Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
National Metrology Institute

INTERNATIONAL COOPERATION

Steps towards a National Metrology System

Proposals for development, organization and operation

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german cooperation
DEUTSCHE ZUSAMMENARBEIT

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**The publications mentioned can be ordered from 9.3-Medien@ptb.de*

On behalf of the German federal government, the Physikalisch-Technische Bundesanstalt promotes the improvement of framework conditions for economic activity, thereby supporting the establishment of metrology.

Part I – Introduction

This paper is addressed to decision and policy makers with limited knowledge of metrology on the one hand, and metrologists working in "young" metrology institutions on the other. It may also be useful for third parties (donors) and their implementing agencies. Its aim is to:

- facilitate dialogue between the parties mentioned above
- show possibilities for improving essential parts of the metrology infrastructure and
- encourage efforts for establishing metrology as a national system

For a better understanding of the significance of metrology, the paper contains:

- a short overview of the wide variety of activities that require metrology and of the typical quantities to be measured, the measurands
- basic information on metrology and on elements of a metrology infrastructure
- requirements and recommendations for the development, organization and operation of the elements that are part of a national metrology system (these are primarily defined by governmental rules and international standards) and
- a proposal for steps towards a national metrology policy

Examples and references are given for further information and consideration.

The paper proposes actions to ensure that the metrology system is adequate for the economy and society of a given country. This requires an overview of the country's metrological needs and capabilities and a policy for the development of an adequate national metrology system. The argument "we need this equipment because other countries have it" may be valid only if all preconditions are more or less the same. Otherwise, the risk exists that the expected benefits will not be realized and the non-expected impacts will be detrimental. An impact assessment[1] is therefore necessary before starting investments. An in-depth analysis requires time and expert knowledge, which are often not available, not requested, or ignored. One intention of this paper is to encourage completion of the first steps (with affordable resources) for data collection and classification of needs; these steps serve as a beginning on the path towards a national metrology policy.

The paper will deal neither with metrology as the science of measurement nor with details of specific metrological problems. For information on international issues of metrology, consultation of the websites www.bipm.org of the *Bureau international des poids et mesures* (BIPM, International Bureau of Weights and Measures), and www.oiml.org of the *International Organization of Legal Metrology* (OIML) is recommended. All documents on these websites are accessible free of charge. Metrological terms are used as defined in the international vocabularies.[2]

1 **Impact Assessments** are formal, evidence-based procedures that assess the economic, social, and environmental effects of public policy (Wikipedia)

2 International Vocabulary of Metrology – Basic and General Concepts and associated Terms (VIM) 3rd edition 2012, and International Vocabulary of Terms in Legal Metrology (VIML) ed. 2013

Part II – Activities that Require Metrology

The keywords listed below characterize sectors and fields of activity and typical quantities to be measured.

Trade: An internationally accepted system of measurement units and of reliable measurements facilitates the exchange of goods, particularly across national borders.

Typical measurands: Weight, volume, length.

Industrial production: Specified tolerances for parts, components and modules must be ensured to fulfil quality requirements and interchangeability.

Typical measurands: Dimensional and electrical quantities, temperature, pressure.

Healthcare: Physicians rely on analyses for diagnosis and treatment of patients.

Typical measurands: Biochemical and chemical quantities and composition of substances.

Conformity assessment: Specialized laboratories determine the characteristics of products, materials or substances with regard to standards or regulations.

Typical measurands: Physical quantities, composition of material and substances.

Enforcement of legislation: All regulations specifying thresholds quantitatively for measurands need measurements, otherwise enforcement cannot be assured.

Typical measurands: All quantities for which tolerable limits are prescribed.

Part III – Elements of a National Metrology Infrastructure

The elements of a national metrology infrastructure are:

- governments (for legislation and financial contributions)
- national metrology institutes (NMIs)
- verification offices
- designated institutes (DIs) and
- calibration laboratories

Their tasks are described in general terms. Their status, tasks, operations and interactions may vary according to prevailing national conditions.
Metrology interacts with standardization, regulation, accreditation and conformity assessment, together forming the national quality infrastructure. The following section focusses on metrology.

3.1 The Role of Government

The role of government is to

- establish a legal corpus on metrology
- maintain national metrology institutions
- encourage and support interactions of constituents of the quality infrastructure
- enable interactions with regional and international metrology organizations
- provide necessary resources

Details on this are given in the following chapters.

3.2 The National Metrology Institute (NMI)

In many countries, a national body exists that is called "National Metrology Institute" (NMI) or another name. The main tasks of an NMI are:

- to maintain national measurement standards and certified reference materials (CRMs)[3]
- to ensure their traceability[4] to the SI, or to a higher-order method of CRMs
- to enable traceable calibrations of lower-level (secondary) measurement standards
- to advise and cooperate with government and clients
- to cooperate with regional and international metrology organizations
- to carry out research in metrology, if possible

One source of details of a typical NMI laboratory for the physical quantity of mass is given below:

The Road to a Mass Laboratory*

This publication by Martin Firlus contains details for the design and specification of equipment of a mass laboratory and training requirements. Examples and photos are included.

The brochure is also available in French, Russian and German language

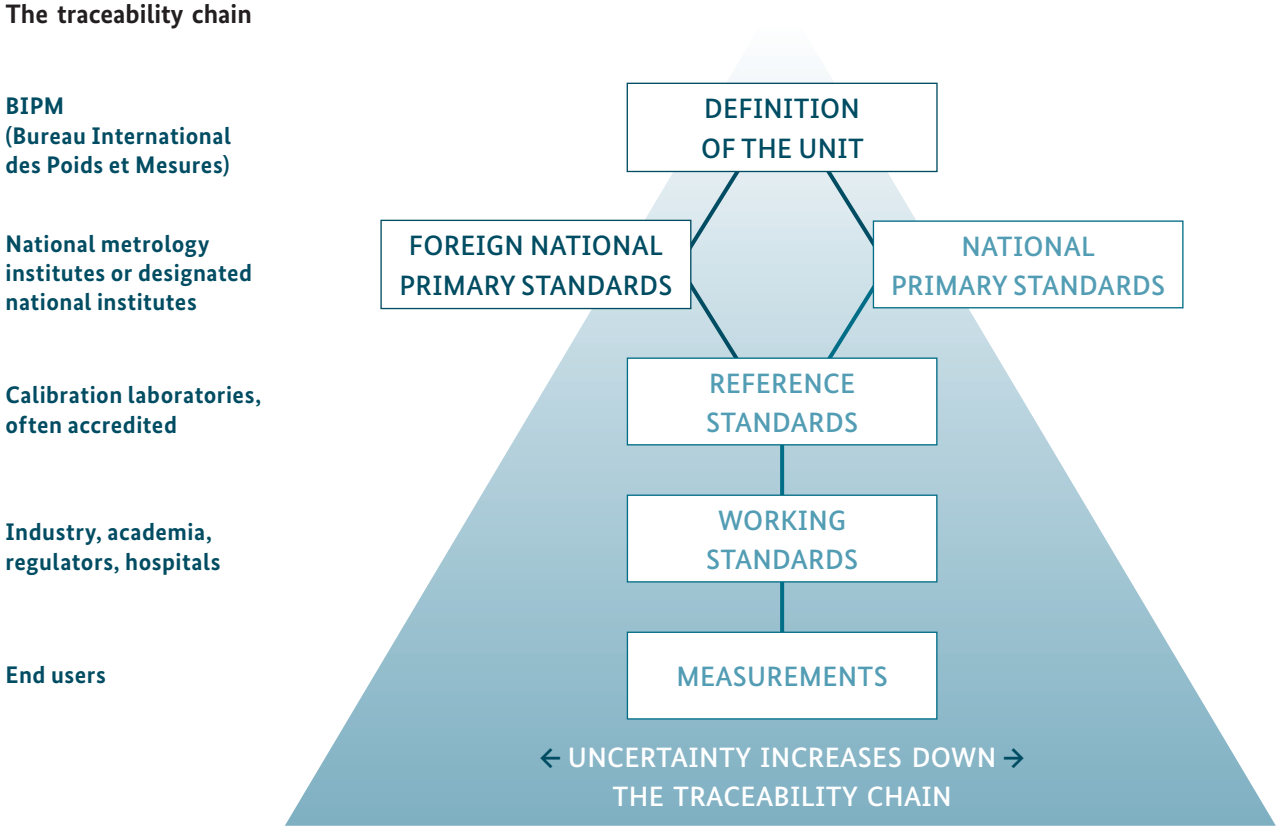
Le laboratoire de masse pas a pas

Создание Лаборатории Массы

Der Weg zum Masselaboratorium

3 Certified reference materials are used in fields such as composition of material for validation of analytical measurement methods.
4 Traceability is an unbroken chain of comparisons, all having stated uncertainties. This ensures that a measurement result or the value of a standard is related to references at the higher levels, ending at the primary standard (see Fig. 1).

The traceability chain



Source: Metrology in short (3rd edition by EURAMET)

3.3 Verification Offices

Verification offices (also called weights and measures bureaus or the like) are institutions of legal metrology. The aim of legal metrology is to ensure that correct weights and measures are used in trade and in other sectors of public interest such as health, safety and environmental protection. Enforcement of regulations is the main task of verification offices. Authorized bodies may be appointed for specific tasks, if necessary. These specific tasks include:

- approval of type tests and conformity tests of measuring instruments[5]
- verification of measuring instruments[6]
- market surveillance and metrological supervision
- checks of the net content and labels of pre-packages
- cooperation with regional and international legal metrology organizations

3.4 Designated Institutes

Laboratories of universities, ministries, hospitals, utility providers and research/testing institutes may calibrate their equipment using their own standards or may use other means (e.g. proficiency tests) to ensure the accuracy and compatibility of their results. If a standard of such a laboratory is up to the international level, the laboratory can be appointed a *designated institute* (DI) by the government, by another appropriate national authority, or by the NMI itself when it is authorized to do so. The DI will then be responsible for maintaining this standard as a national standard and for disseminating traceability. DIs must comply with the same requirements as NMIs with regard to quality management systems, proficiency tests and comparison measurements.

3.5 Calibration Laboratories

NMIs and DIs occupy the top level of the calibration hierarchy and are officially entrusted with calibrations. The following section concerns laboratories that carry out calibrations. In contrast to verification, calibration of measuring instruments is not prescribed by regulations, but must be initiated by the owner/user of measuring instruments in order to ensure that measurements are reliable. The following different types of calibration laboratories exist:

- specialized private entities
- in-house calibration laboratories of companies that operate either exclusively in their own interests or also for third parties on request
- university and research laboratories
- legal metrology institutions, if qualified and authorized to perform calibrations

Calibration involves comparing the indication of a measuring instrument with that of a measurement standard (the reference) that has a sufficient metrological performance (better accuracy/smaller uncertainty). The result is a quantitative statement about the measuring instrument's deviation from the standard and about the range within which a measurement can be expected with a given probability, the so-called uncertainty. Uncertainty is caused by different factors (e.g. calibration environment, calibration method, operator) and must be estimated and documented. One example of the description of a calibration result is given below.[7] The acceptance of calibration certificates by third parties may depend on the quality requirements of national and international standards.

Calibration is not compulsory, in contrast to verification.

5 Approving type tests and conformity tests provides official recognition that the tested type of instrument is fit for use in regulated sectors. The procedures for type tests and conformity tests may be the same. The official approval will be issued by a governmental body, but not necessarily by the verification office.

6 Verification is a check of whether the indication of a measuring instrument is within specified tolerable error limits. The result is "yes" or "no". If the indication of the instrument is not within the error limits, the measuring instrument is not acceptable for use in regulated sectors.

7 The result of calibration of a weight:
m = (100.004 ± 0.005) g for coverage factor k = 2
The value 100.004 g can be expected within the interval of 100.004 g+ 0.005 g and 100.004 - 0.005 g with a probability of about 95 % (coverage factor k = 2). This presentation allows a decision to be made on whether or not the results of measurements are compatible. For details, see: *Guide to the expression of uncertainty in measurement*, BIPM website.

Part IV – Challenges

Remark: The term "requirement" includes the notion of a "challenge" in cases where the requirement still needs to be fulfilled.

4.1 Challenges for Governments

Most countries in the world already have certain laws and regulations concerning metrology. However, the world is changing constantly, and with it, countries' needs and requirements for metrology are changing as well. The development of metrology's potential for the wellbeing of a given country's society and economy may not be included in its government's agenda. If this is the case, it will be necessary to gain the attention of the governmental administration. If a focal point is not already in place, one should be created to deal with metrology issues and to initiate activities according to governmental rules and procedures. This focal point should be known and visible in the structure of the government. Decisions on investments should be based on facts, justifiable arguments and the results of impact assessments. Good governance is needed to achieve efficiency and effectiveness of the national metrology system.

4.2 Challenges for National Metrology Institutes

Emerging NMIs must build competence and create confidence in their work to satisfy the needs of their current clients and to attract new clients. This work must be carried out professionally in accordance with good laboratory practices. Qualification and motivation of staff is of high priority. The ultimate goal should be the international recognition of the NMI's calibration and measurement capabilities. The path to achieving this goal is long and arduous, requiring internationally peer-reviewed and recognized operation of the NMI and its results, followed by signing of the CIPM[8] Mutual Recognition Arrangement (CIPM MRA). To do so, a sound foundation of the institute's capabilities must be laid and continuity of the work ensured.

The successful management of NMIs requires not only a broad knowledge of metrology, but also a realistic concept of the development of metrology according to national needs and capabilities, as well as the skills and commitment necessary for its realization.

Towards mutual recognition of metrological competence*

This PTB publication by Christin Kulgemeyer describes the five steps to mutual recognition of metrological competence, the different steps of the review process, the intra-regional and the inter-regional review of calibration and measurement capabilities, CMCs and the publication of the CMCs in the KCDB key comparison database.

The brochure is also available in French language:

Vers une reconnaissance mutuelle de la compétence métrologique

4.3 Challenges for Verification Offices

The main task of verification offices is enforcement of legal regulations. These activities are visible and perceptible to the public. The work must be carried out impartially and in strict accordance with the regulations, and should result in added value for owners of measuring instruments and for the public. Penalties for infringements must be fair and adequate. A strong work ethic is required. Governments must ensure that staff members are qualified and adequately remunerated. Suitable measures should be in place to prevent corruption; otherwise, verification will be seen as a burden and a specific expense for the parties concerned.

8 CIPM: *Comité international des poids et mesures* (International Committee of Weights and Measures of the BIPM)

4.4 Challenges for Designated Institutes

The official status as a "Designated Institute" carries with it a great deal of prestige, as DIs maintain standards that have the rank of national standards. Here, the challenge for DIs is to comply with the same requirements as those that apply to NMIs. Doing so provides a rationale for the government to contribute to compensating expenses for additional activities. Competent institutes are challenged to strengthen the national metrology system and to take on responsibilities on a national, regional and international level.

4.5 Challenges for Calibration Laboratories

If demand exists for calibrations which are not required to be or cannot be provided by the NMI, then companies or private/public institutes may establish new calibration facilities or use existing ones in order to serve third parties. Such possibilities should be made known and promoted, specifically by NMI representatives. The parties concerned must be open-minded and ready to explore their chance to provide calibration services. This requires detailed information with regard to the necessary equipment, laboratory environment, operation procedures, quality assurance and potential clients. There should be no unfair competition by governmental institutions. These details must be clarified before starting a commercial calibration service.

Part V – Recommendations

Remark: Recommendations concerning all institutions, such as training, are given in Chapter 6.

5.1 Recommendations for Governments

Organization within Governments

Governments should offer contact possibilities for all parties who are interested in or affected by the metrology (quality) infrastructure. This requires functional structures within governmental departments and authorities. In terms of their function, the following elements are recommended (see also OIML Document 1, *Considerations about a law on metrology*, Chapter 3.2.4, *Organization of the authorities*):

Ministerial board of directors, representing ministries as stakeholders of metrology (or in a broader context: as stakeholders of the national quality infrastructure) and responsible for policies and budgets.

Metrology unit in one of the ministries charged with the following functions and tasks:

- acting as a national focal point for metrology
- serving as the secretariat of the ministerial board of directors and the advisory board
- enlisting experts and working groups for specific tasks
- administrative supervision of the NMI and verification offices (legal metrology)
- other functions and tasks as assigned by the ministerial board of directors

Advisory board set up by the ministerial board of directors with the following tasks:

- advising the ministerial board of directors and governmental metrology institutions
- reviewing and commenting on legislation projects and on activities of governmental metrology institutions
- proposing and initiating actions with regard to the development of the national metrology system
- carrying out other tasks on request by the ministerial board of directors

The advisory board should be composed of a small number of permanent members who meet regularly. There should be an equal number of representatives from public and private sectors. For specific problems, experts or working groups should be recommended by the metrology unit or the ministerial board of directors for hiring/installation. The mode of operation needs to be set according to national rules. The advisory board may be part of a quality infrastructure board, if one exists. This will facilitate a balanced development of all QI components.

Legislation should be based on the work of the OIML. OIML D1, *Considerations for a Law on Metrology*, should be checked for drafting national laws or their amendments as well as OIML D2 *Legal Units of Measurement*. A structure of a legal corpus on metrology is given below.

OIML Recommendations are model regulations that establish technical and metrological requirements for types of measuring instruments; these Recommendations are to be considered when national regulations are drafted or amended. OIML Recommendations include instruments of advanced technologies (electronic devices and data processing) which constitute a large part of the requirements. If high technology is not the prevailing technology for measuring instruments used in the country, it is recommended that special documents be drafted that contain only the relevant requirements and perhaps larger error limits for appropriate transition periods. All recommendations and documents should be checked with regard to their national applicability prior to national instructions being drafted and should be adjusted to meet prevailing national conditions.

Structure for the Development of a Legal Corpus on Metrology

Laws	References
Law on metrology	OIML D1, *Considerations for a law on metrology*, mentions 36 elements. Those relevant for the national law can be chosen; additional ones can be added. Regulations about units may be included instead of drafting a separate law.
Law on units of measurement	OIML D2, *Legal units of measurement*, presents a model law. It does not include elements such as realization, maintenance and dissemination of units, which can be found in other documents of the OIML and BIPM.
Decrees/regulations on technical issues (legal metrology)	**Contents and references**
Measuring instruments subject to legal control	List of types of measuring instruments and their field of use, to be updated according to national need and capacity.
Type approval, conformity assessment	OIML D19 and the EU Measuring Instruments Directive, MID, describe methods and procedures.
Performance requirements of types of measuring instruments subject to legal control	OIML Recommendations, EU MID
Verification instructions for types of measuring instruments	OIML Recommendations, EU MID, instructions of regional legal metrology organizations
Exemption from verification Re-verification periods Statistical initial verification	List of instruments ■ which are exempt under special conditions ■ for which a period other than the regular period is prescribed ■ for single-use instruments and simple instruments and materials that ensure uniform performance characteristics (e.g. glassware)

Part 1 of 2

Structure for the Development of a Legal Corpus on Metrology (continued)

Decrees/regulations on administrative issues	Contents and references
Infringements and penalties	Reference to the relevant paragraphs of the law(s) and specification of penalties
Obligations of owners, users, importers of legal instruments	Work of legal metrology agents must be enabled and supported
Maintenance and repair of legal instruments	Conditions to carry out this work; power and obligations of recognized service providers
Metrological supervision/ control	OIML D9, *Principles of metrological supervision* OIML D16, *Principles of assurance of metrological control*
Market surveillance	WELMEC Market Surveillance Guide http://www.welmec.org
Instructions	**Contents**
Addressees may be: ■ users of legal instruments ■ authorized agencies ■ verification agents ■ customs ■ others	The content may concern: ■ handling of special problems ■ clarification of ambiguities ■ updates ■ other topics
Contracts	**Contents**
With ■ designated Institutes ■ appointed service providers ■ others	Setting duties and responsibilities, and financial, administrative and other issues

Table: ©PTB/Eberhard Seiler

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In general, national regulations should not be in contradiction with international agreements such as the *Technical Barriers to Trade Agreement* (TBT) of the World Trade Organization (WTO) if this cannot be justified. An impact assessment should always be applied (see Chapter 6.5).

Details on drafting regulations and their enforcement are available in the paper mentioned below.

Technical Regulations – *Recommendations for elaboration and enforcement of technical regulations**

Contents: Technical regulations and standards from the point of view of the state and its authorities and from the point of view of users and affected parties, reference to standards in technical regulations, enforcement of technical regulations by means of effective market surveillance, written by Alex Inklaar.

The brochure is also available in French language

Règlememts Techniques – Recommandations pour leur élaboration et leur mise en application

5.2 Recommendations for National Metrology Institutes

NMIs are service providers whose main task is to calibrate measuring instruments. An NMI's management should ensure that calibrations are performed in such a way that they are to the satisfaction of the client. Requirements for this task are laid down in the international standard ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*. These requirements should be part of a quality management system and applied regardless of whether an accreditation is planned for the future. The management should ensure that staff members:

- obtain the necessary training
- are entrusted with responsibilities that are in line with the competence they have demonstrated
- can work under adequate conditions
- deliver reliable and acceptable outputs

An adequate share of the institute's budget should be allocated for human resource development and training. Chapter 6.1 contains details on this.
Insufficient work performance cannot be compensated for by means of excellent equipment or a good laboratory environment. Participation in bilateral and/or regional inter-comparison measurements is recommended for all measurands. The results reveal the measurement capabilities of the participants.

The paper mentioned below contains details on these comparison measurements.

Interlaboratory comparisons for emerging NMIs*

Contents: Necessary steps for initiating such comparisons, including workshops for discussion of results and drafting reports/publications, by A. Praba Drijarkara, and Clemens Sanetra.

Successful participation in comparison measurements creates confidence in the work of the institute. It attracts new clients and contributes to the reputation of the NMI. This is essential for the future development which requires contacts to the outside world and creation of awareness about metrology. Details are given in Chapter 6.3.

In addition to performing comparisons with other NMIs, cooperation within the region should also be used to:

- exchange experience and working documents
- perform common training events
- establish a pool of experts
- maintain traceability to the SI (without being a signatory to the Metre Convention) by having NMIs with the relevant qualification provide calibrations
- specialize to achieve better efficiency of expensive but rarely used equipment

Membership in international metrology organizations should be achieved in due time if active participation in relevant programs is possible and financial resources are available.

Leadership of an NMI requires good communication skills and an understanding of economics. In order to introduce new metrology regulations and new verification obligations, or to provide voluntary calibrations for new applications of measurements, an assessment of the impacts and cost-benefit estimations has to be made. This assessment will reduce the risk of unwanted or unexpected effects and should always be carried out with the active support of metrology experts. Details of the assessment procedure and the different steps towards a national metrology system are given in Chapter 7.
Recommendations concerning awareness-raising and customer relations can be found in Chapter 6.3 and Chapter 6.4.

5.3 Recommendations for Verification Offices

Enforcement activities

Enforcement activities entail inspecting the compliance of measuring instruments with regard to regulations. Verification offices should apply quality requirements according to ISO/IEC 17020, *General criteria for the operation of various types of bodies performing inspection*. The management must ensure that staff is competent, qualified for their jobs, and informed about their duties and powers. Details are given in Chapter 6.

Legal metrology mainly involves outdoor work. Vehicles are needed for transportation of staff and equipment. Effective organization of routes and a combination of different activities saves time and money. The work involved should not be restricted by a lack of transportation possibilities.

Checking the net content and correct labelling of prepackages is an activity of high importance for consumer protection. This work is to be carried out at the packer's site, including supermarkets if packages are prepared in the absence of buyers. Careful documentation of results is recommended in order to check whether the filling process is under the control of the packer. If infringements of regulations are high and do not decrease after regular checks, checking should take place at shorter intervals. Imported pre-packages need to be checked at customs authorities or on the premises of importers. They should be informed accordingly and asked for cooperation. Checks should focus on products of high demand.

Utility providers for water, gas and electricity usually operate test facilities that check the accuracy of their measuring instruments in order to measure the quantity delivered to their customers. Because the sale of water or gas is a commercial transaction, the relevant measuring instruments should be verified. Since utility providers may operate under ministries other than the ministry responsible for legal metrology, an agreement should be concluded between the parties concerned with the aim of ensuring "harmonized" regulations, entrusting verification authorities with the supervision of the test procedure and accepting measuring instruments as verified if they have been tested by utility providers under this regime. Such a procedure has been applied in several countries. It avoids conflicts of competence and ensures consumer protection by using the available test equipment and workforce in an optimal way.

Legal Qualification of Measuring Instruments

Measuring instruments intended for use in regulated fields have to fulfil certain quality standards. This fulfilment may take the form of a type approval or a conformity assessment. Generally, the numerous tests involved in this process make use of the same international standards. Resources for test equipment and qualified staff are neither affordable nor necessary for many countries. It is therefore recommended to benefit from systems in place:

- the certificate system for *OIML Type Evaluation of Measuring Instruments* and for *Mutual Acceptance Arrangement on OIML Type Evaluations*
- the European Union's "Certificate of Conformity" for instruments regulated by the *Directive on Measuring Instruments (MID)*
- national conformity or type approval certificates

All of these certificate types may be used to issue national approvals without repeating tests. The national legislation should therefore enable this possibility. If needed, test results can be requested from the holder of the conformity or type approval certificate.

Regional and International Cooperation

There is a tendency towards closer cooperation among neighbouring countries and towards the creation of regional markets. The latter will be facilitated by means of harmonization of technical regulations and mutual acceptance of relevant certificates. Legal metrology should contribute to and benefit from such cooperation by means of:

- harmonization of verification instructions and regulations
- common use of expensive equipment
- mutual acceptance of verifications and calibration certificates
- stronger influence on the activities of the OIML

5.4 Recommendations for Designated Institutes

Potential DIs should establish close contact to the NMI and to governmental authorities in order to discuss details of tasks, responsibilities and support. Essential issues should be set in a contract. Contact should be maintained after tasks and responsibilities have been assigned and should be used to inform potential customers about the new calibration possibilities.

5.5 Recommendations for Calibration Laboratories

Preparing a business plan is preferable for the establishment of a calibration laboratory, but should be considered mandatory if calibration is the only business activity. The NMI should be seen as a source of information and a partner for an exchange of experiences, and should be contacted with regard to:

- suitable measurement standards and calibration equipment
- calibration procedures
- calculation of measurement uncertainties
- issuing calibration certificates
- laboratory and quality requirements

Calibration laboratories should perform comparison measurements either with the NMI or with other recognized partners to prove their competence. Accreditation should take place in due time if:

- it is a requirement of customers
- it is seen as an advantage to demonstrate competence
- financial resources are available and acceptable and
- requirements of international standards can be fulfilled

An agreement with the responsible government authority should be concluded to prevent unfair competition of subsidized public laboratories.

Part VI – Recommendations Concerning General Issues

6.1 Human Resource Development and Training

Human resource development is more than training on measurements, calibrations and verifications. It should also include staff motivation, communication with clients and rules for establishing a corporate identity. These skills contribute to the quality, effectivity and efficiency of the work and the reputation of the institute. The management is responsible for the training policy of the institute and for the implementation of this policy.
It is not easy to find personnel that are fit for work in metrology as, in general, they must be trained on the job. A comparison of job requirements with job performance will reveal training needs. Staff members should have the opportunity to express and discuss their training needs with their superiors.

Training plan

A training plan should comprise:

- content of training, anticipated results, identification/preparation of work to be carried out at the home laboratory after training
- prequalification and preparation of trainees for the envisaged training
- selection of the training provider
- qualification of trainers
- duration of the training
- location and training requirements (equipment and environment)
- tests to check the knowledge gained by participants
- documentation of contents and test results
- evaluation of the training

After training, the trainees should carry out tasks in their home laboratories as planned, preferably under the supervision of an experienced person (coach). This is necessary to gain experience and self-confidence, and to demonstrate competence. Responsibilities of trained staff members should be updated and documented. If the trainee is not assigned work that corresponds to his/her training, or if the necessary equipment is not available, there will be no benefit for the laboratory.

Staff should also be trained on the general work policy of the institution with regard to:

- customer relations
- receiving, storage and handling of test and calibration items
- confidentiality
- neutrality
- impartiality
- good housekeeping
- safety and environmental issues

These skills are part of quality and accreditation requirements.

Training providers should be selected according to the training required:

- **In-house training** on basic issues as an integral part of the institute's work. Competent staff members should transfer knowledge to less experienced colleagues as part of their job. For general topics such as terminology, units, measuring principles, errors and uncertainties, documents are available free of charge from BIPM, the OIML and regional metrology organizations. The content of the training should be defined, results tested and documented.
- **Manufacturers of measuring instruments** for hands-on training to teach the correct and safe use and maintenance of the equipment in question. Such training should be included in purchasing contracts for new equipment whenever possible.
- **Accredited calibration laboratories** may be used for training on verification procedures and calculation of uncertainties for different types of instruments so that experience may be gained that can be applied to everyday work.
- **Other NMIs** can provide training on quantities for which calibrations are needed.

If unavailable within a country, training should take place abroad. As training abroad is expensive, the number of participants may be limited; furthermore, language problems may exacerbate difficulties. Conditions may also differ from those of the home laboratories with regard to

the available instrumentation and the environmental conditions. This may make it difficult for unexperienced trainees to correctly apply the knowledge they have acquired once they have returned home.

Training for Legal Metrology Staff

In addition to technical competence, knowledge of the following elements is indispensable for legal metrology staff:

- relevant legislation
- rights and duties
- interactions with clients and authorities
- methods of market surveillance

OIML Document D14, *Training and qualification of legal metrology personnel*, contains details of the structure, contents, organization and follow-up measures for training, as well as examples of curricula. This document should be used to identify and select topics for training.

Whereas experienced officers can train young staff members, experts are needed to provide training on the verification of new types of measuring instruments; these experts can be from either the instrument manufacturer or from other verification offices.
Legal aspects can be taught by ministerial staff or other legal experts. Such experienced persons should be designated part-time trainers/teachers.
Training should be organized as part of the work schedule and concluded with an examination and documentation of the result. Responsibility for training should be assigned to officers according to proven and documented competence.

6.2 Quality Management

It is good laboratory practice to implement and operate a quality management system. This is a must for NMIs and DIs if they want to be recognized internationally. The relevant international standard, also for calibration laboratories, is ISO/IEC 17025, *General requirements for testing and calibration laboratories*.

Whereas Chapter 4 of this standard (Management requirements) is compatible with the requirements of ISO/IEC 9001:2000, Chapter 5 (Technical requirements) contains additional requirements specifically for testing and calibration laboratories. Chapter 5 describes in detail requirements such as those for personnel, laboratories, equipment, handling of test and calibration items, and reporting of results.
The details of this standard should be known and understood by all staff members, at least as far as their work and responsibilities are concerned. It is the management's responsibility to introduce and implement a quality system and to check its application.
The relevant standard for verification (a form of inspection) is ISO/IEC standard 17020, *General criteria for the operation of various types of bodies performing inspection*.

6.3 Raising Awareness about the Importance of Metrology

Why should a company spend money for the calibration of its measuring instruments? Why should a government invest in the development of a national metrology system? What are the benefits of legal metrology for the public? These questions reveal the need for information and actions in order to raise awareness of the different parties involved or affected. Awareness actions should be on the agenda of the management of metrology institutions and enabled by means of sufficient resources.

Awareness actions may be addressed to:

The public: Time, temperature, weight, length and other quantities are part of our daily lives and used without recognition of the global efforts to ensure reliable measurements. A special occasion to raise awareness of metrology is World Metrology Day, celebrated on the 20th of May (the date of the signing of the Metre Convention in 1875). Posters are prepared by the BIPM every year in collaboration with NMI partners and can be downloaded free of charge from the website of the BIPM. A statement from

the NMI or the responsible authority about the current situation of metrology in the country concerned and examples of benefits for the public should be added and published by the media.
The media should be contacted not only on this special occasion but also in case important milestones are reached, such as new calibration possibilities for industry and protection of customers from fraud.

The academic and teaching community should be encouraged and supported by the management of metrology institutions in preparing and updating teaching material about metrology and the national and international metrology systems. Besides awareness-raising for students and scientists, cooperation in special fields of metrology should be explored and established.

Industrial firms should be informed about calibration possibilities and advised on questions of measurement and calibration (for details, see 6.4)

Ministries and relevant governmental bodies should be informed by the management of metrology institutions about new achievements in their fields of responsibility. Anticipated projects for expanding or changing metrological activities should start with awareness-raising by presenting facts about the existing demand and opportunities for improving the situation, including an initial (perhaps even qualitative) estimation of costs and benefits so that the necessary commitment may be obtained.

6.4 Customer Relations

Metrology institutions should seek and establish contacts to current and potential clients in order to promote their services. This can be done by means of actions such as:

- information on measurement and calibration possibilities
- advice on measurement and calibration techniques
- invitation to visit the NMI laboratories
- participation in training workshops

Contacts should also be established to current and potential partners such as

- chambers of commerce and industry
- universities and teaching institutes
- professional associations
- test laboratories
- accreditation, certification and standardization bodies

Information material such as the example mentioned below should be distributed among specific clients and kept available for other clients or other purposes.

The *Measurement Practice Improvement Guide**

This guide is designed for small and medium-sized manufacturers with the objectives of:

- improving metrology awareness
- empowering companies to instil good measurement practice
- improving quality and competitiveness
- increasing customer confidence in the company and its products

The guide leads companies through three steps: the importance of measurement; measurement within companies and measurement improvement within companies by means of a self-assessment comprising questions, a rating system and proposed actions for improvement.

Compiled and designed by the National Metrology Institute of South Africa, NMISA and the Physikalisch-Technische Bundesanstalt (PTB).

Part VII – Towards a National Metrology Policy

Is there a need for a given country to adopt a national metrology policy, or is it sufficient to follow international trends and recommendations, as far as instrumentation, specifications and regulations are concerned? All countries that have a strong economy are members of the Metre Convention and the OIML. Within these two organizations, these countries set rules and recommendations to satisfy their needs in accordance with to state-of-the-art technology. The challenge for other non-member countries is to develop a metrology system that is affordable and responds primarily to their most urgent and important needs. Of course, under such a metrology system, general principles and procedures such as traceability or uncertainty calculations must be observed, but the scope and the measuring capabilities and capacities of the system should correspond to the needs of the economy and the society of the given country. The metrology needs of a country and their impact on its economy and society must be considered. Whereas the "needs" aspect is the domain of metrology experts, the impacts are the concern of those affected by metrology, specifically in regulated areas (legal metrology). Experts on both sides have to cooperate for the national metrology system and its elements to develop successfully.

The following section focusses on the "needs" aspect. The costs of equipment, personnel, laboratory space and operation can be expressed in terms of money. Estimating cost/benefit relations and creating impact assessments are more complex activities that require input from economists and from the parties concerned (governmental authorities, entrepreneurs, enforcement agencies etc). Because of the complexity and diversity of these activities, details are not given here but in the following study, together with a collection of examples from different sources, specifically the impacts of legal metrology:

Benefit of Legal Metrology for the Economy and Society

A study for the International Committee of Legal Metrology
By John Birch A.M.; 2003, 83 pages

Another collection of references of studies and methods used to estimate cost/benefit relations and impacts is published by the BIPM.

This collection also contains examples from many countries and regions with regard to metrology and to quality infrastructure as prepared by different organizations or individuals. It is recommended to check the references which might contain examples that could facilitate impact assessment for questioning purposes.

The results of impact assessments and cost/benefit estimations are important for decisions on investments in metrology and should be a requirement of a national metrology (quality infrastructure) policy.

7.1 Steps

The following steps describe the assessment of metrology needs. If awareness of metrology is limited and needs are not articulated, initiative should be taken by the management of the NMI with the support of stakeholders (e.g. governmental authorities, chamber of commerce and industry). It is assumed that the necessary contacts have been established as described in the chapters mentioned above.

The following steps are proposed:

1. Identification of one or several sectors or fields that can make important contributions – for example, to the gross domestic product (GDP), to the enforcement of legislation, or to governmental projects
2. Identification of quantities to be measured (measurands) for activities in selected sectors or fields
3. Classification of measuring ranges and accuracies of the measurands
4. Gap analyses (what is needed vs. what is already available)
5. Estimation of resources needed
6. Searching for alternative solutions that require fewer resources

To date, metrology experts have been able to deliver the main input.

7. Ranking of needs

Step 7 requires other experts and special methods, as mentioned above. A suitable example that can be adapted to the situation in question may be helpful. Based on the results of the impact assessment and the cost/benefit estimation, a ranking of needs can be established.

8. Drafting a national metrology policy

Once results and experience have been gained step by step, a national metrology policy can be formulated, discussed and adopted by the relevant authority.

Using such a policy as a basis, a "road map" for the further development of a national metrology system can be elaborated. Details are given below and illustrated using examples.

The metrology policy should preferably be part of a wider national quality policy including regulation, standardization, accreditation and conformity assessment. This will ensure a balanced development of the national quality infrastructure.

The development of a special and fairly new part of metrology, but one that is growing in importance is described in *A guide to creating or improving a national metrology in chemistry infrastructure* by the ***Asia-Pacific Metrology Programme***. It contains information on general topics that are similar or complementary to the topics examined above.

Metrology in Chemistry*

A guide to creating or improving a national metrology in chemistry infrastructure

21 pages, prepared by Dr Laurie Beslay (principal author) with contributions of other international experts as an activity initiated by the Developing Economies' Committee of the Asia-Pacific Metrology Programme.

7.1.1 Example: Important Sectors with Regard to their Contributions to the Gross Domestic Product (GDP)

Step 1

Table 1, Part 1: Identification of important sectors with regard to their contributions to GDP and export share thereof (Remark: Data are chosen arbitrarily)

Contribution to GDP (%)	Export share thereof (%)	Sector[9]	HS section number	Link to Table 1, Part 2
7	32	a) Live animals; animal products	I	Sector a
12	57	b) Textiles and textile articles	XI	Sector b
9	96	c) Mineral products	V	Sector c
15	24	d) Vegetable products	II	Sector d
4	0.6	e) Machinery and mech. appliances	XVI	Sector e

Table 1 © PTB/Eberhard Seiler

Data on economic activities (Table 1, Part 1 and Part 2) may be readily available from official sources such as departments of statistics or the databases of chambers of commerce and industry. The *Harmonized Commodity Description and Coding System* is used as an example for the classification of a product. Since this system was developed for export statistics, national systems may be used if the export share is of no relevance.

Table 1, Part 2: Ranking of main activities of the above sectors

Sector	Main activities/products[10] (Ranking according to HS)	*Link to Tables 1 & 2*
Sector a	a1; a2; a3; a4; a5; ...	*Table 2a (not included)*
Sector b	b1; b2; b3; b4; b5; ...	*Table 2b (not included)*
Sector c	c1; c2; c3; c4; c5, ...	*Table 2c (not included)*
Sector d	d1; d2; d3; d4; d5; ...	*Table 2d (included)*
Sector e	e1; e2; e3; e4; e5	*Table 2e (not included)*

Table 2 © PTB/Eberhard Seiler

9 Classification according to Harmonized Commodity Description and Coding System **HS**

10 Instead of generic terms, arbitrary symbols are assigned to activities/products. Only Sector d, *Vegetable products*, is chosen as an example in Table 2d.

Step 2

Table 2d: Identification of metrology needs by quantities to be measured for vegetables (as indicated by producers)

Product (unprocessed)	Measurand: weight	Measurand: relative humidity
d1 Tea	X	--
d2 Coffee	X	--
d3 Maize	X	X
d4 Wheat	X	X
d5 other Vegetables	X	--

Data for quantities to be measured may be obtained from stakeholders in the sector and from (and checked by) experts.

Step 3

Table 3: Specification of measuring ranges and accuracies

Product	Measurand: weight[11]		Measurand: rel. humidity[11]	
	Range	Accuracy	Range	Accuracy
Tea	(0.1-100) kg	OIML 76-1	---	---
Coffee	(0.1-100) kg	OIML 76-1	---	---
Maize	(0.1-50,000) kg	OIML 76-1	OIML R59	OIML R59
Wheat	(0.1-50,000) kg	OIML 76-1	OIML R59	OIML R59
Other vegetables	(0.1-100) kg	OIML 76-1	---	----

For the classification of the measuring ranges and accuracies of the measurands, the relevant OIML Recommendations, ISO Standards or other international standards may be used; classification may also be obtained from experts or from actors. This information is important for choosing adequate measuring ranges and accuracies because investment costs increase substantially the greater the measuring range and accuracy are. The high costs of equipment include high costs for housing, maintenance and depreciation of the equipment, which can reach 10 % of the equipment's value per year.

11 The OIML Recommendations (R 76-1 Nonautomatic weighing instruments and R 59 Moisture meters for cereals and oilseeds) contain the necessary specifications that are not explicitly mentioned here.

Step 4

Table 4: Gap analysis for measurands of vegetable products in Table 3

Measurand	Regulation in place?	Regulation required?	Verification/calibration equipment available?	Needs
Weight	yes	yes	At verification office up to 500 kg	Verification equipment for weighbridges up to 50 t
Humidity	no	yes	no	Regulation and equipment

The gap analysis requires inputs from national metrology institutions (including legal metrology and calibration laboratories) in order to compare the available capabilities and capacities with the metrology needs of the sector under investigation. In addition, needs for regulations must be detected if verification of the measuring instruments concerned is intended.

Step 5

Table 5: Estimation of resources for needs in Table 4

Remarks: Costs are characterized by the "$" symbol and the number of this symbol. The "§" symbol characterizes the work needed on regulations and the impact of the regulation that is not included in the cost estimation.

Estimations for	Verification standards (regulation)	Reference standards	Auxiliary equipment	Transport, labs and storage	Maintenance	Manpower training
Weighbridges	$$$$ (R47)	$$$ (R47)	$$	$$$$	$$	$
Humidity regulat.	$$ (R59) §§	$ (R59)	$	$	$	$

The estimation of needed resources should be based on results of Step 4. Whereas the resources for additional equipment, personnel, laboratory space and operational costs can be expressed in terms of money and estimated by members of the institutions concerned, the assessment of non-monetary effects requires the involvement of experts (see above).

Step 6
Searching for alternative solutions requiring fewer resources

Here: Alternatives requiring fewer governmental resources for verification of high-capacity weighing instruments up to 50 t (see Table 4)

a) Authorizing a private company to perform verification under supervision of the authority

b) Having the authority or the owners of weighing instruments rent transport capacities for verification equipment (heavy weights, handling equipment)

c) Restricting procurement of heavy standard weights to 1/5 of the maximum load to be verified, applying a substitution method and obliging owners of weighbridges to provide suitable substitution material (scrap, concrete)

d) Sharing equipment with or using equipment from neighbouring countries (especially relevant for small countries)

These alternatives need to be checked with regard to their feasibility.

Step 7
Ranking of needs

The results of more than one important sector may reveal that needs exceed resources. A ranking of metrological needs (prioritization) will then be necessary. This process should include all sectors investigated and all estimations of expected benefits to and impacts on specific indicators (in some cases, these benefits cannot be expressed in monetary units). A mathematical algorithm for calculating priorities, if possible, will be sophisticated, and should not be worked out at the beginning. A ranking proposal should be prepared by a special working group composed of representatives of government and of the sectors affected. This group should define priority criteria based on facts and data in combination with common sense and undeniable arguments. The ranking proposal should be sanctioned by the relevant governmental body. The experience gained can serve as input for drafting a national metrology policy. The actions described above contribute significantly to "metrology awareness" and lay the groundwork for the development of a national metrology policy.

Step 8
Drafting a national metrology policy

This task should be initiated by the responsible governmental authority based on the experience it has gained to date. Such a policy facilitates the planning and allocation of the resources necessary for the metrology system and its institutions. It guides the work of the management of metrology institutions and allows results to be evaluated with regard to policy expectations. Policies should be periodically reviewed and updated.

7.1.2 Example: Enforcement of Regulations

Step 1
Identification of important regulated sectors

Remark: Sectors are chosen arbitrarily .

Table 1: Important regulated sectors and ranking of their metrological needs

Metrological support for enforcement classified as

Regulated sectors	Very high	High	Medium	Low
1 Road traffic control	X			
2 Consumer protection		X		
3 Environmental control		X		
4 Drugs and narcotics			X	

Table 1 © PTB/Eberhard Seiler

Step 2
Identification of measurands and measuring instruments in selected sectors

Table 2: Measuring instruments required for road traffic control

Type of measuring instrument
Speedometers, odometers, chronotachographs
Radar equipment for speed control
Exhaust emissions of vehicles
Evidential breath analyzers
Axle load meters, weighbridges

Step 3
Table 3: Classification of measuring ranges and accuracies of the measurands

Measuring instrument	Specification
Speedometers, odometers, chronotachographs	OIML R55
Radar equipment for speed control	OIML R91
Exhaust emissions of vehicles	OIML R99
Evidential breath analyzers	OIML R126
Axle load meter, weighbridges	OIML R134, R76-1, R57

Specifications are given by OIML Recommendations and should be used. They can be adapted to national conditions if necessary.

Step 4

Table 4: Gap analysis, matching needs and available capabilities

Road traffic control by means of	Regulation in place?	Regulation required?	Needs?	
			Equipment	Manpower
Speedometers, ...[12]	yes	no	yes	yes
Radar equipment	yes	no	no	no
Exhaust emissions	no	yes	yes	yes
Evidential breath analyzers ...	no	yes	yes	yes
Load meters, ...	no	yes	yes	yes

Step 5

Alternatives that require fewer resources

Efforts for drafting regulations can be reduced by using/adapting international standards and/or OIML Recommendations. Test centres should be checked concerning whether they can be approved for carrying out specific tasks under the supervision of governmental authorities.

Step 6

Estimation of resources to fill the gaps

Traffic control by means of	Needs?		
	Regulations	Equipment	Manpower
Speedometers, ...	In force	$$	$$
Radar equipment	In force	no	no
Exhaust emissions	§	$$$	$
Evidential breath analyzers	§§	$$	$
Load of vehicles	§	$$$$	$$

Costs are characterized by the $ symbol and the number of this symbol. The § symbol characterizes the work needed on regulations as an impact that is not included or is only partly included in the cost estimation.

12 Verified by authorities, installation usually obligatory for trucks and rental cars

7 Ranking

A simple method for general application cannot be proposed; for details, see previous chapters.

8 Drafting a national metrology policy (see previous chapters)

7.2 Estimation of Workload

The necessary workload for providing the service required must be considered for cost estimations. A simple method is used to obtain a rough estimate with reasonable efforts. Further details are given below.

Example: Estimation of workload for verification of non-automatic weighing instruments, OIML class II

Type of instrument:					
Non-automatic weighing instrument			OIML Class II		
Measuring range			≤ 200 g		
Field of application (Sectors)	number of actors	sample size	no. of instr. per sample	mean per actor	number per sector
Pharmaceuticals	220	10	16	1.6	358
Precious metals & stones	65	5	9	1.8	117
Food industry	24	3	4	1.3	32
Medical laboratories	70	5	5	1.0	70
Hospitals	32	4	2	0.5	16
Other laboratories	19	6	4	0.7	13
Total no. of instruments					**606**

Remark: All data used are chosen arbitrarily.

Explanations:

1. The sectors and actors will be identified as described under chapter 7.1.
2. Instruments of equal or similar performance characteristics are used to define clusters (here: non-automatic weighing instruments of accuracy class II according to OIML R76-1 with a weighing capacity of up to 200 g).
3. The number of actors in different sectors is determined using data kept by ministries, chambers of commerce, stakeholders or other sources.
4. For the estimation of the total number of instruments in use, a few representative actors are selected as a sample and the number of instruments counted in the sample is used to estimate the mean per actor.
5. The product of *number of actors* multiplied by *mean/actor* is an estimate of the instruments in use that are to be verified.

Besides the number of instruments to be verified, time for travelling/preparation and the verification frequency must also be taken into account for an estimation of workload per year and for the calculation of costs and revenues (fees).

Part VIII – Concluding Remarks

Creating and developing elements of a national metrology infrastructure is a challenging task. The above-mentioned proposals and recommendations are designed to stimulate and support efforts in this direction. They also show that parties outside metrology institutions should provide their expertise and input for analyzing impacts on the economy and on society. Furthermore, working relations must be maintained on a regional and on an international level. All these activities require resources which may prove to be a burden for weak and small economies. Investments should therefore be carefully planned and should include an adequate part for qualified and motivated personnel who are able to produce the expected benefits and create ideas for shaping the future of the national metrology.

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