



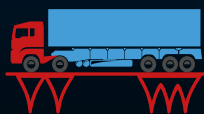
**ISWIM**

**Practitioners'  
Guides**

# Calibration of WIM Systems

FOR IN-ROAD AND BRIDGE WIM

2024 • MAY



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The **International Society for Weigh-In-Motion** (ISWIM) is a global non-profit organization, bringing together all stakeholders with an interest in Weigh-In-Motion (WIM) technology, its application, data it collects and information it generates. Our members are users, researchers and vendors of WIM systems including systems in or under the road pavement, bridges, rail tracks and on-board vehicles.

The **International Society for Weigh-In-Motion** has produced and is disseminating this publication to make the information contained herein available for use by ISWIM members. The information in this publication was reviewed by the ISWIM Editorial Board. This document does not circumvent any available standard Weigh-In-Motion (WIM) specifications, international standards, or other official WIM documentation.

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# Preface

This document is part of the publication series “ISWIM Practitioners’ Guides” produced by the International Society for Weigh-In-Motion (ISWIM). The aim of this publication series is to provide WIM practitioners, technicians, and end-users with a series of guides illustrating “best practices” concerning the various aspects of WIM technology and its applications. This document does not circumvent any available standard WIM specifications.

On behalf of ISWIM, I would like to acknowledge and thank Olga Selezneva for taking the lead in championing the development of the ISWIM Practitioners’ Guides Series, and the support of the individual Editorial Board members. Specific to this guide, I would like to thank the members of the working group and authors, namely Andy Lees, Deborah Walker, Hans van Loo, Olga Selezneva, Aleš Žnidarič and Chris Koniditsiotis.

**Deborah Walker**

President  
ISWIM

# Foreword

This guide, developed by a group of ISWIM volunteers, serves as a valuable resource for contractors, transportation agency personnel, and road owners involved in the calibration of WIM equipment. It offers recommendations based on proven best practices from the WIM industry and published documentation, aiming to assist in the successful calibration of in-road and bridge WIM systems.

The purpose of this document is to provide step-by-step procedures for the calibration of high-speed WIM equipment. It may also be used to serve as a basis for the establishment of specific requirements and procedures for a successful WIM operation.

It is important to emphasize that this guide does not intend to serve as a standard or dictate what actions individuals or organizations should take. Rather, it provides an overview of the best practices in the Calibration of In-Road Highway and Bridge WIM Systems used in the international WIM industry. This document was designed to be informative, and users can decide if they would like to utilize its recommendations. Calibration processes can vary depending on the specific applications, operational conditions, and financial/organizational constraints.

Any comments or questions for this guide could be provided by email to: [\*info@is-wim.net\*](mailto:info@is-wim.net).

Note: This guide is specifically designed for systems used in general traffic monitoring, statistical applications, and pre-selection for roadside weight enforcement controls. Definitions of WIM terms used in this document can be found in the "ISWIM Glossary of Terms" published on the ISWIM website, available for download at <https://www.is-wim.net/iswim-glossary-of-terms/>. Please be aware that this guide is not intended for systems used in legal metrology applications, such as direct enforcement.

**Gustavo Garcia Otto, PhD**

Editor-in-Chief for Practitioners' Guides Series

ISWIM

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# Introduction

Weigh-in-motion (WIM) calibration is the process of evaluating measured values of a WIM system against traceable and accepted reference values to determine the measurement error, followed by adjusting the WIM system to reduce the measurement error and provide measurements that meet the users' requirements. (It should be stressed that in legal metrology adjustment is considered separate from calibration.) The measured values include truck weight, axle and wheel loads, axle spacing, overall vehicle length or wheelbase, and speed values reported by the WIM system.<sup>1</sup> The measured values are compared to known reference values such as: static weights obtained from certified static scales; manually measured axle spacing; and vehicle length. Both the WIM-measured and reference values must be collected using the approved methods and procedures provided in the standard WIM specifications supplied by the vendor or by the specification issued by the agencies requesting WIM data collection services.

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. Practice has shown that reduction of measurement bias (i.e., mean measurement error computed using all collected test values) to less than 2% across all measured parameters can be achieved on a routine basis. The WIM system calibration is typically performed by a qualified WIM technician in accordance with the manufacturer's specifications and guidelines presented in international specifications such as COST323, ASTM E1318-09 or the NMI WIM standard.<sup>2</sup>

While this document provides valuable insights and recommendations for WIM calibration, users should consider it as a guide rather than a definitive standard. It aims to facilitate the calibration process and enhance the accuracy of WIM measurements, but it may not cover all possible scenarios or address specific regulatory requirements in every jurisdiction.

Computation of the measurement error is an important part of WIM calibration. The measurement error is the difference between the value measured/calculated by the WIM system and a reference value, such as static weight obtained from certified scales or manually measured axle spacing. It is vital that great diligence is taken when obtaining the static reference measurement since any error at this point will transfer to the calibration factors for the WIM system.

Once the average WIM measurement error has been computed based on multiple test heavy vehicle passes, this value can be used to compute the adjustment (calibration) factors necessary to calibrate the WIM system.

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<sup>1</sup> It is not necessary that the WIM system collect all the identified parameters.

<sup>2</sup> European Cooperation in Science and Technology (COST) 323, American Society for Testing and Materials (ASTM) E1318-09, Netherlands Meet Instituut (NMI)

# Types of WIM Calibrations

It is essential to calibrate a WIM system immediately after a new installation; sensor replacement; software update; during an annual check (if needed); changes in heavy vehicle weights, composition, or speed, based on WIM data analysis; or if the pavement surface leading to and/or at the sensor changes. There are two basic types of calibrations: initial installation and routine.

## Initial Calibration

The purpose of the initial calibration is to verify that, upon initial installation or major repair (such as a sensor replacement), the WIM system provides the level of weight, speed, and axle spacing measurement and classification accuracy stipulated in the specification.<sup>3</sup>

The initial calibration is typically performed by the WIM vendor or their representative (i.e., WIM contractor or WIM specialist), based on the manufacturer's procedures and any additional standards or specifications listed in the WIM procurement documentation. The end-user or purchaser may use the results of the initial calibration (along with other contractual matters) to determine the acceptability of the WIM system installation. This is sometimes referred to as verification or confirmation.

At a minimum, it is recommended that the WIM vendor or the WIM specialist do the following:

1. Select heavy test vehicles meeting specification requirements for calibration. For a proper calibration, it is recommended to use the most common type of heavy vehicle observed at the site to ensure the system is performing to the manufacturer's specifications. If possible, use two different types of heavy vehicles, such as a 2-axle rigid heavy vehicle and 5-axle tractor + semi-trailer combination. The heavy vehicle(s) in most circumstances should be loaded close to their maximum permissible loads. (It should be noted that for specific cases depending on the application or user requirements, empty vehicles may be used.)
2. Use a certified scale to statically weigh and measure each axle and record each axle spacing and total bumper-to-bumper length of each of the calibration test vehicles.
3. Use two heavy test vehicles to perform enough test runs (at least ten are recommended per heavy vehicle, up to 40 runs preferred by some specifications) to develop a reasonable confidence in the accuracy of the WIM system, especially regarding speed, temperature (if applicable), and vehicle type.
4. Run test trucks at speeds covering the range of typical speeds for the site. If typical speeds are above the speed limit, prior approval should be obtained from legal authorities to drive above the posted speed.

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<sup>3</sup> The specification should be an integral part of the WIM procurement contract.

5. Use the results of the test vehicle runs to calculate the average measurement errors and compare these errors against the acceptable tolerances specified in purchaser's specification. Determine if the WIM system calibration factors require an adjustment to achieve the target measurement accuracy and consistency.
6. Calculate and install the system calibration factors to compensate for the measured bias.
7. This step and step 8 are optional and may be added to the procedure. Conduct additional test vehicle runs to confirm that the changes had the desired effect on the WIM system measurement bias for the desired degree of confidence. At least a further ten runs will permit a more statistically accurate measure of system performance and will allow computation of WIM bias (mean measurement error) and precision (defined by the margin of error for the 95% confidence interval of mean error) values.
8. Recalibrate, if necessary, to remove bias and to meet contractual specifications.
9. Document for future reference the calibration factors used; type of test vehicle(s) used; number and percentage of test vehicle runs result in pass or fail<sup>4</sup>; and achieved outcomes, that is computed WIM accuracy statistics, such as mean error and range of errors (or 95% confidence interval of mean error).

Prior to the approval of WIM calibration results, the end-user or purchaser should review the initial calibration results to ensure that the WIM system is providing data with acceptable measurement error tolerances. The end-user or purchaser may employ their own agent, who is independent of the WIM contractor to evaluate the quality of the WIM installation and determine if the WIM performance measures meet the user's specification for error tolerances (especially if in-house expertise is lacking). Independent WIM assessment involves the actions described in 1-4 above and a WIM confirmation involves the action in 8.

The following table illustrates how WIM calibration results can be reported.

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4 ASTM E1318-09: Standard Specification for Highway Weigh-in-Motion (WIM) Systems with User Requirements and Test Methods

## WIM System Performance Evaluation

Performance Parameter	Total Test Runs	Failed Runs Count	% of Runs Passed	Measured Bias, Mean Error %	Precision, 95% CI Margin of Error ( $\pm$ Range)	Error Range From 95% CI	Error Range To 95% CI	ASTM Type I Specification Tolerance ( $\pm$ )	Pass/Fail
Wheel Load (%)	29	6	79%	-0.4%	$\pm$ 24.7%	-25.1%	24.2%	25%	Fail
Single Axle Load (%)	29	0	100%	0.6%	$\pm$ 6.5%	-5.9%	7.0%	20%	Pass
Axle Group Load (%)	29	0	100%	-0.3%	$\pm$ 6.4%	-6.7%	6.0%	15%	Pass
Gross Weight (%)	29	0	100%	-0.6%	$\pm$ 3.3%	-3.9%	10.0%	10%	Pass
Vehicle Length (ft)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Axle Spacing (ft)	29	0	100%	0.1 ft	$\pm$ 0.3 ft	-0.3 ft	0.4 ft	0.5 ft	Pass

## Routine Calibration

The purpose of the routine calibration (or system adjust) is to maintain the WIM system at the level of weight and axle spacing measurement, and classification accuracy stipulated in the specifications.<sup>5</sup>

The routine calibration is typically performed by either the end-user, purchaser's in-house staff, WIM vendor, or a contracted WIM specialist. The routine calibration is conducted as per the international specifications mentioned previously or as described by the purchaser. No matter which specification is used, heavy vehicles should be used for routine calibration and the calibration needs a sufficient number of test vehicle runs (10 to 40 per traffic lane), depending on the site, and the sensor number, layout and characteristics to quantify the average weight, axle spacing, and speed measurement error of the WIM system.

At a minimum, it is recommended that the WIM vendor or the certified WIM specialist do the following:

1. Select heavy test vehicles meeting specification requirements for calibration.
2. Use a certified scale to statically weigh each axle, axle group, and gross vehicle weight. Use tape to measure each axle spacing for the calibration test vehicles. The length of the vehicle and overhang also might be needed, if this is being verified with the calibration runs.

<sup>5</sup> The specification should be an integral part of the WIM procurement contract.

3. Perform enough test vehicle runs, as recommended in the specification you are working with, and compute errors between the static values and WIM-measured values.
4. Use measured mean measurement errors to compute adjustment (calibration) factors and make changes to the WIM system calibration factors to compensate for the measured system bias.
5. If required, conduct additional test vehicle runs per the specification requirements to confirm that the changes had the desired effect on the WIM system measurement bias.
6. Recalibrate, if necessary to meet specification requirements.
7. Document for future reference the calibration factors used; type of test vehicle(s) used; number and percentage of test vehicle runs that would have resulted in pass or fail; and achieved outcomes, such as mean error and range of errors (or 95% confidence interval of mean error).
8. Develop a record of whether the WIM system would have passed or failed the WIM performance requirements.
9. Store the calibration settings both in the field and in the office for later use.

It is important to emphasize that prior to performing the WIM calibration steps—initial or routine—certain pre-calibration activities are recommended to be done to ensure a successful check of the WIM system. See Appendix A for the recommended pre- and post-calibration activities.

# WIM Calibration Procedure

This section details practical steps to take to prepare for and perform proper calibration of in-road WIM systems. The five steps are shown in the flowchart (Flowchart of WIM Calibration Steps) with a descriptive detail for each step following the chart.

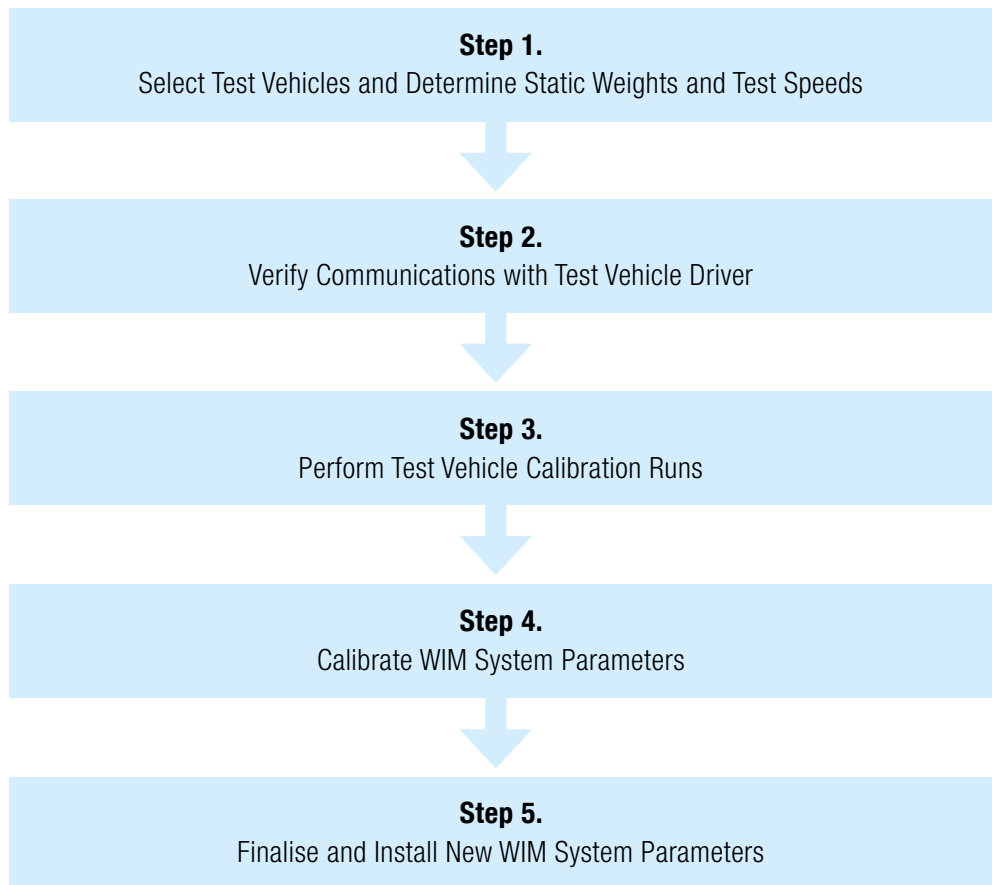


Figure 1. Flowchart of WIM Calibration Steps.

The following steps describe how to calibrate a WIM system:

## Step 1. Select Test Vehicles and Determine Static Weights and Test Speeds

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

### Test Vehicle(s) Selection

Test vehicle(s) should represent heavy vehicle type(s), with GVW of at least 13.5 tonnes (30 kips), most frequently observed at the site. Typically, a rigid 2-axle heavy vehicle and/or a 5-axle semi-trailer vehicle are used for calibration. If a 5-axle semi-trailer vehicle is used for calibration, its weight should be above 27 tonnes (60 kips) to assure accurate measurements of heavy loads. If the WIM system is being used for weight enforcement, fully loaded vehicles must be used for calibration. Most international WIM calibration procedures recommend using these types of heavy vehicles. The exceptions are load-restricted or commercial heavy vehicle-restricted roads; the heaviest vehicle class that routinely uses the road is recommended for calibration.

Use the following as a guide when selecting calibration vehicle(s):

- 1a. If possible, use more than one calibration vehicle to better calibrate the dynamic loading conditions encountered at the site.
- 1b. Select calibration test vehicle(s) that best represents the dominant heavy vehicle at the site.
- 1c. If two calibration vehicles are used, one vehicle should be at or near full load capacity and be configured with typical tandem spacing and have air suspension on the tractor unit and trailer.
- 1d. Select a different loading for the second heavy vehicle to better represent the most frequently observed loading conditions at the site.
- 1e. The test vehicles should 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 vehicle speed requirements.
  - Loads must be non-shifting, such as crane counterweights, steel plates or beams, or concrete blocks.
  - If cargo loads or trailers that allow the collection or absorption 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.
  - Be mechanically sound and road legal, and the loads should be evenly distributed.

- 
- 1f. Locate the nearest certified weigh scale location to the WIM site.
  - 1g. Obtain certified individual axle and gross vehicle weights for each calibration vehicle prior to and after the calibration test runs. If possible, repeat the static weighing three times to detect possible outliers and/or measurement errors. Average the results of the multiple static weights of the same calibration truck.

### **Test Vehicle Speed Determination**

It is important that the test vehicle's speed is as close as possible to the dominant heavy vehicle speed range at the WIM site. The range of the test vehicle speeds should represent a 15 to 30 km/h (10 to 20 mph) range of typical heavy vehicle speeds for the site.

Testing at multiple speed points (ideally three) is recommended to minimise error dependency on speed if the WIM system supports this option. WIM systems with multiple speed points consistently show more accurate calibration results.

### **Temperature Consideration**

It is recommended to use two test vehicles over the widest ranges of temperatures observed at the site, if possible. For WIM systems with measurements affected by pavement temperature changes, testing over a 15 °C (60 °F) pavement temperature range is recommended, if possible.

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## **Step 2. Verify Communications with Test Vehicle Driver**

- 2a. Review the calibration procedures with the driver(s), including proper speeds, in-lane behaviour, turnaround locations, and individual calibration run duration. The test vehicle should not accelerate or decelerate while in the WIM scale area and must travel down the centre of the travel lane.
- 2b. Review safety procedures with the test vehicle driver(s) and establish a working timetable to ensure drivers hours and regulations are adhered to during the calibration.
- 2c. Instruct the driver(s) to make test runs over the WIM scales at predetermined speeds.
- 2d. Establish communications with the test vehicle driver(s) by exchanging cellular numbers. It should be stressed that the driver operates a “hands free” device.

If the WIM equipment, pavement condition, vehicle classification and communication with the test vehicle driver are deemed to be working satisfactorily to specification then the calibration can take place.

## Step 3. Perform Test Vehicle Calibration Runs

This step describes how to conduct the calibration runs.

- 3a. Determine the number of test vehicle calibration runs. This number depends on the data variability observed at a site. Sites that have low variability of errors require fewer calibration runs than sites that have high error variability to collect a representative sample. If WIM performance is measured in terms of total measurement error (i.e., mean error +/- 95% CI of the error), then sample size becomes very important. Statistical computation of 95% confidence interval for small samples is affected by the value of t-statistic (which is a function of sample size). Increasing the number of runs will improve accuracy of 95% CI estimation. If WIM performance is measured in terms of passed or failed passes, too few runs may result both in false-positive and false-negative outcomes. Generally, calibration requires:
  - At least 10 runs for sites that have a spread of GVW errors for the test vehicle of 5 percent or less after 10 runs and show no dependency of weight measurements on temperature. Or,
  - At least 20 calibration runs for sites that have a spread of GVW errors for the test vehicle over 5 percent after 10 runs or demonstrate measurement error dependency on pavement temperature.
- 3b. Conduct calibration test truck runs.
- 3c. Run each test vehicle over the widest range of speeds determined during the pre-visit analysis. Select three target speed points covering the range and conduct the same number of runs at each speed. Use a laser or radar gun (laser is recommended) to measure the test vehicle's speed when it is crossing the sensor for comparison with the WIM system's output.
- 3d. For systems that use temperature compensation factors, check the manufacturer's guidelines regarding whether to keep this function turned on or off.
- 3e. For WIM systems that demonstrate temperature influence on measurement error, conduct test runs over a 15 °C (30 °F) temperature range or the widest temperature range possible.
- 3f. For each run of the test vehicle, measure and record the pavement surface temperature reading at a location near, but not on, the WIM sensor. Use a hand-held laser temperature device, positioned approximately 75 cm (30 in) from the pavement surface, to collect pavement surface temperature after each test vehicle runs over the sensors.

3g. For each pass of the test vehicle, record the WIM system's output for the following data:

- The sequence number of the calibration run.
- The date of the calibration run.
- The time of the calibration run.
- Test vehicle identification (if more than one test vehicle is used: for example, Truck 1 and Truck 2).
- Axle weights of the test vehicles as they pass over the sensors (weights in the left and right wheel paths for WIM systems that allow left and right wheel path adjustments).
- Spacing between each axle on the test vehicle.
- Vehicle length.
- Speed of test vehicle.
- Pavement temperature for each calibration run.

For WIM systems that use the piezo polymer sensor for weight measurement, and any other WIM systems that demonstrate measurement error dependency on temperature, it is recommended that a review of prior calibrations 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 4. Calibrate WIM System Parameters

This step describes how to calibrate the WIM system parameters.

- 4a. Based on the WIM system measurement error calculated during the calibration runs, calculate the adjustments to the current WIM system weight and distance error calibration factors. The example in Figure 2 provides formulas and computational steps for computation of adjustment (calibration) factors.
- 4b. Enter the new calibration factors into the WIM system firmware for post-calibration confirmation testing.
- 4c. Keep a record of all changes to the WIM system calibration factors.

## WIM Calibration Factor Computation Example:

**Step 1. Compute the average static GVW of each calibration vehicles (results show average of 2 or more static GVW measurements per truck).**

	Test Vehicle 1	Test Vehicle 2
Static GVW		Static GVW
	44000 kg	40000 kg

**Step 2. Obtain the WIM-measured GVW from each test vehicle run (minimum 10 runs total).**

	Test Vehicle 1	Test Vehicle 2
WIM GVW		WIM GVW
Test Run 1	43900	40500
Test Run 2	44500	38500
Test Run 3	43000	39100
Test Run 4	42800	39500
Test Run 5	43100	38200

**Step 3. Compute the relative measurement error for each measurement = (Static-WIM)/Static**

	Test Vehicle 1	Test Vehicle 2
Rel. Error		Rel. Error
Test Run 1	0.0023	-0.0125
Test Run 2	-0.0114	0.0375
Test Run 3	0.0227	0.0225
Test Run 4	0.0273	0.0125
Test Run 5	0.0205	0.0450

**Step 4. Compute the average relative error from all test runs from all test vehicles.**

Average Relative Error:	=	0.0166
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**Step 5. Compute the Correction Factor = 1 / (1-Av.Rel.Error)**

Correction Factor:	=	1.0169
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**Step 6. Obtain old (current) calibration factor from WIM system settings and compute the New Calibration Factor = Old Calibration Factor x Correction Factor**

Old Calibration Factor:	=	0.9555
New Calibration Factor:	=	0.9717

**Step 7. Verify if the Average Relative Error after correction equals zero.**

	Test Vehicle 1:	Test Vehicle 2:
Average GVW:	43460	39160
Corrected Average GVW:	44195.2	39822.5
Average Relative Error:	-0.0044	0.0044
Total Average Relative Error:	0	

Figure 2. WIM Calibration Factor Computation Example.

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## **Step 5. Finalise and Install New WIM System Parameters**

Based on the results of the prior steps, document and install the new system parameters.

- 5a. If all the parameters are within the tolerances, install the new/final calibration factors into the WIM system firmware, otherwise repeat steps 3 through 5 until the WIM system performance parameters are within tolerances (up to three times, if needed).
- 5b. Keep a record of the final values of each WIM system performance parameter and final changes to the WIM system calibration factors.

# WIM Calibration Summary Report

To assist in proper recordkeeping and future planning, it is recommended that the field technician develop and submit an agreed report format to the WIM program manager and end-user. A typical WIM calibration summary report states if the WIM system passed or failed the WIM performance requirements based on international and/or purchaser's specifications. At a minimum, the following information should be included in the report:

- WIM site inventory information (optional).
- Date of calibration and calibration protocol used (ASTM, COST323, NMI, LTPP, or agency-specific).
- Test vehicle inspection results, including vehicle type, static weights, axle spacing, and length measurements.
- Pavement condition assessment (optional).
- Temperature during testing and weather conditions.
- Equipment status and visual inspection.
- Results of electrical WIM sensor testing (optional).
- Initial pre-calibration test vehicle runs results (records of individual measurements for each test vehicle run).
- Total number of test vehicle runs, and the number of individual test vehicle runs that passed or failed any of the performance criteria.
- Computed error statistics (mean percent error and 95% confidence of mean error), if LTPP method is used, or percent of test vehicle runs that meet WIM tolerances for each parameter tested.
- Calibrate/do not calibrate decision and reasoning.
- Changes to system calibration factors.
- Confirmation of test vehicle runs results (records of individual measurements for each test vehicle run after WIM system calibration factors have been updated).
- Total number of test vehicle runs, and the number of individual test vehicle runs that passed or failed any of the performance criteria after calibration that you are working towards.
- Results of classification verification test (optional).
- Conclusions whether the WIM system met measurement accuracy requirements after calibration, including measurement error calculated based on test truck data (if required by end-user, including mean error, standard deviation of error, and 95% CI).
- Any corrective actions and recommendations (optional).
- Supplementary documentation, including photographs (optional).
- Pre-visit and post-visit data analyses and findings, including recommended calibration interval based on site-specific trend in weight measurement accuracy changes over time (optional).

Some of the activities listed above are labelled as optional. This means these activities represent good practice. However, they are not required for WIM equipment calibration.

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# Conclusions

The main purpose of this guide is to share and disseminate proven best practices. However, manufacturers specifications and approved national WIM calibration standards should be used to conduct proper WIM calibrations. Following are some of the key takeaways for novice and experienced WIM practitioners:

- The calibration frequency depends on the WIM sensor type and road conditions. In general, the following sensors may be calibrated at the recommended frequency:
  - Piezo polymer sensors – quarterly or bi-annually.
  - Piezo quartz sensors – annually.
  - Strain gauge strip sensors – annually.
  - Bending plate sensors – bi-annually with preventive maintenance every 6 months.
- One fully loaded calibration truck representing dominant heavy vehicle type observed at the site may be sufficient, if vehicle dynamics is minimal (achieved by smooth, straight road ahead of WIM sensors, uninterrupted event truck flow), otherwise two or more calibration trucks are recommended.
- Higher number of test vehicle runs will assure statistical accuracy and reliability of computed errors. At least 10 test vehicle runs should be performed, 30 is recommended (10 runs at three different speeds).
- Calibrating at wide speed range and at wide temperature range assures applicability of calibration results to wide range of conditions observed at the site.
- The calibration report provided to the end user should include, at a minimum, information about test vehicle(s) type, static weight(s) and axle spacing(s), number of test truck runs, computed WIM measurement error statistics (mean error, standard deviation of error, and 95% CI), old and new WIM calibration factors, conclusion if calibration was successful, and any recommended remedial actions or repair for pavement or WIM equipment.
- Post-visit WIM data analysis is recommended to evaluate if calibration was successful. The analysis should include comparison of vehicle weight, speed, and axle spacing statistics using 2-weeks of WIM data before and after calibration.

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# Appendix A

## Optional Pre- and Post-Calibration WIM Activities

This appendix contains optional calibration activities that can be conducted in conjunction with or after calibration of the WIM equipment. These additional activities include WIM site equipment and pavement field inspection prior to calibration, and data analysis after calibration. The inspection can help to identify factors that may lead to poor WIM measurement accuracy and are also useful in making decisions about WIM calibration needs. The pre- and post-calibration data analysis steps help to ensure the long-term success of calibration and therefore, are considered a good practice.

### Conduct Pre-calibration Activities

Prior to performing the WIM calibration steps—initial or routine—certain pre-calibration activities are recommended to be done to ensure a successful check of the WIM system. The following are suggested steps to follow when performing pre-calibration activities.

#### 1. Assess WIM Site Conditions

Perform an onsite assessment of the WIM location to determine the possible effects of pavement, equipment, and site conditions on the accuracy of WIM weight and distance measurements. This step will help to troubleshoot measurement accuracy and consistency issues related to vehicle dynamics.

##### *Pavement Inspection*

- 1a. Conduct a visual pavement distress survey from the safety of the roadside to identify surface anomalies that may affect heavy vehicle motions across the sensors.
- 1b. Identify items such as potholes, patches, rutting, cracking, asphalt to concrete transition joints, and bridge expansion joints.
- 1c. Use the most recent pavement profile data to determine specific high roughness locations and examine these locations closely during the onsite assessment. Ideally, this data should be collected during the same season as WIM calibration.
- 1d. Document observations and photograph any pavement anomalies that may affect the accuracy of the WIM scale measurements. Decide if any pavement irregularities are likely to have an effect on WIM measurement accuracy.

### *Vehicle-Pavement Interaction*

- 1e. Document and observe several heavy vehicle dynamics while they pass over the pavement or bridge site to determine if vehicle movement is showing adverse characteristics such as bouncing, swerving, braking, or accelerating within 40 metres (135 feet) of the sensors. Include the distance from the WIM scale area where adverse dynamics are observed.
- 1f. If feasible, visually observe whether the heavy vehicles' tyres come into full contact with the sensors. For bridge WIM installations, it may be useful to assess how well the vehicles are following the same wheel path. This may not be always possible or practical.
- 1g. Decide if any of the observed vehicle dynamics are likely to influence the WIM measurement accuracy. If so, **postpone the calibration**.

## **2. Inspect WIM Equipment**

This step will help to troubleshoot measurement accuracy and consistency issues related to WIM equipment.

- 2a. Perform a visual inspection and static electrical and electronic tests of all WIM site support components.
- 2b. Identify and record deficiencies involving the equipment that will require repair.
- 2c. Identify all items where the present or deteriorating condition will eventually adversely affect the operation and/or accuracy of the WIM equipment.
- 2d. If any discrepancies or deficiencies exist that will affect the measurement accuracies and that cannot be remedied on-site, **postpone the calibration**, and arrange for relevant maintenance work to be carried out.

## **3. 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 Reference Data Set (RDS). It also provides information needed to establish the requirements for the test vehicles, including type, weight, length, and speed.

Prior to the site visit, perform the following:

- 3a. Collect a recent data sample from the WIM system. A statistically acceptable sample size would be around 5,000 heavy vehicle records. Analyse the data to determine the current traffic characteristics for the WIM site, including:
  - Most common heavy vehicle type for the site to be used as a test vehicle.
  - Percentile of heavy vehicle speed distribution and a range of speeds for calibration test runs (25<sup>th</sup> to 85<sup>th</sup> percentile speed range as an example).
  - GVW distribution for the prevalent heavy vehicle type and the target weight of the calibration vehicle.

- Axle spacing for the prevalent heavy vehicle type (use standard tandem unless spread tandem is prevalent).
- 3b. Compare the heavy vehicle axle weight and spacing, and traffic flow characteristics developed based on the data collected immediately after the most recent calibration (the RDS) 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 calibration factors to be applied in the field.
- 3c. Record 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.
  - Changes in average heavy vehicle speeds.
  - Changes in axle spacing or vehicle length for prevalent heavy vehicle type or vehicle class.
  - Changes in vehicle weights over time that may be caused by environmental (temperature, changes in pavement support under sensor) influences.

## Evaluate WIM Estimates and Compute Measurement Errors

Once the data from the test vehicle calibration runs have been collected in the field, measurement error statistics must be computed to determine whether the WIM site meets the required accuracy parameters stated in the WIM performance specifications being used.

WIM system performance parameters can be evaluated using several methods such as those outlined in ASTM E1318-09, the LTPP field operations guide, COST323 and the NMI International WIM standard. These are all effective methods for determining the calibration results. The examples below show application of ASTM E1318-09 Pass/Fail Method and the LTPP Statistical Confidence Interval (CI) methods.

### Example of ASTM E1318-09 Pass/Fail Method

These summary statistics are used to determine whether the scale requires calibration using the ASTM procedure:

- A1. 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.

Parameter	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)		

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

- A2. For each test vehicle pass, determine if any calculated measurement difference exceeds the tolerance value specified in Table 1.
- A3. Using all passes of the test vehicles over the sensors, determine the number of passes with calculated differences that exceeded the tolerance values shown in Table 1 for each parameter and express this number as a percentage of the total number of vehicle passes—that is, the percentage of all test measurements for a given parameter (like GVW) that exceeded the tolerance.
- A4. If more than 5 percent of the calculated differences for any parameter from Table 1 exceed the specified tolerance for that parameter, the WIM system requires adjustment/calibration.

### Example of FHWA LTPP Statistical Confidence Interval Method

The basic statistic used for this method is the error expressed as a percentage of the known value of the certified static weight. The percentage of error, calculated from the data collected for each test vehicle pass, is used to compute a series of summary statistics.

These summary statistics are used to determine whether the scale requires calibration using the following procedure:

- L1. 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.
- L2. Use all computed percentile errors to compute the mean error, standard deviation, and statistical 95<sup>th</sup> percentile confidence interval (95% CI) for the mean error (use t-distribution for sample sizes less than 38).
- L3. Use the mean error and the margin of error for the 95% CI values to compute the overall range of errors: mean error +/- 95% margin of error for the CI.
- L4. Compare the resulting overall error range with the tolerances specified in Table 1.
- L5. If the overall error range is within the tolerance levels specified in Table 1 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.

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## Perform Confirmation Test Runs and Evaluate Results

While this activity is not required, it is good practice to perform confirmation runs using heavy vehicles dominant to the site are done to evaluate the success of the calibration. Typically, these are the same heavy vehicles as those used for calibration (Step 3 of the main report). The purpose of confirmation test truck runs and subsequent analysis of WIM measurements for test trucks is to confirm that calibration had the desired effect on WIM measurement error reduction. This is particularly important for the sensors whose output is affected by environmental conditions (temperature sensitivity or changes in the pavement support beneath the sensor).

### Determine the Number of Confirmation Test Vehicle Runs

A minimum of 10 confirmation test vehicle 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 minimised (less than 2 percent average error for 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 specified tolerance range for 95 percent compliance (for example, for GVW tolerance of  $\pm 10\%$ , one run outside of the range is allowed for samples of ten test vehicle runs or larger based on ASTM E1318-09 for Type I WIM systems) or the 95 percent confidence interval computed based on the test data is within the acceptable performance tolerances.

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

### Conduct Confirmation Runs

Conduct confirmation test runs using the procedure described above and collect post-calibration test of vehicle weight, axle spacing, and length measurement data.

Check if WIM system performance parameters are within the tolerances specified using the procedure and examples described above. If any of the parameters are outside the tolerances, go back to Step 3 in the main document and repeat calibration.

## Check Accuracy of Vehicle Classification

This check is essential to ensure that the WIM equipment can identify and classify vehicles correctly. The check is performed at a WIM site location and may involve additional data analysis after a site visit. It involves visual observation and manual classification of vehicles passing WIM sensors and comparison of manual classification results with the vehicle identification or classification results from WIM system. In addition, collection of time-stamped video images of the test vehicles passing WIM sensors during manual classification sampling is highly effective for post-visit data analysis.

Vehicle classification checks involve first testing that the WIM system algorithm classifies vehicles properly as compared to the end-user's vehicle classification scheme, and second that the scheme itself classifies vehicles effectively at the WIM site location. For example, if a short 2-axle bus is classified as a 2-axle rigid vehicle, verify the axle spacing. If the axle spacing is within the range based on the agency's vehicle classification scheme, it passes the first check but could fail the second check.

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

1. Aim to perform the vehicle classification testing during peak heavy vehicle traffic hours. Peak hours could be identified from the hourly heavy vehicle volume data sample during pre-visit data analysis.
2. Collect a manual sample of at least 100 heavy vehicles, or as many samples as can be collected in three hours. In addition, collecting time-stamped video of the traffic stream in WIM test lane during manual study would be helpful for the follow-up analysis of misclassified vehicles.
3. During the manual data collection, record the vehicle ID's 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 the method, as described below.
  - Determine the total number of vehicle samples and the total number of misclassified vehicles in the manual sample of heavy vehicles.
  - Calculate the percentage of misclassified heavy vehicles in the manual sample. Compare misclassification percentage for the sample with the agency's acceptable misclassification percentage. It is recommended that the percentage of misclassified heavy vehicles should be no greater than two percent.
  - Calculate the number and percentage of heavy vehicles in the manual sample that were not classified by the WIM system. It is recommended that the percentage of unclassified heavy vehicles should be no greater than two percent.

If fewer than 50 heavy vehicles are observed in a three-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 heavy vehicle can be allowed for classification test to pass.

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## Conduct Post-calibration Data Analysis

The post-visit data analysis allows 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, as well as a comparison with the RDS developed based on the data collected immediately after the previous successful calibration.




For this analysis, a traffic data sample from the 14 days (30 days for low heavy vehicle volume roads with less than 100 5-axle semi-trailer heavy vehicles per WIM lane per day) immediately following the calibration is collected and compared with the RDS from the previous calibration event and the pre-visit data sample. To conduct post-visit analyses, follow these steps:

- PC1. 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.
- PC2. Obtain RDS developed after previous successful calibration.
- PC3. Compare the following parameters between the RDS data, pre-visit data sample, and the post-visit data sample for each WIM lane:
  - 5-Axle semi-trailer heavy vehicle average GVW and GVW distribution by load bins (tabular or plot).
  - 5-Axle semi-trailer heavy vehicle average front axle weight and front axle weight distribution by load bins (tabular or plot).
  - 5-Axle semi-trailer heavy vehicle tandem axle group axle load distribution by load bins (tabular or plot), including average weights of loaded and empty trucks.
  - 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).
  - 5-Axle semi-trailer heavy vehicle tractor average tandem axle spacing.
  - 5-Axle semi-trailer heavy vehicle total length of vehicle.
  - Speed distribution for heavy vehicles, including 25<sup>th</sup> and 85<sup>th</sup> percentile values.
  - Vehicle class distribution for moderate and heavy vehicles (with GVW of 7 tonnes (16 kips) or greater).
- PC4. Note whether differences from the previous RDS observed in the pre-visit data set have been resolved or reduced because of calibration.
- PC5. 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.
- PC6. Document findings in a WIM calibration summary report.

## WIM Vendors Affiliated to ISWIM

 <a href="http://www.apm.pl">www.apm.pl</a>	 <a href="http://www.axtec.co.uk">www.axtec.co.uk</a>	 <b>Betamont</b> <a href="http://www.betamont.sk">www.betamont.sk</a>	 <a href="http://www.camea.cz">www.camea.cz</a>
 <a href="http://www.pesage-captels.com">www.pesage-captels.com</a>	 <a href="http://www.ciemsacomuy.com">www.ciemsacomuy.com</a>	 <a href="http://www.cestel.eu">www.cestel.eu</a>	 <a href="http://www.cross.cz">www.cross.cz</a>
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 <a href="http://www.intercompcompany.com">www.intercompcompany.com</a>	 <a href="http://www.quarterhill.com">www.quarterhill.com</a>	 <b>BiSON</b> <small>an IWIM</small> <a href="http://www.iwim.it">www.iwim.it</a>	 <b>KISTLER</b> <small>measure. analyze. innovate.</small> <a href="http://www.kistler.com">www.kistler.com</a>
 <a href="http://www.mikros.co.za">www.mikros.co.za</a>	 <a href="http://www.osmos-group.com">www.osmos-group.com</a>	 <b>sterela</b> <small>ADVANCED SOLUTION MAKER</small> <a href="http://www.sterela.fr">www.sterela.fr</a>	 <a href="http://www.q-free.com">www.q-free.com</a>
 <a href="http://www.traffic-data-systems.com">www.traffic-data-systems.com</a>	 <a href="http://www.tramanco.com.au">www.tramanco.com.au</a>	 <a href="http://www.vanjee.net">www.vanjee.net</a>	 <a href="http://www.fardeu.com">www.fardeu.com</a>

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