Church of St. John of Kanevo in Ohrid, North Macedonia

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Technical Manager of mass laboratory

She has been working at Bureau of metrology (National metrology institute from North Macedonia) since 2006. She completed her doctoral studies at the University of Ss. Cyril and Methodius, Faculty of technology and metallurgy in Skopje, in 2005. Science of the New Materials was the topic of her thesis work. After the University, she has continued her professional development in the mass laboratory of the Bureau of Metrology as a Technical Manager. In 2013, she published CMC’s for mass standards for the range from 1 mg up to 20 kg and began to develop the national mass standard of 1 kg through improvement of the realization of the mass scale. She is a member of EURAMET technical committees (TC-M, TC-Q, TC-IM and BoD WGCB) and WELMEC working groups (WG2, WG6) as well as represents Bureau of metrology on OIML and BIPM general assembly meetings. As a participant in EMPIR project for Real Mass, she has been working on implementation of dissemination of unit of mass in the laboratory since 2020.

RADWAG

ČESKÝ METROLOGICKÝ INSTITUT

Mass metrology needs in emerging institutes

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Contents

- General information about BoM - emerging metrology institute
- Mass laboratory
- Investigation/comparison
- Future research and development

Short History of BoM

1945 to 1947	Ministry of Trade of the People's Republic of Macedonia - Department of Weights and Measures
1947 to 1953	Administration for Measures and Precious Metals of the People's Republic of Macedonia within the framework of the Federal Administration for Measures and Precious Metals
1956	Federal Control for Measures and Precious Metals - Skopje
May 1992	was founded Department for measuring instruments and precious metals within Ministry of Economy
April 1995	former Department has been transformed into Bureau for standardization and metrology, according to the new Macedonian Law on measuring unites and measuring instruments ("Official Gazette of RM" No.23/95)
September 2001	Bureau for standardization and metrology has been transformed into Service for Standardization and Metrology, according to the Law on Government Bodies
July 2002	was founded Bureau of Metrology (BoM), according to the new harmonized Law on Metrology ("Official Gazette of RM" No.55/2002)

Institutional framework

✓ Metrology system in the Republic of North Macedonia has been established in accordance with international and EU trends, and it consists of the following subjects:

- The Ministry responsible for metrology legislation (Ministry of Economy)
- Bureau of metrology (BoM) – National metrology institute
- Metrology Council – advisory body
- Accredited calibration and testing laboratories
- Authorised bodies for verification of measuring instruments

Quality infrastructure in North Macedonia

National quality infrastructure

Ministry of economy

Free movement of goods legislation

Standardization
ISRSM

NMI
Bureau of metrology

Accreditation
IARSM

- *OIML member since 1996*
- *BIPM/ CGPM associate member since 2006*
- *CIPM MRA signed in 2007*
- *WELMEC member since 2008*
- *IAAO member since 2009*
- *EURAMET full member since 2010*

Bureau of metrology (BoM)

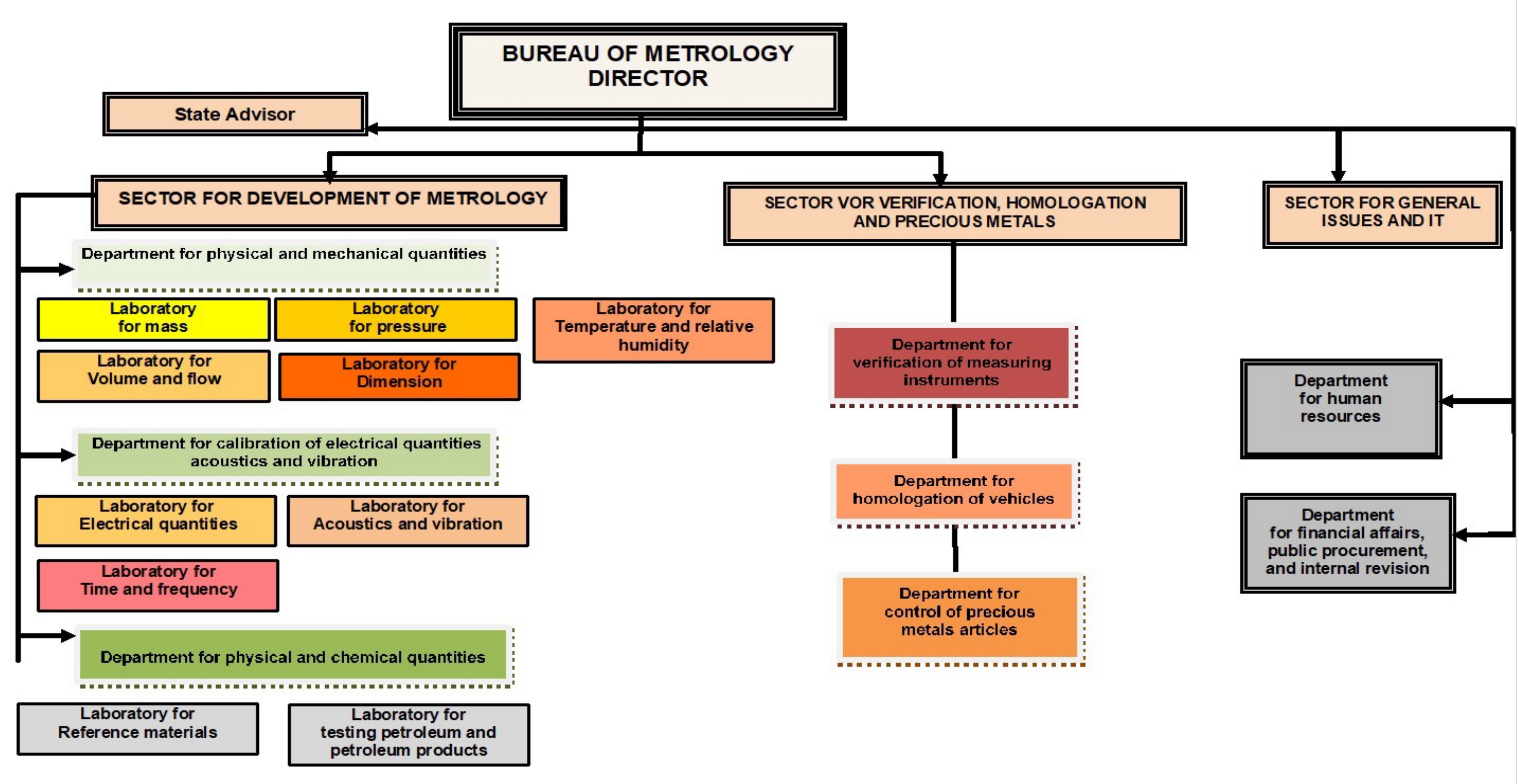
- BoM is responsible governmental body for implementation of:

  - **Law on metrology** (“Official Gazette” No.55/2002)

  - **Law on control precious metals articles** (“Official Gazette” No.23/92)

  - **Law of vehicles** (“Official Gazette” No.140/08) **– administrative body**

Organogram of BoM



Vision and mission of BoM

- ✓ ***Vision:*** The vision of BoM is to provide metrological services in all strategically important areas at the national level and to ensure international recognition of measurements and calibrations performed in the Republic of North Macedonia.

- ✓ ***Mission:*** The mission of the BoM is to ensure the functioning and development of the entire metrological infrastructure, which will contribute to the protection of the environment, the improvement of the quality of products and life, and the provision of support to the competitiveness of the national economy, as well as to identify the stakeholders of the national metrology system that will be involved in fulfilling the strategic goals.

BoM in function of industrial/scientific metrology

- Providing a framework for traceable and internationally recognized measurements;
- International recognition of the national metrology infrastructure;
- Realization and maintenance of measuring standards;
- Development of measurement procedures and methods;
- Representing North Macedonia at international and regional metrology organisations;
- Research;
- Quality assurance;
- Accredited activities.

EUROPEAN ACCREDITATION

ilac-MRA

CIPM MRA

North Macedonia

Signatory/NMI

Bureau of Metrology, Ministry of Economy
→ BOM
Skopje

Participating in the CIPM MRA since: 14 November 2007
Signed by: Sonja MIRAKOVSKA (then Director, BOM)

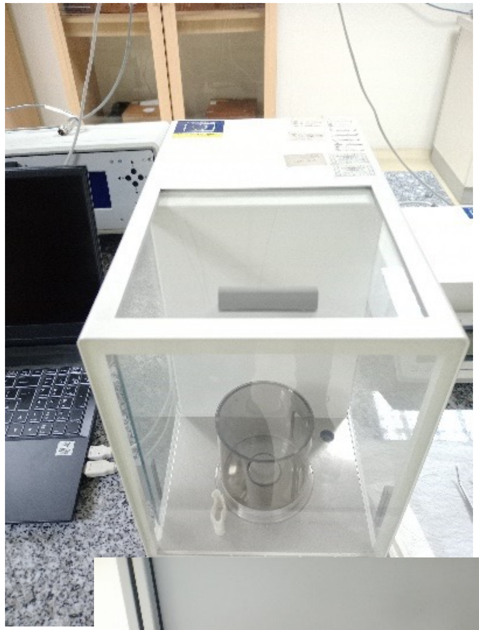
BoM in function of industrial/scientific metrology

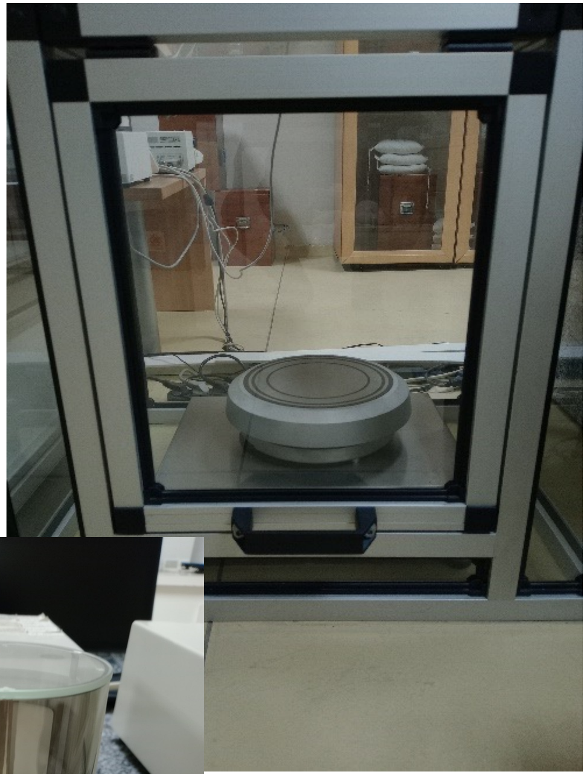
- Supported by country`s budget and EU funds, in 2005 the following laboratories of BoM were developed:
  - Mass (accredited from 2012, published CMC`s in KCDB BIPM from 2013);
  - Pressure (accredited from 2012);
  - Length and angle (under the accreditation process);
  - Volume and flow (accredited from 2012, published CMC`s in KCDB BIPM from 2013);
  - Temperature (accredited from 2012, published CMC`s in KCDB BIPM from 2016) and relative humidity (accredited from 2016);
  - Time and frequency (accredited from 2021);
  - Electrical quantities (AC/DC LF) - accredited from 2016;
  - Acoustic and vibration (accredited from 2016);
  - Laboratory for testing quality of petroleum products (26 accredited methods for testing and sampling, since 2019).
- BoM for the first time, presented its QMS to EURAMET in 2012.

Mass laboratory

- Mass calibration laboratory within the BoM is a national laboratory for calibration, realization and maintaining of the reference standards for mass (1 mg - 20 kg), E1 class of accuracy, through comparison with other National institutes and National laboratories, which are traceable to BIPM in order to provide traceability to National mass standards;
- Accredited on National level, since 2012 (weights and balances) up to 500 kg;
- Published CMC in KCDB BIPM in July, 2013 for the range from 1 mg - 20 kg, E2 class.

Mass laboratory




Current state in the mass laboratory

Overview

In the field of mass measurements, main stakeholders' needs are calibration of weights (E2, F1, F2, M1 class of accuracy) and balances (analytical, precise, electronically), through which they will provide their measurement traceability;

Need

Mass laboratory have to be equipped with the best mass comparators in order to be able to provide calibration service for E1 class weights, available guidance and appropriate software tools if plan to provide the best possible service for industries such as the automotive or pharmaceutical sectors;

Objective

Improving calibration methods for the realisation of the mass scale in the range from 1 mg to 20 kg with uncertainties of 0.001 mg – 3 mg or better, with suitable mathematical and statistical tools for determining the results and related uncertainties of the weights.

Strategic determination of mass laboratory

- Establish the continuity of the laboratory development, improve metrology and promote new calibration services such as volume or density measurements of the weights to enable validity and assurance in measurements for trade, health care, consumer protection and to grow key sectors of industry;
- Upgrading the CMC's on E1 level and planning procurement of the new equipment;
- Provide strategic development of metrology system which maintains the national standards and facilities, make them available to users through knowledge transfer and a wide range of services and develop new measurement techniques and services in response to requirements from business and the public sector.

Investigation of mass comparator`s effect in dissemination of the 1 kg mass unit

- The idea was to bring to attention the scientific potential of mass measurements, which aim to improve one of the most important techniques in mass metrology, ***the realisation of the mass scale;***
- The study proposes different models for the dissemination of the mass unit in the context of the new definition of the kilogram;
- Laboratories of CMI (Czechia) and BoM (North Macedonia) compared dissemination procedures techniques on automatic and robotic mass comparators;
- The comparison focused on manipulation of weights, duration of dissemination process and time used to set up all data needed to actually run the measurements;
- The final step was controlling the conditions during the measurements and comparing the obtained measurement results at the same time.

Investigation of mass comparator`s effect in dissemination of the 1 kg mass unit

CMI – Automatic mass comparator

Laboratory of primary mass metrology of Czech metrology institute is equipped with manual and automatic mass comparators, to performed calibration of mass unit in range from 1 mg – 10 kg, on the level of E1. Within this study only limited range from 100 g – 1 kg was used.

The measurements were done on vacuum mass comparator, with maximum capacity 1 kg and resolution 0.1 µg. It had 6 positions for weights. The weights can be loaded through front window or through load-lock system.

The measurements were controlled by software, provided together with the comparator. The software recorded all data and calculated average and standard deviation of the measurement. It has also simple database of all weights.

Weights

Laboratory used 1 kg stainless steel weight, as the reference weight, for this comparison. Other weights were from primary weight set and special cylindrical weights, for safer stacking of the selected weight composition. Only 1 weight of the standard OIML shape was used at any combination of the weights.

Investigation of mass comparator`s effect in dissemination of the 1 kg mass unit

BoM - Robotic comparator

Mass calibration laboratory at BoM is equipped with Robotic system to perform calibration of weights in range from 1 mg – 1 kg, on the level of E1. Fully automatic mass comparator (Robotic system) has maximum capacity of 1002 g, resolution 0.1 µg/1 µg and 62 magazine positions for the weights. The measurements were controlled and calculated the obtained results to the calibration certificate by software, provided with the robotic system.

Weights

Laboratory from BoM used 1 kg stainless steel weight, E0 class of accuracy, OIML shape. Traceability of the reference standards is provided by NMIs, signatories of CIPM MRA, with recognized calibration measurement capabilities that are included in Appendix C of the MRA, drawn up by the CIPM. The other reference standards were from the laboratory, E1 class of accuracy (1 kg, 500 g, 200 g and 100 g, cylindrical shape and discs). The disc-shaped weights were used because of the possibility to perform measurements on an automatic comparator for safer stacking of the selected weight composition.

Measurement process

- **CMI** used 18 weights for this study: 4 pieces of 1 kg weights (OIML shape), another 4 pieces of 500 g weights (2 OIML shape, 2 cylindrical). The same composition was for 200 g weights. 6 weights of 100 g were used, from which 2 were of OIML shape, 2 had cylindrical form and last 2 were disc weights. In theory only 4 weights of 100 g should be used but because the measurement and calculations were prepared for total of 6 weights in each measurement, laboratory decided to use additional 100 g weights.
- After placement of the weights onto the load alternator, the centring process started. It consisted of 5 times loading of each position to the weighing pan. Reason of this process was to align centre of gravity of the weight or weight combination with the weighing pan, so the pan didn’t move during the measurement. Setting up and centring process took about 1 – 2 hours.

For the purpose of this study, laboratory used 6*ABBA cycles, repeated only 1 time for measurements. **The measurement time was 18 hours. All dissemination procedure took 1 week to complete the measurements.**

Measurement process

- **BoM** used a robotic mass comparator with capability of loading the combinations of weights automatically from the mass standard`s magazine, without the need for manual stacking. A design with 12 combinations was used for the measurements, with a repetition of three times for each combination.
- For the purpose of this study, mass laboratory used 6*ABBA cycles, with one pre-cycle for centring process. Setting up and centring process took around 1 hour.

The total measurement time and calculation of uncertainty budget took 17 hours.

Results

The software which was developed as a part of project EMPIR RealMass, CMI was used for evaluation of the results. Standard deviations for measurements on 1000 g was less than 0,3 µg. Standard deviations for other measurements were about 3 µg. Reason for this increase is smaller number of ABBA repetitions and not repeating the whole process.

All results were in line with older calibrations.

ID	True mass difference (mg)	Uncertainty (mg)	Conventional mass difference (mg)	Uncertainty (mg)
1 kg 51699	0,647	0,043	0,119	0,043
1 kg 15936	0,53	0,19	0,021	0,043
1 kg 15936*	0,64	0,19	0,131	0,043
500 g 15936	0,39	0,55	0,104	0,033
500 g 15936*	0,27	0,55	-0,015	0,034
200 g 15936	0,15	0,22	0,034	0,016
200 g 15936*	0,14	0,22	0,024	0,016
100 g 15936	0,06	0,11	0,0060	0,0080
100 g 15936*	0,08	0,11	0,0224	0,0079

Results

BoM`s laboratory used RealMass software and software which was installed to operate the robotic comparator and has capabilities to evaluate the dissemination process.

ID	True mass difference (mg)	Uncertainty (mg)	Conventional mass difference (mg)	Uncertainty (mg)
1 kg 25329512	-0.36	0,040	-0.18	0,039
1 kg 40503314	-1.16	0,043	-0.26	0,041
500 g A39	0.33	0.028	-0.023	0.021
500 g 17329511*	-0.13	0.022	-0.034	0.020
200 g B9	0.092	0.011	0.035	0.0082
200 g B10*	0.12	0.011	0.063	0.0082
100 g A90	0.023	0.0057	-0.0063	0.0042
100 g 601503B*	0.064	0.0044	-0.0268	0.0043

All results were in line with calibration certificates.

Conclusions

- The dissemination of the unit of mass with automatic mass comparators is a time consuming process;
- Due to necessity of stacking the weights the operator must be experienced and careful when setting the weights. These weights add more complexity to the measurement system;
- It is almost impossible to rely only on the standard OIML weights without use of disc or cylindrical weights;
- If some measurement fails for any reason, it is easier to repeat just the wrong measurement.

- On the other hand, most of the issues described on the top should be solved with robotic mass comparator, which can set up required weight compositions, without additional weights.

Conclusions

- Considering that redefinition allows mass to be directly realized at any value, the study presents a model of the dissemination of the mass, where the measurements are performed by means of fully automatic (robotic) and automatic mass comparators at the same time, control the conditions during the measurements and comparing the obtained measuring results;

- Analyse the methods for realisation and dissemination of the mass scale, including the impact from the recent redefinition of the kilogram, can create an appropriate methodology in order to optimise different technical requirements and parameters (small uncertainty, properties of different weighing instruments, different types of weights, etc).

Future research and development

- Mass lab will raise the calibration of customer weights and calibration of its own weights to another level;
- Mass lab will continue to participate in international comparisons, in order to provide measurement traceability to international standards;
- Mass lab will continue to participate in research and development projects, in order to build its research capacity;
- Mass lab will continue to organise of workshops on National level for stakeholders' and infrastructure parties;
- According to the stakeholders' needs, mass lab plan to support provision of industry-relevant training and to promote development of measurement principles and benefits of applying good measurement practice of the technical services.

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