WEIGH-IN-MOTION POCKET GUIDE

PART 3

WIM CALIBRATION AND MAINTENANCE GUIDE

U.S. Department of Transportation
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NOTICE

QUALITY ASSURANCE STATEMENT

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https://www.fhwa.dot.gov/policyinformation/knowledgecenter

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A/C	Alternating current
AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt concrete
ACF	Axle Correction Factor
ALDF	Axle Load Distribution Factors
APT	Axles per Truck
B-WIM	Bridge WIM
BP	Bending plate
CDS	Comparison data set
CPU	Central Processing Unit
DC	Direct Current
DOT	Department of Transportation
DOW	Day of the week
ESAL	Equivalent single axle loadings
FHWA	Federal Highways Administration
GFCI	Ground-Fault Circuit Interrupter
GPS	Global Positioning System
GVW	Gross Vehicle Weight
HDF	Hourly Distribution Factor
HOD	Hour of the day
IRI	International Roughness Index
LC	Load cell
LPR	License plate reader
LTPP	Long-Term Pavement Performance
MAF	Monthly Adjustment Factors
MEPDG	Mechanistic-Empirical Pavement Design Guide
MOT	Maintenance of traffic
MOY	Month of the year
MUTCD	Manual for Uniform Traffic Control Devices
NCR	Non-Compliance Report
NEMA	National Electrical Manufacturers Association
OWL	Optimal WIM Locator
PCC	Portland cement concrete
PPE	Personal protection equipment

PV	Photovoltaic
PVC	Polyvinyl Chloride
PVF	Per Vehicle Format
QA	Quality assurance
QC	Quality control
RMC	Rigid metal conduit
SIM	Subscriber identity module
SPS	Special Pavement Studies
TMG	Traffic Monitoring Guide
TMAS	Travel Monitoring Analysis System
TPF	Transportation Pooled Fund
U.S.	United States
UL	Underwriters Laboratories
VCD	Vehicle Class Distribution
VWS	Virtual Weigh Station
WIM	Weigh-in-Motion

INTRODUCTION TO PART 3

The Federal Highway Administration (FHWA) Weigh-In-Motion (WIM) Pocket Guide consists of three main text documents, four instructional video supplements, and six appendices. The video supplements and appendices are only available on the FHWA website: *https://www.fhwa.dot.gov/policyinformation/knowledgecenter.* Part 1 includes a description of each element of the FHWA WIM Pocket Guide (referred as Guide through the rest of the document). This Part 3 was developed to assist WIM technicians in the proper maintenance and calibration of WIM sites. It includes step-by-step instructions for calibrating a WIM system; suggestions for tools, forms, and reporting processes that can be used for calibration and system maintenance; and a recommended process for troubleshooting system faults.

The WIM Calibration section of the Guide includes valuable information for conducting a successful WIM calibration that is based on best practices, including a pre-visit traffic and profile data analysis to develop WIM system accuracy expectations for the validation, on-site activities to ensure the proper operation and calibration of the WIM system, and a post-visit analysis to assess the effectiveness of the calibration. Properly conducting these activities will ensure high-quality WIM data collection.

The WIM System Maintenance section of the Guide includes a scope of recommended maintenance activities, recommended schedules, description of field checks, and recommendations for field logs, acceptance testing, and maintenance reports. This section also includes a comprehensive WIM troubleshooting procedure.

Throughout this document, action items are identified using numerical sequencing or the checkmark (✓) icon. Please also refer to manufacturers’ documentation for additional guidance on recommended maintenance schedules and specific calibration requirements.

WIM Standards and Performance Requirements

The ASTM International E1318-09 *Standard Specification for Highway Weigh-In-Motion (WIM) Systems with User Requirements and Test Methods* is a primary WIM standard accepted in the U.S. *(1)*. Other countries have their own standards *(2, 3)*. The ASTM E1318-09 standard classifies WIM systems according to four distinct types, depending on the application and functional performance requirements.

> **ASTM E1318-09 WIM Types**
>
> - **Type I and Type II systems:** Suitable for traffic data collection purposes, with Type I systems having slightly more stringent performance requirements. Vehicle speed range to meet functional performance requirements is 10 to 80 mph.
> - **Type III systems:** Suitable for screening vehicles suspected of weight limit or load limit violations and have stricter functional performance requirements than Type I and Type II systems. Vehicle speed range to meet functional performance requirements is 10 to 80 mph.
> - **Type IV systems:** Not approved for use in the United States but intended for use at weight enforcement stations. Vehicle speed range to meet functional performance requirements is 2 to 10 mph.

Table 1 summarizes the ASTM E1318-09 WIM system performance requirements. The 95 percent compliance defined in ASTM E1318-09 specifies the minimum percentage of measurements (i.e., no less than 95 percent) that should be within the specified tolerances to satisfy the performance requirements. Since Type IV WIM systems have not yet been approved for use in the United States, specifications for these systems are not provided.

Table 1 – ASTM 1318E-09 Functional Performance Requirements for WIM Systems

Function	Tolerance for 95% Compliance		
	Type I	Type II	Type III
Wheel Load (single or dual tires)	±25%		±20%
Axle Load	±20%	±30%	±15%
Axle-Group Load	±15%	±20%	±10%
Gross Vehicle Weight	±10%	±15%	±6%
Speed	±1 mph		
Axle-Spacing and Wheelbase	±0.5 ft		

Enhanced WIM performance requirements were developed under the FHWA Long-Term Pavement Performance (LTPP) Program in an effort to collect research-quality WIM data *(4)*. LTPP tolerances are the same as in ASTM E1318-09, but instead of 95 percent compliance (i.e. percentage of measurements within the specified tolerances), LTPP uses a statistically computed 95 percent confidence interval plus mean error to characterize the spread of measurement error and compares it with the tolerances listed in Table 1. The LTPP performance requirements include provisions for performance testing at three temperature and three speed ranges, requirements for road smoothness, and requirements for the accuracy of the vehicle length measurements.

WIM CALIBRATION

What is WIM Calibration?

WIM calibration is the process of evaluating the measured weight, axle spacing, overall vehicle length, and speed values reported by the WIM system against known static weights and manually measured axle spacing, vehicle lengths, and speed and making necessary adjustments to the WIM system operating parameters to compensate for those errors. The initial calibration is performed to ensure that the WIM system accuracy meets contract specifications after the site has been installed. Periodic routine WIM calibrations are performed to ensure that the data accuracy remains consistent and within the selected performance specification.

Figure 1 – Calibration Test Truck Approaching WIM Scale

As a result of the calibration, the mean error in WIM measurements (i.e., measurement bias) should be reduced to as close to zero as practically possible for all measured parameters. The WIM system calibration is typically performed by a qualified WIM technician in accordance with the manufacturer's specifications and guidelines set forth in ASTM E1318-09 or in FHWA's *LTPP Field Operations Guide for SPS WIM Sites (1, 4).*

Purpose of Calibration

Per ASTM E1318-09, the function of calibration is to define 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, axle spacing, and wheelbase values for the static vehicle *(1).* Calibration reduces the influence of speed, temperature, truck type (if multiple test trucks are used), and environmental changes in the supporting pavement structure on the WIM system's measurement accuracy for each lane measured.

The influence of temperature changes on measurement error beyond those observed during calibration cannot be addressed without vendor assistance in setting site-specific temperature compensation factors. Also, unless multiple test trucks are used, the WIM systems accuracy as a function of type of truck cannot be effectively determined.

Types of Calibration

Initial Installation Calibration

Purpose

The purpose of the initial calibration is to verify that, upon initial installation or major repair, the WIM system is providing the level of weight and spacing measurement and classification accuracy stipulated in the WIM procurement contract.

Scope

For the initial calibration, the WIM vendor or their certified representative (WIM contractor) typically calibrates the site according to the manufacturer's procedures and any additional standards listed in the WIM system procurement contract. The contracting highway agency may use the results of the calibration to determine the acceptability of the system.

To perform the initial calibration, a qualified WIM technician may do the following:

1. Statically weigh and measure each axle and record each axle spacing and total bumper to bumper length of each of the calibration test trucks (see Figure 2).

Figure 2 – Measuring Test Truck Axle Spacing

2. Perform a sufficient number of test truck runs (at least 10 are recommended) to develop a reasonable confidence in the accuracy of the WIM system, especially with regard to speed, temperature, and truck type.
3. Calculate and install the system error compensation factors to compensate for the measured system bias.
4. Conduct additional test truck runs to confirm that the changes had the desired effect on the WIM system measurement bias for the desired degree of confidence (more runs means higher confidence).
5. Recalibrate, if necessary to meet contract specifications.
6. Document the compensation factors installed in the WIM controller, the number of test truck runs resulting in pass or fail of the WIM performance requirements, and WIM performance parameters, such as mean error

and range of errors, for future reference. Table 2 shows an example of such documentation.

Table 2 - Example of Test Truck Run Statistical Results

Parameter	Mean	2SD	P/F
Steering Axle	-0.3%	5.0%	Pass
Tandem Axles	1.7%	5.0%	Pass
GVW	1.4%	3.1%	Pass
Vehicle Length (ft)	-0.2	1.4	Pass
Vehicle Speed (mph)	0.0	0.6	Pass
Axle Spacing (ft)	-0.3	0.2	Pass

7. Develop a record of whether the WIM system passed or failed WIM performance requirements based on ASTM or agency-specific performance requirements.

A representative from the contracting agency reviews the initial calibration results to ensure that the WIM system is providing data with acceptable measurement error tolerances. WIM installation or sensor replacement is accepted only after the contracting agency has approved the initial calibration. Additional details are provided later in this chapter, in the section titled Calibration Procedure.

Routine Calibration

Purpose

The purpose of the routine calibration is to maintain the WIM equipment at the maximum level of accuracy possible for the service life of the system. An annual calibration is recommended.

Scope

Typically, the routine calibration is conducted by agency's in-house staff or a WIM maintenance contractor staff using procedures described in the ASTM E1318-09 standard. The guidelines provided in the FHWA *Field Operations Guide for*

LTPP SPS WIM Sites could also be used for calibration of ASTM E1318-09 Type I WIM systems *(4)*. No matter which specification is used, the person performing the calibration needs to conduct a sufficient number of test truck runs (10 to 40, depending on the site, sensor array, and sensor characteristics) to quantify the weight, axle spacing, overall vehicle length, and speed measurement error of the WIM system with a 95 percent level of confidence.

To perform the routine calibration, a qualified WIM technician may do the following:

1. Statically weigh each axle, axle group, and gross vehicle weight (GVW) and measure each axle spacing for the calibration test trucks. The length of vehicle and overhang also might be needed if this is being verified with the calibration runs. Figure 3 shows a truck being weighed at a certified truck scale.

Figure 3 – Weighing Truck at Certified Truck Scale

2. Perform a sufficient number of test truck runs per ASTM E1318-09 or agency specification to develop a reasonable confidence level in the accuracy of the WIM system, especially with regard to speed. Figure 4 shows GVW measured at low, medium, and high speed ranges. Sometimes, only two different speed ranges can be used.

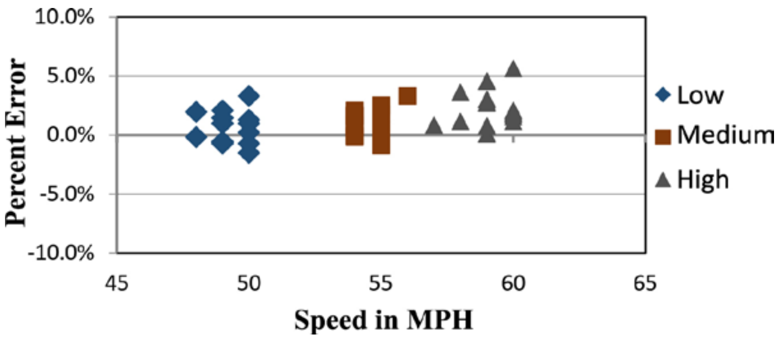


Figure 4 – Gross Vehicle Weight by Speed

3. Make changes to the system error compensation factors to compensate for the measured system bias.
4. Conduct additional test truck runs per ASTM E1318-09, LTPP, or agency specification requirement to confirm that the changes had the desired effect on the WIM system measurement bias *(1, 4)*.
5. Recalibrate, if necessary to meet ASTM, LTPP, or agency-specific accuracy requirements.
6. Document the changes to compensation factors installed in the WIM controller, the number of test truck runs resulting in pass or fail of the WIM performance requirements, and WIM performance parameters, such as mean error and range of errors, for future reference. Table 3 shows an example of such documentation.

Table 3 - Example of Compensation Factors

Calibration Factors				
Overall Factor		103		
Wheel Path	Left		Right	
Sensor	1	3	2	4
Speed Factor 1	3312	3300	3312	3300
Speed Factor 2	3255	3364	3255	3364
Speed Factor 3	3220	3343	3220	3343
Speed Factor 4	3120	3280	3120	3280
Speed Factor 5	3120	3280	3120	3280

7. Develop a record of whether the WIM system passed or failed the WIM performance requirements.
8. Store the calibration settings both in the field and in the office for possible later use.

Types of Calibration Methods

The recommended calibration methods are ASTM E1318-09 method and LTPP method described in *LTPP Field Operations Guide for SPS WIM Sites (1, 4)*. Both The ASTM E1318-09 and LTPP calibration methods use similar procedures but apply slightly different evaluation criteria to interpret calibration results. Other methods based on the reduced requirements for the number of test truck runs could be used, if test data show consistency over time.

ASTM E1318-09 Criteria

ASTM E1318-09 specifies acceptable WIM accuracy tolerances for four types of WIM systems (see Table 1 above) *(1)*. Based on the ASTM E1318-09 test method, the WIM system has failed to satisfy performance parameters for a given WIM Type if more than 5 percent of the measurements for the test truck runs exceed the error tolerances specified in Table 1 for any measurement type.

Additionally, if mean errors (like GVW mean or average error) calculated based on all test truck passes significantly deviate from zero (user specified value, 2% or more is recommended in this Guide), then the WIM system measures with a systematic bias and calibration has failed.

LTPP Criteria

Based on the LTPP Transportation Pooled Fund (TPF) Study 5(004) test method, the WIM system has failed to satisfy performance parameters if the overall error exceeds the tolerance limits specified in Table 2 *(4)*. The overall error is computed as mean error +/- 95 percent confidence interval of measurement errors. The allowable mean error value for GVW is typically limited to 2 percent. LTPP also provides a vehicle length measurement requirement of ±1.5 feet or 3 percent of the vehicle's overall length, whichever is longer. Table 4 summarizes the LTPP performance requirements.

Table 4 - LTPP Performance Requirements for WIM Systems

Measurement Type	95 Percent Confidence Limit of Error
Steering Axle	±20%
Axle-Group Load	±15%
Gross Vehicle Weight	±10%
Speed	±1 mph (2 km/h)
Axle-Spacing	±0.5 ft (0.15 m)
Vehicle Length	±1.5 ft or 3.0%*

*Whichever measurement is longer.

The basic statistic is the error expressed as a percentage of the known value (i.e., percentile difference between the WIM-measured weight and the static weight of the test truck). The percentage of error values calculated for each run are then combined in one pool and used to compute the mean error, the

95 percent confidence interval for the error, and the overall error.

Tools and Equipment

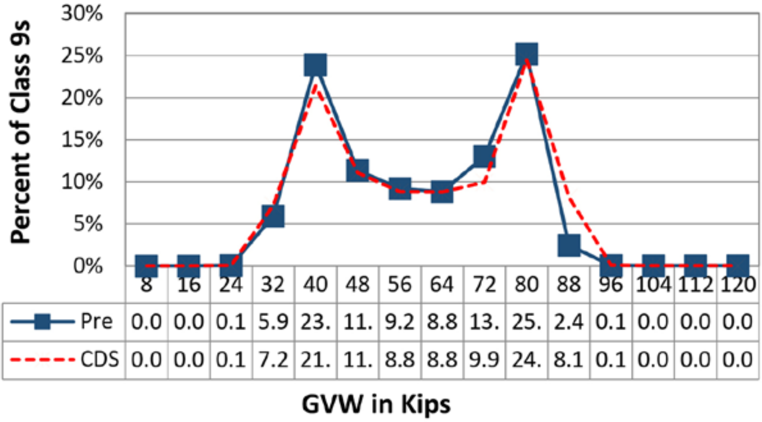
The calibration technician may need the following tools to conduct the calibration:

- WIM manufacturer's operations manual
- Communication equipment for connecting to the WIM system
- Walkie-talkies or cell phones for each driver and one for the WIM calibration crew that works over a suitable long distance
- Laptop
- Calculator
- Multimeter – resistance, inductance, and maybe capacitance
- Megger – ground/insulation resistance meter
- Jeweler's screwdriver
- 100-foot measuring tape
- Flashlight
- Tire pressure gauge
- Tire depth gauge
- Cabinet key
- Non-contact temperature gauge
- Laser speed gun
- Protective safety equipment

Calibration Procedure

Step 1 – Perform Pre-Visit WIM Data Analysis

A pre-visit data analysis provides information on the current operational status of the WIM system. It is used to identify any deviations in weight and length measurements from the values recorded immediately after the most recent calibration and saved in the comparison data set (CDS). It also provides information needed to establish the requirements for the test truck vehicles, including type, weight, length, and speed. Figure 5 shows an example CDS for GVW distribution.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Pre	0.0	0.0	0.1	5.9	23.	11.	9.2	8.8	13.	25.	2.4	0.1	0.0	0.0	0.0
CDS	0.0	0.0	0.1	7.2	21.	11.	8.8	8.8	9.9	24.	8.1	0.1	0.0	0.0	0.0

Figure 5 – Example of Data Comparison for GVW Distribution

Prior to the site visit, perform the following:

1. Collect a recent data sample from the WIM system. Two to 4 weeks' worth of data is recommended, depending on truck volumes, to obtain a sample of at least 5,000 heavy vehicles in classes 4 to 13. Analyze the data to determine the current site characteristics, including:
    - Most common heavy truck type for the site to be used as a test vehicle (typically FHWA vehicle class 9).
    - 85th percentile truck speed and a range of speeds for calibration test truck runs.
    - GVW distribution for the prevalent heavy truck type (typically FHWA vehicle class 9) and target weight of calibration truck.
    - Axle spacing for the prevalent heavy truck type (standard tandem versus spread tandem).
2. Compare the expected traffic flow characteristics developed based on the data collected immediately after the most recent calibration (the comparison data

set – CDS) with the traffic characteristics based on the recently collected WIM data. Use the results to assess the likely need for calibration and to establish the likely range of compensation factors to be applied in the field.

3. Annotate the following information from the data analysis:
    - Changes in the GVW of the most common heavy vehicle type, including averages, by:
        - Hour of the day (HOD)
        - Day of the week (DOW)
        - Month of the year (MOY)
    - Changes in vehicle class distributions by HOD, DOW, and MOY
    - Changes in average truck speeds

Step 2 – Perform Pavement Profile Data Analysis

If pavement profile data are available, an analysis of the most recent data from the WIM site location is recommended. The pavement smoothness analysis may be accomplished using the profile data collected with an automated high-speed profiler and standard agency procedures, or using the Optimal WIM Locator (OWL) module of the Pro-Val profile data analysis software, which can be obtained at http://www.roadprofile.com/proval-software.

1. Process profile data to identify locations of highest International Roughness Index (IRI) values within the 600-foot WIM segment (400 feet before and 200 after WIM scale location).
2. Compare the values computed using the OWL software in the vicinity of the WIM site with the threshold values provided in Table 5, taken from American Association of State Highway and Transportation Officials (AASHTO) specification M331-13 *(5).*

*Table 5 - WIM Roughness Index Thresholds**

WIM Type	Lower Threshold m/km [in./mi]	Upper Threshold m/km [in./mi]
Type I	1.34 [84.8]	2.70 [171.1]
Type II	1.86 [117.9]	3.75 [237.7]

*These values do not take into account sensor and array types and may be too conservative for multi-sensor arrays or high accuracy sensors

3. Create a record of locations that produced values exceeding the upper threshold value. Values above the upper threshold indicate that road roughness is likely contributing to the measurement error.

Step 3 – Select Test Trucks and Determine Test Speeds

This step is accomplished prior to the WIM site visit. The following guidance helps to determine the type of test truck to use for WIM site validation and calibration, including vehicle type (class), weight, axle spacing, suspension configuration, and bumper-to-bumper length and speeds for calibration test truck runs.

Test Truck Selection

Typically, an FHWA class 9 vehicle is used for calibration. Both ASTM and LTPP WIM calibration procedures recommend using this type of truck. Figure 6 shows a photo of a typical calibration test truck. The exceptions are load-restricted or commercial truck-restricted roads; the heaviest truck class that routinely uses the road is recommended for calibration, which could be a class 5 truck. Also, both ASTM and LTPP recommend using two calibration test trucks.

Figure 6 - Calibration Test Truck

Use the following guidance to select calibration truck(s):

1. Whenever possible, use more than one calibration truck to better calibrate the dynamic loading conditions encountered at the site.
2. Select calibration test truck(s) that best represent the dominant heavy trucks (i.e., trucks in vehicle classes 6-10) for the WIM site. Typically, this is class 9.
3. If two calibration trucks are used, one truck should be at or near full load capacity and be configured with typical tandem spacing (4.0 feet to 4.5 feet apart for the truck and trailer) and have air suspension on the truck and trailer.
4. Select different loading for the second truck to better represent the most frequently observed loading conditions at the site.
5. However the trucks are retained, they should each have the following characteristics:
   - ✓ Working speedometer
   - ✓ Suspension systems must be free of mechanical deficiencies, including cracks, punctures, air leaks, or loose fittings
   - ✓ Capable of meeting the test truck speed requirements

- ✓ Loads must be non-shifting, such as crane counterweights, steel plates or beams, or concrete blocks
- ✓ If loads that allow the collection of rainwater are used, the trailer and load must be completely covered to avoid the collection of water and the associated increase/decrease in load weight as water collects or evaporates

6. Locate the nearest certified weigh scale location to the WIM site.

Test Truck Speed Determination

It is important that the test truck's speed is as close as possible to the dominant truck speed at the WIM site, without exceeding the speed limit. The range of the test truck speeds should represent a 10 to 20 mph range of typical truck speeds for the site. Figure 7 shows a typical Class 9 speed distribution plot that is used to determine the test truck speeds for the calibration.

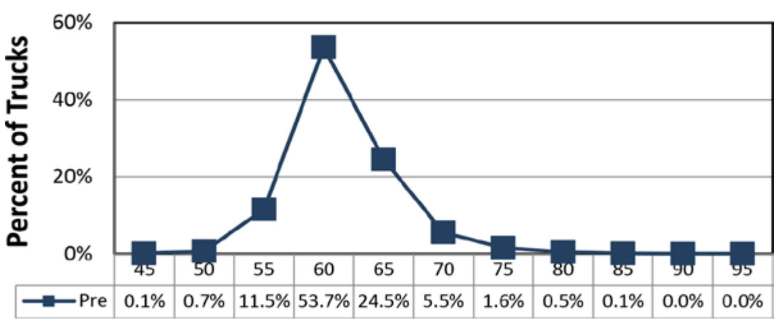


Figure 7 – Truck Speed Distribution Plot

Testing at multiple speed points (at least 2) is recommended to minimize error dependency on speed, if the WIM system supports this option.

Temperature Consideration

The LTPP method recommends using two test trucks over the widest ranges of temperatures observed at the site. For WIM sensors sensitive to temperature changes, testing over a 30 ^{o}F temperature range is recommended.

Step 4 – Assess WIM Site Condition

Perform the site assessment to determine the possible effects of pavement, equipment, and site conditions on the accuracy of WIM weight and distance measurements.

Pavement Inspection

1. Conduct visual pavement distress survey from the shoulder to identify surface anomalies that may affect truck motions across the sensors. Figure 8 shows an inspector conducting a visual inspection.

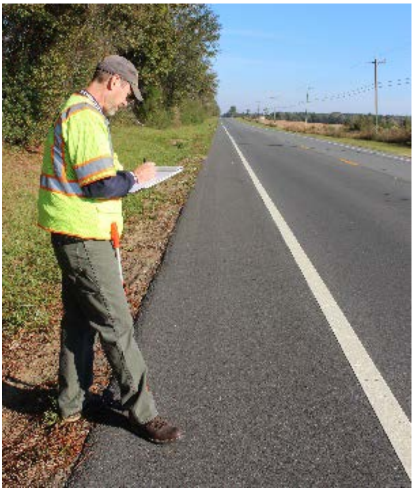


Figure 8 – Pavement Inspection

2. Identify such items as potholes, patches, rutting, and the asphalt to concrete transition.
3. Use the most recent pavement profile data to determine specific high roughness locations and examine these locations closely during the on-site assessment.
4. Annotate observations and photograph any pavement distresses that may affect the accuracy of the WIM scale measurements.

Vehicle-Pavement Interaction

1. Observe several trucks while they pass over the site to determine if truck traffic is showing adverse characteristics such as bouncing, swerving, braking, or accelerating within 135 feet of the sensors.
2. If feasible, determine whether the truck tires are in full contact with the sensors.
3. Document observed truck dynamics, noting any adverse movements that are within the WIM scale approach area and that may affect the measurement accuracy of the WIM system. Include the distance from the WIM scale area.

Step 5 – Inspect WIM Equipment

1. Perform a visual inspection and static electrical and electronic tests of all WIM site support components, as illustrated in Figure 9.

Figure 9 – WIM Sensor Inspection

2. Identify and record deficiencies involving the equipment that will require repair.
3. Identify all items whose present or deteriorating condition will eventually adversely affect the operation and/or accuracy of the WIM equipment.

4. If any discrepancies or deficiencies exist that will affect the measurement accuracies and cannot be remedied on-site, postpone the calibration.
5. For systems that use an auto-calibration routine, check the WIM manufacturer's guidelines to determine whether to keep an auto-calibration routine on or off during calibration.

Step 6 – Inspect and Measure Test Trucks

Once on site, the test trucks must be inspected to ensure that they meet the criteria outlined in step 3. Perform the following:

1. Inspect the type of truck body, the load, and its placement and suspension to ensure that they will not induce adverse truck dynamics into the test. The load must be evenly distributed along the trailer, must be firmly secured to prevent sliding or shifting, and must be covered to prevent the introduction of moisture in rainy weather conditions.
2. Inspect the suspension to ensure that airbags are not leaking, springs are not cracked or broken. See Figure 10.

Figure 10 – Test Truck Inspection

3. The load on the test truck should not be one that can move during transport, such as fluids, sand, soil, or

other items that shift during acceleration or deceleration. Figure 11 shows an example of a suitable test load.

Figure 11 – Test Truck Trailer Load

4. Inspect the truck tires and suspension for defects.
5. Use certified static scales to weigh test trucks.
6. Measure the calibration truck steering axle, single axles (if applicable), and tandem weights at a certified truck scale. Measure the axle spacing and the overall length.
7. Record the static weights, axle spacing, and overall length of test trucks.

Step 7 – Verify Communications with Test Truck Driver

1. Review the calibration procedures with the truck driver, including proper speeds and turnaround locations. The truck should not accelerate or decelerate while in the WIM scale area and must travel down the center of the travel lane.
2. Review safety procedures with the truck driver.
3. Establish communications with the test truck driver.
4. Instruct the driver to make test runs over the WIM scales at predetermined speeds.

Step 8 – Perform Test Truck Runs

1. Determine the number of test truck runs. This number depends on the data variability observed at a site. Sites that have low variability of errors require fewer test runs than sites that have high error variability to collect a representative sample. Generally, this requires:
   - At least 10 runs for sites that have a spread of GVW errors for the test truck of 5 percent or less after 10 truck runs and show no dependency of weight measurements on temperature.

   Or

   - At least 20 test runs for sites that have a spread of GVW errors for the test truck over 5 percent after 10 truck runs or demonstrate measurement error dependency on pavement temperature.
2. Conduct test runs.
3. Run each test truck over the widest range of speeds determined during the pre-visit analysis. Use a laser (best) or radar gun to measure the test vehicle's speed when it is crossing the sensor for comparison with the WIM system's output. See Figure 12.

Figure 12 – Collecting Test Truck Speed

4. For systems that use temperature compensation, check the manufacturer's guidelines regarding whether to keep this function turned on or off.

5. Conduct at least four test truck runs at each of the three WIM system speed points.
6. For WIM systems that demonstrate temperature influence on measurement error, conduct test runs over a 30 °F temperature range or the widest temperature range possible.
7. For each pass of the test truck, take and record a pavement surface temperature reading at a location near, but not on, the WIM sensor. Use a hand-held laser temperature device, positioned approximately 30 inches from the pavement surface, to collect pavement surface temperature after each test truck passage over the sensors. Figure 13 illustrates this step.

Figure 13 – Collecting Pavement Temperature

8. For each pass of the test truck, obtain the WIM system's output for the following data. Record all data, as shown in Table 6.
    a. The sequence number of the test run
    b. The date of the test run
    c. The time of the test run
    d. Axle weights of the test trucks as they pass over the sensors
    e. Spacing between each axle on the test truck
    f. Vehicle length
    g. Speed of test truck

h. Pavement temperature for each test run

Table 6 – Example of Selected Test Truck Run Data

Time	Veh. ID	Class	GVW	Speed	Length
9:42:09	28912	9	66.4	59	64
9:51:19	29037	9	76.7	49	63
9:51:28	29040	9	65.3	49	65
10:00:15	29150	9	77.4	59	63
10:09:36	29272	9	74.7	49	64

For WIM sites that utilize the polymer piezo sensor for weight measurement, and any other WIM sites that demonstrate measurement error dependency on temperature, it is recommended that a review of prior calibration be performed to assist in determining the proper calibration of the WIM system based on seasonal temperatures. Data collected over seasons can eventually be used to fine tune the WIM systems temperature compensation curve, typically performed by the WIM manufacturer.

Step 9 – Evaluate WIM Performance Using Data from Test Truck Runs

Once the data have been collected in the field, statistics must be computed to determine whether the WIM site meets the required accuracy parameters stated in WIM performance specification, which is typically the ASTM E1318-09 specification shown in Table 1 and repeated here in Table 7.

*Table 7 – ASTM 1318E-09 Functional Performance Requirements for WIM Systems**

Function	Tolerance for 95% Compliance		
	Type I	Type II	Type III
Wheel Load**	±25%		±20%
Axle Load	±20%	±30%	±15%
Axle-Group Load	±15%	±20%	±10%
Gross Vehicle Weight	±10%	±15%	±6%
Speed	±1 mph (2 km/h)		
Axle-Spacing and Wheelbase	±0.5 ft (0.15 m)		

The WIM system performance parameters can be evaluated using one of the two methods described below.

ASTM E1318-09 Method

1. For each test vehicle pass, calculate the percent difference between the WIM-measured value and the corresponding reference value (static weight measurement) for each parameter listed in Table 7.
2. For each test vehicle pass, determine if any calculated measurement difference exceeds the tolerance value specified in Table 7.
3. Using all passes of the test vehicles over the sensors, determine the number of calculated differences that exceeded the tolerance values shown in Table 7 for each data item and express this number as a percentage of the total number of observed values of this item—that is, the percentage of all test measurements for a given data item (like GVW) that exceeded the tolerance.
   - If more than 5 percent of the calculated differences for any applicable data item from Table 7 exceed the specified tolerance for that item, the WIM system requires adjustment/calibration.
   - If the mean error for any of the weight or load functions specified in Table 7 calculated based on all

test passes significantly deviates from zero, then the WIM system measures with a systematic bias and requires calibration. A deviation of 2 percent is recommended as the measure of "significant," but users may select another value that meets their customer needs.

4. If calibration has been performed and failed to satisfy the above criteria, repeat the calibration process until it passes or until it fails on three successive attempts. The latter indicates that the system or sensors are malfunctioning and require corrective maintenance. The system could also fail due to deteriorated road conditions or high road roughness.

LTPP Method

The basic statistic used for this test is the error expressed as a percentage of the known (i.e. certified static weight or length measurement) value. The percentage of error, calculated from the data collected for each run, is used to compute a series of summary statistics. These summary statistics are used to determine whether the scale produces acceptable quality data using the following procedure:

1. For each test vehicle pass, calculate the percent difference between the WIM-measured value and the corresponding reference value (static weight measurement) for each parameter listed in Table 1.
2. Use all computed percentile errors to compute the mean error, standard deviation (use t-distribution for sample sizes less than 38), and statistical 95th percentile confidence interval for the mean error.
3. Combine the mean error and confidence interval values (mean error +/- 2 standard deviations of error) to compute the overall range of errors.
4. Compare the resulting overall error range with the tolerance levels specified in Table 8 from the *Field Operations Guide for LTPP SPS WIM Sites (4)*.

Table 8 - LTPP Performance Requirements for WIM Systems

Measurement Type	95 Percent Confidence Limit of Error
Steering Axle	±20%
Axle-Group Load	±15%
Gross Vehicle Weight	±10%
Speed	±1 mph (2 km/h)
Axle Spacing	±0.5 ft (0.15 m)
Vehicle Length	±1.5 ft or 3.0%*

* Whichever measurement is longer.

5. If the overall error range is within the tolerance levels specified in Table 8 and the mean error is close to zero (e.g., less than 2 percent) for GVW, axle group, and front axle weight measurements, then the system does not require calibration. Otherwise, calibration is required. See the example in Table 9.

Table 9 – Example of Test Truck Run Results Based on LTPP Method

Parameter	95% Confidence Limit of Error	Site Values	Pass/ Fail
Steering Axles	±20 percent	0.1 ± 5.1%	Pass
Tandem Axles	±15 percent	1.3 ± 5.2%	Pass
GVW	±10 percent	1.1 ± 3.0%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	-0.2 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150 mm]	0.0 ± 0.1 ft	Pass
Vehicle Speed	± 1.0 mph	0.3 ± 0.5 mph	Pass

6. If calibration has been performed and failed to satisfy the above criteria, repeat the calibration process until the system passes or until it fails on three successive attempts. The latter indicates that the system or WIM

sensors are malfunctioning and require corrective maintenance.

Step 10 – Calibrate WIM System Parameters

1. Based on the WIM system measurement error calculated during pre-calibration runs, calculate the adjustments to the current WIM system weight and distance error compensation factors using the following formulas:
    - For weight:
      *New Factor = (Old Factor * Static Weight)/WIM Weight*
    - For spacing:
      *New Factor = (Old Factor * WIM Measure)/Static Measure*
2. Enter the new compensation factors into the WIM system firmware for post-calibration testing.
3. Keep a record of all changes to the WIM system compensation factors.

Step 11 – Perform Post-Calibration Test Runs and Evaluate Results

Determine Number of Post-Calibration Test Truck Runs

The minimum of 10 post-validation test truck runs (20 runs is recommended) may be performed if the system does not demonstrate the following:

1. A temperature dependency, or the weather conditions on the day of testing do not provide conditions for a wide range of temperature changes.
2. The data from the test runs demonstrate that the speed dependency at each speed point has been eliminated or minimized (less than 2 percent average error for the each speed point).
3. The overall system bias computed based on the data from the available test runs is as close to zero as possible (less than 2 percent error for the mean error).

4. None of the individual runs are outside of the ASTM E1318-09 tolerance range for 95 percent compliance (1 run outside of the range is allowed for samples of 20 test truck runs or larger) or the 95 percent confidence interval computed based on the test data is within the acceptable LTPP WIM performance tolerances.

If a particular site demonstrates a dependency on temperature, up to 20 runs per test truck spread over a longer period of time may be required to accurately determine WIM measurements and confirm that calibration worked as expected.

Test and Finalize New Compensation Factors

1. Conduct post-calibration test runs using the procedure described in step 8 and collect post-calibration test truck weight, axle spacing, and length measurement data.
2. Check if WIM system performance parameters are within the tolerances specified in Tables 1 and 2. If all parameters are within the tolerances, skip #3 below.
3. Repeat steps 8 through 11 until the WIM system performance parameters are within tolerances (up to three times if needed).
4. Install the new/final compensation factors into the WIM system firmware.
5. Keep a record of the final values of each WIM system performance parameter from Table 1 and final changes to the WIM system compensation factors.

Step 12 – Check Accuracy of Vehicle Classification

Vehicle classification testing involves two checks:

- Check 1 – Test whether the WIM system is classifying vehicles properly as compared to the agency's classification scheme or class tree input.

- Check 2 – Test whether the agency's classification scheme or the class tree itself classifies vehicles effectively at the WIM site location.

For example, if a short two-axle bus is classified as class 5, verify the axle spacing. If the axle spacing is within the class 5 range based on the agency's classification scheme or class tree input, it passes the first check but fails the second (and it will always fail the second check for that class tree input).

To test vehicle classification accuracy for a WIM site, perform the following:

1. Aim to perform the vehicle classification testing during peak hours. Peak hours could be identified from the hourly truck volume data sample during pre-visit data analysis.
2. Collect a manual sample of at least 100 vehicles in FHWA vehicle classes 4 through 13 (using FHWA 13-bin classification), or as many samples as can be collected in 3 hours. In addition, collecting video of the traffic stream during manual study would be helpful for the follow-up analysis of misclassified vehicles.
3. During the manual data collection, record the vehicle IDs and time stamps from the WIM records for any vehicle that does not match the classification from the manual observation.
4. Evaluate the results using either Method A or Method B, as described below.
   Method A:
   a. Determine the total number of vehicle samples and the total number of misclassified vehicles in the manual sample for FHWA vehicle classes 4 through 13.
   b. Calculate the percentage of misclassified vehicles in FHWA vehicle classes 4 through 13 in the manual sample. Compare misclassification percent for the sample with the agency's acceptable

misclassification percent. It is recommended that the percentage of misclassified vehicles should be no greater than 2 percent.

c. Calculate the number and percentage of vehicles in FHWA vehicle classes 4 through 13 in the manual sample that were not classified by the WIM system. The percentage of unclassified vehicles should be no greater than 2 percent.
d. If fewer than 50 vehicles in classes 4 to 13 were observed in 3 hour period, record the number of vehicles that passed and failed classification and report that the minimum sample size to test classification was not met. In this case, one unclassified or misclassified vehicle can be allowed for classification test to pass.

Method B:

a. Calculate the percentage of misclassified or unclassified vehicles in FHWA vehicle classes 4 through 13 in the manual sample. To pass the test, each individual class of vehicles from 4 through 13 may have a maximum of 10 percent misclassified vehicles. If the number of vehicles collected during the 3-hour testing period is under 30 for any vehicle class, use the following tolerance criteria for the maximum number of misclassified vehicles:
    - 20-29 for one class = +/-3 vehicles
    - 10-19 for one class = +/-2 vehicles
    - 0-9 for one class = +/-1 vehicle

5. Draw conclusions as to whether the WIM system passed or failed the classification test.

Once the samples have been collected, review each misclassification instance to determine the cause and whether the WIM system failed the classification checks described above. Analyzing video images of moving trucks collected during manual study would be very helpful for this task. The information collected for the classification verification tests will provide information on possible changes that need to be made to the WIM system's classification table or issues with the agency vehicle classification tree inputs. This is very important for sites that have dominant types of vehicles with atypical axle configurations.

Step 13 – Conduct Post-Visit Data Analysis and Develop Calibration Report

The post-visit data analysis allow technicians to evaluate the effectiveness of the calibration. It includes a comparison between the data samples collected just prior to and immediately following the calibration.

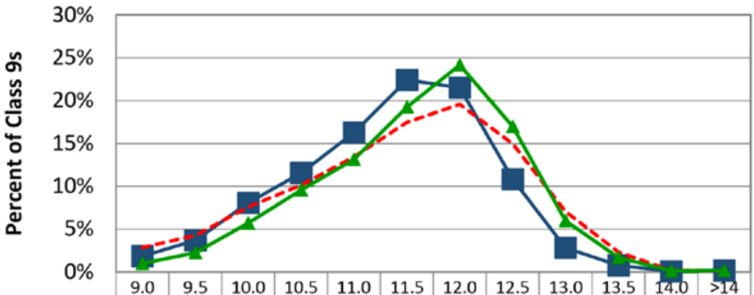
For this analysis, a traffic data sample from the 14 days (30 days for low truck volume roads with less than 100 class 9 trucks per WIM lane per day) immediately following the calibration is collected and compared with the Comparison Data Set (CDS) (see CDS discussion in Step 15) from the previous calibration event and the pre-visit data sample. To conduct post-visit analyses, follow these steps:

1. Download a WIM data sample for the period of 2 to 4 weeks immediately after the calibration visit for each lane instrumented with WIM sensors.
2. Compare the following parameters between the CDS data, pre-visit data sample, and the post-visit data sample for each WIM lane. See Figure 14 for an example.
    a. Class 9 average GVW and GVW distribution by load bins (tabular or plot)
    b. Class 9 average front axle weight and front axle weight distribution by load bins (tabular or plot)
    c. Class 9 tandem axle group axle load distribution by load bins(tabular or plot)
    d. Load bins corresponding to maximum percentage of GVW, steering axle loads, unloaded and loaded tandem axle loads (i.e. peak loads in the axle load or GVW distribution)
    e. Class 9 tractor average tandem axle spacing

f. Class 9 total length of vehicle

g. 85th percentile speed for heavy trucks

h. Vehicle class distribution (FHWA classes 4 through 13)



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	>14
Pre	1.8%	3.7%	8.1%	11.6%	16.3%	22.4%	21.5%	10.8%	2.8%	0.8%	0.1%	0.2%
CDS	2.9%	4.3%	7.6%	10.2%	13.4%	17.5%	19.6%	15.0%	7.0%	2.3%	0.2%	0.1%
Post	1.0%	2.2%	5.7%	9.6%	13.1%	19.3%	24.2%	17.0%	6.0%	1.7%	0.1%	0.2%

Steering Axle Weight in Kips

Figure 14 – Example of Post Visit Analysis of Class 9 Steering Axle Weight Distribution

3. Note whether differences from the previous CDS observed in pre-visit data set have been resolved or reduced as a result of calibration.
4. Determine if the calibration had the desired effect on the data values by comparing the change in the computed parameters with the changes made to the WIM system calibration factors.
5. Document findings in a WIM calibration summary report (see step 14 below).

Step 14 – Develop and Submit Calibration Summary Report

To assist in proper recordkeeping and future planning, it is recommended that the field technician develop and submit to the program manager a WIM calibration summary report that provides the following information:

1. WIM site inventory information and equipment status
2. Date of calibration and calibration protocol used (ASTM, LTPP, or agency-specific)
3. Test truck inspection results, including static weights, axle spacing, and length measurements
4. Pavement condition assessment
5. Temperature during testing and weather conditions
6. Equipment visual inspection
7. Results of electrical WIM sensor testing
8. Initial pre-calibration test truck runs results (records of individual measurements for each test truck run)
9. Total number of test truck runs and the number of individual test truck runs that passed or failed any of the performance criteria specified in Table 1 before calibration
10. Computed error statistics, if LTPP method is used
11. Calibrate/do not calibrate decision and reasoning
12. Changes to system calibration factors
13. Post-calibration test truck runs results (records of individual measurements for each test truck run)
14. Total number of test truck runs and the number of individual test truck runs that passed or failed any of the performance criteria specified in Table 1 after calibration
15. Results of classification verification test (if conducted)
16. Conclusions whether WIM system met accuracy requirements after calibration

17. Any corrective actions and recommendations
18. Pre-visit and post-visit data analyses and findings (optional)
19. Supplemental documentation, including photographs

Step 15 – Develop Comparison Data Set

If the post-visit data analysis confirms that the calibration was successful, the data used for the post-visit analysis and the statistics computed based on these data are considered the Comparison Data Set (CDS). The following parameters are recommended for CDS computation:

1. Class 9 average GVW and GVW distribution by load bins (tabular or plot)
2. Class 9 average front axle weight and front axle weight distribution by load bins (tabular or plot)
3. Class 9 tandem axle group axle load distribution by load bins (tabular or plot)
4. Load bins corresponding to the maximum percentage of GVW, steering axle loads, unloaded and loaded tandem axle loads (i.e. peak loads in the axle load and GVW distributions)
5. Class 9 tractor average tandem axle spacing
6. Class 9 total length of vehicle
7. 85th percentile speed for heavy trucks
8. Vehicle class distribution (FHWA classes 4 through 13)

These data and statistics could be used to compare periodically (biweekly or once a month) with the statistics based on the current data and/or data sample collected prior to scheduling calibration visits. See Table 10 for an example of CDS computation results.

Table 10 - Example of Comparison Data Set Computation Results

Parameter	CDS
Average Steering Axle Weight (kips)	11.0
Average Axle 4 Weight of Split Tandems (kips)	11.9
Average Axle 5 Weight of Split Tandems (kips)	11.9
Average Tandem Axle Weight (kips)	20.5
Average Loaded Tandem Axle Weight (kips)	32.4
Average Standard (3S2) Class 9 GVW (kips)	52.8
Percent of Overweight Vehicles	9.5%
Peak Steering Axle load (kips)	12.0
Peak loaded tandem (kips)	34.0
Peak GVW empty (kips)	36.0
Peak GVW empty (kips)	80.0
Average Tractor Tandem Axle Spacing (feet)	4.3
Total Vehicle Length (feet)	48.6

Depending on the analysis results, the site calibration schedule may be accelerated or postponed. For example, an accelerated schedule may be warranted if there are changes in the average weight and length measurements or shifts in the weight distribution greater than 5 percent.

Step 16 – Conduct Office Data Quality Checks and Analysis to Aid Future Calibrations

1. Sample WIM data every 1, 2, or 4 weeks, depending on site truck volumes. A minimum sample of 200 class 9 trucks per lane is needed; a sample of 500 or more class 9 trucks is recommended to identify and analyze GVW and axle load distribution characteristics.
2. Use the data sample to develop the following statistics for each lane with WIM sensors:
   a. Class 9 average GVW and GVW distribution by load bins (tabular or plot)
   b. Class 9 average front axle weight and front axle weight distribution by load bins (tabular or plot)

c. Class 9 tandem axle group axle load distribution by load bins(tabular or plot)
d. Load bins corresponding to the maximum percentage of GVW, steering axle loads, unloaded and loaded tandem axle loads (i.e., peak loads in the axle load and GVW distributions) for class 9 vehicles
e. Class 9 tractor average tandem axle spacing
f. 85^{th} percentile speed for heavy trucks
g. Vehicle class distribution (FHWA classes 4 through 13)

3. Use the above statistics to compute differences with the same parameters based on CDS.
4. Flag and report data samples that show differences of more than 5 percent (or other agency-selected value) between the current data set and CDS. These data require close monitoring and trend analysis. An example of a comparison is shown in Table 11.

Table 11 – Example of WIM Data Analysis Results for Typical (3S2) Class 9 Vehicles

Parameter	CDS	Current	%Change
Average Steering Axle Weight (kips)	11.0	10.6	☑ -3.6
Average Axle 4 Weight of Split Tandems (kips)	11.9	11.3	☒ -5.0
Average Axle 5 Weight of Split Tandems (kips)	11.9	11.2	☒ -5.9
Average Tandem Axle Weight (kips)	20.5	19.3	☒ -6.0
Average Loaded Tandem Axle Weight (kips)	32.4	31.5	☑ -2.8
Average Class 9 GVW (kips)	52.8	49.7	☒ -5.8
Peak Steering Axle load (kips)	12.0	11.0	☒ -8.3
Peak loaded tandem (kips)	34.0	33.0	☑ -2.9
Peak GVW empty (kips)	36.0	36.0	☑ 0.0
Peak GVW loaded (kips)	80.0	76.0	☒ -5.0
Percent of Overweight Vehicles	9.5%	3.9%	☒ -6.0
Average Tractor Tandem Axle Spacing (feet)	4.3	4.3	☑ 0.0
Total Vehicle Length (feet)	48.6	48.2	☑ 0.8

5. Subject data that deviate from CDS to monthly trend analysis. Compare data from the current month with the data for the same month from the previous year(s) or to the data from the previous month of the current or past year(s).
6. In areas of harvest or other seasonal production, like timber, analysis of monthly or seasonal average for several values like GVW distribution, peak load values,

and percentage of overweight of class 9 trucks with standard configuration is recommended.

7. If deviation over 5 percent from CDS and seasonal trends persists or increases, an out-of-cycle calibration may be needed.
8. If calibration drift is frequently observed at the site, daily data quality monitoring and daily trend analysis is recommended. For the daily trend analysis, use time series plots to monitor the daily changes in the WIM statistics described in #2 of this list.

An example of a daily average GVW plot is shown in Figure 15. As shown in the figure, from the end of July to the beginning of October, the average daily GVW has been steadily drifting from 59 kips to 50 kips (-15.2 percent).

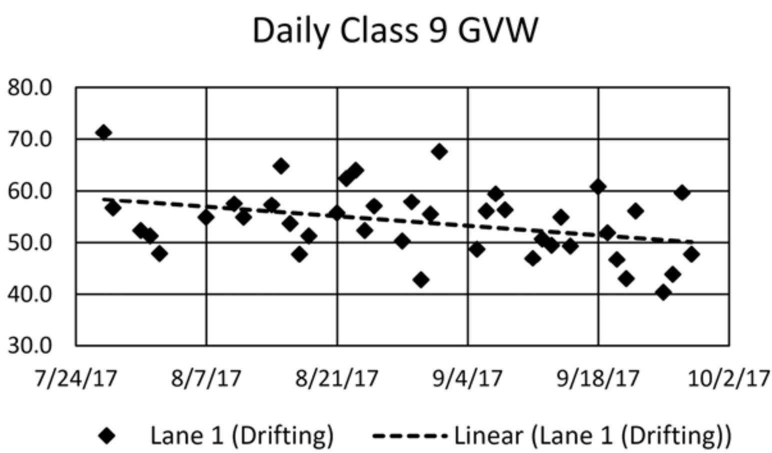


Figure 15 – Daily Average GVW Decreasing Over Time

Calibration frequency depends on the available resources, individual site characteristics, sensor arrays, and sensor types. The following are general recommendations provided for different sensor types.

WIM Systems with Quartz Piezo Sensors or Strain Gauge Strip Sensors

Typically, WIM systems with quartz piezo or strain-gauge strip sensors should be calibrated every 12 to 18 months. However, more frequent calibration may be needed if any of the following is observed:

- Recent maintenance or hardware change is performed
- Demonstrated system dependency on pavement smoothness
- Sensors installed in pavements subjected to seasonal changes in pavement stiffness
- System shows the repeatable drift from past calibration at a higher rate over time, whatever the reason
- Presence of commodity shipment cycles
- Changes in truck classification distribution
- Changes in average truck speed
- If key weight statistics (such as class 9 GVW) drift more than 5 percent from the CDS values

WIM Systems with Polymer Piezo Sensors

Systems with polymer piezo sensors that are used for collection of axle weight data should be calibrated seasonally or have other means for consistent compensation of temperature effect on weigh measurement accuracy. Temperature compensation based on passenger vehicles or front axle weights is frequently not effective for measurements of heavy axle weights. In addition, temperature compensation that is adjusted based on the number of truck samples is problematic when traffic volumes are low and during periods in the day when pavement temperature changes rapidly. Site-specific adjustments to temperature compensation curves may be needed to address accuracy issue for heavy axles.

If seasonal calibrations cannot be scheduled for whatever reason, users should be informed about seasonal deviations in weight measurement accuracy. If seasonal calibrations are not feasible, calibrate every 12 months during the season that has a daily temperature as close to the annual average temperature as possible to avoid introduction of extreme bias, as could occur when calibrating during seasons with extreme cold or hot temperatures.

Data processing and quality assurance personnel can provide inputs on when a WIM site needs to be calibrated based on the comparison analysis of the loading statistics computed based on the recently downloaded 2 to 4 weeks of WIM data and the CDS statistics. For sites that have other contributing factors that lead to changes in "typical" truck weights observed at the site, such as seasonal crop or other commodity movement, these factors must be accounted for during data checks to determine if the data are "typical" for the site or unexpected deviations have occurred.

WIM Systems with Bending Plates or Load Cells

For bending plate and load cell WIM systems, calibration frequency could be greatly reduced if the systems are being properly maintained in a timely manner. In some cases, bending plate WIM did not require calibration over 5-year periods; in other cases, calibration every 2 years was sufficient.

Data processing and quality assurance personnel can provide inputs on when a WIM site needs to be calibrated based on the comparison of the loading statistics based on the recently downloaded WIM data and the CDS statistics. For sites that have other contributing factors that lead to changes in "typical" truck weights observed at the site, such as seasonal crop or other commodity movement, these factors must be accounted for during data checks to determine if the data are "typical" or unexpected deviations have occurred. In addition, major WIM maintenance events may trigger the need for calibration.

WIM SYSTEM MAINTENANCE

Implementation of comprehensive maintenance program helps to maximize the life of the WIM system. This section of the Guide includes a scope of recommended maintenance activities, recommended schedules, description of field checks, and recommendations for field logs, acceptance testing, and maintenance reports. In addition to these guidelines, manufacturers' recommendations for maintenance of the specific WIM equipment should be followed.

Types and Frequency of Maintenance

Maintenance activities include regularly scheduled preventive maintenance and event-driven corrective maintenance. Preventive maintenance is performed to prevent future equipment failures and to extend longevity of different WIM parts and components. Corrective maintenance is performed after a problem is detected in the system or a scheduled part replacement or upgrade is due.

It is important to perform routine preventive maintenance every 6 to 12 months. For corrective maintenance, procedures should be developed to facilitate timely operational checks and repairs of system failures.

The maintenance activities described here are not sensor-specific. For guidance on performing regular maintenance on specific types of sensors, reference the manufacturer's maintenance manuals.

Tools, Materials, and Supporting Documentation

An effective WIM maintenance program must have the proper tools, materials and spare parts to perform regular preventive maintenance and quickly resolve system problems without significant down time and lost data. Manufacturers' maintenance guides typically contain a list of required spare service parts, tools, and equipment necessary to properly maintain the specific vendors' WIM systems.

Materials

- Clipboard
- Shop rags or clothes
- Cleaning solvent
- Pens and recordkeeping paper/forms
- Electrical tape
- Splice kits
- First aid kit
- Spray silicone

Hand Tools

- Digital camera
- Screwdriver sets – slotted and Philips
- Jewelers' screwdrivers – slotted and Philips
- Small socket driver set – those that fit the hardware at the site (solar panel, cabinet WIM controller)
- Pliers – long nose, round nose, curved. Both smooth and serrated types are useful
- Adjustable wrench, small
- Cutters – diagonal and flush
- Linesman's pliers
- Wire strippers – fixed and adjustable
- Wet/dry shop vacuum
- Crimping tool
- Global positioning system (GPS) receiver

- Power inverter
- Tape measure
- Measuring wheel
- Small shovel
- Pry bar

Test Equipment

- Digital multimeter with well insulated test probes (capability for resistance, inductance and capacitance)
- Megger (loop and ground tester)
- Oscilloscope – dual trace, 10 to 20 MHz minimum vertical bandwidth and 10x probes (optional, to check the sensor output waveforms)
- Logic probe – for quick checks of digital circuitry for activity
- Laser speed detection gun

Computer Software

- WIM system connectivity and data download software
- Modem setup script files and/or setup guide

Supporting Forms and Documentation

The following forms and documentation are recommended for use by the WIM maintenance personnel:

- WIM Site Maintenance and Inspection Form
- WIM System Troubleshooting Form
- WIM Site Maintenance Log (to be kept in the WIM cabinet)

Additionally, maintenance personnel should always have on hand:

- Manufacturers' maintenance guides or service manual
- WIM site as-built plans showing locations of WIM components

Safety

When working on-site, several safety procedures must be followed:

- Park any vehicles off the road in a safe area away from traffic (see example in Figure 16).
- If permitted, leave vehicle running and wear the seatbelt when in the vehicle.
- All vehicles must be equipped with safety lights.

Figure 16 – Protected Work Vehicle Location

- Always wear personal protection equipment (PPE), including a reflective safety vest, hard hat, and steel-toed shoes (see Figure 17).

Figure 17 – Field Technician with PPE

- Always use a safety spotter when working near the roadway to alert the inspector of oncoming traffic.
- Carry adequate amounts of drinking water.
- Wear weather-appropriate clothing and protection.
- Carry sunscreen and bug repellent.

Preventive (Scheduled) Maintenance

During each preventive maintenance visit, all in-road sensors should be checked for proper electronic values. The entire WIM system should be visually inspected, including the pull boxes, in-road sensors, communication and power service equipment, and the roadway leading up to and within the WIM scale area. All deficiencies should be recorded, photographed, and reported for correction.

Pavement Inspection

A visual inspection of the pavement in the WIM scale approach will provide an indication of whether the pavement condition may be contributing to any inaccuracies of the WIM system. Figure 18 shows an example of distressed pavement that could affect WIM system accuracy.

Figure 18 – Pavement Distress Identified During Inspection

Any pavement distresses that appear to influence truck dynamics at or near the WIM scale area must be documented on the WIM Site Preventive Maintenance and Inspection Form.

1. From the shoulder, walk the distance from the WIM sensor installation to a distance 400 feet prior to the WIM sensors and 200 feet after the WIM sensors.
2. Photograph and annotate any pavement distresses that may influence truck dynamics.

Visual Equipment Inspection

A visual inspection of all WIM system components is important. It is recommended that a lane closure be set up at least annually so that a close inspection of the roadway and the in-road sensors can be performed. Carefully inspect each WIM system component and annotate any deficiencies on the WIM Site Preventive Maintenance and Inspection Form, including the following:

1. Check the pavement condition around the WIM sensors for cracks, broken pavement, or potholes. Figure 19 shows a close-up of a WIM sensor and surrounding pavement.

Figure 19 – WIM Sensor Observed During Inspection

2. Check cabinet interior for broken components such as thermostats, lights, shelving, heaters, terminal panels, battery and modem.
3. Remove the covers to each pull box and inspect the interior for signs of improper drainage or infestation (see Figure 20). Inspect the exterior for cracks and ensure that all securing hardware is in place. Suspend wiring as needed to keep it out of any water that may be present in the pull box.

Figure 20 – Pull Box Interior

4. Inspect the service pole, pedestal, and foundation for cracks and make sure that it is plumb.
5. Visually inspect power service equipment for structural deficiencies. DO NOT TOUCH BROKEN WIRES, AND DO NOT OPEN ANY LIVE SERVICE BOXES! Check earth ground using a megger.
6. Inspect communication equipment for damage, cut or damaged wires, or a broken antenna.
7. Check exposed conduit for extensive rust, breaks, or cracks.
8. Annotate all readings on the WIM Site Preventive Maintenance and Inspection Form.

Equipment and Site Cleaning

Clean the interior and exterior of all WIM components, including the following:

1. Remove dust or debris with a shop vacuum.
2. Wipe down with cleaning solvents. DO NOT SPRAY COMPONENTS WITH SOLVENT. SPRAY THE RAG OR CLOTH AWAY FROM THE EQUIPMENT.
3. Replace the cabinet filter, if necessary.
4. Clear out clogged drainage pipes.
5. Perform vegetation control in the area of the cabinet and pull boxes. Figure 21 shows the cleared area around a traffic cabinet.

Figure 21 – Traffic Cabinet Location after Vegetation Control

6. Look for indications of insect or rodent problems. Clean up and seal any openings. Consider installation of mothballs or other items to repel the insects or rodents.

Electronic and Electrical Checks

1. As shown in Figure 22, perform electronic and electrical checks of all WIM system components to confirm that each component is operating within the manufacturer's tolerances, including:
   - WIM sensors – list voltage, resistance, and maybe capacitance ranges
   - Loop sensors – list values in microhenrys

- o Power voltages
- o Telephone – list on-hook and off-hook voltages
- o Grounding – list typical distance and ohm range to get

2. If any readings are out of tolerance, double-check the proper readings against the previously documented ranges, specification, or manufacturer's maintenance manuals and begin troubleshooting the system, if necessary, to determine the cause.

Figure 22 – Sensor Testing

3. Annotate all readings on the WIM Site Preventive Maintenance and Inspection Form.

Firmware Upgrades

1. Once the electronic values for the WIM sensors and support equipment have been verified as correct, perform any scheduled software upgrades. Ensure that the instructions provided in the manufacturer's operations guide are followed to protect the equipment from damage caused by electronic surge or improper installation of the firmware.
2. After installing the latest firmware, re-enter all default values and/or system parameters to ensure proper

operation. Verify that the following system settings are correct:

a. Date/time
b. Site information
c. Weight compensation factors (by lane recorded)
d. Axle and loop spacings (by lane settings recorded)
e. Length of vehicle setting (loop setting)
f. Loop sensitivities
g. Lane configurations, sensor assignment and sensor spacing
h. Violation settings
i. Communication settings
j. Data logging information
k. Password information
l. Self-calibration settings (if used)

3. Annotate that the firmware was replaced and record the current version on the WIM Site Preventive Maintenance and Inspection Form.

Operational Testing and Verification

After local, direct communications with the WIM system user interface have been established, perform the following series of operational checks to verify the proper operation of the WIM equipment.

1. Verify the proper operation of the WIM sensors and inductive loops by observing the individual vehicle characteristic values provided by the WIM system after a vehicle passes over the WIM scale area. Determine whether the speeds, distance measurements, and vehicle/axle weights are reasonable and that each axle and axle spacing is reported for each vehicle.
2. Conduct vehicle classification study by observing several vehicles as they pass over the WIM scales and verify that they are being classified properly, according to the classification method that is installed in the WIM system.

3. Conduct weight study. Record the front axle weight for the front axle for a sample of at least 50 class 9 trucks (or the number counted over 3 hours if less than 50). Typically, the average front axle weight for the class 9 trucks should be between 10,000 and 11,000 pounds. If the front axle weight average is less than 9,000 pounds or greater than 12,000 pounds, a calibration of the system may be necessary.
4. Document findings on the WIM Site Preventive Maintenance and Inspection Form.

Communications Checks

As part of the preventive maintenance function, a communication check is important to prevent a return trip to the site.

1. Prior to leaving the site, and once all other preventive maintenance activities have been performed, contact office personnel to verify that the WIM system can communicate remotely with the host computer.
2. Annotate findings on the WIM Site Preventive Maintenance and Inspection Form.

Corrective Maintenance and Repair

Scheduled Corrective WIM Maintenance

Corrective maintenance could include changes to systems parameters, adjustment to sensor operating parameters, firmware upgrades, calibration, or replacement of parts. Many factors must be considered when determining the corrective action: cost, loss of data, availability of replacement parts, and degree of difficulty of the repair. The repair must be cost-effective—a component should not be repaired if the cost of doing so would be comparable to replacing it with a new one or if the pavement condition would prevent long-term data collection.

Many circuit board components are not readily available for replacement. The technician should have "ready-service spares" on hand for all components that may have to be ordered from a manufacturer, vendor, or other supplier.

All replaced parts must be clearly marked, indicating that they are "bad," so that they are not reused.

After all repairs have been completed, the technician should perform the preventive maintenance procedures described earlier to ensure that the system is fully operational.

Unscheduled Corrective WIM Maintenance

Unscheduled maintenance is performed after a problem is detected in the system that prompts a visit to the site. Checking WIM system results by lane and sensor helps with troubleshooting WIM data errors.

If the source of the problem is not already known, preventive maintenance and WIM equipment troubleshooting routines should be performed to attempt to identify the source of the problem.

Once a fault has been found, the problem must be investigated to identify and correct the deficiency. Problems that are detected may be corrected in several ways, including changes to systems/on-site parameters, adjustment to sensor operating parameters, firmware upgrades, calibration, or replacement of parts.

WIM Equipment Troubleshooting

This section provides a general guide for identifying the system fault, troubleshooting the fault to determine the cause, and repairing WIM systems and components. It is based on the information presented in FHWA's *WIM Field Inspectors' Troubleshooting Guide* and the *Traffic Detector Handbook (6, 7)*.

Troubleshooting Approach

The first requirement in troubleshooting is developing a general troubleshooting approach—a logical, methodical procedure of narrowing down the problem. It is important to recognize the fault correctly, find the cause, determine the proper corrective measure, and repair or replace the faulty system component(s). Additionally, it is important to keep in mind that:

1. Intermittent problems are typically due to bad connections and can be fixed by cleaning, removing, inspecting, and replacing connectors or circuit boards.
2. Problems that result in a completely non-functional system or affect a number of different functions or components are usually related to power. Sometimes, just turning the system off and back on may fix the problem.
3. If a power problem is suspected, use sight and smell to search for evidence of burnt components.
4. Intermittent or chattering axle sensors can lead to ghost axles and increases in class 10 and/or class 13 vehicles.
5. Many WIM system vehicle capture problems are created by incorrectly set loop frequencies. Always begin the troubleshooting process by checking system settings.
6. Misclassified vehicles can mean a detuning loop as a vehicle is passing. Class 9 vehicles will be improperly classified as classes 1 and 6. Check to ensure the WIM system properly identifies class 9 vehicles. Did both the class1 and class 6 number jump the same number from the same DOW for a previous week?
7. Improper class data can lead to potential WIM issues, and vice versa.
8. Seasonal changes in traffic streams (agricultural harvests), changes in local economics, and additional rezoning in the area can change WIM readings due to

changes in vehicle characteristics. Knowing the local vehicle travel patterns can help when checking if a site is working properly.

Logical Progression of Troubleshooting

Read the troubleshooting procedure in its entirety before beginning work. Information from one step may directly assist efforts in another. Refer to manufacturer guides for specific troubleshooting techniques and procedures related to WIM system components, including common problems and associated solutions.

The LTPP *WIM System Troubleshooting Outline (TRAFFIC SHEET 23) (4)* is a valuable tool that can be used to guide the user through a systematic troubleshooting routine. It provides a visual way of investigating and fixing the problem, rather than trying to remember what has been already found and remedies that have already been tried.

Use the *LTPP WIM System Troubleshooting Outline* or other similar form to take detailed notes and follow the step-by-step troubleshooting procedure described next.

Step 1 – Develop a Detailed Description of the Problem

The identification of WIM system problems typically begins with the user's inability to communicate with the system or download system data. The user may also report that the data received are questionable or incorrect. When the problem is reported, it is important to obtain very specific and detailed problem descriptions and symptoms.

A lot can be learned from "by lane," "by sensor," and "by vehicle" WIM data analysis. This data troubleshooting does not involve a field visit to track down issues.

1. Download data from the previous day or within the timeframe in question. Compare data values with the CDS values. This process may narrow down the problem to a particular function, such as weight measurement or distance and speed measurement.

2. Determine if the travel characteristics of the site changed due to weather, construction, seasonal agriculture, or some other reason.
3. Conduct thorough WIM data analysis. Drill down to the "by lane" data and even conduct "by sensor" readings if need be.
4. Review "by vehicle" data. The individual by vehicle data will help the user see if the issue is related to heavy or light axles certain vehicle types or maybe some vehicle characteristic, such as time of day when the error occurs.
5. Provide this information to the technician before the site visit. It will help the technician to have the correct parts and information to narrow the issue down to more quickly get the site back working properly.

A WIM system malfunction may also be detected during any regular maintenance routine, such as periodic preventive maintenance, system upgrade, or equipment replacement or repair. Again, it is important to write down exactly what the problem is and the problem's characteristics.

Before proceeding further, if it is available in the manufacturer's maintenance or operational manual, refer to the troubleshooting section to see if the reported problem is listed. If it is not, or the recommended corrective action is not successful, proceed with step 2 below.

Step 2 – Evaluate System Parameters and Data

In order to properly diagnose a system malfunction, accumulate all system operating information, including system data and current operating parameters.

1. If remote connection with the site is possible, connect with the site and record all operator interface mode information prior to traveling to the site. If contacting the site remotely is not possible, or the system data already collected do not provide an indication of the

problem, or the problem discovered through system data cannot be fixed remotely, visit the site.

2. While connected to the site, open a log file and record all system characteristics, including:
   - Weight compensation factors
   - Lane configurations, sensor assignment and sensor spacing
   - Violation settings
   - Communication settings
   - Data logging information
   - Real time view (collect several samples of as many types of vehicles as possible)
   - Vehicle classification and speed data from the past hour
   - Time and date
   - Password information
   - Auto-calibration settings
3. Record all system sensor values available in the system diagnostics mode. Compare current system settings with historical records.
4. After reviewing the site operating parameters, site data, and sensor analog values, add any additional information to the "Problem Description" portion of the troubleshooting form.
5. Double-check all measurements that appear incorrect or out of tolerance.

If required, follow the remaining steps on the *LTPP WIM System Troubleshooting Outline* according to the following guidelines:

- The source of many problems may be discovered during the data collection and analysis portion of the troubleshooting process. If it is strongly believed that the problem has been discovered during step 1 or this step, skip to step 4 – Corrective Maintenance.
- If any system parameters are found to be incorrect, you may typically fix the problem by entering the correct setting. If the setting is off by a small amount, or if the

setting appears to have been typed incorrectly, it is likely that the problem was user-related. Type the setting in as it should be, and restore the system parameters to the system firmware according to the manufacturer's instructions. Correct classification is sensitive to 1/10th-foot increments, so accuracy of the WIM classification settings is paramount with good results.

- If a setting is drastically incorrect, chances are the problem was created by a system "glitch," and if one exists, many exist. The best way to fix these settings is to perform a hard reset of the system that would return all system operational parameters to their default settings. Download all of the data files from the WIM system's memory. Follow the manufacturer's instructions for performing a system reset and restoring the default parameters.

Step 3 – Finding the Source of the Problem

Use the information gathered from the previous steps to determine the probable malfunction. Consider during this process that multiple problems are rare and that all symptoms should be considered to be the result of one problem.

There are two steps that are used to determine the system's faulty component. Each involves the drawing of a conclusion based on the information gathered in steps 1 and 2, as well as the added information gathered during the performance of each level's procedures.

Determine the probable functional failure. There are six primary functions of any WIM system:

- Power – Most power problems are the result of loss of alternating current (A/C) power service, dead battery, blown fuse, or tripped circuit breaker. Investigate these possibilities first. Check the voltage for lower than expected power. A/C voltage should be over 105 volts.

Annual load testing of any system batteries should be performed.

- Classification and Weight (including speed and spacing) – Problems related to the measurement of various vehicle characteristics are usually caused by improper system settings. Verify that all settings are correct before performing further troubleshooting.
- Loop Settings – The second most common problem associated with misclassification of vehicles is the loop frequency and sensitivity settings. Verify that all loop frequencies and sensitivities have been set in accordance with the manufacturer’s setup routine.
- Communications – Communication issues usually are caused by disrupted cellular or landline service, corrupt modem settings, or power problems associated with the modem.
- Data Storage – The inability of the WIM system to store collected data is typically associated with an improper system setting or corrupt system memory.
- Data Download and Processing – The failure of the WIM system to properly download data is typically a result of a communication error. Investigate deficiencies associated with the communication devices first.

Based on the information gathered in this step, make a determination of the probable faulty function. Indicate the faulty function on the WIM System Troubleshooting Outline Form.

Once the faulty function has been determined, troubleshooting flow charts and step-by-step guides are typically provided in the manufacturer’s maintenance manual that can assist in the process of determining the faulty component.

If the faulty component cannot be determined, contact the manufacturer and provide the information gathered above. Many times the manufacturer can provide additional checks to perform or provide the technician with the probable fault component without further troubleshooting.

Maintenance Documentation and Reporting

Proper recordkeeping is an essential function of a WIM system maintenance program. Data from previous maintenance actions can be invaluable for determining high failure rate components and best practices for correcting common problems. Most importantly, past records can provide the WIM program manager with valuable information on predicting the failure of WIM system components so that they can plan and budget for upcoming maintenance costs and prepare the technician with replacement parts before the system fails.

Maintenance records should include preventive and troubleshooting efforts as well as final analysis and repair actions performed. Develop and use standard reporting forms to create historical records of all site maintenance performed, including:

- WIM Site Maintenance and Inspection Form – Detailed record of preventive or corrective maintenance activities and repairs/replacements performed at the site and the results of WIM system operational tests performed before and after maintenance activities.
- WIM System Troubleshooting Form – Detailed record of investigation activities performed at the site to identify problem with the equipment, including steps taken to identify and resolve system problems.

- WIM Site Maintenance Log – This form is kept in the WIM cabinet and provides a historical record of site visits and work completed.
- WIM Site Maintenance Management Tool – A management tool that contains a record of scheduled and completed WIM site maintenance visits and a brief summary of work performed during each visit. This is typically done in the form of a spreadsheet or a maintenance management software application.

Examples of WIM system maintenance and inspection forms and reports are provided in Appendix E. Further troubleshooting recommendations can be found in the manufacturer’s operations guides.

REFERENCES

1. ASTM Standard E1318-09, *Standard Specification for Highway Weigh-in-Motion (WIM) Systems with User Requirements and Test Methods*. West Conshohocken, PA: ASTM International, West Conshohocken, PA, 2009, DOI: 10.1520/E1318-09, www.astm.org.
2. European Cooperation in Science and Technology (COST): Action 323. 1998. *Weigh-in-Motion of Road Vehicles*. Paris: 2002.
3. NMi International WIM Standard: *Specification and Test Procedures for Weigh-in-Motion Systems*, NMi Certin, Dordrecht, Netherlands, 2016. http://www.nmi.nl/nmi-wim-standard/
4. Federal Highway Administration (FHWA). 2012. *LTPP Field Operations Guide for SPS WIM Sites Version 1.0. Draft.* McLean, VA: Federal Highway Administration: 2012.
5. American Association of State Highway and Transportation Officials (AASHTO). 2016. M331-13. *Standard Specification for Smoothness of Pavement in Weigh-in-Motion Systems*. Washington, D.C. 2016.
6. Quinley, Rich. 2009. *WIM Field Inspectors' Troubleshooting Guide*. Publication No. FHWA-IF-10-003. Washington, D.C.: Federal Highway Administration: 2009
7. Klein, Lawrence A. 2006. *Traffic Detector Handbook: Third Edition – Volume I*. Publication FHWA-HRT-09-108. Washington D.C.: Federal Highway Administration (FHWA): 2006.

APPENDICES

The appendices for the FHWA WIM Pocket Guide are available on the FHWA website:

https://www.fhwa.dot.gov/policyinformation/knowledgecenter

General Appendices

- Appendix A – Technical Report Documentation Page Form DOT F 1700.7
- Appendix B – Acknowledgements

Part 1 Appendices:

- Appendix C – WIM Procurement Resources
  - Example WIM Contract Language (GDOT)
  - Example of IRD Standard Warranty Statement
  - Example of IRD WIM System Installation Standards

Part 2 Appendices:

- Appendix D – WIM Site Design and Installation Resources
  - Example Pavement Surfacing Plans (SDDOT)
  - Example Polymer Piezo Installation Plan
  - Example SLC Layout (Mettler-Toledo)
  - Example WIM Installation Standard (NJDOT)
  - Example WIM Site Design (MT DOT)
  - Example WIM Cabinet Wiring Diagram
  - Example Non-compliance Report

Part 3 Appendices:

- Appendix E – Maintenance and Calibration Resources
  - Example WIM Calibration Report (AZ DOT)
  - Example Calibration Test Truck Procurement (LTPP)

- Example WIM Site Maintenance Forms and Reports (AZ DOT)

WIM Program Operation and Management Checklists

- Appendix F – WIM Program Operation and Management Checklists
    - WIM Technology Selection Table
    - WIM Site Selection Checklist
    - WIM Site Design Checklist
    - WIM Site Installation QA Checklist
    - Initial Calibration Checklist
    - WIM Site Acceptance Checklist
    - Test Truck Selection for WIM Calibration
    - Routine WIM Calibration Checklist
    - WIM Maintenance Tools, Materials, and Supporting Documentation
    - WIM Preventive Maintenance Checklist
    - WIM Troubleshooting Checklist
    - WIM Data QA/QC Checklist

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