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Partner 1 MIRS, Slovenia Partner 2 BEV-PTP, Austria Partner 3 CMI, Czech Republic Partner 4 GUM, Poland Partner 5 IMBiH, Bosnia and Herzegovina Partner 6 Metrosert, Estonia Partner 7 DMDM, Serbia Partner 8 PTB, Germany Partner 9 TUBITAK, Turkey	Partner 10 MT, Germany	

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1 Overview

While non-automatic weighing instruments (NAWIs) are routinely calibrated by accredited calibration laboratories based on the Guidelines on the Calibration of Non-Automatic Weighing Instruments EURAMET/cg-18, the calibration of automatic weighing instruments (AWIs) was not as well defined and only little documented guidance was available. The project was focused on the development of reproducible calibration methods and measurement uncertainty evaluation models for different groups of AWIs, which operate in a dynamic mode. The project was also aimed to increase expertise among EURAMET members in the provision of reliable traceability of AWIs. The calibration guides developed for AWIs were submitted to EURAMET for further approval as EURAMET Calibration Guides. The guides will be directly used by calibration laboratories, which will assure traceability of measurements performed by AWIs operating in the dynamic mode.

2 Need

With the development of weighing technology, the number of AWIs, which carry out measurements in a dynamic mode, has increased. In the dynamic measurement mode of operation the instruments operate with a non-stable equilibrium based measuring system during the mass determining process while the load is in motion. Notwithstanding a generally higher purchase price than for Non-automatic Weighing Instruments (NAWIs), AWIs are more effective and efficient for their users in the long term. Improvements in the accuracy of AWIs mean that they are now used in an increasing number of applications from micro to macro weighing.

While NAWIs are routinely calibrated by accredited calibration laboratories according to EURAMET Calibration Guide cg-18, the calibration of AWIs is not as well defined, as there is a significant difference between the static measurement mode of operation of NAWIs and the dynamic measurement mode of operation, which is typical for the majority of AWI applications. There is also limited information about the uncertainties achievable using AWIs and little documented guidance available. There is therefore a need for validated reproducible calibration methods and measurement uncertainty evaluation models for different groups of AWIs operating in a dynamic measurement mode, this project focuses on three groups of AWIs: automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments.

In parallel, integration of emerging EURAMET member countries in the research and development of methods for the calibration of automatic weighing instruments operating in the dynamic mode is necessary to bridge an existing gap in the level of metrology expertise between EURAMET member countries. In particular countries with an association agreement with the EU need to develop their conformity assessment competence in order to support the implementation of the Measuring Instruments Directive (MID) and the Pre-packages Directive.

3 Objectives

The project has been focused on the development of reproducible calibration methods and measurement uncertainty evaluation models for different groups of automatic weighing instruments, which operate in a dynamic mode. The project has also been aimed to increase expertise among EURAMET members in the provision of reliable traceability of automatic weighing instruments.

The specific scientific and technical objectives of the project have been to:

1. **Develop and validate appropriate measurement methods for the calibration of the 3 selected categories of AWIs** (automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments). The results obtained using the new methods for calibration of AWIs operating in the dynamic mode will be compared with the static weighing of objects. The key elements of the specific content of a calibration certificate for calibration of an AWI will be defined. The reproducibility of methods developed will be confirmed by comparison of the dynamic weighing measurements performed by the partners.
2. **Develop and validate error models for the dynamic weighing process** for these three categories of automatic weighing instruments and to determine the potential sources of measurement uncertainty for these instruments.

3. **Develop uncertainty budgets for the determination of the uncertainty of measurement for the calibration of AWIs and for the determination of the uncertainty of a weighing result**. The uncertainty budgets will be validated by comparisons and cross-checked with static methods.
4. **Develop 3 draft calibration guides; one for automatic catchweighers, one for automatic instruments for weighing road vehicles in motion and one for automatic gravimetric filling instruments** respectively and to submit them to EURAMET for approval either as three separate EURAMET Calibration Guides or as one combined Guide.
5. **Develop individual strategies for each partner for the long-term development of their research capability in dynamic mass metrology** including priorities for collaborations with the research community in their country, the establishment of appropriate quality schemes and accreditation (including participation in comparisons and submission of CMCs either to the KCDB or an accreditation body as appropriate). The internal funded partners will also develop a strategy for offering calibration services from established facilities to their own country and neighbouring countries. The individual strategies will be discussed within the consortium and with other EURAMET NMIs/DIs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

4 Results

This section presents the project's technical outputs (i.e. results and conclusions) against each of the project's objectives

1. **Develop and validate appropriate measurement methods for the calibration of the 3 selected categories of AWIs** (automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments). The results obtained using the new methods for calibration of AWIs operating in the dynamic mode will be compared with the static weighing of objects. The relevant specific content of a calibration certificate for calibration of an AWI will be defined. The reproducibility of methods developed will be confirmed by comparison of the dynamic weighing measurements performed by the partners.

With the development of weighing technology, the number of Automatic Weighing Instruments (AWIs), which carry out measurements in a dynamic mode, has increased. Notwithstanding a generally higher purchase price than for Non-automatic Weighing Instruments (NAWIs), AWIs are more effective and efficient for their users in the long term. Improvements in the accuracy of AWIs mean that they are now used in an increasing number of applications from micro to macro weighing.

While NAWIs are routinely calibrated by accredited calibration laboratories (based on the Guidelines on the Calibration of Non-Automatic Weighing Instruments EURAMET/cg-18), the calibration of AWIs is not as well defined, as there is a significant difference between the static measurement mode of operation of NAWIs and the dynamic measurement mode of operation, which is typical for the majority of AWI applications. In the static measurement mode the instruments operate with a stable equilibrium based measuring system during the mass determining process. The load transport system, the load receptor or the load itself is stationary during a moment of weighing. In the dynamic measurement mode of operation the instruments operate with a non-stable equilibrium based measuring system during the mass determining process while the load is in motion. Consequently, the dynamic measurement mode of operation enables much faster weighing process. This is very significant for many branches of industry.

There is also limited information about the uncertainties achievable using AWIs and little documented guidance available.

The partners initially based the methods development on existing calibration methods, the experience of and practices from legal metrology and the procedures for NAWIs and AWIs.

Because of the dynamic character of the measuring process on AWIs, where speed of operation and properties of weighed product have a direct influence on the measuring results, it will usually not be possible to calibrate a measurement range for automatic weighing instruments. The calibration will deliver a measurement error of the instrument in comparison to a reference mass value under the conditions of the calibration such as speed of the load transport system and the load properties.

In agreement with the client, the calibration is performed at individual nominal values, which are defined by mass of the test loads, and it is only valid for the specified test loads (with a small bandwidth for mass, volume and shape).

Calibration is performed at the location where the instrument is being installed. Test loads are made of the type of product, which is normally weighed on the calibrated instrument. A calibration is performed at the rate of operation requested and specified in advance by the client. Normally these conditions are the same as conditions during the actual weighing process.

The reference mass of the test load is usually determined on situ. Several methods for determination of the reference mass are available however, it is necessary to look for a suitable compromise between the accuracy and simplicity of the selected method. Additionally, a density of the test load does not need to be known without significant influence to the measurement uncertainty.

The process of determination of the reference mass value of the test load and its associated measurement uncertainty is one part of the whole process of AWI calibration. An appropriate method of determining the test load reference mass value needs to be selected in consideration of the required measurement uncertainty and complexity of the method of determining the test load reference mass value. Some of possible methods of determining the test load reference mass value are summarised below:

A. Test load is calibrated prior to calibration of AWI. Its conventional mass is reported together with uncertainty, e.g. in a calibration certificate.
B. Mass of test load is determined by comparison with standard weight at the time and place of calibration of AWI on a weighing instrument, which is used as a mass comparator.
C. Mass of test load is determined by weighing on control weighing instrument at the time and place of calibration of AWI and the control instrument is calibrated at the same time as the calibrated AWI, too.
D. Mass of test load is determined at the time and place of calibration of AWI by weighing on control weighing instrument, which had been calibrated prior to calibration of AWI. Results of calibration the control instrument had been reported in the certificate.
E. Mass of test load is determined at the time and place of calibration of AWI by weighing on the calibrated control instrument, which satisfy a given specification.

The conventional value of mass of the test load is a priori not known, its density normally significantly differs from the conventional value of weight density $8000\,\mathrm{kg/m^3}$ and the air density at the time of calibration is normally different from a reference value of air density $1{,}2\,\mathrm{kg/m^3}$. The reference value of mass of the test load therefore depends on the air buoyancy correction. It can be seen that the correction is very small and that usually it is not necessary to apply the correction.

Case A could be applicable only in a case when comparable dynamic behaviour of pre-prepared test loads with loads normally weighed on the instruments is achieved. In this case a drift mass of the test load within a time is relevant. A density of the test load needs to be known. Since it is expected that the density considerably differs from $8000\,\mathrm{kg/m^3}$, air buoyancy correction in not negligible.

In Cases B to E the mass of test loads is determined at the time and place of calibration of AWI. Consequently no significant drift of the test load is expected. A density of the test load does not need to be known. The air buoyancy correction is very small or negligible and does not depend on a density of the test load.

A critical point of Cases D and E is evaluation of uncertainty of the control instrument in use.

In general, if the same control instrument is used, uncertainty of the reference mass value increases from Case B to Case E.

Calibration of AWIs in a dynamic mode of operation cannot be performed directly with standard weights. To determine the errors of an instrument, test loads are applied. The test loads should preferably be the type of articles, which are normally weighed on the calibrated instrument. For the purpose of calibration, the traceability of test loads to the SI unit of mass shall be demonstrated using a control weighing instrument. The control instrument may be either separate (a weighing instrument other than the instrument being calibrated) or integral (when a static weighing mode is provided by the instrument being calibrated). The control instrument should ensure the determination of the mass of each test load to accuracy, which is appropriate to the expected uncertainty of calibration of the calibrated instrument.

A brief description of the measurement methods for the selected groups of AWIs are given in the following three subsections.

Automatic catchweighing instruments

The object of calibration for the automatic catchweighing instrument, which is symbolically shown on Figure 1, is the indication of the instrument in response to an applied load with reference value of mass of the test load.

Figure 1. Automatic catchweighing instrument.

Tests are performed to determine:
- the errors of indications, repeatability of indications, and
- the effect of eccentric application of a load on the indication.

The test for errors and repeatability of indication consists of the passing repeatedly the same load over the middle of the load receptor, under identical conditions of handling the load and the instrument, and under constant test conditions. The purpose of this test is an appraisal of the accuracy and repeatability of the instrument at least in points of usual application of the instrument. Each test point is characterised by its own repeatability.

The effect of the eccentric application of the load on the indication is tested when applicable. The effect of eccentric loading shall be determined using the selected test load using the middle of load transport system, the portion of the load transport system that is halfway between the centre and the back, and repeated with the same test load using the portion of the load transport system that is halfway between the centre and the front.

Automatic gravimetric filling instruments

The object of the calibration the automatic gravimetric filling instruments, which is symbolically shown on Figure 2, is the preset value error of the instrument, determined at different preset values, i.e. values, expressed in units of mass, preset by the operator, in order to define the nominal value of the fills. The fill is one load, or more loads combined, that make up the predetermined mass.

Figure 2. Automatic gravimetric filling instrument.

The test for preset value error and repeatability consists of repeated filling the fills with the same nominal value, and under constant test conditions. The purpose of this test is an evaluation of the accuracy and repeatability of the instrument at least in points of usual application of the instrument. Each test point is characterised by its own repeatability.

Automatic instruments for weighing road vehicles in motion

The object of calibration for the automatic instrument for weighing road vehicles in motion, which is symbolically shown on Figure 3, is the indication of the instrument in response to an applied load with reference value of mass of the test load.

Figure 3. Automatic instrument for weighing road vehicles in motion.

A complete automatic instrument for weighing road vehicles in motion is checked using control vehicle and other measuring equipment at rated operating conditions of the instrument, according to its characteristics.

The mass of control vehicle should be such that it can be as close as possible to the maximum measuring range of the instrument.

Speed of vehicles while checking should be fixed, without acceleration and braking, and should include the full speed range.

For each of vehicle and for each set of the weight and speed and specified driving directions, take at least 5 passages (3 runs down over the centre of the load receptor, 1 ride left side of the load receptor, 1 ride right side of the load receptor).

The change in mass of control vehicles (e.g. fuel consumption) on the route of the control instrument to the tested WIM instrument is adjusted if has a significant influence on the result, e.g. after completion of series trips a given vehicle type.

The project developed reproducible and harmonised measurement methods for the calibration of the three selected categories of AWIs (automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments). The comparison of the dynamic weighing measurements performed by the partners, which were used to confirm reproducibility of methods developed, is presented in the following section.

2. **Develop and validate error models for the dynamic weighing process** for these 3 categories of automatic weighing instruments and to determine the potential sources of measurement uncertainty for these instruments.

3. **Develop uncertainty budgets for the determination of the uncertainty of measurement for the calibration of AWIs and for the determination of the uncertainty of a weighing result**. The uncertainty budgets will be validated by comparisons and cross-checked with static methods.

The project needed to develop the error model for the results of the weighing process in the dynamic mode for the 3 categories of AWIs, to determine potential sources of measurement uncertainty and to develop uncertainty budgets for the determination of the uncertainty of measurement for the calibration of AWIs and the uncertainty of a weighing result obtained using these instruments. The aim is that the error models and uncertainty budgets developed for automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments should be applicable to a range of instruments within each of the 3 categories of AWIs. The error model and uncertainty budget for static weighing using NAWIs is already well defined, so this task will address errors and uncertainties that occur in and significantly influence the dynamic mode of operation of AWIs, e.g. the speed of the assembly line or a belt speed, the rate of operation, the vehicle speed, the dynamic properties of a vehicle, the physical properties of the weighed material, and environmental conditions.

In addition, it was necessary to experimentally validate the measurement methods for the calibration of the three selected categories of AWIs on-site, compare the results obtained using the calibration procedures for AWIs operating in the dynamic mode with static measurements of the weighed objects, validate the measurement uncertainty budgets for the three selected categories of AWIs by comparisons and cross checking with static methods and confirm the reproducibility of the methods developed by comparison of measurements of dynamic weighing obtained by the partners.

ERROR MODELS AND UNCERTAINTY

The first step in the process is the establishment of the measurement model, which is a mathematical relation between the measurand and all quantities, which are involved in the measurement. The actual value of weighing is affected by various dynamic effects of instrument operation, the load type and its properties, and the rate of operation of the instrument. Due to the dynamic behaviour of their operation, functional relationship between weighing result, parameters of operations such as rate of operation, type of material and nominal value of the test load is very complex and currently out of the scope of the calibration procedure.

For AWIs the uncertainty of measurement depends significantly on properties of the calibrated instrument itself, the characteristics of the test loads, the control instrument, and not only on other capabilities of the calibration laboratory. Additionally, a density of the test load does not need to be known because it doesn't have a significant influence to the measurement uncertainty.

Automatic catchweighing instruments

The object of calibration for the automatic catchweighing instruments is the mean indication of the instrument in response to the applied test load with reference value of mass. The mean error of indication equals the difference between the mean indication of the instrument and reference value of mass.

The standard uncertainty of the mean error of indication depends on the standard uncertainty of indication and standard uncertainty of reference value of mass.

To account for sources of variability of the indication, i.e. the effect of the resolution of indication, repeatability of the instrument and error due to off-centre position of the test load, the mean indication of the instrument is amended by correction terms. The corrections have the expectation value 0.

Due to effects of air buoyancy and other minor effects, the reference value of mass is not exactly equal to the conventional mass value of the test load. If the reference value of mass is determined by weighing on the previously calibrated control instrument, the reference value of mass is equal to the result of weighing of the test load on the control instrument, corrected for the overall air buoyancy correction. It can be shown that it is usually not necessary to apply the buoyancy correction.

The standard uncertainty of the weighing result could be evaluated according to EURAMET Calibration Guide cg-18 either for the case when errors of the control instrument are accounted by correction or for the case they are included in the “global” uncertainty. The standard uncertainty for the weighing result under conditions of the calibration could be used if the control instrument was calibrated or adjusted right before its use.

The uncertainty of measurement depends significantly on properties of the calibrated automatic catchweighing instrument itself, the control instrument, the characteristics of the test loads and the equipment of the calibrating laboratory. Due to the dynamic behaviour of operation, functional relationship between the weighing result, parameters of operations such as rate of operation, dimensions of products and nominal value of the test load is very complex and currently out of the scope of the calibration procedure. Consequently, it will usually not be possible to calibrate a measurement range for such instruments.

The calibration is only valid for the specified test loads (with a small bandwidth for mass, volume and shape) and speed of operation. Each test point is characterized by its own repeatability.

Automatic instruments for weighing road vehicles in motion

The object of calibration for the automatic instruments for weighing road vehicles in motion is the value indicated by the instrument in the certain entity (gross mass or axle load) in response to the applied test load (vehicle) with reference value of mass. The error of indication equals the difference between the mean indication of the instrument and reference value of mass.

The standard uncertainty of the mean error of indication depends on the standard uncertainty of indication of the calibrated instrument and standard uncertainty of reference value of mass of the vehicle, obtained on the control instrument.

To account for sources of variability of the indication, i.e. the effect of the resolution of indication at load and no-load and repeatability of the instrument, the mean indication of the instrument is amended by correction terms. The corrections have the expectation value 0.

The uncertainty of the control instrument value for the given load (the value is obtained from the control instrument calibration certificate) and expanded by an uncertainty of indication of the same instrument. The value of the uncertainty taken from a calibration certificate is valid only for a control instrument intended for weighing the gross mass of a reference vehicle.

Automatic gravimetric filling instruments

Users of the automatic gravimetric filling instruments are in general interested in information on a deviation between average mass of the fills and preset value. In this case for the purpose of calibration of the automatic gravimetric filling instruments, the preset value of fill is taken into account. The indications of calibrated instrument, if available at all, are not recorded.

The object of the calibration the automatic gravimetric filling instruments, is therefore the preset value error of the instrument, determined at different preset values, i.e. values, expressed in units of mass, preset by the operator, in order to define the nominal value of the fills. The preset value error for the test fill equals the difference between the mean reference values of test fills and the preset value.

Due to effects of air buoyancy and other effects, which may lead to minor correction terms, the reference values of mass of test fill, is not exactly equal to the conventional mass of the test fill. The conventional mass of the test fill cannot be determined directly, but through determination of conventional mass of the filled container (gross value) and conventional mass of the empty container (tare value).

To account for sources of variability of the preset value error, the error model is amended by correction terms for the repeatability error of the preset value, the repeatability error of tare of the container, the total buoyancy correction factor for preset value, and resolution of the device.

The uncertainty of calibration depends significantly on properties of the calibrated instrument itself and the characteristics of the material which is filled, uncertainty of the reference mass values depends on properties of the control instrument and its traceability. The density of the material, which is filled, is not necessary to be known and does not influence the measurement uncertainty.

VALIDATION

For this purpose the validation plans were prepared for each group of AWI concerned. The plans take into account instrument selection, test loads selection, determination of the test load mass, preparation and execution of measurements, monitoring environmental condition, calculation of measurement results and reporting.

The results obtained using the calibration methods developed for automatic instruments operating in the dynamic mode were compared to the reference values obtained by static measurements of test loads on non-automatic weighing instrument and to the measurements obtained using the automatic instrument calibrated in the static mode of operation, each time taking into account the uncertainty of measurement.

Automatic catchweighing instruments

The project partners made test measurements following the draft guide "Calibration of Automatic Catchweighing instruments". It was under the responsibility of the partner to organise the access to a respective instrument. The validation procedure was described in the document "Validation Instructions ACI" and for the collection of the respective data “Validation Protocols ACI” were prepared.

Measurements were carried out at DMDM, Metrosert, IMBiH, CMI, BEV-PTP, TUBITAK, PTB and MT.

All partners used automatic checkweighing instruments as test objects. The used mass values of the test loads differ between 50 g and 40 kg.

The draft guide offers different ways of calibration of the test loads. Not all laboratories used the same methods. A summary of the validation conditions are given in Table 1.

Table 1. Methods used for the determination of test loads within the automatic checkweighing instruments task group.

Type of catchweigher	Control Instrument (CI)	Calibration of CI	Use of calibrated CI	CI as comparator (ABBA)	Static calibration of ACI
Checkweigher	NAWI, AWI itself	On-site, Certificate	Yes	Yes	Yes

The participating institutes carried out most of the proposed measurements and tried to find out additional information by extra measurements.

No one of the partners used a verified control instrument. A verified instrument may only be used as a comparator within the field of traceable calibrations.

As expected, repeatability, eccentricity and resolution of the weighing instruments have the largest impact to the uncertainty of the measurement results. The influence of the belt speed was identified as well as an important aspect in the tests.

The term “test load” probably caused some irritations. It is proposed to differentiate in future more exactly between “test load” (package in use at the AWI) and “reference weight” (used for the calibration of the test loads and/or the control instrument).

The main aspect for traceable calibrations of automatic checkweighing instruments is the determination of the test loads. It came out, that all of the proposed methods for the determination of the test loads can be realised, but some of them have to be adjusted to the practise of automatic weighing instruments that usually measure real bags or pre-packages and not weights as used in mass metrology. It might be helpful to concentrate on the loads used later on with the calibrated checkweigher. Thus, as an example, in practise it will not be possible to determine the buoyancy effect as described in the guide without appropriate effort of time. Presumably, the effect will be negligible if the test loads are “calibrated” on-site. It seems to be preferable to not determine the buoyancy effect in this case but add an additional uncertainty.

Another aspect is the use of “scientific” test loads that will never show the same behaviour as “real” test loads at the automatic checkweighing instrument. It should be required to use the product and the conditions of normal use of the instrument during calibration. If there are different products and/or conditions several calibration cycles are recommended.

Automatic instruments for weighing road vehicles in motion

The involved partners compare weighing results from different automatic instruments for weighing road vehicles in motion in selected countries for different types of vehicles and their axis arrangement. The project members made validation and measurements following the "Validating instruction of AWIM". The measured and calculated data were recorded in the Excel template "Validation protocol AWIM".

The members took measurement at appropriate places in their countries: BEV - Bruck/Leitha, CMI - Starý Hrozenkov, Metrosert - Maardu, GUM - Tarnowo Podgórne, DMDM – Ćuprija. The vehicle weight (loaded, unloaded or both), number of its axis and speed were chosen freely. A summary of the validation conditions are given in Table 2.

Table 2. Different approaches to validation of automatic instruments for weighing road vehicles in motion.

Static calibration of AWIM	Determination of static reference vehicle loads	Standard weights accuracy	Vehicle measurement speed	Vehicle mass range	Number of vehicle axes
Yes	Yes	M_1, M_{1-2}	2-70 km/h	1,5 – 42 t	2, 3, 4, 5

All participants except Estonia have done low speed measurements. Because of the much higher measurement speed (minimum speed 50 km/h) than in the rest countries (maximum speed 15 km/h), it is hard to compare it with the others.

The differences between static and dynamic weighing results were within the range of maximum permissible error except for the lightest car in Estonia with the highest error about 7 %. As the received data showed, the speed of the measured vehicle had big influence on the result. The higher vehicle speed has resulted in higher error. The vehicle total mass had only a small impact on the measurement result; it is negligible in comparison with the speed factor. The number of axes had its influence too, especially with different types of suspension. The suspension itself had biggest influence in static mode notably the air suspension.

The recommendation is to do more measurements for trucks with air suspension, and if it is possible at slowest speed.

Automatic gravimetric filling instruments

For the main aim of the project i.e. preparation of robust and reproducible calibration methods of AWIs, a validation study was done on automatic gravimetric filling instruments by TUBITAK, MIRS, IMBiH, DMDM and CMI. In this validation study the draft measurement method was experimentally validated on-site and compared the results obtained in the dynamic mode with the static mode as well as the measurement uncertainty budget.

The experimentally study was carried out on automatic gravimetric filling instruments on-site by means of the developed validation instruction. According to procedure, the static calibration of automatic gravimetric filling instruments was performed in accordance with EURAMET Calibration Guide cg-18 and nominal mass values for indication test were chosen equal or close to the filling values in order to compare the observed indication values in static mode and dynamic mode. The dynamic calibration of automatic gravimetric filling instruments was done based on the developed draft calibration guidelines. The reference mass values of each test fill were determined based on the developed draft calibration guidelines as well as calculation of the standard uncertainty of the weighing result for filled containers (gross).

In static mode measurement methods were performed on the chosen gravimetric filling instruments according to EURAMET Calibration Guide cg-18. The measurement methods were repeatability test, test for errors of indication at different loads and eccentricity test.

Table 3 shows the metrological properties of the chosen automatic gravimetric filling instruments as maximum capacity, minimum capacity, maximum filling capacity, minimum filling capacity, number of fills and scale interval and etc.

Table 3. The metrological properties of the utilized automatic gravimetric filling instruments by participants

Accuracy class	Maxfill	Scale interval	Product
X(0,5), X(1)	2 kg – 1000 kg	20 g – 200 g	feeding mixtures, flour, flouder, fruit syrup, distilled water

The conventional mass of test fills in containers and the conventional mass of empty containers were determined by an appropriate control instrument according to the chosen criteria's of the control instrument of developed draft calibration guidelines. The control instruments used by participants were separate from automatic gravimetric filling instruments, except for one instrument.

All control instruments were calibrated at time and place of calibration of automatic gravimetric filling instruments by participants according to the developed draft calibration guidelines of automatic gravimetric filling instruments.

The tests were performed to determine the preset value error at different preset values and also the repeatability. The test consisted of repeated filling with the same nominal value, and under constant test conditions. The purpose of this test is to evaluate the accuracy and the repeatability of the instrument.

The repeatability test was done at minimum fill and maximum fill or only minimum fill or only maximum fill by participants.

The reference mass value of the fills is determined by applied one of the three cases:

A. Test load weighed on the continuously calibrated control instrument
B. Test load weighed on the previously calibrated control instrument
C. Test load weighed on the previously verified control instrument

Each participant calculated the preset value error, standard uncertainty of the weighing result of automatic gravimetric filling instrument for the each nominal fill value, the utilized methods in dynamic mode and also the indication error and standard uncertainty of the indication error for the each nominal value.

In the validation of the test methods, DMDM and IMBiH have completed work on method A and MIRS on method A and B and also TUBITAK on method A, B and C. The best method is method A. Because in method A, the control instrument is calibrated at loads near the fill values of the filling device and these values are used to determine the reference mass value of fills and also the standard uncertainty values of these loads are also an uncertainty parameter in determining the standard uncertainty of the weighing result for filled containers. In addition, the value of air buoyancy correction and uncertainty are not effective in the weighing results and the standard measurement uncertainty. In method B, since the control instrument is calibrated before the calibration of the filling device, the indication error of the loads used in the calibration is used to determine the standard uncertainty of the weighing results for filled containers. In determining the reference mass value of fills, the control instrument's indication error is not used. If the control instrument's errors are out of tolerance according to OIML R 76, the standard uncertainty of the weighing results for filled containers will increase. For the method C, if a control instrument with a verification certificate is used, the tolerance of the control instrument is used in determining the standard uncertainty of the weighing results for filled containers. In this case, approximately 3 times greater uncertainty is obtained.

As a result, no matter which method is selected, the control instrument's indication error values and corner load error should be checked before calibration. However, if the calibration laboratory will perform the calibration of the filling device with its own control instrument, the criteria specified in EURAMET Calibration Guide cg-18 shall be observed. Furthermore, it is observed that the control instrument has a great contribution in determining the standard measurement uncertainty of the filling device.

Based on a general validation plan for the validation of developed calibration methods, error models and uncertainty budgets, and several additional proposals of what to include in the validation, instrument specific detailed validation plans and templates of validation reports were developed. The project partners have liaised with the collaborators and obtained confirmation from them that their AWI facilities are available for the on-site validation activities. All planned validation measurements have been executed by the partners. Based on reported results of validation, the validation reports and analyses were prepared. Outcomes of the validation were used to improve content of the draft calibration guides.

INTERCOMPARISON

Finally, it was necessary to validate, both experimentally and on-site, the measurement methods, error models and measurement uncertainty budgets developed and also to check the reproducibility of the draft calibration methods and uncertainty budgets developed for the calibration of the selected categories of AWIs with the interlaboratory comparisons.

Automatic catchweighing instruments

The comparison in the field of automatic catchweighing instruments was carried out within the time frame July 2017 – February 2018. The comparison was coordinated and piloted by PTB, with participating partners CMI, DMDM, IMBiH, MT, Metrosert, TUBITAK and PTB.

The instrument, which was calibrated, was Mettler-Toledo model C3570 with Max_1 = 200 g / e_1 = 0,1 g and Max_2 = 2000g / e_2 = 0,2 g. The load conveyor was 15 cm wide, with 111 cm total length and 33 cm of weighing belt.

Two nominal masses of test loads were used, about 100 g and about 500 g. For both nominal masses different kind of test loads were available: realistic material – chocolate bars (two kinds); 10 or 60 bars available, and test material – two small cartons (loose and solid filling)

The control instruments available were Mettler-Toledo checkweigher of model C3570 with increased resolution and NAWI with resolution of d = 0,001 g up to 500 g and d = 0,01 g from 500 g on.
Proposed measurements according to draft calibration guide:

- Calibration measurements with realistic and test materials at 100 g and 500 g at two different belt speeds (20 m/min and 40 m/min)
- 60 cycles per measurement are recommended, except for the eccentricity measurement.
- Use of the Excel-sheets (validation protocol) as for the individual measurements is proposed. That includes calibration of the control instrument, the test loads and the static calibration of the checkweigher.

The participants performed different numbers of tests with different test samples. Finally, only one of the participants went through all measurements including all eccentricity measurements as described in the draft guide. Only three participants used the indications of the onside calibrated control instrument for the determination of the test loads. All others used the ABBA-system.

The proposed templates of the validation protocol were individually adapted by all participants.

Figure 4 to 7 show the results of all measurements. The dots show the results at 20 m/min, the crosses the results at 40 m/min.

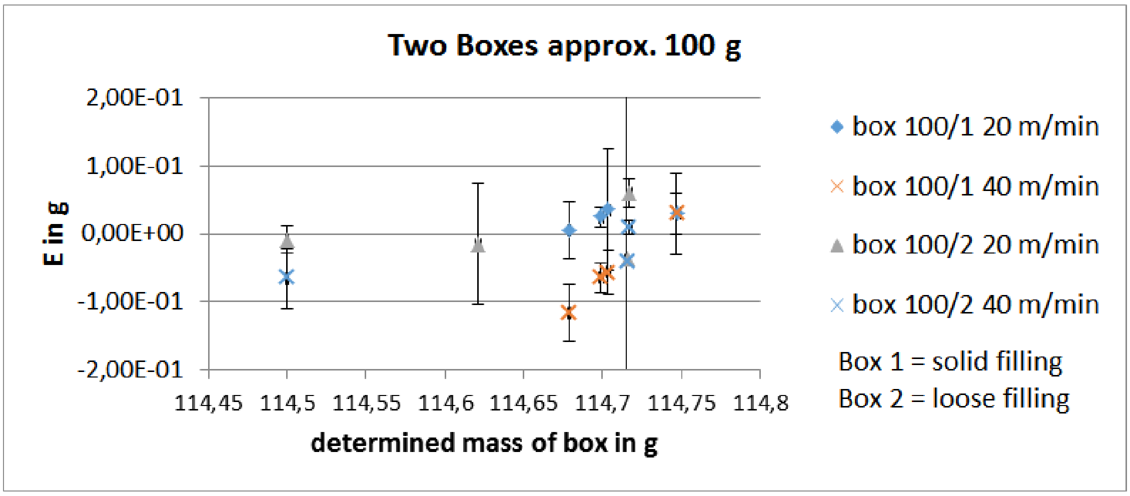

Figure 4. Comparison results for box with nominal mass 100 g.

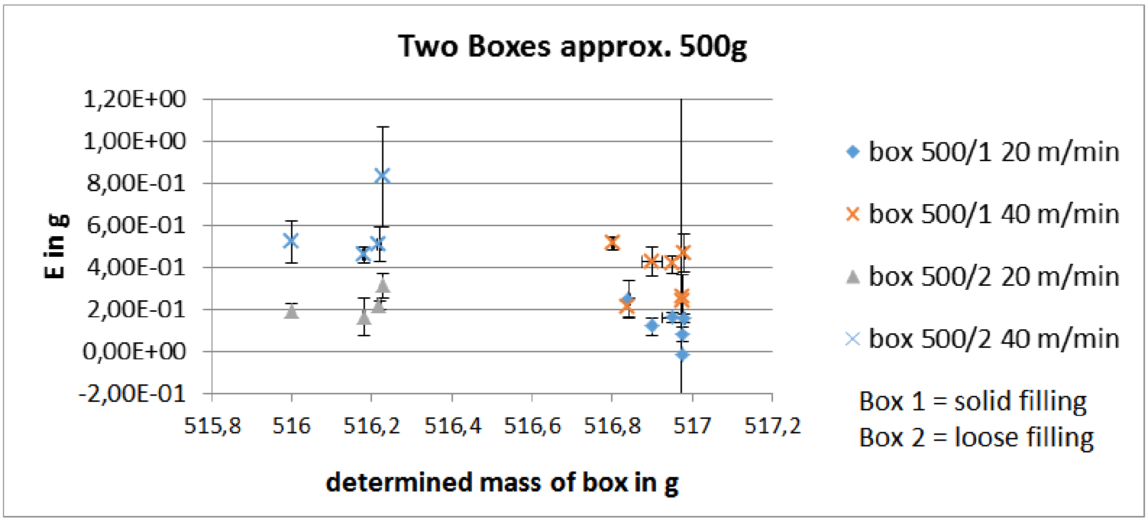

Figure 5. Comparison results for box with nominal mass 100 g.

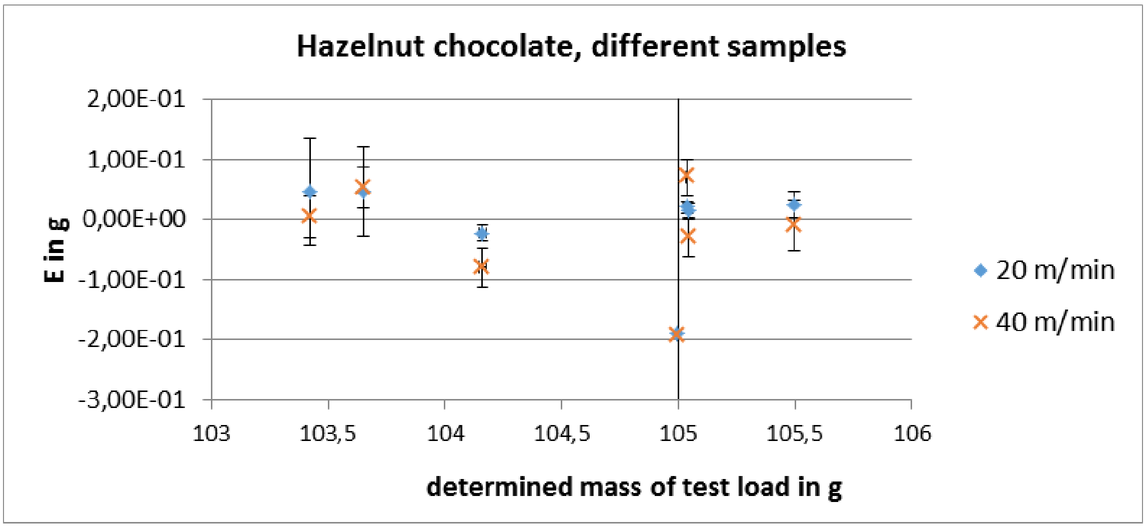

Figure 6. Comparison results for box with nominal mass 100 g.

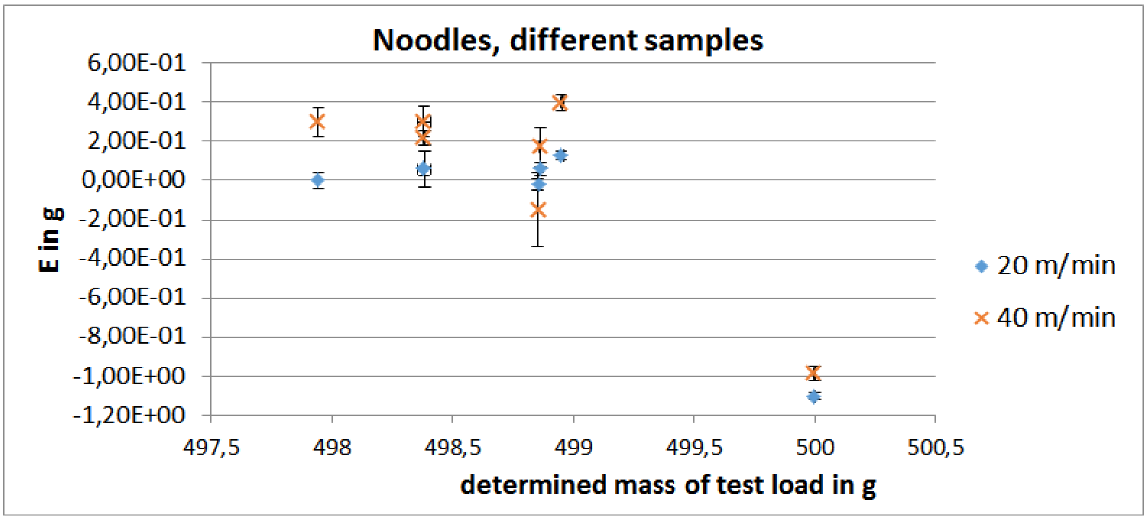

Figure 7. Comparison results for box with nominal mass 100 g.

In general, the results show good agreement of the participants. As expected, due to dynamic influence of belt speed the mean of the results at 40 m/min are a bit below, i.e. they seem to be a bit "lighter", as the results at 20 m/min for all different test loads.

Automatic instruments for weighing road vehicles in motion

CMI in cooperation with company (Tenzováhy s.r.o., Czech Republic) arranged access to stable automatic instrument for weighing road vehicles in motion.

There were three series of measurements performed, first on 31. 7. 2017, second on 8. 9. 2017 ant third on 29. 11. 2017. The first measurement was performed and calculated by CMI only. The second measurement was participated by representatives of BEV-PTP, CMI, Metrosert and GUM. The last measurement was participated by representatives of CMI, IMBiH and DMDM.

Each participating country should have prepared calculation of weighing results including uncertainties. All the excel files with the result have been uploaded at AWICal webpage.

The chosen truck was Scania G450, equipped with one liftable axle. There were ten tons of M1 CMI's weights (20 x 500 kg). The truck was measured on two axles unloaded and on three axles with weights.

Before the AWI measurement it was necessary to know the precise weigh of the truck. The weighbridge Schenck (Min = 400 kg; Max = 60 000 kg; e =d = 20 kg; accuracy class … **III**; temperature range -20/+40 °C; DE-16-NAWID-PTB002; Nr: AS16121) was used for this propose.

The automatic dynamic weighing system was located in Starý Hrozenkov, Czech Republic, near the Slovakia border. Its parameters were: Min = 800 (400) kg; Max = 20 000 (10 000) kg; e = 20 kg; d = 2 kg (static measurement); speed range 0,5 – 16 km/h.

Each axle of the truck was measured statically, first with weights (three axles), then without weights (two axles). Next step was to load/unload the measuring plates with weights and measure the weight. Finally, the truck's weight was measured dynamically at different speeds – approx. 5 km/h was low speed, approx. 10 km/h was high speed.

The main comparison results for automatic instruments for weighing road vehicles in motion are summarised in Tables 4 to 7.

Table 4. Two axles weighing results

Masses and errors in kg	2 axles, low speed			2 axles, high speed		
Date	31.7.	8.9.	29.11.	31.7.	8.9.	29.11.
Total mass average.	18054	15983	18247	18232	16278	18338
Total mass max	18180	16100	18385	18340	16340	18450
Total mass min	17960	15885	18170	18120	16140	18110
Vehicle mass reference value	17803	15880	18020	17803	15880	18020
Error	251	103	227	429	398	318

Table 5. Three axles weighing results

Masses and errors in kg	3 axles, low speed			3 axles, high speed		
Date	31.7.	8.9.	29.11.	31.7.	8.9.	29.11.
Total mass avg.	25706	25772	26110	26046	26200	25928
Total mass max	25760	25795	26125	26140	26365	26020
Total mass min	25680	25760	26075	25960	26000	25880
Vehicle mass reference value	25547	25880	25960	25547	25880	25960
Error	159	-109	150	499	320	-32

Table 6. Uncertainties (2 axles)

Uncertainties in kg	2 axles, low speed			2 axles, high speed		
Date	31.7.	8.9.	29.11.	31.7.	8.9.	29.11.
Resolution at zero	5,8	5,8	5,8	5,8	5,8	5,8
Resolution at load	5,8	5,8	5,8	5,8	5,8	5,8
Eccentricity	63,5	62,1	62,1	63,5	57,7	98,1
Repeatability	61,9	69,4	82,4	70,7	55,1	97,3
Standard unc. of indication	89,0	93,4	103,5	95,4	80,2	138,5
Standard unc. of control instrument	9,0	8,1	9,1	9,0	8,1	9,1
Standard uncertainty of the error	89,5	93,8	103,9	95,8	80,6	138,8
U(E) = ku(E)	179,0	187,6	207,8	191,6	161,2	277,5

Table 7. Uncertainties (3 axles)

Uncertainties in kg	3 axles, low speed			3 axles, high speed		
Date	31.7.	8.9.	29.11.	31.7.	8.9.	29.11.
Resolution at zero	5,8	5,8	5,8	5,8	5,8	5,8
Resolution at load	5,8	5,8	5,8	5,8	5,8	5,8
Eccentricity	23,1	10,1	14,4	52,0	105,4	40,4
Repeatability	25,0	10,3	17,2	66,0	128,0	47,3
Standard unc. of indication	35,0	16,6	23,9	84,4	166,0	62,8
Standard unc. of control instrument	13,0	13,1	13,2	13,0	13,1	13,2
Standard uncertainty of the error	37,3	21,1	27,3	85,4	166,5	64,1
U(E) = ku(E)	74,7	42,3	54,5	170,8	333,0	128,3

Automatic gravimetric filling instruments

Automatic gravimetric filling instruments are used in different areas of industry such as preparation, production and quality assurance of pre packed products with the development of weighing technology.

This comparison was arranged to check the reproducibility of the measurement method and measurement uncertainty. Transfer standard was provided by Esit Electronic Ltd. Co., Turkey and all measurements were carried out at Esit Electronic Ltd. Co.

UME was the pilot laboratory and the other participants were IMBiH, CMI, DMDM and MIRS.

The automatic gravimetric filling instrument used in this comparison was provided by Esit Electronic Ltd. Co., Turkey. The technical properties of the automatic gravimetric weighing instrument, which was calibrated, were the following: type ECI BF, accuracy class X(2), Max Fill = 200 g, d = 1 g, filling material was cracked wheat.

The measurements in dynamic mode were carried out by sixty fillings of bulk material at two different preset values as 50 g and 200 g to determine preset error and repeatability according to draft calibration guide for automatic gravimetric filling instruments. The control instrument used to determine the reference value of mass of the test fills based on weighing of filled and empty containers is a non-automatic weighing instrument with maximum capacity of 500 g and readability of 0,01 g of Kern company. In order to determine the reference mass value of the test fills, the Method A was chosen. The control instrument is calibrated immediately at time and place of calibration of AGFI. The calibration of the control instrument was done accordance with EURAMET Calibration Guide cg 18 in static mode. The container material was cardboard cups. Since the mass of containers was virtually constant, the average mass of empty containers was determined by simultaneous weighing of a sample of several empty containers (e.g. 10 or more). The environmental conditions were recorded during the calibration of control instrument and the automatic gravimetric filling instrument.

The two reference values and their associated uncertainties are shown in Table 8.

Table 8. Result of the reference values

Preset value	Reference value	Uncertainty (k=1)
50 g	0,05 g	0,135 g
200 g	0,16 g	0,178 g

The preset value errors with associated standard uncertainties are given in Figures 8 and 9 for the preset values 50 g and 200 g, respectively. The reference value has been taken to be a weighted mean of the reported the measurement uncertainties and calculated preset value error by each participant.

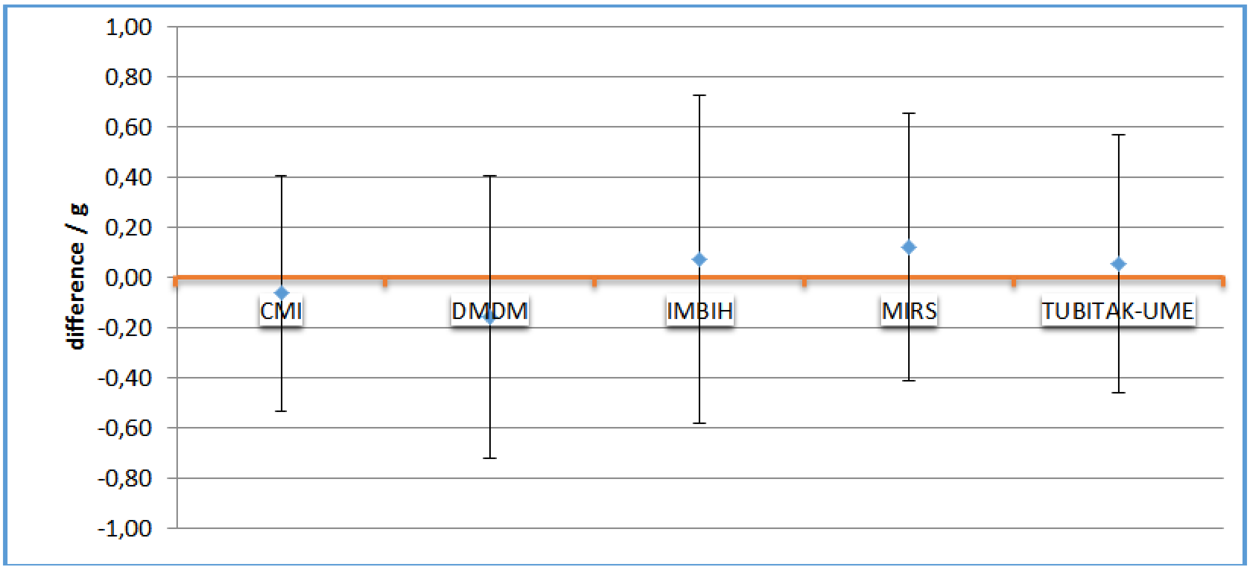

Figure 8. Differences between participants' results and reference value, and uncertainty (*k*=2), for 50 g.

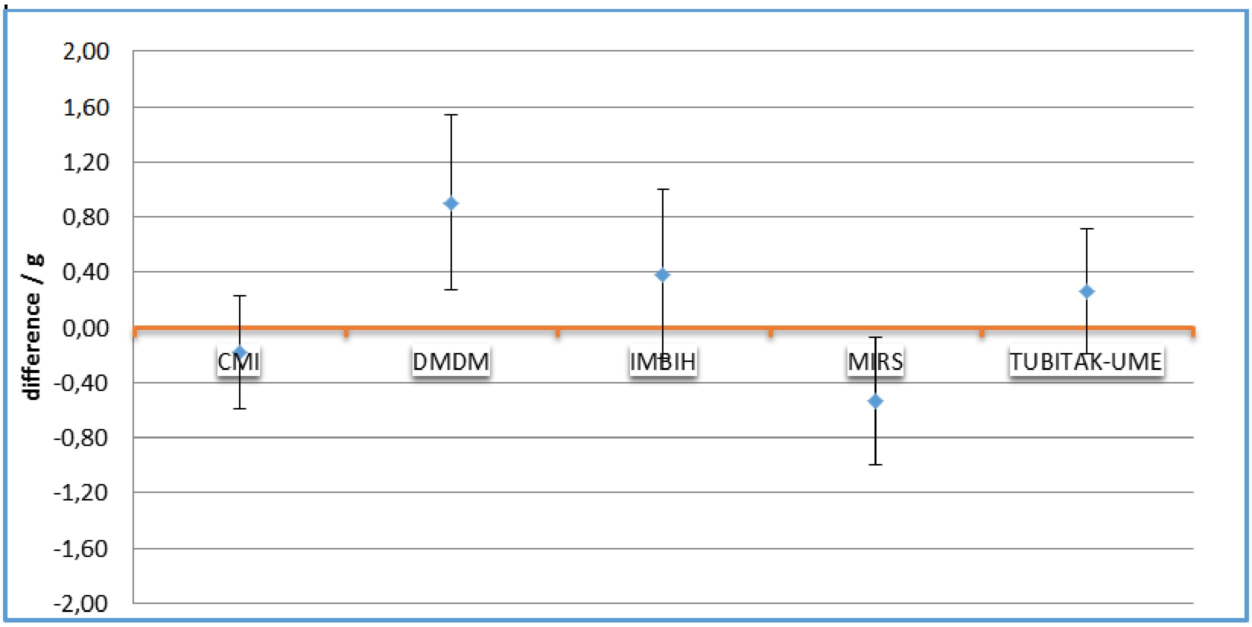

Figure 9. Differences between participants' results and reference value, and uncertainty (*k*=2), for 200 g.

Reference value was calculated by weighted mean of the reported the measurement uncertainties and calculated preset value error by each participant. One of the five laboratories, DMDM was not consistent with the reference value at 200 g within it's the expanded uncertainty with a coverage factor, k= 2, as shown in Figure 8. Finally, the calibration method developed and uncertainty modelling are consistent and repeatable.

For the interlaboratory comparison of calibration of AWIs based on the draft calibration guides, the technical protocols have been prepared and access to facilities with instruments ensured and agreed with the project collaborators. The comparison measurements for the automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments were carried out at three different locations. One instrument was provided by a producer, which were also the project partner. The other two instruments were provided by the project collaborators. The planned comparison measurements have been executed by the partners. Based on reported comparison results, the comparison reports and analyses were prepared. During the AWICal workshop at EURAMET TC-M meeting in Dublin in April 2018, the intercomparison results for select three groups of AWIs were presented and discussed by other partners and workshop participants. After that, agreed comparison reports for the interlaboratory comparisons were prepared. Outcomes of the intercomparisons were used also to improve content of the draft calibration guides.

4. **Develop 3 draft calibration guides; one for automatic catchweighers, one for automatic instruments for weighing road vehicles in motion and one for automatic gravimetric filling instruments** respectively and to submit them to EURAMET for approval either as three separate EURAMET Calibration Guides or as one combined Guide.

The main goal of the project was to develop 3 draft calibration guides for the 3 selected categories of AWIs; automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments respectively, which will be suitable for subsequent approval by EURAMET for publication either as three separate EURAMET Calibration Guides or as one combined Guide. This task will also define the key elements of the specific content of a calibration certificates for AWIs.

Automatic weighing instruments (AWIs), which perform measurements in a dynamic mode, are extensively used in the preparation, production and quality assurance of pre-packed products as well as for products, whose content or composition is determined by weighing.

While NAWIs are routinely calibrated by accredited calibration laboratories according to EURAMET Calibration Guide for NAWIs, the calibration of AWIs is not as well defined, because there is a significant difference between the static measurement mode of operation of NAWIs and the dynamic measurement mode of operation, which is typical for the majority of AWI applications. The growing dissemination of AWIs emphasises the need to confirm their metrological quality by calibrations and the reliable estimation of their measurement uncertainty in order to judge the accuracy of the weighing result. Thus, the development of calibration methods for dynamic measurements with AWIs is the scope of the EMPIR project 14RPT02 “Traceable calibration of dynamic weighing instruments operating in the dynamic mode”, with a short name AWICal, funded by EURAMET. This project developed harmonised calibration methods and uncertainty evaluation models for the three selected categories of AWIs, i.e. automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments, selected to represent the most commonly used instruments.

The project developed 3 draft calibration guides for AWIs, one guide for each instrument group respectively.

The documents for the calibration of automatic instruments should include at least guidance on:

- determination the mass of test loads,
- measurements to be performed,
- calculation of the measuring results,
- evaluation of the uncertainty of measurement,
- contents of the calibration certificates.

Details about the developed calibration methods, error models and uncertainty evaluation are given in the previous subsections.

The documents were submitted to EURAMET for subsequent approval and publication. For the selected groups of AWIs, i.e. for automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments, the structure of the guide is basically the same and comparable to that of EURAMET calibration guide for non-automatic weighing instruments. The guides contain measurement methods with calculation of the measuring results, error models for the dynamic weighing process, potential sources of measurement uncertainty and measurement uncertainty budgets for the determination of the uncertainty of measurement for the calibration of AWIs and for the determination of the uncertainty of weighing results, methods for determination of the reference value of mass of test loads, contents of the calibration certificates and calibration example. During their preparation, the draft guides were publically available at the project website www.awical.eu. The draft calibration guides were presented to wider audience of technical experts from EURAMET TC-M NMIs/DIs and members of the Stakeholder Committee in April 2018 during EURAMET TC-M meeting in Dublin at AWICal workshop. After submitting the final version documents to EURAMET, the final versions are available at the project website, too.

5. **Develop individual strategies for each partner (except MT) for the long-term development of their research capability in dynamic mass metrology** including priorities for collaborations with the research community in their country, the establishment of appropriate quality schemes and accreditation (including participation in comparisons and submission of Calibration and Measurement Capabilities (CMCs) either to the BIPM Key Comparison Database (KCDB) or an accreditation body as appropriate). The internal funded partners will also develop a strategy for offering calibration services from established facilities to their own country and neighbouring countries. The individual strategies will be discussed within the consortium and with other EURAMET NMIs/DIs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

The aim of this part of the project was to develop an individual strategy for each partner (except MT) for the long-term development of their research capability in dynamic mass metrology and to develop a strategy for the provision of calibration services from established facilities in their own country and / or neighbouring or other countries. Additionally, the aim was also the exchange of knowledge and expertise related to the establishment of suitable traceability of AWIs which operate in the dynamic mode amongst the NMI partners and to ensure that partners have sufficient detailed expertise related to the principles of operation of the 3 categories of AWIs.

All three planned training workshops aimed to exchange knowledge and expertise among partners being especially intended for the partners from emerging EURAMET member countries have been successfully organised and carried out. The training on automatic gravimetric filling instruments (OIML R61-1:2004 and calibration principles) was provided TUBITAK from 30 May – 3 June 2016. The training on automatic catchweighers (OIML R-51-1:2006 and calibration principles) was provided by MIRS from 11-14 October 2016. The training on automatic instruments for weighing road vehicles in motion (OIML R-134-1:2006 and calibration principles) was provided by ČMI from 14-17 November 2016.

Figure 10: The training on automatic catchweighers, October 2016.

Exchange of experience between project partners was carried out also at the project technical meetings (Brno, January 2016, Budva, May 2016, Espoo, April 2017, Sarajevo, January 2018) and via email communication during preparation of the draft guides.

In January 2018 an additional meeting of AWICal project partners was held at IMBIH, Sarajevo, specially dedicated to presentation and discussion of the project results of all partners with the aim of exchanging experiences related to establishment of suitable traceability of automatic weighing instruments which operate in the dynamic mode. The participants presented their experience in calibration of automatic weighing instruments performed within the framework of validation and intercomparison activities. The report, which was prepared after the meeting, summarised experiences of the partners related to establishment of suitable traceability of AWIs which operate in the dynamic mode

During the preparation on individual strategies at the national level the following issues were taken into consideration:

- status on research in field of dynamic measurements, status on conformity assessment in the field of AWI as well as on calibration of AWI;
- establishment of own calibration services for three types of AWIs or upgrade existing services;
- smart specialisation by NMI with regard to the provision of calibration services for AWIs within their own country and neighbouring countries;
- establishment of services accredited to ISO/IEC 17025 and the publication of CMCs in accredited scopes for all three categories of automatic weighing instruments;
- for less experienced in research activities, focus on conformity assessment related to AWIs;
- consultation with national stakeholders from the research community, industry, manufacturers of AWIs, calibration laboratories and the national accreditation body;
- survey on the potential users at national level for accredited calibration services for three types of AWIs, preparation of questionaries' for potential users, scales manufactures, accreditation body;
- development of expertise for assessors for ISO/IEC 17025 for calibration of AWIs;
- research on calibration method and procedure for other types of AWIs.

Feedback from stakeholders was sought based on questionnaires (separated questionnaires for industry, calibration laboratories and accreditation bodies), which included the following group of questions:

- Did you calibrate AWIs in your factory in the past? Who was calibration laboratory? Was this accredited service? Do you need calibration of AWIs and confirmation of traceability of dynamic measurements in your industry/manufacturing process? If recommended procedures for calibration of AWIs be adopted at the level of EURAMET would you implement these calibrations at your factory?
- Have you accredited calibration services on AWIs which you perform? What was the calibration procedure and would you implement the new proposed guides?
- Have you already accredited the calibration laboratories for AWIs, which type, how long to you provide these services, what was their accredited scope? Do you plan do extent the accreditation scheme for calibration on calibration of AWIs? Do you have in your pool of technical assessors the technical assessor for calibration of AWIs?
- Please provide your opinion on the impact of the new guides for calibration?

After consultation which involved national stakeholders, the process of preparation of individual strategies resulted in the following summarised conclusions:

<u>Priorities for collaborations with the research community in their country</u>

- Further exploitation and evaluation of measurement data, which were collected during the validation and intercomparison activities of AWIs. Results of these analyses are going to be published in a scientific journal.
- A further good long-term collaboration with universities, calibration laboratories and producers of automatic weighing instruments will be maintained. It is expected that this kind of cooperation could provide further valuable data about behaviour of the automatic weighing instruments and a relation between actual long term metrological performance of the instruments and results reported in the respective calibration certificates. Especially in the field of weighing in motion several manufacturers are interested in scientific support
- Cooperation with other members of EURAMET TC-M, the technical committee for mass and related quantities, beyond the finalisation of the AWICal project. It is expected that there will be some remarks and questions concerning the proposed calibration guides, which will require explanation, clarification, change or improvement of the content of draft guides. After adoption of the draft guides by EURAMET TC M, it is again expected that modification of the guides will be necessary from time to time.

Establishment of appropriate quality schemes and accreditation

- As soon as there exists harmonised guidance on calibration of AWIs, accepted at the level of EURAMET, the accreditation bodies will prefer accreditation against it.
- The expertise for technical assessors for ISO/IEC 17025 assessment for calibration of automatic weighing instruments has been developed within the automatic weighing instruments project.
- The accreditation bodies would also welcome any intercomparison between calibration laboratories in this field. However, it is from a practical point of view very hardly expected that there will be an opportunity to occasionally organise the comparisons for calibration of AWIs.

Offering calibration services from established facilities to their own country and neighbouring countries

- A majority of partners are not going to offer calibration of AWIs as a standard service. They will support probable calibration laboratories, assessors and outstanding calibration applications with specific metrological challenges on request.
- Some partners are going to extend or establish calibration services for AWIs based on the developed guides.

Sustainability of the project achievements both in the short term and the longer term

- Preparation of the calibration guides for the automatic weighing instruments is a base of ensuring sustainability of the project achievements both in the short term and the longer term. The draft guides, which will be prepared within the project, will be at the end of project submitted to EURAMET TC M, and this TC will be responsible within EURAMET for the consideration, approval and publication of the proposed calibration guides.
- Supporting calibration laboratories, assessors and customers in the use and implementation of the respective guides. Project achievements sustainability will be realised by knowledge transfer by/at seminars and consultations, conferences, technical fairs, trainings for participants originating from AWI manufacturers and servicing organizations, end users, calibration laboratories, accreditation bodies and technical assessors,

As a result of the project, individual strategies for each NMI partner for the long-term development of their research capability in dynamic mass metrology and a strategy for the provision of calibration services from established facilities in their own country and/or neighbouring or other countries were developed. Based on the agreed action plan the process of preparation of individual strategies involved also interviews with various national stakeholders. The strategies took into account requirements for international cooperation and smart specialisation, including priorities for collaborations with the research community in the partners' countries. The strategies aim at sustainability of the project achievements. The presentation of the research strategies took place in April 2018 during EURAMET TC-M in Dublin at AWICal workshop. The workshop was well attended by the project partners and other experts from EURAMET TC-M NMIs/DIs and members of the Stakeholder Committee.

Figure 11: AWICal workshop, April 2018.

Finally, the capabilities developed in emerging EURAMET members during the project will support their local industry and weighing sector and developed conformity assessment competence of these members in order to support the implementation of the MID and the Pre-packages Directives.

Overall results summary

The project developed calibration methods and uncertainty evaluation models for three categories of AWIs.

- These methods and models were validated via on-site tests at end-users/manufacturers.
- Draft calibration guides for the three categories of AWIs based on these calibration methods and uncertainty evaluation models were developed, providing the first guides available for these instruments/application.
- The draft calibration guides for the three categories of AWIs will be directly used by calibration laboratories, which will assure traceability of measurements performed by AWIs operating in the dynamic mode. In addition the guides may serve as harmonised standard documents. The measurement uncertainty evaluation models will also be of benefit to the conformity decision process for AWIs used for legal metrology purposes, which are subject to the requirements of the MID. These draft calibration guides for automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments were submitted as three separate guides to EURAMET for further approval as EURAMET Calibration Guides.
- The project increased metrology research capabilities and expertise of emerging EURAMET member countries in the provision of reliable traceability of dynamic mass measurements. This will also assist countries with an association agreement with the EU in developing their conformity assessment competence in order to support the implementation of the MID and the Pre-packages Directives.
- The expected impacts of the EMPIR AWICal project are to provide basis for traceable dynamic measurements on three groups of AWIs based on the draft guides submitted to EURAMET and improved weighing process control in different industries such as production pre-packed products and transport. Consequently, the calibration laboratories for the calibration of AWIs could be accredited by accreditation bodies based on the harmonised guidance. Supporting information on measurement uncertainty will be available to conformity assessment bodies for AWIs.

5 Impact

A Stakeholder Committee was established for the duration of the project. It consisted of 16 members representing end-users of AWIs, calibration laboratories in the field of weighing instruments, AWI manufacturers, and conformity assessment bodies of AWIs and legal metrology bodies. The committee has been regularly updated on the project progress. Some committee members have provided their comments of the draft calibration method, which are available on the project web page. During 2016 GUM carried out three training sessions for Polish stakeholders from industry and then in 2017 a further three training sessions for Polish end-users of WIM instruments. In January 2016, 2017 and 2018, PTB held a presentation about the project for national stakeholders from industry. In September 2016 CECIP and AWI producer representatives took part at the consortium meeting in Göttingen. Stakeholder forums were carried out also by MIRS, IMBiH and Metrosert during 2017, while other partners will organise similar activities during the end of the year. The project partners have closely cooperated with collaborators from industry, which provided access to automatic weighing instruments for the purpose of validation of developed calibration methods. During second half of 2017 and May 2018 also other project partners (MIRS, CMI, DMDM, TUBITAK and Metrosert) organised and held national workshops at their locations. The outputs of the project were presented there including the draft calibration guides for AWIs. In addition, AWICal workshop took place on 19 April 2018 during EURAMET TC-M in Dublin. The workshop was attended by the project partners and other experts from EURAMET TC-M NMIs/DIs and members of the Stakeholder Committee. Results of the AWI intercomparisons and draft guides were presented and discussed between the project partners and auditorium of mass experts.

The EURAMET TC-M was informed during its annual meetings in May 2016, April 2017 and April 2018 about the progress achieved in the project. The committee was further invited to be actively involved in the development of the calibration guides. The project was presented also at the COOMET annual mass group meeting in October 2016.

WELMEC WG2 considers and provides guidance on the MID with regard to AWIs to facilitate its implementation and WELMEC WG6 considers issues related to the EU prepacked product legislation. The partners involved in the WGs disseminated the outputs of the project results among the WG members. During the meetings of WELMEC WG2 in Bratislava, Slovakia in October 2015 and in Göttingen, Sweden in September 2016, the project was presented to the group by BEV and MIRS, respectively. CMI presented the project to WG6 in Paris in June 2016 and MIRS presented the final project results to WELMEC Committee meeting in Sarajevo in April 2018. Positive feedback on the project goals and results was received from all above mentioned WELMEC groups.

OIML recommendations R51, R61 and R134 define conformity assessment procedures of AWIs, and R51 and R61 are normative documents for the MID Directive. Their future revisions will need to implement the OIML Document on the measurement uncertainty in conformity assessment in legal metrology. In February 2016 the project partners BEV/PTP, GUM, CMI, DMDM and PTB were involved in a web discussion related to the revision of OIML R61 for automatic gravimetric filling instruments within the TC9/SC2 “Automatic weighing instruments”. The involved project partners disseminating information about the project and its outputs to this group.

At XXI IMEKO World Congress in September 2015 PTB and MGRT presented challenges for the calibration of automatic weighing instruments in dynamic operation to a scientific and industrial audience. Three peer reviewed conference papers summarising the mid-term project results were presented at IMEKO TC3, TC5 and TC22 International Conference 2017 by MIRS and TUBITAK. MIRS gave a presentation about traceable calibration of AWIs at CIM2017 congress in September 2017. Another paper has been accepted for a presentation at IMEKO XXII Wold Congress in September 2018 and two papers about calibration methods for AWIs were published in OIML Bulletin in July 2018.

Impact on relevant standards

The EURAMET TC-M was briefed on the developments and results of the project during a May 2016 meeting in Budva, Montenegro, an April 2017 meeting in Espoo, Finland and an April 2018 meeting in Dublin, Ireland. Some members of EURAMET TC-M also provided their input to the draft guides. The final versions of calibration guides for automatic catchweighers, automatic instruments for weighing road vehicles in motion and automatic gravimetric filling instruments were finalised in May 2018 and submitted to EURAMET TC-M for further approvals as EURAMET Calibration Guides.

Impact on industrial and other user communities

The main stakeholder groups, which directly benefit from the outcomes of the project, are calibration laboratories, accreditation bodies, producers of AWIs and conformity assessment bodies.

- The validated calibration techniques, associated uncertainty formulation and new and harmonised calibration guides on AWIs developed by the project will be directly used by calibration laboratories, which will assure traceability of measurements performed by dynamically operated AWIs. Harmonised and traceable calibration based on accreditation is a basic requirement for mutual recognition of calibration results, offering a cost saving to European exporters. The recognised traceability of calibration results will also provide an important contribution to consumer protection.
- Accreditation bodies accrediting laboratories for the calibration of AWIs according to EN ISO/IEC 17025 and laboratories calibrating AWIs will benefit from the project outcomes as the calibration methods and guides developed will assure harmonised methods for calibration of the instruments and harmonised accreditation scopes of commercial calibration laboratories across Europe.
- Manufacturers of AWIs cooperate closely with the end users of these instruments. The project will enable important improvements in the quality of information on the performance of three different categories of AWIs. With the information provided by an accredited calibration certificate, the producer will be able to better meet the requirements of their clients. This will provide increased reliability and confidence in the performance of instruments for the end-user community.
- The conformity assessment bodies for instruments covered by the MID are usually accredited according to EN ISO/IEC 17025 for the testing of AWIs within the type evaluation or verification procedure. The guides on the calibration of AWIs operating in the dynamic mode will provide harmonised uncertainty evaluation procedures, which will provide supporting information to those bodies with respect to the requirements of the standard related to uncertainty evaluation.

Until now, five companies (from Turkey, Croatia, Estonia, Germany and Slovenia) expressed their intention to implement one or two of calibration guides into practice and later ask for the accreditation of their laboratory in offering a calibration service (based on customer’s demands).

During preparation of the research strategies it came clear that the calibration guides, developed by the project, would have their highest value when adopted as the EURAMET calibration guides. There exist a larger number of calibration laboratories, which will approach their partners, end users of AWIs, offering calibration of AWIs in the dynamic mode of operation, after the EURAMET calibration guides for AWIs are formally adopted.

Impact on the metrological and scientific communities

The project will have impact on development of Calibration and Measurement Capabilities (CMCs) of laboratories which calibrate AWIs, through the provision of harmonised calibration methods. The accredited CMCs are proof of competence of calibration laboratories and the guide will ensure harmonised accreditation scopes among calibration laboratories and accreditation bodies.

Longer-term economic, social and environmental impacts

The individual strategies developed by the partners for the long-term development of their research capability in dynamic mass metrology were discussed within the consortium and with other EURAMET NMIs/DIs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole. The strategies aim at sustainability of the project achievements. The presentation of the research strategies took place in April 2018 during EURAMET TC-M in Dublin at AWICal workshop. The strategies are published on the project website.

6 List of publications

1. O Mack, T Klein, C Schlegel, M Grum, *Challenges for the calibration of automatic weighing instruments in dynamic operation*, Proceedings of XXI IMEKO World Congress, 2015
2. M Grum, G Grgić, *Test Load Reference Mass Value for AWI Calibration*, Proceedings of IMEKO TC3, TC5 and TC22 International Conference 2017
3. M Grum, G Grgić, *Two Model Functions for Calibration of Automatic Gravimetric Filling Instruments*, Proceedings of IMEKO TC3, TC5 and TC22 International Conference 2017
4. S Kaçmaz, C Yılmaz, L Kangı, M Telli, S Yelekçi, *Calibration of automatic gravimetric filling instruments in dynamic weighing*, Proceedings of IMEKO TC3, TC5 and TC22 International Conference 2017
5. M Grum, *Traceable calibration of automatic weighing instruments in dynamic operation*, Proceedings of CIM2017 18th International Metrology Congress, 2017
6. M Grum, *Traceable calibration of automatic weighing instruments operating in dynamic mode*, OIML Bulletin, Volume LIX, Number 3, July 2018
7. S Kaçmaz, *The role of control instruments in the calibration of automatic gravimetric filling instruments in dynamic mode*, OIML Bulletin, Volume LIX, Number 3, July 2018
8. M Grum, *Calibration of automatic catchweighing instruments in dynamic mode of operation*, Proceedings of XXII IMEKO World Congress, 2018

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