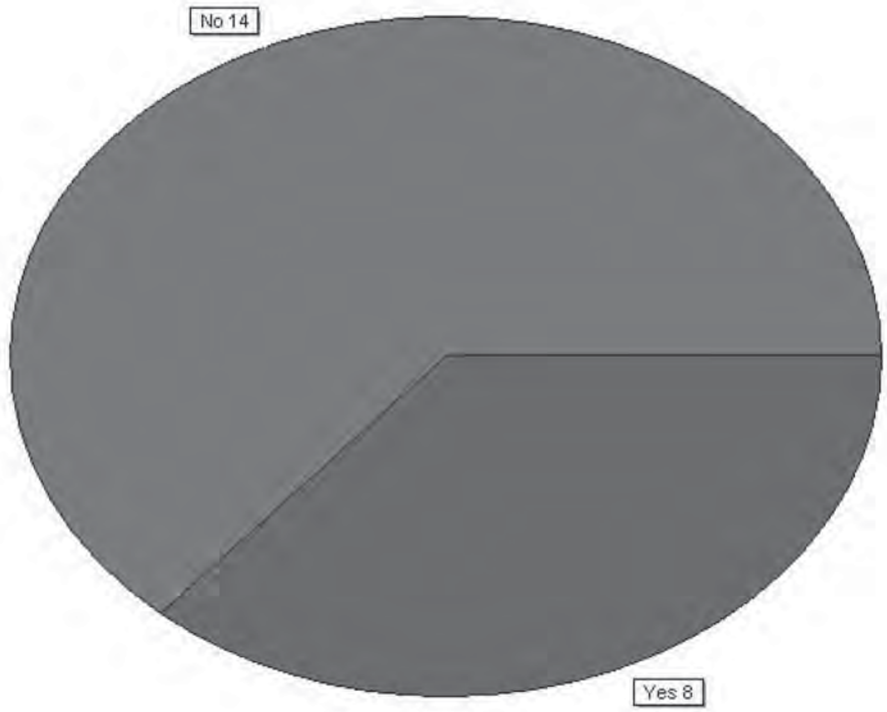
Other Responses:

MT-Traffic: We watch not only our test truck, but other types of trucks as well.
OK: Calibrations factors are unstable

Comment Responses:

VA-Traffic: We use the LTPP WIM Smoothness Software to get the LRI and SRI

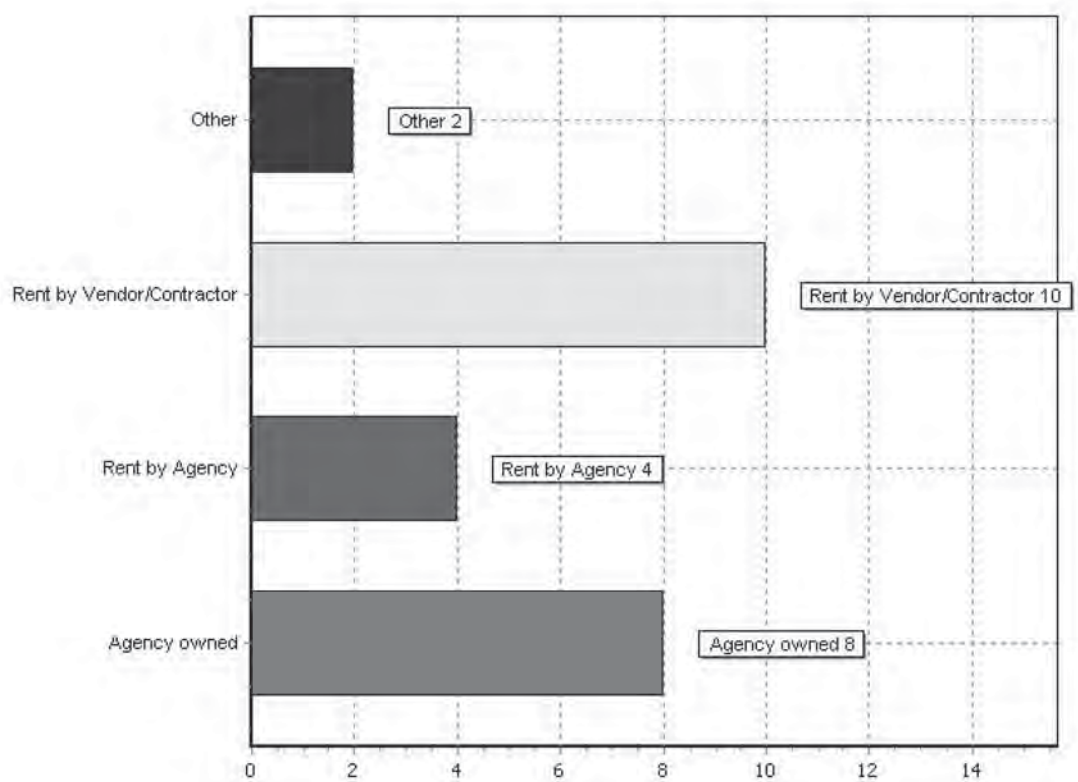
3.5.6 In conducting WIM calibrations with test trucks, do you consider the structural condition (deflection) of the pavement supporting the WIM sensors?



Comment Responses:

CT-R: So not have FWD, consider deflection when selecting site based on pavement structure.
MT-Traffic: We capture sensor wave form output using the test truck on a storage oscilloscope. Wave form analysis, along with road construction data, allow us to assess structural condition.
We mainly look for signal noise coming from the WIM sensor that may be caused by a bad supporting structure for the WIM sensors.
NY: Visual
MS: Our WIM sites are chosen in locations where the pavement conditions are the best. If there is rutting in the pavement it can cause a truck to bounce and give inaccurate readings. If it is consistantly a problem the WIM site will be moved.
PA: Stored in the WIM system
AK: Portland cement pads provide consistency at all temperatures.
GA: Asphalt or Concrete
TX: Research Project

3.5.7 How are test trucks procured? Check all that apply.



Other Responses:

CT-R: Post-installation sometimes aquired by vendor, all other calibrations, DOT rents with operator. Negotiates who supplies load.
NJ: Using trucks owned by other state agency.
RI: Installation contractor provides test truck as specified in the contract

Comment Responses:

NJ: Calibration can only be done during Saturdays when trucks are not in use. NJDOT pays only the driver overtime and gas used.
NY: Trucks are provided by the Resident Engineer at the NYSDOT Residency closest to the WIM site.

3.5.8 How many test trucks are used by class or type?

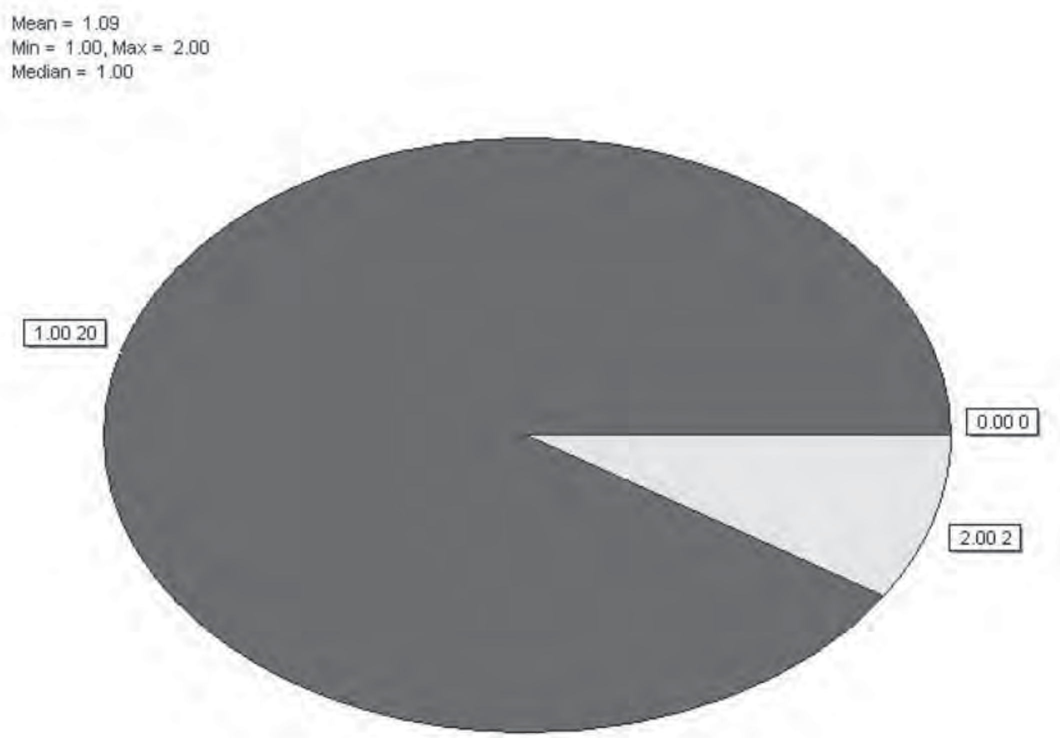
FHWA Class or Type	Number	FHWA Class or Type	Number	FHWA Class or Type	Number	FHWA Class or Type	Number	Additional comments (If more than 4 types are used please indicate the type (s) and number(s) here):
9	1							
9	2							CT-R: Over the years we have used many different configurations. Most recently we have used on box (5 axle) moving van, loaded with steel tiles. And one dump truck eveny loaded with tiles. We found it critical to the calibration to rent at least one of the same vehicles (not type- exact vehicle) from the previous calibration to baseline if the change is from the test truck or individual vehicles.
9	1							
9	1							
Class 9	1							
Class 9	1							
10	1							
Class 9	1							NY: Class 9 Lowboy with a dump truck filled with half a load on it.
9	1							
Scheme F Type 9	1							
vc 9	1							
Class 9	1							
9	2							
9	1							
9	1							
9	1							
9	1							
type 9	1							
9	1							
6	1							
9	1							
Type 9	1	Type 5	1					

FHWA Class or Type (3.5.8 How many test trucks are used by class or type?)

FHWA Class or Type
9
9

9
9
Class 9
Class 9
10
Class 9
9
Scheme F Type 9
vc 9
Class 9
9
9
9
9
9
type 9
9
6
9
Type 9

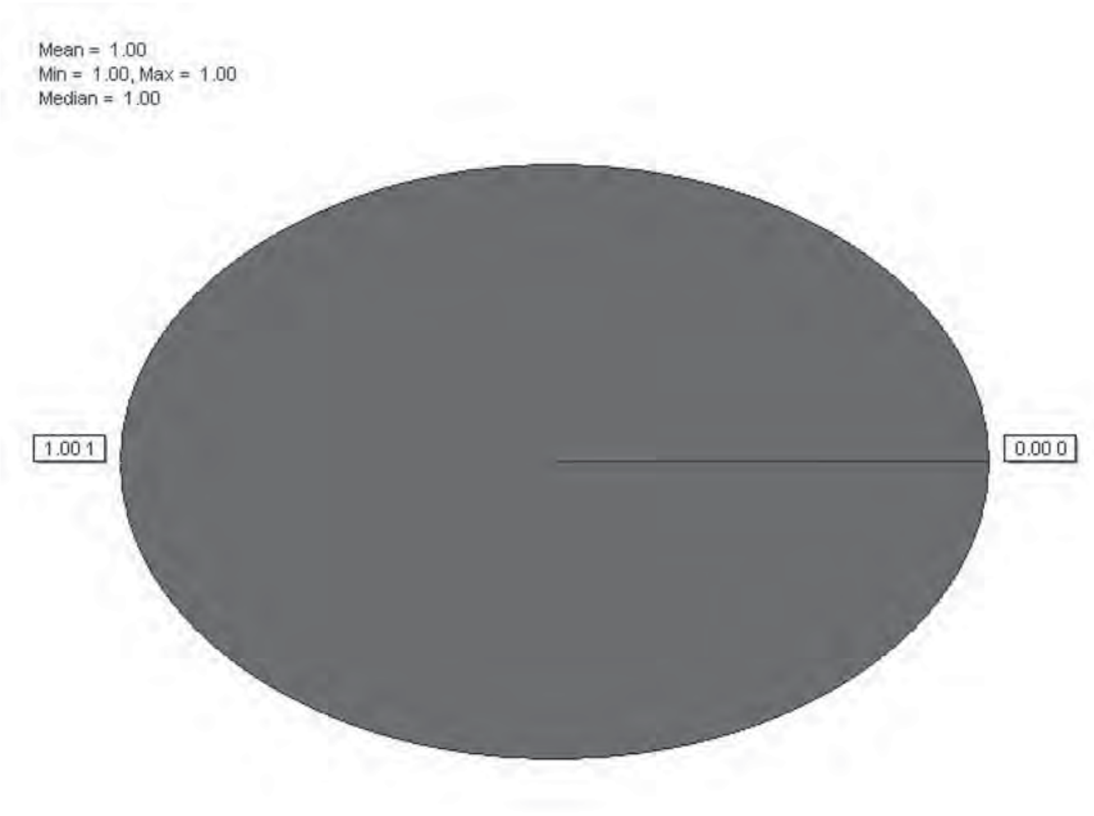
Number (3.5.8 How many test trucks are used by class or type?)


Mean = 1.09
Min = 1.00, Max = 2.00
Median = 1.00
1.00 20
0.00 0
2.00 2

FHWA Class or Type (3.5.8 How many test trucks are used by class or type?)

FHWA Class or Type
Type 5

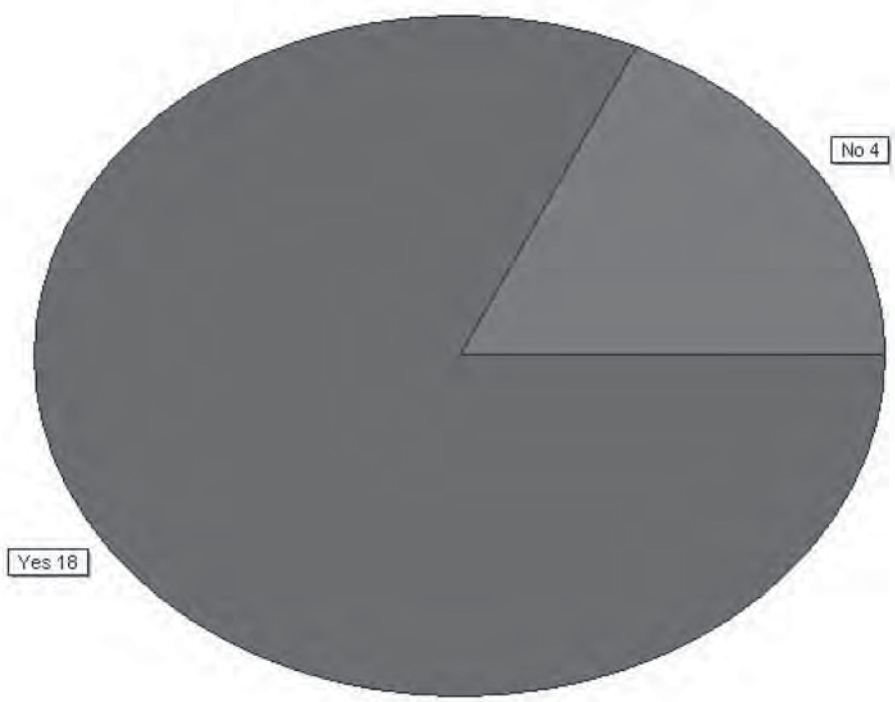
Number (3.5.8 How many test trucks are used by class or type?)



Additional comments (If more than 4 types are used please indicate the type(s) and number(s) here): (3.5.8 How many test trucks are used by class or type?)

CT-R: Over the years we have used many different configurations. Most recently we have used on box (5 axle) moving van, loaded with steel tiles. And one dump truck eveny loaded with tiles. We found it critical to the calibration to rent at least one of the same vehicles (not type- exact vehicle) from the previous calibration to baseline if the change is fromthe test truck or individual vehicles.
NY: Class 9 Lowboy with a dump truck filled with half a load on it.

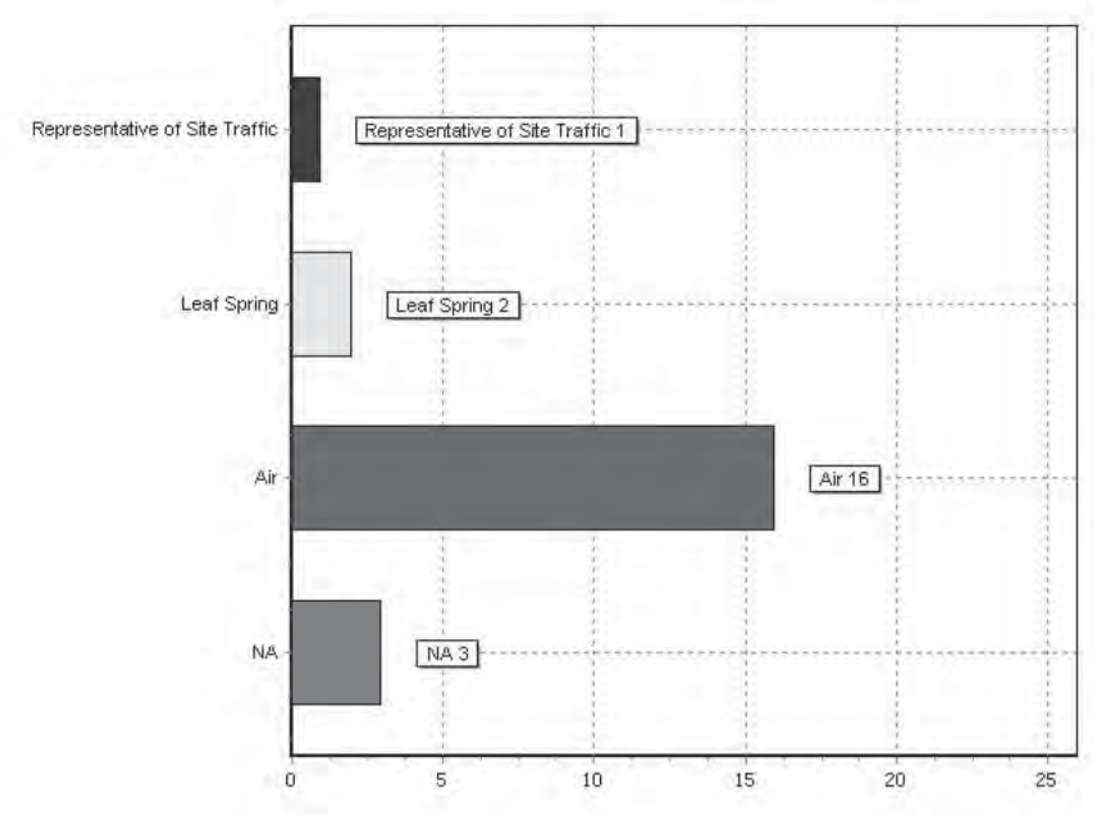
3.5.9 Do you specify the suspension type of these test trucks?



Comment Responses:

MD-Traffic: Don't specify but it always an air suspension
AK: leaf springs are prevalent to the general population

If Yes, which types are specified? Check all that apply.



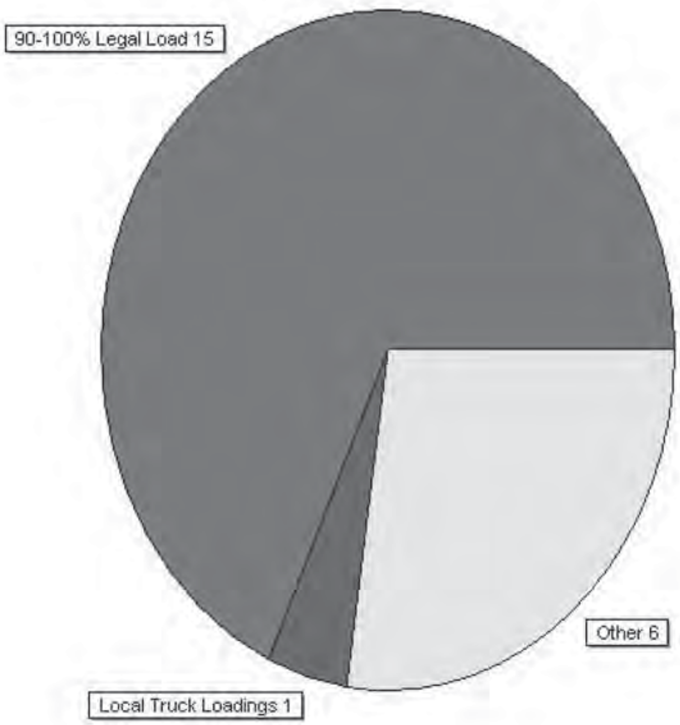
Other Responses:

CT-R: Often what you specifiy and what arrives at the site differ. Some vehicles are fully air-ride others say they are airride but it is on the trailer only. So you need to further specify.

Comment Responses:

NJ: Air suspension is preferred but not always used.
MS: Air ride trucks are used to help minimize the bounce that might be encountered.

3.5.10 What is your test truck loading criteria?



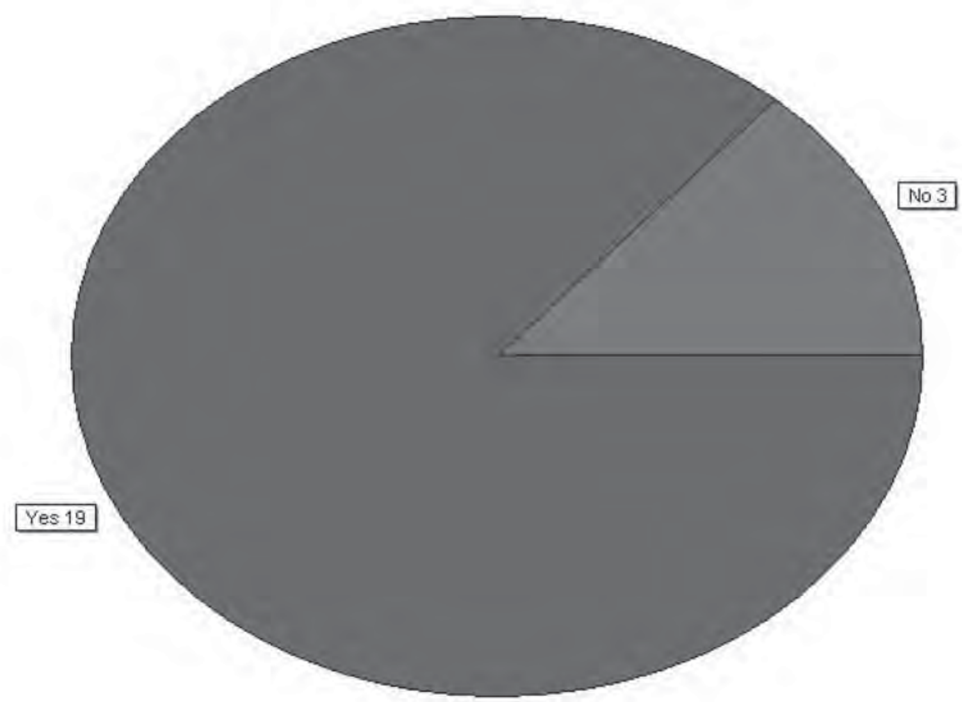
Other Responses:

CT-R: Fully loaded best they can. Often this is in the 60-70,000 lbs range. They tend to not load too full to save gas if they are rented on a contract hourly rate. The fuller load provides a stable vehicle. Have tried different loadings for research
VA-Traffic: Lowboy trailer with heavy piece of construction equipment, typically a loader or grader. GVW has been 63 to 75 KIPs.
NY: Loaded to approximately 80,000 lbs.
WV: 70,000 to 80,000

Comment Responses:

NJ: Axles configured with no bridge violation

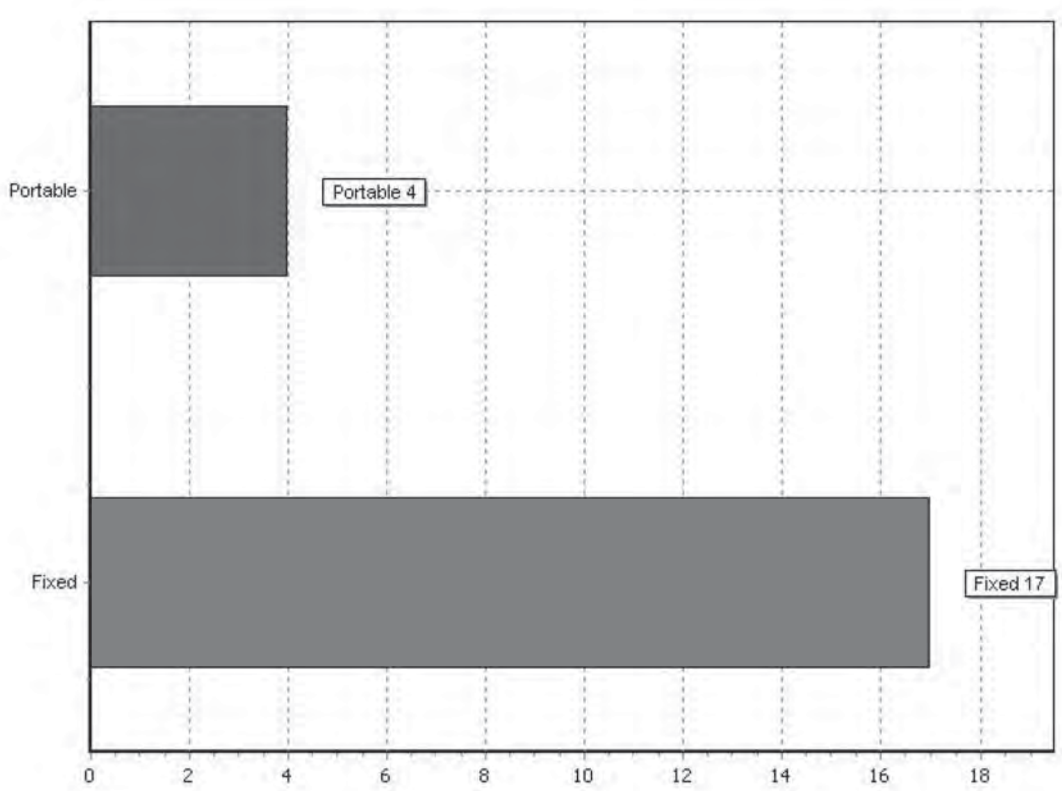
3.5.11 Please provide the following details on static weighing in conjunction with WIM calibration using test trucks. Do you require that static scales be certified?



Comment Responses:

MT-Traffic: Certification is the responsibility of Motor Carrier Services
WV Do not use static scales
MS: Our truck is weighed at MDOT truck scale facilities or at certified truck stops.
KS: Grain Elevator scales are common

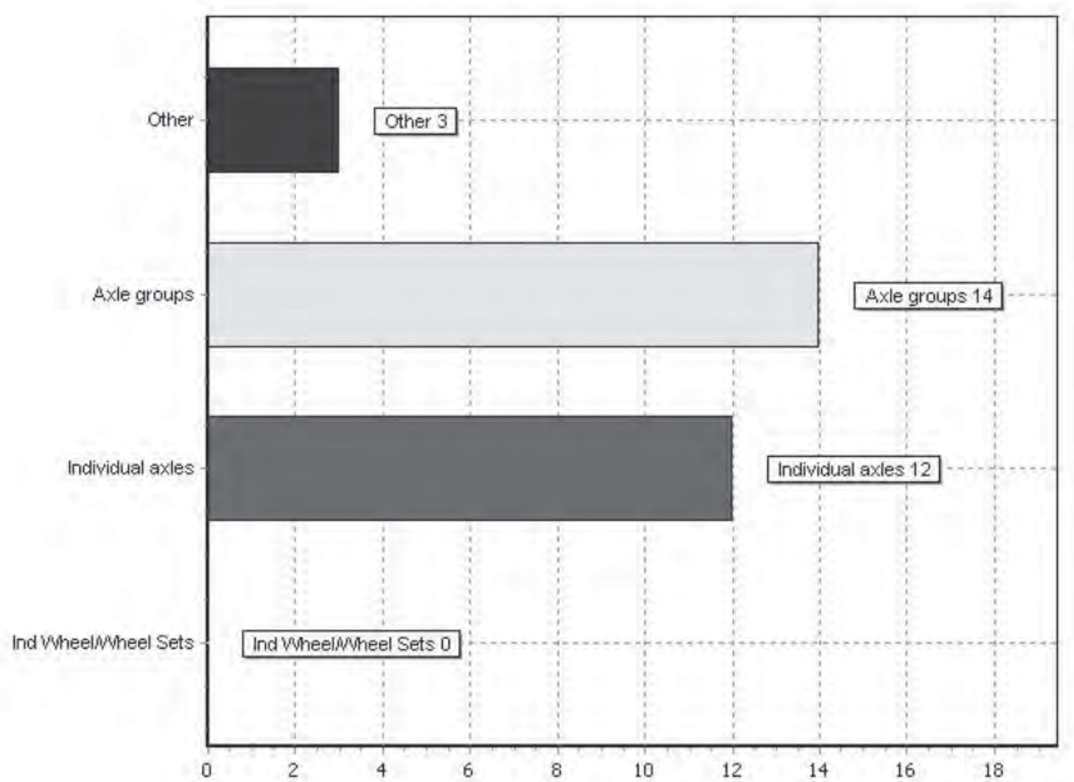
Which types of static scales do you use? Check all that apply.



Other Responses:

CT-R: Full-vehicle. This is important- some fixed, but the vehicle is on grade. Also require off brake.

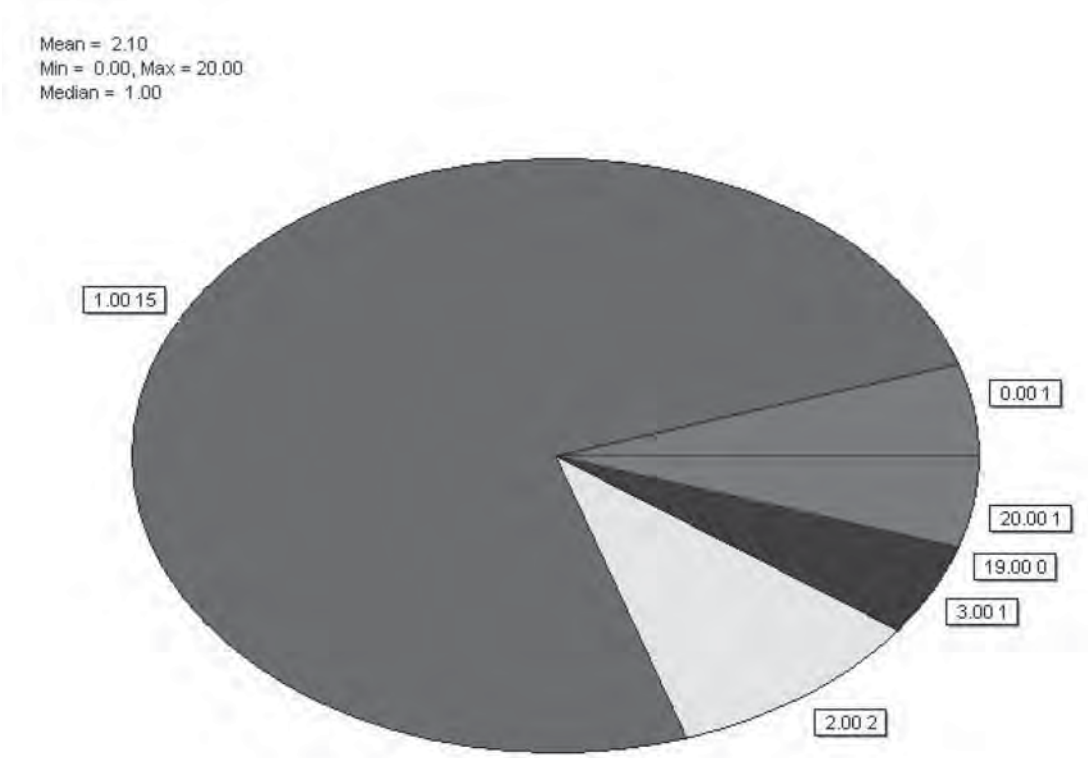
Which static weights are obtained? Check all that apply.



<u>Other Responses:</u>

FL: Also GVWT
CT-R: Roll on scale, therefore try to get by axle, but is more practical by axle group.
NJ: Front axle and GVW only
NY: Individual wheel/wheel sets are obtained and axle weights are calculated for each axle.

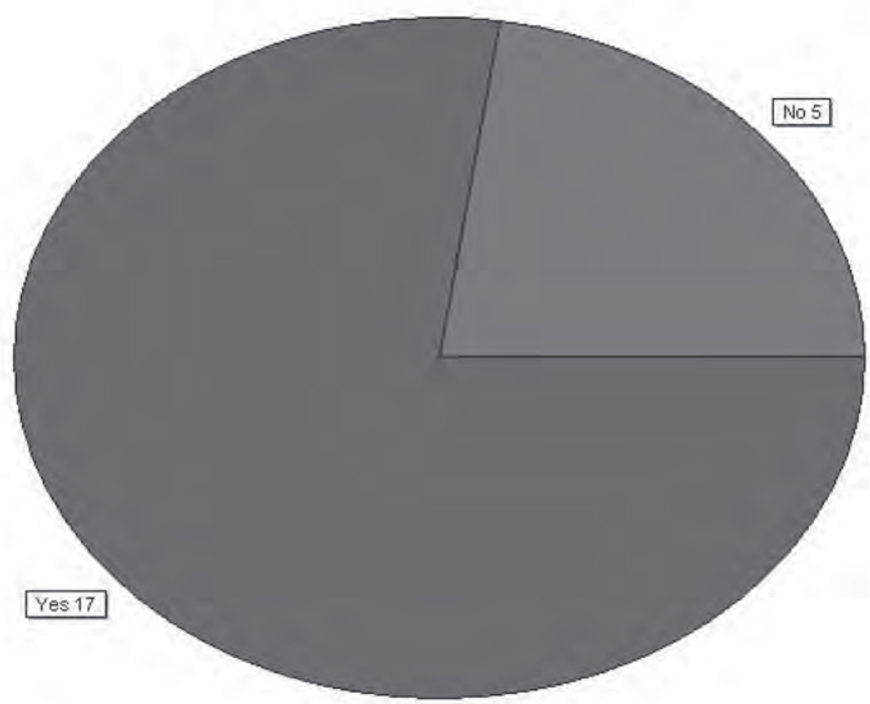
How many times is each static weight measured?



Additional comments regarding static weight practices:

MT-Traffic: Static weight is taken at the nearest scale house as often as is possible. In Montana, there are many more WIM systems than there are static scales sites, and many of those static scale sites are not manned 24/7. We weigh the truck as often as possible over the six week period in the spring, and the six week period in the fall, that comprises our calibration time.
VA-Traffic: This is done by a mobile enforcement crew using their established procedures. All wheels/wheel sets are weighed simultaneously on level ground with brakes locked. This uses 12 portable scales for a 6 axle tractor trailer.
MS: Our test truck is also weighed at MDOT truck scales when calibration sites are in close proximities.
AK: the second weight check will exclude the last weigh pad.
OK: Once before each WIM site is calibrated.

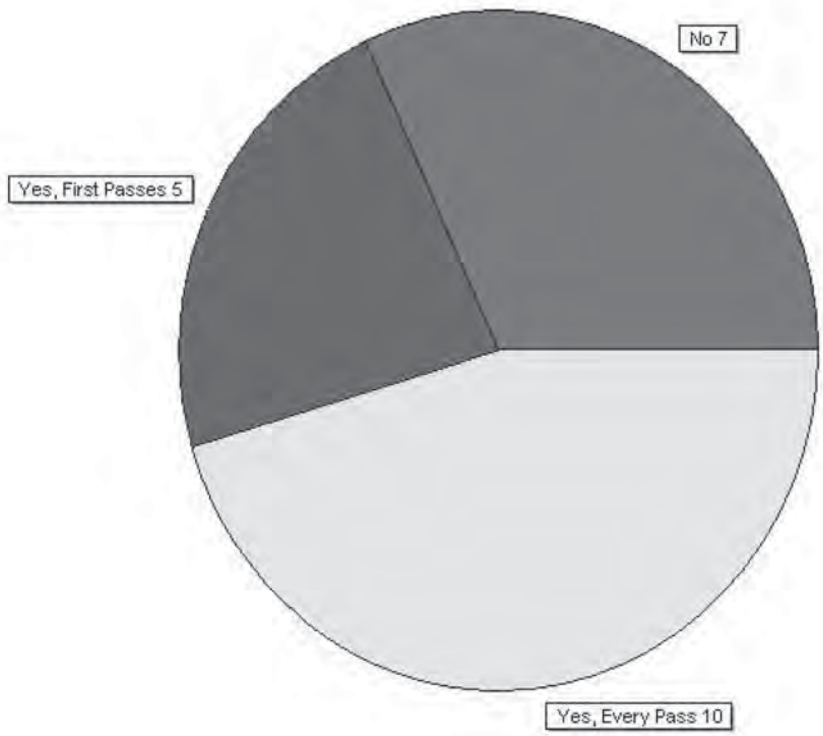
3.5.12 Are the axle spacings for each test truck measured?



Comment Responses:

NY: Distances between the test vehicles axles are measured in feet
MS: Axle spacing is looked at on a daily basis for the WIM sites as a QA/QC. If any spacings are out of tolerance, it is looked at immediately. However, at the time it is not a requirement during calibration with test trucks.

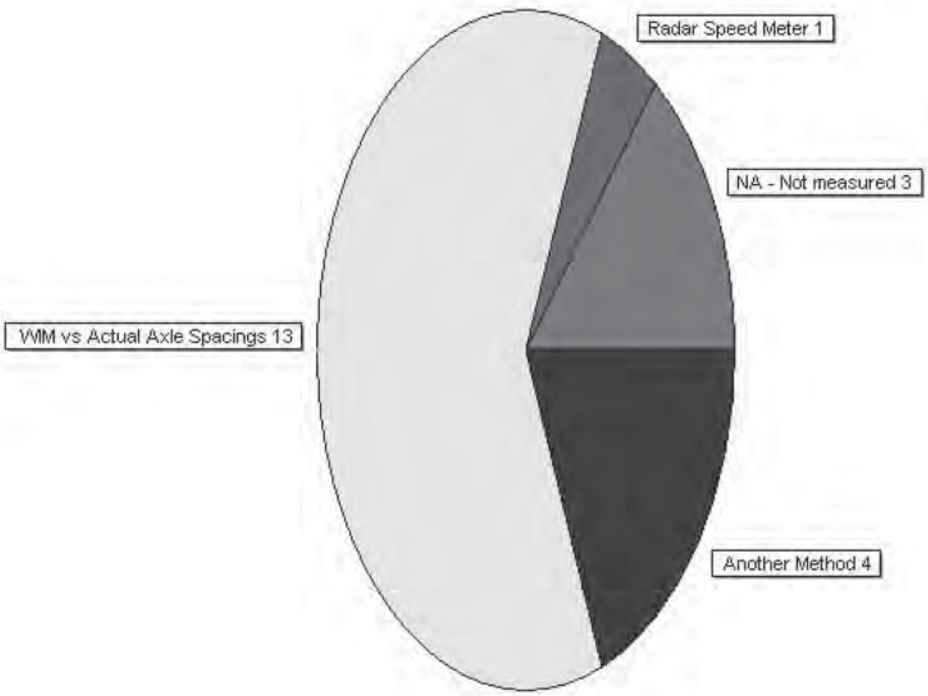
3.5.13 Are the test truck speeds measured as they cross the sensors?



Comment Responses:

MT-Traffic: We record WIM speed on every pass. It is verifed against the axle spacing.

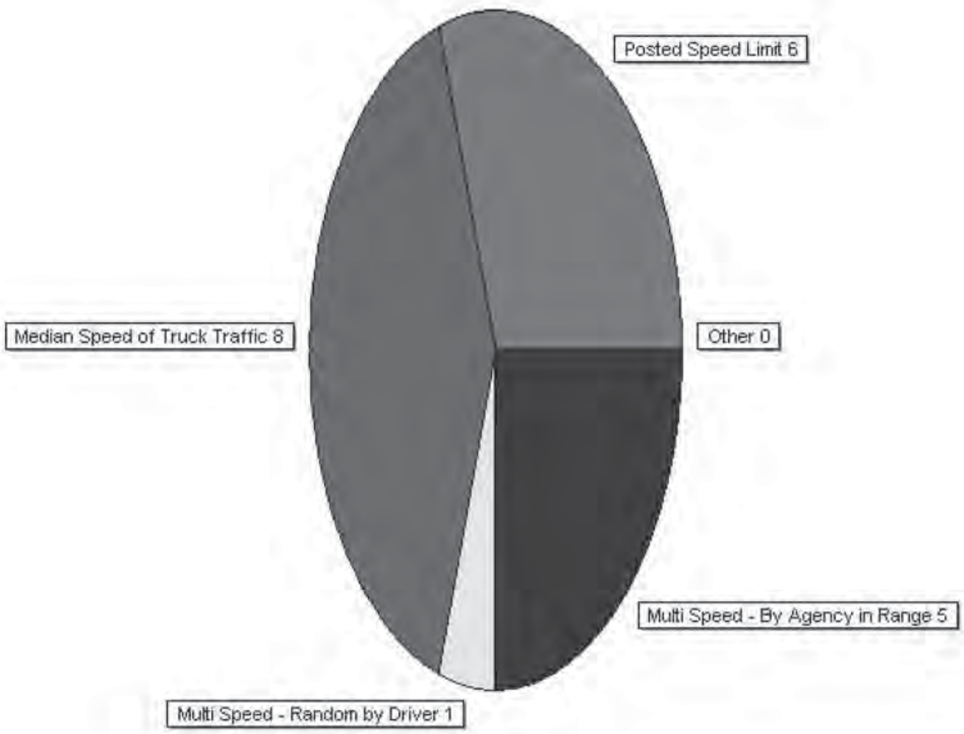
3.5.14 How is test truck speed measured?



Comment Responses:

CT-R: All are checked during the post-installation, after that WIM speeds are compared to truck speedometers, lengths are checked and if something is really off, usually there is a breakdown.
NJ: Speed is also check using radar speed gun.
NY: Speed is recorded from the counter display on a laptop computer that is connected to the site through our TRAFMAN software.
WV: Speed of test truck
GA: Speedometer in test truck

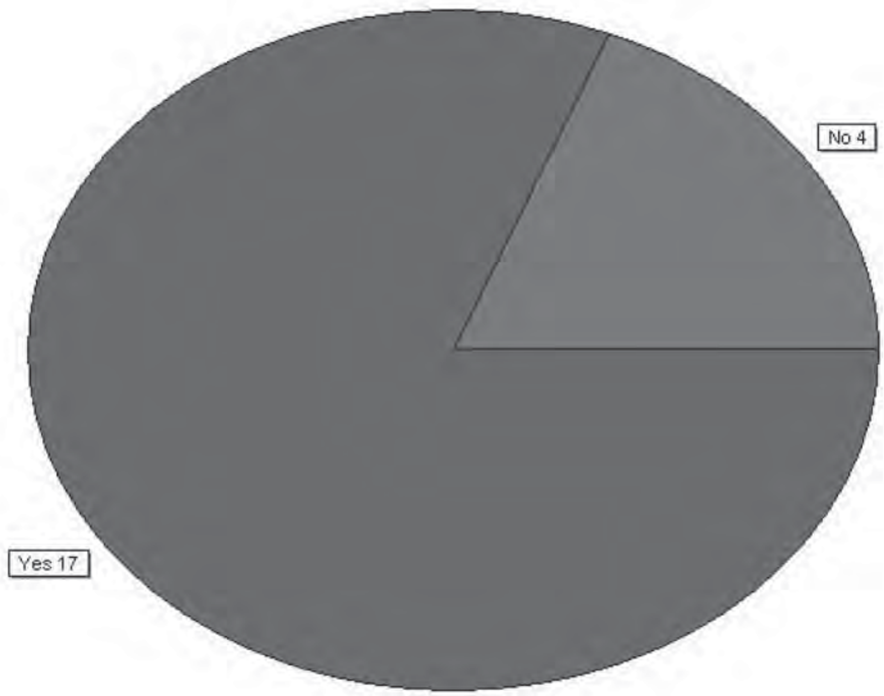
3.5.15 At what speeds do the test trucks run?



Comment Responses:

CT-R: At other location, 2 lane rural- uses posted speedlimit (35)
MT-Traffic: Speed limits in Montana are different for trucks than for other vehicles. We run as close to the posted speeds as we can. Some WIM sites are located in areas where the truck cannot reach the posted speed limit (due to road topography).
WV: 50-55 for lower speed roads and 65-70 for high speed roads
KS: Prevailing speed, or as fast as able. Avoid acceleration over scale

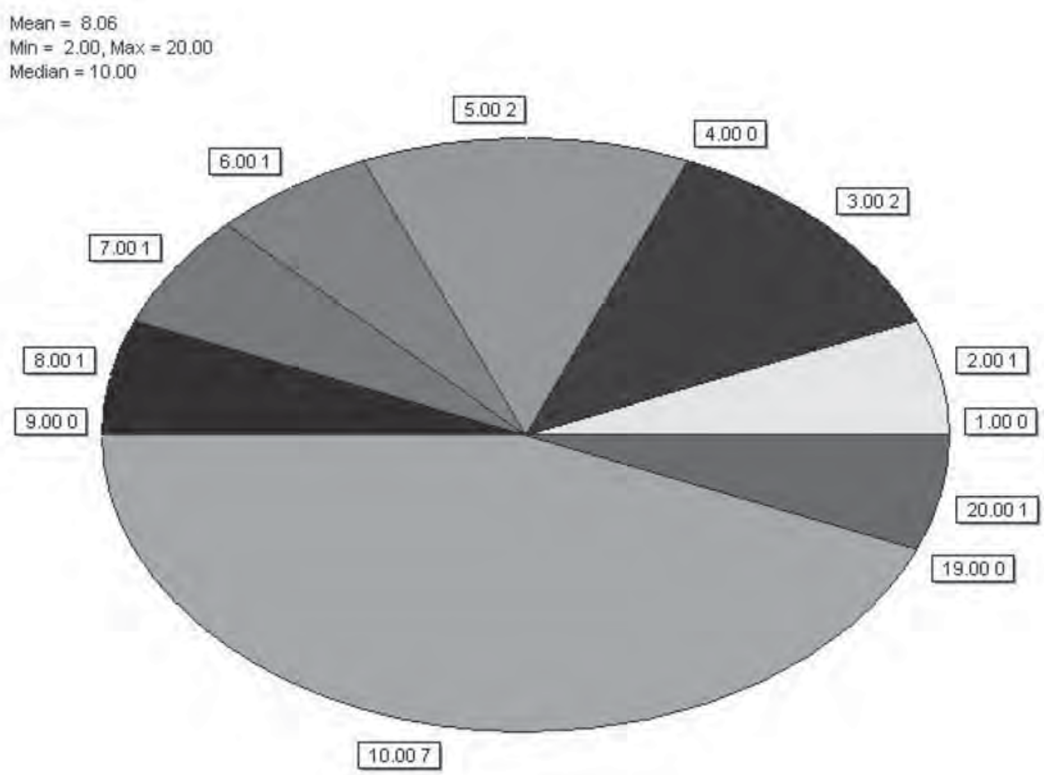
3.5.16 Is there a minimum number of test truck runs required at each speed?



If Yes, please specify the minimum number of runs:

Number of runs for each speed.
3
5
6
10
5
10
10
7
3
20
10
10
10
8
10
2

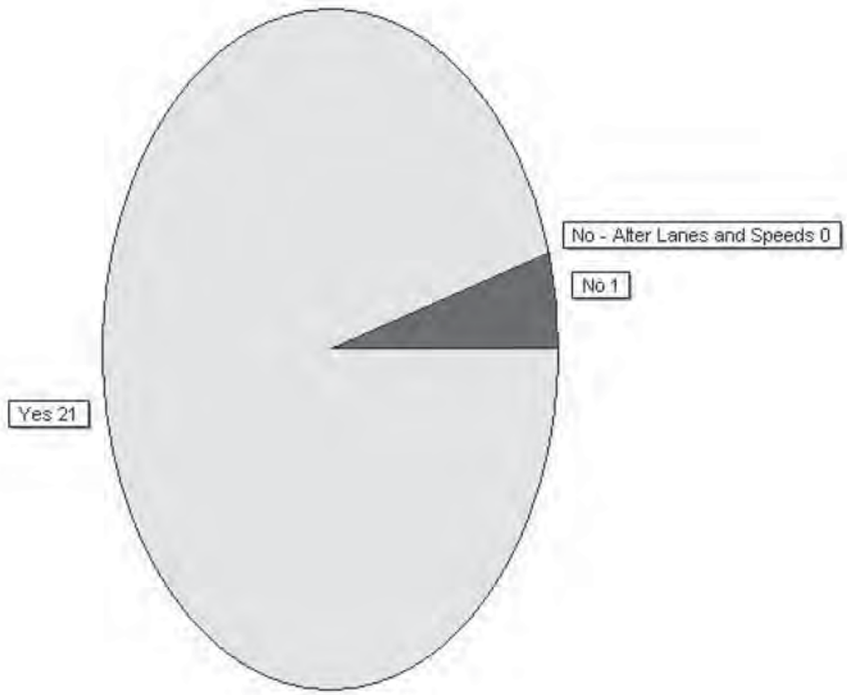
Number of runs for each speed. (If Yes, please specify the minimum number of runs:)


Mean = 8.06
Min = 2.00, Max = 20.00
Median = 10.00
5.00 2
4.00 0
6.00 1
3.00 2
7.00 1
8.00 1
2.00 1
9.00 0
1.00 0
20.00 1
19.00 0
10.00 7

Additional comments:

MT-Traffic: One pass is made in each lane to take raw sensor output data on the oscilloscope. Five passes are made in each lane to record the WIM data that will be used to determine calibration factors for the system.
NJ: 5 runs or or more until enough consistent weight is obtained.
MS: The seven runs have to be consecutive and withing tolerance.
AK: 10 passes after optimum cal factor is identified.
KS: I would stop with 4 if the weights are within the readout precision.

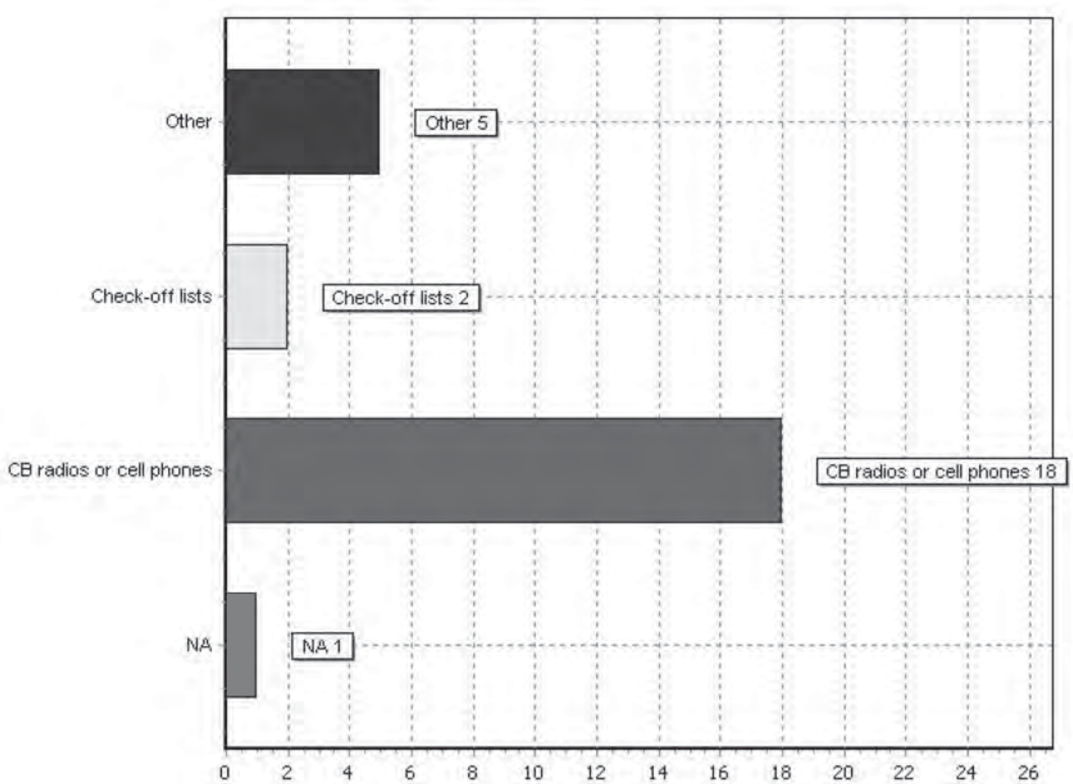
3.5.17 Are the test truck drivers given specific instructions as to the desired lane and speed for each run?



Additional comments:

MT-Traffic: The driver and the site tech talk ahead of each calibration to determine the lane order. The speed is based on the truck speed limit for that roadway, if possible.
AK: Consistant speed across the array (whatever speed hey are carrying) must be maintained.

If Yes, by what means are the instructions given? Check all that apply.

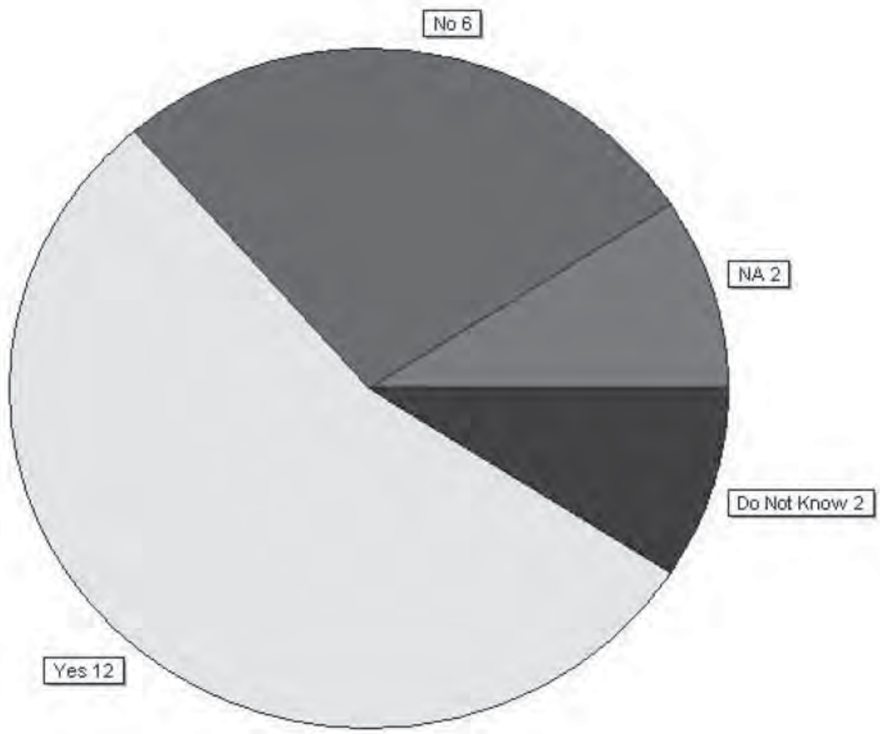


Other Responses:

CT-R: State provided radios- asked to alter lanes and speeds, but specific instructions are given depending upon outcome and needs at time of calibration.
NY: Meeting with driver and directions given prior to testing
RI: visual signals
WY-Traffic: Precalibration Meeting
TX: hand held radios

Comment Responses:

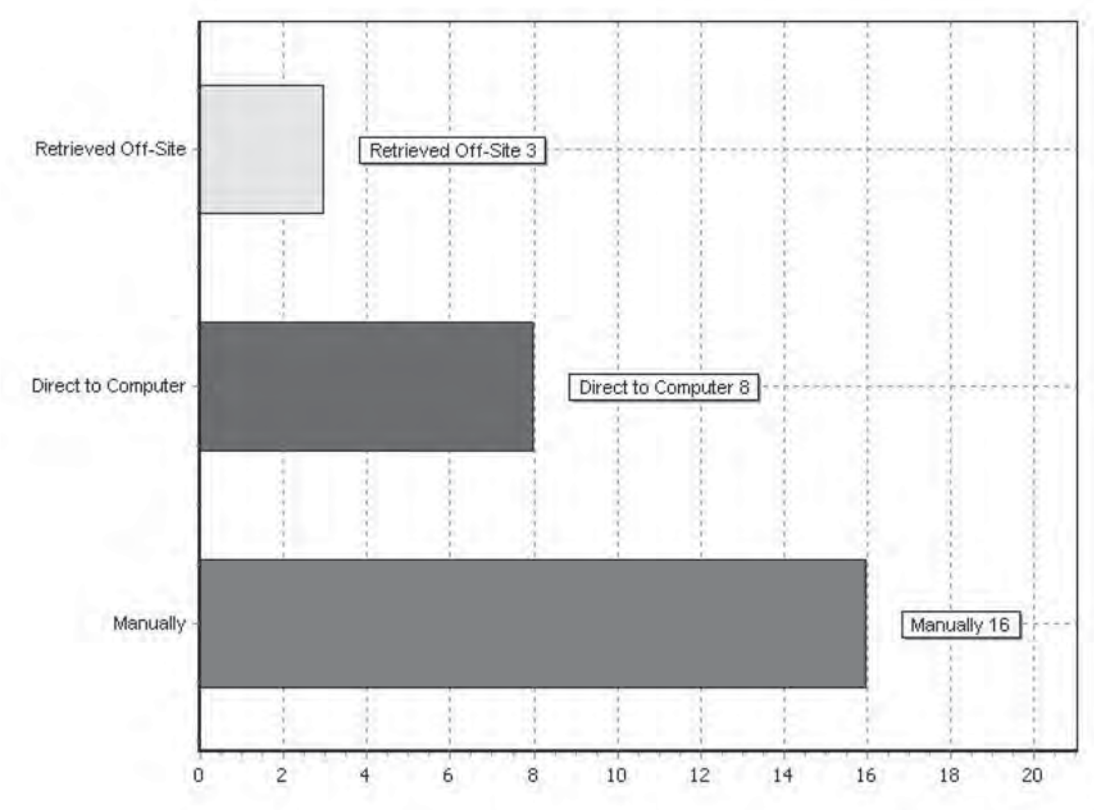
3.5.18 Is the system auto-calibration turned off during test truck runs?



Comment Responses:

MT-Traffic: The Kistler based systems do not have auto-calibration enabled at all.
NJ: Off only during initial calibration.
KS: test truck is not an auto-calibrate class

3.5.19 How is the test truck data being recorded during WIM calibration testing?



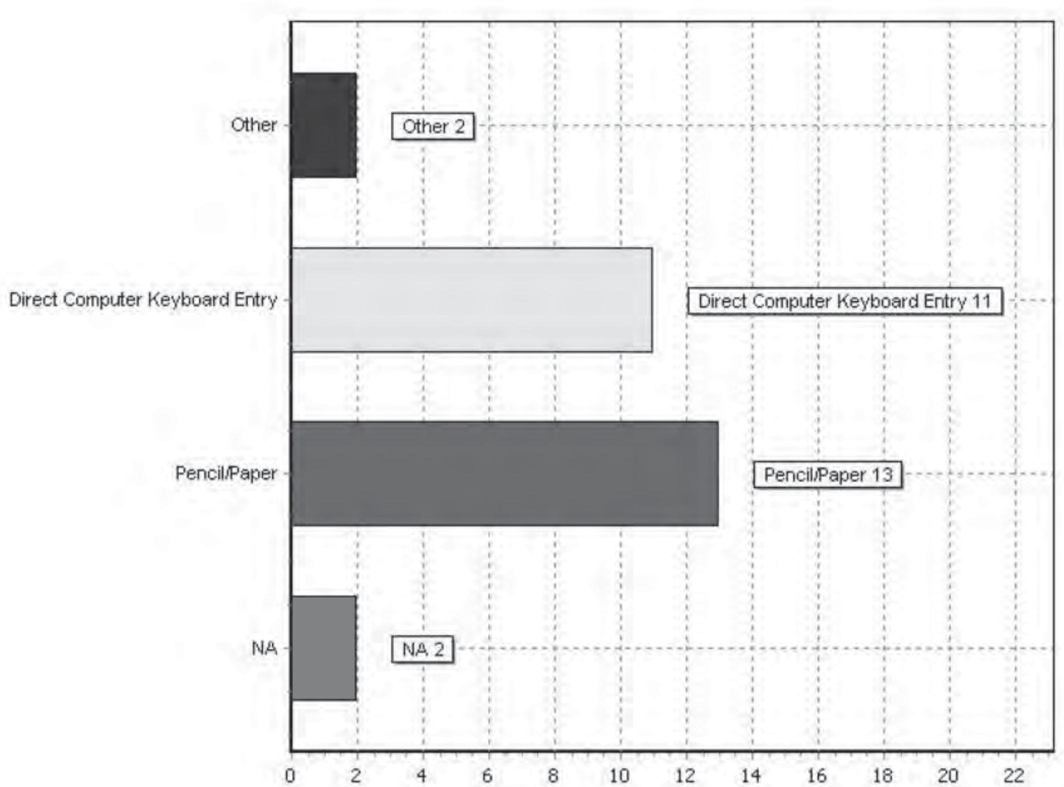
Other Responses:

CT-R: both manual and computer output on dotmatrix in field.
RI: Unknown- you may want to check with IRD to find out what their proceedure is

Comment Responses:

NJ: Each sensor is calibrated independently

If test truck data is manually recorded, what method is used?



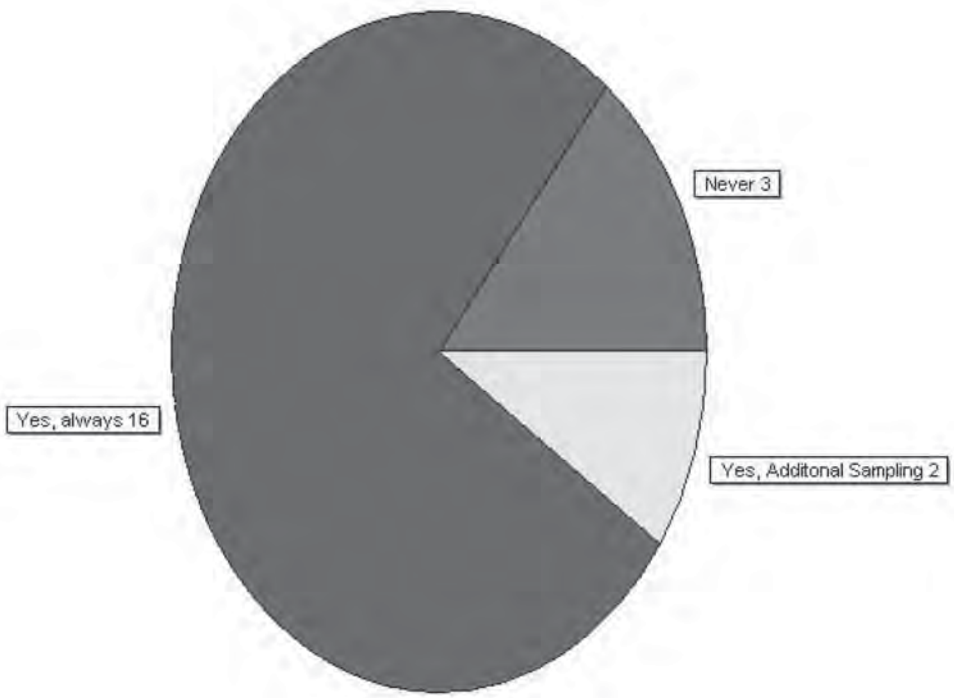
Other Responses:

write in book, if time input into spreadsheet in field, otherwise in office post-calibration.
AK: click and paste through wireless connection through to laptop.
TX: Log File matching manual recordings

Comment Responses:

MT-Traffic: We use a form that is designed specifically for WIM calibration. We also capture the electronic data that is shown on our laptop screens in a separate file from any of the other WIM files.
RI: infomation entered into an Excel Spreadsheet

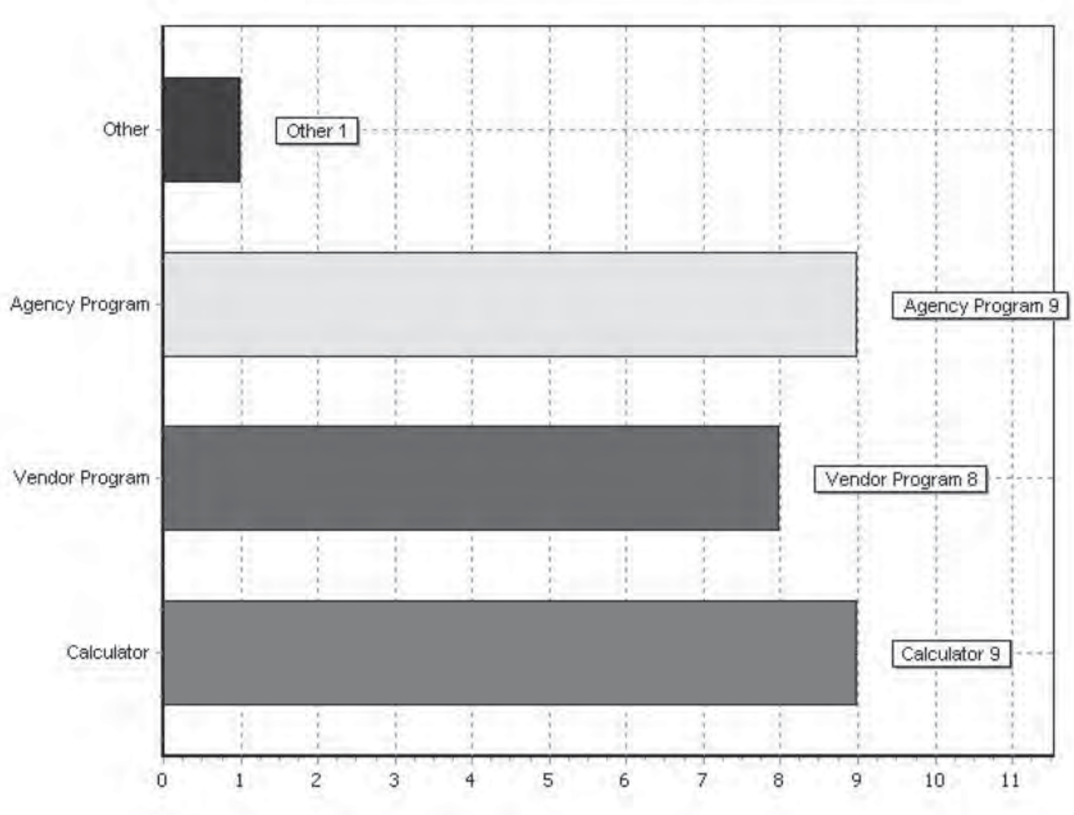
3.5.20 When performing on-site calibration using test trucks are the WIM error computations performed on-site?



Comment Responses:

CT-R: We always try to, unless problems encountered when time does not permit and it is known that additional runs will be conducted next day.
MT-Traffic: On-site calculations are performed on Kistler bases systems only.
VA-Traffic: This is usually done the next day in the office
Unknown- Check with IRD
AK: Required to produce an optimum cal factor.

3.5.21 During on-site calibration using test trucks how are the WIM error computations carried out?



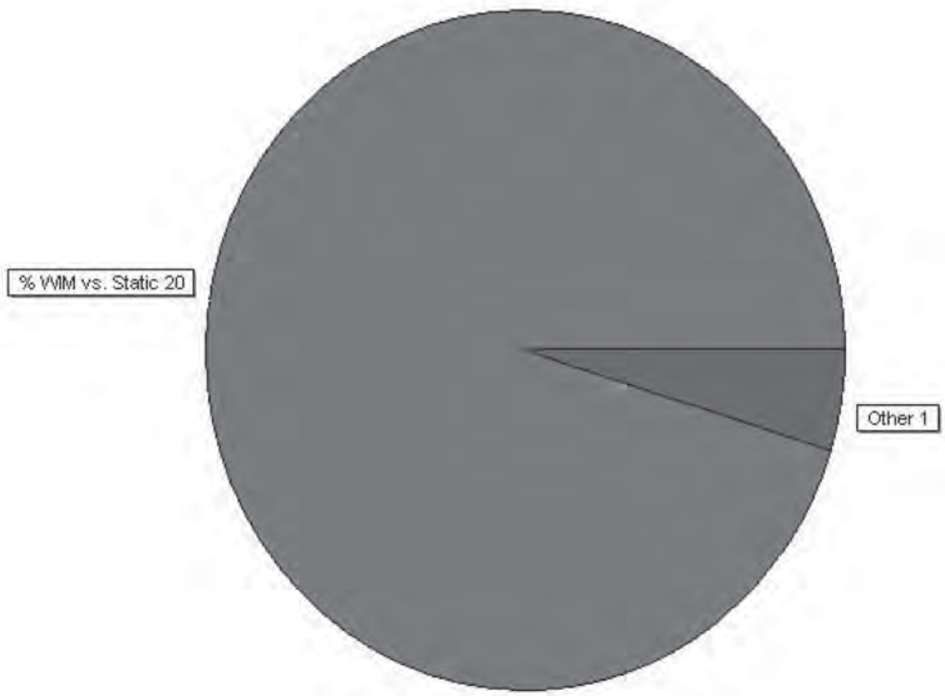
Other Responses:

GA: Using a spreadsheet or other analysis program supplied by contractor

Comment Responses:

MT-Traffic: Manual computation is done on Type I Kistler systems only. Spreadsheet analysis is done in the office for all other sites.

3.5.22 During on-site calibration using test trucks what error formula is used?



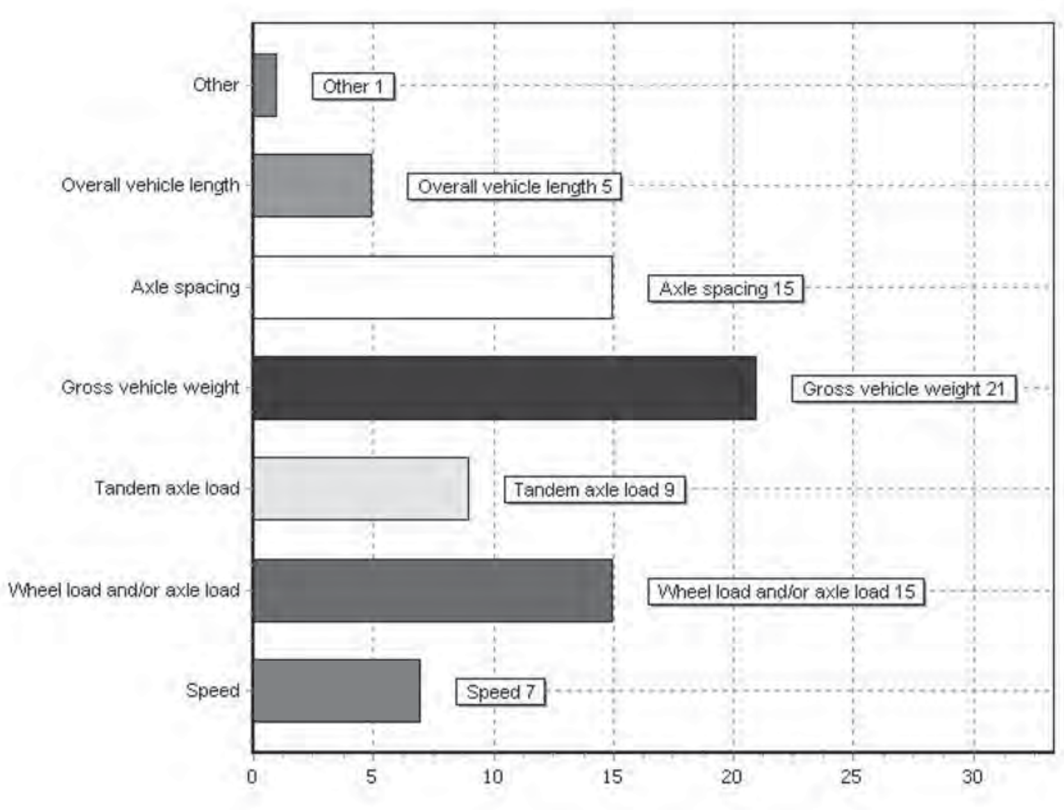
Other Responses:

PA: WIM measurement vs weigh sheet measurement

Comment Responses:

MT-Traffic: This is used for manual calibration only. Many other factors are considered when using spreadsheet analysis.

3.5.23 For which of the following measurements are WIM errors computed during on-site calibration using test trucks? Check all that apply.



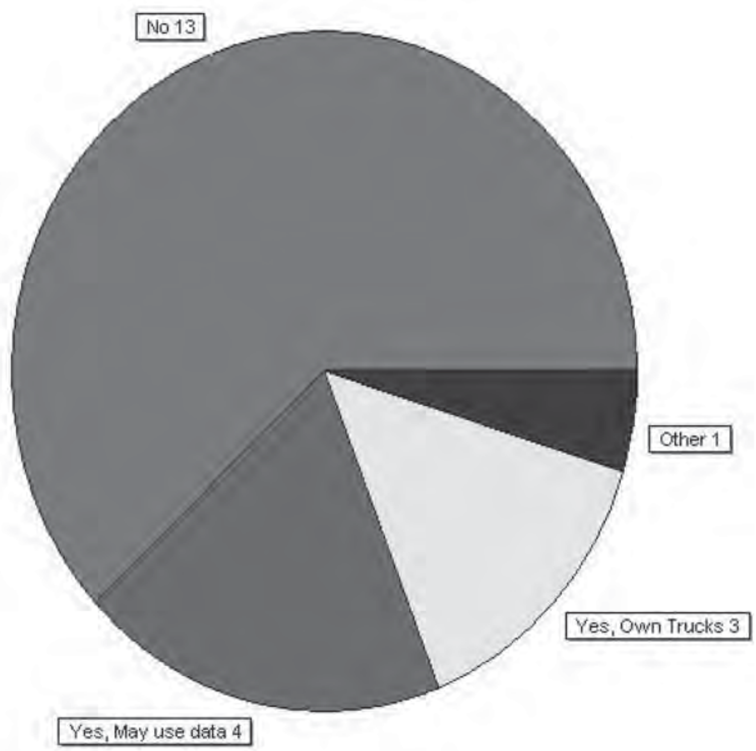
Other Responses:

Primarily Gross Vehicle Weight, check if other items look okay,-if time allows other items are calculated. If not adjustable, time not spent on-site.
KS: Classification - analog for spacing error

Comment Responses:

MT-Traffic: Speed and length are checked during the calibration. Gross weight errors are looked at separately during the office analysis process.

3.5.24 Are test trucks ever run for the sole purpose of determining WIM system accuracy tolerance pass/fail (e.g. new site acceptance, warranty, etc.)?

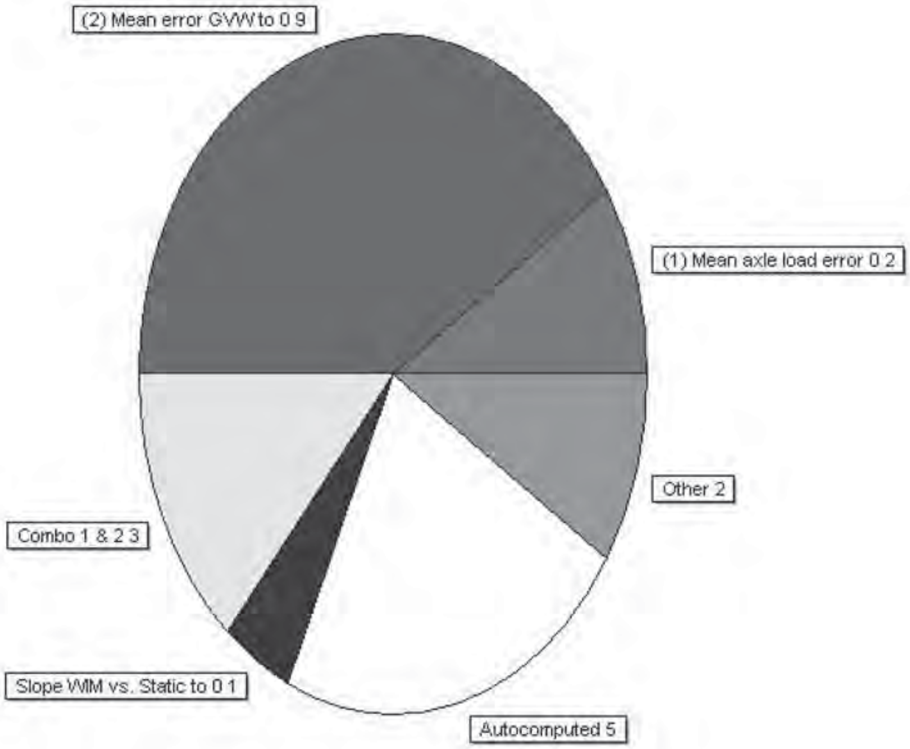


Other Responses:

Comment Responses:

MT-Traffic: In most cases we do combine calibration with accurracy validation, but not always.

3.5.25 During on-site calibration using test trucks, what method is used to compute the calibration factors?



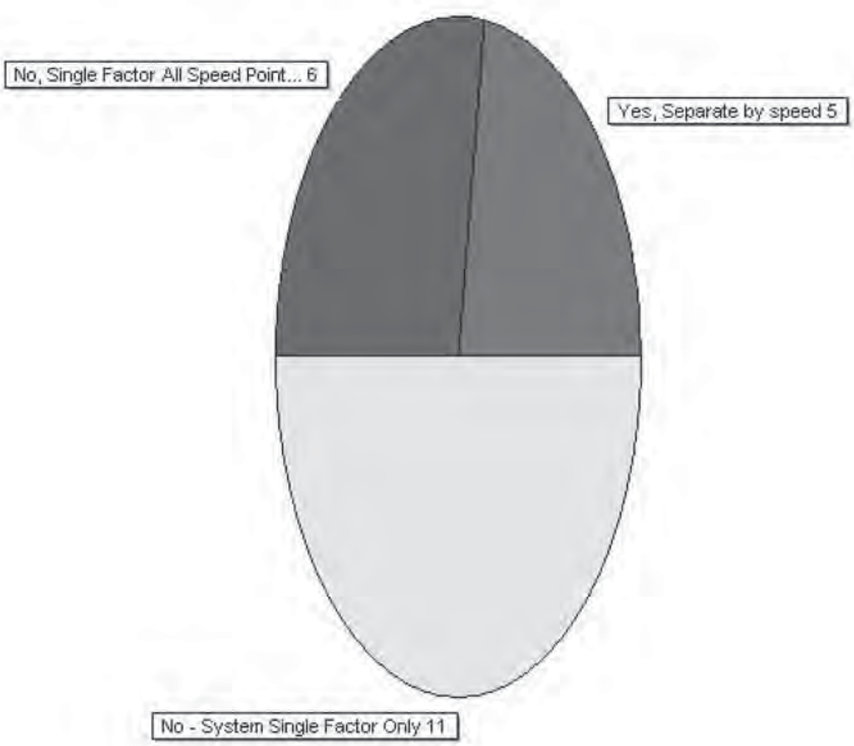
Other Responses:

CT-R: Or close to- using what seems most reasonable based on the truck consistency- zero is sometimes too precise for these measurements.
MT-Traffic: The factors are calculated using an in-house designed spreadsheet that incorporates many parameters to determine calibration factors.

Comment Responses:

MT-Traffic: The prime factor is based on the mean error of GVW, but many other parameters influence the final factor(s).

3.5.26 During on-site evaluation using test trucks do you compute calibration factors for two or more speed points?



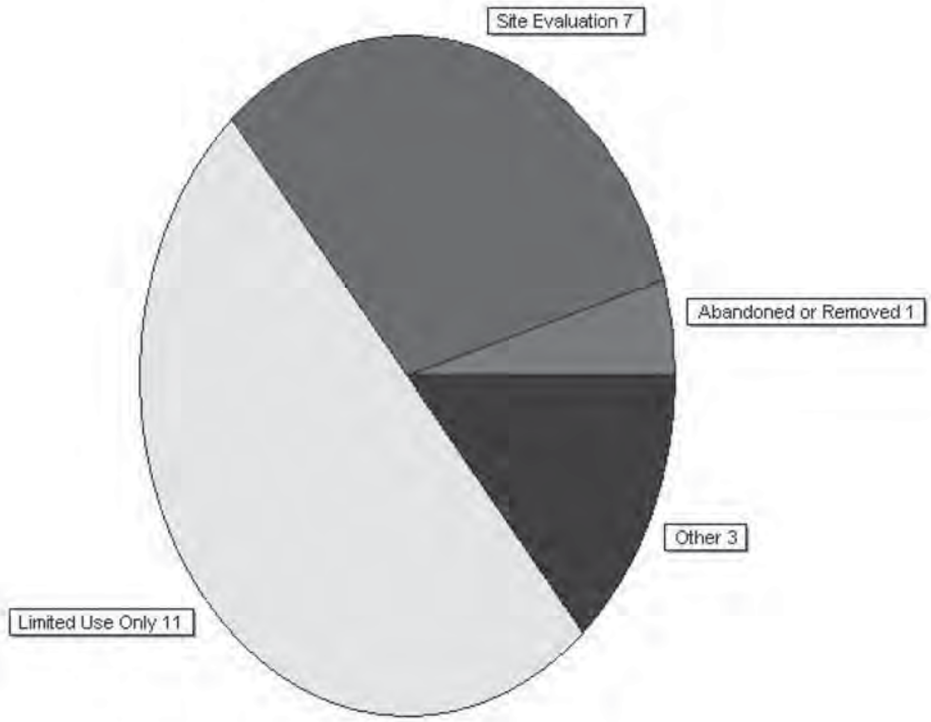
Other Responses:

CT-R: Tests show that weights are not dependent on speed- may have capability of factors for multiple speeds, but test results did not show needed.

Comment Responses:

MT-Traffic: We run at posted truck speed limits when possible. Montana posts lower speeds for trucks than for other vehicles on all roads.
RI: Unknown - check with IRD

3.5.27 What remedial action is taken for WIM systems that fail to meet accuracy tolerances during test truck testing?



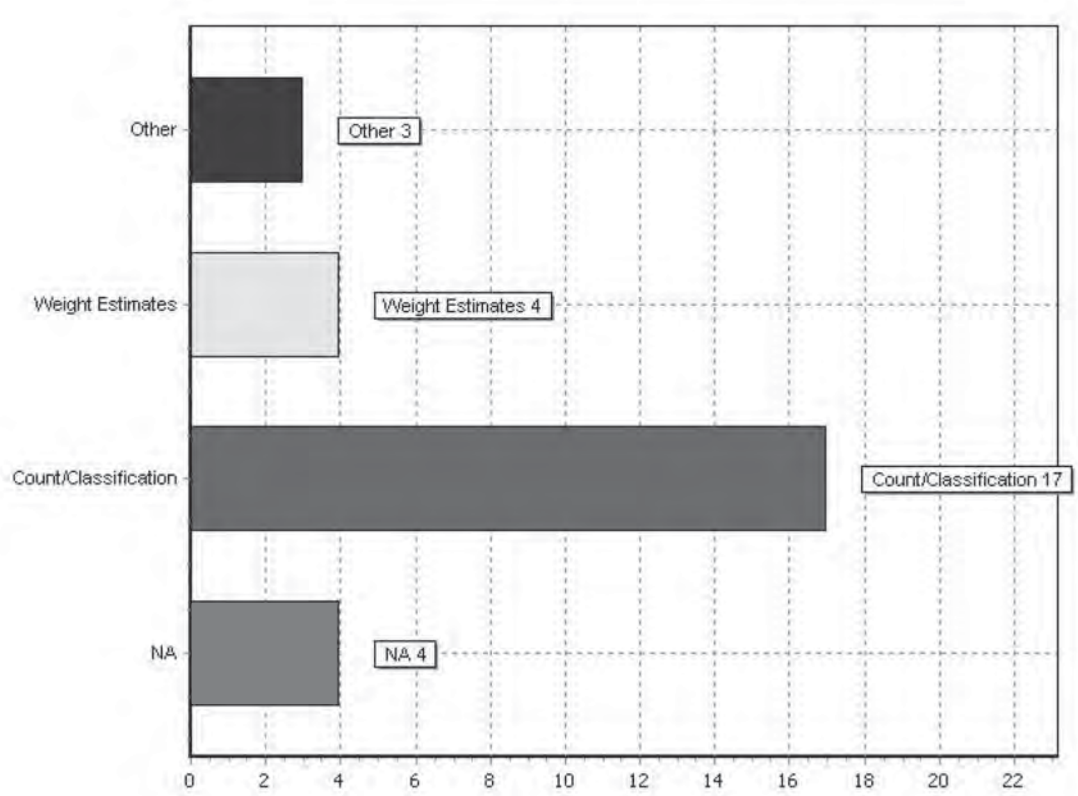
Other Responses:

CT-R: Try to determine cause of failure, see if vehicle dependent or if any remedies are feasible.
MT-An immediate site evaluation is conducted. The site is re-scheduled for calibration as soon as the problem is fixed.
PA: Electrical tests/site conditions evaluated

Comment Responses:

Sites are evaluated structurally, and using data analysis on traffic stream data. If shown to be out of spec, and there is no way to correct the problem structurally, the site may be shut down.
WA-Traffic: site may be downgraded to a classification only format
NJ: Site is downgraded to Classification/Counting station.
RI: Depends on what is causing the problem
If the problem is sensors, they will be replaced.

What is the use of the data being generated by WIM systems that fail to meet accuracy tolerances?



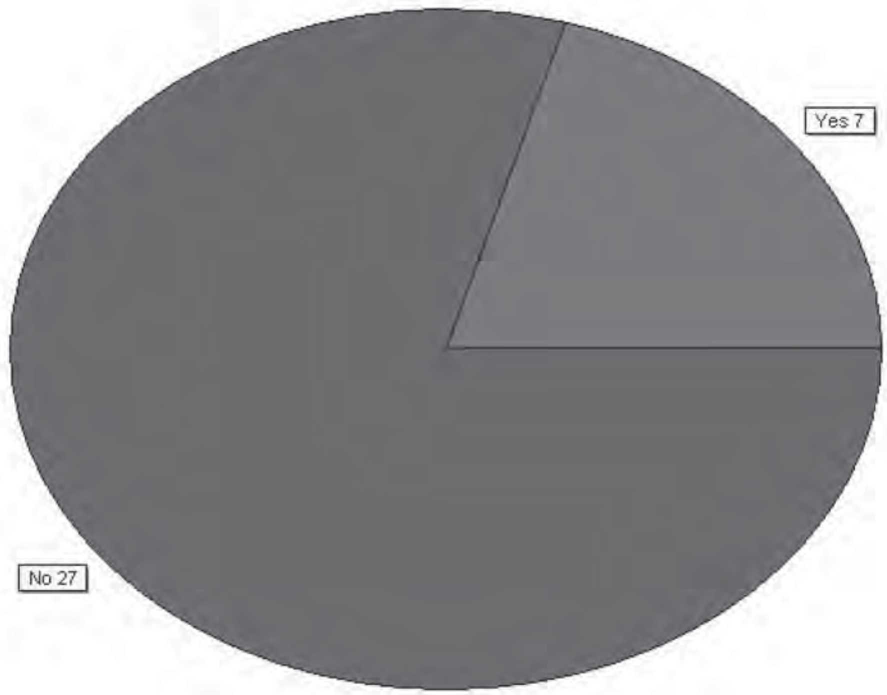
Other Responses:

CT-R: Viewed with caution, depending upon site and issues. Different if did not meet inital accuracy versus changed over time. Only one lane installed, where data weight data extremely suspect. Still used for count/ trucks vs small vehicle for class.
NJ: speed monitoring
PA: Site is repaired

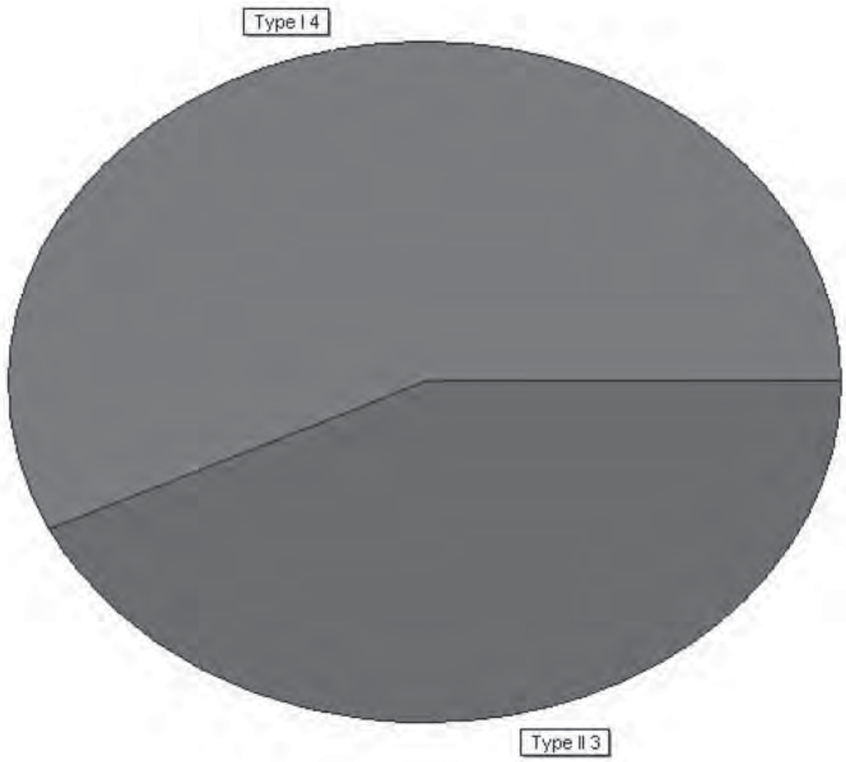
Comment Responses:

Count class data is monitored for consistency and historical accuracy. If error rates become too high, the site is shut down.

3.6 WIM On-Site Evaluation/Calibration Using Traffic Stream Trucks of Known Weight NOTE: In this section we are referring to on-site evaluation/calibration by sampling trucks from the traffic stream for which you are able to obtain static weights. Do you perform on-site evaluation/calibration using traffic stream trucks of known weights?



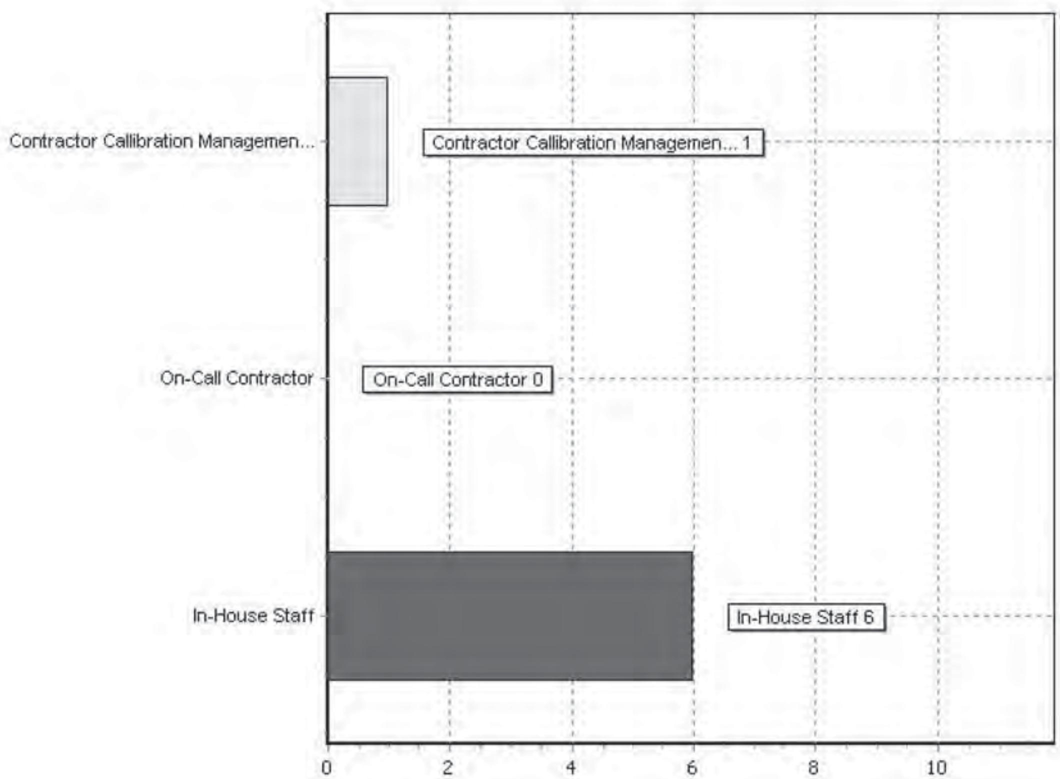
In the series of questions under 3.6 please describe the procedure you use for the MOST COMMON WIM type in your unit (department/division/agency). What is the most common WIM type in your unit for which traffic stream trucks of known weight are used for calibration?



Other Responses:

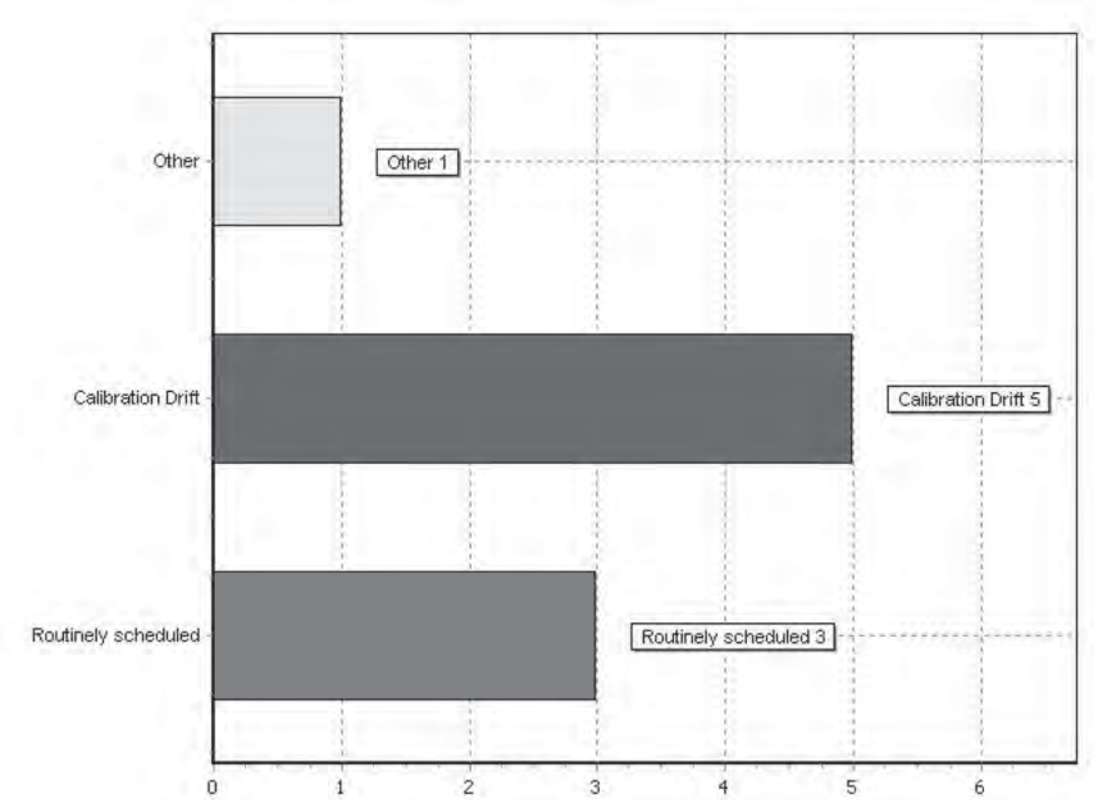
We currently run all but two Type I sites as the WIM part of Pre-Pass systems. We only use traffic stream data to confirm our test truck calibration.

3.6.1 Who conducts these on-site evaluation/calibration activities using traffic stream trucks of known weight? Check all that apply.

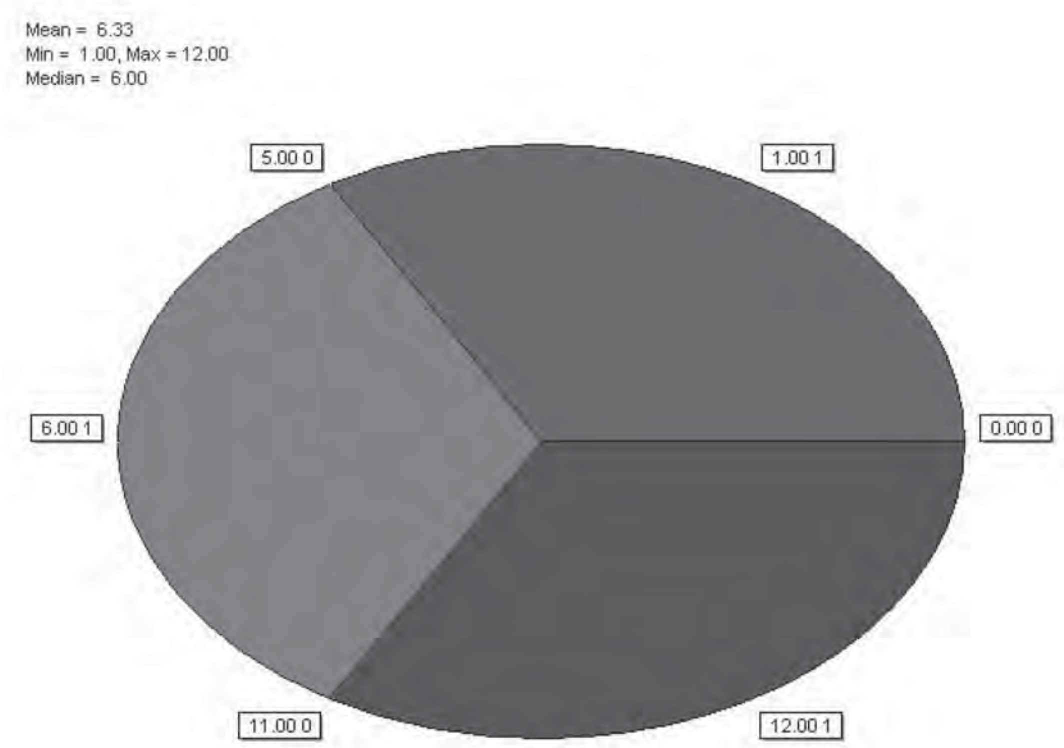


Additional Comments:

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions. 3.6.2 What is the criterion you use to initiate WIM calibration using traffic stream trucks of known weight? Check all that apply.



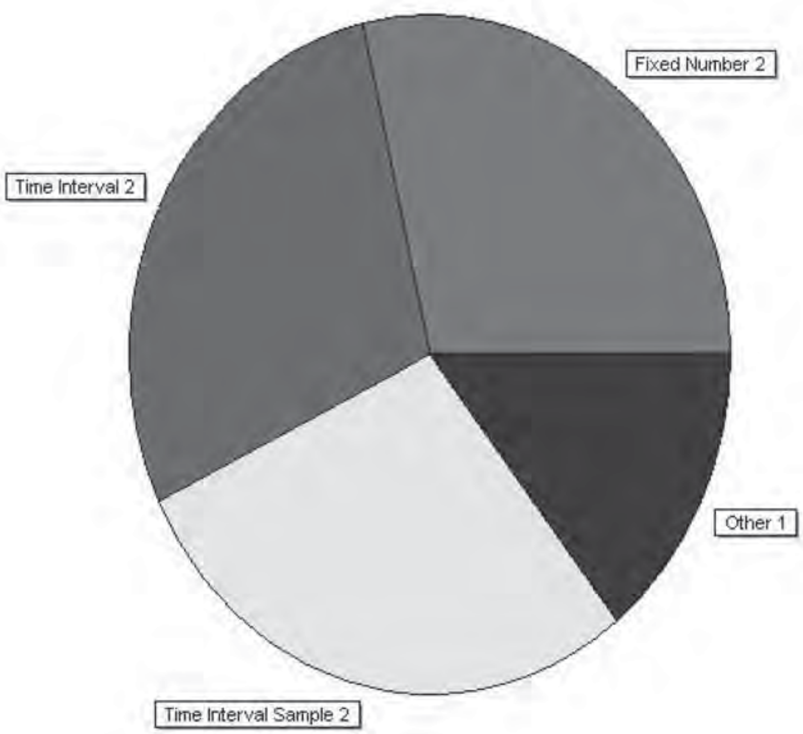
If routinely scheduled, specify typical interval (months):



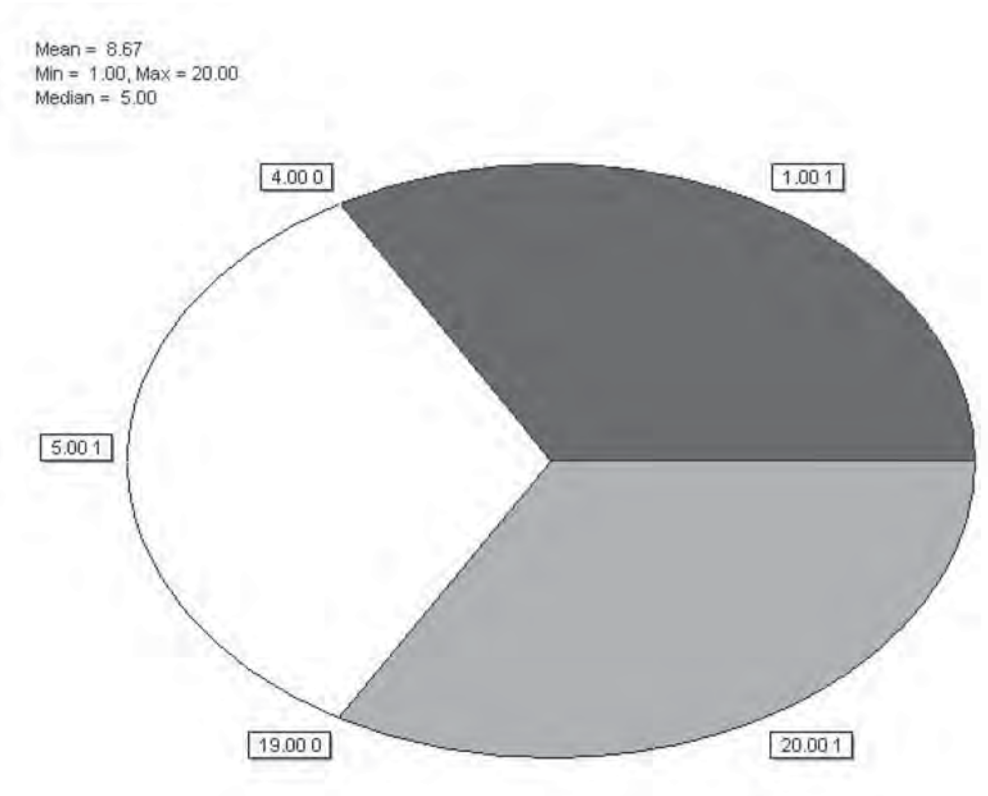
Additional comments:

MT-Traffic: We only use traffic stream trucks to adjust calibration when we have evidence of drift, or when we want to confirm our test truck calibration. This is only conducted at the Pre-Pass WIM sites, as they are the only ones close enough to a static scale to use the traffic stream method. All of the Pre-Pass sites are Type I.
VA-Traffic: This is usually done about every 6 months.
CT-Traffic: We talk to different motor cariers about the loads that they carry.
TX: 12 months bending plate 6 months coax

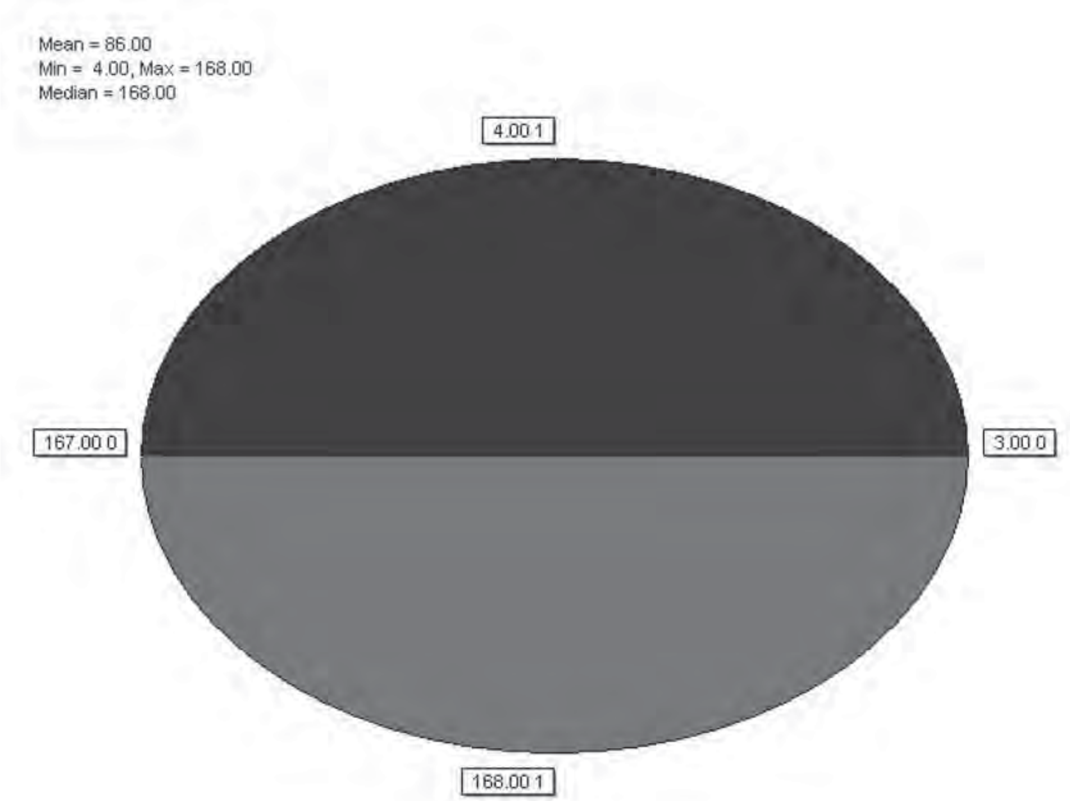
3.6.3 How do you select the number of traffic stream trucks of known weight to be included in the sample?



If a fixed number of trucks are selected, specify the number.



If all of the trucks in a given time interval are selected, specify the time interval (in hours).



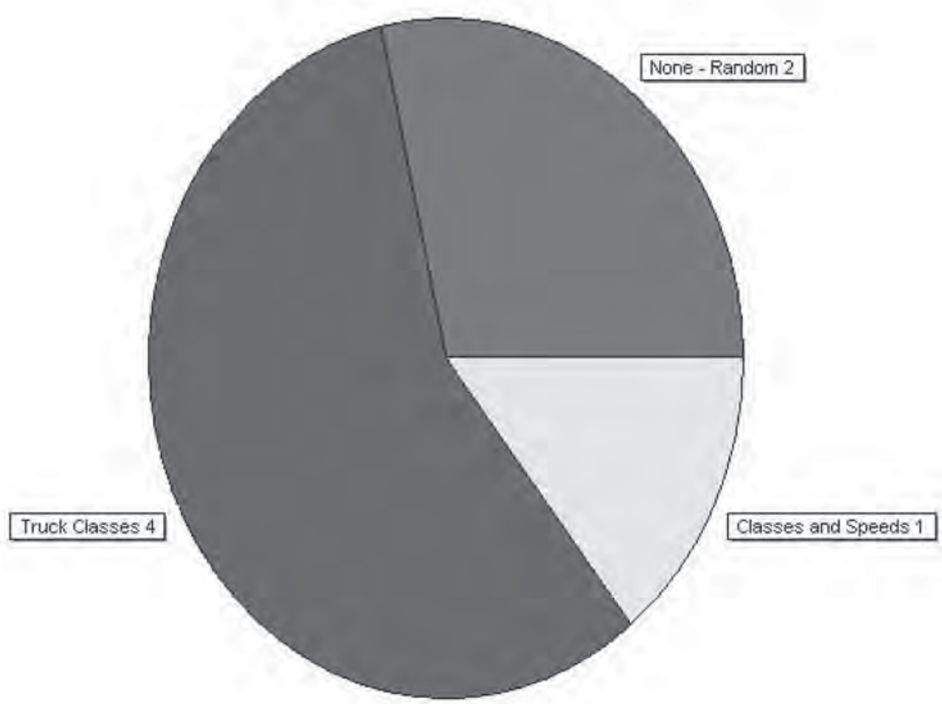
If some of the trucks in a given time interval are selected, specify the number and interval:

Number of Trucks	Time Interval (in hours)
50	1
10	1

Additional comments:

MT-Traffic: The number of trucks used depends on the volume of trucks at the site. High volume sites would not use every truck. Low volume sites will yield a small number of trucks, even after 4 hours. We may take more than 4 hours if the truck volume is judged to be too low.
Agencies cal truck

3.6.4 What are the criteria used for selecting the type of traffic stream trucks of known weight to include in the sample?



Other Responses:

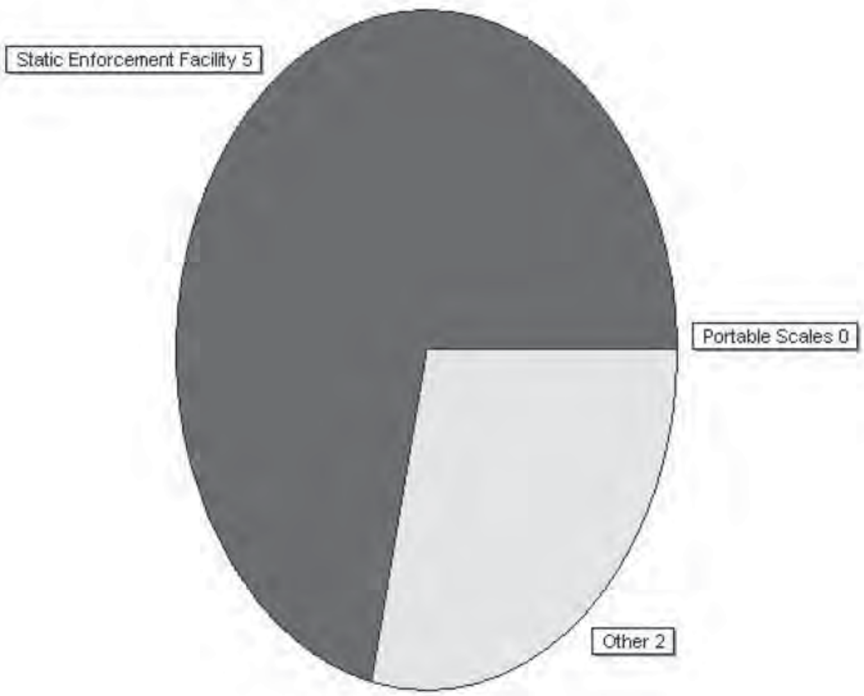
UT: Slow <55 Medium Fast >70

CT-Traffic: Class 9"s

Comment Responses:

NM-Traffic: empty flatbed class 9
Classes 9 and 10
Classes 6 and 9
TX: We look at type 9, typical truck class

3.6.5 How is the static weight of these traffic stream trucks obtained?

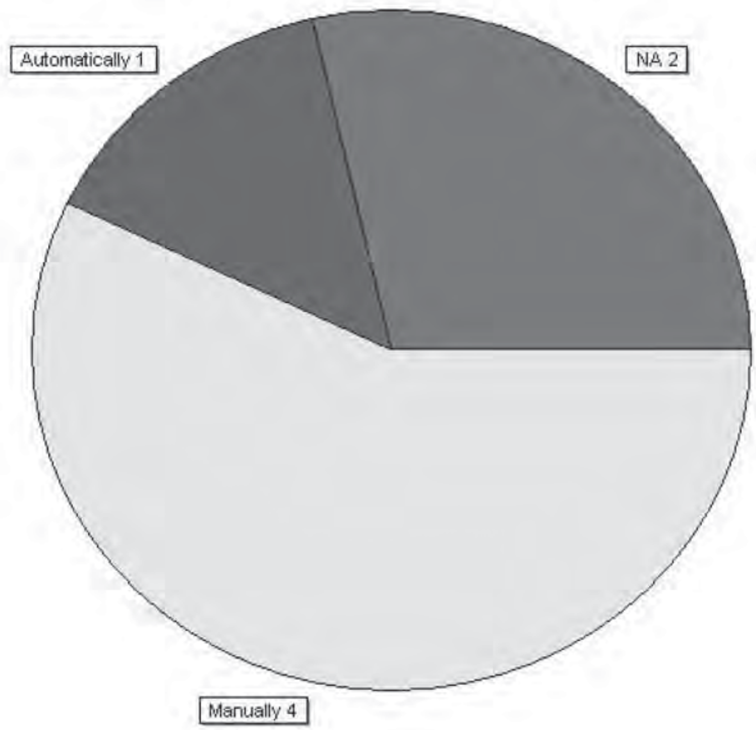


Other Responses:

NM-Traffic: front axle weight
CT-Traffic: Talked with different companies about their loads

Comment Responses:

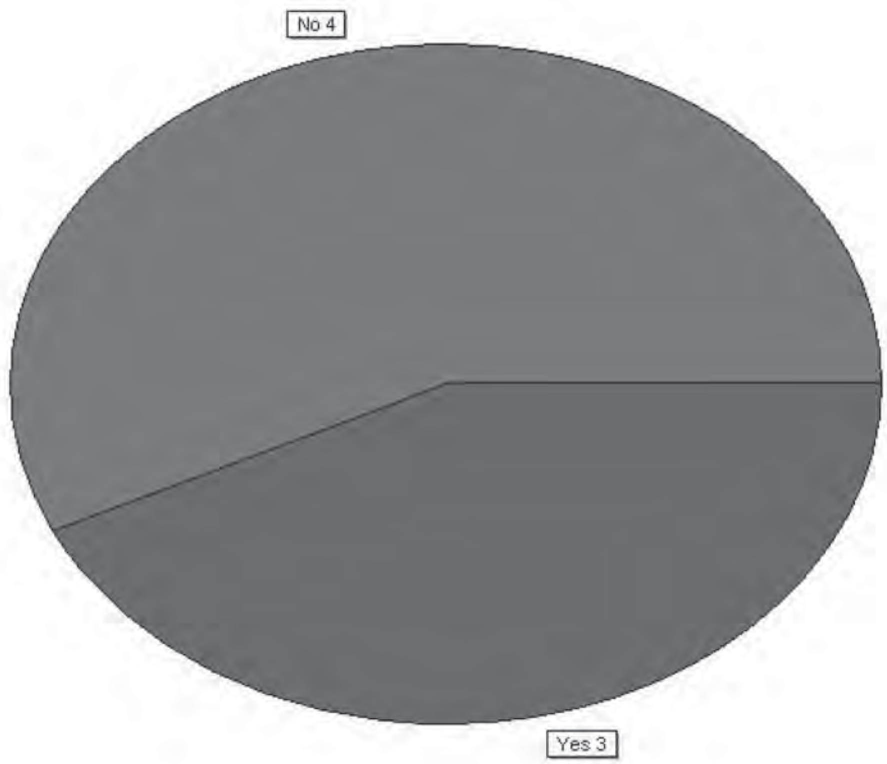
If using a weight enforcement facility, how is the static weight of the traffic stream trucks recorded?



Comment Responses:

Data is relayed via radio or phone between the scale house and the WIM site.

3.6.6 Do you measure the axle spacing for these traffic stream trucks?

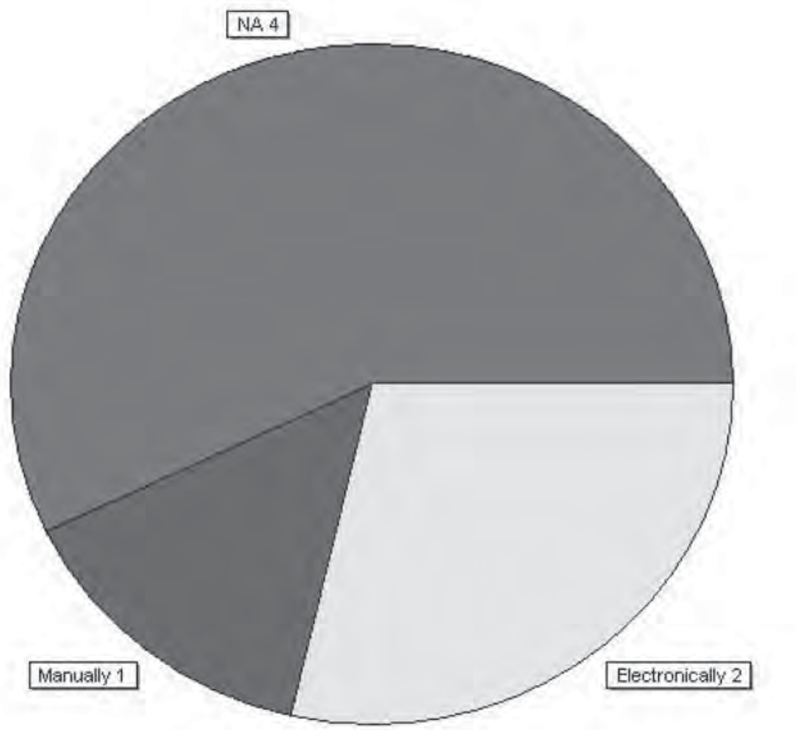


Other Responses:

Comment Responses:

TX: agency cal truck

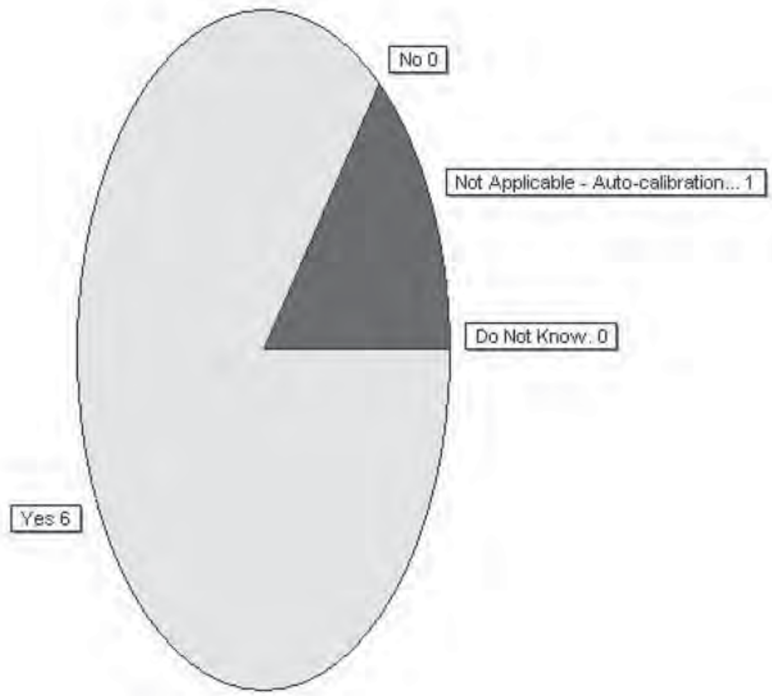
If Yes, how do you measure the axle spacing?



Other Responses:

Comment Responses:

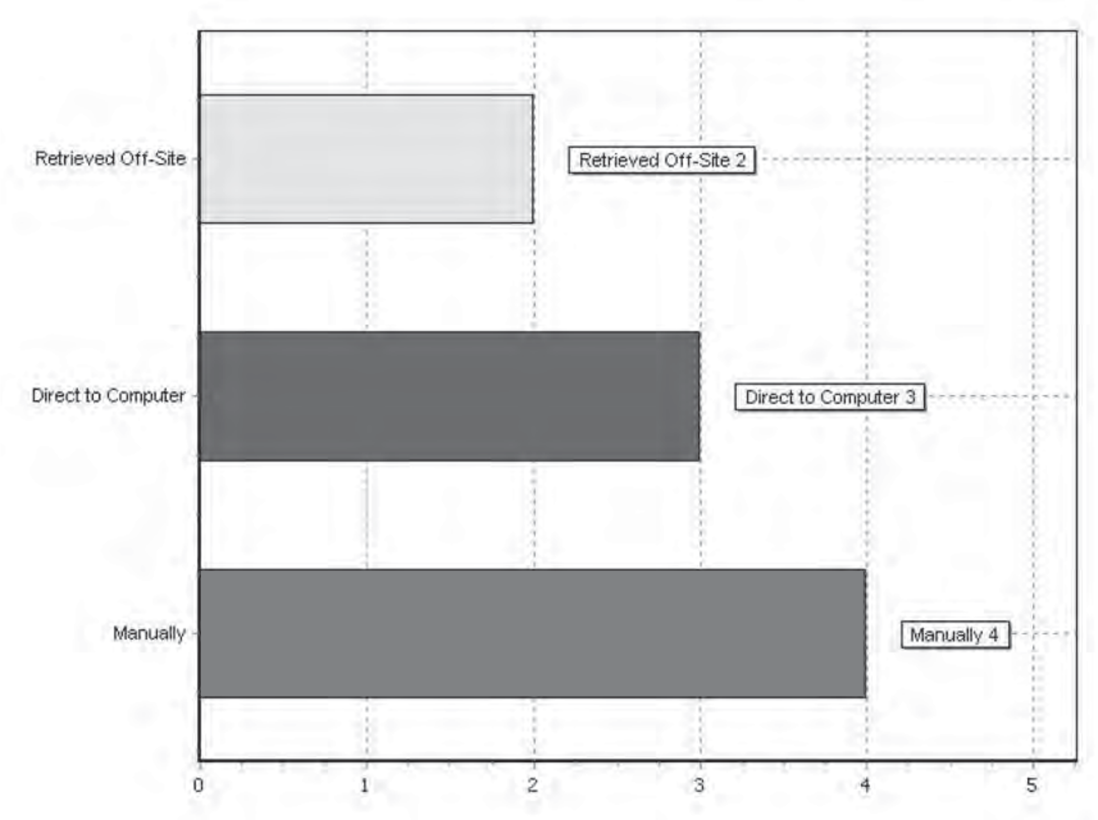
3.6.7 Is the system auto-calibration turned off during traffic stream truck runs?



Comment Responses:

This type of testing is performed only on Kistler based systems at this time. We do not run auto-calibration with Kistler systems.

3.6.8 How is the WIM data of the sampled traffic stream trucks of known weight recorded?

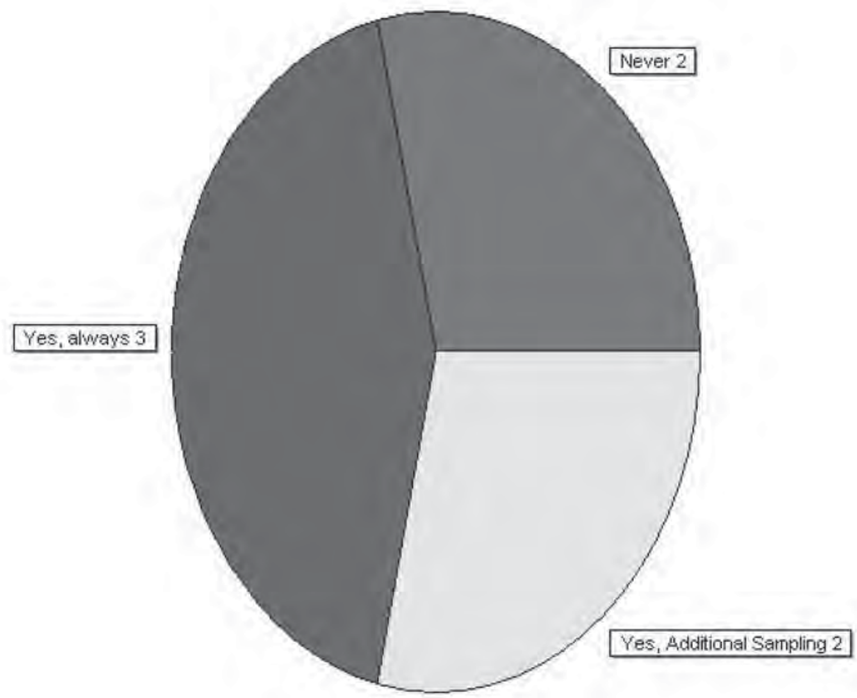


Other Responses:

Comment Responses:

We use a form designed specifically for this purpose, along with capturing the data real-time on our laptop computers.

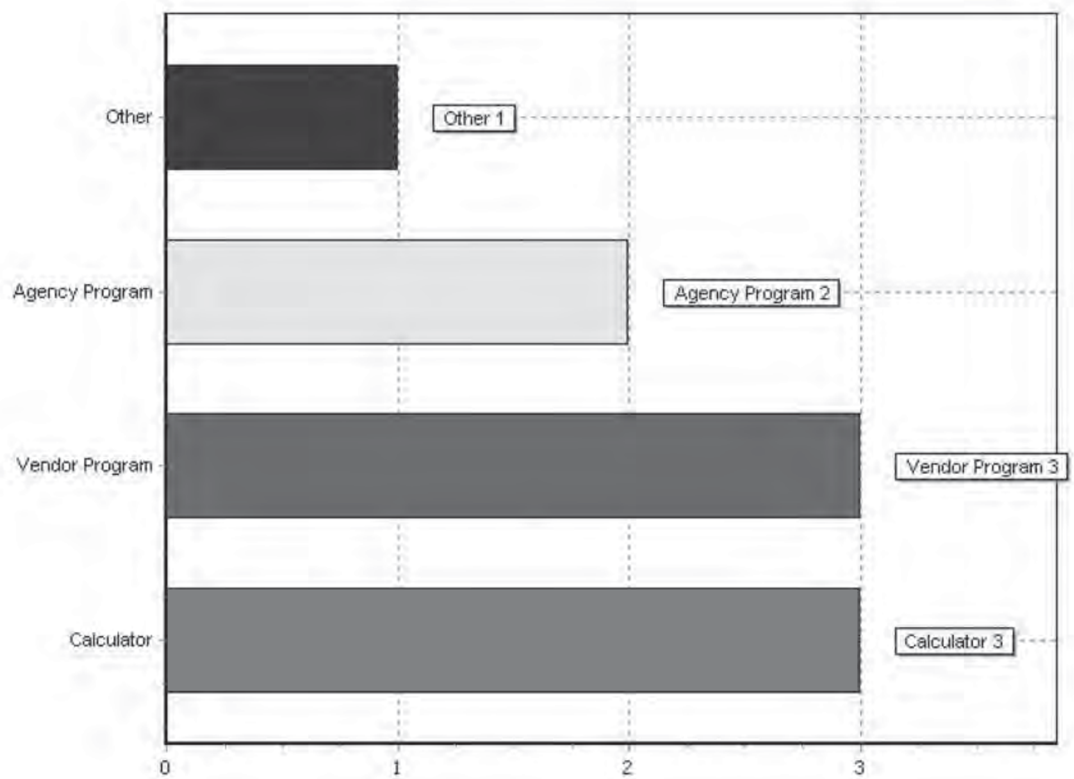
3.6.9 Are the on-site calibration using traffic stream trucks of known weight WIM error computations performed on-site?



<u>Comment Responses</u>:

If adjustments are needed, additional samples will be taken after the adjustments are made. This applies to Kistler systems only.
VA-Traffic: This is done the next day in the office

3.6.10 During on-site calibration using traffic stream trucks of known weight how are the WIM error computations carried out?

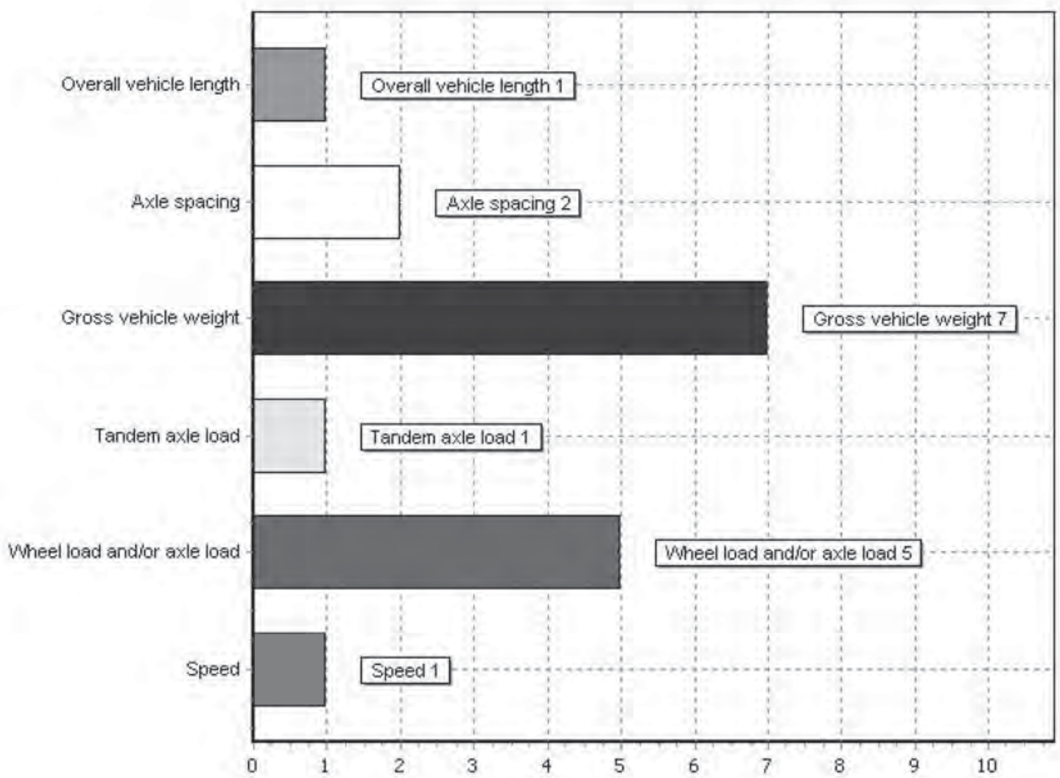


Other Responses:

GA: Using a spreadsheet or other analysis program supplied by contractor

Comment Responses:

3.6.11 For which of the following measurements are WIM errors computed? Check all that apply.

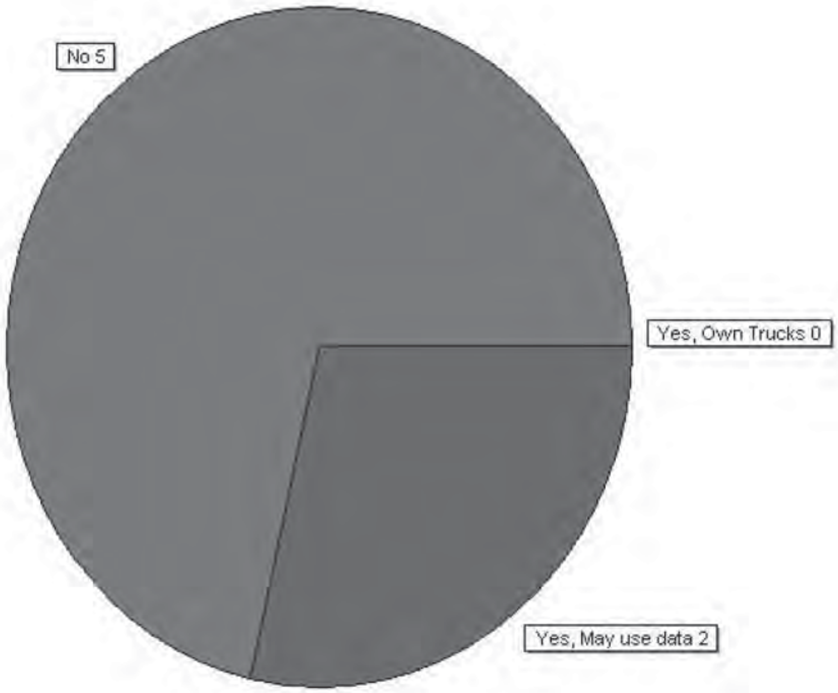


Other Responses:

Comment Responses:

Traffic stream calibration is only used to correct drift or verify the GVW portion of normal test truck calibration procedures.

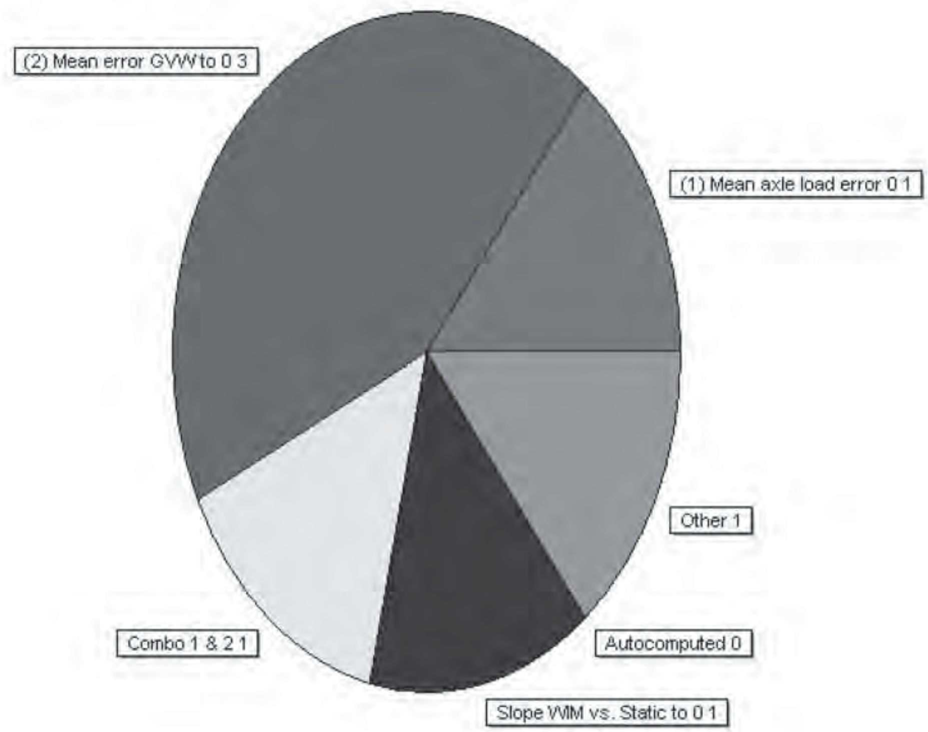
3.6.12 Are traffic stream trucks of known weight ever sampled for the sole purpose of determining WIM system accuracy tolerance pass/fail (e.g. new site acceptance, warranty, etc.)?



Other Responses:

Comment Responses:

3.6.13 During on-site calibration using traffic stream trucks of known weight, what method is used to compute the calibration factors?



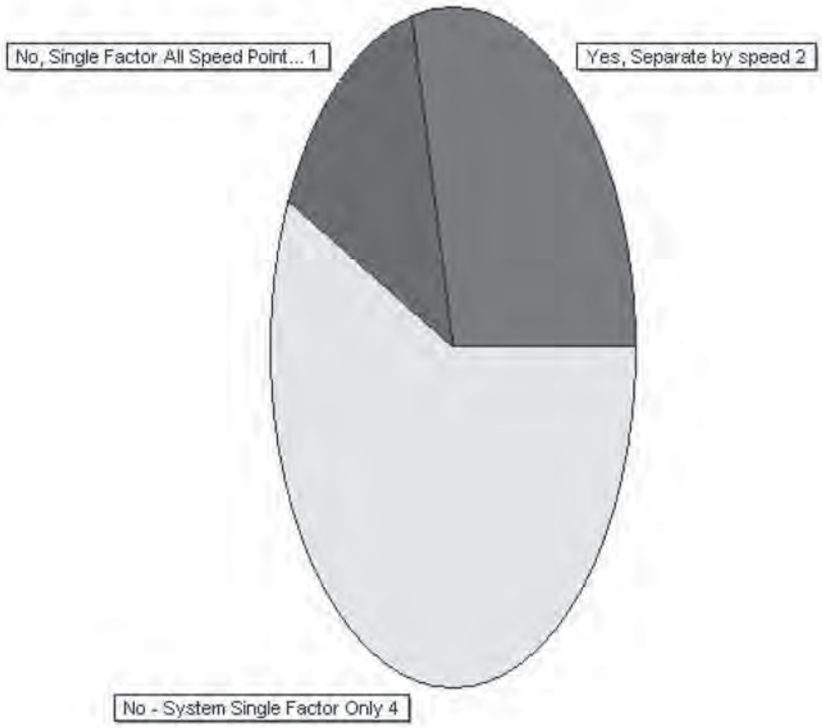
Other Responses:

CT-Traffic: Auto cal & weight factor adjustment

Comment Responses:

More emphasis is usually given to GVW than to axle weights, but axle weights are considered as well.

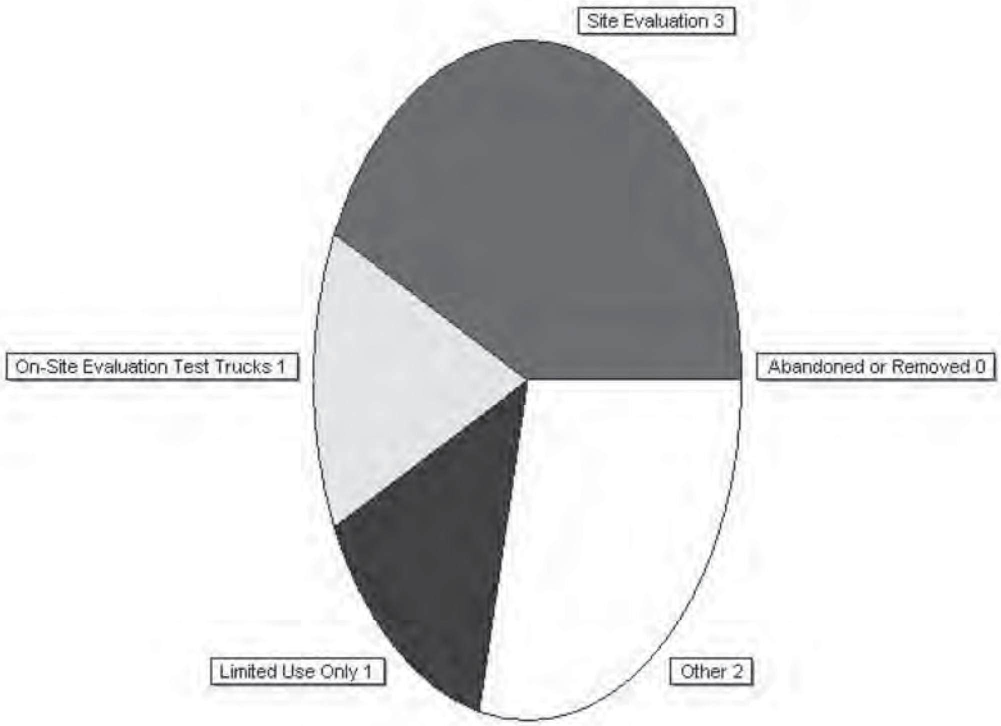
3.6.14 During on-site calibration using traffic stream trucks of known weight do you compute calibration factors for two or more speed points?



Other Responses:

Comment Responses:

3.6.15 What remedial action is taken for WIM systems that fail to meet accuracy tolerances during traffic stream truck evaluation?



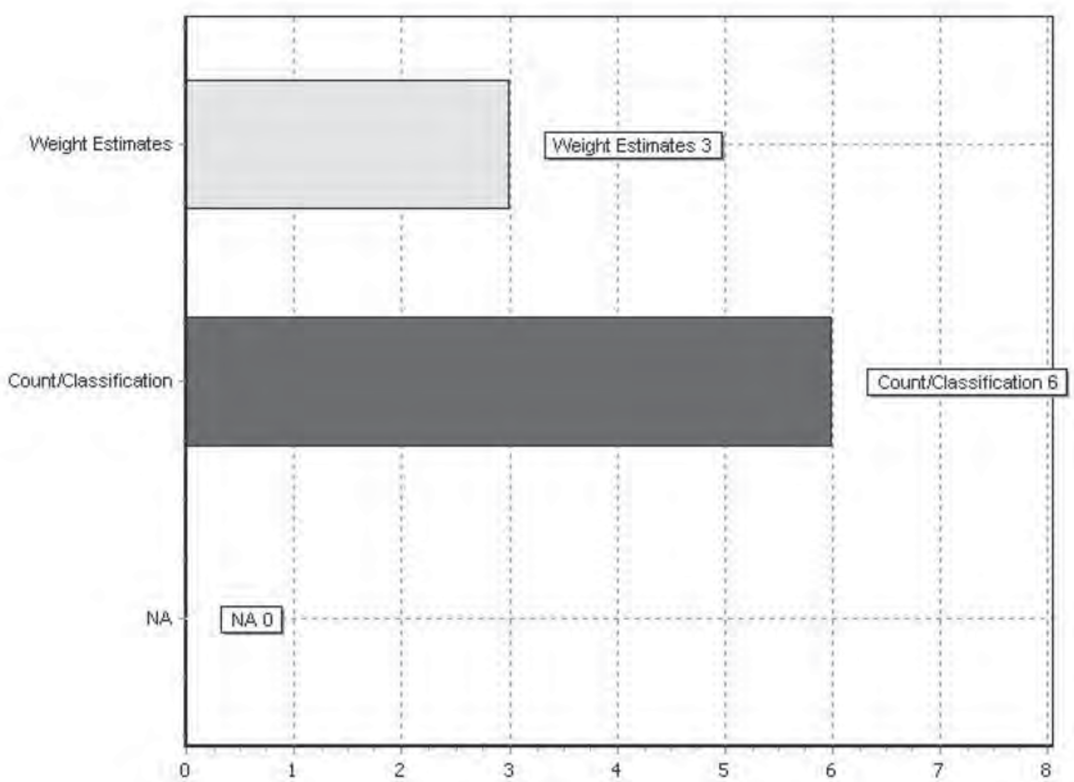
Other Responses:

We use a test truck to obtain a structural evaluation as well as a weight evaluation to obtain overall system performance.
UT: Post collection Calibration

Comment Responses:

If the system cannot be corrected, WIM data will no longer be collected. If the errors are too high, then the site will be shut down.

What is data from systems that remain in use but fail to meet accuracy tolerances used for?

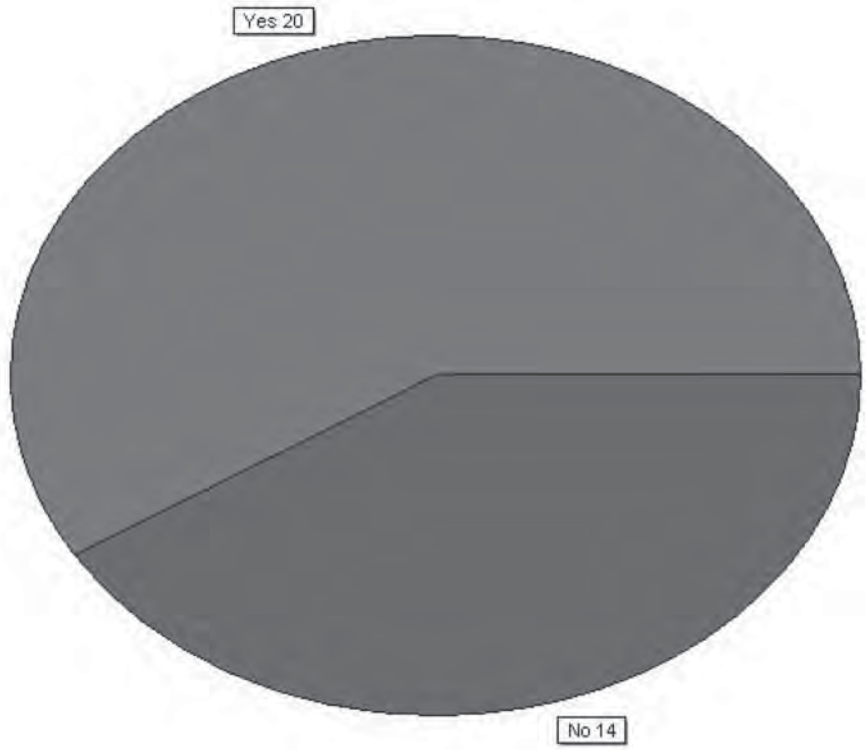


Other Responses:

Comment Responses:

If the site cannot provide accurate count/class data, it will be shut down.

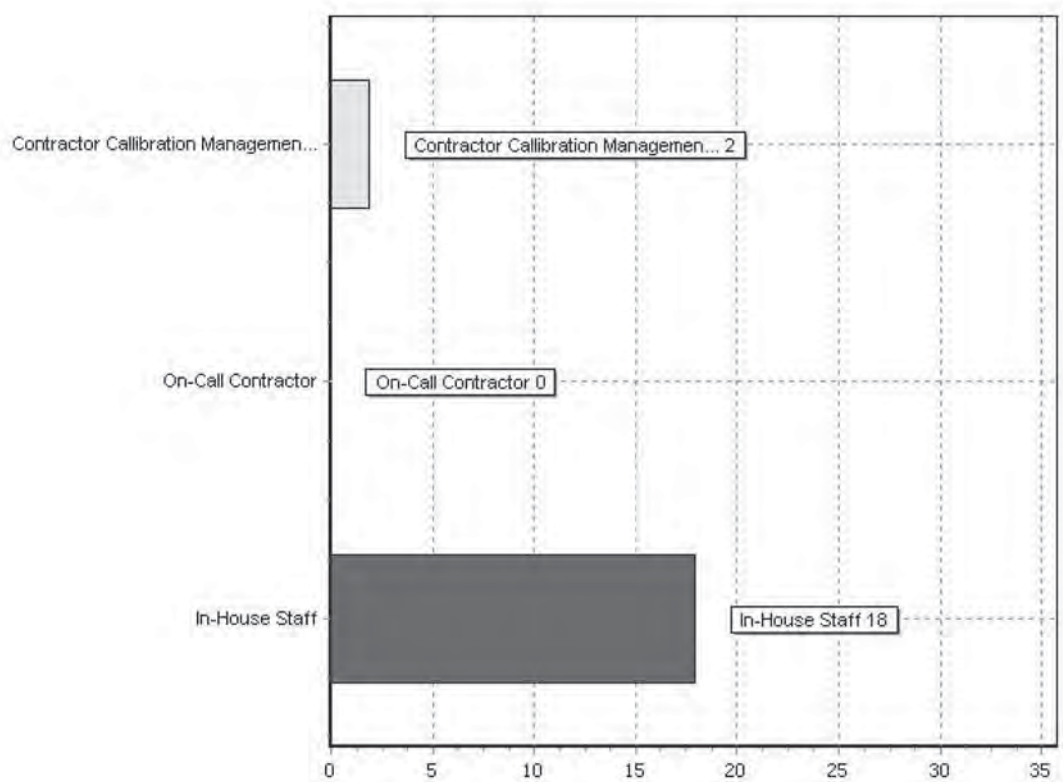
3.7 WIM Calibration Monitoring Using Traffic Stream WIM Data Do you use WIM calibration monitoring using traffic stream WIM data to monitor your WIM systems?



Comment Responses:

WIM data is processed through our office and monitored by both the office and field staff.
AL-Traffic: We perodically check the steering axle weights of loaded class nine trucks
KS: For peizos only.

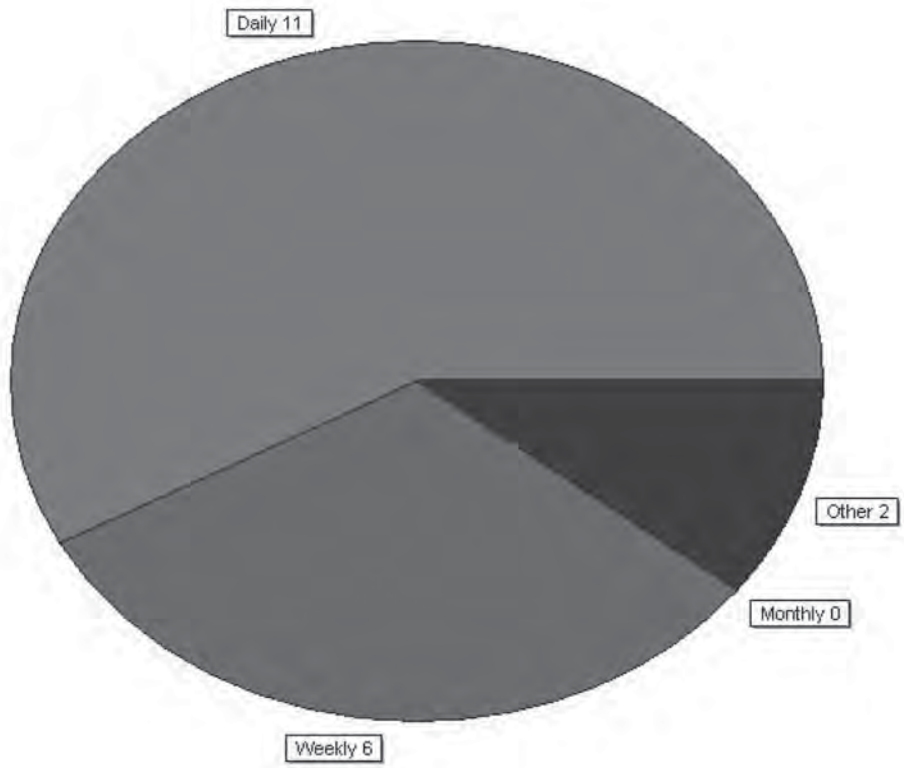
3.7.1 Who conducts WIM calibration monitoring using traffic stream WIM data? Check all that apply.



Additional comments:

MT-Traffic: In-house monitoring is conducted by both data analysis and field staff. Calibration data is processed using software developed specifically for us to perform that task.

If you are outsourcing WIM calibration, you may want to ask for the contractor's assistance in responding to the following questions. 3.7.2 Typically, how often are your systems' data files downloaded?



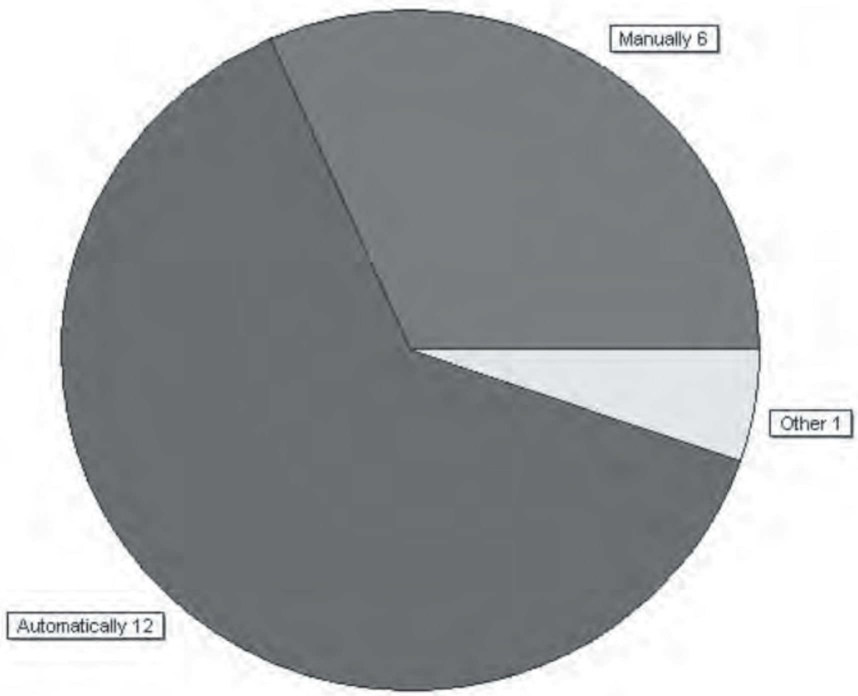
Other Responses:

CT-R: At times when we had more personnel, it was weekly. Try to download monthly- except at sites if modems are working. If not working, how time permits.
Every other day.

Comment Responses:

MT-Traffic: Higher volume sites may be downloaded as often as 3 times per week.

3.7.3 How are your systems' data files downloaded?

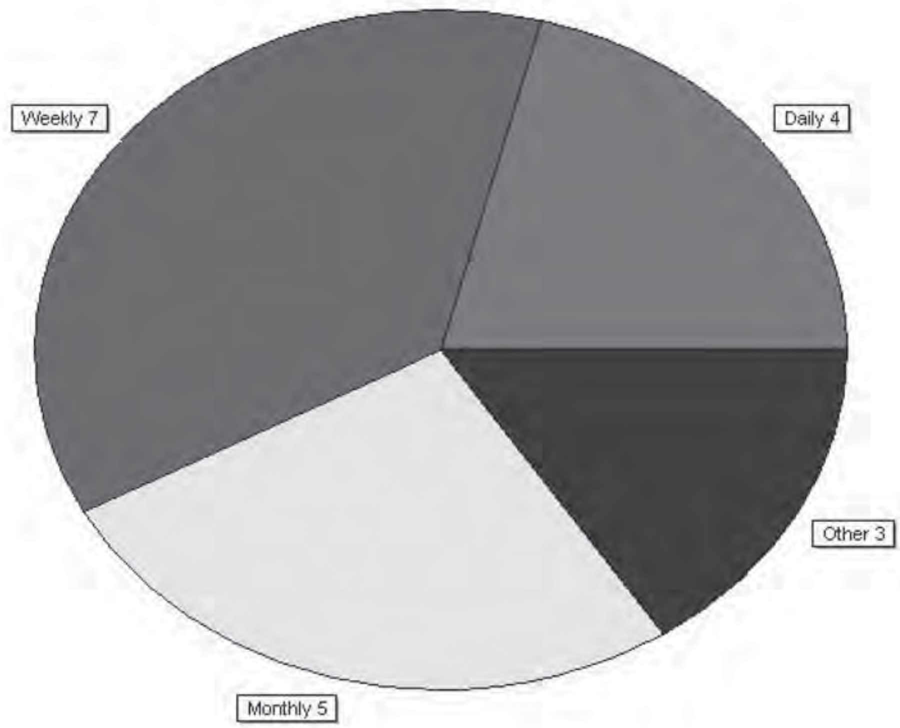


Other Responses:

FL: Automatically using custom polling software.
CT-R: Used to use autopoll- don't recall why we stopped, but only have a few sites. At sites where there are modem/telephone issues, visit site with laptop for field download.

Comment Responses:

3.7.4 How often do you perform checks of the WIM data?



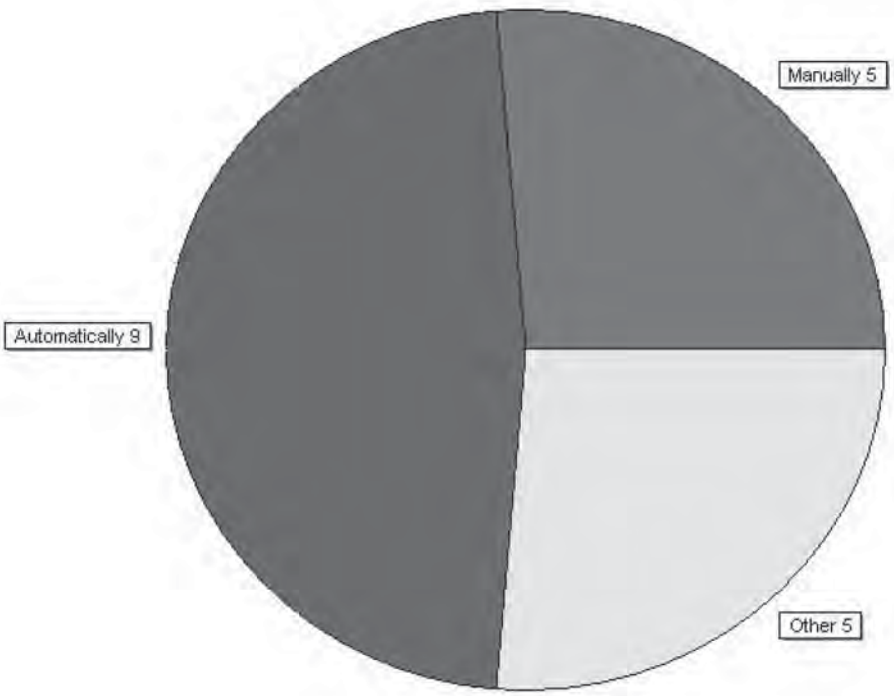
Other Responses:

FL: QC edits automatically run against daily file.
CT-R: When had more personnel and Department had a cooperative education program, was able to do weekly checks. Currently backlogged.
WY-Traffic: Class/Count Daily, Weight Weekly

Comment Responses:

MT-Traffic: Data is reviewed weekly for a number of parameters. Calibration graphs are generated monthly.
WA-Traffic: Or whenever data personal show possible problems they have noticed from their graphs or observations.
NJ: Visual class check weekly and weight analysis monthly.

3.7.5 How is your WIM data analysis performed?



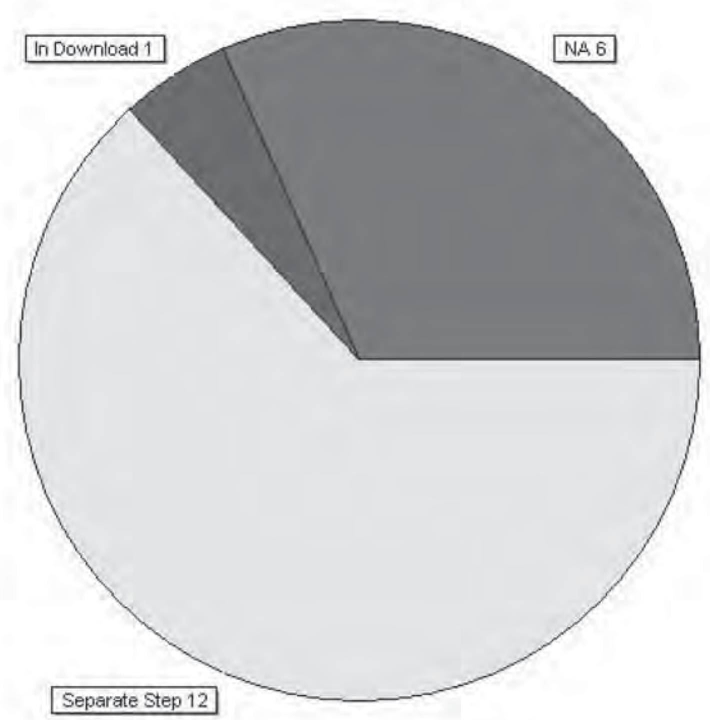
Other Responses:

FL: Realtime traffic stream data and sensor d...
CT-R: Both manual and automated practices are utilized.
SC: In house program
WY-Traffic: Combination of both manual and automatic.
ID-Traffic: Both manually and also using automatically produced reports.

Comment Responses:

MT-Traffic: Data is also analyzed manually if any problems are found with the automatic process, and to make sure the automatic process is checking all that it should be.
ID-Traffic: This would be a good question to allow an answer of "both". We use both manual judgement, plus we pay close attention to our automatically produced reports.

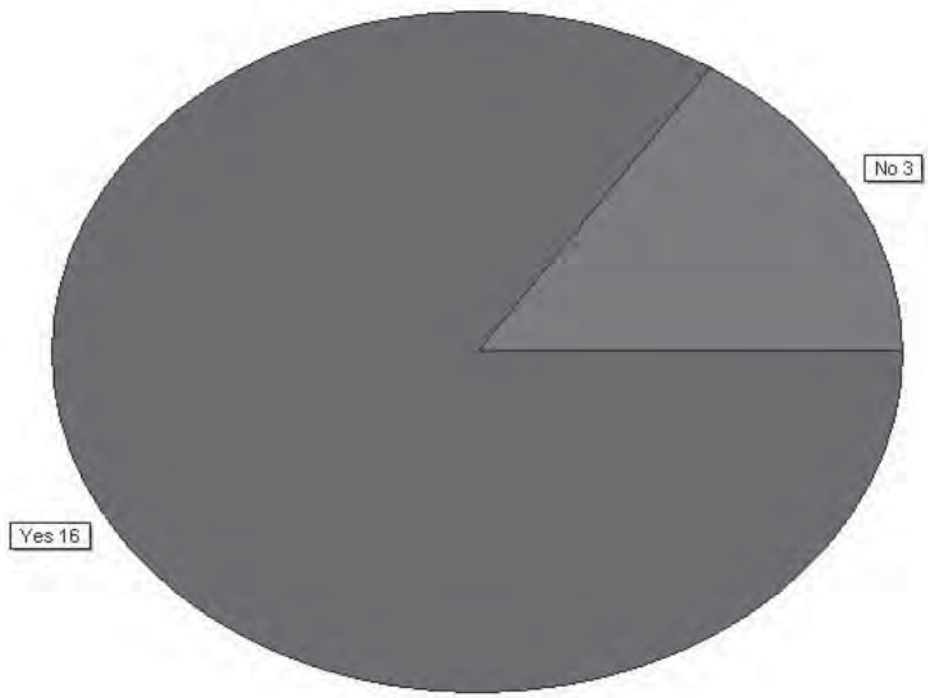
If your data analysis is performed automatically using software, when is it carried out?



Comment Responses:

FL: Both actually, although the nightly QC edi...
MT-Traffic: We have custom software for this procedure.
WI-Traffic: Tests are performed Using TRADAS that validate the file and identifies anomalies.

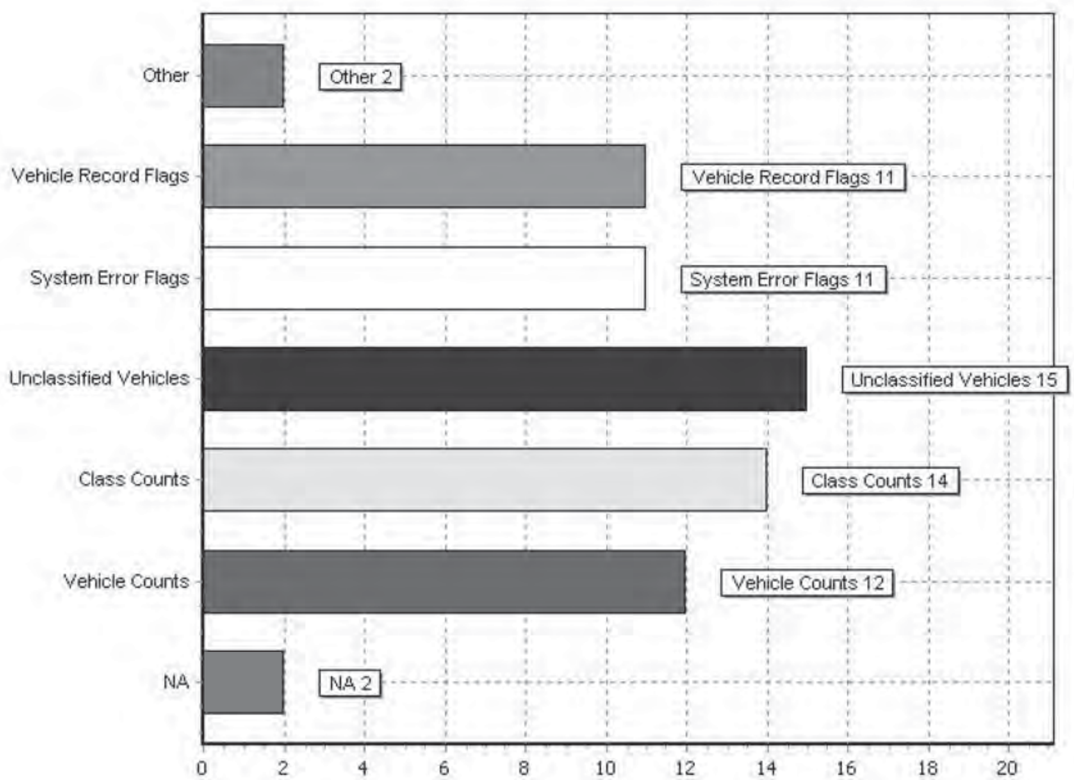
3.7.6 In your opinion, do the analyses of your WIM data identify most system operational problems and atypical traffic characteristics?



Comment Responses:

MT-Traffic: Our custom software was designed, and is being upgraded as needed, to perform these functions.
UT: Congestion doesn't show up well

If Yes, which types of system operational problems and/or atypical traffic characteristics are identified? Check all that apply.



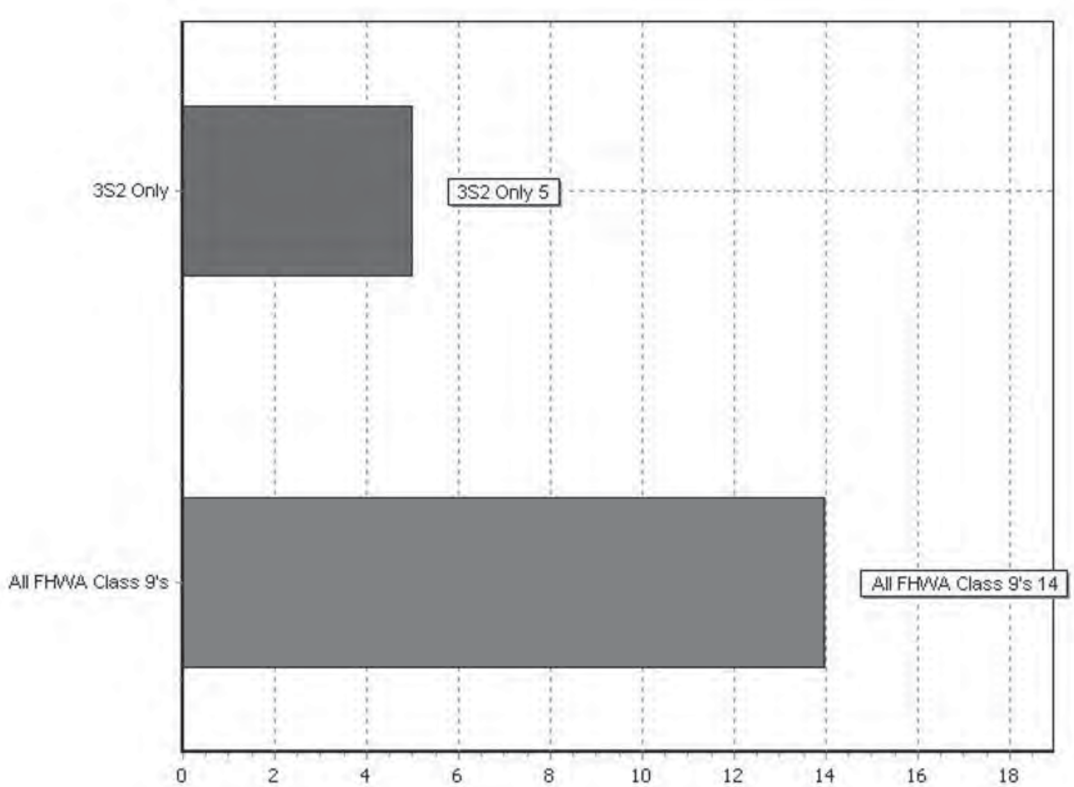
Other Responses:

CT-R:Series of checks begin with file size, include the checked items above, as well as, Front Axle weight distributions for unloaded and GVW distributions for Class 9 vehicles. Finally the data is run through the LTPP data checks that includes graph
MT-Traffic: Software also can generate error tracking graphs so months and years of historical operation can be viewed.
WI-Traffic: Data file integrity

Comment Responses:

ID-Traffic: Sensor and loop related problems are most common -- sensor misses for various reasons are detected and corrected using a combination of manual observations and report analysis.

3.7.7 Which traffic stream vehicle types are utilized for calibration monitoring? Check all that apply.



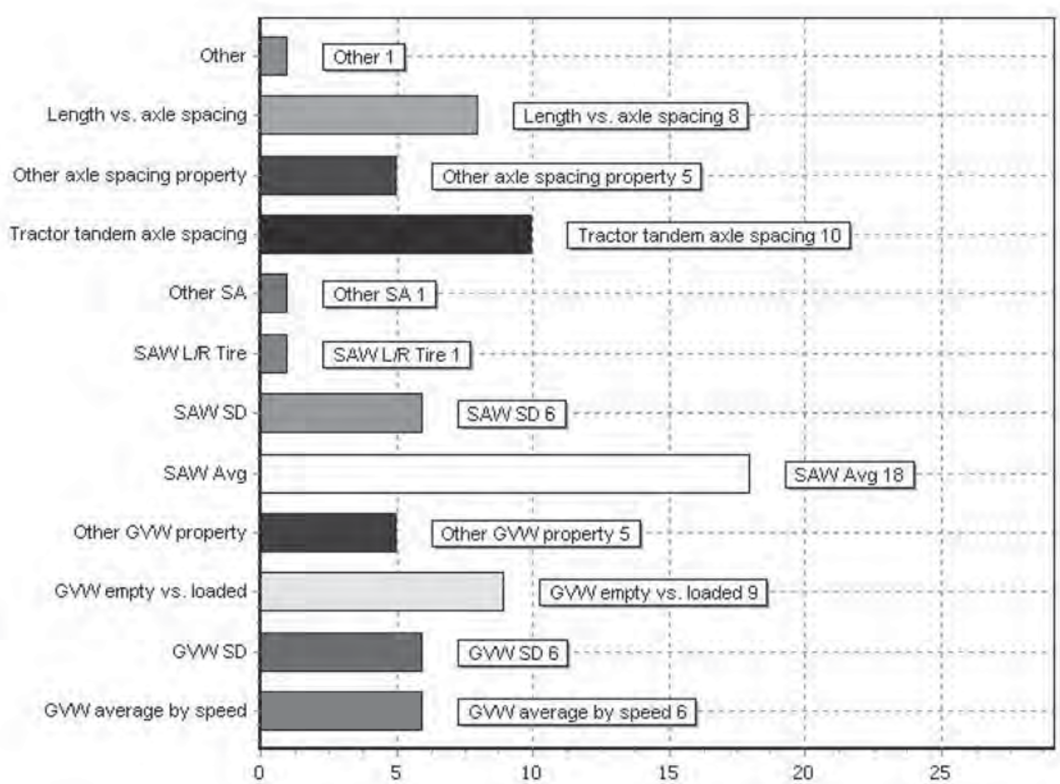
Other Responses:

CT-R: Have monitored subsets of Class 9's, but only for investigations.

Comment Responses:

WI-Traffic: FHWA 9 for initial. If detail is desired we drill down to just 3S-2
NJ: 3s2 with front axle weight bet 8-12K and GVW bet 30-85K
ID-Traffic: Empty 3S2 flatbeds are good observations. Front axles of 3S2's are also helpful. Other visable loads can be compared based on experience.

3.7.8 Which characteristics are monitored through WIM calibration monitoring using traffic stream WIM data? Check all that apply.

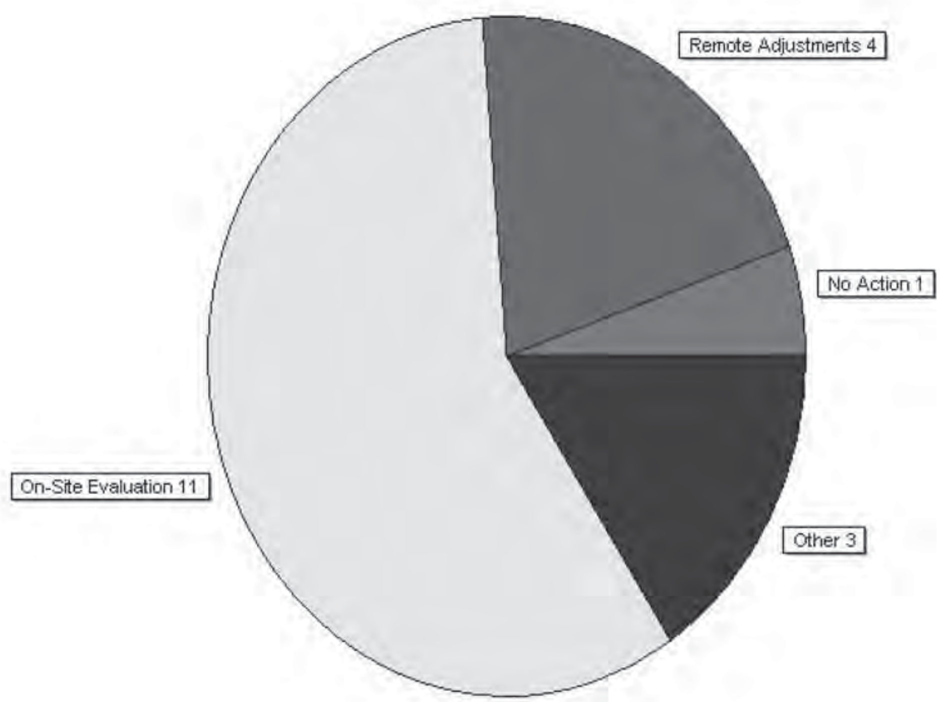


Other Responses:

CT-R: others only on limited investigations---
MT-Traffic: This data is also monitored for vehicles that may not meet our current classification table definitions, and need to have new definitions added.
GVW Average

Comment Responses:

3.7.9 If the monitoring of traffic stream characteristics indicates a system is experiencing calibration "drift" what action is taken?



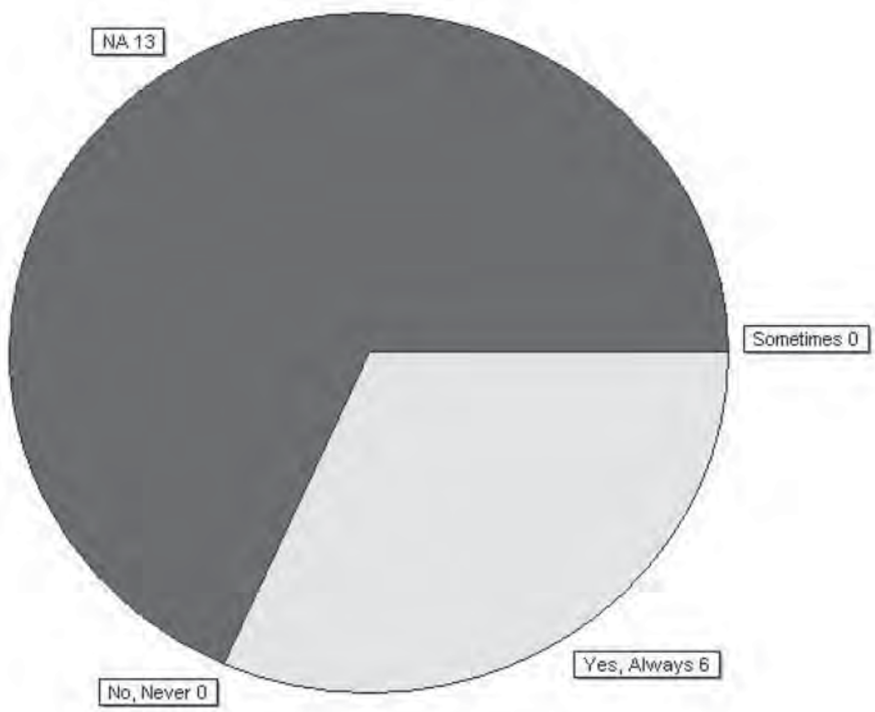
Other Responses:

CT-R: Only case where that was not the case when there had been recent changes to software- check factors are correct and software was not changed.
MT-Traffic: It depends on the site. Office adjustment with post-adjustment data monitoring may be sufficient. If not, on-site calibration procedures may be executed.
adjust or replace manually
PA: Vendor notifies that a site visit may be required

Comment Responses:

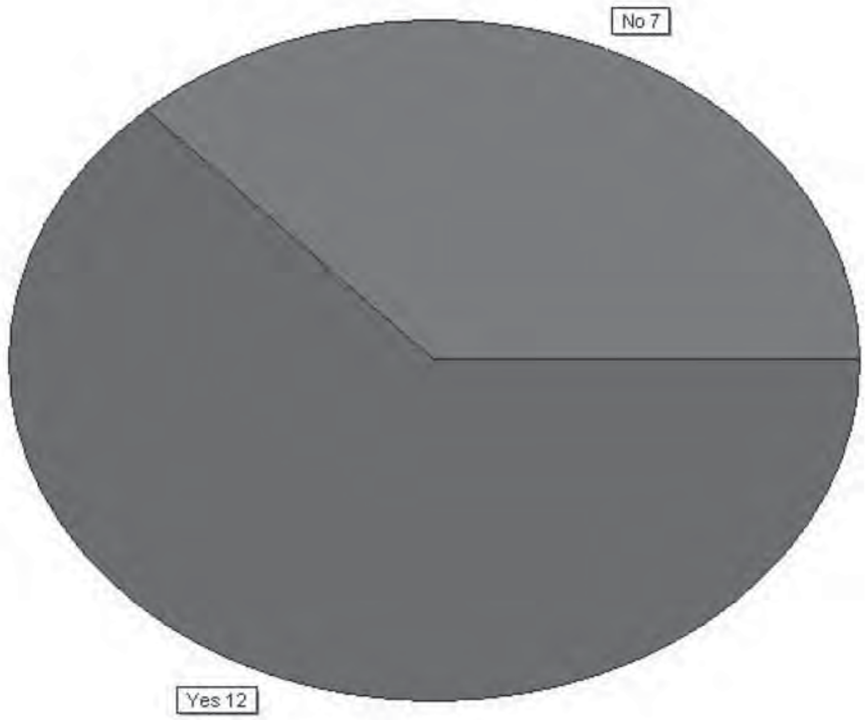
NJ: Calibration with test vehicle is scheduled.
VA-Traffic: Data that has been affected by a known amount of calibration drift is post-processed to bring it back into line.
ID-Traffic: Factors are also adjusted directly at the site.

3.7.10 If calibration factors are adjusted from the office, do you check the effect on the traffic characteristics described in 3.7.8? Those characteristics included: (GVW Average, GVW Average by speed, Steering axle weight average, etc.). To view a complete list click on Previous Page below.



Comment Responses:

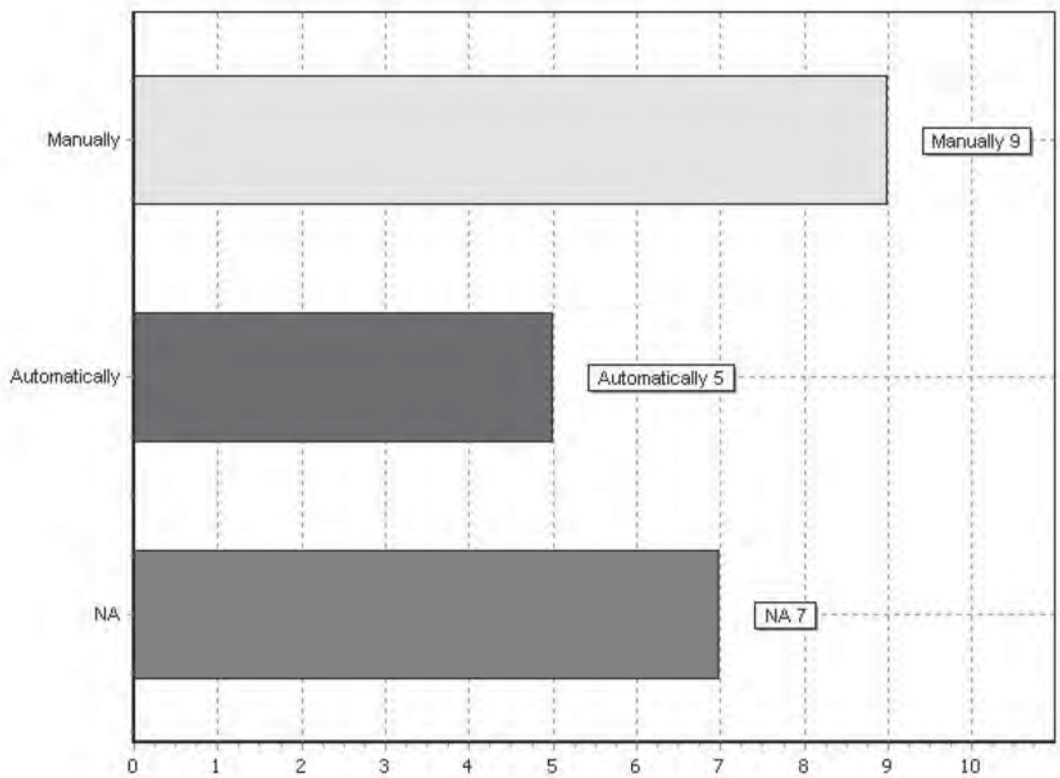
3.7.11 Do you keep records of WIM calibration factor adjustments?



Comment Responses:

MT-Traffic: Any adjustments made are recorded in a spreadsheet, and history for each site is maintained
WI-Traffic: Records of initial calibration are kept.

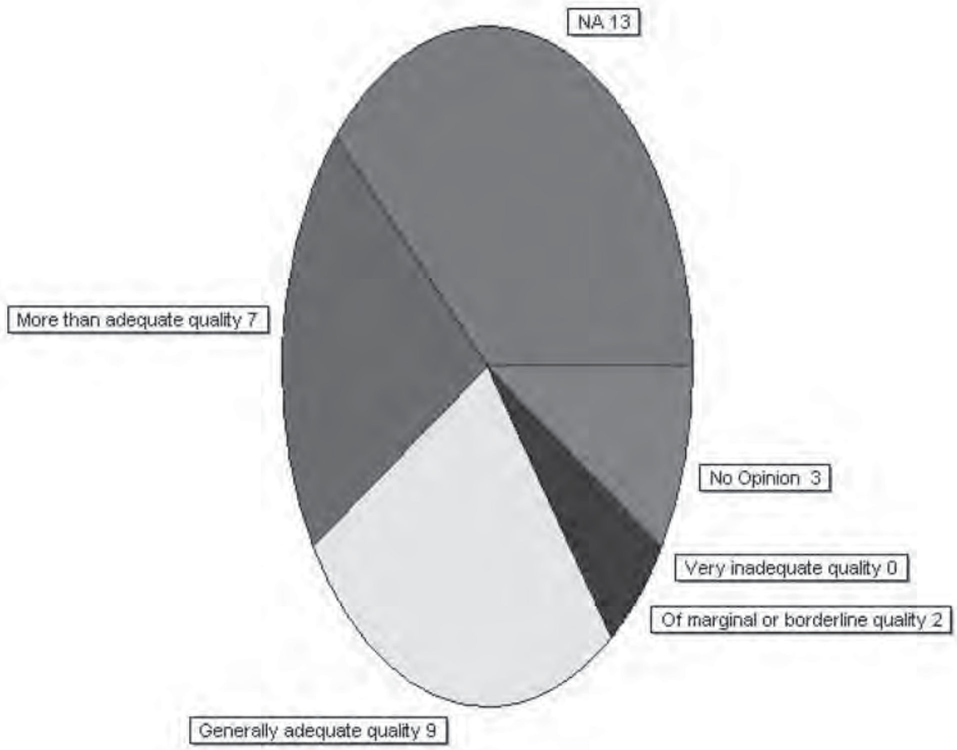
If Yes, how are records kept?



Comment Responses:

Database calibration factor tables, and paper copies.
MT-Traffic: Factors are recorded in spreadsheets for each site every time new factors are calculated, or if factors are changed for drift adjustment.
Date and factors are recorded

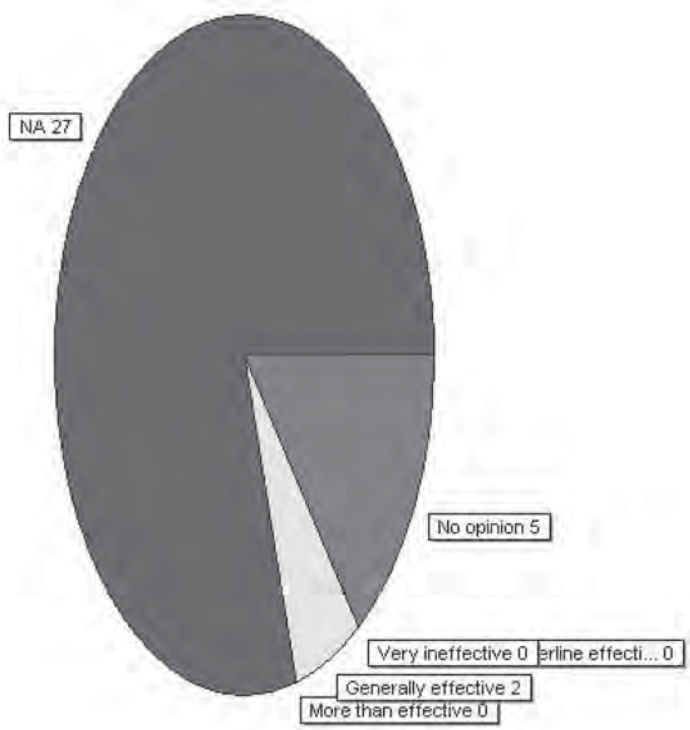
Part 4: YOUR OPINION 4.1 In your opinion, are your Type I traffic data systems generating data of adequate quality to meet the requirements for the intended purposes?



Additional comments:

MT-Traffic: The Kistler based systems generate good quality data. The two Type I systems that use MSI-BL type sensors generate adequate data.
NJ: Used to maintain 4 bending plate sites and required constant maintenance which cannot be done. Data are no better than Type II sites.
RI: Our data must be adaquate, I have heard of no complaints from FHWA-Washington.
IL: We are not using the data, so it would be difficult to determine the quality.
TX: Very satisified with bending plate data

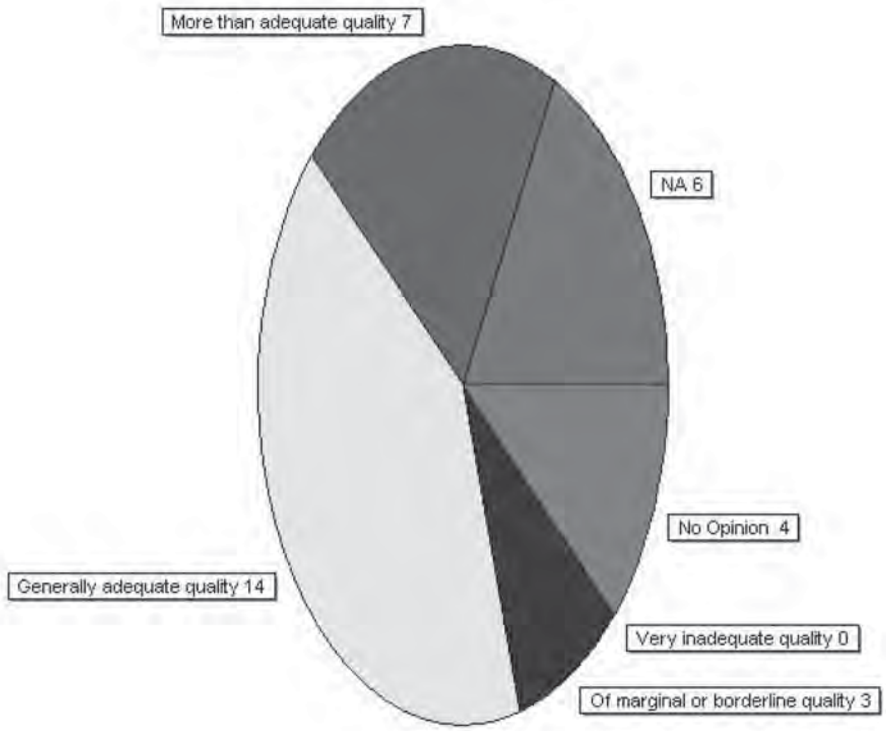
4.2 In your opinion, are your Type I main line enforcement screening and/or sorting systems effective?



Additional comments:

MT-Traffic: That information should be obtained from Dennis Hult at Motor Carrier Services.
IL: We are not using the data, so it would be difficult to determine the effectiveness.

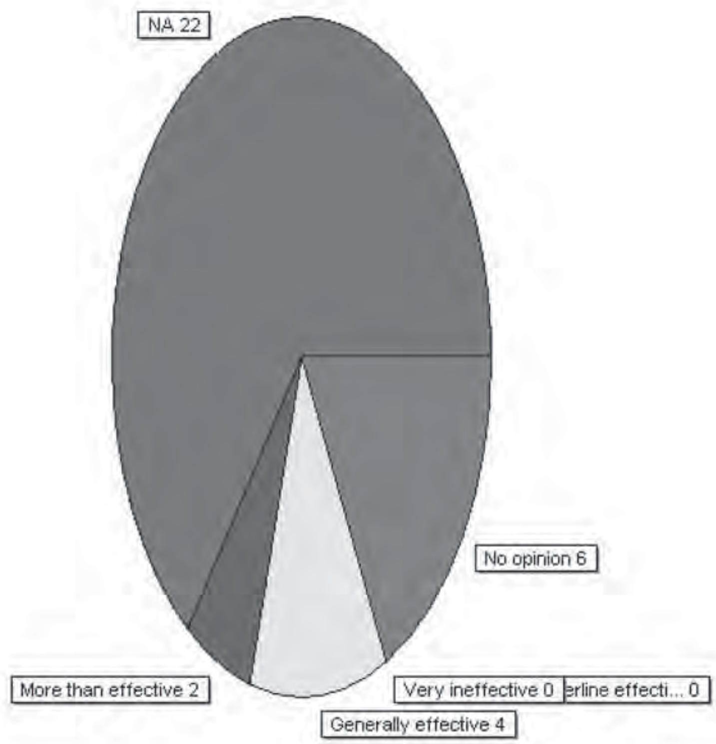
4.3 In your opinion, are your Type II traffic data systems generating data of adequate quality to meet the requirements for the intended purposes?



Additional comments:

AR-Traffic: Volume and classification data are adequate, but weight data is borderline.
AL-Traffic: If proper data validation, maintenance procedures and calibration schedules are followed, the accuracy is adequate for planning and pavement design purposes.
TX: Not very satisifed with the coax sensors. Texas is trying hard to get away from these.

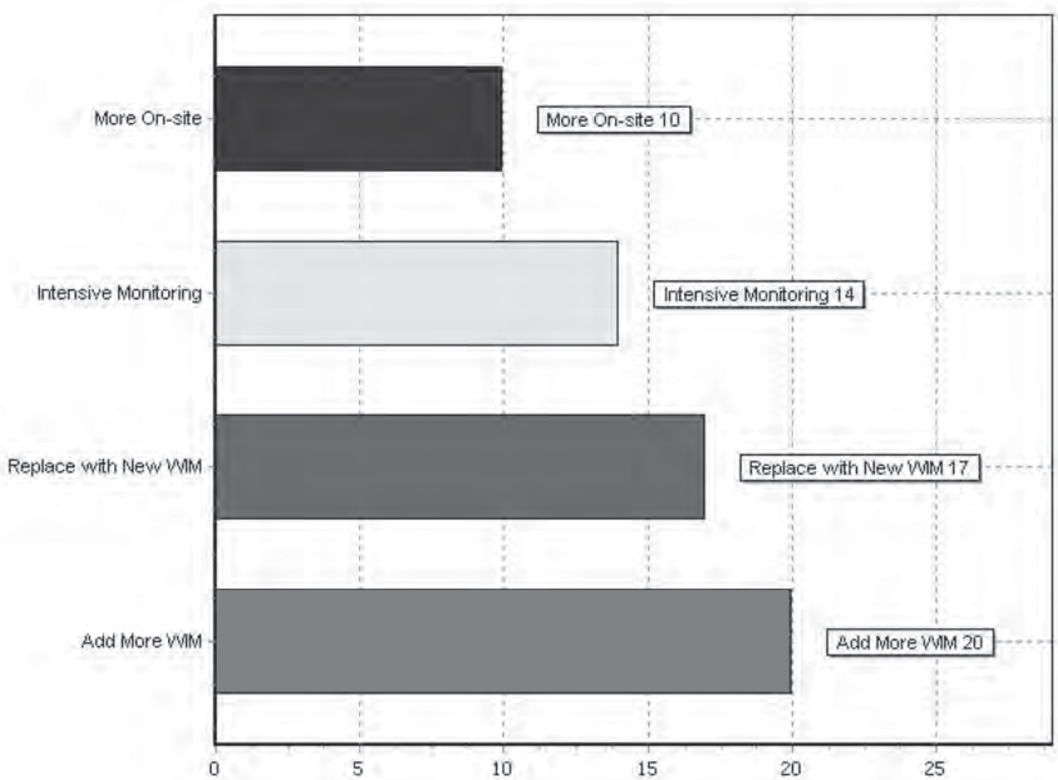
4.4 In your opinion, are your Type II main line enforcement screening and/or sorting systems effective?



Additional comments:

MT-Traffic: Again, that information can be obtained from Dennis Hult at Motor Carrier Services. Traffic Data Collection does not maintain any Type II systems that are used as part of enforcement screening.
NJ: Just in a process of starting the program.

4.5 In your opinion, given additional resources for high speed WIM traffic data collection and enforcement, which of the following would your unit consider? Check all that apply.



Additional comments:

MT-Traffic: Our biggest need is more in-house personnel, both in the field and in the office. Unless FHWA can mandate that States must fully staff their traffic data collection programs, none of this can occur for us.
WI-Traffic: Before I would consider major expansion of WIM I would focus on Classification data. In 22 years of looking at WIM data there has been very little change in average GVW or Loading. I don't see where more will tell us what we don't already know about truck loading. It is more important for us to know how many trucks are utilizing routes.
MA: Imbedded axel sensors (type I piezos) frequently fail due to a variety of reasons. (epoxy/grout deterioration, improper installation procedures, etc...)
UT: Our sites have been in uses for 7 years and are beginning to fail. I would like to replace with quartz
AK: Staffing and timely processing of the data is very important.
KS: Replace old sites that are inadequate
TX: To follow the TMG guidelines, Texas has developed a plan to install WIM site per truck group and functional class of roadways

4.6 In your opinion, what is the main factor hindering proper WIM calibration and how could it be solved?

FL: Time & money and qualified personnel--need more of each.
CT-Research: Resources and Priorities hinder proper WIM calibration. We use the Quartz Sensors and they do not need as much calibration adjustments if they are function as designed. This is still dependent upon the roadway structure. Calibration is labor intensive and takes people and money. If the cost can be shown to be worthwhile by the need for accurate data for the applicatons, then the priority can be supported. That is why this survey needs to include how the data are used so that calibration can be economically justified. In addition, if there were more cost and less labor intensive techniques of achieving the same goals, it may become more realistic to calibrate many WIM sites.
MT-Traffic: More data analysis (using computers and software) so systems can be fine-tuned to their specific environment (make up and volume of traffic stream, speed, road condition, temperature, etc.)
WI-Traffic: Money.
AR-Traffic: Inadequate resources to adequately perform calibration; additional funding would solve this problem. Sensors are not capable of producing accurate data over temperature variations (often over one day). Don't know how to solve this problem. Pavement type (superpave, mostly) leads to site failure; rutting is also a problem. This could be corrected by replacing asphalt with concrete at WIM sites, but again, run into funding problems.
NM-Traffic: budget,having a class 9 solely for calibration
WA-Traffic: To me, the main factor in achieving good WIM data is to first do a quality installation. If sensors are not installed for optimum operational characteristics your data quality will be inconistant. Also equally important is to set your Auto-calibration correctly. Pay special attention to the temperature curve, and your speed bins. It is not the matter of how many times you calibrate the sites with the known weigh trucks, in another words, if you don't set your systems right, you can calibrate your systems with known weigh trucks once a month, but you still end up with bad data.
NJ: The effect of temperature change. Develop new sensors materials that are not affected by temperature change.
VA-Traffic: Vehicle dynamics caused by rough pavement and calibration drift due to pavement wear. This could be solved by having smoother, more wear resistant pavement.
NY: Excessive traffic volumes - no opinion on how to solve it
SC: Cost of test trucks
WV: Additional of second test truck and pavenment smoothness.
MD-Traffic: WIM sensors that are suseptable to environmental variances in flexible pavements.
MS: The main factor MDOT is faced with is maintenance issues with the equipment.
PA: Road deterioration is an issue; more weight enforcement could help with this issue.
MA: Insufficient staff, time, and funding to calibrate the WIM sites. A vehicle (FHWA Scheme F - Type 9) of known weight should make a minimal of five runs per lane to ensure accuracy.

AZ-LTPP: outdated systems, expensive to replace, not-user-friendly vendor software packages.
RI: Money and Manpower
AL-Traffic: Lack of qualified personnel.
UT: Temperature drift
CO-Traffic: Maintenance of piezo grout (better grouts for re sealing piezos)Condition of roadway surface.
WY-Traffic: Autocalibration using characteristic vehicles from the traffic stream is marginal when used on many rural roadways. Solution- sensor technology not dependent on autocalibration schemes, reasonably priced with easy installation.
CT-Traffic: Limited resources
IN-Traffic: Road smoothness. Older sites were never properly smoothed during initial road construction. Ensure road meets ASTM smoothness specs before WIM installation.
AK: Not reviewing the data on a daily basis to identify problems quickly.
GA: Resources and inexperienced personnel
KS: Site conditions. Pavement problems. Need concrete at every site, and long stretches without curves or cross-roads. Staff requirements make the site visits inconvenient.
OK: Money. More money.
ID-Traffic: Time, staff, budget requirements for a test vehicle of known weight -- with minumum of ten passes per each lane -- distant turn around at many sites -- this would take us most of the summer.
TX: Equipment cost, and road conditions
NH: Logistics of runing a test truck on the interstate system - turning around, changing lanes, police escort, etc.

4.7 In your opinion, what are the most urgent WIM technical needs at present and what studies need to be conducted to address them?

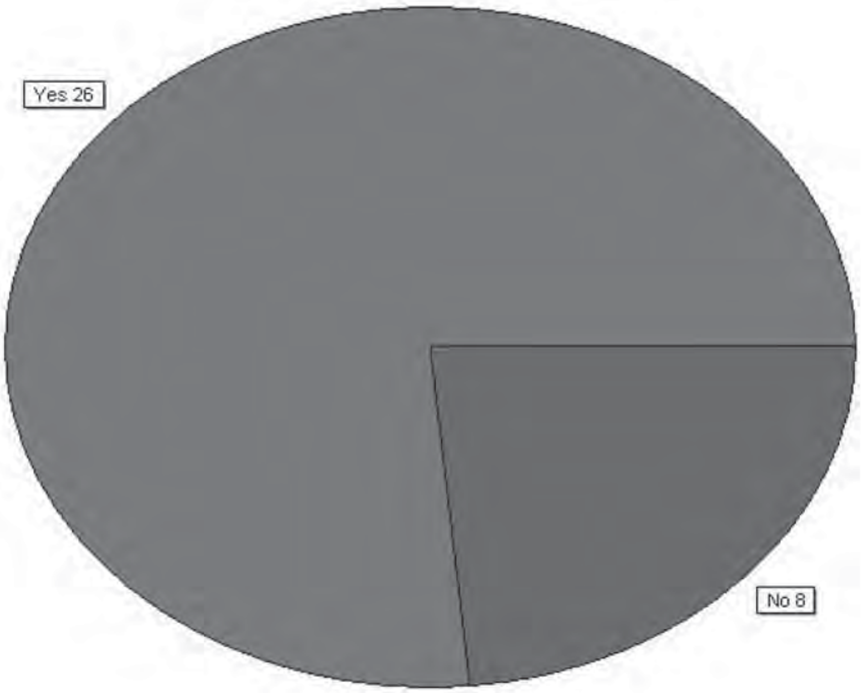
FL: I think we know what to do and how to do it, and which equipment works well. What I need are better pavements into which the WIM sensors can be installed.
CT-Research: We need to understand how the test vehicles relate to the traffic stream to better understand the data quality or assumed quality. We need to know how to relate pavement roughness to the WIM accuracy for how our pavements are actually built. The AASHTO provisional protocols are helpful but unrealistic to many pavement structures. It would be great if we could calibrate without using test trucks- perhaps through simulation programs that have been field tested. We need to know the accuracy needs of the many different data users to know what is really needed. We need nonintrusive systems or methods to "get out of the road." We need better methods to check data based on the actual vehicle configurations. We need to understand the limitation of the data and educate States on the limitation of data. We need to find best methods of sharing data between states and traffic data collection and law enforcement to improve both operations.
MT-Traffic: Better, more reliable sensors. Better epoxy. Modernize the electronics to reduce power consumption and footprint. Improve communication techniques for retrieving data. Temperature of road (sensors) factored into auto-calibration routines for systems using sensors that are temperature sensitive. Better software for both office and field operations. Software needs to be modernized to work with today's operating systems, and it needs to be more user friendly, especially for those users who are not technically inclined. Sensor and epoxy studies should be a joint venture between states and vendors. Softare and communications upgrades should be performed by the vendors in response to their customers' needs. Factoring in temperature as part of maintainingcalibration on temperature sensitive sensors could also be a joint venture with states. Joint studies (vendors and states)have one major drawback--time. Since it appears that most states are understaffed in their traffic data collection areas, participation from a state standpoint would be nearly impossible to do. Once again, if FHWA truly believes that this data is important, then they need to work with state legislatures to make sure that adequate staff is obtained, not only to collect and process data, but to aid in the advancement of data collection tools and methods.
WI-Traffic: I believe that there is too much money already being thrown at WIM and the same questions that were debated 20 years ago are still the same ones today.
NM-Traffic: making the BL piezos last longer regardless of what kind of traffic
WA-Traffic: As you all know, BL piezos are temperature and speed sensitive. I've talked to IRD to expand their temperature and speed bins, but they said there was limitation to the DOS operating system's memory. If all of us can pitch in some

money to pay for IRD to develope their WIM software in Windows that would be a plus.
NJ: Develop more accurate sensors.
VA-Traffic: Smoother, more wear resistant pavement. Sensors with reduced sensitivity to rutting. Lower cost sensors.
NY: N/A
SC: Sensor accuracy. Temperature and so called "auto cal" corrections to WIM data.
WV: Difficulties exist with calibration of small trucks(Duals-class 5's) or less.
MD-Traffic: Not sure
PA: Updating to a Windows based software. PennDOT is looking intoacquiring a new version of WIM Windows based analysis software from IRD called I-analyze which can be used for all PennDOT's WIM sites.
MA: Mass Highway does not utilize telemetry to poll data. We currently use Peek ADR2000's with a maximum of 8 megs storage. This limits us to three to four week studies.
RIDOT has no full time AVC/WIM people. I look at wim data when/if I have the time to.
UT: I need beter access to my sites. The POE sites are being eleminated and one of my eight WIM sites has no power, and none are on the net.
CO-Traffic: Better grouts for piezos and for CDOT better accuracy out of our roadway sensors.
WY-Traffic: From a Type II WIM perspective sensors are still the weak link. I feel fiber optics may hold promise and warrant increased study.
CT-Traffic: Limited resources
IN-Traffic: Constant and regular data monitoring to ensure consistent data.
AK: A good database to retrieve, qc and process the data.
GA: Technological improvement
OK: More reliable automated data collection and analyses software.
ID-Traffic: Diagnostic guidelines for calibration of WIM sites from centralized office location.
TX: Selection of roadways. Types of ACP versus CRC to support WIM systems
NH: Sensors and installation methods that last.

Please provide any additional comments you may want to share about high speed WIM calibration.

MT-Traffic: We have found, here in Montana, that not only is regular calibration important, site maintenance is also a crucial factor in obtaining consistent performance from a WIM site, reguardless of its Type. And running the entire program in-house gives us a much more controlled and consistent product.
NM-Traffic: manufacturing better piezo's to last at least 5 years
WA-Traffic: I've made some modification to the IRD WIM software in order to get a tigher curve: 1- Expand the temperature curve to 40 bins with 2 degree increment instead of 30 bins 5 degree increment. 2- Changed the weigh limit of the Auto-calibration type so the system does not include trucks run off the fog line or crossing the center line in the Auto-calibration process.
NJ: Percentage of errors changes with temperature change. Properly calibarted system verified in the morning will have a significant error in the afternoon? Does test truck calibration really makes that much difference?
PA: We try to have a minimum of 7 passes per calibration. Most times there are 10 pases.
MA: Auto Cal. feature of ADR2000's is accurate. Calibration is done on steering axle, target value of 10 kips, auto cal set to adjust or compensate after 25 vehicles.
IN-Traffic: Location of site should play an important part. Sites near on/off ramps or area's where traffic is changing lanes more than usual has an affect on data.
ID-Traffic: We have considered the test vehicle procedures on several occasions -- even trying to estimate cost and time involved. It has never appeared practical or cost effective for us.

Part 5: INVENTORY OF WIM SYSTEMS This last part of the questionnaire is optional. It is an inventory of WIM systems in your state. Do you want to complete it?



Dual Use - A Single WIM System Used for Both Traffic Data Collection AND Enforcement Screening

Approximate number of Type I WIM Systems	Approximate Number of Type I WIM Lanes	Sensor Type(s)
0	0	
3	6	Kistler
0		
0	0	0
0		
0	0	
0	0	
3	10	VA-Traffic: Quartz Piezo
0	0	
0	0	
0	0	
1	4	MS: Bending Plate
0	0	
0	0	
0	0	0
3	3	UT: Load cells
0	0	
0	0	
6		AK: bending plate and 2 load Cell
0	0	
0	0	0
0	0	
0	0	
0	0	
0	0	

Single Use - Traffic Data Collection ONLY

Approximate Number of Type I WIM Systems	Approximate Number of Type I WIM Lanes	Sensor Type(s)
7	22	FL: Bending Plate
5		CT-R: Quartz
2	4	MSI-BL sensors
1	4	WI-Traffic: PAT bending plate
0	0	0
3	12	
1	2	

0	0	
4	10	VA-Traffic: 8 Lanes Quartz Piezo, 2 Lanes Bending Plate
22		
0	0	
0	0	
0	0	
0	0	
0	0	
11	22	AZ-LTPP: B/Plate & Piezo Sensors
0	0	
0	0	
0	0	
0	0	
2	3	KS: Ceramic, Bending Plate
0	0	0
0	0	
18	40	ID-Traffic: Channel Type I and BL
12	48	TX: bending plate
0	0	

Single Use - Enforcement Screening ONLY

Approximate Number of Type I WIM Systems	Approximate Number of Type I WIM Lanes	Sensor Type(s)
0	0	
0		
0	0	0
0		
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	0
0	0	
0	0	
0	0	

0	0	
0	0	
0	0	0
0	0	
0	0	
0	0	
0	0	

Dual Use - A Single WIM System Used for Both Traffic Data Collection AND Enforcement Screening

Approximate Number of Type II WIM Systems	Approximate Number of Type II WIM Lanes	Sensor Type(s)
0	0	
0		
0		
0	0	0
0	0	
0	0	
0	0	
0	0	
0	0	
12	44	SC: piezo
0	0	
15	4	MS: BL
0	0	
0	0	
0	0	0
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	0
0	0	
0	0	
0	0	
0	0	

Single Use - Traffic Data Collection ONLY

Approximate Number of Type II WIM	Approximate Number of Type II	Sensor Type(s)

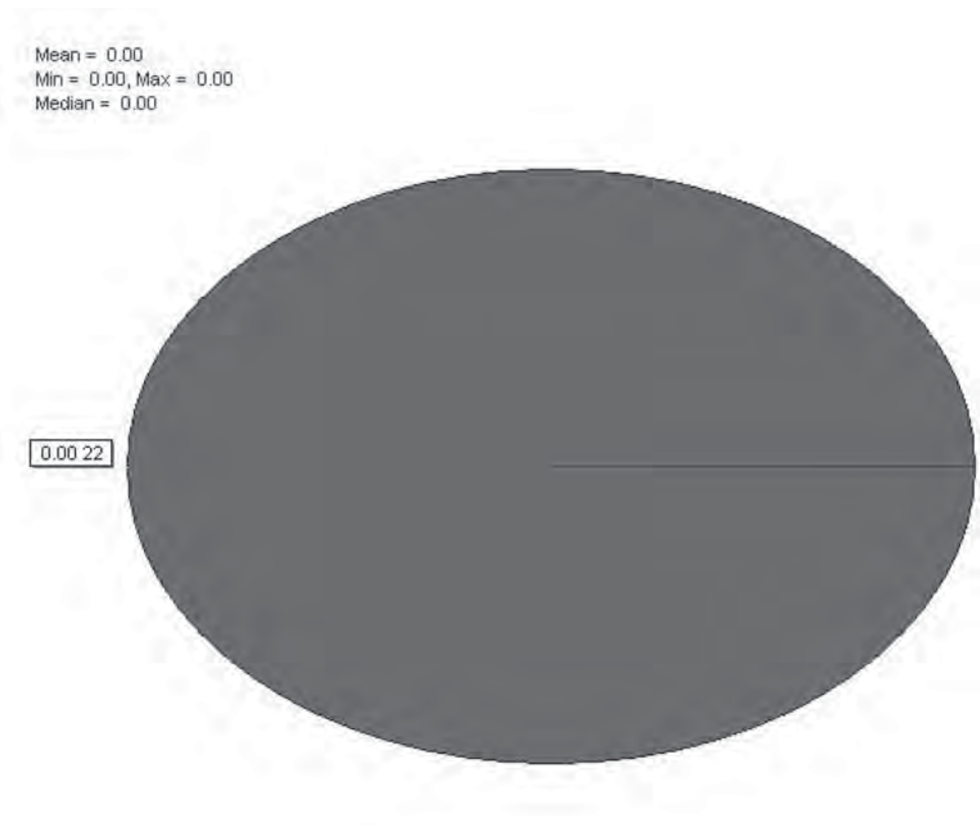
Systems	WIM Lanes	
34	90	FL: Bending Plate, Quartz Piezo, Ceramic Piezo
24	66	ECM encapsulated sensors
10	30	WI-Traffic: Piezo
54	174	piezoelectric (linguine-type) and Quartz piezo
13	48	
32	90	
65	260	
0	0	
0	0	
0	0	
6	6	MD-Traffic: BL Piezo sensor
0	0	
8	9	PA: kistler-loop-kistler
12	30	MA: Piezo, Loop Piezo
7	7	AZ LTPP: Piezo
9	56	UT: Piezo
16	62	
9	22	WY-Traffic: Piezoelectric
0	0	
8	17	KS: piezo-cable
30	2	TN: Diamond Traffic Piezos
20	76	OK: Piezo
0	0	
4	16	TX: piezo
4	18	NH: Piezoelectric

Single Use - Enforcement Screening ONLY

Approximate Number of Type II WIM Systems	Approximate Number of Type II WIM Lanes	Sensor Type(s)
0	0	
0		
0	0	0
0	0	
0	0	
0	0	
0	0	
0	0	

0	0	
0	0	
0	0	
0	0	
0	0	0
0	0	
0	0	
0	0	
0	0	
0	0	0
0	0	
0	0	
0	0	
0	0	

Approximate Number of Type II WIM Systems (Single Use - Enforcement Screening ONLY)



Generated: 6/2/2007 12:48:02 PM

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation