Bonneagar Iompair Éireann
Transport Infrastructure Ireland

TII Publications

GE PE DN CC OP AM RE

Requirements for Weigh-In-Motion Systems

DN-ITS-03085
October 2023

DN Design

Standards

About TII

Transport Infrastructure Ireland (TII) is responsible for managing and improving the country's national road and light rail networks.

About TII Publications

TII maintains an online suite of technical publications, which is managed through the TII Publications website. The contents of TII Publications is clearly split into 'Standards' and 'Technical' documentation. All documentation for implementation on TII schemes is collectively referred to as TII Publications (Standards), and all other documentation within the system is collectively referred to as TII Publications (Technical).

Document Attributes

Each document within TII Publications has a range of attributes associated with it, which allows for efficient access and retrieval of the document from the website. These attributes are also contained on the inside cover of each current document, for reference.

TII Publication Title	*Requirements for Weigh-In-Motion Systems*
TII Publication Number	*DN-ITS-03085*

Activity	*Design (DN)*		**Document Set**	*Standards*
Stream	*Intelligent Transport Systems (ITS)*		**Publication Date**	*October 2023*
Document Number	*03085*		**Historical Reference**	**N/A**

TII Publications Website

This document is part of the TII publications system all of which is available free of charge at http://www.tiipublications.ie. For more information on the TII Publications system or to access further TII Publications documentation, please refer to the TII Publications website.

TII Authorisation and Contact Details

This document has been authorised by the Director of Professional Services, Transport Infrastructure Ireland. For any further guidance on the TII Publications system, please contact the following:

Contact: Standards and Research Section, Transport Infrastructure Ireland
Postal Address: Parkgate Business Centre, Parkgate Street, Dublin 8, D08 DK10
Telephone: +353 1 646 3600
Email: infoPUBS@tii.ie

TII Publications

Activity:	Design (DN)
Stream:	Intelligent Transport Systems (ITS)
TII Publication Title:	Requirements for Weigh-In-Motion Systems
TII Publication Number:	DN-ITS-03085
Publication Date:	October 2023
Set:	Standards

Contents

Updates to TII Publications resulting in changes to
Requirements for Weigh-In-Motion Systems DN-ITS-03085

Date: October 2023

Page No:

Section No:

Amendment Details:

a) This document supersedes DN-ITS-03085 published in April 2019.

b) Inclusion of the definition of "Run" in Section 1.2.1.

c) The anticipated time taken to complete one lap in section 2.10 has been removed.

d) Section 2.2, related to Road Geometry, has been updated through Tables 1 and 2.

e) The reference values for Classification Accuracy from Table 3 have been changed.

f) The Number of Axles from Section 3.1.6 has been modified.

g) Sections 3.1.14 and 3.2.2 have been rewritten.

h) Sections 4.3.5 and 4.4.5 have been completed with further information.

i) Table 7 added to Section 4.4.1. along with a modification of its text.

Contents Table

1. Introduction

This document addresses the design, supply, installation, operation and performance testing of Weigh-In-Motion (WIM) systems.

The WIM system shall also comply with CC-SPW-01500, Specification for Traffic Control and Communications, CC-GSW-01500, the TII Publications Series 1500 Standard Construction Details and DN-ITS-03029 Traffic Control and Communications Infrastructure Design.

TII have based their WIM standards on the following source documents:

- COST323 Weigh-in-Motion of Road Vehicles - Final Report (COST323, 2002).
- NMi International WIM Standard (NMi, 2016a).

1.1 Implementation

This standard should be used forthwith on all WIM deployments prepared by Transport Infrastructure Ireland unless otherwise defined within the contract documents.

1.2 Definitions

The main terms used in this document are listed here. For this document, TII have adopted a similar definition of the main terms as the NMi International Weigh-In-Motion Standard (2016a).

1.2.1 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 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 – see Figure 1.

Axle Group Load: The total load on all wheels included in an axle group.

Axle Load: The sum of all the wheel loads of an axle of a vehicle.

Axle Spacing: The distance between the centres of two axles – see Figure 1.

Gross Vehicle Weight: 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.

Headway: Time interval from the front of the relevant vehicle to the front of the previous vehicle in that lane.

Instation: A system for storing, managing, reporting and viewing of the WIM systems and gathered data.

Outstation: All site-based equipment associated with the WIM sensors, including all electronic equipment which allows data to be gathered and transmitted between the site asset and the Instation.

Reference Scales: Weighing apparatus used to determine the gross vehicle weight and individual axles weights of the reference vehicle.

Reference Vehicle: Vehicle of known weight, used as a reference during performance testing to measure the accuracy of the WIM system.

Run: The passage of a single reference vehicle over a single lane of the WIM System.

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

SNMP (Simple Network Management Protocol) Traps: Alert messages sent from a remote SNMP-enabled device to a central SNMP manager when an issue needs to be reported.

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

Statistical 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 Length: Distance between the front and the back of a vehicle – see Figure 1.

Wheelbase: Distance between the first and last axle of a vehicle – see Figure 1.

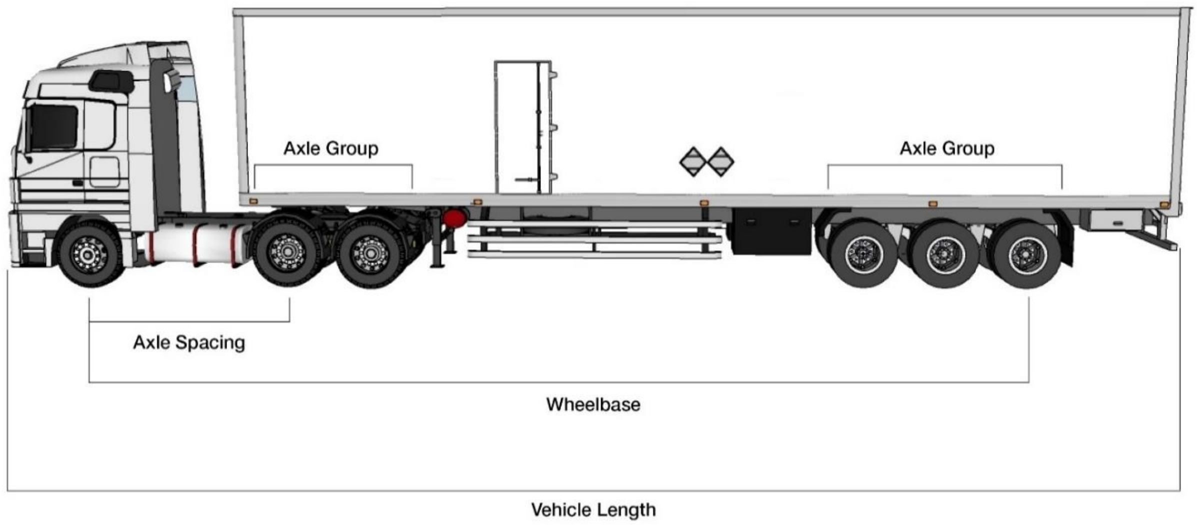

Figure 1 Truck properties

1.2.2 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 Level: Integer value [δ] used to quantify the maximum allowed relative error. The Accuracy Level [δ] is used to specify the maximum size of the two Standard Deviation Interval [-2σ, +2σ]. This means that for 95 % of all measurements the (unknown) true value lies within ±δ% from the measured value.

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

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

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 High Speed WIM measurements generally, a static measurement is used as a reference value.

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

1.2.3 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 (95%) is used to qualify the reliability of the outcome of a test procedure.

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

In-Service Verification: The regular Performance Test to verify if a system is still operating according to specification.

Performance Test: A test to determine whether a measurement instrument can perform according to its specified functions.

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 may be a formal document stating international Type Approval of the system.

2. Site Selection

2.1 Scope

This section details the requirements that shall be considered when selecting a site for a WIM installation. The accuracy of the data gathered is highly dependent on the site characteristics: road geometry and road evenness. Prioritising other criteria, such as the location of power, to select a site may result in a WIM installation that is not fit for purpose. A series of tests and measurements shall be undertaken during site selection to demonstrate that the characteristics of the site meet the site selection requirements.

2.2 Road Geometry

The geometrical characteristics of the road section at the WIM site shall meet the requirements of Table 1 and Table 2 for each lane where a WIM system is installed. The road geometry shall, at a minimum, be ‘Sufficient’ for the required accuracy class, according to Table 2. The road section between 200m upstream and 50m downstream of the WIM system should meet the recommended requirements.

Table 1 Criteria for pavement geometry of WIM sites (COST323, 2002).

			WIM Site Class	
			I (Excellent)	**II (Good)**
Rutting (3 m – beam)		Rut depth max. (mm)	≤ 4	≤ 7
Deflection	Semi-rigid	Mean deflection (10^{-2} mm)	≤ 15	≤ 20
(quasi-static)	All bitumen	Mean deflection (10^{-2} mm)	≤ 20	≤ 35
(13t - axle)	Flexible	Mean deflection (10^{-2} mm)	≤ 30	≤ 50
Deflection	Semi-rigid	Deflection (10^{-2} mm)	≤ 10	≤ 15
(dynamic)	All bitumen	Mean deflection (10^{-2} mm)	≤ 15	≤ 25
(5t - load)	Flexible	Mean Deflection (10^{-2} mm)	≤ 20	≤ 35
Evenness	IRI index	Index (m/km)	0 - 1.3	1.3 - 2.6
	APL[(1)]	Rating (SW, MW, LW)[(1)]	9 – 10	7 - 8
Longitudinal slope			< 1%	< 2%
Transversal slope			< 3%	< 3%

[(1)] The APL is a car-towed device used to measure longitudinal profile in the short (SW), medium (MW) and long wavelengths (LW) respectively.

Table 2 WIM site class required for each accuracy class (COST323, 2002).

Accuracy Class	WIM Site Class	
	I (Excellent)	**II (Good)**
A(5)	Sufficient	Insufficient
B+(7)	Sufficient	May be Sufficient
B(10)	Sufficient	Sufficient
C(15)	More than Sufficient	Sufficient

In addition, the characteristics of the pavement shall be consistent with manufacturer's recommendations for the WIM technology deployed and it shall not contain any bumps or other types of sudden local changes in slope.

The horizontal radius of curvature of the road shall not be less than 1000m.

2.3 Traffic Conditions

The WIM system shall be installed in locations which are characterised by or conducive to free-flowing traffic, and away from any area of expected frequent lane changes, acceleration or deceleration, (e.g., close to traffic lights, toll station, slip roads), to weigh vehicles travelling at uniform speed.

2.4 Pavement Condition and Remaining Service Life

Older pavements are susceptible to cracking, ravelling and potholing and may also require resurfacing, all of which affect the integrity of the WIM sensors. The remaining service life of the pavement should be determined to ensure the integrity of the pavement for the expected service life of the WIM sensors.

2.5 Constructability Considerations

The siting of WIM sites shall allow for safe maintenance access and shall be sited in locations where the road verge is sufficient to accommodate cabinets, ancillary items and infrastructure including plinths, access steps, ducts, chambers and maintenance vehicle lay-by areas. Cabinets should be sited in accordance with DN-ITS-03029 Traffic Control and Communications Infrastructure Design.

2.6 Future Plans

Future plans for the proposed location which may affect its feasibility shall be considered. These may include road upgrade works, resurfacing, and junction upgrades. Other development in the proximity of the location should also be considered as this may affect the traffic conditions at the site.

2.7 Drainage

The site must provide proper drainage away from the WIM components. The chambers and roadside cabinet must be placed away from water collection areas.

2.8 Disturbance of Sensors

Sensors shall not be installed under a bridge, structure or high voltage power line, and shall not be positioned in close vicinity to radio transmitting equipment and railway tracks.

2.9 Communication

The proposed communications – see 3.1.11 – shall be tested to ensure they can consistently deliver a connection suitable for the data transfer requirements of the equipment.

2.10 Accuracy Testing Runs

The site selection requirements in 2.1 to 2.9 shall be given priority to ensure the WIM site can collect accurate data. However, some consideration should also be given to the feasibility of completing performance test runs at the proposed site. The time required for the test vehicles to complete a test lap may affect the feasibility of completing a test in one day. The impact of performance tests on road network operations should also be considered. This is particularly relevant if heavy goods vehicles are required to complete test runs in the overtaking lanes. This may influence the time and day by which performance tests can be implemented and warrants consideration within contract requirements, method statements and Standard Operational Procedures.

2.11 Reporting

The suitability of a proposed site shall be verified by the provider of the WIM sensors. A report detailing the suitability of the proposed site and detailing the tests performed to confirm the appropriateness of the proposed site shall be provided to the Employer for acknowledgement.

3. Requirements

The WIM system shall include, without limitation, all Outstation, transmission network(s), telemetry equipment, cabinets, shelves, cameras, camera mountings, connections, power supplies, sensors, ducting, cable chambers, software, software licences, suitable maintenance access facilities and all cabling necessary to produce the required outputs and transmit them to Employer's Instation or any other location specified by the Employer.

The typical WIM system shall consist of sensors in all carriageway lanes except for the hard shoulders.

3.1 Performance

3.1.1 Completion Rate

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

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

The minimum rate of detection, of vehicles over 3.5 tonnes, shall be 98%. A correct and completed record, as defined in 3.3.1, shall be generated for 98% of those vehicles detected.

3.1.2 Interruption to Traffic Flow

The WIM system shall record vehicle classification and axle load data without interruption to traffic flow.

3.1.3 Length Measurement

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

- The accuracy of the vehicle length measurement should be ±50 cm for at least 95 % of the measurements;
- The accuracy of the wheelbase measurement should be ±15 cm for at least 95 % of the measurements;
- The accuracy of the measurement of the axle spacings should be ±5 cm for at least 95 % of the measurements.

The unit of axle spacing, wheelbase and vehicle length used by the system is the meter [m].

3.1.4 Vehicle Classification

Vehicle class shall be determined in accordance with the 7 vehicle classes and required classification accuracy described in Table 3.

Table 3 TII vehicle classes and required accuracy.

Class No.	Description	Classification Accuracy
1	Motorbike	60%
2	Car	96%
3	Light Goods Vehicle (LGV)	90%
4	Bus	70%
5	Heavy Goods Vehicle (HGV) Rigid	85%
6	HGV articulated	90%
7	Caravan – car pulling a trailer or LGV pulling a trailer	50%

3.1.5 Data Accuracy Tolerances

The WIM system shall operate within the performance limits of the criteria detailed in Table 4.

Table 4 Accuracy of measurements.

Parameter	Required Accuracy
Speed Range	1 to 130 km/h
Speed	±2%
Headway	±7%

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

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

3.1.6 Number of Axles

At a minimum, the system shall be capable of capturing vehicles with up to 40 axles.

3.1.7 Operating Temperature

The WIM system shall operate in the temperature range: -20 °C to +60 °C.

3.1.8 Electrical Protection

The WIM system must be protected against lightning and against any external electrical or magnetic field.

3.1.9 Operating Weather Conditions

The WIM system shall provide reliable information, in accordance with the requirements of Section 3, in all weather conditions that do not impact on the vehiciles ability to evenly transfer load directly to the road surface (e.g. high winds and thick snow).

3.1.10 Rack Size

The Outstation cabinet shall accommodate 19" Rack mountable equipment. The Outstation equipment shall be 19" Rack mountable.

3.1.11 Communication

The Outstation equipment shall be capable of communicating with the Instation via Ethernet and cellular telecommunications.

Cellular telecommunications routers shall accommodate dual SIM cards for automatic swap-over of communications should one service provider signal fail.

The Outstation equipment shall have maintenance and communications ports which allow connection to a standard laptop.

3.1.12 Site Programming

The System will provide for on-line modification of the WIM Outstation's software parameters, such as speed and weight calibration factors, date and time, axle weight bins, etc.

3.1.13 Robustness of Product

The products provided shall be suitable for roadside use and shall provide protection against vibration, shock, vandalism and electromagnetic disturbances.

3.1.14 Temperature Sensors and Sensitivity

Some WIM systems are temperature sensitive and require a temperature input from the road pavement to facilitate a temperature correction algorithm. If such WIM systems are being used, a minimum one per lane, plus an additional temperature sensor shall be installed on the concrete plinth adjacent to the roadside equipment cabinet. This allows the temperature in each carriageway to be measured independently as well as providing an extra sensor in each carriageway for redundancy in the case of sensor failure.

3.1.15 Synchronising of Time Stamps and Adjusting for Daylight Saving

The system shall provide a means of ensuring that the time and date stamps for all equipment are accurate to Irish Standard Time to within a 100th of a second. The system shall be configurable to automatically adjust for Daylight Saving.

3.1.16 Storage and Back-Up Systems

The Outstation shall provide back-up facilities designed to ensure that data gathering continues in the event of power failure. Vehicle-by-vehicle records, in accordance with 3.3.1, shall continue to be recorded during power failures of up to 120 hours. Related images, in accordance with 3.2, shall continue to be recorded during power failures of up to 10 hours.

Where the Outstation is unable to transfer data to the Instation, the Outstation shall store Vehicle-by-vehicle records, and the associated images according to the requirements in Section 3.2, for at least 100 days. The storage capacity of the system shall be expandable up to a minimum of 300%.

Stored data not transferred to the Instation during outages shall be transferred once power or transmission links are restored. This shall be an automatic process.

Should the capacity of the internal storage of the Outstation be reached, the system shall operate a 'First In, First Out' (FIFO) storage policy whereby the data captured from the most recent vehicle passage will be retained at the expense of the oldest vehicle passage data record.

This will ensure that most recent vehicle passages will always be available locally, up to the storage capability of the Outstation.

3.1.17 Fault Monitoring

The equipment shall be capable, and configurable, of monitoring its status and communicating this, or any faults with its status, to a fault monitoring system through automatically generated SNMP Traps.

Alarms shall be provided which shall indicate any loss of receipt of data from and/or loss of power at any site.

3.1.18 Lane Numbering

For the purposes of recording the WIM data, lanes shall be numbered with lane 1 being closest to the Outstation cabinet and lane numbers increasing consecutively moving across the road, away from the cabinet – see Figure 2.

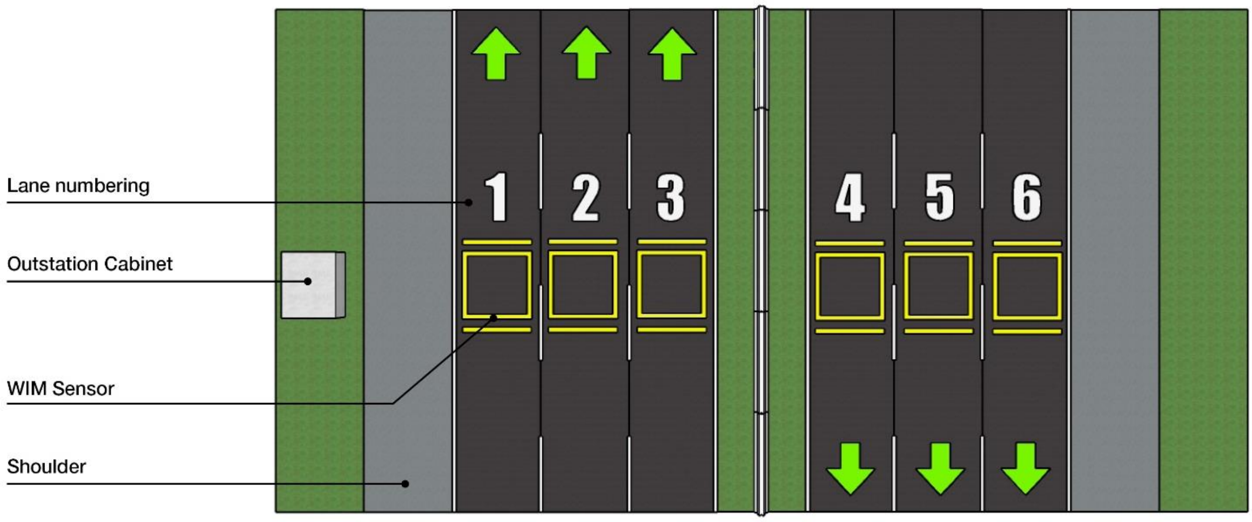

Figure 2 Lane numbering

3.1.19 Structural Integrity of Sensors

The WIM sensor and all other road surface components shall be designed to remain in place for the design life of the road without impacting on the road surface integrity, even if they are no longer collecting data.

3.1.20 Sensitivity of Sensors

Sensors shall be insensitive to water and salt exposure.

3.2 Overview Images

Overview cameras shall be installed at all sites. These cameras shall gather side view still images of vehicles in all WIM lanes.

Images shall be linked to the vehicle-by-vehicle record recorded by the WIM sensors (3.3.1) and shall be labelled with the same unique identifier as the WIM record – see 3.3.5.

3.2.1 Triggers

Images of vehicles with any of the following properties shall be captured by the system:

- An individual axle weight greater than 16 tonnes;
- A tandem weight exceeding 28 tonnes;
- A tridem weight exceeding 35 tonnes;
- A gross weight exceeding 50 tonnes;
- More than 8 axles.

The limits shall be set as described above but shall be configurable to allow for future changes.

3.2.2 Day and Night Time Images

The camera shall capture vehicle images for both day and night time. Day time images shall be of sufficient quality to clearly identify the vehicle class (as per 3.1.4), vehicle outline, and each of the vehicle axles. Night time images shall be of sufficient quality to identify the vehicle class and vehicle outline.

3.2.3 Camera Layout

The side view image shall be captured as the front axle of the vehicle is over the sensor. This ensures that all vehicles are at the same location within the image. A typical image is outlined in Figure 3. The whole vehicle shall be captured within the image.

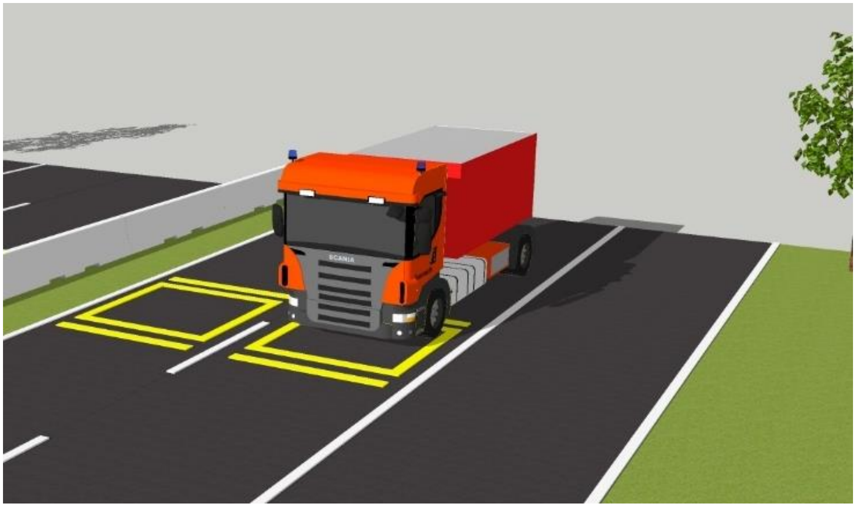

Figure 3 Typical image required

3.3 Data

3.3.1 Vehicle-by-Vehicle Records

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

- Unique identifier - see 3.3.5;
- Site;
- Direction;
- Lane;
- Date + Time (yy-mm-dd + hh:mm:ss.cc) – see 3.3.2;
- Gross vehicle weight;

- Axle Load;
- Wheel load (where applicable);
- Axle spacings (centre to centre);
- Number of axles;
- Wheelbase;
- Vehicle length;
- Vehicle Classification – see 3.1.4;
- Headway;
- Vehicle Speed;
- Road temperature;
- Error codes or any other flags which may indicate a sub optimal record; and
- Vehicle overview image – see 3.2.

The fields described are minimum requirements. Additional information recorded by the system shall not be discarded.

3.3.2 Timestamp Accuracy

Timestamps shall be to one hundredth of a second accuracy and record the instant that the first axle of the vehicle is over the first sensor in that lane.

3.3.3 Real Time View

The WIM software will provide for on-line monitoring of traffic, both on-site and remotely. The contents and format for the real time display will have as a minimum the time and date of passage, lane number, vehicle classification, speed, vehicle length, gross vehicle weight, individual axle weights and headway. The user will have the option of displaying all traffic or to filter any combination of vehicle classifications on any lane or combination of lanes.

On site on line monitoring shall be, when required, by means of a laptop plugged into the Outstation at the roadside cabinet location.

3.3.4 Manual Data Retrieval

The Outstation shall allow for the downloading of selected data files from the Outstation to a standard laptop or standard storage device with accredited software, using standard cables and connections. The outstation software will provide a listing of the data files stored in the WIM Outstation and will allow user selection of the file or files to be downloaded from such a listing. The outstation software will allow for downloading of the current day's data stored as of the time of downloading.

3.3.5 Unique Identifier

Each vehicle record shall have a unique entry which shall be time and date stamped: - Site Address/ Lane /DD/MM/YY/: HH/MM/SS/CC. The time shall be referenced to Irish Standard Time. The time stamp shall have an accuracy of one hundredth of a second.

3.3.6 Upload of Data from Outstation

The WIM system shall be capable of providing data files in a machine-readable format suitable for the Employer’s Instation. The format shall be specified by the Employer and shall be configurable to allow for future changes.

Data shall be pushed to the Instation every 5 minutes, and this interval shall be configurable.

Subject to 3.1.16, the system shall be designed such that data will be retained at the Outstations until a confirmation has been given by the Instation that the data has been properly received and stored.

3.3.7 Ownership and Possession of the Data

The Employer shall own all data that is generated and stored by the WIM system and have the right to retrieve it.

The Employer shall be provided with a copy of all vehicle-by-vehicle records in machine readable format with all data fields described in 3.3.1 provided. The Employer shall also be provided with a copy of all vehicle images collected under the requirements in 3.2.

All metadata, such as column headers and field code identifiers, shall be provided.

4. Weighing Accuracy

4.1 Introduction

Performance Tests are used to provide assurance that the system is delivering data that meets the requirements, as described in this document. There are two types of Performance Test:

- Initial Verification; and
- In-Service Verification.

4.1.1 Initial Verification

The Initial Verification Test is a more comprehensive test and is typically done after installation 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 the Employer to accept a system. The procedure used is similar to COST323 (2002) Test Plan No. 2.

Initial verification shall also be performed after the completion of any repairs affecting the sensors. Repairs or changes that have an impact on the performance of a WIM system may result from maintenance, a change to hardware or a software upgrade.

4.1.2 In-Service Verification

In-Service Verification is a less comprehensive test executed when a system has been operational for a period of time to verify if a system is still operating according to specification. The procedure used is based on the In-Service Verification test for statistical applications described in the NMi International WIM Standards (NMi, 2016).

4.2 Weighing Requirements

4.2.1 Accuracy Class

The WIM System shall automatically and accurately weigh, within the tolerances set forth herein, each axle of a multi-axle vehicle and calculate the gross weight of the vehicle by summing the individual axle weights. The gross and individual axle weights of each vehicle with gross weight over 3.5 tonnes shall be accurately established to within the tolerances for the accuracy class C(15) at a minimum as outlined in Table 5. These error limits shall be maintained within a confidence level of 95%.

Table 5 Accuracy levels per class (from COST323, 2002)

Criterion (for each sub-population)	Accuracy Class: Tolerance Interval width δ (%)			
	A(5)	B+(7)	B(10)	C(15)
Gross Weight	5	7	10	15
Group of axles	7	10	13	18
Single axle	8	11	15	20
Axle of a group	10	14	25	25

4.2.2 Type (Model) Approval of a WIM System

The type approval of a WIM system should be in accordance with the Cost 323 European WIM specification.

4.2.3 Weighing Range

The minimum weighing range for Axle Load measurements is from 100kg up to 50,000kg.

If the actual Axle Load(s) of a vehicle is/are outside the overall operating weighing range of the system during measurement, the system must indicate or print out the value of the measured Gross Vehicle Weight, Axle Group Load(s) and Axle Loads of the vehicle, and at the same time indicate a clear warning that the measurement is outside the system's operating weighing range.

4.2.4 Scale Divisions

The smallest increment that the WIM system can measure must not exceed the values given per accuracy class in Table 6.

Table 6 Maximum Scale Divisions

Class	A(5)	B(10)	C(15)
Axle Loads	20kg	50kg	100kg
Vehicle Weights	50kg	100kg	200kg

4.2.5 Units of Measurement

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

4.3 Initial Verification

4.3.1 Timing

The WIM system shall be calibrated and adjusted prior to completion of the Initial Verification.

Manufacturers recommendations shall be followed to ensure sufficient time is allowed between installation or maintenance of the WIM sensors (to allow sufficient curing time for the resin, etc) and the Initial Verification.

4.3.2 Reference Vehicles

Two 5-axle articulated lorries shall be used. One shall be fully laden to its legal limit and the other half laden.

The Contractor shall submit details of the vehicles to the Employer before undertaking the required Performance Test on the WIM site.

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

The vehicles shall be in good mechanical condition.

4.3.3 Reference Scales

The gross vehicle weight and the axle (group) loads of the reference vehicles shall be determined using a static weigh bridge as the reference scales. The weigh bridge shall be 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 4.2.1.

The availability and accuracy of the scales shall be confirmed in advance of the day of the Initial Verification.

A calibration certificate for the reference scales shall be obtained and included in the performance test report.

4.3.4 Determining Reference Values

The reference value for the gross vehicle weight value for each reference vehicle, shall be determined by static weighing on a reference weigh bridge where the entire vehicle is weighed at once.

The axle load on each axle of the reference vehicle is determined subsequently. This may be completed by moving the vehicle in one axle increments across a weigh bridge or using an axle scales that measures one axle at a time. Each axle weight shall be measured at least three times, resulting in at least three measurements of each axle weight. The mean axle load ($Axle_i$) is calculated as the arithmetic average of the recorded values.

The axle weights shall be corrected if the sum of the axle weights does not equal the reference gross vehicle weight. The corrected mean reference load value ($CorrAxle_i$) per axle is calculated as:

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

where:

VM_{ref} is the reference gross vehicle weight determined by weighing the entire vehicle at once;

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.

4.3.5 Performance Testing

The Contractor shall undertake performance testing in accordance with the test plan described in this document. Performance shall be checked by comparing WIM System weights with actual vehicle weight samples from the reference scale.

Each reference vehicle shall make at least 15 test runs over the WIM system. The following runs shall be used:

- 3 times near the maximum legal operating speed for the reference vehicle at the location, v_{max},
- 3 times near the minimum operating speed for the reference vehicle in free-flowing traffic at the location, v_{min},
- 9 times near the middle of the operating speed range for the reference vehicle in free-flowing traffic at the location, v_{med}

This results in a total of at least 30 test runs (i.e. 2 vehicles with 15 runs each).

At all times, the reference vehicle shall travel at a speed which does not cause a hazard or safety risk to the reference vehicle or other road users.

The reference vehicle shall not travel at speeds slower than would normally be expected for that vehicle type in normal free-flowing traffic at the location.

Prior to undertaking Performance Testing, the Contractor shall propose, for approval by the Employer's Representative, the values for v_{max}, v_{min} and v_{med} for each site.

The vehicle speed shall be kept as constant as possible during each test run and there shall be some lateral position variations (according to the real traffic paths).

The test shall comply with the COST323 E1 environmental repeatability, which states that the test time period is limited to a number of hours within a day or spread over a few consecutive days, such that the temperature, climatic and environmental conditions do not vary significantly during the measurements.

The Performance Test shall demonstrate to the satisfaction of the Employer that the WIM System consistently meets the performance requirements of the test and shall serve as the basis for acceptance or rejection of the WIM System as a result of demonstrated performance.

The Performance Test shall, at a minimum, meet the requirements established in Figure 4. In addition, if any part of the WIM System fails to function properly during the performance test, the WIM system will be deemed to have failed the Initial Verification.

The acceptance criteria is calculated as follows:

- The relative errors with respect to the weights and reference values are calculated, for each measurement of the different sub-populations (i.e. the single axles (not in groups), axle group, axles of groups and gross vehicle weights) as:

$$E_i\% = \frac{(Wd_i - Ws_i)}{Ws_i} \times 100$$

  - Wd_i = is the value measured by the WIM system
  - Ws_i = is the corresponding reference value measured by the reference scales
- The mean ‘m’ and the standard deviation ‘s’ of the relative errors in each sub-population sample are calculated.
- δ = accuracy class tolerances. For the Initial Verification, δ is calculated by multiplying the accuracy class tolerances in Table 5 by a factor of 0.8.
- n = sample size for the relevant sub-population. It is used to decide on the acceptance criteria line in Figure 4.
- For each sub-population, δ/s and |m|/s is calculated and plotted on Figure 4. To meet the requirements for the accuracy class, each sub-population shall be plotted in the relevant acceptance area of the figure.

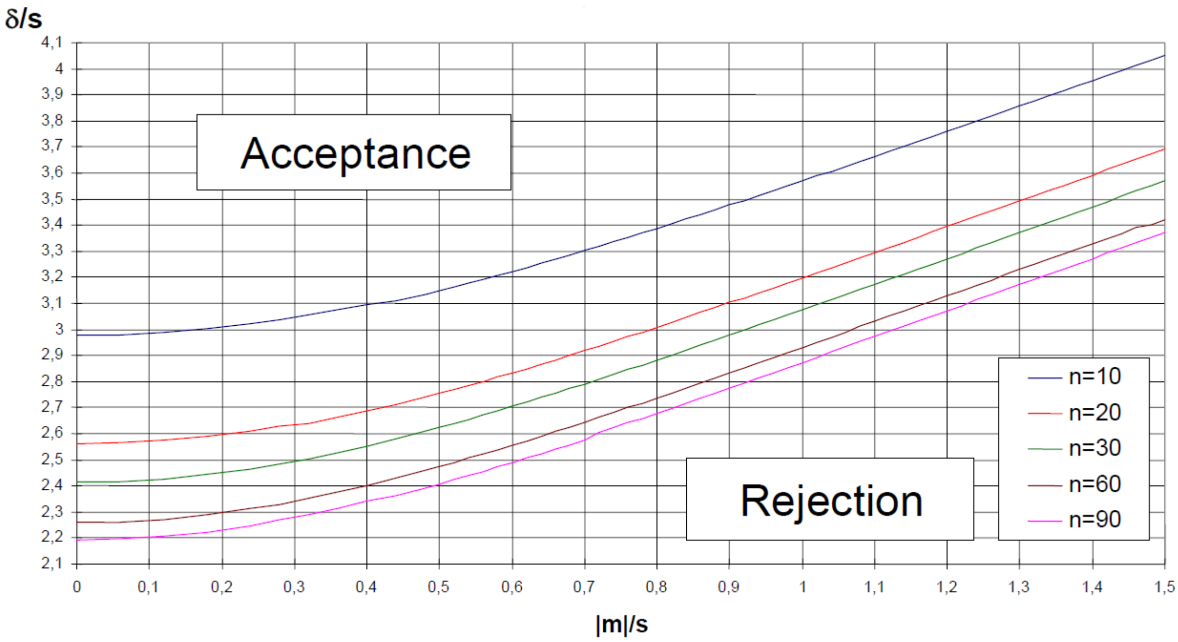

Figure 4 Charts for acceptance of test.

Reference vehicle runs shall not be excluded from the sample because large measurement error was recorded. Runs may only be excluded from the test if they are marked as a non-correct vehicle passage by the system.

Test runs completed prior to calibration and adjustment of the system shall not be used as part of the performance test.

4.3.6 Other Tests

4.3.6.1 Completion Rate Test

Description of test: For at least 100 vehicles that have correctly passed the system (see 3.1.1), verify that 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 passing vehicles shall be detected and result in a correct and complete vehicle record by the system.

4.3.6.2 Classification Rate Test

Description of test: For at least 100 consecutive vehicle records from vehicles that have correctly passed the system (see 3.1.1), verify that the system makes a correct classification of the vehicle. The sample size shall be increased, if required, to ensure it includes at least 20 vehicles from each of the following vehicle classes:

- Car
- HGV Rigid
- HGV Articulated

This test may be done by visual inspection from the road side or by using a video recording.

Criteria for acceptance: All correctly passing vehicles shall be classified correctly by the system according to the classification accuracy in Table 3 at a 95% confidence level.

4.3.6.3 Length Measurement Test

Description of test: For all test vehicles used for testing the weighing accuracy (see 4.3.2), the reference vehicle length, wheelbase and all axle spacings should be measured using a certified length measurement tool. For all runs by the test vehicles as described in 4.3.5 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 spacings, vehicle length and/or wheel base) shall be within the accuracy specified in 3.1.3.

4.4 In-Service Verification

4.4.1 Timing

In-Service Verification shall be performed every six months for slow lanes and every 12 months for fast lanes. Slow lanes and fast lanes are defined in Table 7.

Table 7 Slow lane and fast lane definitions.

Road Type	Example	Slow Lanes	Fast Lanes
1+1 Single Carriageway	Most national secondary roads and some national primary roads.	All lanes.	Not applicable
2+2 dual carriageway and motorway	Most of the national primary motorway network.	Leftmost lane in each direction.	Rightmost lane in each direction.
3+3 dual carriageway and motorway	Some national primary roads.	The 2 leftmost lanes in each direction.	Rightmost lane in each direction.

For WIM systems that are temperature sensitive and require a temperature input from the road pavement, In-Service Verification and adjustment shall be performed in March/April and September/October. These months have mid-range temperatures which tend to be neither very hot nor very cold. Using these months helps to avoid adjusting the system to reduce the measurement error during the extremes of the operational temperature range. The scheduling and undertaking of testing should take due regard of actual forecast temperatures to avoid unseasonal variations in temperature.

Calibration drift may have occurred since the previous Verification. To quantify this drift, a full In-Service Verification Performance Test shall be performed before any adjustment is made to the system. This will quantify any drift that has occurred since the last verification. Once the calibration drift has been quantified, the system should be adjusted, if required. If an adjustment is made, another In-Service Verification shall then be performed to quantify the system accuracy following adjustment.

4.4.2 Reference Vehicles

See 4.3.2

4.4.3 Reference Scales

See 4.3.3

4.4.4 Determining Reference Values

See 4.3.4

4.4.5 Performance Testing

Performance shall be checked by comparing WIM System weights with actual vehicle weight samples from the reference scale.

Each reference vehicle shall make at least 10 test runs over the WIM system. The following runs shall be used:

- 2 times near the maximum legal operating speed for the reference vehicle at the location, v_{max},
- 2 times near the minimum operating speed for the reference vehicle in free-flowing traffic at the location, v_{min},
- 6 times near the middle of the operating speed range for the reference vehicle in free-flowing traffic at the location, v_{med}

This results in a total of at least 20 test runs (i.e. 2 vehicles with 10 runs each).

At all times, the reference vehicle shall travel at a speed which does not cause a hazard or safety risk to the reference vehicle or other road users.

The reference vehicle shall not travel at speeds slower than would normally be expected for that vehicle type in normal free-flowing traffic at the location.

Prior to undertaking Performance Testing, the Contractor shall propose, for approval by the Employer's Representative, the values for v_{max}, v_{min} and v_{med} for each site.

The vehicle speed shall be kept as constant as possible during each test run and there shall be some lateral position variations (according to the real traffic paths).

The test shall comply with the COST323 E1 environmental repeatability, which state that the test time period is limited to a number of hours within a day or spread over a few consecutive days, such that the temperature, climatic and environmental conditions do not vary significantly during the measurements.

Reference vehicle runs shall not be excluded from the sample because large measurement error was recorded. Runs may only be excluded from the test if they are marked as a non-correct vehicle passage by the system.

Test runs completed prior to an adjustment shall not be used to calculate the accuracy class following the adjustment.

The values of all gross vehicle mass measurements and all axle load measurements are recorded. For each of the different sub-populations (i.e. the single axles (not in groups), axle group, axles of groups and gross vehicle weights), the relative error E% is calculated in percent:

$$E_i\% = \frac{(Wd_i - Ws_i)}{Ws_i} \times 100$$

where:

- Wd_i = is the value measured by the WIM system
- Ws_i = is the corresponding reference value measured by the reference scales

The number of relative errors E% that exceeds the required accuracy level is determined separately for each sub-population (i.e. the single axles (not in groups), axle group, axles of groups and gross vehicle weights). 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.

To be accepted, the percentage P of relative errors exceeding the specified maximum error shall not be greater than 5 %, for each quantity.

In addition, if any part of the WIM System fails to function properly during the performance test, the WIM system will be deemed to have failed the In-Service Verification.

4.4.6 Other Tests

Not required for the In-Service Verification.

4.5 Maintaining Accuracy

The system shall maintain the required weighing accuracy class throughout the period between verification. The Employer may verify this with independent testing.

4.5.1 Monitoring Calibration Drift

The Contractor shall undertake monthly quality assurance checks between verifications to help identify if loss/drift of calibration has occurred. The following parameters should be monitored:

- **Mean Steer Axle Weight:** This involves tracking the steer axle (front axle) weight on five-axle trucks. The weight of these axles is expected to have a fairly constant average value (6.2 tonnes) and a low standard deviation. This occurs as this axle carries the cab and engine and is not significantly influenced by the load which the truck is carrying. With high traffic volumes, the mean daily value should have little variation. The mean steer axle weight for 'slow' lanes is calculated on a daily basis whereas the mean weekly value is used for the 'fast' lanes as they have lower truck flows. Figure 5 shows an example of plots outputted by a data reporting platform. The temperature should also be plotted, if available, to help identify if changes in the weights are related to temperature.
- **Mean Truck Weight:** The mean weekly gross vehicle weight is recommended as a secondary weight check – see Figure 6. Although the steer axle weight is used as the primary check, a secondary weight check is useful to verify the results. As this statistic can contain a significant degree of variability, the mean weekly value is recommended.
- **Last axle spacing on 5 axle trucks:** This check helps identify if the axle spacings are being recorded correctly. It plots a histogram of the rearmost axle spacing on all 5-axle trucks – see Figure 7. Typically, the item being measured is the spacing between axles in a tandem/tridem, to the rear of an articulated truck; this is expected to measure approximately 1.3 m. If the peak in the histogram is not at this location, it may indicate that the axle spacings are not being recorded correctly.

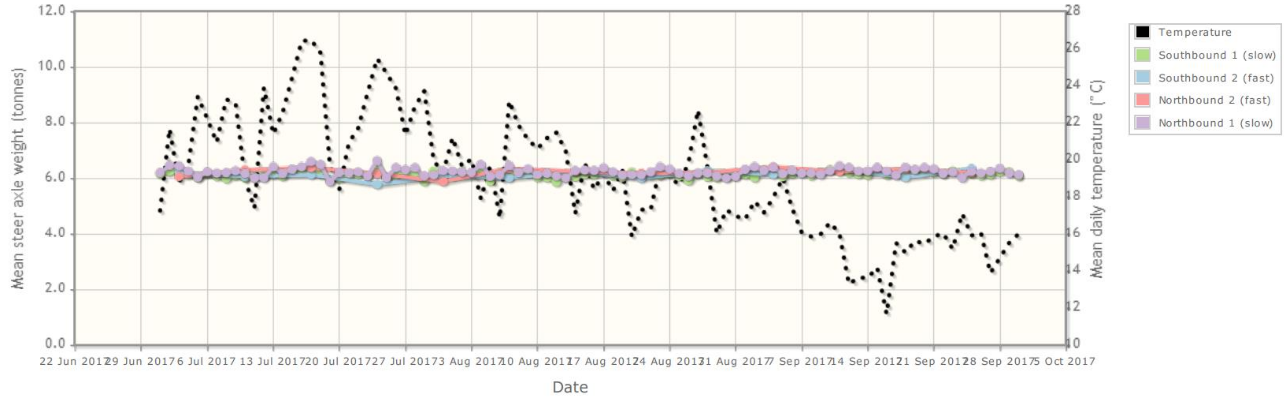

Figure 5 Mean steer axle weight on five-axle trucks.

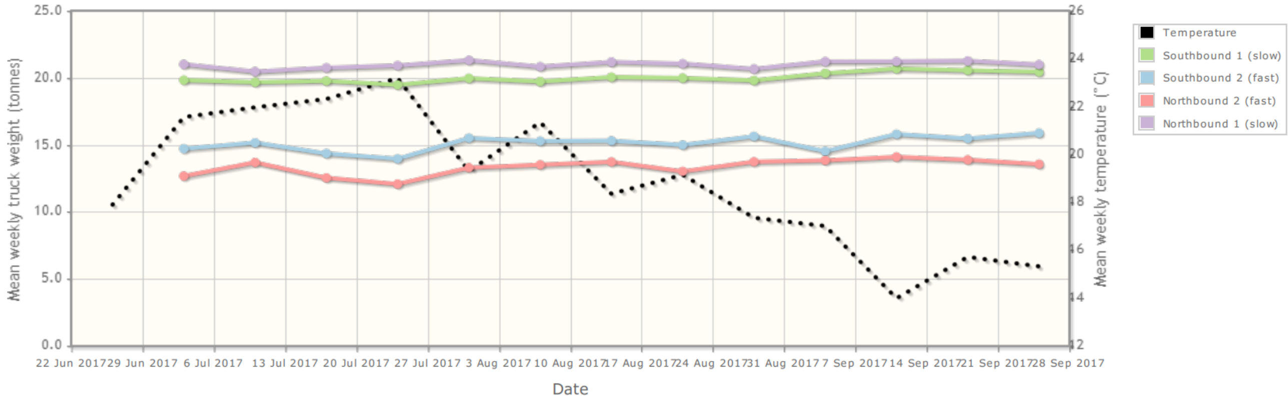

Figure 6 Mean weekly truck weight.

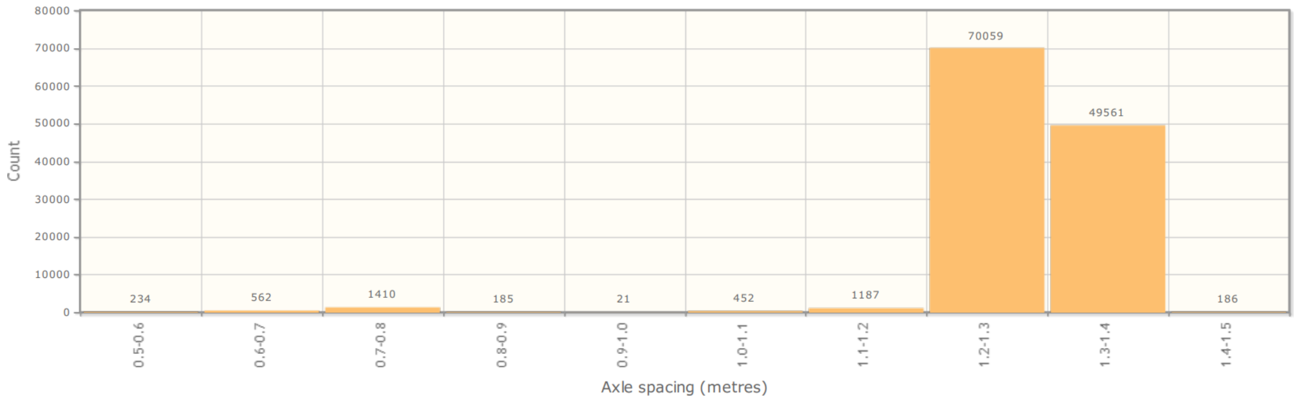

Figure 7 Histogram of rearmost axle spacing on five-axle trucks.

4.6 Witnessing

All Initial and In-Service Verifications shall be witnessed by the Employer or the Employer's Representative.

5. References

Much of the content in this standard was taken from, or based on text from, the following WIM documents:

- COST323 (2002) *Weigh-in-Motion of Road Vehicles - Final Report*. Edited by B. Jacob, E. OBrien, and S. Jehaes. PARIS: LCPC.
- NMi (2016a) *NMi International WIM Standard*. Dordrecht, Netherlands: NMi Certin.

Other related references:

- NMi (2016b) *Guide to NMi WIM Standard*. Dordrecht, Netherlands.

5.1 TII Publications (Standards)

CC-SPW-01500 Specification for Traffic Control and Communications

CC-GSW-01500 Guidance on Specification for Traffic Control and Communications

DN-ITS-03029 Traffic Control and Communications Infrastructure Design

Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Ionad Ghnó Gheata na Páirce,
Stráid Gheata na Páirce,
Baile Átha Cliath 8, D08 DK10, Éire

www.tii.ie

+353 (01) 646 3600

Parkgate Business Centre,
Parkgate Street,
Dublin 8, D08 DK10, Ireland

info@tii.ie

+353 (01) 646 3601