Asia-Pacific
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APEC Capacity Building Workshop on Understanding Conformity Requirements for Software-controlled Weight and Measuring Instruments for Sustainable Trade

APEC Sub-Committee on Standards and Conformance

November 2022

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1. Executive Summary

Standards and conformity assessment related to software used in measuring instruments are gaining popularity among APEC economies for more than a decade; attracting attackers to exploit the devices' software (including the embedded code) to manipulate weighing and measurement value used for trade. The main challenge in this area is to disseminate and harmonize knowledge between conformity practitioners and industry players in accordance to respected standards.

Software controlled weight and measuring instruments are widely used for trades among APEC economies (i.e. digital scale, weighbridges, electricity meter). Measuring instruments used for trades are regulated by law in each economy in this world. Each instrument shall pass certain criteria and requirement before it can be allowed to be used for trades. Nowadays, software became one of the most essential part of the instrument itself,

However, the software part is not sufficiently controlled. Attract attackers to exploit the instruments or devices software as well as the embedded code in order to gain revenue illegally. Tampering of these devices would heavily affect the following parties: relevant authorities in APEC economies, as the gain of trade tax would be tremendously reduced; consumers, since they have to pay more than the actual price; and producers, as they might get less payment than the actual price.

The project helps to achieve towards common understanding and practices in regulating software within the APEC economies as software which has passed certification from any economy within APEC can be accepted by another without much difficulty. This would help to boost the confidence and remove barrier for trades among APEC economies. Hence, the objectives of this project are; to be familiar with standards pertaining to software for measuring instruments, to understand software testing techniques and methods and to understand the best approach to construct a good software for measuring instrument

A preliminary study that was carried out on the potential participants shown that most respondents have a high level of awareness on software conformance and perception towards the importance of Software Conformity. And most respondents have a moderate knowledge in software conformance and believe that the level of readiness of their economy to adopt software conformance is still moderate

An online workshop was held from 10-12 May 2022, each day from 9am to 1pm Malaysia time. In total, 47 participants who work in the area of software controlled measuring instruments and another 132 academics from 13 APEC member economies, including the speakers join the workshop. 30% of the main speakers and 45% of the participants are female.

The workshops sessions consist of welcoming remarks, four sharing sessions, two case studies presentations, four lectures on guidelines and pre and post-test. Sharing sessions topics include Current Practice in Participants' Economies, Challenges in Examining Software for Pattern Approval, IT in Metrology: Scientific Advancement, Software for Measuring Instrument: Good Practice. Case studies covers Non-Automatic Weighing Instrument and Energy Meter Instrument. Whilst lectures cover Overview of OIML Document and WELMEC Document, OIML D31, WELMEC 7.2 and Industrial Practice in Software Testing and Software Documentation.

Pre and post-test were done to measure whether there is an increase in the participants' knowledge and awareness of the related matters during the implementation of the workshop. Finding from test shows that there is an increase in the participants' knowledge and awareness in all three measured aspects.

After the workshop, a post survey was carried out to collect feedback on the workshop, participants' learnings from the conference, and other recommendations. Overall, the organization and the implementation of the project is a success. In addition; a follow-up survey was done and it supports the idea towards implementing software regulations in instruments, mutual recognition of software examination certificate among APEC economies, as well as conducting future workshops that also cover hands-on skills and involving more software manufacturers as participants.

2. Introduction

2.1 Background

The APEC Capacity Building Workshop on Understanding Conformity Requirements for Software Controlled Weight and Measuring Instruments for Sustainable Trade is an APEC project proposed and overseen by the Universiti Kebangsaan Malaysia (UKM) and National Metrology Institute of Malaysia (NMIM), supported by co-sponsoring economies which include Australia; Japan; and Thailand.

Measuring instrument used for trades are regulated by law in each economy in this world. Each instrument shall pass certain criteria and requirement before it can be allowed to be used for trades. Software which is now became one of the most essential part of the instrument itself, isn't sufficiently controlled.

Data collected from a survey in 2017 has shown that most economies in South-East Asia are still having difficulties in examining software for measuring instruments due to several technical constraints such as 1) lack of knowledge and experience on software testing; 2) no developed procedure and 3) insufficient facility (Muhammad Azwan Ibrahim et. al 2018). In the latest Asia Pacific Legal Metrology Forum (APLMF) report, insufficient knowledge on the software part of the instruments opens up possibilities of the instruments being manipulated [25th Asia-Pacific Legal Metrology Forum and Working Group Meetings]. Hence, the workshop will try to address the top two issues stated above by exposing the participants of each economy on technical-know-how in examination of software for regulated instruments. Furthermore, the training materials will help the participants to understand the knowledge in an interesting and structured way.

As devices related to weight and measuring instruments are widely used for trades among APEC economies (i.e. digital scale, weighbridges, electricity meter); attracting attackers to exploit the devices software as well as the embedded code in order to gain revenue illegally. Tampering of digital devices would heavily affect two parties: 1) relevant authorities in APEC economies, as the gain of trade tax would be tremendously reduced; and 2) consumers, since they have to pay more than the actual price. Hence, securing digital devices with secure software will directly benefit both parties, in which it will accurately reflect the actual value and promote fair trade, as well as recognizing the compliance of the devices among APEC member economies.

This workshop also helps to achieve common understanding and practices in regulating software within the APEC economies as software which has passed certification from any economy within APEC can be accepted by another without much difficulty. This would help to boost the confidence and remove barrier for trades among APEC economies.

2.2 Project Objectives

This project aims to build the capacity of project participants through workshop to better support the Roadmap to 2010/2020 under the Osaka Action Plan, regarding Standards and Conformance: to identify common working environment related to weight and measuring software for Asia-Pacific software to enable conformity harmonization. This project also aims to support the Malaysia's Individual Action Plan (IAP) in APEC under Chapter 5: Standard and Conformance, with one of the objectives is to actively participate in international standardisation activities. Hence, the specific objectives of the project are:

a) To be familiar with standards pertaining to software for measuring instruments

b) To understand software testing techniques and methods

c) To understand the best approach to construct a good software for measuring instrument

This initial step is hoped to lead towards a common framework regarding software conformance among APEC economies in the future.

2.3 Project Approach

Jan-March '22 **Feb - April '22** **10-12 May '22** **12 May 2022** **July 2022**

2.3.1 Preliminary Study (Jan-March 2022)

A preliminary study was conducted as the first step of this project, which consists of 2 parts; survey and desk-based study. In the desk-based study, involved a review on articles related to Software Conformance issues and issues in Measuring Instruments,

Whilst the survey aims to measure the level of awareness and readiness on software conformance for measuring instruments among potential participants from APEC member economies, specifically regarding (a) standards pertaining to software for measuring instruments, (b) software testing techniques and methods, and (c) approach to construct a good software for measuring instruments.

Results were presented in the form of description analysis with respondents' demographic and respondents' level of awareness and readiness of software conformity for measuring instruments.

2.3.2 Workshop Preparation (February-April 2022)

A workshop programme was drafted by the organizers; UKM and NMIM and further refined after discussion with the workshop speakers. The programme is comprised of three main knowledge;

> 'Standards related to Software Metrology' topic covered OIML Document (D32) and Recommendation (R76-Non-Automatic Weighing Instrument, R46-Energy Meter), and Welmec Guide 7.2 (Software guide). Both Universal Computer and Embedded Device Software will be discussed.
>
> 'Software Testing Technique' topic focused on some techniques that are relevant to the practice in software metrology examination; static analysis (documentation examination) and dynamic analysis (functional testing-tampered the software, accuracy, data security). OIML Document will be the test basis.
>
> 'The Importance of Software Documentation' enlightened the participants of the importance of good software documentation. Good documentation reflects good software design. In this topic, discussion will focus on the way to write documentation that responds to the OIML Document.

The speakers were identified based on the APLMF and UKM suggestions and on early communication during the preparation of the proposal. Also, by consultation with other interested APEC economies. To achieve gender balance, female speakers were prioritised. The speakers also presented some of their case studies. Speakers were requested to provide 3-5 questions to be used as pre- and post-test questions.

2.3.3 Online Workshop (10-12 May 2022)

The 3-day online workshop was held from 10th to 12th May 2022, for about four hours each day.

Before presentation, participants were invited to answer pre-test questions. After the sharing by speakers, all the participants were invited to share their inputs or questions in chat menu, and hence answered on the third day. Also, at the end of each day, participants were invited to answer post-test questions in a form of gamification.

The target audience are APEC economies' stakeholders especially members of APLMF including standards bodies, accreditation bodies, policymakers and regulators, private sector and industry associations, conformity assessment bodies, as well as interested academics.

2.3.4 Post-workshop survey

After the workshop, a post workshop survey was conducted to collect feedback on the conference and attendee learnings from the workshop, and other recommendations.

A project report is composed to summarise the collected information and discussion outcomes throughout different stages of this project.

3. Preliminary Study

3.1 Approach

This study was the first step of the project. It was conducted in two forms; survey and desk-based study.

This study is essential for measuring the knowledge and experience of the Asia Pacific Economic Cooperation (APEC) economies in performing software testing for measuring instruments. This is to prevent the vulnerability of software measuring instruments from software tampering and illegal activities. Hence, this study measures the level of awareness and readiness on software conformance for measuring instruments among the potential participants. Their early knowledge is obtained based on the following: (a) standards of software for measuring instruments, (b) software testing techniques and methods, and (c) methods for constructing good software for measuring instruments.

The implementation of this study is based on the educational training Kirkpatrick model, which is useful as a reference guide that emphasizes the achievement of learning objectives and considers the short-term of the study. An online survey method was used, in which questionnaires were distributed via email. Data collected were analysed using version 21.0 of the statistical package for the social sciences to obtain the mean values and percentages. Results were presented in the form of description analysis with respondents' demographic and level of awareness and readiness of software conformity for measuring instruments.

Whilst a A desk-based study was conducted using a literature review method. This method can help a researcher retrieve and analyse relevant research from past studies.

3.2 Desk-based study findings

3.2.1 Software Conformance for Measuring Instruments

Most consumers are unaware of the legal metrology control in measuring instruments applied in their daily activities, such as buying groceries, refueling a car, or paying for utility bills. Legal metrology control ensures that trade and business transactions are fairly conducted and profitable. This control not only covers end-user transactions but also involves various levels of business transactions, such as planting, harvesting, and manufacturing. Therefore, measuring and weighing instruments should undergo a process known as pattern or type approval.

The International Vocabulary of Terms in Legal Metrology defines pattern approval as "*a decision of legal relevance based on the review of the type evaluation report and that the type of a measuring instrument complies with the relevant statutory requirements and results in the issuance of the type approval certificate* (OIML, 2013)."

Law compliant with national certification bodies, such as the National Metrology Institute, notified bodies, and/or pattern approver agencies, is responsible for evaluating and issuing the pattern approval certificate (Said, Shukur, & Ibrahim, 2017). The instrument evaluation process for pattern approval, such as pattern approval evaluation, is defined in the same document as a "*conformity assessment procedure on one or more specimens of an identified type (pattern) of measuring instruments, which results in an evaluation report and/or an evaluation certificate* (OIML, 2013)."

Pattern approval evaluation comprises the following:

1. Evaluating and assessing documents (test certificate and results) of the measuring instrument;
2. Assessing the measuring instrument against legal standard requirements, such as those from the International Organization of Legal Metrology (OIML);

3. Testing and evaluating the measuring instrument against maximum permissible error, as stated in the legal standards.

A software-based device is an instrument that uses software to control its operation, which is defined as “a device used to compute and process using software” (NIST, 2014). An advanced and precise measuring instrument, such as an electronic weighing scale in a market or small shop, relies on its software for measurement purposes (Ma, Lu, Mao & Shen, 2012). Therefore, the software for measuring instruments has become a crucial element that must be evaluated in the pattern approval processes to ensure the reliability of instruments.

Studies show that some traders manipulate and cheat on measuring and weighing instruments. Mechanical methods were previously used to manipulate the readings of measuring and weighing instruments to gain additional profit. However, the software of measuring instruments has become the most vulnerable element to be manipulated (Al Wosabi, Shukur, Ibrahim, 2015). Numerous cases have been reported in Malaysia (Ibrahim, Shukur, Zainal & Al Wosabi, 2015).

Software evaluation, verification, and assessment during pattern approval are crucial for ensuring a credible and smooth operation for weighing and measuring instruments and systems. The penalty for using fraudulent measuring instruments is stated in Section 17 of the Weight and Measures Act, 1972 (International Law Book Services, 2009) as follows: *whoever owns any weight, measure, or instrument for weighing or measuring, which he knows to be false and intending that the same may be fraudulently used or having fraudulently used such weight, measure, or instrument for weighing or measuring shall be guilty of an offense and shall, on conviction, be liable to a fine not exceeding five thousand ringgit or to imprisonment for a term not exceeding four years or to both. Any weight, measure, or instrument for weighing or measuring used or in any person’s possession for use in contravention of this section shall be liable to be forfeited*.

Therefore, software for measuring instrument should also be checked and verified to ensure that the measuring instrument system work as intended within the specified standards and tolerances.

3.2.2 Issues of Software Conformance for Measuring Instruments

Everything in the digital era now relies on software. It plays an important part in banking, trading, medicine, production, entertainment, and education. Its vulnerabilities cause software piracies, code stealing, and software tampering. This does not only affect the software industries but can also cause serious trouble in economic and legal situations, where people nowadays tamper with or manipulate software in every sector to favour their needs. This includes manipulation and illegal deception of measuring instruments and scales previously for mechanical methods but involves software vulnerability in a modern nowadays.

There are several real-life cases where software tampering could be a serious threat to the community. A recent case occurred in Rompin, Pahang, in 2021, where KPDNHEP confiscated computerized vehicle weighing equipment in exchange for palm weighing equipment. The computer system for this tool is believed to have been manipulated to make excessive profits (N. Yusof 2021). Furthermore, Ibrahim et al. (2015) reported other cases in several locations in Malaysia. In 2013, the authorities identified a scam that occurred at a petrol station in Silibin, Ipoh. A similar case also found occurred in India in 2008 (Abdo et al. 2015).

Several cases, which involved software fraud on vehicle scales for agricultural use (APEC 2009), were reported in Thailand. The United States is no exception; Tasić (2012) reported that as early as 1999,

the software for calculating oil prices was modified and was only accurate to the value of a coefficient of 5 gallons. Thus, the price was higher than usual. This is because the tool verification oil in the United States is equivalent to five gallons. Brazil has also been reported to have lost USD 300 million over 5 years because of metrological fraud (Soratto et al. 2018).

In 2019, a house in Sibu Sarawak was found to have modified an electric meter. Authorities detected this theft because the bill differences were very significant compared with previous usage (DayakDaily 2019).

Simultaneously, economies in the APEC have also raised concerns about the functionality and use of software in measuring instruments, such as oil pumps and electronic scales. Some of the 24 concerns are related to the accuracy and security of software embedded in generating measurement values (MCS 2010).

These situations occur because the regulation of software on measuring instruments is still uncontrolled, and this software is extensively vulnerable to manipulation.

3.2.3 The Needs of Awareness Program

Software used on weighing and measuring equipment is one of the most essential measuring instruments, and users should obtain software compliance approval before using it for trading. Weighing and measuring instruments (such as digital scales, weighbridges, and electricity meters) are widely used for trades among APEC economies, thus attracting attackers to exploit the software and embedded code of devices to illegally obtain income. However, there are challenges in checking software for measuring instruments, such as a lack of knowledge and experience to perform software tests, no developed procedures, and standards to be adhered to, and inadequate facilities (Muhammad Azwan Ibrahim et. al 2018). Insufficient knowledge is a major challenge as it opens the possibility of manipulated instruments (the 25th Asia Pacific Law Metrology Forum and Working Group Meeting).

Furthermore, the APEC member economies should be enlightened about the risks and hazards associated with fraudulent software measuring instruments. Previous research identified that awareness training programs can provide employees with the initial knowledge, which is the key to reducing the number of security breaches (Ghazvini & Shukur 2017). Awareness is an effective tool for reducing illegal software activities. Thus, APEC economies should be aware of the potential threats of software fraud and the consequences of their actions. An effort to develop a level of awareness of software conformance for measuring instruments is crucial for APEC members as a means of protecting information assets. Continuous and adequate awareness, education, and training programs will make them the first line of defense against fraudulent software (Innab et al. 2018).

3.3 Survey findings

An online survey (using questionnaire) was distributed to respondents via email to potential participants from APEC economies, specifically the APLMF members. A total of 17 responses received from the respondents were compiled and analysed to examine the level of awareness and readiness of software conformance for measuring instruments.

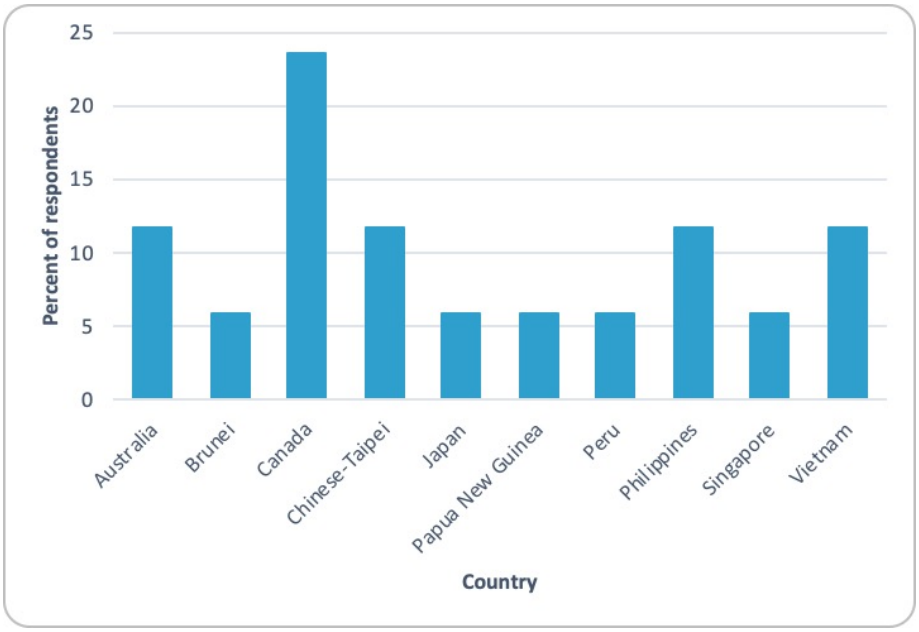

Figure 1

These findings show that most of the respondents are males who have a background in engineering and have more than 6 years of experience in related fields.

The overall mean level of awareness and readiness in this study includes moderate and high levels as respondents consist of APEC software practitioners and officials working in the area of software measuring instruments.

Moreover, findings show that most respondents have a high level of awareness (mean value exceeds 3.0) for software conformance of measuring instruments. The item shows that the OIML/WELMEC are international organizations in legal metrology, which recorded the highest mean value of 3.82. This is because most respondents are from member economies of the OIML (88.2%). However, the two items regarding the proper techniques that can be used in a software examination and the appropriate methods for preparing good software documentation only obtained a moderate level with the mean value of 2.65 and 2.47, respectively, which can later be improved through the current emphasis in the workshop.

Meanwhile, respondents' knowledge levels were high for items relevant to the OIML document, which specifically contains requirements for the software, and items related to the OIML D and OIML R documents. However, they have a moderate level of knowledge regarding the differences between OIML D and OIML R, the relevant WELMEC document that specifically contains requirements for the software, the basic category of requirements for software in the WELMEC document, the general process flow of approval in the software examination, how to perform software examinations using the correct software testing techniques, and the difference between good or bad software documentation. The reason for this moderate result is that most respondents do not know the process during the software examination because they have never been involved in software testing techniques.

Furthermore, the findings show that all respondents agreed that the level of readiness of their economies to adopt the software conformance for measuring instruments is still moderate. This is because most economies of the respondents do not have regulations covering the software part, and their software for measuring instruments does not go through pattern approval checks and thus is not checked during market surveillance. This makes their software vulnerable to tampering.

Finally, the results show a high level of respondents' perception of the importance of software conformity with a mean value exceeding 3.0 for each item. This proves that most of the respondents have high perceptions and awareness in terms of understanding the importance of applying software conformity, but this application cannot be practiced because of their economy's lack of readiness to implement software conformity for measuring instruments.

Overall findings include the level of awareness and readiness of respondents on software conformity for measuring instruments to determine their understanding of software standards for measuring instruments, software testing techniques and methods, and the best method for constructing good software documentation. This in turn achieves the objective of the implementation of the preliminary study.

More details of the preliminary study report can be found in Annex 3

4. Workshop Discussion

The workshop was a 3-day online event that delivered a tailored programme to disseminate information and share experience of Understanding Conformity Requirements for Software-Controlled Weight and Measuring approaches and practices implemented in APEC member economies. The workshop included several sessions with expert sharing and presentations, participant question and answer, and breakout sessions to maximise learning and knowledge retention.

4.1 Workshop objectives

The workshop objectives are aligned with the overall project objectives, that is to equip participants with:

- familiarisation with standards pertaining to software for measuring instruments
- Understanding of software testing techniques and methods
- Understand of the best approach to construct a good software for measuring instrument

4.2 Workshop date and time

The online workshop was held from 10-12 May 2022, each day from 9:00 am to 1:00 pm Malaysia time. The workshop agenda can be found in Annex 1.

4.3 Participants

The workshop was attended by in total 47 officials who work in the area of software measuring instruments from 12 APEC member economies, including the speakers. They are from Australia, Brunei, Canada, China, Japan, Papua New Guinea, Peru, Philippines, Singapore, Chinese Taipei, Viet Nam and Malaysia. In addition, there are also another 132 participants from academia, mostly from Malaysia and Indonesia also joined the programme.

The complete list of participants can be found on Annex 2.

4.4 Workshop Sessions

The workshop was comprised of 5 sessions:

- Welcoming remarks
- Sharing Session
    - Current Practice in Participants' Economies
    - Challenges in Examining Software for Pattern Approval
    - IT in Metrology: Scientific Advancement
    - Software for Measuring Instrument: Good Practice
- Case Studies
    - Non-Automatic Weighing Instrument
    - Energy Meter Instrument
- Lecture
    - Overview of OIML Document and WELMEC Document
    - OIML D31
    - WELMEC 7.2
    - Industrial Practice in Software Testing and Software Documentation
- Pre and post test
    - Pre-test is done by filling in online questionnaire before the case studies and lectures.
    - Post-test is done by playing gamification after the case studies and lectures.

4.4.1 Welcoming Remarks

The workshop is organized in collaboration of UKM and SIRIM, as well as with the support from Asia Pacific Legal Metrology Programme (APLMF), hence three parties were invited to give opening remarks; First was President of Asia-Pacific Legal Metrology Forum (Dr. Osman Zakaria), second was Deputy Vice-Chancellor in Research and Innovation of Universiti Kebangsaan Malaysia (Prof. Dato' Ir. Dr. Hj. Abdul Wahab Mohammad) and finally wasPresident and Group Chief Executive of SIRIM Berhad (Dato' Dr. Ahmad Sabirin Arshad, FASc.).

Prof. Dato' Ir. Dr. Hj Abdul Wahab thanked Center for Cyber Security of UKM and NMIM for organizing the workshop and hoped that the participant will gain valuable knowledge in the workshop.

Dr. Osman introduced the APLMF to the audience and emphasized on the importance of software inside measuring instruments to be regulated. He also briefed the steps that required within the pattern approval process of measuring instruments.

Dato' Dr Ahmad Sabirin said that the workshop was held timely for Malaysia as the Government is also promoting fit-for-purpose metrology for the Malaysian economy and social benefits. He hoped all participants and observers will gain new knowledge and insights from the training course while sharing own experiences among the trainers, overseas participants as well relevant local communities.

4.4.2 Sharing Sessions

a. **Current Practice in Participants' Economies**

Sharing Session on **Current Practice in Participants' Economies** was coordinated by Dr. Tsuyoshi Matsumoto, a senior member of Asia Pacific Legal Metrology Forum. Four economies: Australia, Canada, Japan, and Malaysia shared their current practices in Software Metrology examination. It was carried out on the first day of workshop.

National Measurement Institute Australia (NMIA) was represented by Dr. Philip Mitchell. NMIA regulates measuring instruments used for trade. Requirements for pattern approval are generally based on OIML Recommendations. NMIA Pattern Approval laboratory carries out the approval process and NMIA also accept test results from other laboratories (including OIML-CS). In regards to verification, it is performed by third-parties which are authorised by NMIA. Generally, NMIA does not perform verifications. Third-parties and verifications are inspected and audited by NMIA. For in-service inspection, it is performed by NMIA (Trade Measurement Inspectors).

Mr. Pascal Turgeon representing Innovation, Science and Economic Development Canada (ISED), Canada. **Measurement Canada** is a special operating agency within the department of ISED. They administer and enforce Electricity and Gas Inspection Act; and Weights and Measures Act; as well as responsible on their related regulations and specifications. Measurement Canada develop rules and requirements; approve devices for use in Canada; administer programs for initial inspection and periodic reverification of devices to ensure measurement accuracy is maintained; accredit private sector companies to perform inspections; investigate business and consumer complaints of suspected inaccurate measurement; and certify measurement standards. For electricity and gas devices, the software requirements are documented in S-EG-05 for software control and S-EG-06 for event loggers. (These 2

documents are mainly based on OIML D-31 (2008)). For weights and measures devices, limited software requirements from D31 and Welmec 7.2 have been introduced for certain device types but further implementation is needed.

Dr. Satoshi Matsuoka from **National Metrology Institute of Japan** (NMIJ) shared about current practice in Japan. NMIJ responsible in the maintenance of measurement standards in Japan. Type approval of measuring instruments including NAWIs, taxi meters, fuel flow meters, etc. NMIJ is one division of National Institute of Advanced Industrial Science and Technology (AIST). The Measurement Law in Japan stipulates basic elements of legal metrology, and it refers to Japanese Industrial Standards (JIS). JIS specifies technological regulations about measuring instruments. NMIJ in charge of type approval for NAWs, Taxi Meters, Fuel Flow Meters, Water meters, etc. There are Verification Offices (in each prefecture and in major cities. Software examination are done on the following measuring instruments; taxi meters, NAWs and fuel flow meters.

Ms. Haslina Abdul Kadir represented **National Metrology Institute of Malaysia** (NMIM) and shared current practice in Malaysia. NMIM is a special Business Unit under SIRIM. It facilitates domestic and international as well as ensuring safety, health and environment for Malaysians through measurement. Malaysia started software examination in 2019, for software-controlled measuring instruments. The examination is on the fulfilment of the respective software against the related requirements. For energy meters, the requirement is based on OIML R 46-1/-2 clause 3.6 (Protection of metrological properties), and the examination is based on OIML R 46-3:2013 Item 3 (Validation procedure). For weighbridge control software, the requirement is based on OIML R 76-1 clause 5.5 (Additional requirements for software-controlled electronic devices) and the examination is based on OIML R 76-1 Annex G.

During the session, **several questions and issues** were raised by the participants. The issues related specific on the regulations such as from Malaysia (Dr. Muhammad Azwan) raised the issue on the real cases happening in Canada, from Singapore (Faith Tan) regarding the the accuracy and software tampering check during market surveillance, and from Philippines (Ahdrian Gernale) regarding on how to encourage applicants to apply for the software approval where the regulations in certain economies which don't have the mandatory requirements for software and also from Brunei regarding whether the verification is done by the government or third-party organisation.

There were also several questions regarding the process of the examination itself such as from Canada (Daljit Dhaliwal) regarding the issuance of separate approval certificate for software and whether the source code is required within the process of examinations. Dr. Hasimi Sallehudin raised a question regarding the direction of development of standards on software for measuring instruments in Japan, while Japan (Dr. Tsuyoshi Matsumoto) highlighted that Japan has developed their own requirements based on OIML along with additional unique requirements that suit for Japan industries.

And lastly, general questions such as on the cybersecurity issues in software for measuring instruments from Malaysia (Dr. Siti Norul Huda), from Singapore (Faith Tan) regarding the challenges with regards to software issues specific to weight and measuring devices. Adnan Rashid from Malaysia raised additional question regarding the metrology programs for electric vehicle in Japan and lastly from Singapore (Faith Tan) raised the issue on sharing the approval information for companies that have successfully obtained the approval certificates.

b. **Challenges in Examining Software for Pattern Approval**

Informal sharing about **Challenges in Examining Software for Pattern Approval** by Japan, China and Malaysia was carried out in the 3rd day of workshop. Following that was Q&A moderated by Dr. Tsuyoshi Matsumoto. Japan was represented by Dr. Satoshi Matsuoka (NMIJ), China by Ms. Zhou Bihong (SIMT) and Malaysia by Dr. Muhammad Azwan Ibrahim, National Metrology Institute of Malaysia (NMIM).

Dr. Satoshi discussed the applicable law related to software examinations in Japan. He also discussed some of the real examination processes during software examination. Ms Zhou then discussed the process practiced in real situation and how the developer could provide the evidence whether certain relevant requirements OIML have been complied. Lastly Dr. Muhammad Azwan from Malaysia presented the common mistake in designing software for measuring instruments as well as common errors found inside technical documents submitted by applicants during examination process.

c. IT in Metrology: Scientific Advancement

The last presentation of day 2 was given by Dr. Muhammad Azwan Ibrahim from National Metrology Institute of Malaysia (NMIM). He shared about IT in Metrology: Scientific Advancement by. He presented the practical method to measure the security level for software in legal metrology by using risk analysis combined with attack tree. In the previous study, the attack tree in the legal metrology could not be proven in terms of the correctness. He then proposed a new technique to be added in the risk analysis framework where the attack tree is converted into finite state transition domain. By using this method, the correctness properties of the attack tree can be successfully determined.

d. Software for Measuring Instrument: Good Practice

The 3rd day session was continued with sharing on Software for Measuring Instrument: Good Practice by an established metrology related software manufacturer that was Mettler Toledo. The presentation was given by Mr. Suresh Candra Bose from Mettler Toledo (M) Sdn Bhd, Malaysia and the introduction was given by Mr. Herb Atens from Mettler Toledo, USA. Mr. Suresh started the presentation with the generic architecture of a weighbridge system, data integrity key elements as well as highlighted all the vulnerable points that possibly being exploited traders. He then introduced the latest technology offered by Mettler-Toledo; which is digital loadcell in combination of cryptographic techniques in order to secure transactions against manipulation and preserve data integrity.

4.4.3 Case studies

a. Non-Automatic Weighing Instrument

First case study is on Non-Automatic Weighing Instrument, and shared by Dr. Satoshi Matsuoka from National Metrology Institute of Japan (NMIJ), Japan. Regarding OIML D31, there are some part that Japan exercise differently. In Japan, password protection is allowed, but in EU, it is not allowed. In OIML D31, activities that are legally relevant and which may influence the metrological characteristics, should be recorded with time stamped. It is a kind of ‘change log’. However, Dr Satoshi commented that if the instrument has been secured and/or sealed, there should not be any changes. Dr Satoshi further commented that software interface is also regarded as legally relevant software (not non legally relevant software).

Dr Satoshi continued his presentation by giving an overview of OIML R76-1. The gist of this document is to classify software controlled NAWIs into “Embedded” type and “PC” type; and to

classify software controlled NAWIs into that with data storage devices (DSD) and that without DSD.

In Japan, a NAWI is specified to be under legal control, this include utility meters, fuel dispenser, taxi meter. Measurement Law refers to Japanese Industrial Standards (for short JIS), and JIS B 7611-2 is for NAWIs, which is basically, Japanese translation of OIML R76-1:2006. NMIJ prepared the template for documentation of a manufacturer: based on PTB's document. Also, making internal manuals of NMIJ for software examination.

Japan started in 2009 which they received 24 submissions from five companies; two were "PC" type and the others are "Embedded" type. Each examination took at least a half day

Besides NAWIs, Dr Satoshi also shared his experience in examining taxi meters and fuel flow meters. Based on his experience running software examination for three kinds of measuring instruments, he said that NAWI's examination is most complicated.

b. Energy Meter Instrument

Second case study is on **Energy Meter Instrument** and presented by Ms. Zhou Bihong from Shanghai Institute of Measurement and Testing Technology (SIMT), China. Ms Zhou started her presentation with an overview of Energy Meter instrument, and the related requirements as described in document OIML R46. Based on validation procedure mentioned in OIML R46 for specified requirements, Ms Zhou shared seven interesting cases that she encountered when examining related software. This sharing gave ideas to the audience the real situation when examining software. Ms Zhou challenged the audience to give opinion whether to approve the software, or not.

c. Questions and Answer

Several issues were raised during this session such as from the Chairperson herself (Prof. Dr. Zarina) regarding whether source code is being examined in Japan, and Japan confirmed that they did not examine the source code.

Two representatives from Malaysia, (Wan Jazmi) raised several issues on the firmware updates, parameters protection, key management system and time synchronization. (Syarizal Zainal Abidin) asked regarding the time required by SIMT to complete an approval for software as well as on how to check the originality of certificates and reports issued by SIMT.

4.4.4 Lectures

a. Lecture on Overview of OIML Document and WELMEC Document

Lecture on Overview of OIML Document and WELMEC Document was given by Dr. Daniel Peters from Physikalisch - Technische Bundesanstalt (PTB), Germany. OIML document is an International Recommendations for measuring instruments subject to pattern evaluation and approval. It is suggested by International Organization of Legal Metrology (OIML). Whilst WELMEC document is a kind of similar document suggested by WELMEC which is a body set up to promote European cooperation in the field of legal metrology.

b. Lecture on OIML D31

Following that, a lecture on OIML D31 (NMIM) was presented by Dr. Muhammad Azwan Ibrahim from National Metrology Institute of Malaysia (NMIM), Malaysia. OIML D31 is general requirements for software-controlled measuring instruments. It does not cover all technical requirements however it can be found in the relevant Recommendation, e.g weighing instruments.

c. Lecture on WELMEC 7.2

Lecture on WELMEC 7.2 was given by Dr. Daniel Peters from Physikalisch-Technische Bundesanstalt (PTB), Germany. This document provides technical guidance for the application of the Measuring Instruments Directive (MID) [2], for software-equipped measuring instruments.

d. Lecture on Industrial Practice in Software Documentation

Lecture on **Industrial Practice in Software Documentation** was given by Prof. Dr. Okfalisa from Universitas Islam Negeri Sultan Syarif Kasim Riau, Indonesia. Dr Okfalisa started with different understanding of software among management, customer, and practitioner. Hence, there is a need to have mechanism that can provide standard communication among different stakeholders and within practitioners themselves. Two classes of software document; document that record the process of development and maintenance, and document that describe the product being developed. IEEE Standard for User Documentation can be used as a tool to develop a framework for software user documentation. There are also other standards that covers on process, product and interchange related to software.

e. Lecture on Industrial Practice in Software Testing

Lecture on **Industrial Practice in Software Testing** was given by Assoc. Prof. Dr. Jamaiah Yahaya from Universiti Kebangsaan Malaysia, Malaysia. Dr Jamiah discussed several terms that seems similar; validation testing versus defect testing, validation versus verification, inspection versus testing. Validation testing is to demonstrate to the developer and the system customer that the software meets its requirements, whilst defect testing is to discover faults or defects in the software where its behaviour is incorrect or not in conformance with its specification. Next verification is to check that the software conforms to its specification, whereas validation is to check that the software does what the user really requires. Inspection related to static verification, and testing related to dynamic verification. She then further discussed the process in software testing.

4.4.5 Pre and post test

Pre-test was done by filling in online questionnaires before the case studies and lectures. In total there are about 29 questions related to the respective topics. There were 12 questions were asked on the first day, 10 questions on second day and 7 questions on the last day. Whilst, post-test was done through a gamification activity which was carried out every day, at the end of the workshop. The result is discussed in section 5.

4.5 Gender balance

4.5.1 Speakers

The number of female speakers was 4 out of a total of 10 speakers, which was 40% and exceeded the project target of 30%.

4.5.2 Participants

The number of female participants was 14 out of 47 officers which was 30%, and 67 out of 132 academics which was 51% and both categories exceeded the project target of 30%.

5. Pre and Post Test

5.1 Introduction

Pre and post-test were carried out to measure whether there is an increase in the participants' knowledge and awareness of the related matters during the implementation of the workshop. 37 participants from APEC economies involved in the study. Three main aspects were measured namely Software in Legal Metrology (Standard), Software Examination, and Software Documentation.

5.2 Result and Discussion

The results of the percentage of accuracy for the three aspects in the pre and post-test are shown in Table 1, Table 2, and Table 3. The percentage of accuracy refers to the correct answer responses by all participants in percent. Overall, there is an increase in participants' knowledge and awareness after participating in the workshop for all three aspects.

Table 1 shows that 37 participants have their knowledge and awareness increased in all 12 items in the Software in Legal Metrology aspect. On average, there is an increase in awareness of standards about software for measuring instruments from 21% during the pre-test to 49% during the post-test.

Table 1 Software in Legal Metrology/Standard (Day 1)

#	Item	Percentage of Accuracy	
		Pre-test	Post-test
1	How many Risk classes does WELMEC 7.2 have?	3%	51%
2	OIML has two security levels.	38%	70%
3	Which device is a risk class D device according to WELMEC?	8%	37%
4	Generally, in the OIML D31, software requirement is divided into how many categories?	22%	35%
5	What are the two most commonly used OIML Publications?	27%	62%
6	Which section in the OIML D31 documents that explain the software requirements?	22%	51%
7	How many methods for software examinations in D31?	16%	40%
8	What is the most basic software examination method and applicable to all purposes?	27%	43%
9	What is the missing word?"6.1.1 The software identification shall be ___ linked to the software itself"	16%	45%
10	Name 3 Security Characteristics:	24%	51%
11	Which guide enhances the WELMEC 7.2 with risk analysis techniques?	19%	43%
12	Code slicing as described in the presentation is a static analysis method.	32%	56%
	Percentage Average :	21%	49%

Meanwhile, there is an increase in the overall items for the Software Examination aspect from the 20 participants who responded (refer to Table 2). However, there is no increase in knowledge and awareness for item 7 which is "Which options are legally relevant for an energy meter in the following choices?" who recorded the same percentage (20%) in the pre and post-test. The average percentage increased from 50% (pre-test) to 65% (post-test).

Table 2 Software Examination (Day 2)

#	Item	Percentage of Accuracy	
		Pre-test	Post-test

1	The version number of a measuring instrument must be kept secret to verification authorities.	65%	60%
2	The owner of a measuring instrument can change legally relevant parameters of the instrument anytime he/she wants without leaving the evidence.	80%	90%
3	In the case of unavoidable circumstances, the software identification of a measuring instrument does not need to be displayed in the indicator, but should be labeled on its plate.	60%	80%
4	The use of Cyclic Redundancy Check (CRC) is not appropriate for software identification.	45%	70%
5	Storing measuring values obtained from a measuring instrument for later transactions is prohibited.	55%	70%
6	Which option shall be stated in the type approval certificate? It shall be inextricably linked to the software itself and shall be presented on command or displayed during operation.	60%	75%
7	Which options are legally relevant for an energy meter in the following choices?	20%	20%
8	Which two options are practical for software validation procedures?	50%	60%
9	The audit trail shall contain at minimum the following information:	10%	45%
10	Exchanging the software with another approved version in service should be considered as a modification of the measuring instrument.	55%	80%
	Percentage Average :	50%	65%

The result in Table 3 shows increased knowledge and awareness in the preparation of software documentation from the 19 responses received. Compared to other items, Item 1 obtained the lowest percentage, only 21% increase was recorded during the post-test, from 5% during the pre-test. On average, participants' knowledge and awareness increased from 35% (pre-test) to 53% (post-test) for the Software Documentation aspect.

Table 3 Software Documentation (Day 3)

#	Item	Percentage of Accuracy	
		Pre-test	Post-test
1	The target audience for user documentation, except…	5%	21%
2	The document that explain how the software will be tested and record result:	42%	73%
3	The reason used content management system for documentation storage, except…	16%	47%
4	During the Static testing method, the code is not executed, and it is performed using the software documentation.	53%	57%
5	What are the different levels of Testing?	63%	78%
6	In which environment we can perform the Alpha testing?	42%	47%
7	In which environment we can perform the Beta testing?	21%	47%
	Percentage Average :	35%	53%

In conclusion, there is an increase in the participants' knowledge and awareness in all three aspects measured. However, the percentage of accuracy is inconsistent since not all participants who participated provided feedback during the pre-and post-test. In addition, the implementation of online

workshops also affects test results due to limitations in the process of delivering a topic or information, in addition to the different levels of understanding of the participants.

6. Post workshop survey

6.1 Introduction

The purpose of this post workshop survey was to collect feedback on the workshop, attendees' learnings from the conference, and other recommendations. After the workshop, an online post workshop survey was conducted to collect feedback on the workshop and attendee learnings from the conference, and other recommendations.

The respondents were invited to share the level of satisfaction of the workshop including quality and relevance of the objective, agenda and topics, speakers and their content, organising of the conference, materials distributed, time allocated, level of knowledge improvement, and whether the conference achieved the objectives.

Besides that, a follow-up survey was carried out in order to obtain participants' intention of having the following:

a) software regulation in instruments used for trade in participating economies
b) mutual recognition of software examination certificate
c) disseminating the knowledge to their industries
d) more technical workshops for software industries
e) more activities in the future in harmonizing the software in measuring instruments

6.2 Results of the Workshop Survey

The total number of respondents was 9.

Overall, the implementation of the "APEC Capacity Building Workshop on Understanding Conformity Requirements for Software Controlled Weight and Measuring Instruments for Sustainable Trade" project was successful. Over 80% of the 9 participants gave positive feedback to this workshop. They either "Agree" or "Strongly Agree" with the statements about the workshop.

Most participants agreed that the workshop was relevant and helpful for their jobs. They admit that this workshop meets their expectations, and helps them with new learnings or knowledge. The speakers or presenters that were selected are knowledgeable. Only more than half agreed on the duration of the workshop implementation. Overall, all participants were satisfied with the implementation of this workshop where many key takeaways were obtained. Among them is an understanding of software testing, the requirement for software control, software verification used in trade, an overview of WELMEC 7.2 and OIML D31, and software examination.

From the context of logistic facilities, more than 78% percent of participants were satisfied with email communication, welcome activity, venue, activities, and closing ceremony. Some reflections from the participants on what can be improved in the future include the difficulty in seeing the slides being displayed, waiting time for gamification that took too long, more question and answer sessions and a longer break was needed due to different time zones.

In terms of workshop content, the majority of the participants believed that the Welcome activity session, Sharing Session - Current Practice in Participants Economies, Overview of OIML Document and WELMEC Document (PTB), OIML D31(NMIM), WELMEC 7.2 (PTB), Non-Automatic Weighing Instrument (NMIJ), Energy Meter Instrument (SIMT), IT in Metrology: Scientific Advancement (NMIM), Challenges in Examining Software for Pattern Approval, and Industrial Practice in Software Testing and

Software Documentation (UIN RIAU and UKM) were the most relevant for this workshop. Only 67% of participants responded that the "Software for Measuring Instrument: Good Practice" session was relevant.

In summary, the participants gave positive feedbacks and found the workshop was excellent, very well organized, very interesting, and informative.

6.3 Results of the Follow-up Survey

The total number of respondents was 9.

Nearly all of the respondents agree that software regulation in instruments should be implemented for trade in their economies. However, in term of mutual recognition of software examination certificate among APEC economies, majority (66.7%) of the respondent agree, whilst the rest are not sure. Nearly all agree that the knowledge delivered during the workshop should be disseminated to the respective industries as well. In addition, all of the respondents agree that more technical and hands-on workshops should be conducted for software industries. In the future, nearly all of the respondents agree that more activities in harmonizing the software in measuring instruments should be organized.

7. Recommendations

The following recommendations were derived through the observations and follow-up surveys.

a. Continued sharing of good practices, exchange experiences and case studies on requirements and examination of Software Controlled Weight and Measuring Instruments

b. Continue to raise awareness of requirements and examination of Software Controlled Weight and Measuring Instruments

c. Initiatives to encourage harmonisation of standards related to Software Controlled Weight and Measuring Instruments

d. Technical assistance for standards related to Software Controlled Weight and Measuring Instruments

e. Cross fora collaboration within APEC, and even beyond APEC

Annex 1 – Workshop agenda

Annex 2 – List of participants

Annex 3 – Details of preliminary study results

Annex 4 – List of standards referenced in this project