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FEHRL Institutes WIM Initiative (Fiwi)

WIM Initiative der FEHRL Institute (Fiwi)

Initiatives WIM des Institute FEHRL (Fiwi)

Empa, Swiss Federal Laboratories for Materials Science and Technology

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Forschungsauftrag ASTRA 2008/008_009 auf Antrag des Bundesamtes für Strassen (ASTRA)

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Zusammenfassung

Seit Anfang der 90er Jahre gibt es beträchtliche Entwicklungen im Bereich „Weigh-in-Motion“ (WIM oder „dynamische Achslastwaagen“) in Europa. Zusätzlich zu den technischen Verbesserungen der WIM-Sensoren und WIM-Systeme gibt es auch Entwicklungen in den Anwendungsbereichen. Zurzeit sind die COST323-Spezifikationen de-facto der Standard für die „Europäische Norm für WIM-Systeme“. WIM-Sensoren müssen in der Schweiz gemäss “Kontrollreglement für WIM-Anlagen” und “Spezifikation für Abnahme und periodische Achslastwaagen” eingebaut und kontrolliert werden. Beide Dokumente basieren auf den COST 323-Spezifikationen. Um die COST 323-Norm auf den neuesten Stand zu bringen, hat eine ausgewählte Anzahl FEHRL-Mitglieder - Die Schweiz ist durch die Empa vertreten. - ein Projekt namens „FEHRL Institutes WIM initiative“ oder „Fiwi“ initiiert.

Das Hauptziel dieses Projekts ist die Überarbeitung und Einreichung der COST 323-Norm als künftige Euro Norm (EN) „Weigh-in-Motion of Road Vehicles“. Die prEN-Version vom 25. Januar 2010 ist die inoffizielle Version dieser Norm und befindet sich zur Kenntnisnahme im Anhang 1 dieses Berichtes. Diese Norm wurde an das Europäische Komitée für Normierung, CEN, eingereicht. Wenn diese Norm genehmigt würde, würde eine Revidierung und Anpassung der relevanten Schweizer Dokumente empfohlen werden. Die wichtigsten Änderungen sind in diesem Bericht aufgelistet. Einige dieser Änderungen sind z.B. die minimal benötigte Anzahl vollständig vollzogener Überfahrten, Toleranz der Achsdistanz, minimale Umwelt- und Fahrzeuganforderungen, um eine Genauigkeitsklasse entwickeln zu können. Ein Hauptergebnis dieser Norm ist ein vereinfachtes Vorgehen, welches in Teil 1 der Norm beschreiben wird.

Während dieses Projekts würde sich die “International Society for Weigh in Motion (IS-WIM)” mit Hauptsitz in der Schweiz etablieren. Das Ziel dieser Gesellschaft ist, die Benutzung und Anwendung von „Weigh-In-Motion“-Technologien und -Daten zu fördern.

Das Projekt „Fiwi“ hat zusätzlich verschiedene Dokumente vorbereitet, die sich mit der Benutzung von WIM zur Dimensionierung von Strassen und Brücken, sowie für die Nutzung zur automatischen Bussenvergabe („direct enforcement“) befassen.

Eine wichtige Anwendung der WIM Sensoren ist die automatische Bussenvergabe („direct enforcement“). Das Projekt „Fiwi“ hat verschiedene Möglichkeiten aufgezeigt, wie man WIM-Systeme für das Büssen überladener Lastwagen einsetzen könnte. Zusätzlich erhält man einen Überblick über die Vor- und Nachteile jeder Anwendungsmethode.

Résumé

Des progrès considérables ont été réalisés en Europe depuis le début des années 1990 par l'industrie dans le domaine du pesage en marche (weight in motion, WIM). A côté de l'amélioration technique des capteurs et des systèmes WIM, on observe un développement parallèle dans les applications de cette technologie. Actuellement les directives de l'action COST 323 représentent de facto la norme européenne pour les systèmes WIM. En Suisse, les capteurs WIM doivent répondre aux spécifications formulées dans le «Règlement de contrôle pour les installations WIM» et aux «Spécifications pour la réception et le contrôle périodiques des pèse-essieux». Ces deux documents sont basés sur les spécifications COST 323. Dans le but d'actualiser les spécifications COST 323, un certain nombre des membres du FEHRL ont lancé le projet «FEHRL Institutes WIM initiative», Fiwi.

Ce projet a pour objectif principal d'actualiser les spécifications COST 323 pour en faire une nouvelle norme Européenne sur le pesage en marche des véhicules routiers. Cette prEN n'est pas encore approuvée officiellement mais sa version du 25 janvier 2010, jointe dans l'appendice 1 à titre d'information, a été soumise au Comité européen de normalisation CEN pour enquête publique. Une fois cette norme européenne approuvée, il serait vivement con-seillé de procéder à la révision des documents suisses mentionnés plus haut. Les change-ments les plus importants sont résumés dans ce rapport. Il s'agit là entre autres de la fré-quence minimale d'enregistrement complet, des tolérances sur l'espacement des essieux, des conditions touchant l'environnement et les véhicules ainsi que les conditions de test mi-nimales exigées pour atteindre une classe de précision donnée. Une innovation majeure est l'inclusion de procédures simplifiées pour les utilisateurs courants.

Au cours de ce projet, la International society for weigh in motion (ISWIM) a été fondée avec son siège en Suisse, La ISWIM a pour objectif de promouvoir les progrès en matière de pe-sage en marche ainsi que la plus large diffusion des technologies et des applications du pesage en marche.

Le projet Fiwi a préparé différents documents sur la recherche et les applications WIM qui traitent des applications WIM pour la conception des revêtements routiers et celle des ponts ainsi que pour la répression directe des véhicules en surcharge.

Une des plus importantes applications WIM est la répression directe des véhicules en sur-charge. Le projet Fiwi a identifié différentes possibilités d'utilisation de systèmes WIM pour la détection et le contrôle des poids lourds en surcharge avec un résumé des avantages et des désavantages de chacune de ces applications.

Summary

Since the early 90’s, there has been considerable developments in the Weigh-in-Motion (WIM) industry in Europe. In addition to technical improvements of WIM sensors and WIM systems there have also been parallel developments to focus on applications. At the moment COST323 specifications are the de-facto European standard for WIM systems. WIM sensors in Switzerland must follow the specifications listed in “Kontrolreglement für WIM-Anlagen” and “Spezifikation für Abnahme und periodische Achslastwaagen”. Both these documents use the COST 323 as a basis. In order to update the COST323 standards, a selected number of FEHRL members including Switzerland represented by Empa have initiated this project named FEHRL Institutes WIM initiative or Fiwi.

The main focus of this project was to update the COST 323 standards and submit it to become a new European standard for Weigh-in-Motion of Road Vehicles. This prEN is not officially approved yet but the version from January 25th, 2010 is included for information in Appendix 1 which was submitted to the European Committee for Standardization, CEN, members for public enquiry. Once a European standard is approved, it is strongly recommended that the Swiss documents listed above be revised. The most important changes are summarized in this report. They include minimum rate of complete registrations, tolerances for axle spacing, environmental and vehicle conditions and minimum test conditions that are required to achieve a particular accuracy class. A major addition is the inclusion of simplified procedures for common users.
During the course of this project, the international society for weigh in motion (ISWIM) has been established with its base in Switzerland. The goal of ISWIM is to support advances in and the more widespread use of Weigh-In-Motion technologies and the applications of WIM data.

The Fiwi project has prepared several documents addressing research and application of WIM as follows: Application of WIM to pavement design, to bridge design and for direct enforcement.

One of the most important applications of WIM is direct enforcement. The Fiwi project has identified different ways that WIM systems may be used for the enforcement of overloading by heavy road vehicles. In Addition, an overview is given on the advantages and disadvantages of each of these applications.

1 Introduction

Since the early 90’s, there has been considerable developments in the Weigh-in-Motion (WIM) industry in Europe. In addition to technical improvements of WIM sensors and WIM systems there have also been parallel developments to focus on applications. The development of WIM systems and their applications is reflected in a series of international projects: OECD/DIVINE, COST323, WAVE, Top-Trial and REMOVE. Currently, for the enforcement applications of Weigh-in-Motion no international (EU) regulations and specifications exist.

At the moment COST323 specifications [COST323 1999] are the de-facto European (and even worldwide) standard for WIM systems. Even though formally this is not an official international standard, it is widely used as a reference in the testing and acceptance of WIM systems.
WIM sensors in Switzerland must follow the specifications listed in “Kontrolreglement für WIM-Anlagen” [WIM-Ko 2001] and “Spezifikation für Abnahme und periodische Achslastwaagen” [WIM-Ab 2001]. Both these documents use the COST 323 as a basis.

In the past 10 years there have been a number of new developments in both technology and applications that were not fully included and it was decided that it was necessary to update the COST323 specifications. In addition to a general update of the content of the COST323, also new paragraphs have been added, above all for Bridge-WIM and WIM for direct enforcement. Furthermore an update was made to include research and applications in the field of Weigh-in-Motion in Europe. This concentrates on the following areas: traffic monitoring & safety, pavement engineering, bridge engineering and enforcement.

A selected number of FEHRL members have initiated this project named FEHRL Institutes WIM initiative or Fiwi. The idea of this project plan was to have a relatively small project with a few well defined tasks that will lead to concrete results. Therefore only a few FEHRL members were involved in the project, however, the results are available for all FEHRL members. Empa was invited to participate in this project. The other FEHRL members are: LCPC, France, ZAG, Slovenia, BAST, Germany, UCD, Ireland, DWW, Holland and CEDEX, Spain.

Three general topics were identified and addressed in this project as shown below:

- Topic 1: Standardization of WIM
- Topic 2: International exchange
- Topic 3: Update on Research and Applications

At the time of print of this report, the FEHRL report was not completed. The goal of this report is to summarize the project results and define how this new standard will affect the Swiss procedures on WIM as the project has officially ended in 2010.

2 Standardization of WIM

The main focus of this project was to update the COST 323 standards and submit it to become a new European standard for Weigh-in-Motion of Road Vehicles. This standard is not officially approved yet but the version from January 25th, 2010 is in Appendix 1 for information only. The project has accomplished its intended goal and the prEN for “Weigh-in-Motion of Road Vehicles” in Appendix 1 was submitted to the European Committee for Standardization, CEN, members for public enquiry.

2.1. General Update of COST323 Specifications

A general assessment of the COST323 specifications was made. It was decided by the project partners that the standard should be divided in two parts to correspond to the different needs of the users of WIM sensors.

Part I provides simplified and minimum requirements of practical use for common users.
Part II is recommended for advanced users, scientific investigations of WIM systems, and to accommodate non standard test plans. The General requirements (Part II) are divided into the following parts:
- Site selection
- Accuracy classification
- System calibration and testing

The informative annexes I, II, III and IV provide respectively:
- comparison with the OIML R134-1 international recommendation,
- guidelines for system calibration,
- guidelines for data and test result presentation, and computer tools for accuracy assessment,
- comments and explanations of the main clauses.

2.2. Summary of differences between prEN and current Swiss practice

WIM sensors in Switzerland must follow the specifications listed in “Kontrolreglement für WIM-Anlagen” [WIM-Ko 2001] and “Spezifikation für Abnahme und periodische Achslastwaagen” [WIM-Ab 2001]. Once a European standard is approved both these documents need to be revised. The most important changes are listed below (sections refer to Appendix 1):

1. Table 4 in [WIM-Ab 2001] should be revised to reflect Table a
2. It is allowed to use intermediate classes such as A(1), A(2)…, B(11), B(12)… where the tolerance on the gross weight is given in parentheses as an integer
3. The measurement intervals for axle loads and gross vehicle weights are given in Table b, and the maximum scale divisions are given in Table c
4. The minimum rate of detection (percentage of vehicle detected by the system) is 90%
5. A registration is complete if all the quantities listed in I.5.6 are recorded. That means that the right number of axles are recorded. The minimum rate of complete registration is 80%
6. The tolerance on the axle spacing is 20% with a maximum error of 0.3 m, and on the vehicle length or wheelbase is 10% with a maximum error of 1 m. These criteria, for, both axle spacing and vehicle length, apply for a minimum of 95% of the measurement
7. Three Environmental and four vehicle sample conditions are defined see section 1.7.3.1.

8. Minimum test conditions are required, combining environmental and sampling conditions (section I.7.3.2), according to the accuracy class to be assessed as shown in Table d. The choice of the reference vehicles should be based on the most common types in the traffic flow or the target vehicles of the user. The bogie axles should be equipped, as far as possible, with air suspensions, in order to minimise gross errors in the static reference axle loads. It should be noted that in order to reach an accuracy class of A or B+ considerably more vehicles are needed in the prEN in comparison to COST323

3 International Exchange

During the course of the project two meetings a year took place that provided a basis for international exchange of ideas. The result of this exchange was the establishment of the international society of weigh in motion that is based in Switzerland and the International seminar on weigh in motion in Brazil.

3.1. International Society of Weigh in Motion (ISWIM)

The purposes of the association are to support advances in and the more widespread use of Weigh-In-Motion technologies and the applications of WIM data. According to the statues of the society, this will be achieved through:

(a) Dissemination of knowledge and understanding of WIM through:

(i) The periodic organisation of conferences on WIM in different countries and continents, with the support of local and international organisations. In addition, seminars and other events may be organised from time to time which serve to disseminate knowledge of WIM technology and its applications.

(ii) The support, collection, distribution and advertising of scientific and technical publications on WIM including books and periodicals.

(iii) The facilitation of exchanges of research staff and postgraduate students where this leads to a sharing of experience, results and data relating to WIM.

(b) The promotion and support of international research and development projects or actions on WIM.

(c) The initiation, participation and/or monitoring of activities relating to WIM standardization:

(i) The development of standards relating to WIM and its applications.

(ii) The promotion and support of common tests of WIM systems, development of harmonised procedures and the publication of scientific results useful for WIM users and manufacturers.

(d) Promotion of use and application of WIM systems and data.

3.2. International seminar on weigh in motion in Brazil

Brazil is facing a serious problem regarding overload of heavy vehicles that is resulting in the untimely destruction of the road infrastructure. A selected number of Fiwi members, US, Australian and Taiwanese experts were involved in organizing the international seminar in Brazil that took place in Florianopolis in April 2011. This seminar was instrumental in disseminating knowledge of WIM technology and its applications in South America.

4 Update on Research and Applications

The Fiwi project has prepared several documents addressing research and application of WIM as follows: Application of WIM to pavement design, to Bridge design and for direct enforcement.

Application of WIM to pavement design is the most common use for this equipment. Changes in traffic trends can have a significant impact on design life of the infrastructures. It is important to use the best locally available traffic data for pavement design as this data is site specific and it changes over time. WIM sensors can deliver the following:

- Monitoring of trends in traffic
- Significant changes in heavy vehicle allowable limits within particular weight categories
- Increase intensity of use on certain routes
- Development of appropriate lane and distributional factors for multilane facilities

Most systems weighing road vehicles in motion provide all the necessary data to calculate equivalent traffic, Neq. An algorithm can be easily developed to calculate the equivalent number of axles corresponding to the passage of any vehicle.

Depending on the type of pavement failure different types of WIM data can be used. Axle loads are important for traditional design methods as outlined above. However vehicle configuration data can be used in the other methods. Rutting can be addressed by using sensors that give lateral position of the wheel, pressure distribution and tyre width.

The different ways that Weigh-In-Motion (WIM) systems may be used for the enforcement of overloading by heavy road vehicles is also discussed. In Addition, an overview is given on the advantages and disadvantages of each of these applications.

Then a short analysis is given of the many aspects of the overloading problem. An enforcement model is discussed consisting of an intelligent mix of different enforcement methods supported by modern (WIM) technology. Finally it is shown how the number of applications of a WIM-system may be increased by adding components to the system.

One of the tasks of the FiWi-project was to create a European data-base with Weigh-In-Motion information. The purpose of the data-base is to increase the use of WIM data by facilitating the international exchange of WIM-data. By showing what data is measured by WIM systems and is available around Europe, as follows:

- facilitate the exchange of WIM data between road directorates and other providers of data;
- facilitate international research with a need for accurate WIM-data, e.g. research on pavement or bridge loading, road transport;
- increase awareness of the availability and possibilities of WIM-data and hopefully generate additional interest in this information.

At the time this report was written, the chapter on application of WIM to bridge design was not complete.

Appendix

I Appendix European Standard on WIM, version 2010/1

Version 2010/1

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

pr**EN (NN nnnnn)**

ICS
Descriptors

English version

Weigh-in-Motion of Road Vehicles

Pesage en marche des véhicules routiers

Wägung von Fahrzeugen während dem Fahrt

This draft European standard is submitted to CEN members for public enquiry. It has been drawn up by the COST323 Management Committee (COST323 European Specification on WIM, 1999) and by the FiWi (FEHRL institutes WIM initiative) members.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat of CEN has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

January 25, 2010

CEN

European Committee for Standardisation
Comité Européen de Normalisation Europäisches Komitee für Normung

Central Secretariat : rue de Stassart 36, B-1050 Brussels

Ref. no. xxxxxxxx

CONTENTS

Foreword

This European Standard has been prepared by the FiWi (FEHRL institutes WIM initiative) working group and is based on the European Specification on WIM of Road Vehicles (COST323, 1999) published in 1999 by the COST323 Management Committee. The statistical background may be found in (Jacob, 2002) and the technical references in (Jacob et al., 2002).

This standard was prepared to deal with aspects related to:

- Simplified requirements (Part I)
- General requirements (Part II), split into:
  - Site selection (chapters 4 and 5);
  - Accuracy classification (chapter 6);
  - System calibration and testing (chapters 7 to 11).

WIM systems used for trade are dealt with in the OIML recommendations R134-1 and R134-2. These OIML recommendations apply to WIM systems installed in controlled weighing areas, on a specified apron and where the vehicle speed is controlled. They mainly apply to WIM systems composed of scales, which are capable of weighing standard masses statically. The OIML recommendations are limited to the highest accuracy classes (0.2 to 10), with tolerances for 100% of the measurements.

This standard applies to any WIM system, which may be installed either in a controlled weighing area, or on a road open to traffic. These systems may use strip sensors and bridge WIM.

This standard covers type approval testing, initial and in service testing.

This standard specifies the required performance and ability of WIM systems in general, but does not aim to standardise products.

Part I provides simplified and minimum requirements of practical use for common users.
Part II is recommended for advanced users, scientific investigations of WIM systems, and to accommodate non standard test plans.

The informative annexes I, II, III and IV provide respectively:

- comparison with the OIML R134-1 international recommendation,
- guidelines for system calibration,
- guidelines for data and test result presentation, and computer tools for accuracy assessment,
- comments and explanations of the main clauses.

Keywords

Traffic, Loads, Pavement, Vehicle, Gross Vehicle Weight, GVW, Axle, Weigh-In-Motion, WIM, Sensors, WIM Systems, Calibration, Data Acceptance, System Acceptance, Traffic Data, WIM Standard.

1. Scope

1.1. This standard specifies the requirements for installation, calibration, performance and accuracy assessment, and test methods for Weigh-in-Motion (WIM) systems, that are used to determine gross weights, axle and group-of-axle loads for road vehicles when they are weighed in motion.

1.2. This standard applies to:

1.2.1. WIM systems installed on road infrastructure (including bridges), but not to the WIM systems installed on-board of vehicles;

1.2.2. high speed WIM (HS-WIM) systems, i.e., systems installed in one or more traffic lane(s) of a road, and operated automatically under normal traffic conditions, and to low speed WIM (LS-WIM) systems, i.e., systems installed in a controlled weighing area, and operated under controlled conditions;

1.2.3. WIM systems using either scales which are able to weigh standard masses statically, or other sensors which may measure the loads indirectly;

1.2.5. on-site full WIM system performance assessment and model (type) approval, but excludes laboratory (product) tests or tests on parts of systems (e.g. sensors only).

1.6. The scope of this standard covers all WIM applications, except trade.

NOTE: For load enforcement of road vehicles, this standard or the OIML (International Organisation for Legal Metrology) international recommendation R 134-1 and 134-2 (OIML, 2004 & 2006) may be applied, depending on the national requirements and legislation.

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2. Normative References

ISO 3534-1 (1993), Statistics - Vocabulary and symbols - Part 1: Probability and general statistical terms.

ISO 3534-2 (1993), Statistics - Vocabulary and symbols - Part 2: Statistical quality control.

ISO/IEC (2007), Guide 99: Vocabulary of International Metrology (VIM).

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

OIML R134-2 (2004), International Recommendation: Automatic instruments for weighing road vehicles in motion. Total vehicle weighing, Part 2: Test Report Format.

3. Terminology, Symbols and Abbreviations

The main terms used in this document are listed here. Some additional terms used in this document are defined in the ***Glossary of terms*** of the COST323 final report (Jacob et al., 2002).

3.1. Definitions taken from the Vocabulary of International Metrology

3.1.0. Quantity: property of a phenomenon, body, or substance, to which a magnitude can be assigned.

Measurement

3.1.1. Measurement : process of experimentally obtaining information about the magnitude of a quantity.

3.1.2. Measurand: quantity intended to be measured.

3.1.3. Measurement method/procedure: generic description of a logical sequence of operations used in a measurement / detailed description of a measurement according to one or more measurement principles and to a given measurement method.

3.1.4. Measurement result: information about the magnitude of a quantity, obtained experimentally.

3.1.5. Measurement uncertainty: parameter that characterizes the dispersion of the quantity values that are being attributed to a measurand, based on the information used.

3.1.6. Standard (measurement) uncertainty: measurement uncertainty expressed as a standard deviation.

3.1.7. Calibration :(a) operation establishing the relation between quantity values provided by measurement standards (French "étalon") and the corresponding indications of a measuring system, carried out under specified conditions and including evaluation of measurement uncertainty; or

(b) operation that establishes the relation, obtained by reference to one or more measurement standards (French "étalon"), that exists under specified conditions, between the indication of a measuring system and the measurement result that would be obtained using the measuring system.

3.1.8. (Metrological) traceability: property of a measurement result relating the result to a stated metrological reference through an unbroken chain of calibrations of a measuring system or comparisons, each contributing to the stated measurement uncertainty

3.1.9. Verification: confirmation through examination of a given item and provision of objective evidence that it fulfils specified requirements.

3.1.10. Influence quantity: quantity which, in a direct measurement, is neither the measurand nor the quantity being measured, but whose change affects the relation between the indication of the measuring system and the measurement result.

3.1.11. Correction: modification applied to a quantity value obtained from measurement, to compensate for a systematic effect.

3.1.12. (Measurement) Precision : closeness of agreement between quantity values obtained by replicate measurements of a quantity, under specified conditions.

Devices for measurement

3.1.13. Measuring instrument: device or combination of devices designed for measurement of quantities.

3.1.14. Measuring transducer: device that provides at its output a quantity having a determined relation to the quantity at its input.

3.1.15. Measuring system: set of measuring instruments and other devices or substances assembled and adapted to the measurement of quantities of specified kinds within specified intervals of values.

3.1.16. Sensor: element of a measuring system that is directly affected by the phenomenon, body, or substance carrying the quantity to be measured.

3.1.17. Detector: device or substance that indicates the presence of a phenomenon, body, or substance when a threshold value of an associated quantity is exceeded.

3.1.18. Adjustment : set of operations carried out on a measuring system in order that it provide prescribed indications corresponding to given values of the quantity to be measured.

Characteristics of measuring system

3.1.19. Measuring interval: set of values of the quantities of the same kind that can be measured by a given measuring system, with specified measurement uncertainty under defined conditions.

3.1.20. Steady state condition: operating condition of a measuring system in which the possible variation with time of the quantity being measured is such that a calibration of the measuring system carried out with a measurand constant with time remains valid.

3.1.21. Rated operating condition: condition that must be fulfilled during measurement in order that a measuring system perform as designed.

3.1.22. Limiting condition: extreme condition that a measuring system is required to withstand without damage, and without degradation of specified metrological characteristics when it is subsequently operated under its rated operating conditions.

3.1.23. Reference condition: condition of use prescribed for evaluating the performance of a measuring system or for comparison of measurement results.

3.1.24. Resolution: smallest change, in the value of a quantity being measured by a measuring system, that causes a perceptible change in the corresponding indication.

3.1.25. Stability: ability of a measuring system to maintain its metrological characteristics constant with time.

3.1.26. Drift: change in the indication of a measuring system, generally slow and continuous, related neither to a change in the quantity being measured nor to a change of an influence quantity.

3.1.27. Instrumental uncertainty: component of measurement uncertainty attributed to a measuring instrument and determined by its calibration.

3.1.28. Accuracy class: class of measuring instruments that meet stated metrological requirements which are intended to keep instrumental uncertainty within specified limits under specified operating conditions; or

class of measuring instruments that meet stated metrological requirements which are intended to keep errors (3.1.40) within specified limits under specified operating conditions.

3.1.29. True value (of a quantity): quantity value consistent with the definition of a quantity. Also an accepted reference to which a measurement (result) is compared to assess an error.

3.1.30. Accuracy of a measurement: closeness of agreement between a quantity value obtained by measurement and the true value of the measurand.

Accuracy of a measuring system: ability of a measuring system to provide a quantity value close to the true value of a measurand.

3.1.31. Trueness: closeness of agreement between the average that would ensue from an infinite number of quantity values obtained under specified measurement conditions and the true value of the measurand.

3.1.32. Error: difference of quantity value obtained by measurement and true value of the measurand.

3.1.33. Random error: difference of quantity value obtained by measurement and average that would ensue from an infinite number of replicated measurements of the same measurand carried out under repeatability conditions.

3.1.34. Systematic error: difference of average that would ensue from an infinite number of replicated measurements of the same measurand carried out under repeatability conditions and true value of the measurand.

3.1.35. Maximum permissible error: one of the two extreme values of the error permitted by specifications or regulations for a given measuring system.

3.1.36. Intrinsic error (of a measuring system): error of indication when determined under reference conditions.

3.1.37. Bias (of a measuring system): systematic error of indication of a measuring system

3.2. Specific statistical and metrological definitions

3.2.1. Confidence interval: interval which contains the true value of a quantity value represented by a random variable, with a given probability, π, or a minimum required probability π_0.

3.2.2. Confidence level: probability, π, that an interval contains the true value of a quantity value represented by a random variable.

3.2.3. Tolerance – tolerance interval: width of an interval (δ) in which an error must lie with a minimum required probability. $[-\delta;+\delta]$ is called the tolerance interval.

3.2.4. Outlier(s): value(s) in a series of measurement results of a given quantity value which has(ve) a much lower probability of occurrence than expected according to the sample size and distribution; an outlier is suspected of being an erroneous measurement, and may be eliminated under certain conditions.

3.2.5. Performance or acceptance test: test to determine whether an equipment is capable of performing its specified functions or meet a given accuracy class under specified operating conditions.

3.2.6. Correction factor: a numerical factor by which a quantity value obtained from measurement is multiplied, to compensate for a systematic effect.

3.2.7. Calibration factor: a numerical factor by which a quantity value obtained from measurement is multiplied, to fit a true value..

3.3. Definitions related to vehicles

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

3.3.2. Wheelbase: distance between the first and last axle of a vehicle, a portion of vehicle or a bogie or group of axles (3.3.8).

3.3.3. Single axle: axle that is spaced more than 2.2 m from its nearest neighbouring axle of the same vehicle, unless an alternative definition is agreed [1].

3.3.4. Group of axles: a set of axles on the same vehicle spaced, each from the next one, less than 2.2 m, centre to centre, unless an alternative definition is agreed [2].

3.3.5. Tandem axle: group of two axles, with a wheelbase less than the value specified in 3.3.4.

3.3.6. Tridem axle: group of three axles, with wheelbases less than the value specified in 3.3.4.

3.3.7. Axle of a group: one axle of a vehicle that belongs to a group of axles (see 3.3.4).

3.3.8. Gross vehicle weight (GVW): a force due only to the external force of gravity acting vertically downward on the total mass of a vehicle, including all connected components; its magnitude is the total vehicle mass multiplied by the acceleration due to gravity ($g=9.81\ m/s^2$).

3.3.9. Wheel load: the portion of the gross weight imposed upon the weighing device by the tyre(s) of a stationary wheel at the time of weighing, expressed in units of mass, due only to the vertically downward force of gravity acting on the mass of the static vehicle.

3.3.10. Axle load: sum of all the wheel loads of an axle of a vehicle.

3.3.11. Axle group load: sum of all the axle loads of the axles which belong to a group of axles (see 3.3.4).

3.3.12. Dynamic (impact) tyre force: the component of the time-varying force applied perpendicular to the road surface by the tyre(s) of a wheel of a moving vehicle.

3.3.13. Dynamic (impact) wheel/axle/group of axles/vehicle force: force applied to the pavement by the moving tyre(s) of a wheel/axle/group of axles/vehicle. For the purposes of this standard, the WIM system shall be adjusted or calibrated to indicate the magnitude of the vertically downward, measured dynamic forces in units of mass. The indicated mass shall be converted to units of force by multiplying it by the acceleration due to gravity: $g=9.81\ m/s^2$.

3.3.14. Impact factor: ratio of an impact force to the corresponding wheel/axle/group of axles load or gross vehicle weight.

3.3.15. Reference (or test) vehicle: vehicle which has accepted true values of the quantities to be measured, e.g. axle loads, gross weight, axle spacing, length. Axle loads and gross weight may be measured statically on approved scales.

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[1] In vehicle engineering, a single axle is an axle not linked to another axle by a common suspension.

[2] In vehicle engineering, a tandem (resp. tridem) axle is a set of two (resp. three) axles linked by a common suspension.

3.4. Definitions related to WIM systems

3.4.1. Wheel load scale (wheel load weigher): a device on which the whole wheel imprint is applied and which measures a wheel load.

3.4.2. Axle load scale (axle load weigher): a device on which all the wheel imprints of an axle are applied at once and which measures the combined wheel loads of an axle. If verified to appropriately small maximum permissible errors in relation to the intended tolerance of a WIM system, it may be used for generating static axle load reference values.

3.4.3. Weigh-bridge: a weighing device on which a complete stationary vehicle may be weighed at once. If verified to appropriately small maximum permissible errors in relation to the intended tolerance of a WIM system, it may be used for generating gross weight reference values.

3.4.4. Strip sensor: sensor installed perpendicular to the direction of travel of a road, with a longitudinal extent (in the traffic direction) of a few centimetres, but smaller than a tyre imprint length.

3.4.5. Weigh-In-Motion (WIM): process of estimating the gross weight of a moving vehicle, and the portion of that weight that is carried by each of its wheels or axles, by measurement and analysis of dynamic vehicle tyre forces.

3.4.6. Weigh-In-Motion system (station): set of mounted sensor(s) and electronics with software which measures dynamic vehicle tyre forces and vehicle presence of a moving vehicle with respect to time and provides data for calculating wheel and/or axle load and gross weight estimates, as well as other parameters such as speed, axle spacing and silhouettes.

3.4.7. Bridge WIM (B-WIM): WIM using an instrumented bridge as a axle or vehicle scale; the strains measured in some of the bridge elements are used to estimate, through software, the gross weights and axle loads of a vehicle crossing the bridge.

3.4.8. Low Speed WIM (LS-WIM): weighing a (generally slowly) moving vehicle, on a specific area usually outside the traffic flow, on a horizontal, straight, and even pavement surface under controlled conditions, such as constant and limited speed (e.g. ≤ 10 or 15 km/h) in order to minimise dynamic effects.

3.4.9. High Speed WIM (HS-WIM): weighing a vehicle in motion in the traffic flow, at its actual speed.

3.5. List of Symbols and Abbreviations

3.5.1. Symbols

A(5), B+(7), B(10), C(15), D+(20), D(25), E(30)…: main accuracy classes for WIM systems (see chapter 6).

δ : tolerance for a given quantity; $[-\delta;\delta]$ is a tolerance interval. δ concerns relative errors and is expressed as a %.

δ_c : tolerance (in %) of a gross vehicle weight, which defines the accuracy classes (see chapter 6).

δ_{min} : minimum tolerance (in %) which ensures, for a given sample and specified test conditions, that an individual random error lies in the tolerance interval $[-\delta_{min};\delta_{min}]$ with a minimum required probability π_0.

m : sample mean of individual relative errors.

n : sample size of a set of individual relative errors.

π : probability that an individual random error lies in a tolerance interval; or probability that a confidence interval contains a true value of a quantity.

π_0 : minimum required probability π.

E1, E2, E3: environmental repeatability and reproducibility test conditions (see chapter 7).

R1, R2, R3, R4: sample repeatability and reproducibility test conditions (see chapter 7).

s : sample standard deviation of individual relative errors.

V_m: mean traffic speed.

W : Measured load (may be a vehicle gross weight, an axle load or a group-of-axles load).

W_s, : Static or reference load (of a vehicle, an axle load or a group of axles).

W_d : In-motion or dynamic (measured by a WIM system) load (of a vehicle, an axle load or a group of axles).

x, x_i : individual relative errors in a set of measurements; $x = 100*(W_d - W_s)/W_s$ (in %).

3.5.2. Abbreviations

APL: Analyseur de Profil en Long, the APL index which gives an account of the pavement profile consists of 3 ratings, in short, medium and long wavelengths.

IRI: International Roughness Index; give an account of the pavement profile unevenness; higher the index, rougher the pavement.

ISWIM: International Society for Weigh in motion.

WIM: Weigh in motion.

B-WIM: bridge weigh in motion.

HS-WIM: high speed weigh in motion.

LS-WIM: low speed weigh in motion.

MS-WIM: multiple sensor weigh in motion.

PART I - Simplified Requirements

The section numbers of this part I corresponds to the chapter numbers of the part II as far as they concern the same topics. E.g. the section I.4 corresponds to chapter 4 of the part II, etc. While this part I is a simplified version of the part II, references are made to the part II were applicable.

I.4. WIM Sites

The site classification is given in the part II, chapter 4.

NOTE: It is neither mandatory to use a specified class of WIM site, nor to use the site classification. However, if users or suppliers want to specify or to refer to a site class, they shall use the standardized site classification given in chapter 4.

I.5. Operating Conditions and Environmental Requirements

A WIM system specification should contain a description of its rated operating conditions consisting at least of ranges for:

- Traffic intensity;
- Vehicle speeds;
- Temperature;
- Humidity;
- Electromagnetic conditions;
- Mechanical condition.

I.5.1. Traffic intensity range consists of the minimum (zero by default) and maximum numbers of heavy vehicles that can be recorded by the WIM system per hour and per day.

I.5.2. Speed range extends from the minimum to the maximum speed of passing vehicles.

I.5.3. The supplier must specify the maximum and minimum ambient temperature in which its system will operate with its claimed performance. It should be specified whether the WIM system is designed for condensing or non-condensing humidity.

I.5.4. One of three electromagnetic environment classifications should be specified as described below:

- EM1, locations with electromagnetic disturbances corresponding to those likely to be found in residential, commercial and light industrial buildings;
- EM2, locations with electromagnetic disturbances corresponding to those in other industrial buildings or roadside locations;
- EM3, locations where the electrical power is supplied by a battery of a car or a generator with possible sudden peaks or reduction in the power supply.

I.5.5. One of three mechanical condition classifications should be specified as described below:

- M1, locations with vibrations and shocks of low significance, e.g., office conditions;
- M2, locations with significant levels of vibration and shock, e.g., road side conditions with passing vehicles;
- M3, locations with high levels of vibration and shocks, e.g. equipment directly mounted on machines or vehicles.

I.5.6. A vehicle record made by a WIM system shall contain at least:

- Unique registration number
- Location
- Traffic lane and direction
- Date and time stamp (yy-mm-dd + hh:mm:ss:cc)
- Axle loads
- Gross vehicle weight
- Numbers of axles and axle distances (centre to centre)
- Wheelbase
- Vehicle Length (not mandatory, if possible)
- Vehicle speed
- Vehicle class according to a specified system (e.g. as in the Annex IV, AIV-12).

I. 6. Accuracy Class Tolerances

I.6.1. The accuracy of a WIM system is defined by a tolerance δ such that, for each criterion (single axle load, axle of a group, group of axles and gross weight), the probability that an individual measured value *W* falls in the tolerance interval [W_s(1-δ);W_s(1+δ)], is greater or equal to **95%** (level of confidence). W_s is the true value, i.e., the corresponding static load, or other accepted reference value.

NOTE: if an individual value *W* is measured, the associated 95% confidence interval is [*W*/(1+δ);*W*/(1-δ)], i.e. this interval contains the true value W_s with a probability ≥ 95%.

E.g.: For a tolerance δ of 10% (gross weight in accuracy class B(10)), the probability (before the measurement) that an individual measurement *W* falls in the tolerance interval [0.9W_s;1.1W_s] is 95%. After an individual measurement which gives a result *W*, and if W_s is unknown, the 95% confidence interval [0.909*W*;1.111*W*] can be found, which contains W_s with a probability of 95%. This interval is not centred on *W*.

I.6.2. Accuracy Classes

An accuracy class is named by the tolerance $δ_c$ for the gross weight. The main accuracy classes are named also by letters: A(5), B+(7), B(10), C(15), D+(20), D(25), E(30), E(35), etc.

The tolerances δ for each accuracy class and criterion are given in Table a.

Criterion (type of measurement)	Accuracy Classes : Tolerance interval width δ (%)										
	A(5)	**B+(7)**	**B(10)**	**C(15)**	**D+(20)**	**D(25)**	**E(30)**	**E(35)**	**E(40)**	**E(45)**	**E(50)**
1. Gross weight ($δ_c$)	5	7	10	15	20	25	30	35	40	45	50
2. Group of axles	7	10	13	18	23	28	33	39	44	49	55
3. Single axle	8	11	15	20	25	30	36	42	48	54	60
4. Axle of a group	10	14	20	25	30	35	41	47	53	59	65

Table a : Tolerances of the accuracy classes (δ in %)

The accuracy class of any WIM system is the lowest class obtained for all the relevant criteria.

If a WIM system does not provide axle of group loads, the accuracy requirements for this axles do not apply, and it shall be explicitly mentioned.

NOTE: It is allowed to use intermediate classes such as A(1), A(2)…, B(11), B(12)… where the tolerance on the gross weight is given in parentheses as an integer. The corresponding tolerances for the other criteria are interpolated as explained in the Part II, section 6.2.4.

The WIM system shall meet all requirements specified in this standard for the range of axle and gross vehicle weights listed in Table b. The scale divisions for axle and gross weights shall not be greater than those listed in Table c.

Weighing interval	Min (kg)	Max (kg)
Axle loads	1000	20 000
Vehicle weights	3500	100 000

Table b. Measurement intervals

Class	A(5)	B(10)	C(15)	D(25)	E(30)
Axle loads	20	50	100	200	200
Vehicle weights	50	100	200	500	500

Table c. Maximum scale divisions

I.6.3. Other tolerances

The minimum rate of detection (percentage of vehicle detected by the system) is 90% [3].

A registration is complete if all the quantities listed in I.5.6 are recorded. The minimum rate of complete registration is 80%.

The tolerance on the axle spacing is 20% with a maximum error of 0.3 m, and on the wheelbase is 10% with a maximum error of 1 m. These criteria, for both axle spacing and wheelbase, apply for a minimum of 95% of the measurement.

I.7. On Site System Checks, Calibration and Test Condition

I.7.1. A newly developed WIM system shall pass a type (model) approval before it can be claimed to be capable of achieving a specified accuracy (see I.8 and Part II chapter 8).
A newly installed WIM system, or a modified WIM system, shall pass an initial verification (see I.9.1 and Part II chapter 9), if the supplier or user wishes to claim any accuracy of its data, or to fulfil a contractual agreement on the accuracy between the vendor and the client.

Any WIM system shall periodically pass an in-service verification (see I.9.2 and Part II chapter 10) if the user wishes to claim any accuracy of its data over time.

NOTE: In any case initial and in-service verifications are highly recommended.

I.7.2. Calibration Methods

NOTES:

1. It is recommended to calibrate any WIM system prior to a type approval or an initial verification test.
2. There are various calibration methods for WIM systems which may be used, separately or combined, depending on the users' requirements and means, which are described in Part II, section 7.2.

I.7.3. Definitions of Test Conditions

Depending on the environmental (climatic) conditions and the sample of reference vehicles used for a test, the test repeatability or reproducibility conditions are defined as follows.

NOTE: The minimum required conditions depend on the accuracy class to be assessed and are specified in section I.10.2.

[3] It does not mean that any detected vehicles can be eliminated from a sample, up to 10% of the sample size !

I.7.3.1. Environmental conditions

(E1) Limited environmental variations (environmental repeatability): the test is carried out over a couple of hours, a day or a few consecutive days, such that the temperature, climatic and environmental conditions do not vary significantly during the measurements;

(E2) Extended environmental variations (limited environmental reproducibility): the test time period extends at least over a full week or several days spread over a month, such that the temperature, climatic and environmental conditions vary during the measurements, but no seasonal effect has to be considered;

(E3) Full environmental variations (full environmental reproducibility): the test time period extends over a whole year or more, or at least over several days spread all over a year, such that the temperature, climatic and environmental conditions vary during the measurements and all the site seasonal conditions are encountered.

I.7.3.2. Vehicle Sample conditions

(R1) Minimum or no reference vehicle variation (full repeatability conditions): only one vehicle passes several times at the same speed, the same load and the same lateral position;

(R2) One reference vehicle with variations (extended repeatability conditions): only one vehicle but it passes several times at different speeds (according to the traffic lane conditions), different loads (e.g. fully loaded, half-loaded and empty), and with small lateral position variations (according to the real traffic paths);

(R3) Small set of reference vehicles (limited reproducibility conditions): a small set of vehicles (typically 2 to 10), representative of the whole traffic composition expected on the site (silhouettes and gross weights), is used, each of them passing several times, at different speeds, different loads, and with small variations in lateral position;

(R4) Large set of reference vehicles from the traffic flow (full reproducibility conditions): a large sample of vehicles (i.e. some tens to a few hundred) taken from the traffic flow and representative of it, pass on the WIM system and are statically weighed before or after it.

I.7.4. Minimum Required Test Conditions

Minimum test conditions are required, combining environmental and sampling conditions (section I.7.3.2), according to the accuracy class to be assessed as shown in Table d. The choice of the reference vehicles should be based on the most common types in the traffic flow or the target vehicles of the user. The bogie axles should be equipped, as far as possible, with air suspensions, in order to minimise gross errors in the static reference axle loads.

Accuracy class	**A or B+**	**B**	**C**	**D+ or D**	**E**
Type Approval Test	R4 & E3 (200)	R4 & E3 (200)	R3 or R4 & E2 (60)	R3 or R4 & E2 (60)	R2 toR4 & E2
Initial verification	R3 or R4 & E2 (60)	R2 to R4 & E1 (30)	R2 to R4 & E1 (30)	R1 & E1 (10)	R1 & E1 (10)
In-service verification	R3 or R4 & E2 (60)	R2 to R4 & E1 (30)	R2 to R4 & E1 (30)	R1 & E1 (10)	R1 & E1 (10)

R2 : two significantly different loads (≥15 runs/load) and various speeds
R3 : two vehicles and one load per vehicle (≥ 15 runs/ vehicle) if R2 to R4, or 3 vehicles and 2 significantly different loads per vehicles (10 runs/vehicle and load case) if R3 or R4.

Table d. Minimum required test conditions per accuracy class (in brackets, minimum number of runs)

NOTE: Any increase in the test conditions (sample or environmental), is accepted.

I.8. Type (Model) Approval

NOTE: This section will be developed in a later version of this standard, based on a European reference test for type approval.

I.9. Initial and In-Service Verifications of a WIM System

I.9.1. Initial Verification

After installation, modifications, repair or part replacement, a WIM system must be (re)calibrated. At that point, an initial verification is required if an accuracy class for the system is to be claimed. For such a verification [4], the tolerances given in Table a (I.6.2) are reduced by a multiplicative factor $k = 0.8$.

I.9.2. In-Service Verification

If the system is checked using repeated runs of reference vehicles during its operation life [5], the tolerances given in the Table a are used.

I.10. Procedure to Check the Accuracy of a WIM System by testing.

I.10.1. General Rules

This section specifies the accuracy assessment of a WIM system while in situ testing, using either repeated runs of reference vehicles, and/or the use of single runs of reference vehicles from the traffic flow.

Reference vehicles shall be pre- or post-weighed on an approved static scale, weigh-bridge or low speed WIM system. The clauses of Part II section 6.3 apply. The standard deviations of the static axle loads, based on repeated weighings of the same vehicle, shall be less than 1/3 of those measured in motion.

Minimum test conditions are required with respect to the accuracy class to be assessed, as described in section I.10.2. However, vendors and users may agree to use more extensive test plans than the minimum required. If some tests are carried out with a test plan below the minimum required, the obtained accuracy class cannot be claimed with respect to this standard.

Some examples of test plans are given in appendix A, § I.A.1.

I.10.2. Confidence Level

The confidence level of the interval defined in I.6.1 is 95%.

I-10.3 Test Results Analysis

I.10.3.1. Any system failure or malfunction shall be reported.

I.10.3.2. Before the analysis, the numbers *n* of recorded gross weights, groups of axles, single axles and axles of a group must be counted. The number of gross weights should be equal to or exceed the value specified in the test plan.

I.10.3.3. The outliers properly identified by relevant statistical tests shall be accounted for and counted as missing data after elimination, if agreed with the users.

[4] E.g. if the same data is used for the (re)calibration and accuracy classification, which is NOT recommended
[5] The data used for accuracy classification being different from that used for (re)calibration

I.10.3.4. It is highly recommended to check that the results are Normally distributed (e.g. follow a Gaussian law), both because non-Normality often reveals some dysfunction, and because the Normality is assumed for the accuracy class acceptance procedure.

I.10.3.5. The procedure for assessing WIM system accuracy is described below:

1. For each entity (gross weight, single axle, group of axles and axles of a group) the individual relative errors with respect to the static load (weight) or the accepted reference values are calculated:

$$x_i = \frac{W_{di} - W_{si}}{W_{si}} * 100 \text{ (in\%)}$$

where W_{di} and W_{si} are the in-motion measured value and the static (reference) values respectively.

2. The sample statistics: number *n*, mean *m* and standard deviation *s*, of each sub-population of x_i (same entity) are calculated.

3. For each criterion (gross weight, group of axle, single axle, axle of a group), the tolerance δ of the proposed accuracy class is taken from Table a (for an initial verification, δ is replaced by *k*.δ - clause I.9.1). Then a statistical procedure agreed between the involved parties shall be applied to assess the proposed accuracy class. Three alternative recommended procedures are given in appendix B.

I.10.4. Decision Procedures (Not mandatory)

Some decision procedures are given in appendix B. They use the sample statistics of the test results (I.10.3.5) and the tolerance of the accuracy class to be assessed for each criterion.

Appendix A (Informative)

I.A.1. Examples of standardized Test Plans (see § I.7.4, table e)

Test plan N°1 - One lorry, one load, 10 runs, sample conditions (R1)

The lorry shall be chosen from the target group, generally the one with the most common silhouette encountered on the WIM site. It is recommended that it has both single axle(s) and bogie axles. The lorry shall be loaded either to the mean gross weight of the same type of vehicles in the traffic flow, or to 80% of its maximum allowed gross weight. The test is carried out within a single day, in environmental condition (E1).

Reference vehicle	**Speed**	**Number of runs**	
Representative of the traffic	1.2.Vm	2	--
	Vm	6	*7*
	0.8.Vm	2	*3*

Vm : mean lorry speed in the traffic flow - *last column, only if 1.2.Vm exceeds the speed limit.*

Test plan N°2 – One lorry, two loads, 30 runs, sample conditions (R2)

The lorry shall be chosen from the target group, generally the one with the most common silhouette encountered on the WIM site. It is recommended that it has both single axle(s) and bogie axles. The test is carried out within a single day, in environmental condition (E1).

Reference vehicle	**Speed**	**Load cases and number of runs**			
		fully loaded		half loaded	
Representative of the traffic	1.2.Vm	3	--	3	--
	Vm	9	*10*	9	*10*
	0.8.Vm	3	*5*	3	*5*

Vm : mean lorry speed in the traffic flow - *last column, only if 1.2.Vm exceeds the speed limit.*

Test plan N°3 - Two lorries, two loads per lorry, 60 runs, sample conditions (R1)

2 lorries representative of the traffic on the WIM site are used. One shall be a rigid lorry and the other a an articulated (tractor with semi-trailer) or a combination of a rigid lorry and a trailer. At least one of these vehicles shall have a bogie axle (tandem or tridem). The test is carried out within one to three consecutive days but under the same climatic conditions, in sample conditions (E2). The assessed level of confidence will be 94.2% instead of the 95% commonly used.

Reference vehicle	**Speed**	**Loading and number of runs**			
		fully loaded		half loaded	
Rigid	1.2.Vm	5	--	3	--
	Vm	8	*12*	6	*8*
	0.8.Vm	5	*6*	3	*4*
Articulated or combination	1.2.Vm	5	--	3	--
	Vm	8	*12*	6	*8*
	0.8.Vm	5	*6*	3	*4*

Vm : mean lorry speed in the traffic flow - *last column, only if 1.2.Vm exceeds the speed limit.*

Test plan N°4 - Four lorries, 120 runs, sample conditions (R3)

4 lorries, representative of the traffic flow. The test shall be carried out over a year, i.e. at least three periods of 1-2 days in the coldest, hottest and medium season, i.e. in environmental conditions E3. The sample conditions are (R3).

Reference vehicle	Speed	Total no. runs	Breakdown in nos. of runs	
2 axle rigid	1.2.Vm Vm 0.8.Vm	25	6 13 6	-- *17* *8*
3 or 4 axle rigid	1.2.Vm Vm 0.8.Vm	15	4 7 4	-- *7* *3*
Tractor with semi-trailer	1.2.Vm Vm 0.8.Vm	60	15 30 15	-- *40* *20*
Lorry with trailer	1.2.Vm Vm 0.8.Vm	15	4 7 4	-- *7* *3*

Vm = 75 km/h for high speed WIM systems, mean operating speed for low speed WIM systems - *last column, only if 1.2.Vm exceeds the speed limit.*

I.A.2. Charts for Acceptance Tests

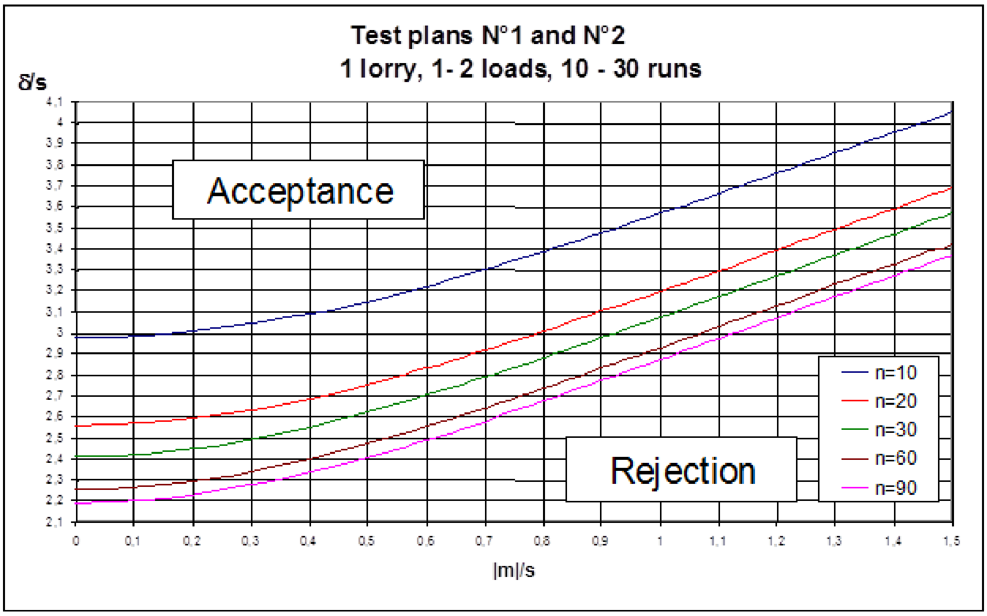

Figure I.1 - Chart of acceptance (Test plans N°1 and 2, level of confidence 95%)

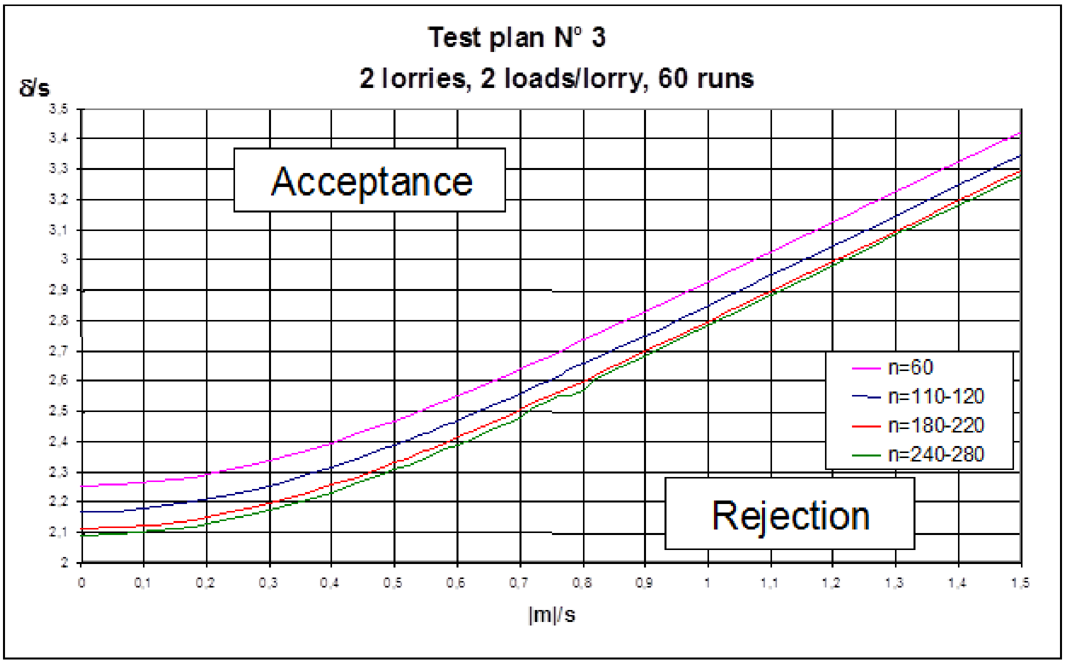

Figure I.2 - Chart of acceptance (Test plan N° 3, level of confidence 95%)

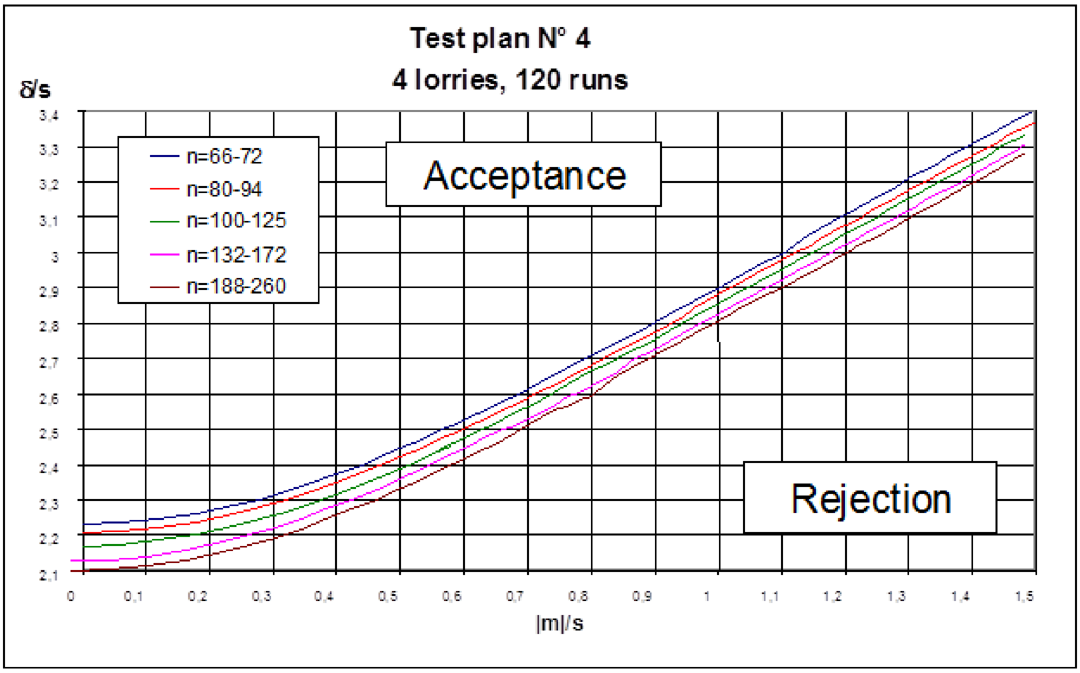

Figure I.3 - Chart of acceptance (Test plan N° 4, level of confidence 95%)

Appendix B (Informative)

I.B.1. Approximate analytical Formula

I.B.1.1. Parabolic-linear Formula

The tolerance, *d*, of the test data is given by:

if $0 \leq |m|/s \leq 0.5$ $d = 0.8\, m^2/s + (2 + 5.2\, n^{-0.735})\, s$
if $0.5 \leq |m|/s$ $d = a(n)\, |m| + b(n)\, s$ where a(n) and b(n) are given in Table e.

I.B.1.2. Tri-linear Formula

The tolerance, *d*, of the test data is given by:

if $0 \leq |m|/s < 0.2$ $d = q(n)\, s$
if $0.2 \leq |m|/s < 0.5$ $d = 0.55\, |m| + c(n)\, s$
if $0.5 \leq |m|/s$ $d = a(n)\, |m| + b(n)\, s$ $(\approx |m| + b(n) s)$
where the coefficients are given in Table e.

In both cases (I.B.1.1 and I.B.1.2), if $d \leq \delta$ (or $k.\delta$ as appropriate) the accuracy class is accepted; otherwise it is rejected, and *d* is compared with the tolerance of a lower class.

n	10	20	30	60	90	110	145	200
a(n)	0.90	0.92	0.94	0.96	0.97	0.98	0.99	1.00
b(n)	2.70	2.30	2.15	1.98	1.91	1.87	1.84	1.80
c(n)	2,88	2,51	2,35	2,17	2,11	2,09	2,05	2,03
q(n)	2,99	2,61	2,46	2,29	2,22	2,20	2,17	2,14

These coefficients may be interpolated for other values of n.

Table e. Tabulated values of a(n), b(n), c(n) and q(n)

I.B.2. Use of Charts

$|m|/s$ and δ/s are calculated, and the point of coordinates ($|m|/s$, δ/s) is plotted in the chart diagram of the applied test plan, as given in appendix A, § I.A.2, Figures I.1 to I.3. If the point is above the curve associated with n, the accuracy class is accepted, otherwise it is rejected, and the test may be repeated with a higher value of δ, i.e. a lower accuracy class.
For the values of n which do not correspond to a curve, the curve may be found by interpolation.

I.B.3. Exact Formula

The formula (10.1) of clause 10.4.6.1 and the test procedure of clause 10.4.7 of Part II is applied.

NOTE: The Excel sheet attached to this standard allows to easily apply this formula and procedure by entering the statistics n, m and s, and the test conditions (E1 to E3 and R1 to R4). The best accepted accuracy class is automatically calculated for each criterion and for the whole system.
This sheet will be also provided in Open Office Calc, a freeware, as soon as a non linear solver will be fully implemented (it is still in a beta format).

PART II - General Requirements

WIM Sites

4. Site Selection Criteria

The performance of any WIM system depends on the site characteristics: road geometry and road evenness. Three WIM site classes are defined in section 4.3.

4.1. Road Geometry

4.1.1. The road section between 50 m upstream and 25 m downstream of the system shall meet the following geometrical characteristics:

- longitudinal slope < 1% (class I site) or < 2% (other site classes), depending on the site class (see section 4.3) and shall be constant;
- transverse slope < 3%;
- radius of curvature > 1000 m,
- absence of any bumps or other type of sudden local change in slope..

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

4.1.3. Areas where the number of lanes changes shall be avoided.

4.2. Pavement Characteristics

4.2.1. The criteria for rutting, deflection and evenness are given in table 1.

4.2.2. The pavements should also meet the following criteria:

- no hard spots in the underlying courses or under the wearing course (toll slabs, service tunnels, etc.);
- thickness of bonded layers greater than 10 cm;
- good mechanical bonding between courses, in particular of bituminous concrete on granular materials stabilised by hydraulic binders. The sensors must be installed in homogeneous layers, not in a joint;
- surfacing shall be deterioration-free in the area of sensor installation;
- pavement shall be homogeneous across each traffic lane, ruling out the presence of joints of coated materials within the length of a sensor.

4.2.3. Road sensors shall not be installed on a bridge or on any structure subject to dynamic effects, except for Bridge WIM systems (see 4.4).

4.3. WIM Site Classes (not for B-WIM)

To be qualified in one of the classes of Table 1, the pavement of the WIM site shall meet all the relevant criteria of column I, II or III of the class, depending on the pavement type and on the parameter measurement method.

NOTES:

1. Except for Bridge WIM, it is not recommended to install a WIM system on a site which does not meet at least class III specification.

2. The recommended site class/WIM system accuracy pairings, according to the current technology and knowledge, are given in Table IV-1 of annex IV.

			WIM site classes		
			I Excellent	**II Good**	**III Acceptable**
Geometry		Longitudinal slope (%)	≤ 1	≤ 2	≤ 2
		Transverse slope (%)	≤ 3	≤ 3	≤ 3
		Radius of curvature (m)	≥ 1000	≥ 1000	≥ 1000
Deflection (quasi-static) (13,000kg - axle)	Semi-rigid pavements	Mean deflection (10^{-2} mm)	≤ 15	≤ 20	≤ 30
		Left/Right difference (10^{-2} mm)	± 3	± 5	± 10
	All bitumen pavements	Mean deflection (10^{-2} mm)	≤ 20	≤ 35	≤ 50
		Left/Right difference (10^{-2} mm)	± 4	± 8	± 12
	Flexible pavements	Mean deflection (10^{-2} mm)	≤ 30	≤ 50	≤ 75
		Left/Right difference (10^{-2} mm)	± 7	± 10	± 15
Deflection (dynamic) (5,000 kg - load)	Semi-rigid pavements	Deflection (10^{-2} mm)	≤ 10	≤ 15	≤ 20
		Left/Right difference (10^{-2} mm)	± 2	± 4	± 7
	All bitumen pavements	Mean deflection (10^{-2} mm)	≤ 15	≤ 25	≤ 35
		Left/Right difference (10^{-2} mm)	± 3	± 6	± 9
	Flexible pavements	Mean Deflection (10^{-2} mm)	≤ 20	≤ 35	≤ 55
		Left/Right difference (10^{-2} mm)	± 5	± 7	± 10
Rutting (3m beam)		Rut depth max. (mm)	≤ 4	≤ 7	≤ 10
Evenness	IRI(1) index	Index (m/km)	0 - 1.3	1.3 - 2.6	2.6 - 4
	APL(2)	Rating (SW, MW, LW)	9 - 10	7 - 8	5 - 6

The rutting and deflection values are given for a temperature below or equal to 20°C and suitable drainage conditions.

(1) *International Roughness Index*

(2) *The APL (Analyseur de Profil en Long) is a device which measures the longitudinal profile; it consists of two single wheel trailers operating at 72 km/h, towed by a car. The rating quantifies the logarithm of the energy dissipated in one of the wavelength ranges:* SW = *Small Wave-lengths (0.7-2.8 m),* MW = *Medium Wavelengths (2.8-11.3 m),* LW = *Large Wavelengths (11.3-45.2 m). The scale is from 10 (lowest energy, excellent evenness) to 1 (highest energy, poorest pavement surface).*

Table 1 : Classification and criteria of WIM sites

4.4. Particular Requirements for Bridges

4.4.1. B-WIM systems should be installed on structures such as bridges, culverts or any other structure which behaves in a similar way.

4.4.2. Braking or accelerating of vehicles on the structure due to junctions close to the site or any other reason must be avoided since non-constant speed over the structure significantly decreases the accuracy of the calculated weights.

If B-WIM system is installed in location where acceleration, deceleration, stopping or lane changing is possible, then the system should identify results of the vehicles during which measurement any of these events occurred.

4.4.3. Detection of vehicles, axles and their velocity can be done with any type of axle detectors, with strain sensors or with any other device if the results provide sufficiently accurate input for other B-WIM calculations.

4.4.4. A B-WIM System should provide a means to compare the measured and the calculated responses of the bridge to the crossing of a specific vehicle in order to verify the results.

5. Environmental Requirements

5.1. Sensors

5.1.1. Climatic conditions

5.1.1.1. The supplier shall specify the upper temperature limit and the lower temperature limit from any of the values below, and indicate whether the instrument is designed for condensing or non-condensing humidity as well as the intended location for the instrument, i.e. open or closed.
Upper temperature limits: 30°C, 40°C, 55°C, 70°C
Lower temperature limits: -5°C, -10°C, -25°C, -40°C
The specified limits shall comply with the extreme temperatures encountered on site.

5.1.1.2. Salt and water ingress: the sensors must continue to function normally when subject, on a regular basis, to water and salt exposure (in areas where snowfalls and/or ice may occur).

NOTE: If the road structure is not well drained, the deflection may increase after rainfall.

5.1.2. Traffic conditions and mechanical resistance

5.1.2.1. The sensors must survive if they are crossed by tanks (up to 60 t) and other tracked vehicles, or by a deflated tyre. In cold climate areas, the sensors must also survive under studded tyres and snow-clearing devices. This requirement may be waived for portable systems used temporarily over short time periods.

5.1.2.2. The sensors must always remain fixed in place under heavy traffic flow, until their removal or the pavement replacement, for safety reasons. This particularly concerns portable WIM sensors and sensors glued or bonded to the pavement surface.

5.2. Electronics

5.2.1. The electronic devices and components must operate within the temperature limits stated by the supplier as defined in 5.1.1.1.

5.2.2. Relative humidity in the range of 0 to 90% (not condensing) must be supported, unless there is another user specification.

5.2.3. The system and all its parts must be protected against lightning as well as against any external electrical or magnetic field.

NOTE: In any cases, it is better not to install systems under high voltage power line, or close to radio transmission towers and railways tracks.

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Accuracy Classification

6. Accuracy Class Tolerances with Respect to the Weight

6.1. General Clauses

6.1.1. A WIM system must be checked following a well defined procedure or test programme and can then be classified into one of several accuracy classes according to the test results. These accuracy classes are defined with respect to the (static) reference weight; but in some special cases another reference may be adopted, such as independently measured impact forces.

6.1.2. The principle adopted for this classification consists of assessing the tolerance δ , i.e. the width of an interval in which any individual measurement lies, with a minimum specified probability (level of confidence) π_0 chosen by the user.

In order to be checked with a test using reference vehicles (clause 7.2.3), the specified level of confidence π_0 shall depend on the test conditions, i.e. the sample size and the repeatability or reproducibility conditions (see clause 10.3).

NOTE:
A system meets an accuracy class δ (see clause 6.2) if any individual measurement W_d (of a single axle, axle of a group, group of axles or gross weight) has a probability π higher than a minimum specified value π_0 of being within the interval $[W_s(1\text{-}\delta);W_s(1+\delta)]$, where W_s is the corresponding static load, or any other accepted reference value. It also means that statistically a proportion π of a large sample of WIM data should be within this same interval. Reversely, it may be said that given an individual measurement W_d, the confidence interval $[W_d/(1+\delta);W_d/(1\text{-}\delta)]$ contains the true value W_s with a probability π higher than a minimum specified value π_0. Hence the customer risk (that an individual measurement fails outside the previous interval) is lower than $(1\text{-}\pi_0)$.

6.1.3. Individual measurements are required to assess the accuracy of a system, and must be given by it. If a WIM systems delivers only statistics during the operational period of use, detailed data should be provided for calibration and accuracy tests (see clause 10).

6.2. Accuracy Class Tolerances

6.2.1. The tolerances for a load of a single axle, a group of axles, an axle belonging to a group and a gross weight are distinguished. They are given in table 2.1. Table 2.2 provides tolerances for further classes E(xx) if needed in some cases. Additional classes may be obtained, either by interpolation or extrapolation using the formulas of 6.2.4.1 or 6.2.4.2, or the curves of figure 1.

The standard classes are designated by numbers δ_c= 5, 7, 10, 15, 20, 25, which are the tolerances for the gross weights. The use of classes A(1), A(2)…A(5) or designated by any integer δ (e.g. C(13) if δ=13) is allowed if needed, with the letter of the closest standard class with a tolerance $\delta_c \geq \delta$.

Criteria (type of measurement)	Domain of use	Accuracy Classes : Tolerance interval width δ (%)						
		A (5)	B+ (7)	B (10)	C (15)	D+(20)	D (25)	E
1. Gross weight	Gross weight > 3,500kg	5	7	10	15	20	25	> 25
Axle load:	Axle load > 1,000 kg							
2. Group of axles		7	10	13	18	23	28	> 28
3. Single axle		8	11	15	20	25	30	> 30
4. Axle of a group		10	14	20	25	30	35	> 35

Table 2.1: Tolerances of the accuracy classes (δ in %)

Criteria (type of measurement)	Accuracy Classes E Confidence interval width δ (%)					
	E(30)	E(35)	E(40)	E(45)	E(50)	etc...
1. Gross weight	30	35	40	45	50	...
2. Group of axles	33	39	44	49	55	...
3. Single axle	36	42	48	54	60	...
4. Axle of a group	41	47	53	59	65	...

Table 2.2: Tolerances of the accuracy classes E

6.2.2. The weighing intervals for axle loads and gross vehicle weights are given in Table 2.3, and the maximum scale divisions are given in Table 2.4. The WIM system shall meet all requirements specified in this standard in these weighing intervals.

Weighing interval	Min (kg)	Max (kg)
Axle loads	1,000	20,000
Vehicle weights	3,500	100,000

Table 2.3: Weighing intervals

Class	A(5)	B(10)	C(15)	D(25)	E(30)
Axle loads	20	50	100	200	200
Vehicle weights	50	100	200	500	500

Table 2.4: Maximum scale divisions

6.2.3. If a WIM system does not provide axle of group loads, the accuracy requirements for this axles do not apply ; in this case any reference to an accuracy class shall be complemented with the mention "except for axles of a group".

6.2.4. Tolerance extrapolation and interpolation

6.2.4.1. If more classes are needed, beyond E(50), the tolerances for each criterion may be extrapolated by:

Group of Axles (GA): $\delta = 1.047\ \delta_c + 2.16$ for $\delta_c \geq 50$
Single Axles (SA): $\delta = 1.133\ \delta_c + 2.67$ for $\delta_c \geq 50$
Axles of a Group (AoG): $\delta = 1.133\ \delta_c + 7.67$ for $\delta_c \geq 50$

where δ_c is the tolerance for the gross weight, and the accuracy class name is E(δ_c). These values must be incremented in steps of 5 (%). The δ values obtained with the above formula must be rounded up/down to the closest integer (see table 2.2).

6.2.4.2. If interpolated classes from 0 to 50 (between the figures given on the line for gross weight in tables 2.1 and 2.2) are used, the tolerances for each criterion may be interpolated by:

Group of Axles (GA): $\delta = \delta_c/0.7$ for $\delta_c<7$, $\delta = \delta_c + 3$ for $7\leq \delta_c<30$,
$\delta = 1.2\,\delta_c - 3$ for $30\leq \delta_c<35$, and $\delta = \delta_c + 4$ for $35\leq \delta_c<50$

Single Axles (SA): $\delta = \delta_c(85-\delta_c)/50$ for $\delta_c<10$, $\delta = \delta_c + 5$ for $10\leq \delta_c<25$,
$\delta = 1.2\,\delta_c$ for $25\leq \delta_c<50$

Axles of a Group (AoG): $\delta = 2\,\delta_c$ for $\delta_c<10$, $\delta = \delta_c + 10$ for $10\leq \delta_c<25$,
$\delta = 1.2\,\delta_c + 5$ for $25\leq \delta_c<50$

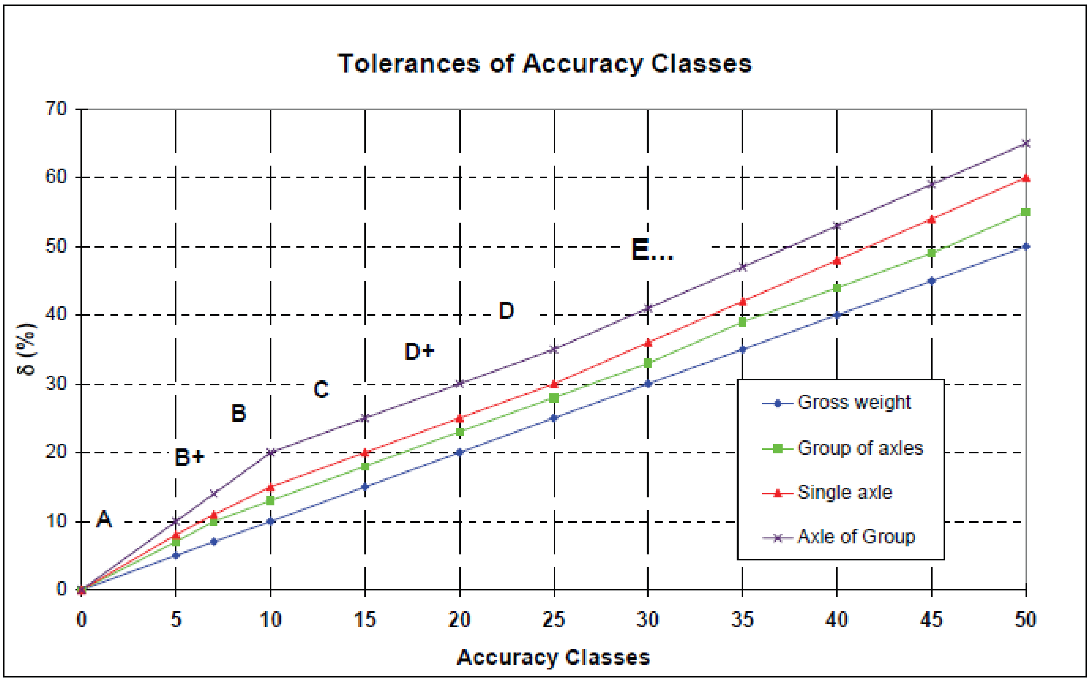

Figure 1: Tolerances of the accuracy classes for the four criteria

6.2.5. The criteria on speed, axle spacing and counting are not mandatory in this standard, as there are other standards for that, which concern much more devices than WIM systems. The tolerances given for these criteria are reasonable accepted values for WIM systems.

NOTE: B-WIM and many strip sensor WIM systems use the speed for the load calculation, and thus any imprecision in speed would have some effect on the weighing accuracy.

6.2.6. For any WIM system other than Bridge WIM (clause 6.2.3), all four criteria mentioned in table 2.1 must be checked, as far as the corresponding data are provided by the system. For all WIM systems, some criteria may be excluded but only if the supplier or vendor clearly claims prior to the test that some of the data provided are not reliable (and this should be stated in writing), and with the agreement of the user (customer),. In this case the accuracy class of the system shall be “for a limited list of criteria” to be specified in writing.

NOTE: If the static reference values are not fully reliable for the axle of a group equipped with steel suspension, these axles may optionally not be considered individually for the analysis, while the group shall be taken into account. That should be clearly stated in writing.

6.2.7. The accuracy class accepted for a WIM system is the best class for which all the criteria are satisfied, or the relevant criteria if axles of a group are excluded according to 6.2.3 or 6.2.6.

NOTE: It is recommended to give an account, after each test, of the results for each criterion separately, in order to inform the user about the reliability of each type of data.

6.2.8. For a specific user's requirement, it is possible to classify a WIM system in different classes for each criterion, but in this case the mention of the accuracy class must always be made with the name of the criterion clearly identified. Without this qualification, only the class defined in 6.2.6 may be mentioned.

6.3. Other tolerances

6.3.1. The minimum rate of detection (percentage of vehicle detected by the system, whatever the results) is 90%.

6.3.2. A registration is complete if all the quantities listed in I.5.6 are recorded, whatever the results. That means that the right number of axles are recorded. The minimum rate of complete registration is 80%.

6.3.3. The tolerance on the axle spacing is 20% with a maximum of 0.3 m, and on the vehicle length or wheelbase is 10% with a maximum of 1 m, both for 95% of the measurement.

6.3.4. Some additional performance specifications are given in Table 2.5, as not mandatory.

Accuracy class	**A(5)**	**B+(7)-C(15)**	**D+(20)-E**
Absolute time stamp (95%)	1 s	1 s	1 s
Speed (95%)	2 km/h	3 km/h	5 km/h
Vehicle class[1]	99%	95%	90%

[1] *With respect to an accepted classification system, minimum rate of right classified vehicles.*

Table 2.5: Other tolerances (not mandatory)

6.4. Reference Gross Weights and Axle Loads Measured Statically

If the reference values used for calibration or accuracy assessment are weights and static loads, the following rules and clauses apply. Any reference value shall be 3 to 5 times more accurate than the tolerance of the WIM system to be checked.

6.4.1. The weighing operations must be done either axle by axle, or by group of axles, or on a weigh-bridge in order to weigh a whole vehicle at once. It is strongly recommended to measure the gross weights on an approved weigh-bridge to get a reliable reference weight W_s.

Static axle loads should be measured by axle or wheel scales, which are approved for enforcement or commercial applications. The road surface on the weighing area should be flat and horizontal. For scales laid on the road surface, it is recommended to:

- use as many scales as the number of wheels/axles to be weighed statically for one vehicle, or
- use steps or similar devices to level all the wheels/axles.

The level difference between axles of a same group should not exceed 2 mm. The level difference between single axles or groups of axles should not correspond to more than 0.5% slope (i.e. 1.5 cm for 3 m spacing).

6.4.2. During wheel or axle static weighing operation, the vehicle brakes must be fully released.

6.4.3. Because the static wheel or axle weighing operation using wheel/axle scales is not fully repeatable (due to the braking conditions and the internal dry friction forces of the vehicle suspensions), it is recommended to repeat *n* times the static weighing axle by axle and then to derive the static reference axle loads W_{si} by:

$$W_{si} = \frac{W_s}{\sum_{i=1}^{q}\sum_{j=1}^{n} W_{s_{i,j}}} \sum_{j=1}^{n} W_{s_{i,j}}$$

where *i* is the axle rank, *q* is the number of axles of the vehicle, *Ws* is the reference gross weight measured on a weigh-bridge, and $Ws_{i,j}$ is the measured load of axle *i* during the j^{th} weighing.

n=10 is recommended, but any value may be accepted. Even for *n*=1, it is recommended to use Eq. 6.1 to get the axle reference static loads, if the gross weight is measured on a weigh-bridge.

If *n* is sufficiently large (i.e. $n \geq$ 8 to 10), it is recommended to eliminate the values which could constitute statistical outliers, identified by a statistical test.

Calibration and Testing

7. On-Site System Checks and Calibration

7.1. General Clauses

7.1.1. After installation and general checking, an initial calibration must be performed before an operational use of any WIM system, according to the vendor specification.

NOTE: The accuracy of WIM data depends greatly on the calibration procedure of the WIM system.

7.1.2. The purpose of the WIM system and its application should guide the selection of a calibration method. The reference values used for calibration must be chosen accordingly.

7.1.2.1. If the WIM data are used to estimate weights and static loads, it is required to minimise the differences (bias) between WIM and weight data. Therefore, the reference values should be either total vehicle weights or static axle loads (or both). The accuracy of these reference values should be appropriate for the expected accuracy of the WIM system to be calibrated, according to general metrological requirements (see also clause 6.3).

7.1.2.2. If the WIM data are used to provide instantaneous impact forces, the reference values should be the “true” impact forces applied by the wheels or axles when they hit the WIM sensors.

7.1.3. The temperature of the pavement should be recorded throughout the calibration procedure. The sensitivity of the WIM system to temperature variations should be checked.

7.1.4. The accuracy of an operational WIM system shall be checked regularly, e.g., once or twice a year (in-service verification, clause 9, or calibration check, clause 10). For a newly installed WIM system, some check(s) (clause 10) shall be carried out during the first three month period of use. Calibration checks may be carried out using the same methods as for an initial calibration (clause 9), but with fewer reference values or test vehicles and runs.

7.2. Calibration Methods

The calibration methods described in this clause are the most common ones. If specified by the vendor and agreed by the customer/user, alternative methods may be used.

7.2.1. Static calibration

The method consists of placing various calibration masses on the scale (sensor), or on the bridge (B-WIM), and relating the system measurements to the masses. At least three masses uniformly distributed within the scale range of the loads to be weighed must be used; three repetitions shall be done for each mass.

7.2.2. Use of shock or pressure variation devices

The method consists of applying to the sensor some repeatable calibrated shocks or pressure variations. The calibration is done with respect to impact forces, but not to the weights.

7.2.3. Use of reference vehicles

7.2.3.1. The method consists of passing reference vehicles, which are weighed on an approved weighing instrument, and provide true values of gross weights and axle loads (see § 6.3), over the WIM system, repeatedly. The calibration is carried out over one or two consecutive days, with homogeneous temperature and climatic conditions (environmental repeatability condition E1, see clause 10.1.4). According to the test plan, the test conditions are defined as:

(R1) full repeatability conditions: if only one vehicle passes several times at the same speed, the same load and the same lateral position;

(R2) extended repeatability conditions: if only one vehicle passes several times at different speeds (according to the traffic lane conditions), different loads (e.g. fully loaded, half-loaded and empty), and with small lateral position variations (according to the real traffic paths);

(R3) limited reproducibility conditions: if a small set of vehicles (typically 2 to 10), representative of the whole traffic composition expected on the site (silhouettes and gross weights), is used, each of them passing several times, at different speeds, different loads, and with small lateral position variations;

(R4) full reproducibility conditions: if a large sample of vehicles (i.e. some tens to a few hundred) taken from the traffic flow and representative of it, pass on the WIM system and are statically weighed before or after it.

7.2.3.2. A proper initial calibration (after installation or modification of a WIM system), shall be done in condition (R3), with at least two (1 and 2 below) or three (1 to 3 below) test vehicles, four being preferred, according to the traffic to be weighed:

1. a rigid lorry loaded between 10,000 and 25,000 kg, close to its maximum permitted load;
2. a tractor with a semi-trailer supported by a tandem or a tridem axle (the tridem is preferred), loaded to more than 30,000 kg.
3. a lorry with a trailer (2+2, 3+2, 2+3 axles), fully loaded.
4. a 2-axle rigid van, fully loaded (around 3,500 kg);

If possible, vehicles 2 and 3 shall be used fully loaded and half loaded. The tandem or tridem axles should be better equipped with air suspensions. However, if mechanical suspensions are used to be representative of the common vehicles on the site, some care should be taken to measure the static reference axle loads (see clause 6.3).

NOTE: It is recommended to use one of the standard test plans described in appendix A of the part I (§ I.A.1), as they were designed to optimise the number of runs and vehicles vs. the confidence level. Moreover, that would allow to use the simplified procedure of the part I.

The conditions must be specified before the calibration, and the results (in terms of accuracy class) must be analysed according to them (see clause 10), for the level of confidence being used.

7.2.3.3. A calibration may be performed in condition (R2), if an agreement between the customer (or user) and the supplier allows it. The calibration vehicle chosen must be of the vehicle type of greatest interest to the client or, if WIM data is required for general statistical purposes, of the most common type to be weighed, and with three loading cases: empty, half loaded and fully loaded.

7.2.3.4. A sample of at least 10 significant runs – i.e. 10 runs with successful measurements – per lorry (or lorry loads) is recommended to guarantee the validity of the method, but the larger this sample the smaller the statistical uncertainty. The sample size will be determined according to the customer’s requirements.

7.2.3.5. The runs mentioned in 7.2.3.4 must be split, for each vehicle (load case) into 2 or 3 speed levels, being representative of the velocity range on the WIM site; e.g. for a free motorway, 70 and 95 km/h may be used, while on other sites, 50, 70 and 90 km/h would be better (however, the speeds used should mostly remain within the legal limits). A recommended simple rule is to take as speed levels the mean velocity V_m, $0.8V_m$ and $1.2V_m$, and then to allocate the run numbers in the following proportions respectively: 60%, 20% and 20%.

7.2.3.6. The initial calibration with only one vehicle and one load case is not recommended and may only be used if it is not possible to do otherwise or if only one type of lorry is to be weighed, under a written agreement with the client. In such a case, 10 significant runs should be made at three speed level, and then the data are analysed in only one sample (with the rules of condition (R1)). But calibration checks may be done in conditions (R1) or (R2).

7.2.3.7. The static weighing operation must be made carefully, such as described in clause 6.4.

7.2.3.8. After the data collection, the calibration may be done following various methods. The calibration methods most commonly used are briefly described in annex II. The choice of the most appropriate method should be made according to the WIM system software performance and to the user's requirements. In any case, the method used must be clearly explained or referred to in the calibration report.

7.2.4. Use of instrumented calibration lorries

7.2.4.1. The method consists of fitting the WIM records to the on-board measured impact forces for the same wheel or axle of one or more instrumented vehicle(s), which provide(s) accepted reference values of these impact forces. The formulas given in annex II should be used, replacing the static loads by the reference impact forces provided by the instrumented vehicle(s). In this method the axle loads and forces must be used instead of the gross weights.

7.2.4.2. The on-board measurements must be very accurately synchronised with the WIM sensor measurements, when a wheel or axle passes on it.

7.2.4.3. The instrumented vehicle must have been itself carefully calibrated under dynamic loading, and its intrinsic accuracy must be in agreement with the common metrological rules, depending on the WIM system expected accuracy (e.g., the tolerances of the on-board measurements should be should be at least 1/3 and preferably less than 1/5 of those of the WIM system).

7.2.4.4. The calibration procedure (test plan) should be made with at least three load cases (full, half load and empty) and two or three speed levels per load case; three significant runs for each load and speed should be made.

7.2.5. Automatic self-calibration procedures and software

7.2.5.1. The method consists in fitting some statistics recorded and computed by the WIM system to some target values depending on the site-specific traffic.

7.2.5.2. An automatic self-calibration procedure requires a good prior knowledge of the site- specific traffic composition and statistics of the axle and vehicle loads.

7.2.5.3. The automatic calibration system is specific to its lane. So in case of more than one instrumented lane, the traffic on each lane should be taken into account separately.

8. Type (model) Approval of a WIM System

8.1. Before being marketed with a quality label and a specified accuracy performance, any WIM system should pass the test procedure described in this chapter. The test must be organised under the responsibility of an agreed official organisation, to ensure the neutrality and the reliability of the conclusions. An official report should be written and published giving an account of the test results. The annex III gives some indication about the result format and presentation.

NOTE: The type approval test intends to assess the accuracy performance of a WIM system under fully specified conditions, and over a short time period. Therefore, it does not give any information about the durability or trend of the system and its parts, which are highly dependent on the environmental and traffic conditions.

8.2. Choice of test site

8.3.1. The type approval test may be organised either on a fully protected site (outside the traffic flow), or on an existing road under traffic. If the WIM system is currently equipped with an automatic self-calibration facility, only the second case is applicable.

8.2.2. The site must be in class I (excellent), according to clause 4. Moreover, the radius of curvature should be longer than 2500 m, and a straight road is highly recommended. All the site characteristics listed in clause 4 must be reported in the test report.

8.3. Installation and pre-calibration of the system

8.3.1. The system should be installed by the supplier, prior to the test, according to the recommended common procedures.

8.3.2. A pre-calibration of the system should be done before the test. For this operation, two reference vehicles will be used, chosen in agreement with the supplier among those listed in 7.2.3.2. One load per vehicle will be used, chosen in agreement with the supplier. Each vehicle will make 8 runs over the WIM system:

- 4 runs at V_m,
- 2 runs at 1.2 V_m and 2 runs at 0.8 V_m.

For a high-speed WIM system, V_m will be taken equal to 75 km/h. For a low-speed WIM system, V_m will be the recommended operational speed.

8.3.3. For a system equipped with an automatic self-calibration procedure using the traffic flow, the system shall be tested according to 8.3.2, after a period specified by the vendor when the calibration procedure has reached its operational level. After this test, the manufacturer or vendor will be allowed to adjust the target values of the self-calibration algorithm.

8.4. Test plan

8.4.1. The test shall be carried out using standard test plan N°4 (see Part I, Appendix A, § I.A.1), with four test lorries and a total of 120 runs, which means that the minimum required level of confidence (clause 10.3.2) will be π_0=95%. The test shall be carried out over all the seasons and environmental conditions, i.e. in full environmental reproducibility (E3). The climatic conditions should be carefully reported in the test report (temperature variation range, weather, precipitation, etc.). Any other special event which could affect the results should also be reported.

8.4.2. In addition to the 120 runs specified in 8.4.1, two of the reference vehicles will make 6 additional abnormal runs in order to check the ability of the system to detect such situations, and to mark the wrong measurements with a violation code.

8.4.2.1. For WIM systems other than B-WIM, these runs will be done as:
- reference lorry #1 (rigid): 3 more runs, one with half of the vehicle (left or right half) outside the sensor(s), one run with the first axle passing on the sensor(s) and the second axle passing outside or partially outside the sensor(s), and one run with the lorry braking while passing on the sensor(s) (speed from 90 km/h to 60 km/h, or 12 to 5 km/h for a low-speed WIM system).
- reference lorry #2 (tractor with semi-trailer): 3 more runs, one with half of the vehicle (left or right half) outside the sensor(s), one run with the tractor passing on the sensor(s) and the semi-trailer (tridem) passing half outside the sensor(s), and one run with the lorry braking while passing on the sensor(s) (speed from 90 km/h to 60 km/h, or 12 to 5 km/h for a low-speed WIM system).

8.4.2.2. For B-WIM systems, these runs will be done as:
- reference lorry #1 (rigid): 2 more runs with the vehicle straddling two lanes or, where this is in-feasible for safety reasons, with the vehicle driving at the edge of the lane (one side of lane for each run).
- reference lorry #2 (tractor with semi-trailer): 1 run with the lorry braking while passing over the bridge.
- reference lorry #1 and #2 (together): 3 more runs, to test the accuracy of weighing lorry #2 when all or part of lorry #1 is also on the bridge.

8.4.3. During the test, the manufacturer or vendor will not be allowed access to the system. After the test measurement completion, the raw data file(s) with the detailed vehicle by vehicle recorded data will be given both to the test organiser and to the manufacturer for their own checks.

8.5. Reference static loads and weights: for both the pre-calibration (8.3) and the test (8.4), the reference vehicles will be weighed on an approved weigh-bridge and on wheel/axle scales. Clause 6.4 will be applied, with $n \geq 6$ (§ 6.4.3). It will be checked that the standard deviations of the static axle loads are less than 1/3 of those measured in motion.

8.6. Test analysis and report

8.6.1. All the recorded data, except those marked with a violation code by the system, will be considered. A careful analysis and report on the abnormal runs will be done in the report.

8.6.2. The data analysis will be done as for an in-service verification (clause 9.2) according to clauses 10.4.1, 10.4.2, 10.4.3.1, 10.4.4, 10.4.5, 10.4.6 and 10.4.7. The test conditions will be (E1) (environmental repeatability, see 10.1.4) and (R3) (limited reproducibility, see 7.2.3.1). The results will be reported according to the annex III format.

8.6.3. A second analysis will be carried out as for an initial verification (clause 9.1), by removing the mean bias on the gross weight for all the runs, applying by software a constant multiplicative factor on all the recorded axle loads. The, *k* factor mentioned in 9.1.3 will be used to assess the accuracy classes for each criterion.

8.6.4. The test report will present both analyses (8.7.2 and 8.7.3). In case of significant discrepancies between both, some explanations should be given, as far as possible, about the effect of the mean bias.

9. Initial and In-Service Verifications of a WIM System

A verification of a WIM system may be done either:

- as an initial verification (clause 9.1),

or

- in-service (clause 9.2).

9.1. Initial Verification

9.1.1. After installation, or some modifications (of sensors, hardware or software), repair or part replacement, a WIM system must be (re)calibrated, according to one of the procedures proposed in clause 7 and annex II and to the manufacturer's specification.

This is an initial verification.

9.1.2. If the WIM system is calibrated using static calibration masses (clause 7.2.1) or with a fully repeatable calibrated shock device (clause 7.2.2), then all the results (relative errors) must be within the interval [-δ/2;δ/2] of the relevant accuracy class and of the criterion considered (single axle, axle of a group, group of axle or gross weight).

NOTE: This clause only applies to systems which are able to measure static loads, such as bending plates, load cell scales, and weigh-bridges. In particular cases it may also be applicable to some strip sensors, and may be extended with caution to sensors calibrated with shock devices.

9.1.3. If the WIM system is calibrated using repeated runs of reference (pre-weighed or instrumented) vehicles, the confidence intervals given in table 2.1 (and 2.2 if needed) are considered, but the tolerance δ is reduced by a multiplicative k factor, where k=0.8.
The required level of confidence of this interval [- k.δ ; k.δ] is given in clause 10.

9.2. In-Service Verification

9.2.1. An in-service verification may be done at any time of the lifetime of a WIM system. It should be done periodically, and when conditions change (traffic conditions, environmental conditions, etc.), or in case of any doubt about the data accuracy.

In such a verification, the data used for the accuracy assessment must not have been used for any calibration or recalibration of the system.

9.2.2. If the WIM system is checked using static calibration masses or using a fully repeatable calibrated shock device, all the results (relative errors) must be within the tolerance interval [-δ;δ] of the relevant accuracy class and of the criterion considered (single axle, axle group or gross weight), according to the measuring scale or sensor capacity.

9.2.3. If the WIM system is checked using repeated runs of reference (pre-weighed or instrumented) vehicles, the confidence intervals, given in table 2.1 (and 2.2 if needed), are used.

The required level of confidence of this interval [-δ;δ] is given in clause 10.

10. Procedure to Check the Accuracy of a WIM System

10.1. General Rules

10.1.1. The assessment of the accuracy of a WIM system requires a test. Clause 10 deals with tests carried out using either repeated runs of reference vehicles, and/or the use of single runs of reference vehicles from the traffic flow.

10.1.2. The supplier risk, linked to the statistical estimation of the mean bias, is fixed at 5%.

10.1.3. The client risk is governed by the probability of an individual error (with respect to the static load or weight) lying outside of the specified tolerance interval. An upper bound of this risk is fixed by specified values ($1-\Pi_0$), where Π_0 is the minimum required confidence level. This risk ($1-\Pi_0$), or the confidence level Π_0, may be chosen by the client (see clause 10.3).

10.1.4. Depending on the time period of the test, so-called "environmental repeatability or reproducibility" conditions are defined by:

(E1) environmental repeatability: the test time period is limited to a couple 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;

(E2) limited environmental reproducibility: the test time period extends at least over a full week or several days spread over a month, such that the temperature, climatic and environmental conditions vary during the measurements, but no seasonal effect has to be considered;

(E3) full environmental reproducibility: the test time period extends over a whole year or more, or at least over several days spread all over a year, such that the temperature, climatic and environmental conditions vary during the measurements and all the site seasonal conditions are encountered.

10.1.5. No recalibration or any manipulation, software adaptation or part exchange can be conducted on the WIM system during the test period. Only in the case of a long term test (E3), or exceptionally in case (E2), if some part of the system (sensor or electronics) fails, the supplier of the system may be authorised to repair it or to replace the broken part, under the control of the test organiser. A detailed report about the failure, its causes and the repair done must be provided.

10.1.6. According to the number of reference vehicles (10.1.7), load and speed cases, and eventually to the use of pre- or post-weighed vehicles from the traffic flow passing the system only once, the test may be carried in (see clause 7.2.3.1) :

(R1) full repeatability
(R2) extended repeatability
(R3) limited reproducibility
(R4) full reproducibility

10.1.7. Reference vehicles are vehicles which are weighed on an approved scale or weigh-bridge to provide reference gross weights and axle loads, and perform repeated runs over the system, or pass once on the system if they belong to the traffic flow (see clause 6.3).

10.2. Test Plans

10.2.1. The definition of a test plan consists of the choice of a sample of vehicles, their loading and speed conditions, and the number of runs. These vehicles may be either:

- reference vehicles (10.1.7) provided by the organiser (pre-weighed or instrumented vehicles),
- and/or reference vehicles taken from the traffic flow and pre- or post-weighed; in this latter case only one run per vehicle is considered.

If both types of vehicles are used, the data of each population should not be merged in the analysis.

10.2.2. If the static weights are taken as the reference values, the guidelines given in 7.2.3 shall apply. If the impact forces are taken as the reference values, the guidelines given in 7.2.4 shall be used.

10.2.3. It is recommended to perform the test in conditions (R3) or (R4). It may be done in conditions (R2) but with at least 3 loading cases uniformly distributed within the range of axle/gross weights to be weighed, and 10 runs per loading case. It is not recommended to perform the test in conditions (R1), unless by special agreement of the user (customer). The requirements of 7.2.3.4 to 7.2.3.6 still apply.

10.2.4. In cases (II) and (III), the sample of reference vehicles used over each day or series of days should be similar (composition and loads), and as far as possible representative of the traffic flow.

10.2.5. The environmental conditions (especially the temperature) should be recorded during all the measurement periods.

10.2.6. The data analysis procedure described in 10.3 is able to deal with any test plan, and then the level of confidence of the results is calculated. Or the customer may choose the appropriate level of confidence (or the highest accepted risk), and build the most convenient test plan which complies with it among all of them.

For common checks, standard simplified test plans are given in the part I, Appendix A (§ I.A.1).

10.3. Minimum required Confidence Levels

10.3.1. When a test of a WIM system is performed according to the principles of 10.2, the confidence level π to get an individual error within the tolerance intervals specified in tables 2.1 or 2.2 may be estimated from the test results and statistics. In the following, the individual errors are assumed to be random, independent of each other and normally distributed.

10.3.2. Depending on the test plan repeatability or reproducibility conditions (R1) to (R4), and on the environmental repeatability/reproducibility conditions (E1) to (E3), the minimum values π_0 of the required level of confidence for the tolerance intervals specified in tables 2.1 and 2.2 are given in tables 3 to 5, and in figure 2. Π_0 increases with the size *n* of the test data sample. These values are also calculated by formula in the computer (Excel sheet) tools presented in annex III.

Sample size (*n*) / **Test conditions**	**10**	**20**	**30**	**60**	**120**	∞
Full repeatability (R1)	*95*	*97.2*	*97.9*	*98.4*	*98.7*	*99.2*
Extended repeatability (R2)	*90*	*94.1*	*95.3*	*96.4*	*97.1*	*98.2*
Limited reproducibility (R3)	*85*	*90.8*	*92.5*	*94.2*	*95.2*	*97.0*
Full reproducibility (R4)	*80*	*87.4*	*89.6*	*91.8*	*93.1*	*95.4*

For sample size n not mentioned in this table, the figures may be interpolated using figure 2, or a linear interpolation, or they are calculated in the Excel sheet presented in annex III.

Table 3 : Minimum levels of confidence Π_0 , of the centred tolerance intervals (**in %**) case of a test under « environmental repeatability » conditions (E1)

Sample size (*n*) / **Test conditions**	**10**	**20**	**30**	**60**	**120**	∞
Full repeatability (R1)	*93.3*	*96.2*	*97.0*	*97.8*	*98.2*	*98.9*
Extended repeatability (R2)	*87.5*	*92.5*	*93.9*	*95.3*	*96.1*	*97.5*
Limited reproducibility (R3)	*81.9*	*88.7*	*90.7*	*92.7*	*93.9*	*96.0*
Full reproducibility (R4)	*76.6*	*84.9*	*87.4*	*90.0*	*91.5*	*94.3*

For sample size n not mentioned in this table, the figures may be interpolated using figure 2, or a linear interpolation, or they are calculated in the Excel sheet presented in annex III.

Table 4 : Minimum levels of confidence Π_0 , of the centred tolerance intervals (**in %**) - case of a test under « limited environmental reproducibility » conditions (E2)

Sample size (*n*) / **Test conditions**	**10**	**20**	**30**	**60**	**120**	∞
Full repeatability (R1)	*91.4*	*95.0*	*96.0*	*97.0*	*97.6*	*98.5*
Extended repeatability (R2)	*84.7*	*90.7*	*92.4*	*94.1*	*95.1*	*96.8*
Limited reproducibility (R3)	*78.6*	*86.4*	*88.7*	*91.1*	*92.5*	*95.0*
Full reproducibility (R4)	*73.0*	*82.3*	*85.1*	*88.1*	*89.8*	*93.1*

For sample size n not mentioned in this table, the figures may be interpolated using figure 2, or a linear interpolation, or they are calculated in the Excel sheet presented in annex III.

Table 5 : Minimum levels of confidence Π_0 , of the centred tolerance intervals (**in %**) - case of a test under « full environmental reproducibility » conditions (E3)

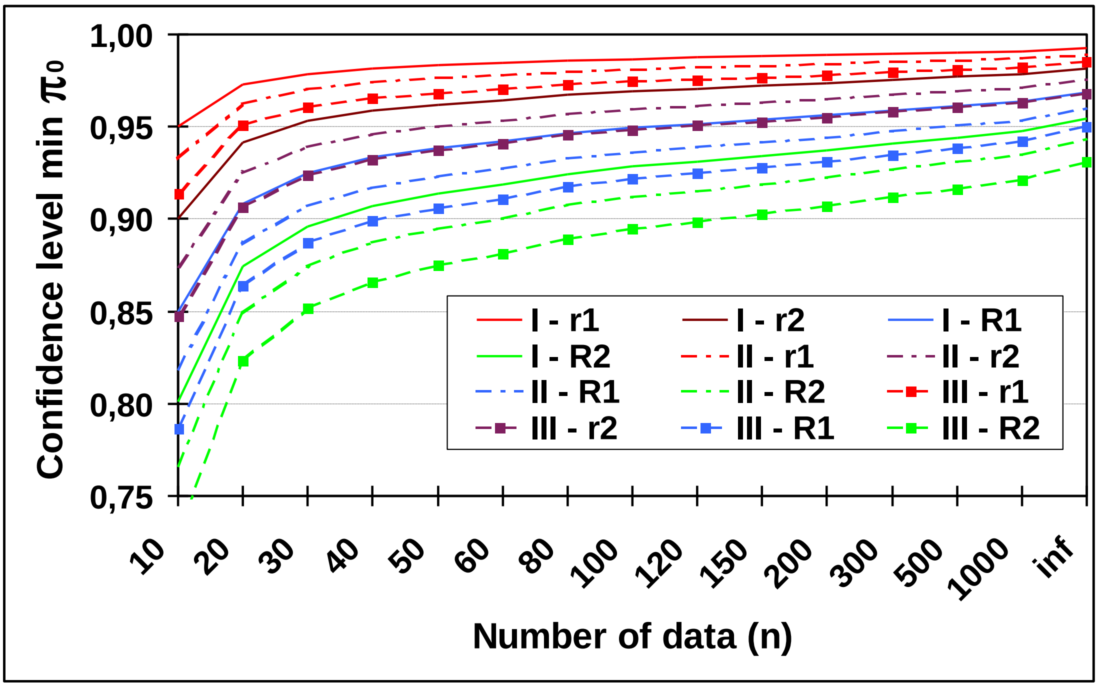

Figure 2: Minimum specified levels of confidence Π_0 with respect to the test conditions

10.3.3. It is recommended to require - by the choice of the test plan - a confidence level greater or equal to 90% in reproducibility conditions (R3) and (R4), and greater or equal to 95% in repeatability conditions (R1) and (R2), but in particular cases it may be less. Without any information, these levels of confidence will be assumed by default.

NOTE: For some applications, especially legal applications (e.g. enforcement), higher confidence levels may be required, such as 99% or 99.5%. Even if such values exceed the maximum value given in the tables 3 to 5, they may be obtained by specifying a large enough interval width δ on the considered criterion (i.e. using a lower accuracy class): for a given system (accuracy), the wider the interval, the higher the confidence level. The effective confidence level is calculated (see section 10.4.6).

10.4. Test results analysis

After the end of the data collection, detailed analysis of the test results will be done through the following steps:

10.4.1. Report on the system failures or malfunctions, including statistics about the time of operation, the time interval between failures, etc..

10.4.2. Statistics about the number of properly recorded vehicles by the WIM system (if any reference is available on the theoretical number of vehicles passed, at least for the vehicles of the test sample). Analysis of the errors automatically detected by the system (error code provided) and the missed ones.

In this step, the percentage of missing vehicles (not including the vehicles recorded with an error code) must be lower than the values indicated in the table 2.5.

The percentage of vehicles recorded with an error code may be higher (without any specified upper limit), but only in so far as it concerns the traffic conditions: vehicle passing partially offscale, braking or accelerating over the specified limits of the system, two vehicles on a B-WIM system simultaneously, etc..

10.4.3. **Outliers** : the issue of the statistical outliers (not detected by the system in its recording process) must be considered carefully. Two cases may be considered, and then only one of them or both may be treated according to the test requirements.

10.4.3.1. No outlier elimination: if the objective of the test is to provide the real system performance for a customer who generally uses the data as they are recorded, without any further statistical analysis, then all the data recorded except those with an error code are included in the analysis described below.

10.4.3.2. Outlier elimination: if the objective of the test is to provide the theoretical system performance for a customer who may perform some further statistical tests on the recorded data, then some statistical tests of outliers must be applied on the homogeneous populations (take care of the Normality required for most of these tests; if it is the case, this Normality must also be checked with a test). The outliers identified by the relevant tests are accounted for and counted as missing data after elimination (return to 10.4.2). The remaining data are only used for the analysis described below. The final report of the test must clearly report on this part of the analysis.

10.4.4. In the case of a large enough data sample, it is recommended to check the Normality of the results when only independent random errors are expected to provide the population variance; this is mostly the case and non-Normality often reveals some dysfunction. Moreover this assumption is made for the level of confidence calculation.

NOTE: if a complete Normality test is not performed, it is recommended to check at least the symmetry of the distribution of relative errors (clause 10.4.5).

10.4.5. The relative errors with respect to the weights and static loads (or any other accepted reference values) are calculated, for each measurement of the different sub-populations, i.e., the axles, axle groups, axles of groups and gross weights, as:

$$x_i = \frac{(Wd_i - Ws_i)}{Ws_i}$$

where W_{di} and Ws_i are the in-motion measured value and the reference (static) value respectively of the same entity.

Then the mean *m* and the standard deviation *s* of the relative errors in each sub-population sample are calculated.

NOTES:

1. While the calibration method applied does not provide individual coefficients by lorry type or axle rank (such as in methods ***1.a.*** to ***1.d.*** of the annex II), the samples considered must include all the gross weight or single axle, axle of group or group of axle load results together. For example all the single axles of any rank must be considered together, and not the front axles and the rear/drive axles separately.

   If different calibration coefficients are defined by vehicle type or axle rank (or type), then the samples considered may distinguish each sub-population.

2. In case of a test in conditions (R1), the data collected for all the speed levels must be merged and analysed in only one sample, even if full repeatability is no longer satisfied.

10.4.6. Calculation of the confidence level

The confidence level π may be either estimated by a theoretical method (10.4.6.1) using the sample statistics of the test, or, in some cases, by a sample proportion (10.4.6.2). Both methods are presented.

10.4.6.1. Calculation of the theoretical confidence level (Jacob, 2000)

A lower bound π, of the probability for an individual value of a relative error, taken randomly from a normally distributed sample of size *n*, with a sample mean *m* and standard deviation *s*, to be in the centred tolerance interval [-δ ; δ], is given at confidence level (1-α) by (Jacob, 2000):

$$\pi = \Phi(u_1) - \Phi(u_2) , \qquad (10.1)$$

where : $u_1 = (\delta - m)/s - t_{\nu,1-\alpha/2}/n^{1/2}$ and $u_2 = (-\delta - m)/s + t_{\nu,1-\alpha/2}/n^{1/2}$,

Φ is the cumulative distribution function for a Student-*t* distribution,

and $t_{\nu,1-\alpha/2}$ is a Student variable with $\nu = n$-1 degrees of freedom. α is taken equal to 0.05.

The estimated level of confidence π, for each sample (and criterion) is calculated by Eq. 10.1.

NOTE: If *n* is greater than 60, the cumulative distribution function Φ in Eq.10.1 may be approximated by the cumulative distribution function of a standardised Normal variable.

10.4.6.2. Estimation of π with the sample proportion π‘

If the sample size *n* is greater than $10/(1-\pi_0)$, where π_0 is the minimum required level of confidence given in tables 3 to 5 (according to the test plan), π may be statistically estimated by the proportion π‘ of the sample test data found within the tolerance interval [-δ ;+δ].

The sample proportion may only be used with the user’s or customer’s agreement, and if there is no possibility to calculate the π value.

NOTE: This estimation may be eventually used while $n > 5/(1-\pi_0)$, but the statistical uncertainty increases as *n* decreases.

10.4.7. Test of acceptance

They are two ways to assess the accuracy level of a WIM system with a test:

10.4.7.1. For each sub-population (sample) corresponding to a criterion of table 2.1, and for the required tolerance δ, the acceptance test is:

- if π (or π‘ in the case of 10.4.6.2) $\geq \pi_0$, the system is accepted in the class δ_c which corresponds to the tolerance δ ;
- if π (or π‘ in the case of 10.4.6.2) $< \pi_0$, the system cannot be accepted in the proposed accuracy class, and the acceptance test is repeated with a lower accuracy class (i.e. a greater δ). If the theoretical value of π is used, it should be recalculated by Eq. 10.1. But π‘is independent of δ.

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10.4.7.2. An alternative way is to calculate, with Eq. 10.1, the (lowest) value δ_{min} of δ which provides: $\pi = \pi_0$, and then to check that δ_{min} is smaller than the value specified in table 2.1 or 2.2 for the proposed accuracy class and criterion.

If the sample proportion Π' is used (10.4.6.2), the smallest value δ_{min} of δ which ensures that the centred tolerance interval contains a sample proportion $\Pi' = \Pi_0$, is chosen, and the same check as above is done.

NOTE: This approach allows to classify a system in any accuracy class, defined by the lowest accepted δ-value (δ_{min}).

10.4.7.3. Another manner to express the accuracy class for one criterion, when a value of δ_{min} has been calculated, consists of calculating the associated δ_c using the formula of clauses 6.2.4.1 or 6.2.4.2. Then the accuracy class may be expressed by this value δ_c (rounded to the closest upper integer) or by the closest upper standard class A(5) to E(50) given in tables 2.1 or 2.2.

NOTE: If required by the customer or the manufacturer, some additional analysis may be performed with the test data, such as: analysis of the environmental effects, of the traffic condition effects, etc..

10.4.8. Appendix A of the part I gives a simplified procedure, based on the use of simplified analytical formula or graphical charts for the acceptance test; this simplified procedure is easy to implement. The given charts only complies with some standardised test plans.

11. Data Storage and Transmission

11.1. Data storage

11.1.1. This concerns the content, structure and format of the data files which contain the information recorded or computed by the WIM systems. Only the detailed data vehicle by vehicle are considered in this standard. Aggregated data highly depends on the system, the softwares and are often customarized.

11.1.2. In order to avoid any confusion while reading the data files or using the data, explicit headings must appear at the top of each column (or line) of data file, table or graph. The units must also be given, and, as far as possible, the S.I. (System International) system used.

11.1.3. Each type of data must be given with a number of digits in accordance with:

- the accuracy of the whole recording device,
- the division scales of the clause 6.2.2,
- the accuracy and number of digits of the entire processing software,
- the accuracy requirement of the user.

11.1.4. If a WIM system is equipped with a software to detect any abnormal result or error, the wrong results shall be kept in the detailed data files, but marked with an error (violation) code.

The wrong results shall be eliminated in the aggregated data files, but recorded in some statistics of errors.

The criteria for wrong result detection must be clearly indicated not only in the technical brochure of the WIM system, but also in any document presenting the data.

11.1.5. The data file itself or the accompanying document must contain some information about the site and the WIM system, such as:

- road identification (name, administrative number - European numbering system, etc.),

- accurate location of the WIM system (milestone, traffic lane measured, etc.),
- type of sensor and of electronics used,
- date of manufacture and of installation of the WIM system,
- date of the last calibration,
- period of measurement,
- owner of the WIM system and contact person in charge of the data collection.

11.1.6. Additional information shall be reported if available, such as:

- environmental conditions (weather, traffic, etc.) during the measurement period,
- calibration coefficient periodically computed by the system in case of an automatic self-calibration (see section 7.2.5),
- report on the eventual breakdown or failure, and any maintenance operation of the WIM system during the measurement period.

11.1.7. In order to facilitate the data transfer and analysis, the consecutive vehicles recorded should be presented one per line of the file. Some lines at the top of the file may contain the general information listed in section 11.1.5.

11.1.8. The same type of information should be in the same column (e.g. date, vehicle length, speed, gross weight or axle of the same rank loads).

NOTE: Therefore it is recommended to group on the left side of the file (the first columns) the data which is common to all vehicles:

- number, error code, date and time of passage, lane, direction, lateral position in the lane, speed, length, number of axles, type (by silhouette), gross weight, etc.,

and on the right side (last columns) the data which only concerns some vehicles:

- axle loads and inter-axle distances (because of the variation in the number of axles per vehicle).

In such a way, the size of the files may be reduced, avoiding having many partially empty columns for the smallest vehicles (only the carriage return symbol - end of line - will be mixed with other data in the same column). If this principle is not applied, the number of columns must be the largest to be used for the longest vehicles..

11.2. Data transmission

11.2.1. The specification of data transmission by telephone line, data network or Herzian wave only depends on the telecommunication standards and technology, and is treated in the relevant official documents. Any customer may specify the standard to be used according to its needs and equipment.

11.2.2. If any future standardised European formats and protocols of transmission appears, they should be used, following the user's requirement and the WIM system capability. The transmission protocol must ensure that no loss of data occurs.

11.2.3. In the case of data transmission while the WIM system is in service, the transmission operation should not interrupt data collection.

11.3. Operating Ranges and Information

11.3.1. The operating range for each measured parameter shall be displayed in the WIM device notice and in the test reports. Ranges for temperature, humidity, speed, number of axles per vehicle, axle spacing, vehicle length, axle load, gross vehicle weight shall be definitively given, as well as electromagnetic and mechanical conditions.

11.3.2. The limitations on the environmental operating conditions of the WIM system shall be displayed in the WIM device notice and test reports shall explain how the test conditions complied with them.

11.3.3. For a Bridge WIM system, the type and characteristics of the bridges on which it may be installed, operated and fulfil the accuracy requirements shall be reported. The sensors installation plan shall also be given, with respect to the bridge type.

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Annex I (informative): Comparison of this Standard and the OIML R 134-1 International Recommendation

This annex highlights the differences and complementarities between the OIML R 134-1 International Recommendation "Automatic instruments for weighing road vehicles in motion and measuring axle loads, Part 1: Metrological and technical requirements – Tests" (version 2006), and this EN standard.

AI-1. Scope and application

The OIML (International Legal Metrology Organisation) initially developed an international recommendation R 76-1 "Non-automatic weighing instruments. Part 1: Metrological and technical requirements – Tests", which specify the static weighing instruments, for trade and enforcement purposes. Afterwards, an international recommendation R 106-1 "Automatic rail-weighbridges. Part 1: Metrological and technical requirements – Tests" was developed, which specify in-motion weighing instruments (weighbridges) for railways, again for trade purpose mainly. The aim and accuracy classes of the R 106-1 are rather similar to those of the R 76-1, while the differences between weighing railways statically or in motion at low speed and on controlled area/tracks, as specified in the R 106-1, is not so important. Finally a third international recommendation was developed, the R 134-1, to extend the automatic and in-motion weighing to road vehicles. However, because of the variety of road surfaces and pavements, the unevenness which may be encountered on in service roads, the suspension, tires, and dynamic interaction between road vehicles and road surface, it is much more difficult to weigh in motion road vehicles than railways. Therefore, the scope of the R 134-1 was initially limited to low speed weighing on specific area (version of 2003), and classes with larger tolerances were introduced, up to 10%. In the revised version of 2006, the scope was extended, and the recommendation now applies to weighing instruments installed on any controlled area, i.e. with a specified smooth apron and controlled speed and travelling conditions.

That allows weighing on some sections of the road network, such as in toll area, access ramps to parking lots or rest area, etc., but not on any current road section where neither the road surface nor the vehicle speed are under control. Even if not clearly specified in the latest version, the R 134-1 mainly covers the so-called "Low-Speed" Weigh-In-Motion (LS-WIM), either for trade or enforcement purposes.

Because there are many other applications of WIM data (e.g. gross vehicle weights and axle loads), for good transport statistics and survey, infrastructure (road and bridges) design and monitoring, and overload detection and screening, the COST323 management committee (COST Transport, 1993-1998) developed European Specification for Weigh-In-Motion of Road Vehicles (published in 1999). The scope of this Specification was to specify all kinds of WIM systems, installed on current road surface and in-service traffic lanes, on parking lots, ramps, or controlled weighing area, and all types of traffic conditions.

To take into account the dynamic behaviour of the axles and vehicles on the road at speed, which induce random errors with respect to the static loads and vehicle masses, a statistical approach was considered. Instead of requiring 100% of the measurements within some specified tolerances, a minimum level of confidence (let say 95% in average) was required for an individual measurement to be within the tolerances of any accuracy class. Moreover, in such a statistical approach, the probability that a weighing instrument installed in a given road surface and section weighs a vehicle or an axle within the specified tolerance, or weighs a given proportion of the vehicles or axles within this tolerance, depends on the test conditions, i.e. the repeatability and reproducibility of the measurements. Therefore, these repeatability and reproducibility conditions are described and specified in this standard, and the minimum required level of confidence for any accuracy class, depends on these conditions.

Thus, when the accuracy of a WIM instrument is assessed by testing, the required level of confidence depends on the sampling conditions and on the test duration. Reversely, depending on the user's or customer's needs, the test conditions shall be adapted to the real measurement conditions. Finally there is a compromise to find between the accuracy (tolerance) and the level of confidence.

For all these reason, there are major differences between the OIML R 134-1 International Recommendations and this EN Standard. However, the accuracy class tolerances were harmonized as much as possible for those which are mentioned in both standards.

The scope of this EN Standard excludes the trade applications, for which 100% of the measurements must fail within the specified tolerances. For these application, only the OIML R 134-1 may be applied.

For enforcement of vehicle loads and weights, both the OIML R 134-1 and this EN Standard may be used, because it is commonly agreed to give some additional "safety margin" before ticketing or downloading and overloaded vehicle. That depends on the National legislation and practices. These laws may accept or refuse the use of this Standard for WIM instruments dedicated to enforcement.

For all the other applications, in traffic or civil engineering, this EN Standard applies and seems to be the most appropriate one. However, users and customers may specify in any call for tender or particular specification, which standard is referred to for the acceptance of a WIM instrument.

AI-2. Detailed comparison of the OIML R 134-1 and this EN Standard scope and requirements

OIML R 134-1	EN Standard (COST323)
Scope To determine the vehicle mass, the axle loads, and if applicable the axle-group loads of road vehicles when the vehicles are weighed in motion. *Main purposes: trade and overload enforcement*	To determine gross vehicle weight, axle loads and group of axle loads when the vehicles are in motion. *Main purposes: Traffic and civil engineering applications, overload detection/screening, possible for enforcement; trade EXCLUDED.*
Application WIM instruments installed: - in a controlled weighing area [1]; - where the vehicle speed is controlled BUT NOT to WIM instruments that determine individual axle loads by multiplying a single wheel load of an axle by two, or are installed on-board vehicles to measure axle load. *Main use: low speed (less than 10 to 20 km/h)*	WIM instruments installed anywhere, without speed control May be applied to WIM instruments that determine individual axle loads by multiplying a single wheel load of an axle by two, BUT NOT that are installed on-board vehicles. *Main use: high speed (50 to 90 km/h or more), but all speeds are possible.*
Accuracy classes Tolerances from 0.2% to 10% (vehicle mass)	Tolerances from 1% to 30% and above.
Maximum permissible errors (100% of the measurements within the tolerances)	Statistical approach, a minimum required level of confidence (probability) to fail within the tolerances, e.g. 95% in common cases
The instrument directly measure the applied wheel or axle load, i.e. the whole tire imprint is on the scale. Thus the instrument calibration and verification must be done with standard masses and in-motion with reference vehicles.	The instrument may measure wheel or axle load indirectly, e.g. with strip sensors and signal integration, or bridge strain measurements and an algorithm to calculate the applied loads. Thus the instrument calibration and verification may be done only with reference vehicles (in- motion test).

[1] *Controlled weighing area:place specified for the operation of instruments for weighing road vehicles in motion, which are installed in conformity with some specified requirements.*

Annex II (informative): Calibration Methods

The calibration methods most commonly used are briefly described below, from the simplest to the most sophisticated; other methods may be considered.

Description of common calibration methods

We note :

Wd_{ijk} = «dynamic» load (impact force) measured in motion of the vehicle *i*, the axle *j*, and the run *k*,

Wd_{ik} = «dynamic» gross weight for the vehicle *i* and the run *k*, calculated by: $Wd_{ik} = \sum Wd_{ijk}$,

Ws_{ij} = static load of the vehicle *i*, and the axle *j*,
Ws_i = static gross weight of the vehicle *i*,
n_i = number of runs of the vehicle *i*,
p = number of test vehicles.

In the conditions (R2), it is recommended to consider the different configurations (loads and speeds) of the same vehicle as different vehicles for the data analysis.

Calibration coefficient : a calibration coefficient is defined as a multiplicative factor $\boldsymbol{C}$ to be applied to a raw recorded « dynamic » load Wd to get the final estimation of the static load (or the « calibrated » result) noted W : $W = \boldsymbol{C}.Wd$.

A calibration coefficient is intended to eliminate as far as possible any systematic bias in the WIM system, which may partially be induced by the pavement profile (spatial repeatability effect).

If the WIM system uses more than one sensor, at least one calibration coefficient must be computed for each of them.

In some « sophisticated » WIM systems, several calibration coefficients may be computed for each sensor, depending on the type of vehicle or on the axle rank (see ***2.*** and ***3.*** below).

For bridges the calibration coefficient is replaced by a calibration curve, an influence line or surface.

Among the proposed methods outlined below, the first two (1.a and 1.b) are the most commonly used, while the third one (1.c) is often recommended; they all provide only one calibration coefficient by sensor.

1.a. Calibration on the mean bias : this method consists of calculating the calibration coefficient ***C*** such that for the mean bias of the relative errors for the gross weights of all the test vehicles measured in motion (one measurement for each run) is removed, each of them being accounted as many times as the lorry passed:

$$C = \frac{\sum_i n_i}{\sum_{i,k} \frac{Wd_{ik}}{Ws_i}} \qquad (1)$$

This method provides an unbiased estimator of the gross weight. It is recommended in (r1).

1.b. Calibration on the total weight : this method consists of calculating the calibration coefficient ***C*** as the ratio of the total static gross weight of all the test vehicles (each of them being accounted for as many times as the lorry passed) to the total gross weight of these vehicles measured in motion (one measurement for each run):

$$C = \frac{\sum_i n_i Ws_i}{\sum_{i,k} Wd_{ik}} \qquad (2)$$

This method provides an unbiased estimator of the total weight of all the vehicles. It is only recommended if the WIM purpose is the estimation of the whole traffic tonnage, such as in economical surveys of goods transportation.

1.c. Calibration on the mean square error (1) : this method consists of calculating the slope of a regression line which passes through the origin in an orthonormal diagram plotting the individual « dynamic » gross weights versus the individual static gross weights of the test vehicles for each passage. It is based on the fact that a WIM system should provide « dynamic » loads which are proportional to the static loads. The calibration coefficient ***C*** is given by:

$$C = \frac{\sum_i n_i Ws_i^2}{\sum_{i,k} Ws_i Wd_{ik}} \qquad (3)$$

This method may be applied for conditions (R2) to (R4), with more than 3 lorries (or loading cases); it minimises the mean square error of the individual gross weight measurements with respect to the static gross weights for all the vehicles passed, with the constraint that the « dynamic » gross weights are proportional to the static ones. It is recommended for most applications, when the purpose is the estimation of the individual lorry weights, because the estimator has a lower variance than the two previous ones and a very small bias.

1.d. Calibration on the mean square error (2) : this method consists of calculating the slope and the ordinate at the origin of the regression line in an orthonormal diagram plotting the individual « dynamic » gross weights versus the individual static gross weights of the test vehicles for each passage. The mean square error should be smaller than with the previous method, but the proportionality between the « dynamic » loads and the static loads is no longer ensured, which is not in accordance with theory. The calibration procedure becomes : $W = \boldsymbol{C}.(Wd - b)$, with b and $\boldsymbol{C}$ given by :

$$C = \frac{\left(\sum_i n_i\right)\left(\sum_i n_i Ws_i^2\right) - \left(\sum_i n_i Ws_i\right)^2}{\left(\sum_i n_i\right)\left(\sum_{i,k} Ws_i Wd_{ik}\right) - \left(\sum_i n_i Ws_i\right)\left(\sum_{i,k} Wd_{ik}\right)} \qquad \textbf{(4)}$$

and

$$b = \frac{\left(\sum_i n_i Ws_i^2\right)\left(\sum_{i,k} Wd_{ik}\right) - \left(\sum_i n_i Ws_i\right)\left(\sum_{i,k} Ws_i Wd_{ik}\right)}{\left(\sum_i n_i\right)\left(\sum_i n_i Ws_i^2\right) - \left(\sum_i n_i Ws_i\right)^2} \qquad \textbf{(4')}$$

This method is not recommended in most cases because of the reason explained above. Furthermore, if applied, the b value should be rather small and independent of the calibration vehicle sample considered, which is not necessarily the case.

*In both methods **1.c.** and **1.d.**, the gross weights may be replaced by the axle loads and the formulas adapted. The calibration coefficients will then be slightly different. This is not highly recommended, because the individual axle loads are more significantly affected by the dynamic motion of the vehicles than the gross weights, and because the static axle loads are not well defined.*

2. Calibration by lorry type : this method provides one calibration coefficient for each type (silhouette) of lorry from the test sample, or for each class of silhouette (e.g. rigid lorry, tractor + semi-trailer, lorry + trailer). It is only applicable for conditions (R3) and (R4), and of interest if the WIM station software is able to manage such a set of calibration coefficients according to each lorry type. The same formulas as in ***1.a.*** to ***1.d*** may be applied, as many times as the number of lorry classes considered. The same remarks apply to each formula and procedure.

3. Calibration by axle rank : this method provides one calibration coefficient for each rank (and/or type) of axle within a lorry, taking into account the fact that the axle dynamic behaviour depends on their rank in the vehicle. It is only of interest if the WIM station software is able to manage such a set of calibration coefficients according to each axle rank. It is recommended to consider the following sub-populations, some of which may be merged for simplification:

- for the rigid 2-axle lorries: the front axles and the rear axles,
- for the rigid 3-axle lorries: the front axles and the rear tandem (sum of the two rear axles),
- for the tractors with semi-trailers: the front axles, the drive axles and the tandem or tridem of the semi-trailer (sum of the two or three rear axles),
- for the lorries + trailers: the front axles, the rear axles (or tandem or tridem) of the tractors, the axles of the trailers.

The formulas given above are again applied to each sub-population by replacing the gross weights by the axle loads. The same remarks apply to each formula and procedure.

Except for bridge WIM, all of these calibration methods are more efficient in cases (R3) and (R4) with a test lorry sample being representative of the expected traffic flow. In the case of (R1) or (R2) it is recommended to choose loads (gross weights and axle loads) which are representative of the load distribution encountered for the same type of vehicles as the test lorry in the traffic flow.

Annex III (informative): Standard Results' Format and Computer Tools for Accuracy Assessment, and Implementation (Example)

AIII-1. Standard Results' Format and Computer Tools for Accuracy Assessment

AIII-1.1. Data presentation and statistics calculation

Figures 6 and 7 give a standardised table, designed under Excel, which contains the most useful information in order to apply this standard and to assess the accuracy of a WIM system. A sample of this Excel sheet is available by Internet on the International Society for WIM (ISWIM) Web site : http://iswim.free.fr

The first part of the table gives the recorded data delivered by the WIM system, which should be easily extracted from the original data files. The vehicles affected by a violation (error) code were eliminated, but accounted for, to be reported in the test report. The general heading only contains a summary of the required information listed in clause 11.1.5 of the standard. The successive columns contain:

- the sequential number of the vehicles (only lorries with a static GW>3,500 kg are kept);
- date (given once per day, in Day/Month/Year) and time of passage (hh:mm:ss); for this application, it is not necessary to use the hundreds of second;
- temperature, in °C;
- velocity in km/h;
- vehicle type, according to any given classification (the COST 323 classification given in the Annex IV may be used by default);
- the gross weight and axle loads, by axle rank, and the group of axle loads (by rank), all measured in motion;
- the static reference values of these weights and loads.

N.B. the axle spacing is used in the pre-processing of the raw data to identify the single axles and axles of group, but are not necessary for the further accuracy analysis.

All the weights and loads are given in kg, but with a scale division of 100 kg according to the sensitivity and accuracy of the system.

The second part of the table gives the relative errors, automatically calculated by formula in the Excel sheet, and the axle type (single axles or axle of group). Finally, the statistics of the relative errors, as required in clauses 10.4.5 and 10.4.6 are automatically calculated by formula, combining the individual relative errors and the type of axle information.

The small table of these statistics are the sufficient information needed to perform the accuracy calculation, using the test conditions (see section AIII-1.2).

AIII-1.2. Accuracy calculation

The accuracy calculation, according to the procedure detailed in the clause 10, may be automatically done using the standardised Excel sheet given in figure 8. The statistics calculated in AIII-1.1 are introduced in the relevant cells, as well as the test conditions. The percentages of identified vehicles in the whole test sample are reported for information. If the system has a violation code, two percentages should be given, taking into account or not the vehicles identified but wrongly measured.

For an initial verification, δ is automatically multiplied by k=0.8 (clause 9.1.3) and the accuracy class calculated accordingly in the sheet.

Then the built-in formula calculate the values of π_0, and using the solver with appropriate arbitrary initial values of δ_{min} automatically fulfils the table. The standardised graph is also provided, which shows both the δ_{min} and δ_c values for all the criteria.

This Excel sheet is also available on Internet (see AIII-1.1).

AIII-2. Example of Implementation of the Checking Procedures

In order to illustrate the procedure explained in clause 10, an example is given hereafter.

AIII-2.1. Calibration Plan

A WIM system was installed and calibrated during one and half day (environmental repeatability conditions (I)), following the procedure described in section 7.2.3. The calibration plan was the following:

- two reference lorries were used, a 2-axle rigid lorry and a 5-axle semi-trailer;
- each of these reference vehicles made several runs past the WIM site, at different speeds, and for the 5-axle semi-trailer at different loads, according to table AIII-1; all together 115 runs were recorded;
- the WIM system was then calibrated on all these run results, with the formula (3) of the annex II, using the gross weights;
- the initial accuracy verification is then done with these results, according to the procedure described in clause 10.

According to this calibration plan, the test conditions are limited reproducibility (R3).

Reference vehicle	Speed (km/h)	Loading and number of runs		
		fully loaded	half loaded	empty
2-axle rigid	80	10 runs	-	-
	65	20 runs	-	-
	50	10 runs	-	-
5-axle articulated	80	10 runs	10 runs	5 runs
	65	10 runs	10 runs	5 runs
	50	10 runs	10 runs	5 runs

Table AIII-1 : Calibration plan with two reference lorries

AIII-2.2. Initial Verification and Accuracy Check

The results of the initial verification using the calibration sample data are summarised in table AIV-2.

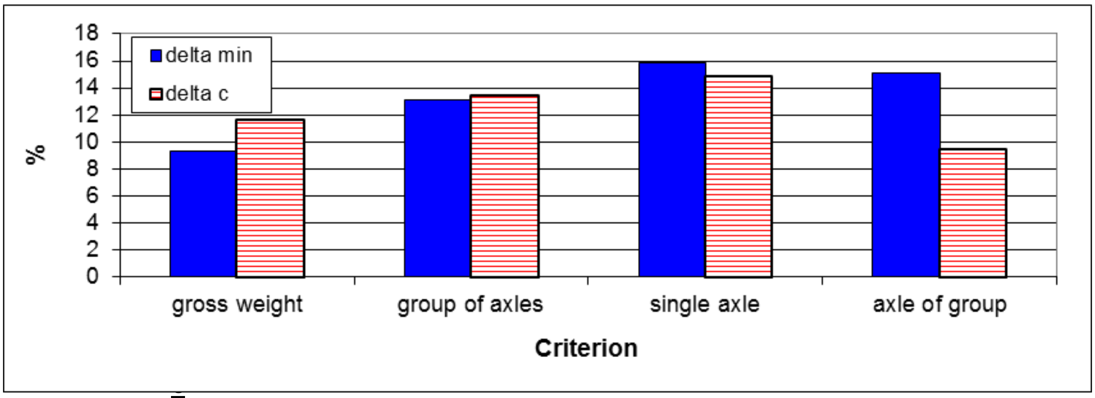
The values of δ are taken from table 2.1 for the classes retained, and multiplied by the reduction factor k = 0.8 (clause 9.1.3). The theoretical probability π is used. The minimum required π_0 are either taken from table 4 (conditions E1 and R3) and interpolated, or automatically calculated by the Excel sheet of the figure 2. Values of δ_{min} obtained for $\pi=\pi_0$ are also given and to be compared to $k.\delta$.

It may be seen that the WIM system fulfils the requirements of class C(15) in this initial verification, and even B(10) for the axles of a group (tridem here). Figure 4 shows the results as well.

	Statistics of relative errors				Accuracy calculation					
entity	**Number** ***n***	**Mean** ***m*** (%)	**St. dev.** ***s*** (%)	Π_o (%)	**Class**	***0.8****δ (%)	δ_{min} (%)	δ_c (%)	Π (%)	**Accepted Class**
gross weight	115	- 0.29	4.28	95.1	**C(15)**	12	9.3	11.7	99.0	**C(15)**
group of axles [1]	75	0.23	6.01	94.6	**C(15)**	14.4	13.1	13.4	96.6	
single axle	235	- 0.62	7.31	95.7	**C(15)**	16	15.9	14.9	95.9	
axle of a group	225	0.26	6.96	95.7	**B(10)**	16	15.1	9.4	96.9	

[1] tridem

Table AIII-2 : Results of the initial verification



4 : Results of the initial verification

AIII-2.3. In-service Check of the WIM System

After the initial calibration, a test was performed to check the accuracy of the system in more representative conditions, i.e., in full reproducibility (R4). For this check, about one hundred lorries from the traffic flow were used, stopped with the help of the police during an enforcement period over three consecutive days (environmental repeatability conditions E1). These lorries were pre-weighed on an approved static scale installed 5 km upstream of the WIM site. The axle loads were measured on this scale. Every pre-weighed lorry was identified by its registration plate (and some visual description) and identified when passing on the WIM site.

The lorry sample composition was chosen in accordance with the traffic composition of this road, following a special agreement with the police. 86 lorries were weighed on the static scale and available for the test analysis.

The results of the test are summarised in table AIII-3, with the same presentation as in table AIII-2. The values of Π_0 are taken from table 4 (interpolated) or calculated.

The alternative method described in 10.4.7.2 is applied by comparing the value of δ_{min}, for which $\Pi=\Pi_0$, to the δ of the required class. δ_{min} gives the right accuracy level between two levels codified by letters. For two criteria (single axles and gross weight) the accuracy level is really in-between the conventional limits of classes B(10) and C(15). For the axle groups it is closer to the class C(15) limit, while for the axles of group the value is just above the limit of the class B(10).

	Statistics of relative errors				Accuracy calculation					
criterion	**Number** ***n***	**Mean** ***m*** (%)	**St. dev.** ***s*** (%)	π_o (%)	**Class**	δ (%)	δ_{min} (%)	δ_c (%)	π (%)	**Accepted Class**
gross weight	86	- 2.27	6.09	92.6	**C(15)**	15	13.0	13.0	96.3	**C(15)**
group of axles [1]	66	- 0.30	8.44	92.1	**C(15)**	18	17.1	14.1	93.6	
single axle	197	- 3.92	7.66	93.7	**C(15)**	20	17.1	12.1	97.3	
axle of a group	169	- 0.19	10.07	93.5	**C(15)**	25	20.3	10.3	97.9	

[1] tridem

Table AIII-3: Results of in-service verification

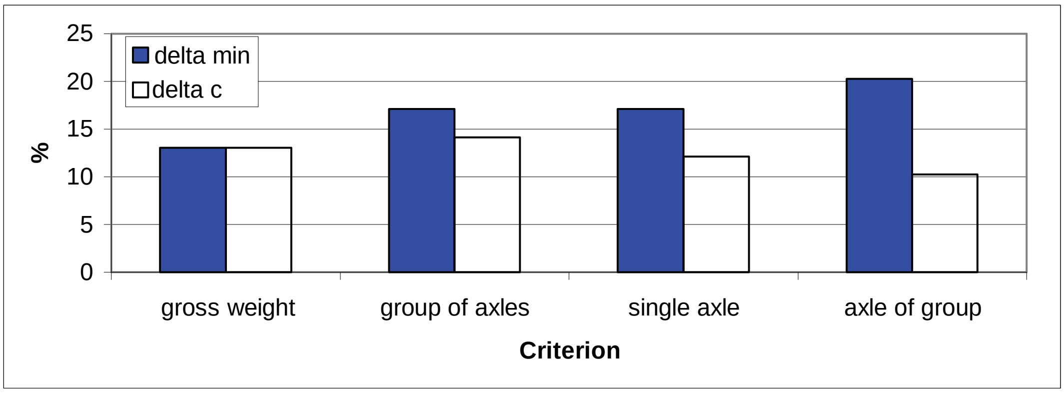


Figure 5 : Results of the in-service verification

The system is accepted in accuracy class C(15) for all the criteria.

In comparison with the initial verification, the bias on the single axle loads and on the gross weights were respectively increased by factors of 5 and 10 (but the last one was very small), while the standard deviations of the axle group and gross weight samples increased by more than 40 %.

System: "Name or manufacturer" **Location: "test site"** **Lane N°: kk** **RECORDED DATA**

Period of the test: "from date1 to date2"

Test conditions: (EI to EIII) and (R1 to R4) **Number of test vehicles: nnnn**

Load and weights may be expressed either in kg, 100 kg, tons or kN; the unit must be specified in the headings

N°	Date/ time	T (°C)	V (km/h)	Type	In motion loads/weights *Wd* (kg)										Static loads/weights *Ws* (in kg)									
					GW	A1	A2	A3	A4	A5	A6	...	GA1	GA2	GW	A1	A2	A3	A4	A5	A6	...	GA1	GA2
1	5/4/98 08:10:25	9,3	85	5	38000	6400	10600	7000	7000	7000			21000		39000	6500	10800	7300	7200	7200			21700	
2	08:11:23	9,5	89	5	39600	6200	13500	6900	6300	6700			19900		40200	6600	12100	7300	7000	7200			21500	
3	08:12:28	9,7	89	5	39400	5900	10300	9400	7300	6500			23200		38500	5900	9600	8700	7900	6400			23000	
4	08:13:06	9,9	88	5	40900	7100	10100	8200	8100	7400			23700		40500	6700	10100	7900	7900	7900			23700	
5	08:13:30	10,1	87	5	40000	8100	11700	7100	7000	6100			20200		39800	7500	11800	6900	6600	7000			20500	
6	08:13:56	10,1	90	5	30700	6700	12500	3600	4200	3700			11500		28200	6700	9900	3900	4000	3700			11600	
7	08:14:54	10,1	89	5	41300	6400	9800	8300	8600	8200			25100		42800	6100	10600	8700	8800	8600			26100	
8	08:16:09	10,1	79	6	36600	6500	12400	9000	8700						35700	6400	11100	9200	9000					
9	08:16:12	10,1	85	5	40500	6500	9200	8500	8100	8200			24800		39500	6500	9400	8100	8200	7300			23600	
10	08:16:32	10,1	88	5	42200	8200	13800	6900	6500	6800			20200		42000	7800	13400	7000	6900	6900			20800	
11	08:17:38	10,1	81	5	48300	8000	13000	8900	9200	9200			27300		48600	8100	13700	8900	8900	9000			26800	
12	08:18:28	10,2	88	5	33500	6100	5600	7300	7400	7100			21800		32600	6000	5200	7000	7200	7200			21400	
13	08:19:03	10,3	89	5	48700	7800	14200	9100	8500	9100			26700		46800	7200	14500	8400	8400	8300			25100	
14	08:19:50	10,4	86	5	37400	6400	8600	7600	7500	7300			22400		38600	6200	8300	8100	8400	7600			24100	
15	08:20:49	10,5	80	6	44900	6700	7200	8300	6400	7400	8900		16300		43900	6500	7500	8000	7100	7000	7800		14800	
16	08:21:03	12	88	5	39000	6200	10100	7500	7900	7300			22700		38400	6000	9700	7400	8000	7300			22700	
17	08:21:20	12	92	5	20200	5400	5300	3500	2900	3100			9500		20600	5200	5400	3400	3300	3300			10000	
18	08:22:29	12,3	86	5	37000	6100	7900	8400	7200	7400			23000		35000	6000	7400	7800	6800	7000			21600	
19	08:23:27	12,3	95	2	6800	2700	4100								6900	2900	4000							
20	08:23:33	12,4	88	5	43300	6900	11400	8800	8200	8000			25000		45400	6700	12100	8900	8900	8800			26600	
21	08:23:37	12,8	85	5	41500	6400	8800	7800	8200	10300			26300		40500	6200	9000	7300	8000	10000			25300	
22	08:25:13	13,4	89	6	42800	8400	12200	6700	7500	8000			18900		42900	7800	12300	6900	8000	7900			19200	
23	08:25:25	13,4	87	5	31300	6500	8800	5500	5000	5500			16000		29900	6300	8200	5200	5100	5100			15400	

Type *: the classification is that recommended by this specification; otherwise the vehicle categories should be given apart*
- axle loads are placed in columns A1 to A6, according to the axle rank; GA1 (and GA2 if needed) contains the group(s) of axle loads
- the type may be replaced by the number of axles, or this number may be added in an additional column
- for more than 6 axles, add columns after A6; for more than 2 axle groups, add columns after GA2

Figure 6: Standardised recorded data format and statistics – part1

Cont'n **STATISTICS**

N°	Relative errors (%)										Type of axle (1=SA, 0=AoG)						
	GW	A1	A2	A3	A4	A5	A6	…	GA1	GA2	A1	A2	A3	A4	A5	A6	…
1	-2,56	-1,54	-1,85	-4,11	-2,78	-2,78			-3,23		1	1	0	0	0		
2	-1,49	-6,06	11,57	-5,48	-10,00	-6,94			-7,44		1	1	0	0	0		
3	2,34	0,00	7,29	8,05	-7,59	1,56			0,87		1	1	0	0	0		
4	0,99	5,97	0,00	3,80	2,53	-6,33			0,00		1	1	0	0	0		
5	0,50	8,00	-0,85	2,90	6,06	-12,86			-1,46		1	1	0	0	0		
6	8,87	0,00	26,26	-7,69	5,00	0,00			-0,86		1	1	0	0	0		
7	-3,50	4,92	-7,55	-4,60	-2,27	-4,65			-3,83		1	1	0	0	0		
8	2,52	1,56	11,71	-2,17	-3,33						1	1	1	1			
9	2,53	0,00	-2,13	4,94	-1,22	12,33			5,08		1	1	0	0	0		
10	0,48	5,13	2,99	-1,43	-5,80	-1,45			-2,88		1	1	0	0	0		
11	-0,62	-1,23	-5,11	0,00	3,37	2,22			1,87		1	1	0	0	0		
12	2,76	1,67	7,69	4,29	2,78	-1,39			1,87		1	1	0	0	0		
13	4,06	8,33	-2,07	8,33	1,19	9,64			6,37		1	1	0	0	0		
14	-3,11	3,23	3,61	-6,17	-10,71	-3,95			-7,05		1	1	0	0	0		
15	2,28	3,08	-4,00	3,75	-9,86	5,71	14,10		10,14		1	0	0	1	0	0	
16	1,56	3,33	4,12	1,35	-1,25	0,00			0,00		1	1	0	0	0		
17	-1,94	3,85	-1,85	2,94	-12,12	-6,06			-5,00		1	1	1	1	1		
18	5,71	1,67	6,76	7,69	5,88	5,71			6,48		1	1	0	0	0		
19	-1,45	-6,90	2,50								1	1					
20	-4,63	2,99	-5,79	-1,12	-7,87	-9,09			-6,02		1	1	0	0	0		
21	2,47	3,23	-2,22	6,85	2,50	3,00			3,95		1	1	0	0	0		
22	-0,23	7,69	-0,81	-2,90	-6,25	1,27			-1,56		1	0	0	1	1		
23	4,68	3,17	7,32	5,77	-1,96	7,84			3,90		1	1	0	0	0		

Statistics of the relative errors (%)				
	GW	**SA**	**AoG**	**GA**
number	**23**	**52**	**60**	**21**
mean	**0,97**	**1,52**	**0,17**	**0,06**
st. dev	**3,22**	**6,31**	**5,88**	**4,77**

GW= gross weight
SA= single axle
AoG= axle of a group
GA= group of axles

- the relative errors are calculated cell be cell from the previous part of the sheet using the formula: e=(Wd-Ws)/Ws
- the type of axle can be delivered by the WIM system, or derived from the axle spacing (AoG if the spacing is less than 2.2 m)
- the statistics of the relative errors are calculated using formula, which combine the relative errors and the type of axle cells

Figure 7: Standardised recorded data format and statistics – part 2

	A	B	C	D	E	F	G	H	I	J	M	O	P	Q
1	**Conditions (1)**	**Test plan**		**Env^t**		**Initial verification (Yes=1, No=0):**					0			
2		R3		EI										
3														
4	**SYSTEM**	**Number**	**Identified**	**Mean**	**Std deviat**	π_o	**Class**	δ	δ_{min}	δ_c	π	**Accepted**		
5	***Entity***		(%)	(%)	(%)	(%)		(%)	(%)	(%)	(%)	**class**		
6	**gross weight**	100	96,2	1,50	3,67	-15,7	**B(10)**	10	8,5	8,5	98,0			
7	**group of axles**	50	96,2	2,00	5,78	-22,4	**C(15)**	18	13,3	10,3	99,0	**C(15)**		
8	**single axle**	170	95,5	2,10	6,54	-12,0	**B(10)**	15	14,8	9,9	95,7			
9	**axle of group**	120	96,0	2,50	9,72	-14,3	**C(15)**	25	21,8	11,8	97,8			

10 (1)
11 "R1"=full repeatability
12 "R2"=extended repeatability
13 "R3"=limited reproducibility
14 "R4"=full reproducibility
15 "EI"=environmental repeatability
16 "EII"=environmental limited reproducibility
17 "EIII"=environmental full reproducibility

Users' instructions:

1. Enter the test conditions in cells B2 and D2, and put "1" in cell M1 if the same data sample was used for calibration (initial verification)

2. Enter the test statistics (on relative errors) in cells B6 to B9 and D6 to E9

3. (option) Initialise the expected values of δ_{min} in cells I6 to I9 ***(only if step 4. fails)***

4. Start the command "Tools/Solver/Solve/keep the results"
- "Outils/Solveur/Résoudre/Garder la solution du solveur"
, and then OK if successful
if the solver doesn't find an accepted solution,
return to step 3. and modify the initial values of δ_{min}

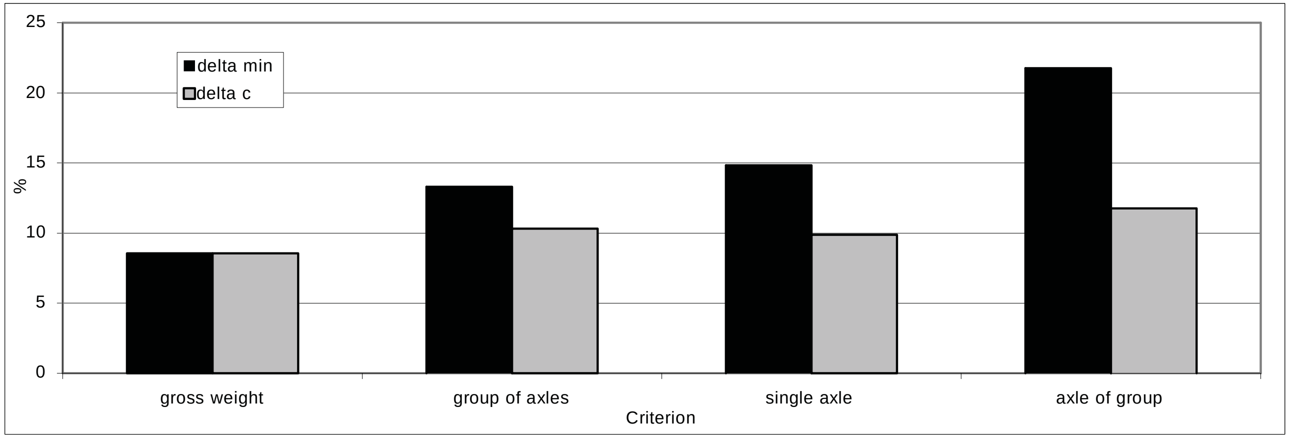


Figure 8: Standardised accuracy calculation sheet and presentation

Annex IV (informative): Comments

The section numbers refer as far as possible to the corresponding clause numbers of the standard.

AIV-1. Scope

The European WIM Specification has been produced in 1999 by the COST323 Management Committee, as part of the COST Transport action "WIM-LOAD". It gives general and detailed recommendations for site selection, installation, operation, calibration and assessment by testing of WIM systems. It is based on COST323 member countries and US experience, and existing national specifications. However there were only a few specification documents and no official standard on WIM in Europe in the late 90's. Moreover, the existing US standard on WIM (ASTM, 2002) is mainly designed for model approval, or to indicate the potential upper limit of performance which can be achieved by the particular type of system as the road surface conditions shall be the best available for conducting the acceptance test. The main objective of this standard is to cover the need for a complete specification, covering both aspects: (1) model approval, and (2) on site acceptance test and accuracy assessment. The COST323 Specification provided a technical basis for this standard and thus was a « pre-standardisation document ».

AIV-1.1. The requirements of accuracy for the different applications are based on the ***Requirements and Needs of Road Vehicles WIM in Europe*** published by the COST-323 Management Committee (Jacob et al., 2002).

Even if in some situations, particularly for legal purposes, lorry weighing is still currently limited to the use of static scales, in many European countries and for multiple applications, Weigh-In-Motion (WIM) systems are routinely or experimentally used. Therefore a standard is useful to assess the real performance of any WIM systems and to organise trials. Moreover, the use of WIM systems for legal enforcement purposes is now becoming a main challenge, and requires a strong legal and standardised basis.

AIV-1.2. This standard may be referenced or used to draft any general or particular specifications, for any call for tender, and to analyse performance or acceptance test data of WIM systems.

AIV-2. Terminology

This section gives some additional definitions which complete those of the clause 3.

AIV-2.1. Bending plate : plate instrumented with strain gauges and placed under wheels or axles to measure their static or dynamic tyre forces.

AIV-2.2. Dynamic vehicle tyre force

In addition to the force of gravity, this force can include the dynamic effects of influences such as road surface roughness, vehicle acceleration, out-of-round tyres, dynamically unbalanced wheels or tyres, tyre inflation pressure, vehicle suspension and aerodynamic features, and wind. For purposes of this standard, the WIM system shall be adjusted or calibrated to indicate the magnitude of the vertically downward, measured dynamic vehicle tyre force in units of mass (kilograms, kg or megagrams, Mg). The indicated mass can be converted to units of force by multiplying it by the local value of acceleration of free fall, if it is known.

AIV-2.3. Fibre optic sensor : strip sensor incorporating an optic fibre; the fibre bending resulting from an applied force (by the tyres on a wheel or an axle) modifies the light propagation conditions; the applied force may be derived from this modification.

AIV-2.4. Gross weight (GW)

The force of gravity – thus, the acceleration of free fall – is different at various locations on or near the surface of Earth; therefore, weighing devices in commercial use or in official use by government agencies for enforcement of traffic and highway laws or collecting statistical information are usually used in one locality and are adjusted or calibrated to indicate mass at that locality. The indicated mass can be converted to weight (in units of force) by multiplying by the local value of acceleration of free fall, if it is known. For purposes of this standard, - and in accordance with common weighing practice – the WIM system shall be adjusted or calibrated to indicate the magnitude of estimated weight and load in units of mass (kilograms, kg or megagrams, Mg), and the direction of the associated force vector will always be downwards toward the approximate centre of Earth.

AIV-2.5. Load cell : a device that produces a signal proportional to the load applied to it.

AIV-2.6. Magnetic (or inductive) loop : insulated copperwire cable buried in the pavement or bonded on the pavement surface, used for vehicle presence detection.

AIV-2.7. Piezoelectric cable : a coaxial cable containing a piezoelectric substance, which converts an applied strain or pressure into an electrical signal which is related to the magnitude and direction of the applied strain or pressure. A **piezoelectric sensor** is a strip sensor containing a piezoelectric cable; it may be of two types: **piezoceramic sensors** and **piezopolymer sensors**. A **piezoquartz sensor** is a strip sensor which uses piezoelectric crystal quartz.

AIV-2.8. Piezoresistive sensor : a sensor which indicates the magnitude of an applied force through a variation in its electrical resistance.

AIV-3. User and Performance Requirements

AIV-3.1. The WIM systems are classified in six main accuracy classes (clause 6): A(5), B+(7), B(10), C(15), D+(20), D(25). Additional classes E(xx) are given for systems which do not meet the main classes.

AIV-3.2. The accuracy is mostly referred to the weights and static loads, i.e. for weighing purposes, and rarely to the real tyre impact forces applied by the wheels/axles on the pavement and on the WIM sensors, such as for technical studies on pavement and vehicles. The distinction must be clearly specified in writing, case by case. In the first alternative, it is recommended to specify how the static loads and weights are obtained, and above all the static axle loads. In the second alternative, the mean to obtain the reference values of the impact forces must be specified.
For practical reasons but also according to the most frequent requirements, reference to the static loads/weights may be assumed unless another reference value is specified.

Both of these references raise some difficult questions and issues, as mentioned in (Jacob, 2000).

The accuracy of a WIM system in its conditions of use, i.e., under moving traffic tyre loads, may only be defined in a statistical way (Jacob, 2000), by a tolerance interval of the relative error of a unit (an axle, an axle group or a gross weight), defined by: $(Wd-Ws)/Ws$, where Wd is the impact force or dynamic load measured by the WIM system and Ws the corresponding static load/weight (or any other specified reference value) of the same unit. Such a tolerance interval centred on the static load/weight, is noted: $[-\delta;+\delta]$, where δ is the tolerance for a confidence level π (for example 90 or 95%).

Even for systems supporting the traditional definition of accuracy (OIML, 2006), weighing statically is not representative of real conditions of WIM system use.

AIV-3.3. According to (Jacob et al., 2002), the main requirements and applications of WIM may be classified with respect to the statistical accuracy as summarised below with increasing levels of accuracy:

1. Statistics : Economical and technical studies of freight transport, general traffic evaluation on roads and bridges, collecting statistical data, etc..
δ **up to 20 to 30% (class D+(20), or D (25))**

2. Infrastructure and pre-selection : Detailed analysis of traffic, design and maintenance of roads and bridges, accurate classification of vehicles, pre-selection for enforcement, etc..
δ **up to 10 to 15 - 20% (class B (10), or C (15))**

3. Legal purposes : Enforcement and industrial applications, but only if the legislation allows the use of WIM for that purpose. Currently static weighing or LS-WIM are required for these applications; but some development is going on to increase the possibilities of HS-WIM for legal purposes.
δ **up to 5 to 10% (class A (5), or B+ (7))**

These figures are only given here as an indication; each user can define his own requirements for his particular application. Moreover the requirements depend on the environmental and road conditions. The clause 6 specifies which figure apply to each entity (gross, axle, etc.).
Any level of accuracy not only refers to the performance of the WIM system used (i.e., the sensor(s) and electronic station with its software), but also to the calibration procedure and frequency, to pavement/road quality and evenness and vehicle behaviour.

The confidence π in the accuracy level δ (the tolerance interval width) of a WIM system depends greatly on the conditions of measurement, that means principally the repeatability or reproducibility conditions of the sample measured, the environmental repeatability or reproducibility conditions and on the sample size and content (types of vehicles).

AIV-3.4. <u>Choice of an accuracy class with respect to the application</u>

Different needs may lead to different accuracy requirements with respect to the weights. The following requirements are given unless otherwise stated by the customer:

Class A(5) : legal purposes such as enforcement of legal weight limits and other particular needs; to provide reference weight values for in-service checks, if the classes B(10), C(15) or D(25) are required, for all the traffic flow vehicles (assuming that it is not possible weigh statically such a large population);

Class B+(7) : enforcement of legal weight limits in particular cases, if the class A(5) requirements may not be satisfied, and with a special agreement of the legal authorities; efficient pre-selection of overloaded axles or vehicles; to provide reference values for in-service checks, if the classes C(15) or D(25) are required, for all the traffic flow vehicles (assuming that it is not possible to weigh statically such a large population);

Class B(10) : Accurate knowledge of weights by axles or axle groups, and gross weights, for:
- infrastructure (pavement and bridge) design, maintenance or evaluation, such as aggressiveness evaluation, fatigue damage and lifetime calculations,
- pre-selection of overloaded axles or vehicles,

- vehicle identification based on the loads.

Classes C(15) or D+(20) : Detailed statistical studies, determination of load histograms with class width of one or two tonnes, and accurate classification of vehicles based on the loads; infrastructure studies and fatigue assessments.

Class D(25) : Weight indications required for statistical purposes, economical and technical studies, standard classification of vehicles according to wide weight classes (e.g. by 5,000 kg).

Additional **classes E(30), E(35), etc.,** are defined for WIM systems which do not meet the class D(25) requirements. These classes are specified in the clause 6, to assess the accuracy of rough systems or of systems installed on poor WIM sites. However, they may be useful to give indications about the traffic composition and the load distribution and frequency.

AIV-4. Criteria for the Choice of WIM Sites

The WIM site characteristics have some influence on the in-motion vehicle behaviour and may lead to large discrepancies between the axle impact forces and the corresponding static loads. Therefore the specified criteria about the road geometry and the pavement characteristics are given in order to reduce these discrepancies and to keep them within some limits in accordance with the required accuracy levels.

The accuracy of a bridge WIM system also depends highly on the selection of the weighing site, particularly on the type of the superstructure and the evenness of the approach.

However these criteria, and above all those relating to the pavement profile, are mainly given as indicative, because only the specified WIM system performance (e.g. accuracy and durability) is mandatory. If some systems, as a result of their principal or intrinsic nature, may tolerate weaker criteria and meet the accuracy and durability requirements - that should be proven by testing -, then they may be installed on other sites than those hereafter specified.

AIV-4.2. Pavement Characteristics

The pavement characteristics directly influence the signal recorded by any WIM sensor, because of:

- the pavement/vehicle interaction leading to dynamic impact forces,
- in most cases, the road is the support for the sensor and therefore forms part of the measurement device.

Thus not only the longitudinal evenness but also deterioration (such as rutting, deformation, etc.) limit the accuracy of the measurements, while cracking may reduce the WIM sensor durability or affect its response. The deflection and the transverse evenness may also affect the reliability and durability of the sensors.

AIV-4.2.1. Comments about the deflection

(i) The deflection criteria are not applicable to concrete pavements (for such pavements, the values should be much smaller than the limits proposed...). Nevertheless for concrete slab pavement, the slab banging motion should be limited to 0.05 mm for sites in class I and to 0.10 mm for sites in classes II and III.

(ii) For granular pavements (pavements in which the granular layer provides the structural strength of the pavement) the deflection values will be much higher. For this type of pavements special care should be taken by the choice of the mounting method and materials.

(iii) The quasi-static deflection is measured using a Deflectograph (long chassis) with a 13,000 kg axle load at 2 to 3.5 km/h; a linear correction may be done for other axle loads. The measuring procedure is as follows: the left and right wheel paths are measured every 4.2 m; the largest of the two values is taken; then the mean is calculated along a section of 200 m (the WIM sensor being in the middle). The difference between the left and right values should not exceed the figures given in the table 1.1 at any distance less than 4.2 m from the WIM sensor(s).

(iv) The dynamic deflection limits are based on FWD measurements, using a Dynatest 8000, with a test load of 5,000 kg, and a reference temperature of 20°C. A linear correction may be made for other loads. It is recommended to make at least three measurements in each wheel path for the section considered, and to apply the same procedure as in (iii) to calculate a mean deflection.

Finally, it should be recalled that the deflection affects the durability of the sensors, while the left/right difference may limit the accuracy of the measurements.

Comment about the evenness:

The measured evenness in terms of ratings at 200 m intervals is sufficient for screening sites; it is however necessary to consider more carefully the exact area of installation within the 200 m so as to avoid a single point having poor evenness:

- for class I and II sites, by accurate-scale operation,
- for a class III site, using the 3 m beam.

AIV-4.2.2. Comment : This table does not give a strict relationship between the accuracy classes and the test site: some types of WIM systems - depending on the type of sensor and the measurement principle - may require higher or lower site classes to meet the same accuracy level. For example, large scales or large-based sensors (i.e. longer than the tyre imprint in the direction of the traffic flow) are less sensitive to the pavement evenness than are narrow-based sensors. Moreover multiple sensor WIM systems may be installed in pavements with poorer evenness, if a suitable algorithm performs calculations to reduce the dynamic effects.

AIV-4.3. WIM Site Classes (not for B-WIM)

According to the current experience of WIM systems using road sensors, except for multiple sensor WIM systems, the expected accuracy class according to the clause 6.2 require a minimum quality of the WIM site, as shown in table AIV-1.

Accuracy	site I (Excellent)	site II (Good)	site III (Acceptable)
class A (5)	+	-	-
class B+(7)	+	-	-
class B (10)	+	+	-
class C (15)	(+)	+	+
class D+ (20)	(+)	(+)	+
class D (25)	(+)	(+)	+

legend: '-' *means insufficient,* '+' *means sufficient,* '(+)' *means sufficient but not necessary*

Table AIV-1 : Choice of a WIM site according to the accuracy required

AIV-4.4. Particular Requirements for Bridges

AIV-4.4.1. The basic bridge selection criteria recommended are summarised in Table AIV-2.

Criteria	Optimal	Acceptable
bridge type	steel girders, prestressed concrete girders, reinforced concrete girders, culvert, steel orthotropic decks (1)	concrete slab
span length (2) (3)(m)	10 - 20	8 - 35
traffic density	free traffic - no congestion (traffic jam)	
evenness of the pavement before and on the bridge	class I or II (Table 1)	class III (Table 1)
skew (°)	≤ 10	≤ 25 or ≤ 45 (*)

(1) expected to be optimal, (2) this criterion applies for the length of the bridge part which influence the instrumentation, (3) except culverts, (*) after inspection of calibration data

Table AIV-2 : Bridge selection criteria

A bridge-WIM system may be installed on:

- culverts: any length if accurate axle and velocity detections are available,
- bridges designed as simply-supported or integral (frame-type) structures, or any variation of these two,
- single or multiple-span bridges,
- structures made of reinforced concrete, pre-stressed concrete, steel or combination of these materials and any other materials (e.g. fibre-reinforced plastics) that ensure linear behaviour under the expected traffic loading,
- bridges designed as slabs or beam/deck structures,
- any other type of bridges (e.g. with an orthotropic deck as the superstructure) which provides requested information (about velocity and axle spacing of individual vehicles, linear dependence between the measured structural response and passing vehicles).

Span (or sub-span) lengths up to 35 m are optimal. Generally, gross weight accuracy increases with the span length, and on spans over 15 m is much higher compared to accuracy of axle, when measuring only the main span strains.

AIV-4.4.2. Skew (angle between the centre-line of the superstructure in direction of driving and the line perpendicular to the abutments) should be minimal. If the angle is less than 10 degrees it can be neglected, otherwise compensations in the calculations should be used. Angles over 40 degrees are generally not acceptable.

Accuracy of the bridge WIM results is strongly related to the number of trucks (axles) which drive over those parts of the bridge which influence the structure at the same time (one truck at a time gives best results). Therefore the length of the structure and the traffic density have to be judged together (the more dense the traffic, the shorter is the optimal length of the structure).

If the influence line is used in the weight assessment algorithm, an influence line based on actual strain readings can improve the accuracy of calculation. This is particularly important when a continuous bridge is instrumented. With this type of structure it is also essential that all the spans which considerably influence the behaviour of the instrumented span (where the strains of the superstructure are measured) are taken into account.

AIV-4.5. Other Requirements

AIV-4.5.1. For calibration and testing purposes, it is recommended to have a static weighing area or a static scale close to the WIM site. A preferable site should allow for a reasonable run time for a calibration or test vehicle to perform a complete loop of the WIM site.

AIV-4.5.2. For maintenance and checking it is recommended to have a parking lot close to the system.

AIV-4.5.3. The availability of following facilities on the WIM site is recommended:

- electricity supply for sensor installation and WIM system operation,
- communication link to connect the WIM station to be remotely monitored and for data collection,
- road side cabinet to protect the WIM station against rainfall, snowfall, sunshine, vandalism, etc..

AIV-5. Environmental Requirements

Most of the suppliers of WIM devices specify some environmental requirements for the use of their equipment. These requirements usually meet some existing standardised criteria, either for civil or military electronic devices. The following criteria are given to provide a common framework or to detail some requirements more specific to WIM sensors. They may be adapted by each customer with respect to the particular conditions of the WIM site chosen.

These requirements mainly concern the climatic conditions, but also deal with the traffic conditions and the facilities needed to install and operate the WIM systems.

AIV-5.1. Sensors

AIV-5.1.1. Climatic conditions

For sensors which are supported by the pavement (such as strip sensors), the pavement modulus may have a strong influence on the sensor response; this is especially the case for bituminous pavements. Bituminous pavement modulus varies by orders of magnitude with the temperature. Some indicative figures are given in table AIV-2

Temperature	- 15 °C	0 °C	15 °C	30 °C
Scale factor of the pavement modulus	10	8	5	1

Table AIV-2: Variation of the pavement modulus (bituminous material) with temperature

This phenomenon may affect both the accuracy of the WIM system and the durability of the sensors. The system should take it into account.

AIV-6. Accuracy Class Tolerances with respect to the Weight

AIV-6.1. General Clauses

The principle used is that the tolerance δ only depends on the accuracy class and on the entity considered, which may be the :

- axle load (single axle),
- axle load (axle belonging to a group),
- axle group load,
- gross weight,

and additionally:

- vehicle speed,
- inter-axle distance,
- vehicle classification (proportion of vehicle of a given type, by silhouette or load).

One criterion is considered for each of these entities.

The level of confidence π of any sample of data only depends on the test sample conditions (R1 to R4), on the environmental test conditions (E1 to E3, see § 10.1.4) and on the sample size (number of runs and of test vehicles), and must be higher than a specified value π_0. π_0 also depends on the test conditions and sample size.

The test plan may depend on the WIM system type, accuracy class required and application.

AIV-7. On-Site System Checks and Calibration

AIV-7.1. General Clauses

AIV-7.1.1.1 A general statistical procedure for calibration and further checking of WIM systems, with respect to the statistical accuracy and classes is described in (Jacob, 2000).

AIV-7.1.1.2. Before the on-site calibration, it is recommended to check by sampling, the expected performance of sensors and electronics. Checking methods have been developed in some countries or are proposed by the vendors, depending on the sensor technology. Some indications are given in the Annex II.

AIV-7.1.2. It is important to note that a WIM system measures instantaneous impact forces, and only estimates weights. WIM data deviations from weights could be considered both as measurement errors and as those resulting from dynamic effects.

AIV-7.1.2.2. These “true impact forces” are generally not easy to measure accurately with a perfect synchronisation with the WIM; however, some techniques were developed, using either shock or pressure devices (clauses 7.2.2 and AIV-7.2.2), or instrumented vehicles (clauses 7.2.4 and AIV-7.2.4)

AIV-7.1.3. The calibration is assumed to be over during a short time period, such as one or two consecutive days, except for automatic self-calibration (clauses 7.2.5 and AIV-7.2.5).

AIV-7.2. Calibration Methods

Different calibration methods are commonly used, which depend on the sensor type, the application and requirements of the user and the time and means available.

AIV-7.2.1. Static calibration

AIV-7.2.1.1. Such a calibration may only be used for those WIM systems which also allow static measurements. It should be noticed that a static calibration will only remove the intrinsic bias of the WIM system, but will not take into account the surrounding pavement conditions and pavement/vehicle interaction, and thus will generally not comply with the objectives of clauses 7.1.2.1 and 7.1.2.2.

AIV-7.2.1.2. The sensors which may be calibrated statically are: strain gauge and load cell scales, piezoquartz crystal bars, capacitive strips or fibre optic sensors, but not piezoceramic or piezopolymer cables, strips and bars. Even for the strip sensors (piezoquartz, capacitive strips and fibre optic), the static calibration is not easy to perform because of the small area of the sensor (and thus the difficulty to apply a mass of several tons), and the loading condition differs from that under traffic flow, because the integration of the signal may not be performed during a static test.

AIV-7.2.1.3. This calibration method is especially convenient if the weight is to be estimated with low speed WIM systems on excellent pavement sites.

AIV-7.2.1.4. For large scales, it is possible to use an accurately pre-weighed lorry and to place its axles successively on the scale, but because of the weak and poor definition of a static axle load (Jacob, 2000), this is not recommended. An alternative method may consists of placing a reference portable static scale between the tire and the WIM scale. In such a case, at least three axles must be used with static loads uniformly distributed within the scale range of the loads to be weighed, and three repetitions for each axle weighing shall be done.

AIV-7.2.1.5. For bridges (Bridge-WIM), it is recommended to use at least one two axle or three axle (single + tandem) rigid lorry, accurately pre-weighed, empty and full. Accuracy can be improved by using two or more calibration lorries with different distributions of weights between axles.

AIV-7.2.2. Use of shock or pressure variation devices

The advantage of this method is to be almost independent of the road profile and of the calibration vehicle characteristics and speed or load (clause 7.2.3 and AIV-7.2.3). However the tests performed have shown that most of the devices used give results scattered along a WIM sensor, not only because of an eventual heterogeneity of the sensor itself, but also because of the impact conditions around the sensor. Moreover, the impact conditions are very different from a tyre imprint and the force applied by an instantaneous vertical force. This method also requires the closure of the traffic lane during the calibration, which may be difficult for busy highways or motorways.

This method is mainly devoted to calibration with respect to impact forces, but not to the weights. It could be of interest if the WIM system is used for impact force measurements (clause 7.1.2.2), as in (Jacob et al., 2000), but until now this method has not yet been proven to be effective.

AIV-7.2.3. Use of reference lorries

AIV-7.2.3.1. This method is recommended when the WIM system is intended to estimate the weights (clause 7.1.2.1).

It is the most commonly used method because of its relative simplicity and directness, and because it is suitable for all kinds of WIM systems. This method partially eliminates the repeatable pavement dynamic effects (bias), but is sensitive to the calibration (test) vehicle characteristics, such as suspension type and parameters, dry friction, etc..

AIV-7.2.3.2. The higher the conditions (from R1 to R4) the more representative the calibration sample of the real traffic conditions, but the procedure becomes longer and more costly! Nevertheless this calibration procedure may be performed without traffic stopping (R1 to R3).

AIV-7.2.4. Use of instrumented lorries

AIV-7.2.4.1. This method is of special interest if the WIM system is intended to measure instantaneous axle impact forces (clause 7.1.2.2), instead of static loads, or to calibrate multiple sensor arrays.

In such a case, the methods described in clause 7.2.3 (and in Annex II) introduce some bias by partially eliminating the dynamic effects being sought. This is the case for some research purposes such as spatial repeatability investigations (Jacob et al., 2000) or pavement/vehicle interaction and pavement damage studies. For multiple sensor WIM systems, the spatial repeatability is used to improve the accuracy of the static load estimator.

The advantage of this method is to make a "true" calibration on the parameter actually measured by a WIM system, i.e. the wheel or axle impact force. Its disadvantage comes from the cost and difficulties of getting and operating such instrumented lorries, which also require specialised technicians. Also there are only very few such instrumented vehicles available actually, and the information and documentation about them is very poor.

The quality of the calibration greatly depends on the accuracy of the lorry instrumentation, which measures continuously each wheel impact force on the pavement as the vehicle travels. But these measurements are indirect, by the mean of accelerations and strain records, and generally require a lot of computation afterwards.

AIV-7.2.5. Automatic self-calibration procedures and software

This kind of method, introduced in France in the early 1980's, has the great advantage of providing a permanent automatic recalibration of a WIM system installed on a trafficked road, and therefore to correct any trend or bias due to sensor, electronics or pavement changes or due to external effects, such as temperature variations. However, it was shown that this procedure requires a prior knowledge of the traffic pattern and may be worst than nothing in some particular circumstances.

AIV-7.2.5.1. In most countries and road networks, there are some « characteristic vehicles » which have some axle(s) and/or gross weight with a low coefficient of variation and a quite constant mean (the target value). In such a case, the moving average of a certain number of these axle loads or gross weights becomes almost constant for a large enough sample size, and may be fitted to the target value. This provides a new coefficient of calibration after the passage of the required number of characteristic vehicles.

Nevertheless it must be noted that such a procedure introduces a statistical error due to the sample size of the considered « characteristic vehicles ». Therefore the time interval between two recalibrations (calculation of a new calibration coefficient) must be a compromise between the reduction in statistical variance (by increasing the sample size) and the delay in recalibration. If the temperature influence is to be eliminated, it is recommended to have such an interval in the range of 1 hour to a few hours. If only some long term trends are to be eliminated, this time interval may be longer (e.g. 1 day to a few weeks).

AIV-7.2.5.2. The method efficiency depends greatly on this prior knowledge but also on the traffic intensity; the higher the traffic flow the more efficient the self-calibration. Therefore this procedure should be used with caution on secondary roads with low traffic volumes.

AIV-7.2.5.3. The frequency of recalibration (or new calibration coefficient calculation) must be adapted to the eigenfrequency(ies) of the perturbations to be eliminated, and to the traffic flow (of characteristic vehicles).

AIV-7.2.5.4. A WIM system needs some time to be automatically self-calibrated (e.g. 1 to 5 days depending on the traffic flow and composition), and to give stabilised results. The user should check that, or the supplier give some warranty, before the system may be used for an operational purpose.

AIV-7.2.5.5. It is recommended to consistently check the self-calibration by screening the calibration coefficients to avoid gross errors which may occur for various reasons, such as a temporary lack of characteristic vehicles, some unexpected change in the target values, vehicles passing partially outside the traffic lane, etc.. Thus, the calibration coefficients should be recorded in permanent files by the WIM systems using this procedure, and easily readable with their date and time (in case of detailed data records; otherwise, some statistics on these coefficients should be given). It is also necessary to perform periodical calibration checks (e.g. once or twice a year) using pre- or post-weighed lorries, or by some coherence tests on the statistics delivered by the system.

AIV-7.2.5.6. It is recommended to record the temperature in order to check the correlation between it and the calibration factor, and to evaluate the statistical error.

Finally it should be noted that even if this type of calibration is very easy and inexpensive to implement after performing the appropriate preliminary studies and after the development of the proper software, it may also introduce some uncontrolled bias or variance.

AIV-8. Type (model) approval of a WIM System

A type(or model) approval is a complete standardised procedure to be applied once to any newly manufactured measuring system, before to market it, in order to deliver a quality label and some target performance under known conditions of use. The clause 8 only deals with the on-site accuracy assessment of a WIM system by testing, as part of a type approval procedure. The same approach and tools as for initial or in service verifications and acceptance tests (see clauses 9 and 10) are used. However, the site characteristics and the test plan are fully described in this chapter, while they are left to the user's decision in clause 10.

The site conditions are chosen as representative of the best quality site for WIM, in order not to introduce too much site effect. Therefore, the real performance on common sites may significantly differ (being below) from those assessed through the type approval.

AIV-10. Procedure to Check the Accuracy of a WIM System

AIV-10.1. General Rules

AIV-10.1.1. The more extensive the test plan means the longer the test period, a higher number of vehicle types and runs and ultimately a higher confidence in the conclusion. This means that the customer risk (i.e., the risk of accepting a system in a higher class than it is) decreases as the test becomes more expensive.

AIV-10.1.2. Lower this risk, longer and more extensive (and expensive) the test. Then the customer should adapt it to its requirements, taking into account the manufacturer specification and the output of other extensive and detailed tests.

It should be emphasised that this risk is only assessed under the conditions of the acceptance test; it means that the farther the test conditions from the real traffic conditions, the lower the confidence and higher the customer risk.

AIV-10.2.5. Depending on the sensor type, temperature variations can cause bias because of sensor sensitivity or indirectly because of pavement modulus or behaviour changes.

AIV-10.3. Confidence levels

The mean error estimation is affected by a statistical uncertainty, which depends on the sample size n (the uncertainty is removed for an infinite sample size !). This uncertainty is taken into account in the specified values of the following tables and in the formulas of section AIV-10.4, assuming that the samples have normal distributions (this may be checked by testing if required).

AIV-11. Data Storage and Transmission

It is out of the scope of this standard to specify in too much detail the content, structure and format, of the data files containing the output from WIM systems. It is mainly the responsibility of the WIM system manufacturers or service suppliers to develop and implement software and data files, adapted to the requirements of each type of customer and user. Moreover, an excessively detailed specification could limit the progress and evolution in this domain, and prevent adaptation to the most advanced WIM technology

AIV-11.1. Data storage

AIV-11.1.1. These general guidelines are given to ensure user-friendliness and facilitate the exchange of data between users. Some of these requirements may evolve with the WIM technology.

AIV-11.1.5. It is highly recommended to record and deliver the time of passage in hh:mm:ss:cc, up to hundreds of second, because at current highway speed (e.g. 20 m/s) the inaccuracy on the vehicle spacing may be too high for many applications if this time is rounded up to the second.

Because most users perform further analysis by software with the data collected, it is recommended that the data files are given either in a widely distributed spreadsheet format (Excel, Quattro Pro, etc.), or in tabulated ASCII format which can easily be converted. The standard sheets supplied in the Annex IV are in Excel.
It is recommended that the data files may be read and processed on common personal micro- computers, and may be exported in ASCII format to other computer systems.

AIV-12. COST 323 Vehicle Classification

There are many vehicle classifications in a few or large numbers of vehicle categories used in Europe. It is not the scope of this standard to require a unique classification, while depending on the application, the regional traffic patterns, etc., one or the other may be better adapted. However, in order to facilitate some comparison between general traffic patterns from one road to another, or to analyse in details the performance of WIM systems with respect of the type of vehicle to be weighed, a simple classification was agreed.
The classification given in figure 9 is mainly based on the silhouette of the vehicles, and on their mechanical dynamic behaviour while travelling at speed. Therefore, it is adapted to WIM studies. According to the limited number of categories, the breakdown of the population of vehicles into the proposed categories should be easy using most of the detailed existing classifications. If that is not possible in some particular cases, the unidentified vehicles will be shared between the two acceptable categories, with a reasonable proportion in each.

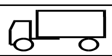
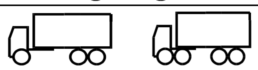
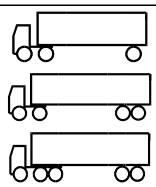
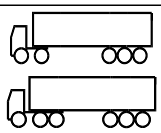
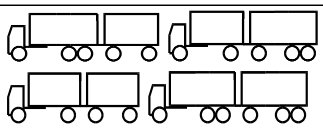
	Silhouette	Description
Category 1	--	Cars, cars + light trailer or caravan (GW<3,500 kg)
Category 2		Two axle rigid lorry
Category 3		More than 2 axle rigid lorry
Category 4		Tractor with semi-trailer supported by single or tandem axles
Category 5		Tractor with semi-trailer supported by tridem axles
Category 6		Lorry with trailer
Category 7		Busses
Category 8		Other vehicles

Figure 9: COST323 vehicle classification

Abbreviations

Begriff	Bedeutung
ASTRA	Bundesamt für Strassen, Swiss Roads Office
BAST	Deutsche Bundesanstalt für Strassenwesen
CEDEX	Centro de estudios y experimentacion de obras Publicas, Spain
CEN	European Committee for Standardization
COST	European Cooperation in Science and Technology
DATEC	Dipartimento federale dell'ambiente, dei trasporti, dell'energia e delle comunicazioni
DWW	Road and Hydraulic Engineering Institute in the Netherlands
EN	European Standards
ETH	Eidgenössische Technische Hochschule
FEHRL	Forum of European National Highway Research Laboratories
Fiwi	FEHRL WIM Initiative
ISWIM	International society for weigh-in-motion
LCPC	Laboratoire central de Pont et Chaussée as of Jan 2011 part of IFSTTAR French institute of science and technology for transport
UCD	University College Dublin
WIM	Weigh-in-Motion
ZAG	The Slovenian National Building and Civil Engineering Institute

References

[WIM-Ab 2001]	Spezifikation für Abnahme und periodische Kontrolle von dynamischen Achslastwaagen (WIM), Bundesamt für Strassen , Version 1.32, erstellt 15.07.2001
[WIM-Ko 2001]	Kontrollreglement für WIM-Anlagen, Bundesamt für Strassen, 15.07.2001
[COST 323 1999]	COST323 (1999), European Specification on Weigh-in-Motion of Road Vehicles, EUCO-COST /323/8/99, LCPC, Paris, August, 66 pp
[prEN-WIM]	European WIM Standard/Version 2/January 2010

Projektabschluss

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für
Umwelt, Verkehr, Energie und Kommunikation UVEK
Bundesamt für Strassen ASTRA

FORSCHUNG IM STRASSENWESEN DES UVEK **ARAMIS SBT**

Formular Nr. 3: Projektabschluss

erstellt / geändert am: 21.04.2011

Grunddaten

Projekt-Nr.: ASTRA2008/008_009

Projekttitel: FEHRL Institutes WIM Initiative, Fiwi

Enddatum: Mai 2011

Projektleiter

Name:

Amt, Firma, Institut:

Strasse, Nr.:

PLZ:

Ort:

Kanton, Land:

Texte:

Zusammenfassung der Projektresultate:

Since the early 90's, there has been considerable developments in the Weigh-in-Motion (WIM) industry in Europe. In addition to technical improvements of WIM sensors and WIM systems there have also been parallel developments to focus on applications. At the moment COST323 specifications are the de-facto European standard for WIM systems. WIM sensors in Switzerland must follow the specifications listed in "Kontrolreglement für WIM-Anlagen" and "Spezifikation für Abnahme und periodische Achslastwaagen". Both these documents use the COST 323 as a basis. In order to update the COST323 standards, a selected number of FEHRL members, including Switzerland represented by Empa, have initiated this project named FEHRL Institutes WIM initiative or Fiwi.

The main focus of this project was to update the COST 323 standards and submit it to become a new European standard for Weigh-in-Motion of Road Vehicles. Once a European standard is approved, it is strongly recommended that the Swiss documents listed above need to be revised. The most important changes are summarized in this report. They include minimum rate of complete registrations, tolerances for axle spacing, environmental and vehicle conditions and minimum test conditions that are required to achieve a particular accuracy class. A major addition is the inclusion of simplified procedures for common users.

Zielerreichung:

The main focus of this project was to update the COST 323 standards and submit it to become a new European standard for Weigh-in-Motion of Road Vehicles. The prEN was submitted to the European

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	Committee for Standardiza-tion, CEN, members for public enquiry.
Folgerungen und Empfehlungen:	Once a European standard is approved, it is strongly recommended that the Swiss documents listed above need to be revised.
Publikationen:	FEHRL report: FEHRL Institutes WIM Initiative is in progress

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Bundesamt für Strassen ASTRA

Beurteilung der Begleitkommission:
Diese Beurteilung der Begleitkommission ersetzt die bisherige separate fachliche Auswertung.

Beurteilung:	Objectifs: Les buts de ce projet ont été la préparation et la mise en examen d'un document servant de norme européenne (standardisation) pour la calibration et la classification de la justesse et précision d'une installation de pesée dynamique de poids-lourds WIM. La comparaison des spécifications et informations de ce nouveau standard avec les pratiques courantes utilisées actuellement en Suisse devaient également être mises en évidence. La préparation de ce document en coopération avec d'autres membres du FEHRL devait également permettre l'échange d'informations sur ce sujet. Réalisation des objectifs: Un document basé sur les normes actuelles COST 323 a été rédigé et proposé à l'organe de révision et de validation des normes et standards européens (CEN) a été soumis. Ce document a été réalisé en coopération avec d'autres membres du FEHRL ce qui a conduit à des échanges d'informations sur les expériences, pratiques courantes ainsi que le développement d'applications intéressantes. Un résumé des principales différences existantes entre les spécifications actuellement en vigueur en Suisse (Règlement de contrôle pour les installations WIM" ainsi que (Spécifications pour la réception et le contrôle périodiques de pèse-essieux" a été élaboré.
Umsetzung:	L'analyse des divergences entre les pratiques courantes actuellement en vigueur en Suisse pour la calibration et l'attribution de la classe de précision d'une installation de pesée dynamique (WIM) d'avec le PrEN actuellement soumis au CEN doit permettre de remettre à jour et d'améliorer les processus et campagne d'ajustement des installations suisses.
weitergehender Forschungsbedarf:	Sur la base des résultats et documents obtenus par ce projet, il n'est pas nécessaire de procéder à d'autres recherches ou de développer le présent projet. La modification des documents de spécifications en vigueur en Suisse doit tout d'abord être réalisée et mise en application. Il sera nécessaire dans les années à venir de tenir compte des avancées technologiques afin de vérifier l'adéquation et la validité des informations et directives fournies dans le nouveau document selon l'application et les nouvelles opportunités.
Einfluss auf Normenwerk:	Sur la base des éléments identifiées comme différences entre le nouveau document proposé comme norme européenne et les deux directives citées ci-dessus actuellement en vigueur en Suisse, il sera nécessaire d'analyser plus en détail le niveau de modification nécessaire afin de suivre les recommandations proposées et d'être compatible avec cette nouvelle "future" norme.

Präsident Begleitkommission:

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Unterschrift Präsident Begleitkommission:

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Bundesamt für Strassen ASTRA

Ittigen, le 22.11.2012, sig. Jonathan Rudaz

List of Research Reports

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1336	ASTRA 2007/006	SPIN-ALP: Scanning the Potential of Intermodal Transport on Alpine Corridors *SPIN-ALP: Abschätzung des Potentials des Intermodalen Verkehrs auf Alpenkorridoren* *SPIN-ALP: Estimation du potentiel du transport intermodal sur les axes transalpins*	2010
1339	SVI 2005/001	Widerstandsfunktionen für Innerorts- Strassenabschnitte ausserhalb des Einflussbereiches von Knoten *Fonctions de résistance pour des tronçons routiers urbains en dehors de la zone d'influence de carrefours* *Capacity restraint functions for urban road sections not affected by intersection delays*	2010
1325	SVI 2000/557	Indices caractéristiques d'une cité-Vélo. Méthode d'évaluation des politiques cyclables en 8 indices pour les petites et moyennes communes. *Die charakteristischen Indikatoren einer Velostadt. Evaluationsmethode der Velopolitiken anhand von 8 Indikatorgruppen für kleine und mittlere Gemeinden* *Characteristic indices of a Bike City. Method of evaluation of cycling policies in 8 indices for small and medium-sized communes*	2010

1337	ASTRA 2006/015	Development of urban network travel time estimation methodology *Temps de parcours en réseau urbain* *Methodologie für Fahrzeitbewertung in städtischen Strassennetz*	2011
1338	VSS 2006/902	Wirkungsmodelle für fahrzeugseitige Einrichtungen zur Steigerung der Verkehrssicherheit *Modèles d'impact d'équipements de véhicules pour améliorer la sécurité routière* *Modelling of the impact of in-vehicle equipment for the enhancement of traffic safety*	2009
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647	AGB 2004/010	Quality Control and Monitoring of electrically isolated post- tensioning tendons in bridges *Qualitätsprüfung und Überwachung elektrisch isolierter Spannglieder in Brücken* *Contrôle de la qualité et surveillance des câbles de précontrainte isolés électriquement dans les ponts*	2011
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