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Quality Infrastructure of National Metrology Institutes: A Comparative Study

Shanay Rab[a,b*], Sanjay Yadav[a], S K Jaiswal[a], Abid Haleem[b] & D K Aswal[a]

[a]CSIR-National Physical Laboratory (CSIR-NPL), New Delhi, India-110 012

[b]Department of Mechanical Engineering, Jamia Millia Islamia, New Delhi, India-110 025

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Each country has its own system of Quality Infrastructure (QI) developed for the effective operations, management, regulations, control of national trade, international exchanges of goods & collaborations and recognition of their products and services to enable them to enter into the global market. These QI systems consist of national governments, civic, public and private institutions, organizations, boards, associations, forums, scientific societies, federations industries *etc.* These agencies work in coordination and with synergy to formulate, suggest, execute, disseminate and implement, as per their relevant responsibilities; the national policies, procedures; guidelines, legal & regulatory structure, and good practices to support and strengthen the quality for safe & environmentally friendly products, services, and processes. It relies on metrology, standardization, accreditation, and conformity assessment. Several countries have strong QI, and accordingly, have proper industrial and economic growth. On the contrary, some of the countries lack the necessary infrastructure to meet the quality standards, and as a result, they face problems and challenges in this competitive world. This paper describes the essential components of stronger International Quality Infrastructure (IQI) and the National Quality Infrastructure (NQI). A comparative study carried out on the NQIs of 9 leading countries is also discussed. A comparative study on the Global Quality Infrastructure Index (GQII) of the top 10 economies is also included. Admittedly, though utmost care is taken to accommodate most relevant information, some of the unnoticed discrepancies are not ruled out, which may be unintentional. It is hoped that this paper would be useful for students, researchers, academicians, scientists, metrologists, quality experts, administrators, and policymakers as an information bank on NQIs and GQIIs of several countries.

Keywords: Quality Infrastructure, Metrology, Standardization, Conformity assessment

1 Introduction

The Quality Infrastructure (QI) of a country is essentially required to ensure the quality expectations, *i.e.*, safety, reliability, compatibility of the users of the products and services, and the fulfillment of the regulatory requirements. It encompasses all the government, public and private institutions responsible for establishing, execution, dissemination, market surveillance, and implementation of the mandatory/voluntary metrological and documentary standards, technical/legal rules and regulations, and conformity assessment, certification, and accreditation. The mandate of the United Nations Industrial Development Organization (UNIDO) also stipulates and advocates for Inclusive and Sustainable Industrial Development (Fig. 1). It is Sustainable Development Goal 9**,** ***"Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation,"*** is basically for promoting and strengthening the QI of the developing countries through formulating quality-related guidelines, good governance procedures, the advancement of metrological activities, standardization and accreditation services, enhancing conformity assessment capabilities, and promoting public awareness[1]. The QI of any country should be well understood, and its functioning be made globally coherent if not absolutely uniform. The diversified metrological and documentary standards, varying calibration, testing, and certification systems often do not adequately improve the quality of products. However, it increases the burden of costs for manufacturers, suppliers, users, and customers. On the other hand, cohesive QI helps remove barriers in the trade and reduce costs, time, and market uncertainties[2-7].

In a nutshell, the strong and robust QI advances the global competence & confidence. With the high quality products, our industries can compete globally and overcome various trade related barriers and finally achieve the export targets. This translates into growth of industries through speedy industrialization, societal upliftment and economic growth. The strong QI is therefore essential for achieving the following objectives;

*Corresponding author: (E-mail: shanayrab753@gmail.com)

Fig. 1 — United Nations Sustainable Development Goals (SDGs)

i) Develop and deploy the most appropriate metrological methods for industries during product design and development cycle.
ii) To ensure that all producers/manufacturers, including farmers, receive the correct payments for their product/goods.
iii) Ensuring that the final products meet regulatory standards, documentary standards and specifications.
iv) The control over the pre-packed goods or commodities helps to minimize fraud.
v) The accurate measurements of exported raw materials enable them to pay the correct price. It also helps governments to collect correct amount of taxes on the exports and help to enhance the economic conditions for all concerned.
vi) The acceptability of measurements & test results across the globe removes several technical trade constraints.
vii) It eases the international trade and contributes to inclusive economic growth, access to opportunities for Small & Medium-sized Enterprises (SMEs).

Further, the NQI comprises with various mechanism that are strongly linked to each other and form a network, whose logical relations are connected to a technical hierarchy. This national network connection is linked to the relevant international systems. Having established the proper international link, the commodity trading and exchange of services globally are possible in an easy manner. The NQI is closely linked with the International QI (IQI) System, which is connected and based on linkages with relevant international organizations. In the case of any NQI, the linkages based on nations needs are established between relevant national institutes and the International Bureau of Weights and Measure (BIPM); Metric Convention, International Committee of Weights and Measure (CIPM), International Organization of Legal Metrology (OIML), Regional Metrology Organizations (RMOs), International Standards Organization (ISO). World Trade Organization (WTO), *International Laboratory Accreditation Cooperation* (ILAC), International Accreditation Forum (IAF), Regional Conformity Boards (RCBs), to name a few.

Gross domestic product (GDP) is defined as the market value of all the final goods and services in a country in a given year. As per World Economic Outlook Database 2020, published by International Monetary Fund[8], the United States of America is the world's biggest economy with a GDP of $20.81 trillion, and India is listed at the sixth position with $2.59 trillion. The countries' ranking positions for GDPs kept on changing with the change in Government policies and improved QI over time. However, due to the current humongous pandemic situation due to COVID-19, most countries' GDPs would be under severe strains during the year 2020 or subsequent years to come. Recently Government of India has focused its attention on reaching a target of $5.0 trillion economies in the next 4-5 years to serve its large population. In the first instant, this targeted GDP looks a bit optimistic

but, on the other hand, achievable if all contributing sectors (industry, agriculture, service) work together responsibly. One of the important factors responsible for energizing all these sectors for achieving this target is stronger, robust, and cohesive NQI.

In India, CSIR-National Physical Laboratory (CSIR-NPL) is the custodian of national measurement standards. Here legal Metrology Department formulates rules and regulations and enforces the metrology for trade and commerce; Bureau of Indian Standards (BIS) deals with documentary standards of products and services while accreditation bodies (NABL, NABH, *etc.*) work under the umbrella of Quality Council of India (QCI) in the country. Other countries also have their own NQIs, similar orbit different structures encompassing several acting bodies/agencies working at various levels. An essential and straightforward pictorial view of the structure of NQI is depicted in Fig. 2, wherein the names of departments and ministries may vary from one country to another country.

To strengthen the NQI, it is appropriate to grasp, analyze, and study the NQIs of leading countries to develop foresight. Therefore, the present paper describes the findings and compares NQIs of nine countries, *i.e.*, USA, China, Japan, Germany, India, France, Republic of Korea, New Zealand, and Canada. The global quality infrastructure index (GQII) is briefly discussed for ten economics in the world to understand QI's role in the growth of any country.

2 International Organizations Related to Quality Infrastructure

Various organizations are focused on promoting international trade & fostering development at global & regional level. In the IQI system, some organizations include authorized national organization as a member. These organizations have supported developing such infrastructure in countries across the globe. Figure 3 shows the various organizational linkage of QI system. Some of these organizations are also responsible for establishing International QI and are briefly described in the coming section.

2.1 United Nations Industrial Development Organization (UNIDO)

UNIDO is a one of the prominent agency of United Nations, which is established in the year 1967 with the aim to assist the developing countries and

Fig. 3 — Linkages of various bodies in the QI system

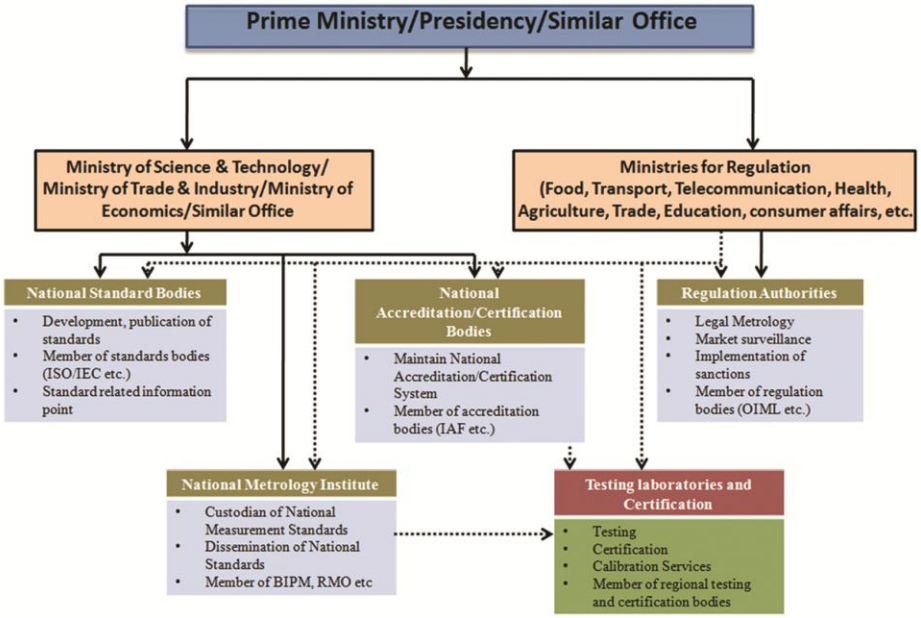

Fig. 2 — A simple organizational linkage of National Quality Infrastructure (NQI) having various Ministries and Departments. Continuous and dotted lines denote supervisory and coordination relationships, respectively

countries with economies in transition in their industrialization efforts. This organization supports activities for developing countries in the preparation of developments plans for national industrial development, technology transfer, investment promotion activities, surveys and undertake research activities, *etc*.

2.2 The World Trade Organization (WTO)

The World Trade Organization (WTO) is an intergovernmental organization established in the year of 1995 to regulate international trade between nations. This organization deals with the rules of trade between counties having goals to help producers of goods and services, exporters, and importers for smooth functioning of their businesses at a global level. It operates through a system of rules and regulations covering global trade and various other associated aspects.

2.3 The International Bureau of Weights and Measures (BIPM)

The International Bureau of Weights and Measures (In French: Bureau International des Poids et Mesures) is an intergovernmental organization established in the year of 1875 by the Meter Convention. The Member states of BIPM act together on matters related to metrology. It is also responsible for defining the International System of Units (SI) and promoting the consistency of measurements across the globe. The organization operates under the supervision of the International Committee for Weights and Measures (CIPM). The CIPM suggests modifications to the International System of Units to the General Conference on Weights and Measures (CGPM) for any formal adoption.

2.4 International Organization of Legal Metrology (OIML)

The International Organization of Legal Metrology (OIML) is an international organization established in the year of 1995 with the aim to promote the global harmonization of the legal metrology related procedures. It underpins and facilitates international trade. Further, it establishes connection between international & regional institutions concerning legal metrology, standardization, and other associated fields.

2.5 International Organization for Standardization (ISO)

International Organization for Standardization (ISO) is an international non-governmental organization. It is responsible for developing market-driven and relevant documentary international standards. It has international experts in the corresponding technical committees to support innovation, provide solutions to international challenges and specifications for services, services and systems. It also ensures safety, quality, efficiency and facilitates international trade.

2.6. International Electrotechnical Commission (IEC)

The International Electrotechnical Commission (IEC) is an international standards organization, which prepares and publishes international standards related to electronics, electrical and other similar field. IEC standards cover a wide range of technologies from power generation, transmission, and distribution to home appliances, batteries, semiconductors, solar energy, fiber optics, marine energy, *etc.*

2.7 International Laboratory Accreditation Cooperation (ILAC)

ILAC is an international organization deals with accreditation bodies operating in accordance with ISO/IEC 17011 and involved in the accreditation of conformity assessment bodies including calibration and testing laboratories, medical testing laboratories, inspection bodies and proficiency testing to name few standards.

2.8 International Accreditation Forum (IAF)

Similarly, the International Accreditation Forum (IAF) is an association of Conformity Assessment Accreditation Bodies and other similar bodies in the area of products, management systems, services, and various other similar domains of conformity assessment.

2.9 Regional Metrology Organizations (RMOs) and CIPM MRA

Globally, NMIs are affiliated with RMOs. NMIs from 39 countries have been signed the International Committee of Weights and Measures (CIPM) Mutual Recognition Arrangement (MRA) in the year of 1999. The MRA, drawn up by the CIPM, under the authority given to it in the Metre Convention, was in response to governments and Regulators' requirements to provide a sound technical foundation for trade agreements. The RMOs play a significant role in the implementation of CIPM MRA. Currently, the following six listed RMOs are recognized within the structure of the CIPM MRA

i) Intra-Africa Metrology System (AFRIMETS);
ii) Asia Pacific Metrology Programme (APMP);
iii) Euro-Asian Cooperation of National Metrological Institutions (COMET);
iv) European Association of National Metrology Institutes (EURAMET);
v) Gulf Association for Metrology (GULFMET); and
vi) Inter-American Metrology System (SIM)

3 Overview of the National Quality Infrastructure (NQI)

Each developing economy, initially, requires a measurement system with appropriate legislation. After that, legal metrology controls are introduced/ imposed for international traceability and regulatory frameworks. The developed economies typically have a complete metrology system, with comprehensive metrological infrastructure and appropriate national regulations and metrological controls. The responsible organizations and their linkages in IQI and NQI systems are summarized in this section.

3.1 Quality Infrastructure of India

3.1.1 National Metrology Institute of India

CSIR-NPL is the National Metrology Institute (NMI) of India. Since its inception, the laboratory is fulfilling its mandate to realize, maintain, and disseminate national standards of measurements. CSIR-NPL works under the umbrella of Council of Scientific and Industrial Research (CSIR), an autonomous body under the Ministry of Science and Technology (MST), Government of India. For ionizing radiation standards, the designated institute of NMI, *i.e.*, CSIR-NPL is Bhabha Atomic Research Centre (BARC), Mumbai. BARC works under the Department of Atomic Energy (DAE), GoI. Figure 4 shows the NQI of India, comprising different organizations.

3.1.2 Legal Metrology Department of India

Department of Legal Metrology is mainly responsible for establishing the standards of Legal Metrology and maintaining the traceability over the Legal Metrology standards. The Department is responsible for formulation and enforcement of regulation to undertake technical field inspections, seizures, searches, registration of offices, and launching prosecutions. Department of Consumer Affairs (DCA) is responsible for the formulation of policies for consumer cooperatives, availability of essential commodities monitoring prices, consumer movement in the country and coordination with statutory bodies like the Weights & Measures and Bureau of Indian Standards (BIS) and. The works performed by the Legal Metrology are therefore essential in the public interest.

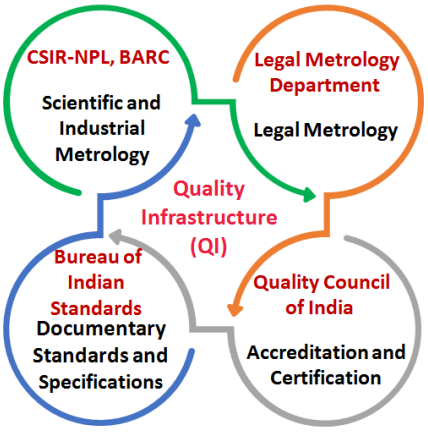

Fig. 4 — Graphical representation of Quality Infrastructures (QI), India

3.1.3 Bureau of Indian Standards (BIS)

The Bureau of Indian Standards (BIS) is the National Standardization body under the Ministry of Consumer Affairs, Government of India. BIS's main activities are standardization, specifications, and certification of goods, articles, processes, systems, and services.

3.1.4 Accreditation and Certification Body

Quality Council of India (QCI) is an autonomous body established for providing accreditation structure in the country under the Ministry of Commerce and Industry, Government of India. It is governed by a Council of 38 members having equal representation of government, industry, and other stakeholders. The Council is responsible for formulating the strategies, general policies, regulations, and monitoring of various components of QCI, including the accreditation boards, with objectives to ensure transparent and credible accreditation system. QCI has five different accreditation boards involved in the accreditation programs (Fig. 5). Each board is functionally independent and works within its core area of expertise.

The other information on India's QI comprising prevailing systems for technical regulations standardization, conformity assessment, and other support activities are depicted in Table 1. While some organizations have multiple subdivisions, only the subdivisions directly linked/involved with standards and conformity assessment are included in the list[3, 9]

Recently, one of the authors introduced a more effective and robust QI system and is now known as the Aswal model for the country's inclusive growth[4, 10]. The given model explains the mechanisms wherein the QI, being an invisible force, facilitates the strong interactions among the four helices of a Quadruple Helix (QH). These four helix such as Government; Universities, Science & Technology institutions;

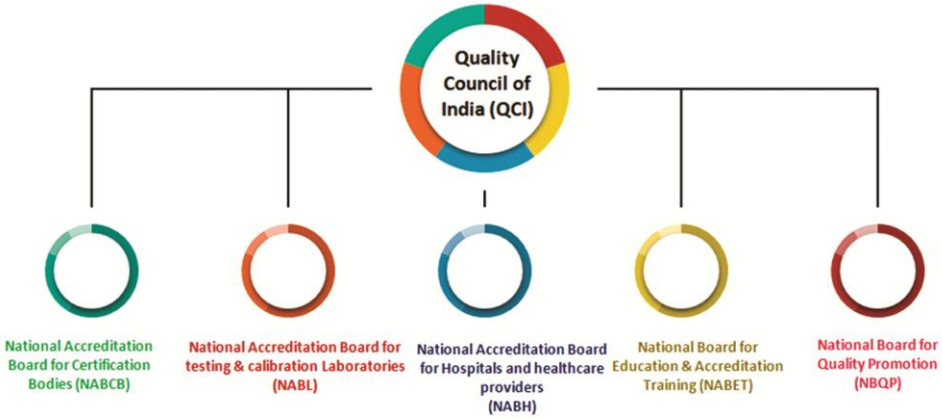

Fig. 5 — Structure of Quality council of India

Table 1 — Partial list of various authorities in India as a part of conformity assessment in India

Name of the organization/body	Status and control	Scope and subject area
Agricultural and Processed Food Products Export Development Authority (APEDA)	An autonomous body under the Department of Commerce, Ministry of Commerce and Industry, Govt. of India	Standards for organic production and Systems
Automotive Research Association of India (ARAI)	Research Institute of the Automotive Industry with the Ministry of Heavy Industries & Public Enterprises, Govt. of India	Standards for Automotive Industries
Bureau of Energy Efficiency (BEE)	Agency Ministry of Power, Govt. of India	Energy performance standards for Appliances, Energy Conservation, Building Code
Central Drugs Standard Control Organization (CDSCO)	Directorate General of Health Services, Ministry of Health & Family Welfare, Govt. of India	Works for the drugs and health care devices or technologies
Central Pollution Control Board (CPCB)	A statutory organization under the Ministry of Environment, Forest and Climate Change, Govt. of India	Works for air quality monitoring, water quality, emission norms for vehicles, prepares guidelines, manuals, codes, related to the treatment and disposal of sewage etc.
Food Safety and Standards Authority of India (FSSAI)	An autonomous body established under the Ministry of Health & Family Welfare, Govt. of India	Works for Food articles and regulates their manufacturing, distribution storage, sale etc
Oil Industry Safety Directorate (OISD)	A technical advisory body in India was established in the year of 1986 by the Ministry of Petroleum and Natural Gas.	Safety standards, Product design, Codes of practices, Guidance standards for Oil and Gas sector
Tea Board of India	State agency of the Government of India	Promote the cultivation, processing, and domestic trade as well as export of tea from India.
Telecommunication Engineering Centre (TEC)	A nodal agency of the Department of Telecommunications, Ministry of Communications and Information Technology, Govt. of India	Formulate the standards about the Telecom network equipment, services and interoperability etc
Railways Design & Standards Organization (RDSO)	Research and development organization under the Ministry of Railways of India	Standards for materials and products needed by Indian Railways
Atomic Energy Regulatory Board	Regulatory Body, Department of Atomic Energy	Technical regulation, commissioning, construction, operation, and decommissioning of nuclear and radiation facilities including Medical and Industrial radiography
University Grants Commission	A statutory body, under the Ministry of Education (Earlier Ministry of Human Resource Development)	Maintain standards of teaching, examination, and research in across the institutions'. Formulate the regulations on standards of education, disbursing grants to the educational institutions. Act as a crucial link between the governments and institutions in the area of research and education

Civil society and Media & Industry for the overall growth and high quality of life in the nation. In this model, metrology is at the core of QI, which is essentially important for all the helices for creating knowledge & innovation for the sustainable development.

3.2 Quality Infrastructure of New Zealand

A guide to New Zealand's Standards and Conformity System gives a comprehensive overview of the QI and conformance system of the country. The guide includes the role of conformance, standards, accreditation, policy and regulations of New Zealand. The Ministry of Business, Innovation, and Employment (MBIE) is the leading policy department for the standards and conformance system in the country [11].

The government of New Zealand has established International Accreditation New Zealand (IANZ), and it endorses the Joint Accreditation System of Australia and New Zealand (JAS-ANZ), which together offers accreditation throughout the nation. For the metrology; the Measurement Standards Laboratory of New Zealand (MSL) acts as NMI of the country. The system of weights and measures for trade is administered and enforced by Measurement and Product Safety Service (MAPSS), under the Weights and Measures Act.

The IANZ provides the calibration and accreditation services. Trading Standards in the country is responsible for legal metrology and, unlike MSL, has enforcement powers under its legislation. Trading Standards sources its measurement traceability from MSL and also operate calibration laboratories, which are accredited to ISO/IEC 17025 by IANZ. It is considered as the national authority for the accreditation of testing and calibration laboratories. The MSL has a MoU with IANZ to advice on all matters related to metrology. Similarly, Standards New Zealand (SNZ) is the national standards body, which also operates as Technical Barriers to Trade Enquiry Point on behalf of the Ministry of Foreign Affairs of the country. The accreditation for conformity assessment bodies in the fields of certification and inspection is provided by Joint Accreditation System of Australia and New Zealand (JAS-ANZ). Figure 6 shows the various standards bodies associated with QI of New Zealand.

In New Zealand, there are five major organizations involved in developing standards, monitoring, and assistance to NQI. Some other agencies/organizations are such as Medicines and Medical Devices Safety Authority, New Zealand Transport Agency, Energy Safety *etc*. Figure 7 provides a brief overview of the linkages of the International and National quality Infrastructure of New Zealand. Overall, part (A) of Fig. 7 and all subsequent figures related to all countries studied are generally identical with minor modifications, while its part (B) and all other figures are different, showing linkages to various pillars of National QI standard bodies. The main pillars of New Zealand's NQI are:

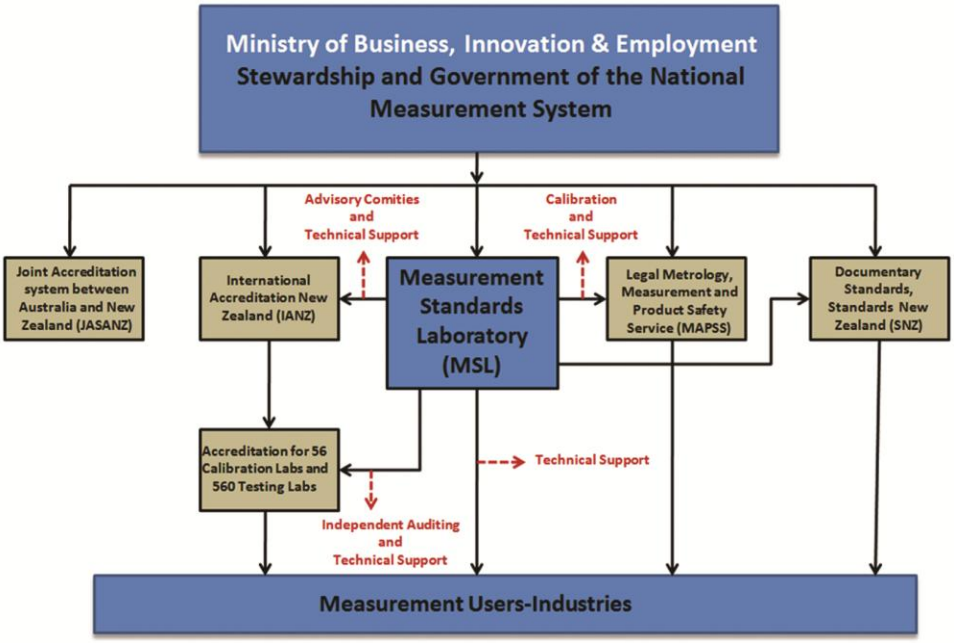

Fig. 6 — New Zealand's standards and conformance infrastructure

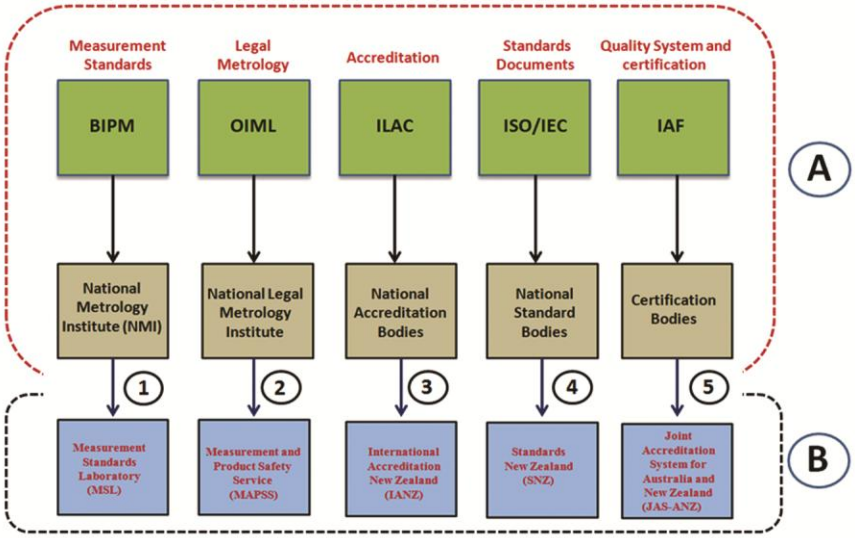

Fig. 7 — Link various bodies in the conformance system of New Zealand, A) International and National bodies; B) NQI bodies

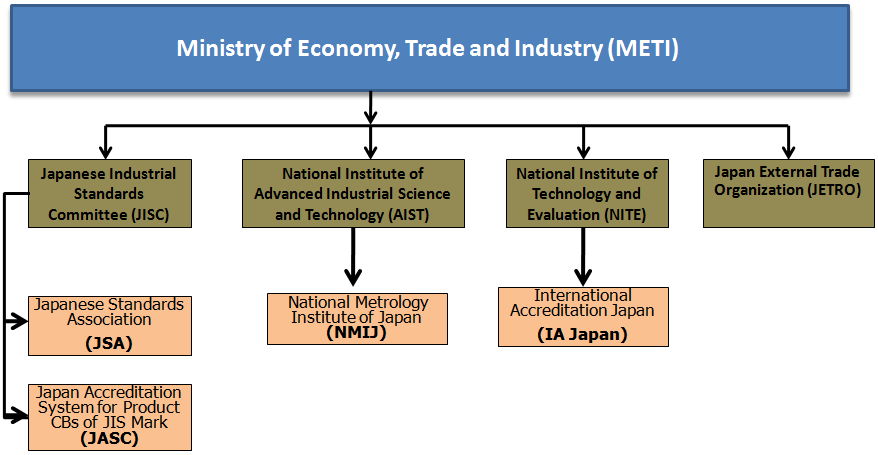

Fig. 8 — Linkages of Japan standards and conformity infrastructure

- ❖ Measurement Standards Laboratory
- ❖ The Standards Approval Board
- ❖ Standards New Zealand
- ❖ Trading Standards
- ❖ The New Zealand Standards Executive

3.3 Quality Infrastructure of Japan

Ministry of Economy, Trade, and Industry (METI), Government of Japan has the jurisdiction over a broad policy area containing country's energy security, industrial & trade policies, control of arms exports *etc*. It also administers the national standards system by drafting and enforcing standards related laws and regulations in the nation[12-13]. Japan has an advanced QI level supported by established standards and conformity bodies that adhere to international best practices. Japan has acquired the membership of almost all the international bodies/forums involved in metrology, standards, and conformity. It is always engaged in a high level of international activities for quality infrastructure. A conformity assessment framework for Japan is shown in Fig. 8.

National Metrology Institute of Japan (NMIJ) is the NMI of Japan, established in the year 2001 as a part of the National Institute of Advanced Industrial Science and Technology (AIST). NMIJ is comprised of 4 Research Institutes such as Chemical Measurement and Analytical Instrumentation Measurement; Center for Quality Management of Metrology; Research Promotion Division and Engineering Measurement, Physical Measurement, Material division.

Japanese Industrial Standards Committee (JISC) develops and distributes the Japanese Industrial Standards (JIS). The committee represents the

countries at International organizations such as ISO, IEC, and PASC. "Industrial Science and Technology Policy and Environment Bureau" of METI covers the standards related works as the secretariat organization of JISC. Similarly, with Japanese Industrial Standards (JIS) mark scheme, product certification bodies accredited by METI, conduct a chain of tests to verify the quality of final goods with JIS.

The Japan Accreditation System for Product Certification Bodies of JIS Mark (JASC) is an accreditation program defined by JIS Law and is operated by the JASC office in METI. The agency accredits product certification bodies in the private sector and allows these bodies to certify companies so that the companies may place the JIS mark on their products.

There are 5 different accreditation bodies in Japan, which are members of ILAC/APLAC/IAF/PAC. International Accreditation Japan (IA Japan), a part of the National Institute of Technology and Evaluation (NITE), which is a government agency that administers four accreditation programs;

i) Japan Calibration Service System (JCSS) for calibration labs seeking measurement traceability;
ii) Japan National Laboratory Accreditation System (JNLA) for testing labs seeking conformance to JIS;
iii) Accreditation System of National Institute of Technology and Evaluation (ASNITE) for testing labs, calibration labs, reference material producers, and product certification bodies seeking conformance to international standards and requirements; and
iv) Measurement Laboratory Accreditation Program (MLAP) for environmental labs seeking conformance to legal requirements.

Japan Accreditation Board (JAB) is one of the largest accreditation bodies in Japan and was established in 1993. It is a private agency that provides the widest scope of services in Japan, covering nine accreditation fields ranging from management system certification bodies to medical laboratories. Figure 9 provides a linkage of the International and National bodies for standards and conformity infrastructure in Japan.

3.4 Quality Infrastructure of China

China's main standards and conformity agency is the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ). It is a ministerial administrative organ directly under the State Council of the country, which is responsible for the get in and out commodity inspection, national quality, metrology, get in and out health quarantine, import & export food safety, certification, accreditation, standardization, as well as the administrative law enforcement *etc*.

The two main wings that carry out the duties of AQSIQ are the Certification and Accreditation Administration of China (CNCA) and the Standardization Administration of China (SAC). Both organizations have full authority to deal with other ministries. A third important agency is the Department of Metrology, which works to implement metrological laws and regulations to coordinate measurements used in standardization. SAC is the central accrediting body deals with developing and promulgating national standards in country. It also represents the country at ISO, IEC and other international and regional standardization organizations. CNCA is primarily in charge of administrating the China Compulsory Certificate (CCC) and certifies other institutions to provide CCC marks. It also supervises the testing laboratories and the inspection bodies.

As a centrally organized economy, government agencies in China do not have much overlapping, and there are clear delineations of responsibilities. For instance, China is one of the few economies with a unified accreditation body; China National Accreditation Service for Conformity Assessment (CNAS) is responsible for accrediting certification bodies, laboratories, and inspection bodies.

The Chinese Metrology Institute has been at the forefront of the international metrology science and has played an important role in the national economic growth, social development and scientific and

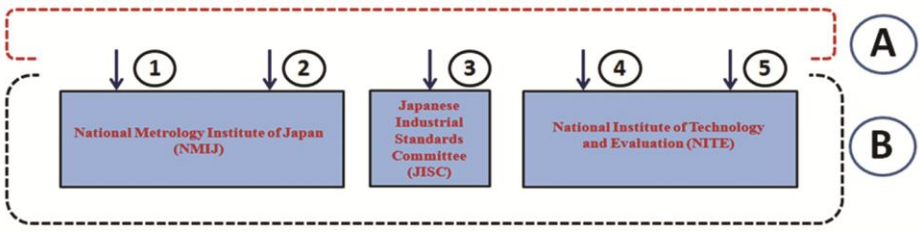

Fig. 9 — Linkages of various bodies of QI in Japan

technological progress in the country. Hangzhou Applied Acoustics Research Institute (HAARI) is a designated institute under the country's NMI generally deals with acoustic research. The conformity assessment framework given for China is shown in Fig. 10. There are also various non-profit research organizations involved in standards and conformity assessment affiliated with AQSIQ. Figure 11 depicts a block diagram of the International and National bodies' linkages for standards and conformity infrastructure in China[14-15].

3.5 Quality Infrastructure of the Republic of Korea

Ministry of Commerce, Industry, and Energy (MOCIE) administers the national standards system by drafting, and enforcing standards related laws and regulations in the Republic of Korea. Ministry is committed for providing the foundation for economic growth by combining its efforts to fulfill its wide range of responsibilities in the areas of Investment, commerce, industry, energy, *etc*. There are various other bodies which work under government and nongovernment manner to make conformity assessment of the country, as shown in Fig. 12.[16-17]

Korea Research Institute of Standards and Science (KRISS) is the NMI of the country by the Framework Act on National Standards (Article 13). The Korean Agency for Technology and Standards (KATS) is the government agency that has been leading in national and international standards since it was founded in the year of 1883 as an Analysis and Testing Laboratory of the Mint Office. After several changes and developments over the last several decades, KATS was reformed under the Ministry of Trade, Industry, and Energy. It deals with the following function and objectives;

- Establishes and distributes country's Industrial Standards
- Represents Korea at various International organizations such as; ISO, IEC, PASC, OIML, APLMF, *etc*.

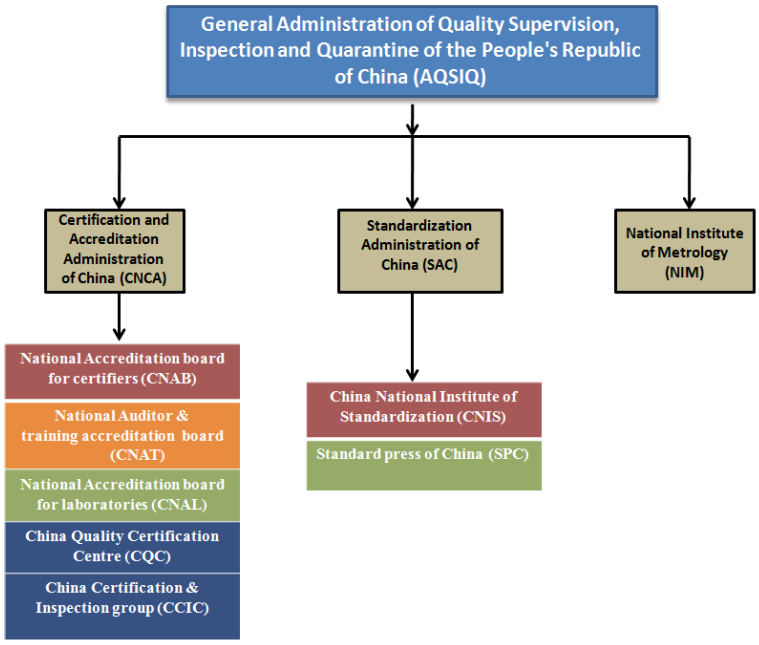

Fig. 10 — Standards and Conformity Assessment Bodies – China

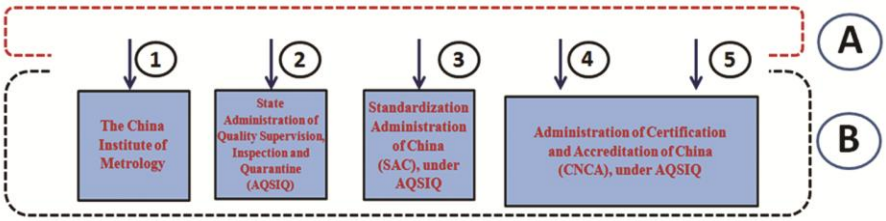

Fig. 11 — Linkages of various bodies to QI in China

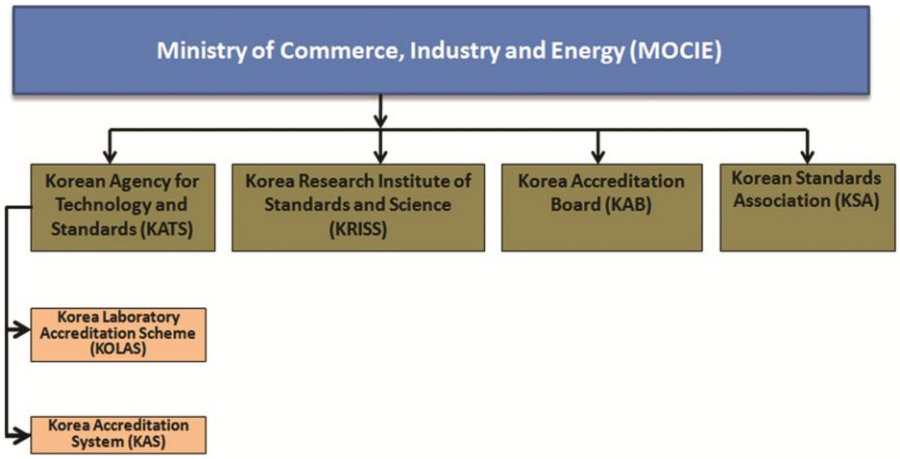

Fig. 12 — Standards and Conformity Assessment Bodies – Republic of Korea

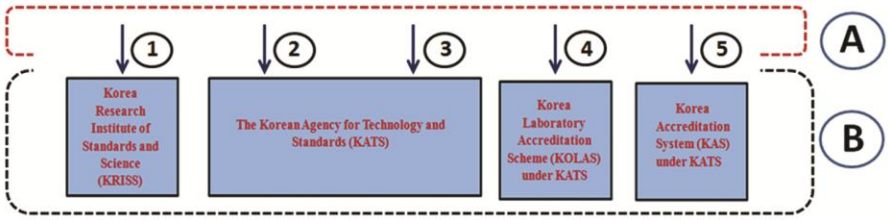

Fig. 13 — Linkages of various bodies to QI in the Republic of Korea

- Functions as the secretariat body of the Korean Industrial Standards Committee

Korea Laboratory Accreditation Scheme (KOLAS) operates under the KATS and provides national accreditation for competent laboratories and inspection bodies. The KOLAS is a governmental accreditation body established in the year 1992 and administered by KATS. KOLAS represent Korea in the International Laboratory Accreditation Cooperation (ILAC) and the Regional Accreditation Cooperation. Korea Accreditation System (KAS) is a national accreditation body established in the year of 2001 within the KATS framework under the Ministry of Trade, Industry & Energy (MOTIE).

The Korea Accreditation Board (KAB) is the accreditation body responsible for conformity assessment and certification for Quality Management Systems (QMS) and Environment Management Systems (EMS). The board is recognized by MOCIE and act as a signatory to the International Accreditation Forum Multilateral Recognition Arrangement (IAF MLA) and represents Korea in the Pacific Accreditation Cooperation (PAC) for QMS and EMS matters.

The Korean Standards Association (KSA) is a certification body accredited by KATS. By the year 1998, KSA is running the Korean Industrial Standards (KS) Certification Scheme, which provides certification mark to the manufacturers in the country. It also carries out the certification according to ISO and other international standard organizations. The Linkages with different bodies at National and International levels are depicted in Fig. 13.

3.6 Quality Infrastructure of USA

The system for conformity assessment in USA is, comprehensive multifaceted and comprised of many diverse activities including testing, management system registration, certification, accreditation, *etc.* The information in Fig. 14 was compiled by the American National Standards Institute (ANSI) to show the linkages of different bodies associated in the countries system for conformity assessment[18].

The National Institute of Standards and Technology (NIST) is the NMI of country, which works under the United States Department of Commerce. The US Naval Undersea Warfare Center Division Newport (NUWC-USRD), the designated institute of NMI deals with US standardizing activity in the area of underwater acoustic measurements.

The International Legal Metrology Program (ILMP) is part of the Office of Weights and Measures within NIST. The primary objective of the ILMP is to facilitate US participation in the technical works of the OIML.

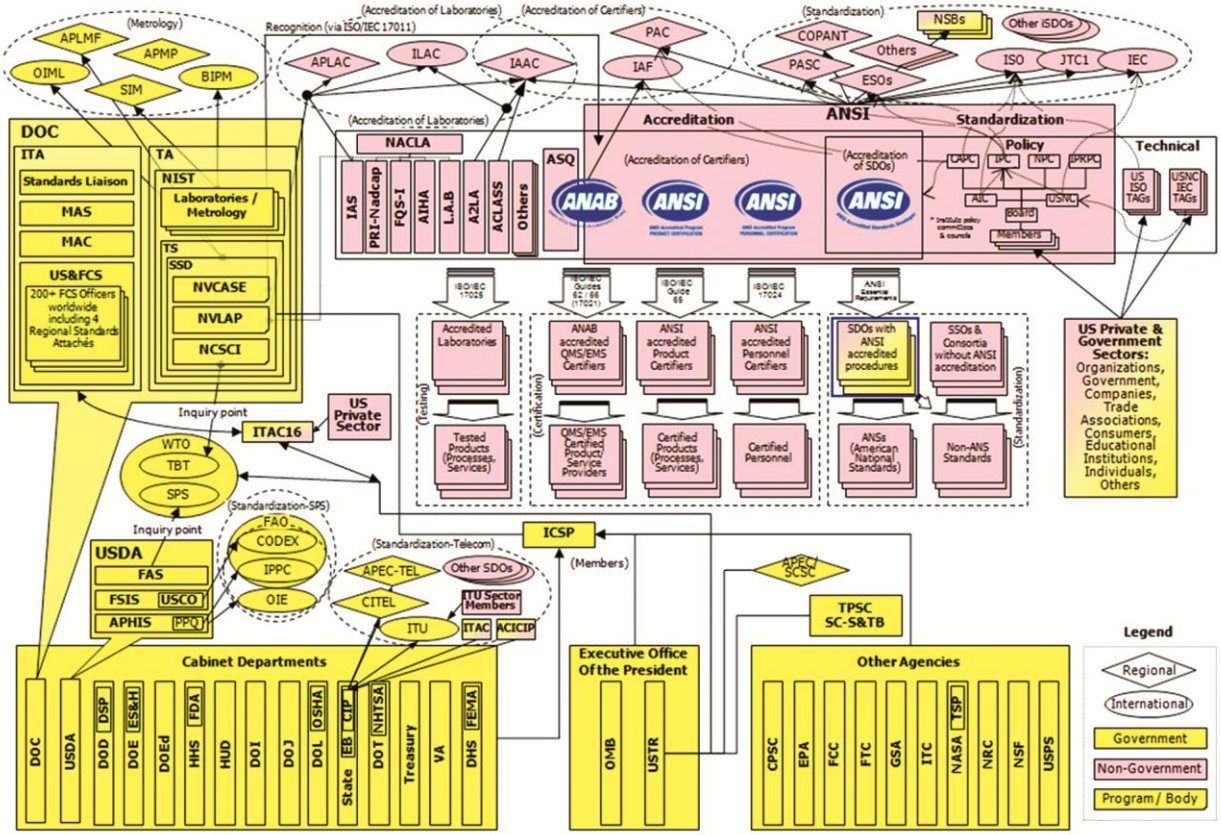

Fig. 14 — Standards and Conformity Assessment Bodies – USA

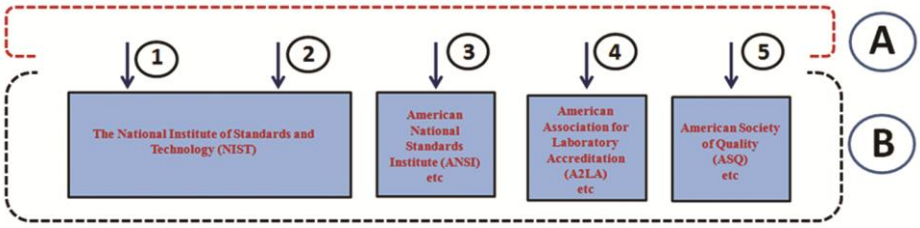

Fig. 15 — Linkages of various bodies to QI in the USA

There are several national accreditation bodies in the country such as American Association for Laboratory Accreditation (A2LA), National Cooperation for Laboratory Accreditation (NACLA), AOAC International, American Council of Independent Laboratories (ACIL), National Voluntary Laboratory Accreditation Program (NVLAP), NCSL International, International Accreditation Service, Inc. (IAS) to name few.

Similar to accreditation bodies, there are various national standards agencies in the USA, which are closely linked with each other;

- ASTM International
- American National Standards Institute (ANSI)
- National Standards System Network (NSSN)

The linkages with different bodies at the national and international level are depicted in Fig. 15.

3.7 Quality Infrastructure of Canada

The Standards Council of Canada (SCC) is a federal Crown Corporation responsible for promoting Canada's standardization. It reports to the parliament through the Minister of Innovation, Science and Economic Development. Oversight for the SCC is provided by the Governing Council, which is supported by the standing committees and advisory committees. The National Research Council of Canada (NRC) is the NMI of the country and counties largest federal research and development.

Measurement Canada (MC) is the National legal metrology authorities of the country. The authority is

responsible to the Parliament of Canada to create legislation and regulations governing the country's weights and measures. Figure 16 shows the Standards and Conformity Assessment Bodies in Canada[19-20]. Figure 17 shows the linkages with different bodies at the national and international levels.

3.8 Quality Infrastructure of Germany

The Federal Ministry for Economic Affairs and Energy (German: Bundesministerium für Wirtschaft und Energie), abbreviated BMWi, is a ministry of the Federal Republic of Germany[21]. Physikalisch-Technische Bundesanstalt (PTB) acts as the NMI of th ecountry. PTB also works as a national legal metrology authority in the country. In Germany, there are two different laws, which define the regulations and requirements in the field of metrology. The German Units and Time Act ('Einheiten- und Zeitgesetz') authorise PTB with the realisation of the units and uniformity in disseminating the units by third parties. This includes the responsibility to ensure the traceability of reference standards used in legal metrology to national standards. The second law in metrology is the German Measurement and Verification Act ('Mess- und Eichgesetz' - 'MessEG'), dealing with all the metrological related subjects under legal supervision.

For the accreditation, Deutsche Akkreditierun gsstelle GmbH (DAkks) is the national accreditation body of the country. Shareholders of the GmbH are the Federal Republic of Germany, the Federal states,

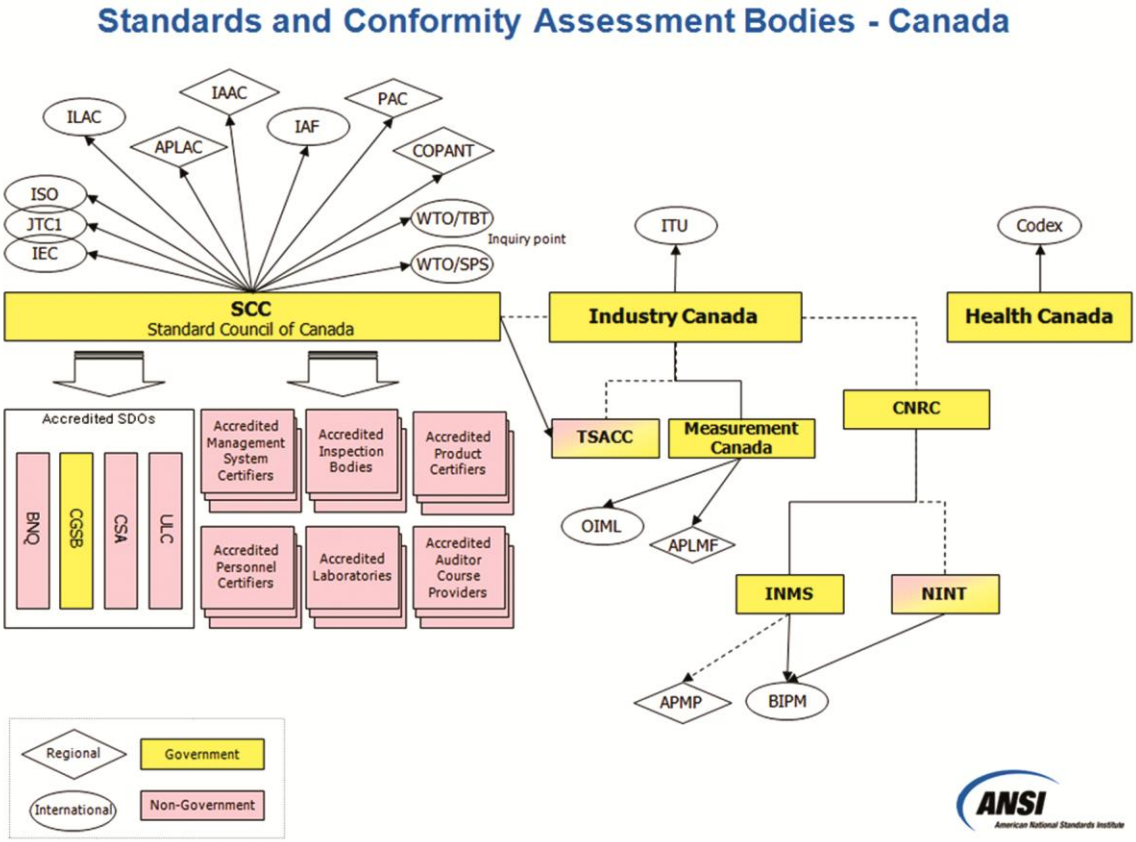

Fig. 16 — Standards and Conformity Assessment Bodies – Canada [20]

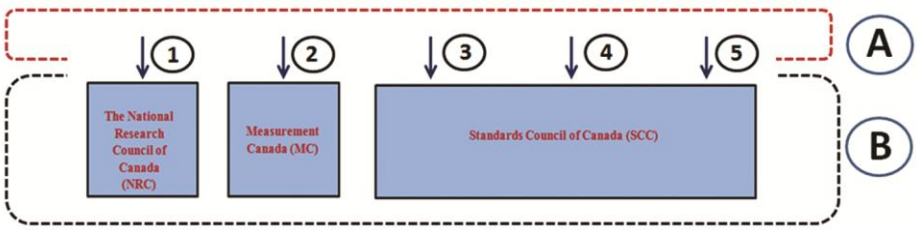

Fig. 17 — Linkages of various bodies to QI in Canada

and the industry represented by the Bundesverb and der Deutschen Industrie e. V. (BDI; Federal Association of German Industry).

Similarly, with standardization**,** DIN, the German Institute for Standardization, is the independent platform for standardization in Germany. It promotes global trade, quality assurance, encourages rationalization, protection of society and the environment and improving security and communication[22].

There are various other important organisations such as German Environment Agency (Umwelt bundesamt – UBA), which is Germany's leading environmental protection agency; The Bundesanstalt für Materialforschung und -prüfung (BAM), which is one of the prime scientific and technical Federal institute with responsibility to the Federal Ministry for Economic Affairs and Energy. The Federal Office of Consumer Protection and Food Safety (BVL) is an agency of the country, which comes under the Federal Ministry of Food and Agriculture (BMEL). The linkages with different bodies at a national and international level are depicted in Fig. 18.

3.9 Quality Infrastructure of France

The Laboratoire national de métrologie *et al* d'essais (National Laboratory of Metrology and Testing) is the NMI of the country. It coordinates all the metrological activities in the country. The laboratory is previously known as the Laboratoire national d'essais (LNE), and still uses the initials. It is state-owned enterprise that operates as an Établissement public à caractère Industriel *et al* commercial, a French type of state-controlled entity of an industrial or commercial nature[23].

A Metrology Committee within the LNE act as an authority responsible for issuing recommendations on scientific and strategic orientations of the LNE's Board of Directors. There are several National Metrology Laboratories (NMLs) and associated laboratories with the LNE (ALS) for specific fields and complement the LNE's mandate.

Comité Français pour l'Accréditation (COFRAC) is a non-profit association taking over the activities of the BNM-FRETAC (Bureau national de métrologie - France Etalonnage Accréditation) and RNE (Réseau National d'Essais). The prime aim of the association is to allow laboratories and organisations receiving accreditation by COFRAC, and the authorities a guarantee of confidence in the services performed by the accredited laboratories bodies.

For Association Française de Normalisation (AFNOR, English: French Standardization Association) is the French national organization for standardization, a member of the ISO. LNE is the partner of the AFNOR group essentially in two capacities. The first objective is standardization. LNE and RNMF laboratory experts participate in the standardization commissions and working groups to develop and formalize national/international standardization projects[24]. The linkages with different bodies in France at the national and international level are depicted in Fig. 19.

4 Global Quality Infrastructure Index (GQII)

In the year 2011, Ulrich Harmes-Liedtke and Juan José Oteiza Di Matteo have proposed a QI

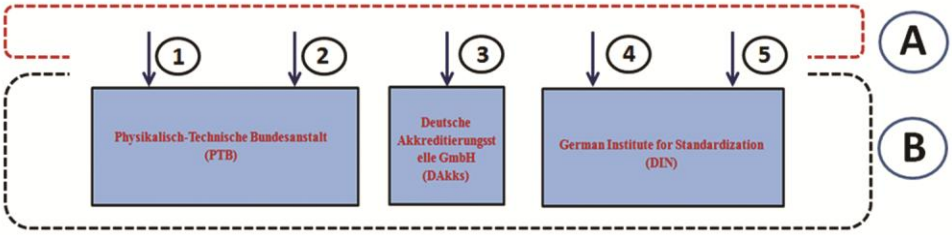

Fig. 18 — Linkages of various bodies to QI in Germany

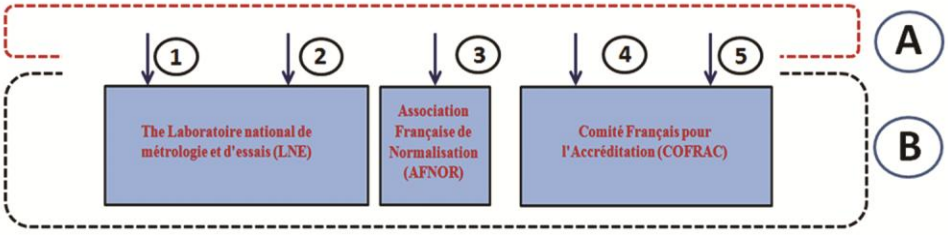

Fig. 19 — Linkages of various bodies in the QI of France

measurement indicator to compare NQIs of different countries[25-26]. It is used for a measure and compares the development and the performance of QI. The mathematical model consists of several factors based on freely available data in public domains such as the total number of accredited bodies in the country; the total number of Calibration and Measurement Capabilities (CMCs); respective ISO 9001 standards in the country; the total number of key and supplementary comparisons carried out by the NMI and associated DIs; Participation in Technical Committees of ISO and the membership of several international organizations backing the credibility of the NQI.

For each component, the data sources' selection is pragmatic, using data from international QI institutions in the public domain and freely available on the internet. Based on the different components' data, a common indicator to measure QI at the national level has been created. Thus, the Index uses QI's key components (mainly Metrology; Standards; Certifications and Accreditation) to measure NQI. The general formula of the Global Quality Infrastructure Index (GQII) proposed by them is as follows:

$$GQII_i = \left(\beta_1 \frac{CMC_i/Pop_i}{max.value} + \beta_2 \frac{K\&SC_i}{max.value} + \beta_3 \frac{ISO_i/Pop_i}{max.value} + \beta_4 \frac{Tech.Comm._i}{max.value} + \beta_5 \frac{CABs\ (9001)_i/Pop_i}{max.value} + \beta_6 \frac{CABs\ (9001)_i/Pop_i}{max.value} + \beta_4 \frac{Membership_i}{max.value}\right) \times \frac{100}{7}$$

Where;

QI = Quality Infrastructure

$Under\ assumption\ of\ equal\ weight$: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 1$

$i = Country_1, Country_2, Country_3, \ldots Country$

Pop = Country Population

CMC = Total $number\ of\ Calibration\ and\ Measurement\ Capabilities\ according\ to\ CIPM - MRA$

K&S Comp. = Total $number\ of\ Key\ and\ Supplementary\ Comparisons\ according\ to\ CIPM - MRA$

ISO = Total $number\ of\ valid\ ISO\ standards\ issued$ (9001, 14001, 22000, 13485 and 27001)

$Tech.Comm.$: No. $of\ Technical\ Committees'\ participations\ according\ to\ ISO$

$CABs$ (9001): No. $of\ Conformity\ Assesment\ Bodies\ under\ ISO/IEC$ 17021 − ISO 9001

$CABs$ (17025): No. $of\ Conformity\ Assesment\ Bodies\ under\ ISO/IEC$ 17025 − $Testing\ Labs\ only$

Membership = No. of Memberships of International QI system ($CIPM$, IAF, IEC, $ILAC$, ISO, ITU, $OIML$,WTO)

5 Analysis and Discussion

The globalization of trade has considerably increased the interest and need for standardization and related conformity assessment at the international level. Nevertheless, most of the economies work towards strengthening innovation and private sector participation. While encouraging greater awareness and participation, some of the developing economies are also attempting to address the need to upgrade the QI. The ability to produce quality products is the means to a strong economy. The country, India has chosen to focus on developing a strong and robust NQI. As per Govt. of India initiatives, 'Make in India' in 2014, Indian National Strategy for Standardization in 2018, and AtmaNirbhar Bharat in 2020, India aimed to prepare itself as a international manufacturing hub, an attractive destination for foreign investment, and finally to become self-reliant. Based on the studies carried out in the present paper, some suggestions are discussed to improve the QI for the country's growth.

In metrology, CMC is one of the most important key factors to improve the quality of life. The primary standards established, maintained, and measurement facilities at NMIs are registered as CMCs at BIPM following a very stringent CMC approval process, involving the evaluation of the measurement capabilities and implementation of the quality system as per ISO/IEC 17025: 2017, at various levels, *i.e.*, peer review by affiliated RMO's appointed technical and quality experts at NMI; reviews by technical committees of respective RMO; reviews by experts from intra and inter RMOs and finally by JCRB at BIPM before publication in the website[27-28].

Figure 20 shows the GQII and GDP status of the top 10 counties. The GQII calculated is in the form of relative or absolute terms. They are then normalised by dividing the maximum value observed in the sample, denoted as the maximum value. This procedure allows the sub-indicators to be summed up, and the average final score is obtained. We have considered only the top ten countries in the analysis, so the ascents and descents in the rankings may occur if one can increase the data set.

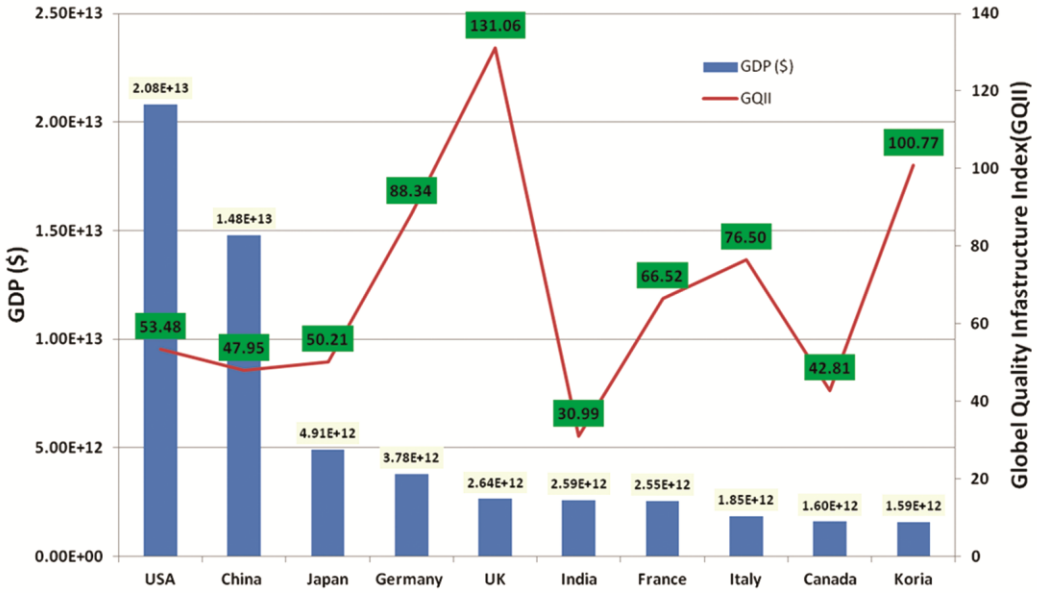

Fig. 20 — GDP and Quality Infrastructure Index status of the top ten economies

Although the Indian GDP is placed at fifth position in the ranking, it is at the lowest level in the case of GQII. Apart from other factors responsible for GQII, it is directly proportional to the number of CMCs and Key and supplementary comparisons, which are the main functions of NMIs. So the quality strength of any country can be improved by increasing these two factors in metrology at NMIs level. It is evident from the plots that it is high time for India to increase the CMCs of CSIR-NPL and its DI, *i.e.* BARC substantially from the existing number of 236 CMCs[29]. The CMCs may further be increased in association with other institutes having excellent measurement capabilities as designated institutes of NMIs as in case of BARC.

As each country implements and upgrades its NQI, also its responsibility to decide how to cater the technological needs; avoid unnecessary technical barriers to trade and mitigate environmental, health, and safety concerns. The road to an internationally recognised NQI is time-consuming, and policymakers face decisions about what type of NQI will be best suited to their countries' for further engagement with the globally integrated economy. Indeed, policymakers also face challenges about how and how quickly to transform the systems they have inherited and how to restructure the conformity assessment infrastructure.

Table 2 shows the QI of various countries studied in the present work and their linkages with respective governmental ministries. It is found that the NQI of developed nations has a more systematic and direct relation with the governmental ministries, which leads to having quick decisions, the framing of policies, arranging administrative and funding resources and regulations *etc.* for manufacturing of quality products, trades, market access, services *etc*..

The import of cheap quality products not only hurt the country's wealth, but also it’s the most significant constrain to Indian industries not owning a brand name at global region. The Indian made products need to earn global respect for quality for India’s economy to change its status from ‘developing’ to ‘developed’ state. For the quality output, Nation needs to inculcate a quality work culture. There are only a few Indian manufacturers, who invest in research and resources to make quality products. Instead, they desperately cut costs to fit into the national market that chooses cheaper products over the better quality products. It is a proven fact that quality comes with a cost. Sooner or later, all the manufacturers and services providers need to realize this fact and act accordingly and start investing in quality.

The lack of knowledge about QI among developing and underdeveloped countries is seen as an important challenge. India's QI needs to be improved to support the economy and quality of life in the country. To support this, all the responsible agencies need to work together in synchronization to develop, support and enhance the QI for safe and environmentally friendly products, services, and processes. As these objectives are mainly centric to metrology, standardization and

Table 2 — The QI Pillars and their linkages ministries/departments

Country	QI Pillar	Associated Governmental Ministry/Department
India	Metrology	Ministry of Science and Technology, Govt. of India[30]
	Accreditation	Ministry of Commerce, Govt. of India[31]
	Standardisation	Ministry of Consumer Affairs, Govt. of India[32]
	Certification	
New Zealand	Metrology	The Ministry of Business, Innovation and Employment[33]
	Accreditation	
	Standardisation	
	Certification	
Japan	Metrology	Ministry of Economy, Trade, and Industry (METI), Government of Japan[34]
	Accreditation	
	Standardisation	
	Certification	
China	Metrology	General Administration of Quality Supervision, Inspection, and Quarantine (AQSIQ) Department, State Council of the People's Republic of China[35]
	Accreditation	
	Standardisation	
	Certification	
Republic of Korea	Metrology	Ministry of Commerce, Industry and Energy, Republic of Korea[36]
	Accreditation	
	Standardisation	
	Certification	
United States of America (USA)	Metrology	US Department of Commerce[37]
	Accreditation	
	Standardisation	
	Certification	
Canada	Metrology	The Standards Council of Canada (SCC) reports to Parliament through the Minister of Innovation, Science and Economic Development Canada[38]
	Accreditation	
	Standardisation	
	Certification	
Germany	Metrology	The Federal Ministry for Economic Affairs and Energy (BMWi), Federal Republic of Germany[39]
	Accreditation	
	Standardisation	
	Certification	
France	Metrology	French Ministry for the Economy and Finance[40]
	Accreditation	
	Standardisation	
	Certification	

accreditation, therefore, the administrators and policymakers in the government may consider QI friendly investment opportunities and funding oriented towards supporting QI related institutions/ schemes.

The first step toward establishing an internationally recognized NQI that supports industrial competitiveness is ensuring good governance and creating institutions that lack conflicts of interest. Thus, to achieve this, the country restructures their NQI and creates independent, transparent institutions that take notice of all stakeholders' voices in the system. An NQI cannot exist without government support. Many countries can take several approaches to upgrade their NQI and so enhance their products, processes, and services and ease technical trade barriers. One such recent study is the development of the Aswal model, which indicates the strength of NQI is essentially required. It should comprise Government; Universities, Science & Technology institutions; civil society and Media and Industry for the economy's overall growth and high quality of life.

6 Conclusion and way forward

Establishing a good QI is a step towards developing the right policy framework conditions and establishes the rule of law. Also, producing quality products is the key to a strong economy. Understanding the role of better QI system of several countries policymakers would be now in a better

position to cope with the implementation of reforms, and they would be more rational and less emotional in decision making. Therefore it is important to investigate and understand the role of QI for the growth of any country. This paper gives a comprehensive overview of the NQIs of the top 9 world countries, including India. The study of the NQIs of leading countries has been analyzed for strengthening our NQI. The case studies of different counties and GQII index analysis reveal that the stronger NQI depends upon the various components of metrology, standardization and conformity. Although there is no direct relation between GDP and GQII standards, it gives a general idea that most advanced countries have reasonably higher GQII. The GQII can be enhanced by increasing the number of CMC; participation in key and supplementary comparisons; acquiring/participating in international committees of various international organization at the NMI level; increasing and granting the accreditation to testing, calibration, medical, biological, chemical, environmental laboratories and accreditation bodies by the level of conformity and assessment bodies (CABs); and developing and implementing more documentary standards for product, service, specification, quality system by the national standardization bodies.

As metrology is one of the prominent pillars of the NQI, NMI's role is undoubtedly pivotal towards fulfilling the goals of "AtmaNirbhar Bharat" (self-reliant India). This will also contribute in various national committees of regulators, stakeholders, standardisation, accreditation, conformity boards/ agencies in formulating guidelines, SoPs, regulations, documents, concept papers *etc*. on various capacities as a member, assessors, advisors and Chairmen *etc*. Studies across the various countries have found that most of the NMIs are directly linked with government/ministries. The direct affiliation/linkages of NMI with ministries help empower NMIs, provide sustainable funding and resources to NMIs and take quick decisions in the interest of national growth.

It is observed from this study that most of the NMIs are directly linked with government/ministries. This direct linkages of NMI with ministries help empower NMIs, provide them with sustainable funding and resources, and take decisions in the national interest. In case of India, NMI is part of CSIR and is connected with Ministry of Science and Technology, Legal Metrology and BIS are with Ministry of Consumer Affairs while Accreditation Boards are under the control of Ministry of Commerce. There are several other regulators associated with other ministries. Although the existing system is providing adequate impetus to industrial growth, it would be more effective, if NMIs are sufficiently empowered to work in synergy and in a more synchronised way similar to other NMIs. It is hoped that this informative study would be very useful as a source of reference for stakeholders.

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