National Metrological Infrastructure

JOINT GUIDE 1

APLMF
ASIA-PACIFIC LEGAL METROLOGY FORUM

ASIA PACIFIC METROLOGY PROGRAMME
APMP

PTB
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Braunschweig und Berlin

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Contents

Foreword

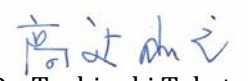
This is the second edition of a guide on metrology for the APEC region. The first edition was drafted by the APEC/APLMF Small Working Group on an APLMF Guide to developing a National Infrastructure for Legal Metrology. This was one of the activities supported by the APEC/APLMF project *APEC/APLMF Seminars and Training Courses in Legal Metrology (CTI25/2007T)*. In June 2-3, 2008, three small working groups were held in PR China to develop three metrology guides that are available on the APLMF website.

Of these, Guide 1 provided an overview of metrology generally, legal metrology in particular and linkages between metrology and legal metrology. Its aim was not to duplicate the content of international documents that are freely available on the internet but to make it more accessible to developing economies.

From 2014 to 2017, the German Federal Ministry for Economic Cooperation and Development commissioned the International Technical Cooperation of PTB (Physikalisch Technische Bundesanstalt) to implement a project to support the regional cooperation in the area of metrology in Asia, which was also referred to as "MEDEA: Metrology – Enabling Developing Economies in Asia". During this time frame, actions were taken to improve the ability of the regional metrology specialist networks in Asia – the Asia Pacific Metrology Programme (APMP) and the Asia-Pacific Legal Metrology Forum (APLMF) – to promote the metrological systems of their economies.

With the advent of the MEDEA project, the decision was taken to prepare a second edition of the guide with an expanded scope that included both metrology and legal metrology, to take account of recent international developments in both forms of metrology and to provide guidance for the development of a national metrology infrastructure. It also makes references to up-to-date documents that will be useful for the developing economies to chart their own national metrological infrastructure including its legislation that will be consistent with international best practices. Two case studies have been included to highlight particular implementation.

The second edition has been prepared by a small working group comprising representatives from the Asia-Pacific Legal Metrology Forum (APLMF) and the Asia Pacific Metrology Programme (APMP) under the auspices of the MEDEA project. The topics covered in this latest edition should be useful to directors and managers who are responsible for the planning and implementation of their respective national metrology infrastructure.



Dr. Toshiyuki Takatsuji
APMP Chairperson

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Glossary

APEC	Asia-Pacific Economic Cooperation
APLAC	Asia Pacific Laboratory Accreditation Cooperation
APLMF	Asia-Pacific Legal Metrology Forum
APMP	Asia Pacific Metrology Programme
BIPM	International Bureau of Weights and Measures
CC	(CIPM) Consultative Committee(s)
CGPM	General Conference on Weights and Measures
CIPM	International Committee for Weights and Measures
CPR	(OIML MAA) Committee of Participation Review
DEC	(APMP) Developing Economies' Committee
DoMC	(OIML MAA) Declaration of Mutual Confidence
GUM	Guide to the Expression of Uncertainty in Measurement
IAF	International Accreditation Forum
IEC	International Electrotechnical Commission
IFCC	International Federation of Clinical Chemistry and Laboratory Medicine
ILAC	International Laboratory Accreditation Cooperation
IUPAC	International Union of Pure and Applied Chemistry
IUPAP	International Union of Pure and Applied Physics
ISO	International Organization for Standardization
JCGM	Joint Committee for Guides in Metrology
JCRB	Joint Committee of the Regional Metrology Organizations and the BIPM
KC	(CIPM) Key Comparison(s)
KCDB	(CIPM) Key Comparison Database
MAA	(OIML) Mutual Acceptance Arrangement
MEDEA	(PTB) Metrology – Enabling Developing Economies in Asia
MRA	(CIPM) Mutual Recognition Arrangement
NLMI	National Legal Metrology Institute
NMI	National Metrology Institute
OIML	International Organization of Legal Metrology
PAC	Pacific Accreditation Cooperation
PASC	Pacific Area Standards Congress
RMO	Regional Metrology Organization
RLMO	Regional Legal Metrology Organization
SI	International System of Units (*Système International d'Unités*)
VIM	International Vocabulary of Metrology (3rd Edition: 2012)
VIML	International Vocabulary of Terms in Legal Metrology (OIML V1: 2013)
WELMEC	European Cooperation in Legal Metrology

1 Introduction

This guide is designed to provide an overview of elements of a national metrological infrastructure, with attention devoted to the situation of member economies in the Asia-Pacific region. Its starting point is a consideration of the international activities that underpin national metrology systems and of the organizations that carry out those activities. Two international organizations are directly involved in metrology; the first was founded under the Metre Convention, with its administrative organ the International Bureau of Weights and Measures (BIPM), while the second was founded under the Convention Establishing an International Organization of Legal Metrology (OIML), with the International Bureau of Legal Metrology (BIML)[1] as its administrative organ. These organizations have already developed extensive documentation that describes their activities, some of which is listed in the bibliography of this guide. There are other international organizations that play an important role in national quality infrastructures; however, as they are outside the scope of this guide, they will be mentioned but not dealt with in the same detail.

The publications under the two conventions are important for member states and developing economies in improving their metrology infrastructure. To this end, this guide aims to make these publications more accessible by providing linkages to appropriate documents and providing the reader with information as to where more detailed information may be obtained.

Since the first edition of the guide, there have been several developments in metrology and legal metrology that impact member economies; it is therefore necessary to include mention of these developments in the second edition.
Furthermore, some of the publications mentioned above have been revised to cover much of the material in the first edition, necessitating a revision of that material.

This guide includes some comments on:

- National quality infrastructure (NQI) – metrology, standards, accreditation, testing and quality systems that are mutually supportive;
- International traceability and the CIPM MRA;
- Mutual acceptance arrangement (OIML MAA) for type approval;
- National metrological infrastructure (metrological traceability[2], legal traceability and metrological control systems);
- Legislation for metrology, legal metrology and trade measurement;
- Further aspects of legal metrology including enforcement strategies. It should be understood that this document is a guide rather than an attempt to elaborate all aspects of an ideal national metrology infrastructure. Accordingly, where detailed material is readily available elsewhere it is referenced and generally only a brief summary included in this document. The exceptions are where the need to repeatedly access references would be an onerous imposition on the reader.

[1] The term convention has been used in both these agreements. The terms convention and treaty are generic terms and largely synonymous. However, the term convention is used for agreements that are open to participation by the international community as a whole. Nevertheless, the term treaty is sometimes used as a shorthand (viz. Treaty of the Metre and OIML Treaty).

[2] Note that metrological traceability embraces both legal traceability and general traceability within an economy.

2 Terminology

This section lists some principal definitions that will be used throughout this document. Extensive lists of definitions have been compiled as vocabularies for metrology by the JCGM (the VIM) and for legal metrology by the OIML (the VIML). Both are conveniently available on the OIML website under publications/vocabularies.

Conformity assessment *(VIML A1, see VIML for notes)*
Demonstration that specified requirements relating to a product, process, system, person or body are fulfilled.

Designated institutes (DIs)
In many countries, the NMI delegates responsibilities for a physical quantity to one or more designated institutes, which, like the NMI, operate at the top of the national metrology system for this particular physical quantity. These institutes play a crucial role in complementing the fields of activities of the NMI and contribute expertise in metrological areas not covered by the NMI.

Legal metrology *(VIML 1.01, see VIML for notes)*
The practice and process of applying statutory and regulatory structure and enforcement to metrology.

Legal metrology control (VIML 2.01*, see VIML for notes)*
The whole of legal metrology activities.

Metrology *(VIM 2.2, see VIM for notes)*
The science of measurement and its application.

Metrological traceability *(VIM 2.41, see VIM for notes)*
The property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty.

Measurement standard (VIM 5.1)
Realization of the definition of a given quantity, with stated quantity value and associated measurement uncertainty used as a reference.

National legal metrology institutes (NLMIs)
Bodies with national responsibility for legal metrology.

National metrology institutes (NMIs)
Bodies with the responsibility of maintaining the national measurement standards and disseminating the SI units nationally (i.e. they provide metrological traceability).

National measurement standard *(VIM 5.3)*
Measurement standard recognized by a national authority to serve in a state or economy as the basis for assigning quantity values to other measurement standards for the kind of quantity concerned.

Type approval *(VIML 2.05, see VIML for notes)*
Decision of legal relevance, based on the review of the type evaluation report, that the type of a measuring instrument complies with the relevant statutory requirements and results in the issuance of the type approval certificate.

Verification *(VIM 2.44, see VIM for notes)*
Provision of objective evidence that a given item fulfils specified requirements.

Verification of a measuring instrument *(VIML 2.09)*
Conformity assessment procedure (other than type evaluation) which results in the affixing of a verification mark and/or issuing of a verification certificate. *Note:* See also OIML V2-200: 2012, 2.44

3 National quality infrastructure (NQI)

3.1 Introduction

The establishment of a coherent and effective national quality infrastructure in accordance with internationally agreed practices is an important step towards ensuring that products and services fulfil the quality requirements demanded by international markets. An NQI is a tool for competitiveness, trade, and social well-being. Quality is the result of the integration and coordination of a series of activities in interrelated areas of metrology, standardization, accreditation and conformity assessment. This includes both public and private institutions, and the regulatory framework within which they operate. An economy should decide the proper level of development in each of the areas. The components of an NQI, based on Guasch et al (2007), are elaborated as follows:

National standards bodies

National standards bodies are organizations that bring together experts from industry, research, consumer protection and the public sector to develop market-oriented standards and specifications that promote global trade and innovations, assure efficiency and quality, and help protect the environment and society as a whole. The standards may be voluntary, in which case there is no obligation to use them, or mandatory, in which case they are enforced by governmental authorities.

Certification bodies

Certification consists of the provision of assurance that a product, service, system, process, or material conforms to one or more standards or specifications. Although there exist some self-certification schemes, certification is usually conducted by a third party that is independent of the supplier or purchaser. Certification bodies are usually commercial for- profit or non-profit entities, although for some types of measurement instruments there is no commercial interest to offer conformity assessment. Therefore, there are sometimes public sector organizations providing conformity assessment of measurement instruments. Product certification can involve various degrees of confidence, depending on the referenced standard. In the simplest case, a prototype or a product from a preproduction run is tested and inspected against a specific standard. More vigilant tests involve surveillance of the manufacturing process, random testing of samples, batch testing, and 100 percent testing, where every product is examined individually. Process certification involves an assessment of the variables that have an impact on a firm's output. For example, certification of a firm's manufacturing process quality to a certain standard may be based on an audit verifying the quality of the components or materials, equipment, equipment calibration and maintenance, the training and experience of the personnel, and the environmental conditions.

Testing laboratories

Testing involves determining the characteristics or performance of a product or process according to a specified procedure. Testing is often a requirement for certification, but it is also used for a variety of purposes such as product design and research, quality control, satisfying contractual agreements, satisfying regulatory requirements, buyer protection and information, medical health and services, or product repair and maintenance. Testing laboratories come in all forms and sizes. They are usually private sector entities when they concern voluntary standards, but they can be found in both the public and private sectors when they test against mandatory requirements.

Inspection bodies

Inspection can be conducted alone or in combination with testing to determine whether a product or process meets certain requirements. The inspection of products is usually conducted by visual means or by using simple instruments. In contrast to test results, the outcome of the inspection process depends highly on the subjective judgment and experience of the inspector. Like testing laboratories, inspection bodies can be either private or public sector entities, depending on their role in enforcing mandatory requirements.

Calibration laboratories

Calibration involves determining the relationship between an instrument's input and the magnitude or response of its output. It also serves to establish the accuracy and precision of a measuring instrument. Calibration must be performed using equipment of known measurement uncertainty. Commercial calibration laboratories compete for final industrial users, or what is called the secondary calibration market. Those users do not themselves offer commercial calibration services.

The national metrology institute

The role of a national metrology institute (NMI) is to establish a country's national measurement system; to maintain, develop, and disseminate measurement standards for basic and other units of measurement such as derived units of measurement; and to diffuse metrological expertise to the economy. Countries often have a single NMI, but can have several designated institutes, each responsible for a distinct area of measurement. It is common for NMIs to be public sector organizations, but they can also be private sector organizations. NMIs operate in the primary calibration market: they disseminate measurement standards by providing calibration services to independent calibration laboratories and to other organizations responsible for regulations and standards. When their industrial measurements are traceable to the NMI through an unbroken chain of comparisons, firms are able to guarantee the accuracy and precision of their calibration instruments, process control instruments, and quality control instruments.

The national legal metrology institute

The national legal metrology institute (NLMI) may be a separate body or combined with the NMI. Its primary function is to ensure measurements made for regulatory purposes are fit for purpose. Originally, NLMIs were concerned with technical

specifications and control of measuring instruments used for trade. Currently they are responsible for controls over a broader range of regulatory measurements (including traffic, health and environmental measurements) and for ensuring that appropriate legislation is in place for legal traceability of measurements to facilitate the conversion of measurement data into evidence acceptable in a court of law. Accordingly, in close cooperation with the NMI, the NLMI contributes to metrology policy development and the maintenance and modernization of metrology legislation.

The national accreditation body.

Accreditation is defined as the procedure by which an authoritative body gives formal recognition that an organization or person is competent to carry out specific tasks. Accreditation is sought on a voluntary basis as proof of competence in a given area. Most countries have a single national accreditation body responsible for all areas of accreditation. It can be either a public or a private not-for-profit organization. Accreditation provides certification and inspection bodies, as well as testing and calibration laboratories, with a means to signal that they are conducting their work according to appropriate standards and that they are able to provide reliable services. The accreditation body evaluates the personnel and supporting management system of the accreditation candidates and, when relevant, can request practical tests for laboratories. These tests take the form of proficiency testing schemes through which the measurement results of different laboratories are compared. Accreditation is usually valid for a few years after initial assessment, during which time the accredited organization is subject to regular surveillance. A more detailed discussion of the elements of an NQI can be found in the EURAMET Guide titled "Metrology – in Short". A schematic representation of the interaction of the components of an NQI is shown in Fig. 1.

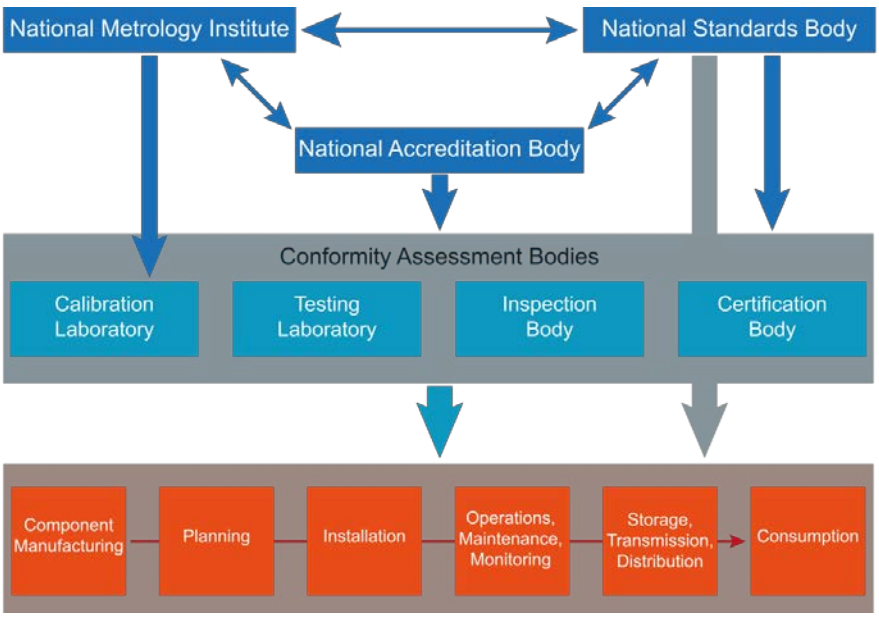

Fig. 1. The national quality infrastructure

In the diagram above, the interaction between the principal bodies (the national metrology

institute[3], the national standards bureau and the national accreditation body) is fundamental. The standards bureau writes standards that define requirements for particular attributes of products that industry and/or the community require. In a complementary manner, the NMI disseminates measurement capabilities to allow conformity assessment bodies to meet those requirements with measurements that are fit for purpose. Finally, the national accreditation body ensures that the various conformity assessment bodies are competent to carry out their functions. In practice, however, the situation is never this simple. Very often, the NMI and/or the national accreditation body will write particular standards (in the case of the NMI, these standards may be in the form of legislation) while other bodies in the economy may also write standards in particular areas such as health and undertake forms of accreditation. Thus, in the above diagram, apart from the NMI, the other principal bodies could more accurately be considered principal functions of a national quality infrastructure. In its day-to-day activities, an economy not only exports goods and services but also imports them from its trading partners. To this end, the NQI also plays an important role in protecting the domestic market from importing substandard goods and services. This role is difficult to achieve for a developing economy whose NQI is not strong or well-established. Members of the World Trade Organization (WTO) benefit from compliance with the WTO Agreement on Technical Barriers to Trade (TBT) and the Application of Sanitary and Phytosanitary Measures. The NQI facilitates adequate compliance with these agreements.

In fact, the ultimate beneficiary of the NQI is the entire population of an economy, because more competitive companies, greater integration into the world trading system, and improved consumer and environmental protection have a positive impact on the labour market, income levels and quality of life.

One challenge for the government of every economy is to coordinate contributions from the elements of the NQI in order to enhance the development of the economy and promote local innovation. Further information on the role of the NQI can be found in the publication titled "The Answer to the Global Quality Challenge: A National Quality Infrastructure" (Sanetra, C & Marbán, M).

3.2 The role of metrology in the NQI

The very brief definition of metrology in the VIM says very little about its scope. The BIPM website provides more context, noting that it applies to any field of science and technology at any level of uncertainty. It points out that metrology supports the network of services that the community largely takes for granted and whose impact can be noticed in navigation, health and trade measurement services, such as delivery of fuel to customers at a service station. This is exemplified in Fig. 1, where it can be seen that the metrology services provided by the NMI complement and support all of the activities undertaken by the other bodies in the NQI.

The sum total of these measurement activities is known as the national metrology system (NMS) or the national metrology infrastructure[4]. It is the collective infrastructure of national facilities, expertise, knowledge and research, and is also a legal framework for reliable, consistent and internationally recognized measurement. The infrastructure encompasses essential elements of both the public and private sectors.

The national metrology institute (NMI) is responsible for the strategic development of the

[3] The diagram's box "National Metrology Institute" represents NMI and NLMI at the same time.

[4] Metrology is defined as the science of measurement. This makes the terms national metrology system and national metrology infrastructure rather esoteric. Accordingly, in dealing with non-metrologists such as government officials, it may be preferable to use the word measurement (viz. national measurement system).

national metrology system and for implementing the regulatory framework as mandated by the respective national laws. The NMI operates specialized measurement laboratories. Their metrologists maintain the national standards and facilities and make them available to users by means of knowledge transfer and a wide range of measurement services. They also develop new measurement techniques and services in response to requirements from industry and from the public sector.

One of the difficulties faced by NMIs is the need to predict the future demand for measurement services and to convince governments that the expense associated with these services is justified. EURAMET Guide 10 on the operation of NMIs reflects the experience of European NMIs, which could be very useful to their counterparts in the Asia- Pacific region.

The NMS can be subdivided into:

a) ***Scientific metrology*** (or simply metrology), the development and organization of the highest level of measurement standards;

b) ***Legal metrology***, the assurance of correctness of measurements where these have an influence on the transparency of trade, on law enforcement, on health, on safety and on the environment;

c) ***Industrial metrology***, the satisfactory functioning of measurement instruments used in industry, production and testing.

One of the important activities of the NQI, and in particular of scientific and industrial metrology, is to underpin innovation. Fig. 2 shows the innovation cycle proposed by Tassey (1993). Tassey has used the term *infratechnologies* to describe:

> *"[…]a varied set of "technical tools" that includes measurement and test methods, artefacts such as standard reference materials that allow these methods to be used efficiently, scientific and engineering databases, process models and the technical basis for both physical and functional interfaces between components of systems technologies such as factory automation and communications."*

The box labelled "infratechnologies" in Fig. 2 could be extended to comprise the elements of the NQI, namely metrology, standards, accreditation, certification, inspection, conformity assessment and training. These elements, and metrology in particular, interact with the science base as technology and measurement techniques evolve. Developed economies usually provide the science base, infratechnologies and generic technologies upon which companies can develop their proprietary technologies.

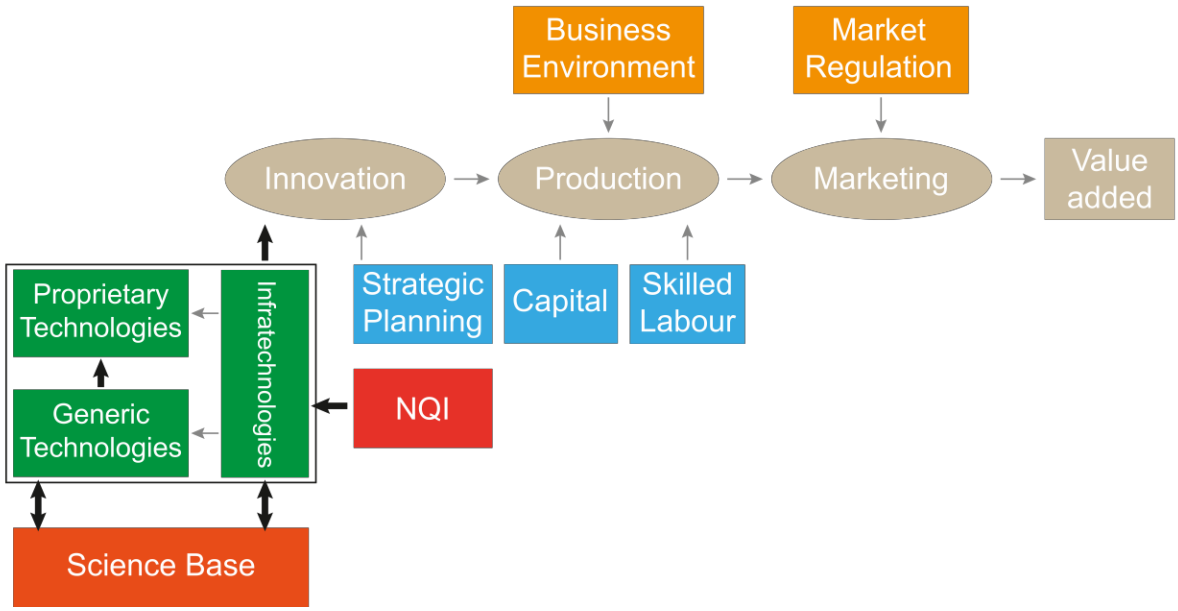

Fig. 2. The innovation cycle

3.3 Legal metrology

The international vocabulary of terms in legal metrology (VIML) defines legal metrology as the "practice and process of applying statutory and regulatory structure and enforcement to metrology", including the following notes.

Note 1 The scope of legal metrology may be different from country to country.

Note 2 Legal metrology includes:

- Setting up legal requirements (e.g. for measurement instruments);
- Control/conformity assessment of regulated products and regulated activities;
- Supervision of regulated products and of regulated activities; and
- Providing the necessary infrastructure for the traceability of regulated measurements and measuring instruments to the SI or national standards.

Note 3 There are also regulations outside the area of legal metrology pertaining to the accuracy and correctness of measurement methods.

Legal metrology is underpinned by scientific metrology and embraces measurements and measuring instruments that are:

- Used for trade (transactions); or
- Used for regulatory purposes.

In many economies, measurements that are used for trade are legally defined as measurements that determine the consideration of a transaction or a tax. These include measurements of the amount of product in a transaction as well as measurements of the quality parameters of a product (such as grain protein and grain moisture measurements) that determine the unit price and, thus, the consideration of the transaction. An example of a measurement used to levy a tax is a measurement for the purpose of determining the payment of a fuel excise.

Examples of regulatory measurements include traffic measurements of speed and breath alcohol content, measurements used to monitor the environment, and occupational health and safety measurements. Legal metrology aims to provide legal certainty for, and community confidence in, measurements, thereby minimizing transaction and disputation costs and avoiding market failure. In this way, legal metrology facilitates both national and international trade. In summary, legal metrology concerns practical measurements that are performed and used on a daily basis in the community; these measurements rely on the legal metrology infrastructure (metrological control systems and legal traceability systems) that is embodied in the legislation of the economy. The place of Legal Metrology in a National Quality Infrastructure is described by Mason in the OIML Bulletin (April 2017).

3.4 Economic benefits of metrology

In their work titled "The Economics of Metrology", Roberston and Swanepoel (2015) review the literature on the economic rationale for measurement and standards, on the economic benefits of metrology and on the associated costs. They summarize the findings of a number of international studies that have analysed the economic impact of measurement standards. They note that the benefit-cost ratios from these studies are very high.

The economic benefits of metrology are also discussed in the Birch report (Birch 2003) under the following headings:

- Reduced disputation and transaction costs;
- Consumer protection;
- Level playing field for commerce;
- Effective stock control;
- Control of fraud;
- Full collection of government excise and taxes based on measurement;
- Full national benefit for commodity exports;
- Support of global trade in measuring instruments;
- Increased compliance;
- Sound evidential basis for the measurements;
- Benefit/cost of metrology regulation can be greater than other policy options;
- OIML International Recommendations provide a level playing field for the sale of measuring instruments appropriate for particular applications; and
- OIML International Recommendations support global regulatory agreements.

In summary, the economic benefits arise principally because metrology aims to remove the asymmetry of information between the trading parties, thereby providing greater transparency in transactions.

3.5 Social benefits of metrology

The Birch Report points out that the benefits of metrology go beyond mere economic benefits. While the economic savings associated with the social benefits can be very difficult to quantify, the savings associated with reduced injury and death can be very large indeed. The report discusses the social benefits of metrology under the following headings:

- Support of a Civil Society;
- Technological Education;

- Reduction of deaths and injuries from accidents;
- Improvement in the natural environment; and
- Improved health from standardization of measurement and testing.

For society, metrology provides confidence in measurement results in areas related to health, safety, environmental monitoring, food safety, protection of consumer interests and law enforcement.

Since the publication of the first edition of this guide, OIML document D1 has been revised and now includes an elaboration of the benefits of metrology under "Part 2 – Rationale".

4 International metrology bodies

4.1 Introduction

In November 2011, BIPM, the OIML, ILAC and ISO signed a joint declaration on metrological traceability. This was a development of a 2006 tripartite agreement among BIPM, the OIML and ILAC. The declaration sets out agreed principles to be followed in order to achieve metrological traceability of measurements; this element is one of several that establish international confidence in the equivalence of measurements. These principles enable legislators, regulators and exporters/importers to take advantage of an international set of mutually supportive systems that demonstrate equivalence of measurements and can therefore significantly reduce technical barriers to trade (TBTs) that might result from lack of equivalence.

The declaration also contains brief statements on the roles of the various signatories that may be read in conjunction with the descriptions of the organizations in the remainder of this chapter.

The relationships between the various bodies that contribute to international metrology, standards and conformance for the APEC region are shown in Fig. 3. Similar relationships exist for bodies in other regions such as Africa, the Americas and Europe.

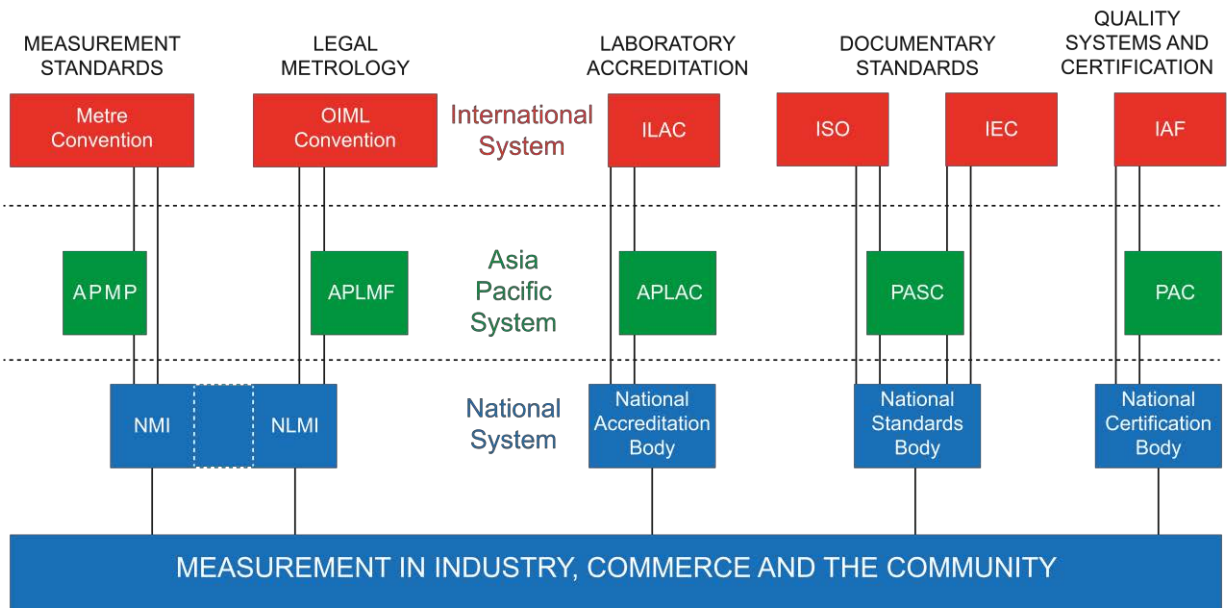

Fig. 3. APEC standards and conformance system

Note: the dotted line between the national metrology institute and the national legal metrology institute indicates that, in some economies, these functions may be combined into a single institute.

4.2 The Metre Convention

The Metre Convention (Convention du Mètre) is a treaty that created an intergovernmental organization under the authority of the General Conference on Weights and Measures (CGPM), with the International Committee for Weights and Measures (CIPM) as an executive body and the International Bureau of Weights and Measures (BIPM) as its administrative and scientific organ. The organs of the Metre Convention act in matters of world metrology, particularly concerning the demand for measurement standards of ever-increasing accuracy, range and diversity, and the need to demonstrate equivalence between national measurement standards.

4.2.1 Structures (CGPM, CIPM, BIPM)

The General Conference on Weights and Measures (*Conférence Générale des Poids et Mesures*, CGPM) is made up of delegates of the governments of the Member States and observers from the Associates of the CGPM. The CGPM meets in Paris, usually once every four years. It receives the report of the International Committee for Weights and Measures (CIPM) on work accomplished; it discusses and examines the arrangements required to ensure the propagation and improvement of the International System of Units (SI); it endorses the results of new fundamental metrological determinations and various scientific resolutions of international scope; and it decides all major issues concerning the organization and development of the BIPM.

4.2.2 Mission and role of the Metre Convention

The mission of the Metre Convention is to ensure and promote the global comparability of measurements, including providing a coherent international system of units for:

- Scientific discovery and innovation;
- Industrial manufacturing and international trade; and
- Sustaining the quality of life and the global environment.

The BIPM, under the responsibility of the International Committee for Weights and Measures (CIPM) publishes the "SI brochure", which is an essential reference document for the application and correct use of the SI units.

4.2.3 Consultative Committees

The CIPM has set up a number of Consultative Committees to advise it on matters related to various fields of metrology. The Consultative Committees are responsible for coordinating the international work carried out in their respective fields and for proposing recommendations to the CIPM concerning units.
The Consultative Committees in 2016 are:

1. The Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV);
2. The Consultative Committee for Electricity and Magnetism (CCEM);
3. The Consultative Committee for Length (CCL);
4. The Consultative Committee for Mass and Related Quantities (CCM);
5. The Consultative Committee for Photometry and Radiometry (CCPR);
6. The Consultative Committee for Amount of Substance: Metrology in Chemistry (CCQM);

7. The Consultative Committee for Ionizing Radiation (CCRI);
8. The Consultative Committee for Thermometry (CCT);
9. The Consultative Committee for Time and Frequency (CCTF);
10. The Consultative Committee for Units (CCU).

4.2.4 Activities

Full details of the activities run under the Metre Convention can be found on the website hosted by BIPM; however, its principal activities are the definition of a set of international units of measurement (UoM – the SI), and disseminating those units of measurement through the CIPM MRA. The role of the CIPM MRA is highlighted in the above-mentioned 2011 joint declaration on metrological traceability (6.1). Fig. 4 below shows how the national metrology institutes (NMIs) and designated institutes (DIs) participate in key comparisons (KCs) of the CIPM MRA. The CIPM MRA is central to the international metrology system, and the comparisons shown in Fig. 4 form the technical basis for this mutual recognition. Further information on the MRA can be found in the foreword and introduction to PTB Guide 9: Inter-Laboratory Comparisons for Emerging National Metrology Institutes (Drijarkara 2012).

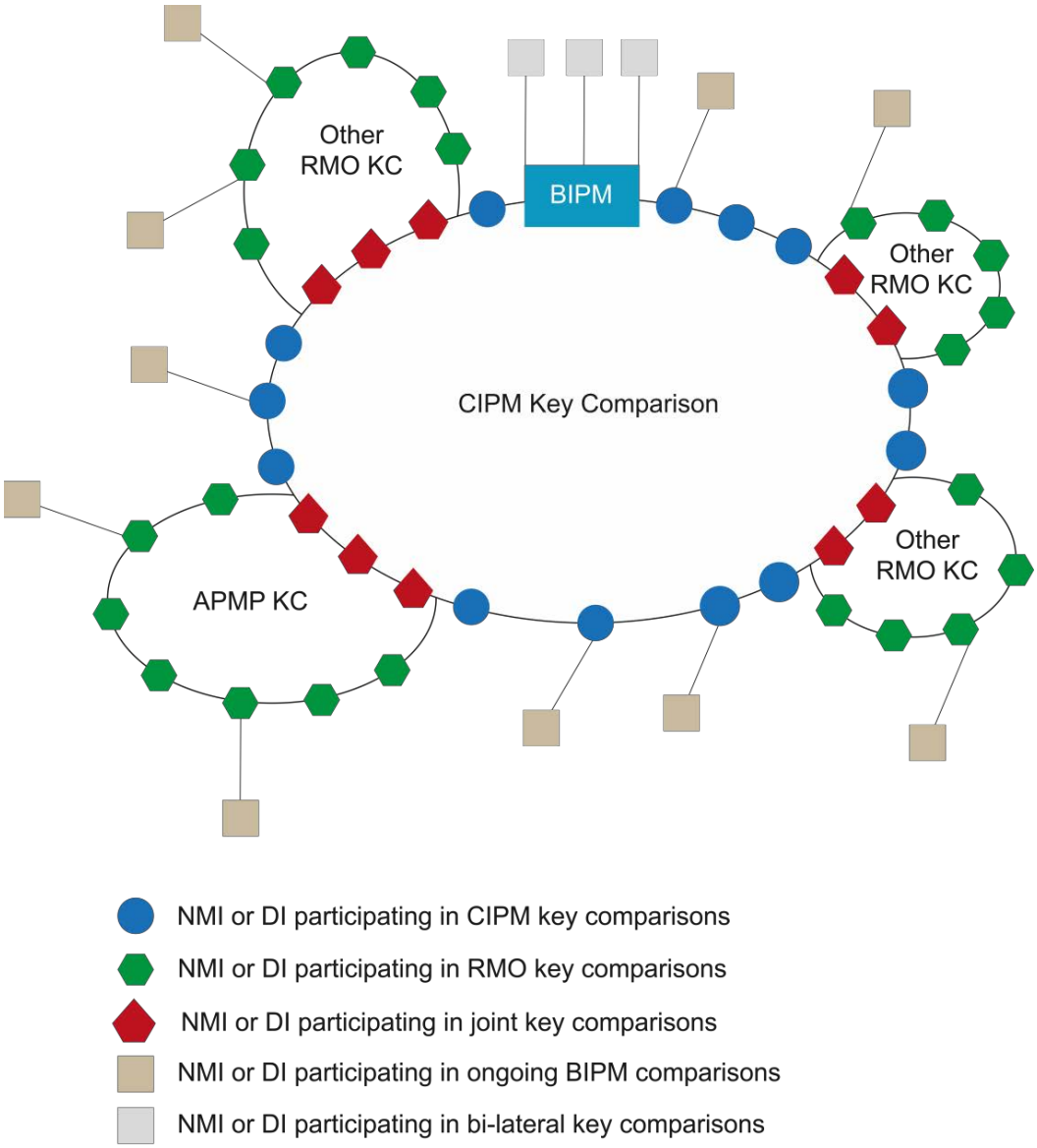

Fig. 4. The CIPM MRA

In Fig. 4, APMP is the RMO for the Asia-Pacific region; several of its NMIs and DIs participate in joint key comparisons, BIPM key comparisons, RMO key comparisons and bilateral key comparisons. PTB Q5 Guide on how to register calibration and measurement capabilities provides further information on this topic.

Further information on designated institutes may be found in the BIPM publication titled "Designated Institutes in the CIPM MR A", obtainable from the BIPM website. The CIPM MRA is somewhat more complex than shown above; full details can be found on the BIPM website under the heading "International comparisons". The technical basis of the CIPM MRA is the set of results obtained over the course of time in scientific key comparisons carried out by the Consultative Committees of the CIPM, the BIPM and the regional metrology organizations (RMOs), and published by the BIPM and maintained in the CIPM MRA key comparison database (KCDB). Further information on mutual recognition in the context of the CIPM MRA may be found in the PTB document titled "Towards Mutual recognition of Metrological Competence". CIPM has delegated to its consultative committees the responsibility for arranging comparisons for each of the quantities it chooses in its field of expertise.

4.3 The OIML Convention

The OIML Convention established the International Organization of Legal Metrology (OIML) and provides the constitution for that organization. The International Organization of Legal Metrology (OIML) is an intergovernmental treaty organization whose membership includes Member States that participate actively in technical activities and Corresponding Members that join the OIML as observers.

The OIML promotes the global harmonization of legal metrology laws and procedures and provides its members with guidance with respect to their national legislation, including the principle that measurements used for trade and regulatory purposes should be made using measurement standards that are legally traceable to the SI. It has developed a worldwide technical infrastructure that provides its members with metrological guidelines for the alignment of national requirements concerning the manufacture and use of regulated measuring instruments. This infrastructure supports the legal traceability of measurements used in regulated activities such as trade, traffic control, healthcare, and monitoring of the environment.

4.3.1 Structures (International Conference on Legal Metrology, CIML and BIML)

The International Conference on Legal Metrology is the highest decision-making body in the OIML. It is composed of representatives of the Member States. In principle, each delegation should include a representative of the national legal metrology institute of each Member State.

The OIML website contains details of the Convention, the International Committee of Legal Metrology (CIML), and the International Bureau of Legal Metrology (BIML).

4.3.2 Mission and role of the OIML

"The mission of the OIML is to enable economies to put in place effective legal metrology infrastructures that are mutually compatible and internationally recognized, for all areas for which governments take responsibility, such as those which facilitate trade, establish mutual confidence and harmonize the level of consumer protection worldwide." (OIML Strategy, 2011) In implementing its mission, the OIML:

- Develops model regulations, standards and related documents for use by legal metrology authorities and industry;

- Provides mutual recognition systems which reduce trade barriers and costs in a global market;

- Represents the interests of the legal metrology community within international organizations and forums concerned with metrology, standardization, testing, certification and accreditation;

- Promotes and facilitates the exchange of knowledge and competencies within the legal metrology community worldwide;

- Cooperates with other metrology bodies to raise awareness of the contribution that a sound legal metrology infrastructure can make to a modern economy.

4.3.3 OIML technical work

Project Groups (PG) within the OIML's Technical Committees (TC) and Subcommittees (SC) develop the Organization's technical publications. There are eighteen TCs, each with a number of subcommittees and project groups. The details of the structure and rules for operation are contained in OIML document B 6-1, Directives for OIML Technical Work.

4.3.4 Activities

The principal activities of the OIML are the writing of technical standards and the promotion of the acceptance of type evaluation test reports in order to avoid duplication of approval testing. In addition, the OIML runs seminars and training sessions, and supports expert studies and reports. It provides an annual "round table" forum for LMOs to meet and share information.

The OIML is an "international standard-setting body" in the sense of the World Trade Organization's Technical Barriers to Trade (TBT) Agreement. OIML publications should therefore be applied, when appropriate, by all signatories of the TBT Agreement when developing technical regulations, in application of Article 2.4 of that Agreement:

> *"Where technical regulations are required and relevant international standards exist or their completion is imminent, Members shall use them, or the relevant parts of them, as a basis for their technical regulations except when such international standards or relevant parts would be an ineffective or inappropriate means for the fulfilment of the legitimate objectives pursued, for instance because of fundamental climatic or geographical factors or fundamental technological problems."*

OIML publications may be accessed on the OIML website. These publications comprise Recommendations (R), Documents (D), Vocabularies (V), Basic Publications (B), Expert Reports (E), Guides (G) and Seminar Reports (S). OIML Recommendations are standards in the form of model regulations intended to be incorporated into the laws of Member States. Thus, they can only be recommendations to Member States.

4.3.5 Harmonization and the MAA

The OIML has introduced a Mutual Acceptance Arrangement (MAA) within the scope of which Declarations of Mutual Confidence (DoMCs) can be signed for particular categories of instruments; under these DoMCs, signatories declare their mutual confidence in the type evaluation reports that underpin certificates of conformity with an OIML Recommendation. Participants may issue test reports (issuing participants) or utilize them (utilizing participants). Participants who issue OIML Certificates under the MAA are required to have their quality

system evaluated either by accreditation bodies or by peer review.

Fig. 5 illustrates the relationships within a DoMC for a particular category of measuring instrument.

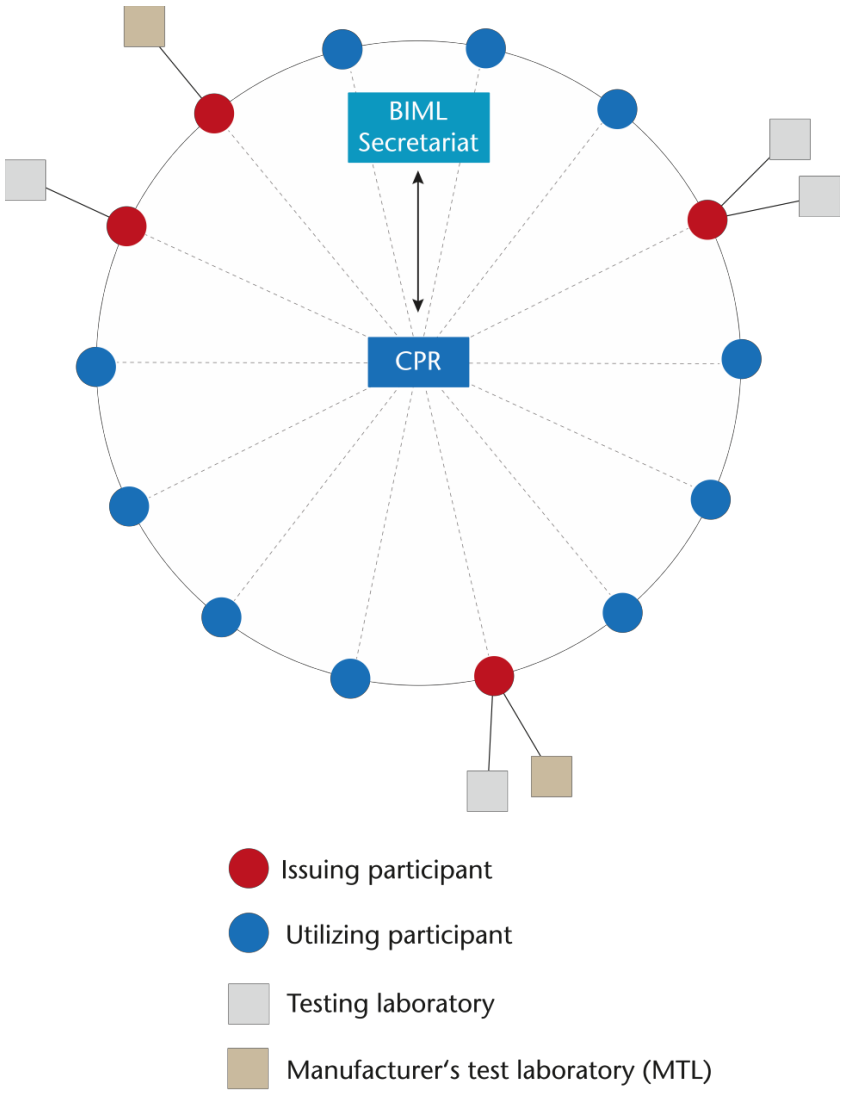

Fig. 5. The OIML MAA

The MAA establishes the rules for a framework wherein Participants agree to accept and utilize OIML MAA Type Evaluation Reports for type approval or recognition in their national or regional metrological controls, when associated with an OIML MAA Certificate. As a general principle, participation in a Declaration of Mutual Confidence (DoMC) commits the Participants to accept and use MAA Evaluation Reports issued by Issuing Participants. The Committee of Participation Review (CPR) coordinates administration of the DoMC. Full details of the framework are contained in OIML publication B 10.

Within the MAA, a formal and mandatory evaluation process for those laboratories that undertake tests and examinations reinforces confidence in test and examination results included in the OIML MAA Type Evaluation Report. Recent amendments to OIML publication B 10 provide for the acceptance of reports from manufacturer's test laboratories (MTLs) on a

voluntary basis. The Basic Certificate System of the OIML is described in publication B 3 and is another earlier mechanism for the voluntary acceptance of test results. OIML B 3 and OIML B 10 are complementary publications.

In 2013, the CIML decided to review the MAA in order to improve the acceptance of OIML Certificates, to improve the management and structure of the CPR, to open the system for more measuring instrument categories, and to make it more attractive for more participants. At its 50th meeting in 2015, the CIML adopted the key principles for a new, single "OIML Certification System" (OIML-CS), which will merge the existing Basic and MAA Systems. A project group has been tasked with developing and submitting a respective framework document for approval at the 51st CIML meeting in 2016. It is intended that the new OIML-CS will become effective from 1 January 2018. The existing Basic and MAA Certification Systems will be operated until the new system becomes operational.

5 Other International quality infrastructure bodies

5.1 Standardization

Written standards and measurements have complementary roles in technology and manufacturing. Standards contain specifications for a particular physical quantity to be measured; these specifications are necessary in order to apply the most cost-effective measurement technology. Furthermore, the standardization process has permeated quality management systems with a corresponding impact on the measurement process itself.

ISO

The International Organization for Standardization (ISO) is the largest international publisher of voluntary standards and is responsible for the publication of a range of written standards and guides that apply to the manufacture and testing of various products. The range of standards is vast, covering such areas as quality management, environmental management, energy management, food safety, information security and occupational health and safety, among many others. Of particular importance to metrology are the following:

- ISO 9000 family of standards for quality management and quality assurance;
- ISO 14000 family of environmental management standards which can be implemented in any type of organization in either public or private sectors;
- ISO/IEC 17000 specifies general terms and definitions relating to conformity assessment, including the accreditation of conformity assessment bodies, and to the use of conformity assessment to facilitate trade;
- ISO/IEC 17011 Conformity assessment – Requirements for accreditation bodies accrediting conformity assessment bodies;
- ISO/IEC 17021 contains principles and requirements for the competence, consistency and impartiality of bodies providing audit and certification of all types of management systems;
- ISO/IEC 17025 General requirements for the competence of testing and

calibration laboratories is the main ISO standard used by testing and calibration laboratories. ISO/IEC 17025 is used in peer reviews (e.g. in the framework of the OIML MAA and the CIPM MRA), by accreditation bodies and other organizations in order to assure technical competence of laboratories.

- ISO/IEC 17040:2005 Conformity assessment – General Requirements for peer assessment of conformity assessment bodies and accreditation bodies. (*Note* See also OIML V2-200:2012, 2.44)

- ISO/IEC 17065 Conformity assessment – Requirements for bodies certifying products, processes and services;

- ISO/DIS 17034 specifies general requirements in accordance with which a reference material producer has to demonstrate that it operates if it is to be recognized as competent to carry out the production of reference materials. It is intended for use by reference material producers in the development and implementation of their management system for quality, administrative and technical operations. Reference material customers, regulatory authorities and accreditation bodies may also use it in confirming and recognizing the competence of reference material producers;

- ISO Guide 68 Arrangements for the recognition and acceptance of conformity assessment results.

IEC

The **International Electrotechnical Commission** (IEC) is a non-profit, non- governmental international standards organization that prepares and publishes its International Standards for all electrical, electronic and related technologies – collectively known as "electrotechnology". IEC standards cover a vast range of technologies from power generation, transmission and distribution to home appliances and office equipment, semiconductors, fibre optics, batteries, solar energy, nanotechnology and marine energy, as well as many others. The IEC also manages four global conformity assessment systems that certify whether equipment, systems or components conform to its International Standards.
The IEC charter embraces all electrotechnologies, including energy production and distribution, electronics, magnetics and electromagnetics, electroacoustics, multimedia, telecommunication and medical technology, as well as associated general disciplines such as terminology and symbols, electromagnetic compatibility (by its Advisory Committee on Electromagnetic Compatibility, ACEC), measurement and performance, dependability, design and development, safety, and the environment. The IEC cooperates closely with ISO and the International Telecommunication Union (ITU).

JCGM

In 1997, the **Joint Committee for Guides in Metrology** (JCGM) was formed by the seven International Organizations that had prepared the original versions of the *Guide to the expression of uncertainty in measurement (GUM)* and the *International vocabulary of basic and general terms in metrology (VIM)*.

The current membership of JCGM comprises eight organizations:

- The two intergovernmental organizations concerned with metrology, BIPM and the OIML, since 1997;
- The two principal standardization organizations, ISO and the IEC, since 1997;

- Three international unions, IFCC, IUPAC and IUPAP, since 1997; and
- One international accreditation organization, ILAC, since 2005.

The JCGM operates through two working groups: JCGM-WG1, with responsibility for the GUM, and JCGM-WG2, with responsibility for the VIM.

5.1.4. Other standardization bodies

Various other international standards organizations exist in special areas, for example:

CISPR – International Special Committee on Radio Interference. This is an offshoot of the IEC that writes standards for radio interference and compatibility.

CODEX Alimentarius or the food code has become the global reference point for consumers, food producers and processors, national food control agencies and the international food trade. The code has had an enormous impact on the approach of food producers and processors, as well as on the awareness of the end users – the consumers. Its influence extends to every continent, and its contribution to the protection of public health and fair practices in the food trade is immeasurable. CODEX was founded in 1958.

5.2 Accreditation

ILAC

The **International Laboratory Accreditation Cooperation** (ILAC) aims to promote the mutual recognition of test and calibration certificates issued by laboratories accredited by national accreditation bodies in accordance with internationally accepted standards for technical competence. ILAC members are peer evaluated and become signatories to the ILAC Mutual Recognition Arrangement (MRA). The ultimate aim of the Arrangement is enhanced international acceptance by industry as well as by governments of the tests and calibrations of accredited laboratories. Standards such as ISO/IEC 17025 require metrological traceability of measurement results to primary realizations of the SI (often referred to as national measurement standards), while in other, similar standards, traceability should either be to the SI or to other agreed international references where SI traceability is not, or not yet, possible.

IAF

The **International Accreditation Forum** (IAF) is the world association of Conformity Assessment Accreditation Bodies and other bodies interested in conformity assessment in the fields of management systems, products, services, personnel and other similar programmes of conformity assessment. Its mission is to develop a single worldwide programme of conformity assessment that reduces risk for businesses and their customers by assuring them that accredited certificates may be relied upon. Accreditation assures users of the competence and impartiality of the body accredited. The primary purpose of IAF is to establish a **Multilateral Recognition Arrangement** (MLA) among its accreditation body members in order to contribute to the freedom of world trade by eliminating technical barriers.

The MLA allows the accreditations and certificates that are issued by the certification/registration bodies that, in turn, are accredited by members of the MLA to be recognized by the other members of the MLA. The objective is that the MLA will cover all accreditation bodies in all countries in the world, thus eliminating the need for suppliers of products or services to be certified in each country where they sell their products or services (i.e., certified once, accepted everywhere). Membership in the MLA is based on peer evaluation of each applicant for membership and continued surveillance of each member to ensure and

confirm that all the members of the MLA operate their accreditation programs and implement the MLA Guidelines consistently and in an equivalent way.

6 APEC Specialist Regional Bodies

All five of the regional bodies listed below are recognized by APEC's Subcommittee on Standards and Conformance (SCSC) as Specialist Regional Bodies (SRBs).

6.1 Metrology – APMP

The Asia Pacific Metrology Programme (APMP) is a grouping of national metrology institutes (NMIs) from the Asia-Pacific region operating within the framework of the APMP Memorandum of Understanding. It is engaged in improving regional metrological capability by sharing expertise and exchanging technical services among Member laboratories. APMP is also a regional metrology organization (RMO) recognized by the International Committee for Weights and Measures (CIPM) for the purpose of worldwide mutual recognition of measurement standards and of calibration and measurement certificates. APMP's mission is to promote and support a measurement infrastructure in the Asia-Pacific region that facilitates international trade, improves industrial efficiency and competitiveness, ensures equity in the marketplace, and enhances the quality of life and the environment.

APMP has two annual week-long meetings: The Week of General Assembly and Related Activities, and the Mid-Year Meetings Week. APMP operates a range of technical committees, the details of which can be found on the APMP website. In addition to the technical committees, APMP also operates the Developing Economies Committee (DEC) that looks after the metrology interests of the developing NMIs such as training, hosting workshops and staff competency. The DEC is allocated an annual budget to implement its activities. It also makes use of the funding provided by agencies such as PTB Technical Cooperation (Germany).

6.2 Legal Metrology – APLMF

The Asia-Pacific Legal Metrology Forum (APLMF) is a grouping of legal metrology authorities in the member economies of the Asia-Pacific Economic Cooperation (APEC) and other economies on the Pacific Rim. APLMF's objectives are the development of legal metrological infrastructure and promotion of free and open trade in the region through the harmonization and removal of technical or administrative barriers to trade. It operates under the APLMF Memorandum of Understanding (MoU).

The objectives of APLMF are: to promote the coordination and integrity of legal metrology activities and services in order to achieve greater harmony of measurement and testing within the Asia-Pacific Region; and to build mutual confidence among its members. Specific objectives of APLMF are set out in the MOU.

APLMF operates a range of working groups, the details of which can be found on the APLMF website. A major activity of APLMF is training to improve infrastructure, skills and knowledge in legal metrology/trade measurement and to promote harmonization in the region, thereby removing barriers to trade.

6.3 Accreditation – APLAC

The Asia Pacific Laboratory Accreditation Cooperation (APLAC) is a regional cooperation among accreditation bodies in the Asia-Pacific region. Initially, these accreditation bodies

accredited testing and calibration laboratories. Increasingly, however, they now also accredit inspection bodies and reference material producers, and provide other related services.

Part of APLAC's role is to provide a forum for the exchange of information among its members on accreditation and related issues, with the aim of continual improvement of accreditation services offered in the region. Through the APLAC Mutual Recognition Arrangement (MRA), APLAC facilitates the acceptance by governments and industry in each economy of reports and certificates from facilities accredited by signatories to the MRA. APLAC is an ILAC-recognized region, and most signatories to the APLAC MRA are also members of ILAC (signatories to the ILAC MRA).

APLAC undertakes various activities to support its member accreditation bodies, including:

- Organizing proficiency testing and measurement audit activities in the region;
- Conducting workshops and training courses on various accreditation issues;
- Preparing appropriate promotional material; and
- Developing technical guidance documents.

6.4 Certification – PAC

The Pacific Accreditation Cooperation (PAC) is an association of accreditation bodies and other interested parties whose objective is to facilitate trade and commerce among economies in the Asia-Pacific region. Its ultimate objective is the creation of a global system that grants international recognition for certification or registration of management systems, products, services, personnel and other programmes of conformity assessment.

PAC promotes the international acceptance of accreditations granted by its accreditation body members based on the equivalence of their accreditation programmes. Further information can be obtained from the PAC website.

6.5 Standardization – PASC

The Pacific Area Standards Congress (PASC) is a forum of standardization organizations from the Pacific area that meets to discuss international standardization issues. Countries on the Pacific Rim have agreed on the need for a forum in order to:

- Strengthen the international standardization programmes of the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO), and to improve the ability of Pacific Rim standards organizations to participate in these programmes effectively;

- Improve the quality and capacity of standardization in economies of the region;

- Support free trade within the region and with economies in other regions;

- Support improvement of economic efficiency and development of the region through the promotion of standardization; and

- Interact with other bodies that represent elements of the standardization technical infrastructure, as well as industry, consumers and government.

The members of PASC have adopted by consensus a number of important resolutions concerning international standardization, the work of the IEC and ISO, and communication and interrelationships among the members. PASC is concerned not only with standards preparation but also with conformance to standards.

6.6 Metrology bodies in other regions

Europe has a number of metrology and legal metrology bodies. One of the more active regional metrology bodies of relevance to developing economies is the European Cooperation in Legal Metrology (WELMEC). WELMEC has several working groups on various aspects of legal metrology and trade measurement, and has published a number of guides useful to developing economies.

In the USA, there are also several bodies relevant to metrology:

- National Conference on Weights and Measures (NCWM);
- National Conference of Standards Laboratories International (NCSLI)
- Two accreditation bodies (A2LA, NVLAP); and
- Two main standards-writing bodies (ANSI, IEEE).

7 National metrology infrastructure

7.1 Overview

The 2012 edition of OIML D1 notes that no two economies will have the same set of governmental arrangements, legislative systems or administrative circumstances. Nevertheless, it provides a description of the various considerations needed to establish a national measurement infrastructure at a sufficient level of abstraction that it can be applied by most economies. It is strongly recommended that OIML D1 be studied in conjunction with this document, Guide 1. In addition, a paper by Seiler provides a discussion of the considerations that underpin the development of a national metrology infrastructure.

The remainder of the present guide complements OIML D1 but places emphasis on areas of metrology that are of particular interest to developing economies. The aim of a metrology infrastructure is to support community confidence in measurements for regulation, trade and manufacturing. It does this by ensuring that measurements are fit for purpose, thereby reducing transaction costs and, in the case of measurements made for trade, minimizing the risk of market failure.

The infrastructure comprises metrological control elements and traceability elements, as shown in Fig. 6. The traceability elements are crucial for measurements made throughout industry and the community, and are disseminated to ensure that these measurements are what they purport to be (viz. of sufficient accuracy for their intended purpose). The traceability elements also underpin the legal control provisions that are designed to ensure that measurements made for a legal purpose (viz. for regulation, trade or contractual purposes) are within the maximum permissible errors prescribed for that purpose.

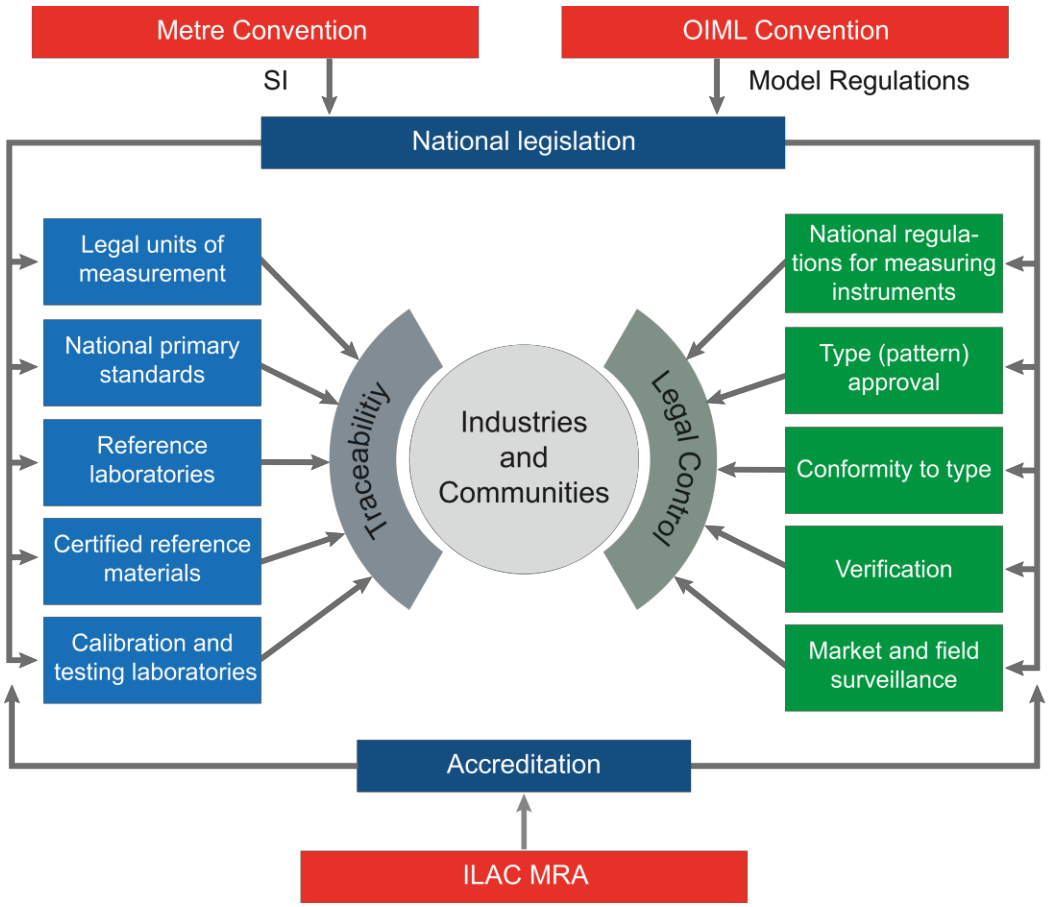

Fig. 6. National metrology infrastructure

While many developing economies in the Asia-Pacific region have internationally recognized calibration and measurement capabilities (CMCs) for physical measurements, only very few have CMCs in chemistry. APMP, in conjunction with PTB, has prepared a "Guide to Creating or Improving a National Metrology in Chemistry Infrastructure" (the MIC Guide) that sets out the steps to be taken in this respect. An important aspect of metrology in chemistry is the preparation and certification of reference materials. ISO Guides 30 to 35 are relevant in this regard. In addition, APLMF has published a guide to "The selection and use of certified reference materials for legal metrological control in food safety & agricultural products" that is available on the APLMF website.

7.2 Traceability infrastructure

7.2.1 National legal units of measurement

Each economy needs to prescribe national legal units of measurement for those quantities (such as mass, length and time) that are (or are likely to be) used in the economy. The units specified should be based on the SI units of measurement with possible additions that may be used in certain circumstances to facilitate international trade and/or for customary purposes. The use of the units must not cause ambiguity in measurements, in trading or in the labelling of prepackages. It is usual to prescribe the SI units of measurement as the national legal units of measurement together with a list of prefixes and rules for combining units with prefixes and other units of measurement.

7.2.2 National standards of measurement

In order to realize the national legal units of measurement, each economy prescribes that national primary and other measurement standards are to be maintained by a nominated organization, the NMI. Often, it is not possible for a single organization within an economy to maintain the primary standards of measurement for all legal units of measurement. For example, the primary standards of measurement for ionizing radiation are often maintained by a separate organization that is appointed by a legislative mechanism as a designated institute (DI). Some economies may need to make legal provisions to recognize overseas standards of measurement as the means of providing legal traceability for some of their national legal units of measurement.

7.2.3 Hierarchy of standards and metrological traceability

Fig. 7 shows the traceability pyramid for an economy. The NMI (and DIs) may maintain primary and secondary measurement standards for the economy and provide calibrations at appropriate levels of uncertainty (accuracy) for calibration laboratories. These calibration laboratories (government or private), in turn, provide lower-accuracy calibrations and measurements to industry and the community. OIML R 111 comprises a hierarchy of measurement standards for standards of weight and contains the principal physical characteristics and metrological requirements for weights that are used:

- For the verification of weighing instruments;
- For the verification of weights of a lower class of accuracy; and
- With weighing instruments.

It is important to be able to calculate the measurement uncertainty associated with a calibration or verification. The calculation techniques are described in the above-mentioned *Guide to the expression of uncertainty in measurement* (GUM). Most NMIs run training courses on the application of the GUM.

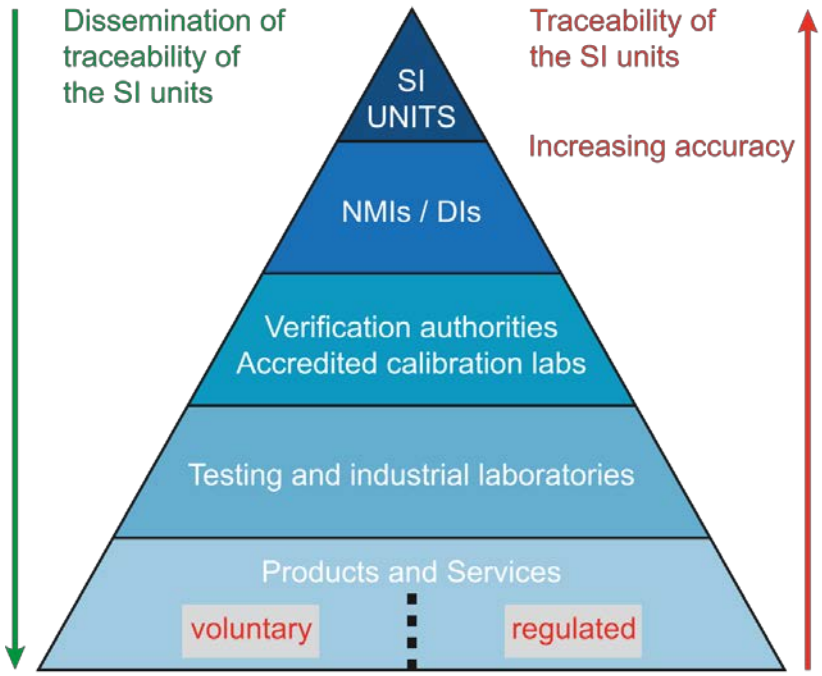

Fig. 7. Traceability pyramid

7.3 Voluntary sector

In the voluntary sector, calibration laboratories provide metrological traceability to industry and the community. Contractual requirements or market forces will determine the need for such traceable calibrations and the level of the associated measurement uncertainty. Calibration certificates should include the period of validity of the calibration under normal conditions of use. Recalibration is the responsibility of the user and will depend on the extent of use and the maintenance of the standard or instrument. The calibration laboratories may or may not be accredited by a third-party accreditation body that is a signatory of the ILAC MRA. Once again, contractual requirements or market forces will determine the need for such third-party accreditation[5].

7.4 Regulated sector

Calibration laboratories may be legally appointed to verify standards of measurement, reference materials or measuring instruments that support the instruments used for legal purposes. In this case, they are usually referred to as verifying authorities. The purpose of verification certificates issued by a verifying authority is to convert measurement results into evidence that would be accepted in a court of law without the need to be supported by a string of expert witnesses, thereby reducing the cost of providing measurement evidence. It should be noted that, depending on the legal system, calibration certificates that do not have legal backing may be regarded as hearsay evidence and, where challenged, ruled as inadmissible in a court of law. Where court systems are adversarial and any evidence is likely to be challenged on technicalities, legal traceability is an advantage[6].

Accordingly, legal traceability, as demonstrated by means of verification certificates, may be advantageous in regulatory areas that are subject to court proceedings, such as traffic measurements, environmental measurements, health measurements and measurements that form the basis of significant monetary contracts (e.g. government defence contracts). It is necessary to seek legal advice from the appropriate government authority (attorney general or equivalent) about the form of legislative provisions necessary to ensure the acceptance of evidentiary certificates in your economy before developing measurement legislation.

Legal traceability pathways

The measurement legislation of an economy should prescribe pathways by which measurements made for trade or regulatory purposes may be shown to be legally traceable to the national primary standards of measurement or primary methods, thereby facilitating the provision of evidence in courts of law. The national measurement legislation should provide that measurements made for legal purposes are made by means of reference to, comparison with, or derivation from the relevant national standards or references through established pathways. These pathways include appropriate primary methods of measurement, primary and other traceable standards of measurement, certified reference materials (CRMs) and verified measuring instruments[7]. Fig. 8 shows the latter three pathways.

The national legislation would normally require the NMI or DI to realize the legal units of measurement and maintain the national primary measurement standards for each quantity. Linkage of these standards to the SI takes place by means of the CIPM MRA.

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[5] See the paper by Seiler in regard to the voluntary sector.

[6] Note that, where there is compelling alternative evidence, even the evidence provided by certificates of verification may also be challenged, in which case it is necessary to call appropriate witnesses to provide evidence on the chain of traceability.

[7] Note that these verified measuring instruments are not in use for trade but are used to provide measurement traceability. For this reason, they are sometimes referred to as certified measuring instruments to make this distinction.

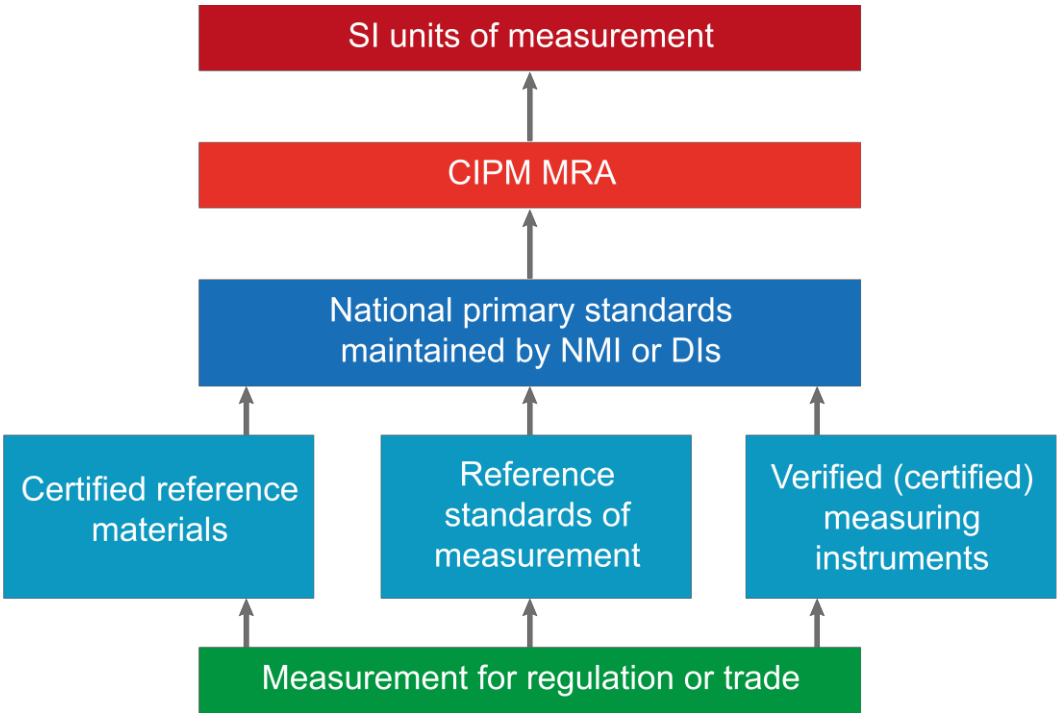

Fig. 8. Legal traceability pathways

The production, selection and use of CRMs should be in accordance with relevant OIML, ISO or other international or regional guidelines. In general, CRMs should be produced by national metrology institutes or other organizations that are accredited for CRM production. Where traceability is established by the use of certified measuring instruments, the instruments should be certified by a competent body that has third-party accreditation by an ILAC signatory. All of the verifying or certifying bodies should demonstrate competence by means of participation in proficiency testing programs.

7.5 Metrological supervision[8]

7.5.1 National regulations for measuring instruments

OIML model regulations (known as recommendations) are concerned with the tolerances referred to as maximum permissible errors (MPEs), within which legal measuring instruments should operate, even when subjected to influence factors such as temperature and humidity variations, line-borne and radiated electromagnetic interference and power supply variations. The intention is to replicate the real-life environment within which measuring instruments will need to operate and provide measurements within acceptable tolerances. OIML Document D1, "Considerations for a Law on Metrology", describes the types of measurement regulation that each economy will need to prescribe. In particular, each economy will need to prescribe national regulations for measuring instruments used for trade or regulation. These regulations should be based on OIML Recommendations (R documents), which are freely available for download from the OIML website. Signatories to the OIML Convention are morally obliged to adopt OIML recommendations as their national requirements for measuring instruments used for trade or regulatory purposes. These recommendations are now being developed in three parts. The first part contains the specifications for the particular class of measuring instrument. The second

[8] The VIML defines this as an "activity of legal metrological control to check the observance of metrology laws and regulations".

part contains the tests to be undertaken to check that the design of a measuring instrument meets the specifications. The aim of this part is to minimize the risk of misinterpretation of the specifications. The third part contains the test report format. The aim of this part is to minimize the risk of misinterpretation of the test results themselves and to facilitate the acceptance of test results between economies.

The regulations of a given economy also need to prescribe the power of the administering authority to undertake testing for type approval, and upon satisfactory examination to grant approval for measuring instrument designs and to issue certification of approved types of measuring instruments. Traditionally, each administrating authority undertakes type approval testing. However, not all authorities have access to the necessary test facilities, and approval test results may be accepted from an issuing authority under the OIML MAA or from another economy with which there is a mutual recognition arrangement.

7.5.2 Type approval or conformity of type to national requirements

The aim of type (or pattern) approval is to test the quality of a measuring instrument design to ensure that an instrument of that design will retain its calibration for an appropriate period of time under conditions of use that are likely to be encountered in normal operation.

The national regulations should make it an offence for a person to falsely represent that a class of measuring instrument has been approved or to falsely represent that a measuring instrument is in accordance with an approved type.

7.5.3 Conformity to type (CTT) of production instruments and systems

The aim of the legal metrology infrastructure and of the associated type approval process is not only to ensure that an instrument that is submitted for testing by a manufacturer can meet the national regulations for a particular type of measuring instrument, but also to ensure that all production instruments of an approved type meet the regulations.

However, there have been many cases reported where production instruments have not conformed to the approved type. In these situations, the application of legal sanctions can be a blunt instrument that can lead to undesirable consequences. For example, the application of a fine or the withdrawal of an approval may have the unintended consequence of putting the supplier (manufacturer or importer) out of business, thereby preventing the supplier from remedying the situation. As a consequence, traders who purchased instruments on the basis of the supplier's approval would not be able to use the instrument, nor would they be able to seek restitution. A preferred approach is to introduce a programme of surveillance that would minimize the risk of non-conformance. This programme could be based on the quality system of the manufacturer's production system and could include a light sampling of production instruments to ensure that the quality of manufacture is being maintained. It would not be necessary to carry out full type-approval testing of sampled instruments. It would instead be sufficient to test only the influence factors where the original approval testing revealed that non-conformity was most likely. The OIML has formed a technical subcommittee, TC3/SC6, to develop a proposal for premarket surveillance activities.

7.5.4 Initial and subsequent verification[9]

The aim of verification is to ensure that a measuring instrument used for legal purposes (regulation or trade) operates within the specified maximum permissible errors prior to its initial usage and throughout its lifetime. A prerequisite for verification is type approval; this ensures that a measuring instrument of that type can retain its calibration between verifications.

[9] Note that the definition of verification of a measuring instrument is given in Chapter 4,Terminology

The legal metrology infrastructure of an economy should make provision for initial and subsequent verification of measuring instruments. While every measuring instrument that is used in legal metrology should be verified at or prior to installation, subsequent verification may be periodic, based on feedback from marketplace surveillance, or by means of appropriate sampling practices.

Instruments that comply with statutory requirements and are verified should be suitably marked to indicate their status. The marking must be removed in the event that the instrument is found to be unsatisfactory for providing reliable measurement results, or needs repairing or reverification.

Verification is usually carried out by trade measurement inspectors, legal metrology officers or private organizations licensed for this activity. With the notable exception of utility meters, initial verification is usually undertaken prior to or at installation. The introduction of electronic instruments has meant that, at installation or in-field, it is no longer feasible for trade measurement verifiers to carry out an evaluation of pattern conformity. They can usually only check the documentation or the marking of the instrument and carry out a visual inspection and a calibration check.

7.5.5 Market surveillance

The legal metrology infrastructure of an economy should make provision to monitor the performance of measuring instruments in use in order to ascertain that they continue to comply with regulatory requirements during service, and in order to detect deviations at an early stage so that the instrument can be removed from service. Instruments that have been relocated, repaired, or that have been subjected to extreme external influence conditions, should undergo re-verification before being used. Subject to the responsibilities stipulated in relevant regulations, verification or reverification of instruments should be carried out by government inspectors or licensed verifiers. A licensed verifier is typically an organization with recognized expertise and a quality system that is subject to an established framework of accreditation, third party review or auditing. The organizations may be legal metrology institutes, private organizations or even the manufacturers/installers of the instruments.

The auditing or review of the competence of licensed verifiers should be carried out at regular intervals, and an audit schedule should be formulated by the auditing/reviewing body. Such a schedule should be harmonized with relevant international practices or recommendations. The auditing/reviewing body should keep a list of competent verifiers of instruments for public reference.

Generally, the legal metrology framework of an economy should include a provision for random auditing and verification of the measuring instruments used by traders to ensure that the instruments to be used comply with regulatory requirements. There should be appropriate corrective actions on the part of a trader in the event that a non-conformance is identified, and follow-up action should be taken by the auditor(s) to ensure compliance before the measuring instruments are approved for use in the market. To ensure transparency, the authority and terms of reference of the authorized government organization should be defined in legislation. The law-enforcing body should maintain a database of verifications and audits and keep track of the performance of the measuring instruments of traders. Good practice would be to strengthen monitoring measures for traders with frequent instances of unsatisfactory performance. The auditing body may consider making recommendations for traders to minimize failures of their measuring instruments.

The legal metrology framework should include the provision that measuring instruments and prepackages in the market are regularly audited and checked by authorized personnel to

prevent market failure. Measuring instruments should perform the expected functions as marked on the instrument or declared by the user. Similarly, prepackages must comply with their labelled descriptions. The legal framework should include offences for any misrepresentation or false labelling, and appropriate sanctions should be taken against such transgressions (illegal actions).

In the case of utility meters, the large number of meters installed means that individual auditing of meters is not practicable. However, a system should be put in place to ensure that utility meters in use in the field conform to their prescribed performance. The legal metrology framework should include a provision for in-field statistical sampling and auditing of utility meters. Such auditing should be carried out by authorized organizations on a planned schedule and should cover all utility meters controlled under the regulations. Auditing should also be carried out under special circumstances, such as when complaints are filed or when the performance of the meters is in doubt.

In general, the testing laboratory responsible for verifying utility meters should be accredited under a quality system that is in compliance with ISO/IEC 17025. Measurement standards used for verifying instruments should be traceable to the national legal units of measurement with appropriate uncertainties.

7.6 Metrological control of prepackages

Packed goods are known in legal metrology as prepackages because they are effectively pre-measured, and because their label contains information about the amount of content. Metrological control of prepackages is needed in order to prescribe and control labelling requirements and the means of determining package quantities.

In October 2006, the OIML held a seminar on the role of prepackaging in international trade. Whereas in the past, most international food trade was in bulk commodities, today, the majority of international trade is in prepackaged goods.

As a result, OIML Technical Committee TC6 has been revising OIML R 79 on labelling and OIML R 87 on the quantity of products in prepackages. At the time of writing (2016), these projects have been completed; OIML R 79 is available on the OIML website, while OIML R 87 is awaiting final approval. TC6 was also asked to develop a new guide document on a certification system for prepackages.

7.6.1 Methods for determining the quantity contained in prepackages

There are several methods for determining the quantity of product in a prepackage. The two most common are the average quantity system (AQS) and the minimum (or marked) quantity system.

- The minimum quantity system ensures that there is no shortfall in the quantity contained in packages of the same kind and stated quantity. This method, and variants of it, may be used by inspectors in the marketplace to check for short-measure offences.

- The AQS is an internationally agreed method for determining the measurement of packaged goods that have a constant nominal content. It provides for the confirmation of goods sold by weight, measure or number by utilizing sampling standards based on those developed by the OIML and contained in recommendation OIML R 87. It is intended to be used in large-

scale packaging plants where goods (e.g. breakfast cereals) are packed in the same quantity in large numbers, but could also be applied to random-quantity packages.

7.6.2 International or regional mark

Sometimes, both of the above systems are used together in order to allow inspectors to check in retail stores and still allow packers to use the AQS for large-scale production including exports. However, if an inspector checks a single package packed under the AQS in a supermarket, the package may still fail the minimum-quantity requirements. Therefore, where the two systems are used together, there should be a mark to indicate which system is being used. In Europe, an "e-mark" is used to indicate that the AQS has been used and that such packages can only be checked statistically at the packing house or a storage facility where a sufficient number of packages is available.

7.6.3 Unit pricing and standardized package sizes

In the past, most economies had standardized sizes for prepackaged goods. This allowed consumers to make meaningful price comparisons. However, following the introduction of unit pricing on supermarket shelves, this is no longer necessary. This type of unit pricing should not be confused with the unit price that must be marked on random-weight packages (for example, in supermarket delicatessens).

7.6.4 Assessment of type approval laboratories

The OIML advises that national authorities that carry out type approvals should be accredited by an ILAC MRA signatory to ISO/IEC 17065. OIML B 10 also provides for type-approval laboratories to be peer assessed outside of the ILAC MRA. This is done in order to provide confidence among stakeholders that the full approval procedure has been carried out according to the national regulations.

Where a laboratory carries out type-approval testing on behalf of an issuing authority, it is recommended that the laboratory be accredited by an ILAC MRA signatory to ISO/IEC 17025 in order to provide confidence in the test results. In this regard, the OIML Mutual Acceptance Arrangement (MAA) requires that issuing authorities are peer assessed by means of accreditation or otherwise according to ISO/IEC 17025 in order to provide confidence in the test results among accepting authorities.

7.6.5 Accreditation of verifying authorities' measurement standards

Government inspectors and licensed private verifiers who verify or re-verify trade or legal measuring instruments use standards that must themselves be verified (i.e., calibrated to meet legal requirements). This verification of standards needs to be carried out in a traceable manner and with a measurement uncertainty that is suitable for the intended use of the standards.

The laboratories that verify these measurement standards are usually appointed under the national legislation for that purpose; one of the conditions of appointment is accreditation in accordance with ISO/IEC 17025 for that purpose. The laboratory is empowered to issue certificates of verification under the national legislation; these certificates will be accepted in a court of law as evidence of the information contained in them.

7.6.6 National instrument test procedures

To ensure that both government verifiers and private verifiers carry out the verification of measuring instruments correctly and in a consistent manner, it is recommended that each

economy prepare national test procedures for measuring instrument verification. Experience has shown that, rather than being a "regulatory burden", such nationally uniform procedures are welcomed by private sector verifiers who would otherwise need to develop their own procedures within their quality systems. Suitable procedures are available from several APLMF economies.

7.6.7 Quality systems for licensed verifiers

Many private companies that are licensed to carry out verifications of measuring instruments used for trade will already have a quality system that has been accredited by an ILAC MRA signatory. However, other private-sector applicants for the verification of measuring instruments may be sole traders or small companies that cannot afford the accreditation costs. In these cases, the national authority may accept a lesser-quality system that has been audited by a government inspector suitably trained for this activity.

7.6.8 Training and competence assessment

Both government inspectors and private-sector verifiers of measuring instruments will need training in the use of the national test procedures. Each economy may develop such training independently or may take advantage of APLMF training as provided from time to time at various venues within the region. It is recommended that economies introduce an assessment of competence following such training. Assessment procedures are available from several APLMF economies.

7.7 Public measurement services

Public weighbridges are high-capacity weighing devices used by the public, typically for weighing vehicles or livestock. National regulations are needed to control the requirements for and issue of licenses to operators of public weighbridges. The authorized government organization should maintain a register of public weighbridge licenses.

The aim of the regulations is to avoid conditions that may lead to incorrect use or fraud. To this end, the regulations also need to prescribe requirements for weighbridges (concerning their location, installation and pits), for their use and for the presentation of the measurement result (ticket).

7.8 Enforcement strategy

It is important to develop a risk-based approach to enforcement wherein the enforcement response is proportional to the severity of the offence and the likelihood of its recurrence.
Fig. 9 shows the possible responses to infringements as the severity of the offence increases.

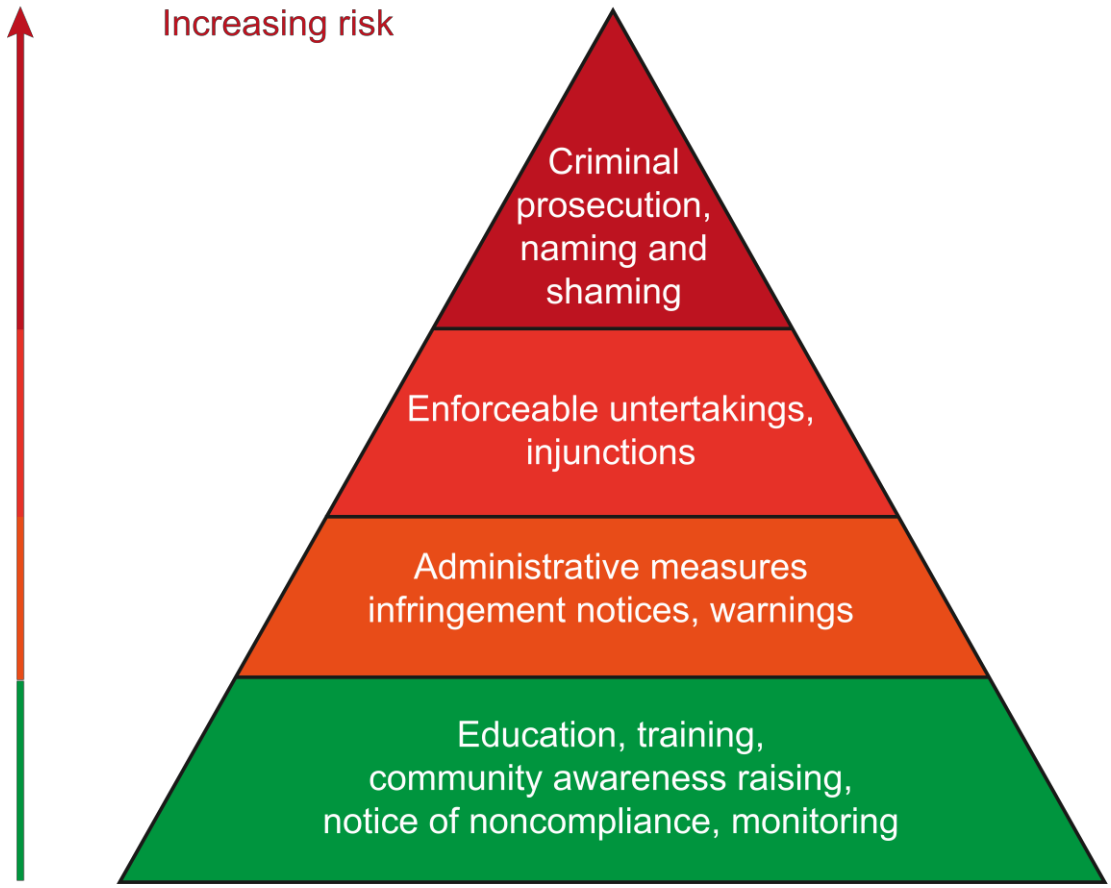

Fig. 9. Enforcement strategy as a function of risk

Ideally, the level of education and awareness-raising should be sufficient such that offences do not occur. Where they do occur, depending on the circumstances, it may be appropriate to issue several warnings before a financial penalty is imposed. For serious offences, it may be necessary to seek a court injunction in order to stop the offending behaviour. Where a company is a repeat offender and has sufficient resources to regard any normal penalty as a cost of doing business, an enforceable undertaking is a powerful tool to change the company's behaviour. Typically, the penalties associated with any further transgressions (i.e. ignoring the directions of a supreme court) are much more severe than are usual in trade-measurement legislation.

7.9 Transition of a developing economy

Initially, a developing economy needs a trade measurement system with appropriate legislation. Thereafter, further legal metrology controls can be introduced for international traceability and regulatory measurements. Finally, a developed economy will have a complete metrology system, with a comprehensive traceability infrastructure and national metrological controls.

7.9.1 Case study 1: Vietnam

The case study below illustrates the process that Vietnam adopted in developing its national metrology infrastructure. Specifically, it was necessary to carry out preliminary work that included liaising widely with other countries, international and regional bodies, and international experts. Development and passage of legislation is never quick, and in Vietnam's case has taken several years

Case Study – The Introduction of a National Metrology Infrastructure in Vietnam

In 2009, the Vietnamese government approved a project for the Directorate for Standards and Quality (STAMEQ – an agency of the Ministry of Science and Technology) to develop a new metrology law that was to be harmonized internationally. The project involved extensive consultation within Vietnam and with some other countries. International experts lent their support to this project by providing advice on its legal framework and on the convergence with international agreements.

The project was also supported by Vietnam's membership in two specialist regional bodies, APMP and APLMF. In 2002, Vietnam hosted the meetings of both APMP and APMLF; this engagement, together with numerous training workshops, was helpful in providing a better understanding of the metrological needs of a developed economy.

The Vietnam Metrology Law was approved by the Vietnam National Assembly on November 11th, 2011 and took effect as from July 1st, 2012. This replaced the Ordinance on Measurement 1999 and was harmonized with OIML D1 and other OIML recommendations. Under this law, measuring devices are classified into two groups: Group 1 is controlled according to technical metrological requirements that are recognized by registered organizations or individuals. By contrast, Group 2 is controlled according to technical metrological requirements that are specified by state management agencies (e.g. STAMEQ – one of these agencies is in charge of specific measuring devices that are assigned to the Ministry of Science and Technology by the government). The latter group includes measuring instruments used for regulation, trade, consumers' rights, healthcare and environmental protection. Organizations that verify, calibrate or test Group 2 measuring devices must be designated before entering the market.

Subsequently, subordinate regulations in the form of decrees and circulars were introduced to make the 2011 law more effective. In particular, Circular No. 23/2013/TT-BKHCN prescribes the list of Group 2 measuring instruments, as well as requirements for their metrological control, such as type approval.

Further circulars were introduced in the period up to 2015 for:

- Registration of the entities involved in the verification, calibration and testing of measuring instruments and measurement standards (Circular No. 24/2013/TT-BKHCN);
- Designation of entities involved in the verification, calibration and testing of Group 2 measuring instruments and measurement standards (Circular No. 24/2013/TT-BKHCN);
- Permissible errors in the weighing and testing of gold products and jewels (Circular No 22/2013/TT-BKHCN); and
- Requirements for the filling and labelling of prepackaged goods and the application of the V mark (No. 21/2014/TT-BKHCN).

7.9.1 Case study 2: Republic of Korea

Because scientific metrology and legal metrology are under the jurisdiction of two different ministries in the Republic of Korea, a close and strong partnership is required for the authorities in order to precisely operate the national standards system (NSS). The case study below explains how the national metrology institute (NMI) in Korea, with its expertise in measurement science, contributes to legal metrology.

Case Study - Collaboration of Legal and Scientific Metrology in South Korea

The national standards system (NSS) in the Republic of Korea is operated by two different authorities: Scientific metrology is overseen by the Korea Research Institute of Standards and Science (KRISS), which is under the jurisdiction of the Ministry of Science, ICT and Future Planning. Other aspects of the NSS — legal metrology, conformity assessment, and standardization — are the responsibility of the Korea Agency for Technology and Standards (KATS), which is part of the Ministry of Trade, Industry and Energy. Against this background, KRISS and KATS cooperate closely with each other in order to better communicate with government stakeholders in the different ministries, and ultimately in order to successfully operate the NSS; taken together, these elements comprise the national quality infrastructure (NQI). KRISS was established in 1975 as the national metrology institute (NMI) of South Korea. KRISS has provided a foundation for the advancement of the NSS by establishing and disseminating national measurement standards, and by establishing R&D measurement technologies. Over the last 40 years, KRISS has increased its capacity up to the international level and now actively joins the many activities of the CIPM and APMP as a world-leading NMI; through various official development assistance (ODA) programmes, KRISS also shares its knowledge and experience with developing NMIs in the region. Such rapid progress has been possible due to initial support from many developed NMIs, including those in the United States, Germany, Japan, and Australia, as well as the ongoing support of the Korean government and the commitment of the members of KRISS. Using its improved capabilities, KRISS has also contributed to national legal metrology. The adoption of the International System of Units (SI) in Korea took place prior to the establishment of KRISS, but operation of the NSS became more stable and systematic after the establishment and growth of KRISS by combining the different types of expertise and responsibility of each authority. In 1961, it was declared in a measurement-related law that national legal units should be set according to the SI. After a number of revisions, this law was wholly revised and activated under the name of the "Measures Act" in 2014. The Measures Act and its Enforcement Decree provide specifications for type approvals, verification and regular inspections of measuring instruments; other specifications include details on the calibration of measuring devices and on the management of prepackaged products. In order to implement these activities, KRISS has — based on its expertise in measurement science and technology on the domestic and international level — provided strong support to KATS. With its knowledge of scientific metrology, KRISS has provided technical support to KATS for the revision and enactment of the Measures Act. KRISS also participates in the Specialized Technical Committee that is specified in the Enforcement Decree of the Measures Act, deliberating on matters such as the criteria for type approval. The interconnection between legal metrology and scientific metrology is important for international activities as well. KRISS also dispatches its experts to nine Working Committees, part of the Specialized Technical Committee operated by KATS, in order to deal with the recommendations and resolutions of the OIML. In addition, KRISS supports the international activities of KATS in the field of legal metrology by offering technical reviews of the publications of the OIML, and participates in meetings of the Technical Committees and Subcommittees of the OIML.

8 National legislation

8.1 Role of legislation

In his presentation to the OIML 2007 Seminar on D1, "Elements for a Law on Metrology", Birch noted as follows:

"Metrology legislation is central to the development of a metrology system. In developing or revising measurement legislation the following features of measurement legislation need to be taken into account.

1. It ensures the consistency of measurements by giving legal standing to the national standards and units of measurement, and requires all measurements used for legal purposes to be traceable to these national standards and only legal units to be used.

2. By providing a legal definition of traceability and by certifying working standards, it provides a sound evidential basis for measurements. This is essential for the effective operation of trade measurement enforcement and has become increasingly important with legal challenges to regulatory requirements based on measurement, particularly traffic speed measurement, breathalysers and environmental measurements. It avoids the difficulties that can be encountered when lawyers in court cases attempt to define the meaning of measurements i.e. 'lawyers' metrology' rather than legal metrology.

3. Having well defined requirements and enforcement mechanisms minimizes fraud in transactions based on measurements.

4. Legislation and enforcement will also provide trust and confidence in measurements that will significantly reduce transaction costs and contribute to the social capital and maintenance of a civil society. The Nobel economic Laureate Kenneth Arrow stated:

   'Virtually every commercial transaction has within itself an element of trust, certainly any transaction conducted over a period of time. It can be plausibly argued that much of the economic backwardness in the world can be explained by the lack of mutual confidence.'

5. The legislative requirement for traceability, together with certification of working standards, can provide an effective mechanism for overcoming fragmentation of the measurement system and coordinating the measurement activities of regulatory authorities.

6. Legislation also defines the commitment of government to the metrology system. Generally, this is a more durable commitment than policy, however it does need to be supported by evidence of the utility of the metrology system.

7. Legislation can unify the national measurement system and contribute to the development of a global measurement system."

In summary, national metrology institutes can provide a sound evidential basis for trade and regulatory measurements by providing for the verification and certification of standards of measurement, measuring instruments and reference materials under national measurement legislation. Such certification provides legal traceability, without which measurements may be incorrectly interpreted by the courts using common law presumptions such as the English common law "presumption of accuracy of notoriously accurate scientific instruments".

8.2 Scope and structure of legislation

OIML D1 makes recommendations about the governance structures that need to be established to support the national metrology infrastructure. It notes the importance of developing measurement legislation in such a way that it will embrace all government and private entities within the economy. This has no impact on the standards setting activities of the various government departments, but does ensure that their complementary measurement requirements are met by measurements that are fit for purpose. Consultation with government departments is best handled within the framework of inter-departmental committees (IDCs).

It is particularly important for NMIs to liaise with the criminal justice and police departments in order to obtain their agreement that the powers of entry, search and seizure of evidence without a warrant is appropriate for trade measurement inspectors. As police themselves usually need to obtain warrants to exercise these powers, it may be necessary to present information to the relevant IDCs on the extent, diversity and geographical reach of trade measurement activities to justify these powers being included in measurement legislation.

The major elements of measurement legislation are listed below. Note that the trade measurement provisions are usually framed in terms of offences and sanctions.

8.2.1 Prescription of units of measurement

- Based on SI System of Units. Refer to BIPM SI Brochure for details.
- Maintained and developed under the Metre Convention.

8.2.2 National standards of measurement

- Hierarchy of standards of measurement: primary, secondary, reference etc.
- Accuracy of standards of measurement expressed as maximum permissible uncertainty.
- Inspector's (trade measurement) standards of measurement.
- Maximum permissible errors (variations) for standards to be deemed equal to their denominations.
- Requirements for verification certificates for standards of measurement.

8.2.3 Metrological traceability

- Requirement that measurements for legal purposes must be traceable.
- Specification of traceability pathways to national legal units of measurement (based on SI) by means of various national standards of measurement.
- Requirements for appointment of private bodies to verify standards of measurement for legal purposes (verifying authorities).

8.2.4 Type (pattern) approval for trade (and regulatory) measuring instruments

- Specification of testing, approval and certification requirements.
- Appointment of approval authorities.

- Requirements for conformity to type.

8.2.5 Traditional trade measurement provisions

- Definition of "in use for trade" to embrace quality measurements, tax (excise and other duties) and freight.
- Requirements for initial verification and re-verification.
- Field surveillance (in-service inspection).
- Trade measurement offences.
- Prescription of certain articles that must be sold by measurement (meat, alcohol)
- Appointment of private licensees for verification of measuring instruments.
- Appointment of public weighbridge licensees.

8.2.6 Trade measurement inspectors

- Appointment, qualifications and identification of inspectors.
- Powers, responsibilities and obligations of inspectors – powers of entry, search and seizure.

8.2.7 Trade measurement sanctions

- Education and warnings.
- Administrative penalties (infringement notices).
- Sanctions for strict liability offences.
- Sanctions for fault element offences.
- Enforceable undertakings.

8.2.8 Provisions for prepackages

- Shortfall offences.
- AQS (OIML R 87).
- Other systems (e.g. minimum quantity) if appropriate.
- Labelling requirements (OIML R 79).

8.2.9 Modernization of legislation

Measurement legislation should be continually maintained to incorporate technological and policy developments. Apart from improving the measurement system, an additional benefit of this approach is that it engages politicians and raises their awareness of the value of the measurement system. For example, it may be necessary to make reforms to include the OIML MAA and the statistical control of utility meters, e.g.:

- Pattern (type) approval and trade measurement provisions that are sufficiently broad to provide for acceptance of OIML MAA test results for pattern approval;
- Statistical in-service inspection of utility meters; and
- Statistical validation of initial verifications of utility meters carried out overseas.

8.3 Consumer laws

In addition to trade measurement legislation, most economies also enact consumer laws known as competition and consumer legislation, trade practices legislation or fair trading legislation. This is less specific than trade measurement legislation and deals with matters such as misuse of market power, unconscionable conduct and consumer protection. Because of the broad nature of the offences, it may sometimes be preferable to prosecute unacceptable trade practices under consumer law rather than under trade measurement law.

9 Bibliography

APLMF Working Groups. http://www.aplmf.org/.

APLMF. Memorandum Of Understanding Of The Asia-Pacific Legal Metrology Forum. http://www.aplmf.org/.

APMP. Memorandum of Understanding of the Asia Pacific Metrology Programme. September 2014. http://www.apmpweb.org/documents/file/mou.pdf.

APMP Technical Committees. http://www.apmpweb.org/.

APMP/PTB. Guide to Creating or Improving a National Metrology in Chemistry Infrastructure (the MIC Guide). https://www.ptb.de/cms/fileadmin/internet/fachabteilungen/abteilung_q/q.5_technische_zusammenarbeit/q5_publikationen/203_Guide_Chemistry_Infrastructure/PTB_Q5_Guide3_Chemistry_Infrastructure.pdf.

BIPM. "CIPM MRA" BIPM. http://www.bipm.org/en/cipm-mra/.

BIPM. CIPM MRA-G-01 Guide to the implementation of the CIPM MRA. Paris, 2013. BIPM. Convention of the Metre. Paris: BIPM, 1875.

BIPM. Designated Institutes in the CIPM MRA. Paris, 2014.

BIPM, OIML, ILAC and ISO. "Joint Declaration on Metrological Traceability." Paris, 2011.

Birch, J. Benefits of Legal Metrology for the Economy and Society. Paris: OIML Expert Report E2, 2003.

Drijarkara, A P & Sanetra, C. "Inter-laboratory Comparisons for Emerging Natonal Metrology Institutes." Braunschweig: Physikalisch-Technische Bundesanstalt, October 2012. https://www.ptb.de/cms/fileadmin/internet/fachabteilungen/abteilung_q/q.5_technische_zusammenarbeit/q5_publikationen/208_Guide_Interlaboratory_Comparisons/PTB_Q5_Guide9_Interlaboratory_Comparisons_EN.pdf.

Euramet, "Metrology – in Short." 2003. http://euramet.org/publications-media-centre/documents-and-publications/metrology-in-short.

Guasch, J L, J L Racine, I Sánchez, and M Diop. Quality Systems and Standards for a Competitive Edge. Washington, D.C.: World Bank, 2007.

JCGM-WG1. Guide to the expression of uncertainty in measurement (GUM). http://www.bipm.org/en/committees/jc/jcgm/.JCGM-WG2. International vocabulary of basic and general terms in metrology (VIM). http://www.bipm.org/en/committees/jc/jcgm/.

Mason, P. "The place of Legal Metrology in a National Quality Infrastructure" OIML Bulletin Volume LVIII, Number 2, April 2017

OIML R 79 Labelling requirements for prepackaged products. 1997. http://www.oiml.org/en/publications/recommendations/publication_view?p_type=1&p_status=1.

OIML R 87 Quantity of product in prepackages. 2004.

http://www.oiml.org/en/publications/recommendations/publication_view?p_t
ype=1&p_status=1.

OIML. B 10-Amended-2012-en Framework for a Mutual Acceptance Arrangement on OIML Type Evaluations (Integrating the changes in the 2012 Amendment). Paris, 2011.

OIML. B 15: OIML Strategy. Paris, 2011.

OIML. B 1-en Convention on Legal Metrology. Paris, 1968.

OIML. B 3-en OIML Basic Certificate System for OIML Type Evaluation of Measuring Instruments. Paris, 2011.

OIML. B 6-1-en Directives for OIML Technical Work. Paris, 2013. OIML. D1 Considerations for a Law on Metrology. Paris, 2012.

PTB. Q5 Guide – Towards mutual recognition of metrological competence.
https://www.ptb.de/cms/fileadmin/internet/fachabteilungen/abteilung_q/q.5_
technische_zusammenarbeit/q5_publikationen/206_Guide_Mutual_recognition/
PTB_Q5_Guide_Mutual_recognition_EN.pdf.

PTB_Q5_Guide, “How to register calibration and measurement capabilities.”

Robertson, K & Swanepoel, J A. “The Economics of Metrology.” Industry, Innovation and Science, Australia, Office of Chief Economist, 2015.

Sanetra, C & Marbán, M. “The Answer To The Global Quality Challenge: A National Quality Infrastructure.” PTB.
https://www.ptb.de/cms/fileadmin/internet/fachabteilungen/abteilung_q/q.5_
technische_zusammenarbeit/q5_publikationen/102_National_QI/PTB_Q5_Natio
nal_QI_EN.pdf.

Seiler, E. “Steps towards a National Metrology System – Proposals for development, organization and operation” Physikalisch-Technische Bundesanstalt (PTB), Germany, April 2017

Tassey, G. The Roles of Standards as Technology Infrastructure. Washington, D.C.: NIST, October 1993.

WELMEC. European Cooperation in Legal Metrology. http://www.welmec.org/.

The general references in this document can be found by searching the relevant websites of the international and regional infrastructure bodies:

BIPM	http://www.bipm.org/
OIML	http://www.oiml.org/
APMP	http://www.apmpweb.org/
APLMF	http://www.aplmf.org/
ISO	http://www.iso.org/
IEC	http://www.iec.ch/
ILAC	http://ilac.org/
IAF	http://www.iaf.nu/
PAC	http://www.apec-pac.org/
PASC	http://www.pascnet.org/

Annex - National Metrology Infrastructure Checklist

This Annex is essentially an abbreviated version of the annual metrology survey, conducted in the framework of the PTB-MEDEA project, that may not be widely disseminated within an economy. The purpose of including it here is to provide more general information on the types of issues that are important for a competent metrology system. Prior to attending any regional training, attendees may be asked to copy and fill in the check list in order to identify any gaps and thereby provide training organizers with feedback on areas that may need to be addressed.

In regard to Q4 and Q5, please note that measuring instruments used for trade include instruments used to determine the quantity of a product or the quality of a product (e.g. grain moisture measurement) where the measurement contributes to the determination of the consideration (i.e. payment in the transaction). Also, the types of measuring instruments used for regulatory purposes may include instruments used for traffic control (speed, intoxication), environmental monitoring (radiation levels, sound levels, pollution levels) and measurements for health monitoring and diagnosis of illnesses.

No.	Subject	Questions	Yes	No	Comments
1.	Law on Metrology	Does your economy have a Law on Metrology or equivalent already in place?			
2.	Units of Measurement	Does the Law on Metrology include regulations about national units of measurement (UoMs)?			
		Are national UoMs covered in a separate Law?			
		Are national UoMs based on SI units of measurement?			
		Do national UoMs include customary units of measurement?			
3.	Measurement traceability	Does your legislation include requirements for measurement traceability?			
		Does your legislation include requirements for traceability of reference measurement standards, e.g., for mass, length, volume, temperature, etc.?			
4.	Verification of measuring instruments subject to legal control	In your economy, must trade measuring instruments be verified?			
		In your economy, must regulatory measuring instruments be verified?			
		Does your economy have verification procedures/instructions?			
		Are some classes of instruments exempt from verification?			
		Has your economy developed re-verification periods for instruments under legal control?			
5.	Type approval of measuring instruments	Does your economy test trade measuring instruments for approval locally?			
		Does your economy test regulatory measuring instruments for approval locally?			
		Does your economy accept international type approval test results or approvals in lieu of local testing?			

		Does your economy have OIML-harmonized test procedures for approval of measuring instruments used in trade and regulation?			
6.	Market surveillance	Does your economy carry out market surveillance?			
		Does your economy enforce penalties?			
7.	National Quality Infrastructure (NQI)	Does your economy have a well- established National Metrology Institute, a National Standards Body and a National Accreditation Body?			
		Does your economy have a network of accredited calibration and testing laboratories operating in the country?			
8.	National Metrology Institute	Is your economy a member of the BIPM?			
		Is your Institute a signatory to the CIPM-MRA?			
		Do you have Designated Institutes operating closely with the National Metrology Institute?			
		Does your NMI conduct regular identification of metrology needs in the country?			
9.	National Measurement System	Does your government establish a national Advisory Board or Council to coordinate policies and activities on measurement?			
10.	Awareness raising	Does your NMI conduct regular awareness raising to stakeholders and regular interaction with customers?			