NMi International WIM standard

Specifications and test procedures for Weigh-in-Motion Systems

NMi Certin

Hugo de Grootplein 1
3314 EG Dordrecht, Netherlands

P.O. Box 394
3300 AJ Dordrecht, Netherlands

T +31 78 6 332 332
E certin@nmi.nl

I http://www.nmi.nl

Changes to the previous version:

1.0 Version 1.0 dated 18 October 2016, issued by the Certification Board of NMi Certin B.V.

Preface

For many years three documents (COST-323, ASTM-E1318, OIML-R134) have been used to determine the performance of Weigh-In-Motion (WIM) systems all over the world. All three documents have their own area of use with specific advantages and disadvantages. For example none of the three covers all the applications and operational conditions for WIM systems, e.g. for direct enforcement of overloading under regular highway conditions.

As a consequence national authorities often have to develop their own specifications and test procedures and elaborated in their national legislation. Because of the specific nature of weighing in motion this requires a specific expertise that is not available in all countries. This has led to the situation where there are several different national sets of requirements on WIM that are not compatible and by many considered too complicated for practical use. This has resulted in unnecessary additional work and costs for both buyers/users and vendors of WIM systems.

All in all there is a need for a full international standard for Weigh-In-Motion systems that covers all applications for high (and low) speed WIM systems.

NMi Certin B.V.

Dordrecht, 17 October 2016

Head Certification Body

TABLE OF CONTENTS

1 General; Context of this standard

1.1 Approach

The Dutch Metrology Institute (NMi) has taken the initiative to bring together a group of experts on metrology and standardisation together with a select number of international specialists on WIM to develop this new WIM standard. The members of this group cover the key-expertise on WIM required to develop a standard that in structure and content has a quality that will be suitable for international use. The document is intended to be practical, easily accessible, widely acceptable, objective and independent for technology or commercial bias.

This document has been written by the members of the NIWS-project, the NMi International WIM Standard. It is published as an international NMi-standard that is open to be used by both buyers and vendors of WIM systems to facilitate their mutual relation and that with national regulators. It may also be used by any National Metrology Institute or Bureau for Weights and Measures in any country as a basis for national legislation.

1.2 Scope

This document:

- Gives specifications for automatic instruments for measuring the vehicle weight and axle loads of road vehicles when in motion, hereafter referred to as Weigh-in-Motion or WIM-systems;
- Specifies the performance requirements for WIM-systems;
- Specifies the minimum testing procedures in order to determine the actual performance of a – type of – WIM-system.

Note: the procedures for testing, acceptance and certification are explained in the support document "Guide to NMi-WIM-Standard".

1.3 Application

This document applies to:

- Automatic WIM-systems, it does not apply to individual parts of WIM-systems, e.g. WIM-sensors.
- WIM systems installed on, in or under the road infrastructure including both roads and bridges independent from which type of measuring technology is used.
- High Speed WIM-systems, i.e. systems installed directly in a normal road and operated under free-flow traffic conditions.
  Note, it may also be used for Low Speed WIM systems since the measurement conditions are more controlled.
- WIM-systems used for Statistical (e.g. Traffic Monitoring, Pavement Loading, Pre-Selection) and Legal (e.g. Trade, Tolling, Direct Weight Enforcement) applications.
- Fixed and portable WIM-systems installed in or under road pavements and bridges.

1.4 Structure of document

This document consists of four parts:

- General part, consisting of chapters 1-3 and applies to all WIM systems.
- Part I, consisting of chapters 4-7 and applies to WIM-systems for Statistical applications.
- Part II, consisting of chapters 8-13 and applies to WIM-systems for Legal applications.
- Recommendations, chapter 14 with non-mandatory information on the installation and operation of WIM systems.

2 General; Terminology

The main terms used in this document are listed here. The definitions were taken from the COST-323 specifications [COST, 2001] and international documents on measurement instruments [VIM, 1993] and [VIML, 2000].

2.1 Weigh-In-Motion

Axle: An axle comprises two or more wheel assemblies with centres lying approximately on a common axis orientated transversely to the nominal direction of motion of the vehicle.

Axle Distance: The distance between the centres of two axles

Axle group: A set of axles on the same vehicles, defined by the total number of axles included in the group where the centres of the axles are spaced less than a specified value.

Axle group load [kg]: The total load of all wheels included in an axle group.

Axle load [kg]: The sum of all the wheel loads of an axle of a vehicle.

Axle Spacing: See Axle Distance

Bridge-WIM (B-WIM): A WIM-system using an instrumented bridge to measure the response of the bridge to passing vehicles. From the measurements, the axle loads and gross weight of the passing vehicles are calculated

Dynamic Vehicle Tyre Force [N]: The component of the time-varying force applied perpendicularly to the road surface by the tyre(s) on a wheel of a moving vehicle.

Gross Vehicle Weight [kg]: The external force of gravity acting vertically downwards on a vehicle, including all connected components, with a magnitude equal to the mass of the vehicle multiplied by the local acceleration of free fall.

High Speed WIM (HS-WIM): The weighing of a vehicle in motion in the normal traffic flow, using a system installed directly on/in/under a normal road.

Legal Applications: Applications of WIM systems with a direct connection to a legal or financial transaction, e.g. Trade, Tolling by weight, Direct Weight Enforcement. Such WIM systems require a legal approval by a notified body that certifies the requirements for each individual measurement.

Low Speed WIM (LS-WIM): The weighing of a vehicle in motion in a controlled weighing area and under controlled traffic conditions, such as limited vehicle speeds in order to minimise the dynamic effects.

Load Receptor: A sensor installed in or under the road pavement measuring the dynamic force exerted by a vehicle on the road.

Pavement-WIM: A WIM-system where the sensor(s) is/are installed in the road pavement.

Sensor: Part of a measuring instrument that is directly affected by the parameter to be measured and produces a related signal.

Static Weighing: Weighing of Gross Vehicle Weights or Axle Loads that are stationary.

Statistic Applications: Applications of WIM systems without a direct connection to a legal or financial transaction, e.g. Traffic monitoring, Pavement Loading, Pre-Selection for weight enforcement. Such WIM systems do not require legal approval by a notified body.

Vehicle Class: Group of vehicles with the same characteristics like number of axles, number of axle groups, vehicle length, etc.

Vehicle Length: Distance between the front and the back of a vehicle.

Weigh Bridge: A weighing instrument which measures the complete stationary vehicle weight at once. (Generally used for gross vehicle weight reference values)

Weigh-In-Motion (WIM): The process of estimating the wheel and/or axle loads and gross weight of a moving vehicle, by measurement and analysis of the Dynamic Vehicle Tyre Forces.

Weigh-In-Motion System (Instrument): A set of mounted Sensors and electronics with software which measures Dynamic Vehicle Tyre Forces and vehicle presence of a moving vehicle with respect to time and calculates wheel and/or axle loads and gross weights estimates, as well as other vehicle parameters such as speed, axle spacing, category, etc.

Wheel Base: Distance between the first and last axle of a vehicle.

Wheel Load [kg]: The portion of the gross weight imposed upon a weighing instrument by the tyre(s) of a stationary wheel at the time of weighing, due only to the vertical downward force of gravity acting on the mass of the vehicle.

2.2 MEASURING

Accuracy of a measurement: qualitative term to indicate the closeness of agreement between a measured value and the true value or a value accepted as a reference.

Accuracy of a measurement instrument: qualitative term to indicate the closeness of the measurements by a certain instrument.

Accuracy Level: Integer value [δ] used to quantify the maximum allowed relative error.

- For Statistical applications (chapters 4-7 of this document) the Accuracy Level [δ] is used to specify the maximum size of the two Standard Deviation Interval [-2σ, $+2\sigma$]. This means that for 95 % of all measurements the (unknown) true value lies within $\pm\delta$ % from the measured value.

- For Legal applications (chapters 8-12) [δ] is used to specify the size of the Maximum Permissible Error [-MPE, +MPE]. This means that for all measurements the (unknown) true value lies within $\pm\delta$ % from the measured value.

Bias: See Mean Error.

Error of measurement: for an individual measurement, is the difference between the measured value and the true value or an accepted reference value.

Influence Quantity: Quantity that is not subject to the measurement but which influences the value of the measurement and/or the indication of the measurement instrument.

Maximum Permissible Error (MPE): extreme value of the measurement error permitted by specifications for a given measurement instrument. For a measuring system, it means that for all measurements the (unknown) true value lies within ±MPE% from the measured value.

Mean Error (μ): The average difference between the measurement results and the true value(s).

Measurement Error: Difference between the measured value and the accepted reference value.

Operating ranges: Range between the minimum and maximum value of influence quantities where the systems performs according to its specifications.

Outlier: A measurement that is numerically distant from the rest of the data in a series of homogenous data which has a much lower probability of occurrence.

Precision: The variation in the measurement results when doing same measurement over and over again.

Rated Operating Conditions: Conditions of use which give the ranges of the influence quantities for which the performance of the system lies within the specifications.

Relative Measurement Error: Error of Measurement divided by the accepted reference value

Resolution: Smallest value of the Scale Interval that a measuring instrument is capable of discriminating.

Scale Interval (d): The difference between two consecutive values indicated by a measurement instrument.

Standard Deviation (σ): The measure of the distribution of data about a mean value. It describes the dispersion (spread) of data on either side of a mean value.

True value: The unknown actual value or the known value accepted as a reference value for a measurement. For HS-WIM measurements generally, a static or LS-WIM measurement is used as a reference value.

Validity of Measurement: an indication of confidence in the quality of a measurement determined by a WIM system itself intended to filter measurement that were disturbed by external factors such as driver behaviour.

Weighing Range: Range between the minimum and maximum value of the measured variable where the system performs according to its specification.

2.3 TESTING

Adjustment: set of operations on a measuring instrument to reduce the measurement error.

Calibration: The process of comparing a measuring instrument against a traceable standard or another accepted reference.

Confidence Level: The chance that, in reality, at least xx % of the measurement errors of the system under test lie within the accuracy interval [-δ, +δ]. The Confidence Level is used to qualify the reliability of the outcome of a test procedure.

- For Statistical applications (chapters 4-7 of this document) the Confidence Level is 95 %.

- For Legal applications (chapters 8-12 of this document) the Confidence Level is 100 %.

Initial Verification: The Performance Test made, after installation or important repair, in order to verify the performance of the measurement instrument under the specific conditions at the site where the system is installed.

In-service Verification: Performance Test in order to verify if a system is still operating according to specification. This is a relatively small test executed when a system has been operational for a period of time.

Performance Test: A test to determine whether a measurement instrument is capable of performing according its specified functions.

Reference Conditions: Conditions of use prescribed for testing the performance of a measuring instrument or for inter-comparison of measurements.

System Approval Test: See Initial Verification.

Type Approval Test: The first extensive Performance Test of a new type of measurement instrument where the performance of the system is tested under the full operating ranges by the NMi, or a national authority, approved by the NMi. The results of this test may be a formal document stating international Type Approval of the system.

2.4 ALTERNATIVE UNITS

This standard refers to the International System of Units (SI) for the expression of metrological units. The SI brochure can be found at the website of the International Bureau for Weights and Measures (BIPM).

Certain units are not part of the International System of Units (non-SI) but are important or are still used in specialized fields (e.g. tonne in vehicle weighing) or in particular countries (the inch, foot, and yard). Consistent with the recommendations of the International Committee for Weights and Measures (CIPM), the units in this category that are accepted for use with the SI are available on the BIPM website. A list of the conversion factors to the SI for such units is also available on the BIPM website.

The SI recommends the use of kg to express masses. In the field of weights and dimensions of heavy road vehicles the unit tonne (t) is generally used by road authorities, police, engineers and legislation. In English speaking countries this unit is usually called "metric ton", where 1 t = 10^3 kg. To match with daily practice in vehicle weighing this standard uses besides the SI-unit for mass “kg” also the unit “tonne” for weight measurements.

3 General; Operating Conditions

The rated Operating Conditions are the ranges of the influence quantities for which the performance of the system lies within the specifications. Each WIM-system should contain a description of its rated operating conditions consisting at least of ranges for:

- Traffic Intensity;
- Vehicle Speeds;
- Temperature + Humidity;
- Dust + Water resistance;
- Electromagnetic Conditions;
- Mechanical Conditions;
- Electrical Power.

In this chapter, only the operating conditions are specified that may have an influence on the accuracy and reliability of the measurements. The user or vendor can specify additional operating ranges for quantities that may influence the durability of the system.

This chapter specifies the minimum requirements for the rated operating conditions and the specifications that should be met by all WIM systems. The user or vendor can specify wider operating ranges, when required, to meet the conditions for a specific country, location or application.

3.1 Vehicle Speed Range

Operating speed range consisting of: the range from the minimum to the maximum speed of passing vehicles where the system must meet the metrological requirements. The overall operating speed range may consist of one or more of the following partial speed ranges:

5 – 20 km/h
10 – 25 km/h
20 – 50 km/h
25 – 70 km/h
50 – 110 km/h
70 – 130 km/h

Note: The performance of a system will be tested for each of the partial speed ranges.

If the actual speed of a vehicle is outside the overall operating speed range of the system' during measurement, the system must:

- Either automatically invalidate (block) measurement results from being issued, or;
- Automatically delete the measurement results, or;
- Indicate or print out the value of the measured actual vehicle speed, and at the same time indicate or print out a clear warning that the measurement is outside the system's operating speed range.

3.2 Temperature Range

Operating temperature range consists of: the range from the minimum to the maximum temperature where the system must meet the metrological requirements.

The minimum range for the operating temperatures is -25 °C to +55 °C, according to OIML D 11, level 3.

If the actual temperature is outside the operating temperatures range of the system during measurement, the system must:

- Either automatically invalidate (block) measurement results from being issued, or;
- Delete the measurement, or switch off the system, or;
- Display a clear warning that the measurement is outside the system's operating temperature range.

3.3 Relative Humidity

The systems must meet the metrological requirements under condensing humidity up to 95 % at an upper temperature of 55 °C, according to OIML D 11, level 2.

3.4 Electromagnetic Fields

The system must not be influenced by Electromagnetic interference, or must react to it in a defined manner (e.g. reporting an error, blocking measurement).

This includes:

- Conducted currents generated by Radio Frequency Electromagnetic Fields, according to OIML D 11, level 3;
- Radiated Radio Frequency Electromagnetic Fields, according to OIML D 11, level 3;
- Electrostatic Discharge with 6 kV for contact discharge and 8 kV for air discharge, according to OIML D 11, level 3

3.5 Mains Voltage Variation

The systems must meet metrological requirements under conditions with normal fluctuation in the mains power supply.

In case of AC-mains:

- Voltage fluctuations between U_{nom} -15 % and U_{nom} +10 %, according to OIML D 11, level 1;
- Frequency fluctuations between f_{nom} -2 % and f_{nom} +2 %, according to OIML D 11, level 1;
- Voltage dips, according to OIML D 11, level 2;
- Bursts on mains with a peak value of 2 kV, according to OIML D 11, level 3;
- Surges on mains with a peak value of 1 kV to line and 2 kV to ground, according to OIML D 11, level 3;

In case of DC-mains:

- Voltage fluctuations between U_{lower} and U_{upper}, according to OIML D 11, level 1;
- Ripple on mains between V_{nom} -2 % and V_{nom} +2 %, according to OIML D 11, level 1;
- Voltage dips, according to OIML D 11, level 1;

If voltage declines below the minimum operating voltage, the scales must be blocked from working or their activity outside specified operating conditions must be clearly indicated, for example by a suitable warning.

4 Statistical Applications; Technical requirements

This applies to WIM systems for Statistical applications only.

4.1 Vehicle Record

A vehicle record is considered Complete when at least the following data items are recorded and correctly measured within specifications:

- Unique record number
- Location, (Lane + Direction)
- Date + Time, (yy-mm-dd + hh:mm:ss)
- Gross Vehicle weight
- Axle Group Load
- Axle Load
- Wheel Load (if possible)
- Axle distances
- Wheel Base and/or Vehicle length
- Vehicle Classification
- Vehicle Speed

4.2 Completion Rate

All vehicles passing over the instrumented lane of the WIM system should be detected by the system and result in a vehicle record. The WIM system should be able to detect if a vehicle was passing correctly over the system. Non-correct vehicle passages include the following conditions to be detected by the system:

- Vehicles changing lanes, in between lanes or partially on the instrumented lane;
- Vehicles passing the system with a too high acceleration or deceleration;
- Extreme weather conditions like snow and heavy rain and/or winds.

At least 95 % of the heavy vehicle records generated by the WIM system - with a Gross Vehicle Weight of more than 3.5 t – identified by the system as having passed correctly over the system should be completed as defined in 4.1.

4.3 Time Recording

The resolution of the recorded time shall be 1 second.

The time measurement used by the system shall be hours:minutes:seconds [hh:mm:ss].

4.4 Speed Recording

The resolution of the recorded speed shall be 1 km/h.

The unit of speed is kilometer per hour [km/h].

4.5 Length Measurement

The length measurement consists of the measurement of the vehicle length and/or the wheelbase of the vehicle and the axle distances.

- The accuracy of the vehicle length measurement should be ±50 cm for at least 95 % of the measurements.
- The accuracy of the wheel base measurement should be ±15 cm for at least 95 % of the measurements.
- The accuracy of the measurement of the axle distances should be ±5 cm for at least 95 % of the measurements.

The unit of axle distance, wheel base and vehicle length used by the system is the meter [m].

4.6 VEHICLE CLASSIFICATION

The vehicle classification scheme depends on the location and the application of the WIM system and should be defined by the users/buyer of the system. The test report should describe to which classification scheme the system was tested, later additional classification schemes may be added.

At least 95 % of the vehicle classification of vehicle records from heavy vehicles that have passed the system correctly (see 4.2) should be correct.

Note: all vehicles classified must be compliant with the approved classification scheme as long as the vehicle class can be accurately determined by the measurement of vehicle length, axle count and axle spacing within the tolerances defined in this chapter.

5 Statistical Applications; Weighing requirements

This applies to WIM systems for Statistical applications only.

5.1 Weighing Specifications

5.1.1 Accuracy Classes

WIM-systems for statistical applications are classified into accuracy classes using the capital letter 'S' and according to their weighing performance. The accuracy classes are: S(5), S(7), S(10), S(15) and S(20).

For Statistical applications the accuracy level quantifies the maximum size of the two standard deviation interval [-2σ, +2σ] of the relative measurement error. Under the assumption of a Normal or Gaussian distribution this interval includes 95 % of all measurements.

The accuracy levels for the different accuracy classes are specified in Table 5.1. The accuracy levels are given in [%].

Class	S(5)	S(7)	S(10)	S(15)	S(20)
Gross Vehicle Weight	5	7	10	15	20
Axle Group Load	8	11	15	20	25
Axle Loads	10	15	20	25	30

Table 5.1, Accuracy levels per Class.

5.2 Weighing Ranges

This paragraph specifies the minimum weighing ranges that should be met by all WIM systems. The user or vendor can specify more extensive weighing ranges when required to meet the conditions for a specific country, location or application.

The minimum weighing range for Gross Vehicle Weight measurements is larger than 3,500 kg.

The minimum weighing range for Axle Load measurements is from 2,000 kg up to 15,000 kg.

If the actual Gross Vehicle Weight and/or one or more Axle Load(s) of a vehicle is/are outside the overall operating weighing range of the system during measurement, the system must:

- Either automatically invalidate (block) measurement results from being issued, or;
- Automatically delete the measurement results, or;
- Indicate or print out the value of the measured actual Gross Vehicle Weight, Axle Group Load(s) and Axle Loads of the vehicle, and at the same time indicate or print out a clear warning that the measurement is outside the system's operating weighing range.

5.3 Scale Divisions

The scale divisions must not exceed the values given in [kg] per accuracy class in Table 5.2.

Class	S(5)	S(7)	S(10)	S(15)	S(20)
Axle Loads	20	50	50	100	100
Vehicle Weights	50	100	100	200	200

Table 5.2, Maximum Scale Divisions.

5.4 Units of Measurement

The units of weight and load used by the system are kilogram [kg] or tonne [t].

6 STATISTICAL APPLICATIONS; INITIAL VERIFICATION

This applies to WIM systems for Statistical applications only.

6.1 INTRODUCTION

The Initial Verification Test is typically done after installation - or major repairs affecting the sensors - in order to assess the performance of the measurement instrument under the specific conditions at the site where the system is installed. The result of this test will be the basis for the decision by a buyer to accept a system.

6.2 TEST EQUIPMENT

6.2.1 REFERENCE VEHICLES

At least 2 different types of vehicles shall be used that are common at the location of the WIM system.

The vehicles used for the test should be loaded up to their legal limit. Only loads should be used whose centre of gravity is stable when the vehicle is in motion, hence no liquid or moving loads.

6.2.2 REFERENCE SCALES

The gross vehicle weight and the axle (group) loads of the reference vehicles shall be determined using a static weigh bridge, portable scales or Low Speed WIM system capable of weighing the complete vehicle at once with an error less than or equal to one third (1/3) of the applicable error specified in 5.1.

6.2.3 DETERMINING REFERENCE VALUES

The reference value for the Gross Vehicle Mass value for each reference vehicle, should be determined by static full-draught weighing on a reference weigh bridge (see 6.2.2).

The axle load on each axle of the reference vehicle is determined subsequently using the reference axle scales. The mean axle load is calculated as the arithmetic average of recorded values. The corrected mean reference load value per axle is calculated as:

$$CorrAxle_i = Axle_i \times \frac{VM_{ref}}{VM}$$

where:

VM_{ref}	is the value of the reference gross vehicle mass determined by full-draught weighing;
VM	is the sum of mean load values on individual axles VM.

The corrected mean axle load value is used as the reference value for each axle of the reference vehicle.

6.3 WEIGH-IN-MOTION ACCURACY TESTS

6.3.1 TEST RUNS

Each reference vehicle must make at least 10 test runs over the WIM system at each of the three following speeds:

- 2 times near the maximum operating speed, v_{max},
- 2 times near the minimum operating speed, v_{min},
- 6 times near the middle of the operating speed range, v_{med}

This results in a total of at least 20 test runs. The vehicle speed must be kept as constant as possible during each test run.

6.3.2 *Test Results*

The values of all gross vehicle mass measurements and all axle load measurements are recorded. For each recorded value (total vehicle mass, axle or axle group load), the relative error E% is calculated in percent:

$$E\% = \frac{C - R}{R} \times 100$$

where:

C is the value measured by the WIM system,

R is the corresponding reference value measured by the reference scales.

The number of relative errors E% that exceeds the relative measurement error as specified in paragraph 5.1 for each quantity is determined. This number is expressed as the relative number of values for each quantity as follows:

$$P = \frac{n}{N} \times 100$$

where:

n is the number of calculated differences exceeding the specified maximum error;

N is the total number of recorded values for the given quantity.

In order to be accepted, the percentage P of relative errors exceeding the specified maximum error shall not be greater than 5 %.

6.4 Other Tests

6.4.1 *Completion Rate Test*

Description of test:	For at least 100 vehicles that have correctly passed the system (see 4.2), verify if the system generates a complete vehicle record. This may be done by visual inspection from the road side or by using video recording.
Criteria for acceptance:	At least 95 % of all correctly passing vehicles should result in a complete vehicle record by the system.

6.4.2 *Classification Rate Test*

Description of test:	For at least 100 vehicle records from vehicles that have correctly passed the system (see 4.2), verify that the system makes a correct classification of the vehicle. This may be done by visual inspection from the road side or by using video recording.
Criteria for acceptance:	At least 95 % of all correctly passing vehicles should be classified correctly by the system.

6.4.3 *Length Measurements Test*

Description of test:	For all test vehicles used for testing the weighing accuracy (see 6.3), the reference vehicle length, wheelbase and all axle distances should be measured using a certified length measurement tool. For all runs by the test vehicles as described in 6.3.1 the specified length measurements recorded by the system shall be compared with the reference values.
Criteria for acceptance:	At least 95 % of all specified lengths measurements (axle distances, vehicle length and/or wheel base) shall be within the accuracy specified in 4.3.

7 STATISTICAL APPLICATIONS; IN-SERVICE VERIFICATION

This applies to WIM systems for Statistical applications only.

7.1 INTRODUCTION

The In-Service Verification is used to verify if a system is still operating within specification. This is a relatively small test executed when a system has been operational for a period of time.

7.1.1 FREQUENCY OF VERIFICATION

The In-Service Verification for Statistical application should be performed at least once a year.

7.2 TEST EQUIPMENT

7.2.1 REFERENCE VEHICLES

At least 1 vehicle type that is most common at the location of the WIM system should be used.

The vehicle used for the test shall be loaded up to its legal limit. Only loads shall be used whose centre of gravity is stable when the vehicle is in motion, hence no liquid or moving loads.

7.2.2 REFERENCE SCALES

See 6.2.2.

7.2.3 DETERMINING REFERENCE VALUES

See 6.2.3.

7.3 WEIGH-IN-MOTION ACCURACY TESTS

7.3.1 TEST RUNS

The reference vehicle must make at least 10 test runs over the WIM system at each of the three following speeds:

- 2 times near the maximum operating speed, v_{max},
- 2 times near the minimum operating speed, v_{min},
- 6 times near the middle of the operating speed range, v_{med}

The vehicle speed must be kept as constant as possible during each test run.

7.3.2 TEST RESULTS

The values of all gross vehicle mass measurements and all axle load measurements are recorded. For each recorded value (total vehicle mass, axle or axle group load), the relative error E% is calculated in percent:

$$E\% = \frac{C - R}{R} \times 100$$

where:

C is the value measured by the WIM system,

R is the corresponding reference value measured by the reference scales.

The number of relative errors E% that exceeds the relative measurement error as specified in paragraph 5.1 for each quantity is determined. This number is expressed as the relative number of values for each quantity as follows:

$$P = \frac{n}{N} \times 100$$

where:

n is the number of calculated differences exceeding the specified maximum error;

N is the total number of recorded values for the given quantity.

In order to be accepted, the percentage P of relative errors exceeding the specified maximum error shall not be greater than 5 %.

7.4 Other Tests

Not required for the In-Service Verification.

8 Legal Applications; Technical requirements

This chapter applies to WIM systems for Legal applications only.

8.1 Vehicle Record

A vehicle record is considered Complete when at least the following data items are recorded and correctly measured within specifications:

- Unique record number
- Location, (Lane + Direction)
- Date + Time, (yy-mm-dd + hh:mm:ss)
- Gross Vehicle weight
- Axle Group Load
- Axle Load
- Wheel Load (if possible)
- Axle distances
- Wheel Base and/or Vehicle length
- Vehicle Classification
- Vehicle Speed

8.2 Completion Rate

All vehicles passing over the instrumented lane of the WIM system should be detected by the system and result in a vehicle record. The WIM system should be able to detect if a vehicle was passing correctly over the system. Non-correct vehicle passages include the following conditions to be detected by the system:

- Vehicles changing lanes, in between lanes or partially on the instrumented lane;
- Vehicles passing the system with a too high acceleration or deceleration;
- Extreme weather conditions like snow and heavy rain and/or winds.

At least 99% of the heavy vehicle records generated by the WIM system - with a Gross Vehicle Weight of more than 3.5 t – identified by the system as having passed correctly over the system should be complete as defined in 8.1.

8.3 Time Recording

The resolution of the recorded time shall be 1 second.

The time measurement used by the system shall be hours:minutes:seconds [hh:mm:ss].

8.4 Speed Recording

The resolution of the recorded speed shall be 1 km/h.

The unit of speed is kilometre per hour [km/h].

8.5 Length Measurement

The length measurement consists of the measurement of the vehicle length and/or the wheelbase of the vehicle and the axle distances.

- The accuracy of the vehicle length measurement should be ±50 cm for at least 95 % of the measurements.
- The accuracy of the wheel base measurement should be ±15 cm for at least 95 % of the measurements.
- The accuracy of the measurement of the axle distances should be ±5 cm for at least 95 % of the measurements.

The unit of axle distance, wheel base and vehicle length used by the system is the metre [m].

8.6 VEHICLE CLASSIFICATION

The vehicle classification scheme depends on the location and the application of the WIM system and should be defined by the users/buyer of the system. The test report should describe to which classification scheme the system was tested, later additional classification schemes may be added.

At least 95 % of the vehicle classification of vehicle records from vehicles that have passed the system correctly (see 8.2) should be correct.

Note: all vehicles classified must be compliant with the approved classification scheme as long as the vehicle class can be accurately determined by the measurement of vehicle length, axle count and axle spacing within the tolerances defined in this chapter.

8.7 MARKINGS

The WIM systems must bear a physical marking with the following items:

- Identification mark of the manufacturer
- Type designation (Accuracy Class)
- Type approval Mark
- Serial Number
- Specific Restrictions (if applicable)
- Weighing Range
- Scale Interval (d)
- Speed Range
- Temperature Range
- Maximum number of axles (if applicable)
- Power supply Voltage
- Power supply frequency

8.7.1 REQUIREMENTS

Markings should be complete, legible, unambiguous, comprehensible and indelible under normal operational conditions. Supplementary markings may be required by the national metrological authority issuing the type approval certificate.

8.8 HARDWARE AND SOFTWARE PROTECTION

WIM systems shall not have characteristics that would facilitate fraudulent use, and there must be a minimum number of ways in which they can be unintentionally improperly used. Components that are not intended to be disassembled or adjusted by the user must be protected from such activity. National legislation may specify the level of security that is required.

8.8.1 GENERAL

All system equipment including software, which is intentionally prevented from disconnection or removal by a user or other individual, must be equipped with a housing or other suitable security means. It must be possible to seal housings after their closure; sealing points must be easy to access in all instances. All parts of the measuring system that cannot be protected by housings must be equipped with sufficiently effective means of preventing operations with possible influence on measuring accuracy.

Each part of WIM systems that could influence measuring results, especially equipment for calibration and adjustment of scales or for correction of measured values, shall be sealed.

8.8.2 MEANS OF PROTECTION

Protection shall consist of sealed housings, encryption, passwords or similar software means in such a way that:

- The software requirements in 8.9 apply;
- Transmission of measurement results data via an interface must be protected from intentional, unintentional and random changes;
- Stored data must be protected from intentional, unintentional and random changes.

8.9 SOFTWARE SUBJECT TO METROLOGICAL CONTROL

The legally relevant software used in WIM instruments must be presented in such a form in the instrument that alteration of the software is not possible without breaking a seal, or any change in the software can be automatically recorded and its nature specified by means of an identification code.

Documentation for software for scales must contain:

- A description of the software subject to metrological verification of measuring devices;
- A description of measurement algorithm accuracy (e.g. programming modes);
- A description of the user interface, menus and dialogs;
- Unique identification of the software;
- A description of included software (e.g. operating environment);
- A hardware system overview, e.g. a topological block diagram, type of computer(s), source code for software functions, etc., if not described in the user manual;
- Software protection measures;
- A user manual.

8.9.1 SOFTWARE PROTECTION

Measures for protecting software subject to metrological control of measuring devices are as follows:

- Only authorised individuals may be given access, for example using codes (passwords) or a special device (hardware key, etc.); codes must be changeable;
- The measuring device's memory must store all accesses, listing the date of the access, identification of the authorised individual performing the access, and the type of access;
- Memory capacity must be sufficient for at least 2 years of expected accesses; if memory capacity for access record storage is exhausted, no automatic erasure of any stored records can take place;
- It must be possible to recall relevant access records to the full extent of information recorded;
- It must not be possible to erase access records without removing a physical seal;
- Downloading of software subject to metrological verification must be possible only via an appropriate secure interface connected to the scales;
- The software must include identification of its version, which changes if any software changes occur (for example a hash of the executable code);
- Functions that are performed or launched via a software interface must meet the terms and conditions of this legislation.

9 LEGAL APPLICATIONS; WEIGHING REQUIREMENTS

This chapter applies to WIM systems for Legal applications only.

9.1 WEIGHING SPECIFICATIONS

9.1.1 ACCURACY CLASSES

WIM-systems for Legal applications are classified into accuracy classes using the capital letter 'L' and according to their weighing performance. The accuracy classes are: L(3), L(5), L(7) and L (10).

For Legal applications, the accuracy level quantifies the maximum size of the Maximum Permissible Error (MPE-interval) [-MPE, +MPE] of the relative measurement error. This interval includes 100 % of all measurements.

The accuracy levels for the different accuracy classes are specified in Table 9.1. The accuracy levels are given in [%].

Class	L(3)	L(5)	L(7)	L(10)
Gross Vehicle Weight	3	5	7	10
Axle Group Load	5	8	11	15
Axle Loads	7	10	15	20

Table 9.1, Accuracy Levels per Class

9.2 WEIGHING RANGES

This paragraph specifies the minimum weighing ranges that should be met by all WIM systems. The user or vendor can specify extended weighing ranges when required to meet the conditions for a specific country, location or application.

The minimum weighing range for Gross Vehicle Weight measurements is larger than 3,500 kg.

The minimum weighing range for Axle Load measurements is from 2,000 kg up to 15,000 kg.

If the actual Gross Vehicle Weight and/or one or more Axle Load(s) of a vehicle is/are outside the overall operating weighing range of the system during measurement, the system must:

- Either automatically invalidate (block) measurement results from being issued, or;
- Automatically delete the measurement results, or;
- Indicate or print out the value of the measured actual Gross Vehicle Weight, Axle Group Load(s) and Axle Loads of the vehicle, and at the same time indicate or print out a clear warning that the measurement is outside the system's operating weighing range.

9.3 SCALE DIVISIONS

The scale divisions must not exceed the values given in [kg] per accuracy class in Table 9.2.

Class	L(3)	L(5)	L(7)	L(10)
Axle Loads	10	20	20	50
Vehicle Weights	20	50	50	100

Table 9.2, Maximum Scale Divisions.

9.4 UNITS OF MEASUREMENT

The units of weight and load used by the system are kilogram [kg] or tonne [t].

10 Legal Applications; Type Approval

This chapter applies to WIM systems for Legal applications only.

10.1 Introduction

Type Approval Test, the first extensive Performance Test of a new type of measurement instrument where the performance of the system is tested under the full operating ranges. The results of this test can be used as a basis for national legal approval for legal applications. It will also form the basis for the Initial verification Tests for the same type of systems.

10.1.1 Simulated Functionality Tests

Simulated functional tests are performed when assessing the resistance of the complete system to external environmental influences under controlled laboratory conditions unless the size and/or configuration of the scales makes it impossible to test them in their complete form. In such cases, testing is allowed with a load signal generator taking the place of load receptors combined with a separate test of the load receptors.

The metrological body approving measuring device types can accept a manufacturer's proposal to modify the method and manner in which simulated functional tests are performed, if suitable, with regards to the specifics of the technology and design of the scales' measurement chain.

10.2 Operating Temperature Test

The test comprises exposure to the specific low and high temperatures under ‘free air’ conditions during a period of time.

The test procedure is described in OIML D 11, §10.1, level 3 [-25 °C, +55 °C].

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.3 Relative Humidity Test

The test comprises exposure to cyclic temperature changes under conditions of high humidity with condensation.

The test procedure is described in OIML D 11, §10.2 (Condensing), level 2.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.4 Immunity to RF Electromagnetic Fields

10.4.1 Conducted Currents Generated by RF EM Fields

The test comprises exposure to electromagnetic fields with frequencies between 0.15 and 80 MHz onto the power and I/O ports of the system.

The test procedure is described in OIML D 11, §13.2, level 3.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.4.2 Radiated RF EM Fields

The test comprises exposure to radiated radio frequency electromagnetic fields onto the system.

The test procedure is described in OIML D 11, §13.2, level 3.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.5 AC/DC Mains Immunity Tests

10.5.1 Immunity to Electrical Bursts

The test comprises exposure to electrical bursts (transients) superimposed on the mains voltage of the system.

The test procedure is described in OIML D 11, §12.3, level 3.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.5.2 *Immunity to Electrical Surges*

The test comprises exposure to electrical surges superimposed on the mains voltage power lines of the system.

The test procedure is described in OIML D 11, §12.3, level 3.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.5.3 *Immunity to Electrostatic Discharge*

The test comprises of exposure to electrical discharges onto the system.

The test procedure is described in OIML D 11, §13.3, level 3.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.6 AC/DC Mains Variation Tests

10.6.1 *DC Mains Voltage Variation Test*

The test comprises of exposure to DC mains voltage variations between the lower and upper limit specified for the DC mains power of the system.

The test procedure is described in OIML D 11, §12.1, level 1.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.6.2 *Ripple on DC Mains Power Test*

The test comprises of exposure to a ripple on the DC mains voltage power of the system.

The test procedure is described in OIML D 11, §12.1, level 1.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.6.3 *DC Mains Voltage Dips Test*

The test comprises of short time mains voltage dips, voltage variations and short interruptions of the DC mains power of the system.

The test procedure is described in OIML D 11, §12.3, level 2.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.6.4 *AC Mains Voltage Variation Test*

The test comprises of AC mains network voltage variations between upper and lower limit specified for the mains network connected to the system.

The test procedure is described in OIML D 11, §12.2, level 1.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.6.5 *AC Mains Frequency Variation Test*

The test comprises of AC mains network frequency variations between upper and lower limit specified for the mains network connected to the system.

The test procedure is described in OIML D 11, §12.2, level 1.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.6.6 *AC Mains Voltage Dips Test*

The test comprises of short time mains voltage reductions of the AC mains power of the system.

The test procedure is described in OIML D 11, §12.3, level 2.

During this test the scales must function normally, and the measurement errors must not exceed the maximum permissible error listed in 9.1.

10.7 Hard- and Software Security Tests

The examination consists of performing the following validation tests:

10.7.1 Analysis of Documentation and Specification and Validation of the Design

Evaluate the functions and features of the WIM system using the verbal description and graphical representations and check whether they comply with the requirements.

10.7.2 Validation by Functional Testing of the Software Functions

Required features described in the operating manual, WIM system documentation or software documentation is checked practically. If they are software controlled, they are to be regarded as validated if they function correctly without any further software analysis.

Featured addressed here are e.g.:

- Normal operation of the WIM system, if its operation is software controlled. All switches or keys and described combinations should be employed and the reaction of the WIM system evaluated. In graphical user interfaces, all menus and other graphical elements should be activated and checked;
- Effectiveness of the parameter protection may be checked by activating the protection means and trying to change a parameter;
- Effectiveness of the protection of stored data may be checked by changing some data in the file and checking whether this is detected by the program;
- Generation and indication of the software identification may be validated by practical checking;
- If fault detection is software supported, the relevant software parts may be validated by provoking, implementing or simulating a fault and checking the correct reaction of the WIM system;
- If the configuration or environment of the software is claimed to be fixed, protection means can be checked by making unauthorised changes. The software should inhibit these changes or should cease to function.

10.7.3 Code Inspection and Walk Through

For enforcement purposes the examination shall be extended with:

The source code is walked through assignment by assignment, evaluating the respective part of the code to determine whether the requirements are fulfilled and whether the program fucntions and features are in compliance with the documentation.

The examiner may also concentrate on algorithms or functions that he has identified as complex, error-prone, insufficiently documented, etc. and inspect the respective part of the source code by analysing and checking.

10.8 Weigh-In-Motion Tests

10.8.1 Reference Vehicles

A minimum of at least 3 different types of vehicles should be used that are common at the location of the WIM system.

The vehicles used for the test should be loaded up to their legal limit. Only loads should be used whose centre of gravity is stable when the vehicle is in motion, hence no liquid or moving loads.

10.8.2 Reference Scales

The gross vehicle weight and the axle (group) loads of the reference vehicles shall be determined using a static weigh bridge, portable scales or Low Speed WIM system capable of weighing the complete vehicle at once with an error less than or equal to one third (1/3) of the applicable error specified in 9.1.

10.8.3 Determining Reference Values

The reference value for the Gross Vehicle Mass for each reference vehicle, shall be determined by static full-draught weighing on a reference weigh bridge (see 10.8.2).

The axle load on each axle of the reference vehicle is determined sequentially using the reference scales (see 10.8.2), with at least three runs in both directions. The mean axle load is calculated as the arithmetic average of recorded values. The corrected mean reference load value per axle is calculated as:

$$CorrAxle_i = Axle_i \times \frac{VM_{ref}}{VM}$$

where:

VM_{ref} is the value of the reference gross vehicle mass determined by full-draught weighing;

VM is the sum of mean load values on individual axles VM.

The corrected mean axle load value is used as the reference value for each axle of the reference vehicle.

10.9 Weigh-In-Motion Accuracy Tests

10.9.1 Test Runs

Each reference vehicle must make at least 30 test runs over the WIM system at each of the three following speeds:

- 5 times near the maximum operating speed, v_{max},
- 5 times near the minimum operating speed, v_{min},
- 20 times near the middle of the operating speed range, v_{med}

This results in a total of at least 90 test runs. The vehicle speed must be kept as constant as possible during each test run.

10.9.2 Test Results

The values of all gross vehicle mass measurements and all axle load measurements are recorded. For each recorded value (total vehicle mass, axle or axle group load), the relative error E% is calculated in percent:

$$E\% = \frac{C - R}{R} \times 100$$

where:

C is the value measured by the WIM system,

R is the corresponding reference value measured by the reference scales.

In order to be accepted not any of the relative errors may be exceeding the 0.5 x Maximum Permissible Error (½MPE) specified in paragraph 9.1.

10.10 Other Field Tests

10.10.1 Completion Rate Test

Description of test:	For at least 250 vehicles that have correctly passed the system (see 8.2), verify if the system generates a complete vehicle record. This may be done by visual inspection from the road side or by using video recording.
Criteria for acceptance:	At least 99 % of all correctly passing vehicles should result in a complete vehicle record by the system.

10.10.2 Classification Rate Test

Description of test:	For at least 250 vehicle records from vehicles that have correctly passed the system (see 8.2), verify that the system makes a correct classification of the vehicle. This may be done by visual inspection from the road side or by using video recording.

Criteria for acceptance:	At least 95 % of all correctly passing vehicles should be classified correctly by the system.

10.10.3 Length Measurements Test

Description of test:	For all test vehicles used for in testing the weighing accuracy (see 10.9), the reference vehicle length, wheelbase and all axle distances should be measured using a certified length measurement tool. For all runs by the test vehicles as described in 10.9.1 the specified length measurements recorded by the system shall be compared with the reference values.
Criteria for acceptance:	At least 95 % of all specified lengths measurements (axle distances, vehicle length and/or wheel base) should be within the accuracy specified in 8.6.

10.10.4 Marking Test

Check if the markings are complete, (see 8.7).

11 LEGAL APPLICATIONS; INITIAL VERIFICATION

This chapter applies to WIM systems for Legal applications only.

11.1 INTRODUCTION

The Initial Verification is typically done after installation or an important repair in order to assess the performance of the measurement instrument under the specific conditions at the site where the system is installed. The result of this test will be to certify that this system performs according to specifications and may be the basis for the decision by a buyer to accept a system.

11.2 TEST EQUIPMENT

11.2.1 REFERENCE VEHICLES

At least 2 different types of vehicles should be used that are common at the location of the WIM system. The vehicles used for the test should be loaded up to their legal limit.

Only loads should be used whose centre of gravity is stable when the vehicle is in motion, hence no liquid or moving loads.

11.2.2 REFERENCE SCALES

See 10.8.2.

11.2.3 DETERMINING REFERENCE VALUES

See 10.8.3.

11.3 WEIGH-IN-MOTION ACCURACY TESTS

11.3.1 TEST RUNS

Each reference vehicle must make at least 30 test runs over the WIM system at each of the three following speeds:

- 5 times near the maximum operating speed, v_{max},
- 5 times near the minimum operating speed, v_{min},
- 20 times near the middle of the operating speed range, v_{med}

This results in a total of at least 60 test runs. The vehicle speed must be kept as constant as possible during each test run.

11.3.2 TEST RESULTS

The values of all gross vehicle mass measurements and all axle load measurements are recorded. For each recorded value (total vehicle mass, axle or axle group load), the relative error E% is calculated in percent:

$$E\% = \frac{C - R}{R} \times 100$$

where:

C is the value measured by the WIM system,

R is the corresponding reference value measured by the reference scales.

In order to be accepted not any of the relative errors may be exceeding the Maximum Permissible Error (MPE) specified in paragraph 9.1.

11.4 OTHER FIELD TESTS

11.4.1 COMPLETION RATE TEST

Description of test:	For at least 100 vehicles that have correctly passed the system (see 8.2), verify if the system generates a complete vehicle record. This may be done by visual inspection from the road side or by using video recording.
Criteria for acceptance:	At least 99 % of all correctly passing vehicles should result in a complete vehicle record by the system.

11.4.2 Classification Rate Test

Description of test:	For at least 100 vehicle records from vehicles that have correctly passed the system (see 8.2), verify that the system makes a correct classification of the vehicle. This may be done by visual inspection from the road side or by using video recording.
Criteria for acceptance:	At least 95 % of all correctly passing vehicles should be classified correctly by the system.

11.4.3 Length Measurements Test

Description of test:	For all test vehicles used for in testing the weighing accuracy (see 10.9), the reference vehicle length, wheelbase and all axle distances should be measured using a certified length measurement tool. For all runs by the test vehicles as described in 10.9.1 the specified length measurements recorded by the system shall be compared with the reference values.
Criteria for acceptance:	At least 95 % of all specified lengths measurements (axle distances, vehicle length and/or wheel base) should be within the accuracy specified in 8.6.

11.4.4 Marking Test

Check if the markings are complete, (see 8.7).

12 Legal Applications; In-service verification

This chapter applies to WIM systems for Legal applications only.

12.1 Introduction

The In-Service Verification is used to verify if a system is still operating within specification. This is a relatively small test executed when a system has been operational for a period of time (regulated in the legislation per country).

12.1.1 Frequency of Verification

The In-Service Verification for Legal applications should be performed at least twice a year, every 6 months.

12.2 Test equipment

12.2.1 Reference Vehicles

At least 2 different types of vehicles should be used that are common at the location of the WIM system. The vehicles used for the test should be loaded up to their legal limit.

Only loads should be used whose centre of gravity is stable when the vehicle is in motion, hence no liquid or moving loads.

12.2.2 Reference Scales

See 10.5.2

12.2.3 Determining reference Values

See 10.5.3.

12.3 Weigh-In-Motion Accuracy Tests

12.3.1 Test Runs

Each reference vehicle must make at least 15 test runs over the WIM system at each of the three following speeds:

- 5 times near the maximum operating speed, v_{max},
- 5 times near the minimum operating speed, v_{min},
- 5 times near the middle of the operating speed range, v_{med}

This results in a total of at least 30 test runs. The vehicle speed must be kept as constant as possible during each test run.

12.3.2 Test Results

The values of all gross vehicle mass measurements and all axle load measurements are recorded. For each recorded value (total vehicle mass, axle or axle group load), the relative error E% is calculated in percent:

$$E\% = \frac{C - R}{R} \times 100$$

where:

C is the value measured by the WIM system,

R is the corresponding reference value measured by the reference scales.

In order to be accepted, none of the relative errors may exceed the Maximum Permissible Error (MPE) specified in paragraph 9.1.

12.4 Other Field Tests

Not required for the In-Service Verification.

13 RECOMMENDATIONS

The recommendation in this chapter are non-mandatory however they may serve as useful practical information for the preparation, installation and testing of WIM systems.

13.1 INSTALLATION REQUIREMENTS

13.1.1 ROAD GEOMETRY

The performance of any WIM system depends on the site characteristics: road geometry and road evenness.

The road section between 200 m upstream and 50 m downstream of the system should meet the recommended minimum criteria for the geometrical characteristics given in the table 13.1.

Pavement			**Criteria**
Rutting (3m – beam)		Rut depth max. (mm)	≤ 4
Deflection	Semi-rigid	Mean deflection (mm)	≤ 15
(quasi-static)	All bitumen	Mean deflection (mm)	≤ 20
(13t – axle)	Flexible	Mean deflection (mm)	≤ 30
Deflection	Semi-rigid	Deflection (mm)	≤ 10
(dynamic)	All bitumen	Mean deflection (mm)	≤ 15
(5t – load)	Flexible	Mean deflection (mm)	≤ 20
Evenness	IRI index	Index (m/km)	< 1.3
	APL	Rating (SW, MW, LW)	9 – 10
Longitudinal slope			< 1 %
Transversal slope			< 3 %

Table 13.1. Criteria for pavement geometry of WIM sites

In addition, the characteristics of the pavement should be consistent with the WIM technology deployed and it should not contain any bumps or other types of sudden local change in slope.

The WIM system should be installed away from any area of expected frequent lane changes, acceleration or deceleration, (e.g., close to traffic lights, toll station, slip roads), in order to weigh vehicles travelling at uniform speed.

13.2 EXAMPLE TEST PLANS

This paragraph describes a number of examples of actual verification procedures used in different countries.

13.2.1 INITIAL VERIFICATION TEST (CZECH REPUBLIC)

General; the following is performed during initial verification:

- A visual inspection;
- Functional weigh-in-motion tests in road traffic;
- Operating speed tests;
- A vehicle recognition device blocking test.

Visual inspection; the following is assessed during a visual inspection of scales submitted for verification:

- Conformance of the scales with the approved type;
- Completeness and condition of the scales' functional wholes;
- That the software version an approved one.

Weigh-in-motion tests in road traffic, a scales accuracy test is performed with by weighing in motion in road traffic at the scales installation location per 5.4.6, with the test scope being restricted to two operating speeds. The following reference vehicles are used:

- One rigid two-axle vehicle;
- And at least one other reference vehicles that must be selected from the three options listed below:
    - One rigid three-axle or four-axle vehicle;
    - One vehicle with four or more connected axles;
    - One two-axle or three-axle rigid vehicle and a two-axle or three-axle drawbar trailer.

Each reference vehicle must thus perform a total of 30 test runs. Alternately, this test can be performed using vehicles directly from the stream of traffic as reference vehicles; in this case, the number of such vehicles must be at least 60.

Test runs, each reference vehicle, unloaded and then loaded, must perform at least five test runs at each of the three following speeds:

- Near the maximum operating speed, v_{max};
- Near the minimum operating speed, v_{min};
- Near the middle of the operating speed range.

For every five test runs at a given tests speed, the vehicle must be positioned above the centre of the load receptor three times, once on the left and once on the right side of the load receptor. Vehicle speed must be kept as constant as possible during each test run. Scales must indicate and record the speed of the tested vehicle as it passes over the load receptors.

Weigh-in-motion accuracy tests, all test runs are performed according to 5.4.6.1 using reference vehicles in accordance with 5.4.2.1. The values of all vehicle mass indications and all axle load indications are recorded. For each recorded value (total vehicle mass, axle or axle group load), the relative error d is calculated in percent:

The number of relative errors d that exceed the stipulated maximum permissible error according to 2.3.1 or 2.3.2 for each quantity is determined, and this number is expressed as the relative number of values for each quantity. The number of relative errors exceeding the maximum permissible error P_{de} must not be greater than 5%, with their distribution among individual vehicle types being recorded.

Operating speed tests; a test run by one reference vehicle must take place at a speed outside the operating speed range, as follows:

- At a speed at least 5% higher than the maximum operating speed, v_{max};
- At a speed at least 5% lower than the minimum operating speed, v_{min}, (if the scales can be used for this).

The scales must detect the above conditions and must react in accordance with specifications.

Operating speed test; to determine and test operating speed during a weigh-in-motion test, six test runs shall take place with an unloaded two-axle rigid reference vehicle across load receptors at a constant speed. Three runs must take place near the maximum operating speed v_{max}, and three additional runs must take place at exactly the listed minimum operating speed v_{min}.

The reference speed value to be used to calculate the error of the indicated operating speed for each test run must be proportional to the distance between the measured axles (to the nearest 10 mm) of the stationary two-axle rigid reference vehicle divided by the measured time interval (to the nearest millisecond) between arrival at a defined point (e.g. the first load receptor) and the rear axle of the moving two-axle rigid reference vehicle.

The indicated operating speed error must not exceed the specified error.

Vehicle recognition test; two reference vehicles are connected by a suitable towing device that ensures constant distance in order to create an atypical sequence of trailers between the rear axle of the pulling vehicle and the front axle of the pulled vehicle. The scales must then:

- Recognize the combined vehicle as two vehicles;
- Determine the correct axle group load or detect an error;

- Detect the fact that all weighed wheels of the vehicle were not weighed during the weighing operation, and not indicate or print any mass or load values if the indication and/or printout has a clear warning.

13.2.2 In-Service Verification (The Netherlands)

Preparation; Prior, and after, the verification the test truck is weighed on certified weighing scales. The following information is measured, recorded and used as reference values:

- Front and back license plate number
- Axle loads of each individual axle
- Gross Vehicle Weight (= sum of the axle loads)
- Axle distances (heart to heart) in centimeters:
- Overhang at the front and back of the vehicle:
- Total length of the vehicle

Vehicle Requirements; The truck used for the test should meet the following requirements:

- Type of truck: a 2 axle tractor + 3 axle semi-trailer combination, the distance between the 3 axles should be more than 1.3 m but less than 1.8 m with a maximum allowed axle load of 9 tonne;
- Minimum length of the vehicle is 7 meter;
- The vehicle should have a sign on the front and back stating 'Testvoertuig Weegpunt'.
- The loading on the vehicle should be such that:
    - The load on the front axle lies between 5 – 8 tonne;
    - The load on the driven axle lies between 10 – 11.5 tonne;
    - The loads on the triple axle lies between 7 – 9 tonne;
    - None of the axles nor the complete vehicle shall be overloaded;
    - It is not moving during the entire verification procedure.

Test Procedure; There should be at least 72 hours between installation or maintenance of the WIM sensors and the verification. During the verification all relevant safety precautions should be observed. Before the start of verification the user needs to ensure that the system is operational and all passages will be recorded. The test truck will make 10 passes over each of the instrumented lanes of the WIM system. The passes will be made under similar weather conditions within a limited time frame typically a (part of one day). During this time the test vehicle may not be used for other activities.

During the procedure the following additional information shall be recorded:

- Name of the driver of the truck and person responsible for the verification
- Date and time period of the verification;
- Weather conditions including the outside temperature;
- Visibility, (sunny, clouded, rain or fog) and position of the sun.

Based on the license plate number of the test truck the matching measurements are retrieved from the WIM system. The results of the verification procedure will be described in a verification report per WIM system. The report will show per passage, the time of passage, the difference between the measured value and the average of the reference values for the gross vehicle weight, the individual axle loads, the total vehicle length, the overhang and the axle distances. Based on these measurements the average error will be calculated for all measured quantities. The results from the verification procedure are sent to the owner/user of the WIM-systems and used for (re-)calibration of the systems.

13.2.3 Data Quality Control (Canada)

Introduction: By taking the difference between the WIM and the static weight in percent, and taking the average, the Mean or Average Error is determined. This is an indication of how closely the system is calibrated and what is happening on average. Ideally the Mean Error should be 0 %, but in reality we see a small deviation due to vehicle dynamics. The Standard Deviation of the errors for a sample of trucks will give the scatter of the readings, or the confidence of being within a certain range of error. One Standard Deviation represents 68 % confidence. (i.e.: 68 % of the readings will be within the limits set above, while the rest will be outside of this range.) A confidence level of 95 % represents approximately 1.96 Standard Deviations. Therefore, an accuracy of ±10 % at 95 % confidence represents an accuracy range of approximately ±5 % at one Standard Deviation. (68 % confidence)

Calibration Procedure; This calibration/acceptance procedure follows ASTM E1318 Standards. Calibration is to be performed by the running of one (1) calibration truck, which is to be supplied by others. The five (5) axle, test vehicle will be of a tractor/trailer combination (3S2), complete with air ride suspension and a non-shifting static load. The truck shall be loaded to within 90 to 100 % of allowable Gross Vehicle Weight for the road under test. The truck shall be in excellent mechanical condition. The calibration procedure is as follows:

1. The vehicle shall be weighed at a government certified static weigh scale. The weight information on the front (single axle), drive (tandem axle group), and trailer (tandem axle group), will be recorded. The Gross Vehicle Weight (GVW) of the vehicle will be calculated by adding the three weights together.
2. The distance between the five (5) individual axles on the truck shall be measured and recorded.
3. For a Bending Plate or Single Load Cell System, the test vehicle will make three (3) test passes over the system under test at a selected speed which is indicative of the truck traffic at the site. Adjustments will be made by IRD personnel on site during this time to fine tune the axle spacing, and weight output of the WIM system.
4. Once all initial adjustments have been made, the test vehicle will make an additional two (2) test passes to confirm the accuracy of the adjustments. If all the readings fall within the ASTM ranges for the WIM Type under test, and IRD personnel do not feel that additional adjustments are required, the tests will continue. If this is not the case, additional adjustments will be performed and two (2) more confirming passes will be made by the test truck.
5. The test truck will then make an additional ten (10) passes at a selected speed that is indicative of the truck traffic at the test site.
6. All of the data will be recorded and placed into a spreadsheet.
7. The mean error and standard deviation for all recorded measurements will be calculated at the end of the ten (10) test passes. The calculations will be as follows:
   a. For weight measurements, the percent error for each test pass shall be calculated using the following formula:

$$\frac{WIM\ Weight - Static\ Weight}{Static\ Weight} \times 100 = \%error$$

   b. The mean error for each weight type (single, group, GVW) shall be calculated as follows:

$$\%errors\ for\ sinle, group\ or\ GVW / \#\ of\ samples = Mean\ error$$

   Each weight type calculated individually.

   c. The error for individual axle spacing shall be calculated using the following formula:

$$\frac{10\ of\ (WIM\ Axle\ Spacing - Actual\ Axle)}{10} = Mean\ Axle\ Spacing\ Error$$

   Each of the four axle spacing calculated individually.

8. All of the calculated errors shall also be entered into the spreadsheet.

9. A check will be made of the calculated result against the acceptable range for the ASTM WIM Type under test. There will be one of two results:
   a. If 95% of all recorded test results, (single axles, axle groups, GVW, axle spacing) fall within the specified tolerance for the ASTM WIM Type under test then the system will have passed the requirements;
   b. If less than 95% of the calculated differences fall within the specified tolerance for the ASTM WIM Type under test then the system will be readjusted and an additional ten (10) test passes will be required to retest the system.
10. The testing shall continue until the system passes all criteria according to ASTM E1318 Standards.

Note: For weigh station applications testing can be performed using mainline traffic that is weighed on the static scale versus use of a test truck.

Recalibration Intervals; Like all types of traditional static scales, the performance of WIM systems must be monitored at regular intervals and the systems do require recalibration. For data collection sites, auto calibration systems may be employed, however the system should have its calibration checked at least yearly. For weigh station and sorter systems, a six month recalibration interval should be used.

13.3 ESAL CALCULATION

Equivalent Single Axle Load (ESAL) is the cumulative number of applications of a chosen standard single-axle load that will have an equivalent effect on pavement serviceability as the application the of various axle loads of a vehicle or vehicles measured in a mixed traffic stream. ESALs are determined by summing the calculated load equivalence factors for each individual axle or axle set according to axle load and type on all vehicles in the measured or assumed mixed-traffic stream for the defined pavement structure.

The full calculation of the ESALs can be found at: https://www.astm.org/Standards/E1318.htm

13.4 REFERENCE LIST

1) ASTM-E1318 (2009), Standard specification for highway weigh-in-motion (WIM) systems with user requirements and test methods, E1318-09, American Society for Testing Materials, West Conshohocken, PA, USA.
2) COST-323 (1999), European Specification on Weigh-in-Motion of Road Vehicles, EUCO-COST /323/8/99, LCPC, Paris, August, 66 pp.
3) ISO 3534-1 (1993), Statistics - Vocabulary and symbols - Part 1: Probability and general statistical terms.
4) ISO 3534-2 (1993), Statistics - Vocabulary and symbols - Part 2: Statistical quality control.
5) ISO/IEC (2007), Guide 99: Vocabulary of International Metrology (VIM).
6) OIML R134-1 (2006), International Recommendation: Automatic instruments for weighing road vehicles in motion and measuring axle loads, Part 1: Metrological and technical requirements – Tests
7) OIML R134-2 (2009), International Recommendation: Automatic instruments for weighing road vehicles in motion. Total vehicle weighing, Part 2: Test Report Format.
8) WELMEC 7.2, (2015), Software Guide (Measuring Instruments Directive 2014/32/EU1), WELMEC Secretariat, www.welmec.org