

Digitalization of Calibration Workflow at National Institute of Metrology Thailand (NIMT)

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Abstract – This paper presents the strategic digital transformation of workflows at the National Institute of Metrology Thailand (NIMT). The implementation of digital technologies has significantly reduced human errors, enhanced accuracy, and increased transparency in data handling. NIMT has proactively developed and deployed digital platforms across the organization to support this transformation. A key outcome of this initiative is the Equipment Management and Tracking System (EMTs), developed in alignment with ISO/IEC 17025, which enables efficient electronic management of measurement instruments. The integration of technologies such as Optical Character Recognition (OCR) and Digital Calibration Certificates (DCC) has further improved data accuracy and reduced processing time. In support of quality assurance, NIMT is also planning to develop a digital system to enhance its audit processes and ensure continued compliance with quality standards. This digital shift not only strengthens NIMT's operational capabilities but also aligns Thailand's measurement infrastructure with international metrological practices.

I. INTRODUCTION AND METROLOGICAL CHALLENGES

The digitalization of calibration workflows at NIMT represents a strategic shift in how measurement data is managed, processed, and utilized. However, this transition is not without its challenges. As with many national metrology institutes worldwide, NIMT faces a complex set of obstacles that must be addressed to achieve an efficient and sustainable digital transformation. These challenges can be categorized into five primary areas [1]:

1. Infrastructure and Budget Limitations

A fundamental requirement for digital transformation is the establishment of a robust and secure IT infrastructure. This includes cloud-based data centers, scalable storage systems, high-speed networks, and cybersecurity protocols, all of which are essential to support real-time calibration workflows and digital certificate issuance.

However, as a public agency, NIMT often faces budgetary constraints, limited flexibility in procurement, and lengthy approval processes. These limitations can hinder the timely acquisition and deployment of critical digital technologies, delaying initiatives such as the integration of real-time data acquisition from calibration instruments or the implementation of secure metrology cloud services [2].

2. Complexity of Metrology Systems and Data Integration

Metrology systems inherently involve the handling of highly sensitive and precise data from calibration values and measurement uncertainty to traceability chains and international equivalence. Migrating such data to a digital system requires absolute precision and consistency. One major challenge lies in integrating data from diverse instruments and legacy systems into a centralized digital platform. These older systems were often developed in isolation and were not designed for digital interoperability, resulting in fragmented databases and inconsistent data formats. Harmonizing such data across platforms without compromising accuracy or traceability presents a significant technical hurdle in the digitalization of calibration workflows

3. Development of Digital Skills for Personnel

While NIMT staff possess deep expertise in scientific measurement and engineering, the shift toward digital workflows requires an expanded skillset particularly in areas such as data analytics, software integration, automation systems, and artificial intelligence. Many personnel need upskilling to adapt effectively to new tools and systems used in digital calibration processes. This skill development requires structured training programs, ongoing knowledge transfer, and a cultural shift toward embracing technological innovation. Without these efforts, the full benefits of digital transformation may not be realized, and the risk of system underutilization or operational errors may increase

4. Data Security and Regulatory Compliance

In the digital calibration context, data integrity and security are non-negotiable. Metrological data not only supports critical industrial applications but also serves as a

legal reference in regulated sectors. As such, digital calibration systems must comply with national cybersecurity laws, such as the Personal Data Protection Act (PDPA), and adhere to international standards for information security. NIMT must ensure that its digital platforms are designed to prevent unauthorized access, data breaches, and service disruptions. At the same time, the integration of new technologies must be carefully aligned with regulatory requirements to avoid legal or operational risks.

5. Policy Changes and Interagency Coordination

Digital transformation initiatives are often influenced by national policy directions and interagency collaboration. At NIMT, policy shifts, especially those related to digital governance or public sector reform, can have a direct impact on resource allocation, strategic focus, and project continuity. Furthermore, digital calibration workflows require coordinated data exchange and system integration with external stakeholders, including government agencies, industry clients, and international metrology networks. Any misalignment in policy, priorities, or technical standards may result in delays or inconsistencies in implementation.

Therefore, the digitalization of calibration workflows at NIMT entails navigating multiple layers of complexity ranging from infrastructure and budget limitations to human resource development, data security, and policy alignment. Each of these challenges must be strategically addressed to ensure that the transition from traditional to digital calibration not only improves efficiency and accuracy but also meets international expectations and national regulatory standards [1, 3]

II. STRATEGIC GOALS FOR DIGITALIZING THE CALIBRATION WORKFLOW

The transition from analog processes to digital systems has become an essential strategy for national metrology institutes, including the NIMT, to respond effectively to the accelerating pace of technological advancement and the growing complexity of industrial demands [3, 4]. The adoption of digital technology is not merely an operational upgrade; it serves as a fundamental enabler for enhancing Thailand's measurement infrastructure to meet internationally recognized standards. Despite the clear benefits, the path toward full digitalization of calibration workflows presents various technical, organizational, and policy-related challenges. To overcome these barriers, it is vital for NIMT to establish well-defined strategies and objectives that provide direction and coherence for the transformation process. The following strategic goals have been identified as central to the success of this digital transition:

1. To enhance operational efficiency: Streamlining calibration workflows through digital platforms reduces manual errors, minimizes redundant processes, and

accelerates service delivery turnaround times. Automation and real-time data exchange support higher productivity and greater responsiveness to customer needs.

2. To elevate the precision and reliability of measurement standards: Digital systems facilitate accurate storage, processing, and analysis of calibration data, ensuring consistency and reducing uncertainty. These capabilities are essential for maintaining traceability and reinforcing confidence in national measurement standards.

3. To promote transparency, traceability, and accountability: The use of centralized digital platforms enhances the traceability of calibration records and strengthens document security. Digital audit trails and secure access controls ensure compliance with legal, industrial, and international standards.

4. To facilitate data and workflow integration across agencies: By harmonizing systems and protocols with both national and international stakeholders, NIMT can improve collaboration and data interoperability. This ensures that calibration results align with global frameworks, such as those promoted by the BIPM and regional metrology organizations.

To foster digital competency and readiness among personnel: A critical success factor lies in developing the digital capabilities of NIMT's workforce. This includes training in digital tools, data analytics, and emerging technologies empowering staff to adapt to new systems and drive innovation from within [4].

III. METHODOLOGY AND EXPECTED RESULTS

1. To handle the challenges of infrastructure and budget limitations

The implementation of digital systems at NIMT will bring several positive outcomes, particularly in enhancing the accuracy and speed of operations. One of the key advantages is the reduction of errors associated with manual data entry. For instance, Optical Character Recognition (OCR) technology, which converts images into editable and searchable text, has been applied in research conducted by Naruesorn Nanna et al. [5]. Their study, titled "A Two-Layer Deep Learning-Powered Optical Character Recognition for Enhanced Calibration Processes," was part of the DX research group at NIMT. The study found that OCR technology significantly reduced calibration times, comparing the traditional method (03:05:58 hours) with OCR software (02:20:02 hours), resulting in a time reduction of up to 24.70%. Furthermore, OCR technology improved the accuracy of data processing. An example of the OCR software in use is shown in Figure 1.

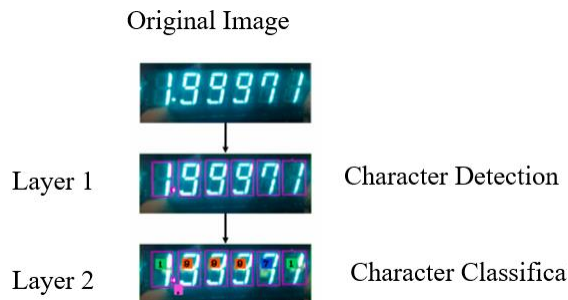


Figure 1. presents the steps for character detection and classification in measurement results using OCR software

The OCR process also helps mitigate budget constraints by reducing the need to invest in full-scale systems to receive or read real-time data from machines and laboratory equipment [5, 6].

2. Complexity of Metrology Systems and Data Integration

To address the challenge, NIMT has established a robust process for maintaining the quality and accuracy of its calibration services. Yearly, the calibration process is thoroughly reviewed to ensure compliance with established standards. This review process, known as the audit, assesses whether the procedures and outcomes meet the required criteria [7]. If any part of the process is found to be non-compliant, the auditor issues a Non-Conformance (N/C) report. Should the N/C be confirmed, the Quality Management (QM) department issues a Corrective Action Request (CAR), directing the responsible personnel to address and resolve the issue.

However, there is currently no system in place to efficiently track and manage the resolution of CARs in a timely manner. To address this limitation and enhance operational efficiency, NIMT plans to implement a digital system for tracking CAR resolutions. This system will facilitate more streamlined, accurate, and faster responses to corrective actions, supporting the broader goal of digitalization and significantly improving operational effectiveness and modernization. In addition, NIMT is currently building a database that captures the scope and capabilities of each calibration service. This system will be connected to the relevant standard body part in Thailand, enabling real-time verification of measurement capabilities and ensuring that NIMT's services remain aligned with national standards.

3. Development of Digital Skills for Personnel

Traditionally, lab staff used Microsoft Excel to record data, calculate results, and print calibration certificates in paper format for customers. Digital Calibration Certificates (DCC) [8, 9] are a new concept for them. To support this shift, NIMT has developed a web-based platform at dcc.nimt.or.th. It allows NIMT staff to generate DCC in PDF/A3 with attached XML files, integrated with

internal systems for accuracy and security. General users can generate XML-only DCC. The platform includes schema and Schematron validation and uses the Electronic Transactions Development Agency (ETDA) verification services that is a government agency under the Ministry of Digital Economy and Society to verify digital signatures, ensuring compliance with digital standards. This approach not only streamlines the DCC generation process but also supports the development of new skills among NIMT staff.

4. Data Security and Regulatory Compliance

NIMT has enhanced its data management processes by making them more systematic and accessible. Electronic documents are now stored in the Equipment Management and Tracking System (EMTs) [8, 10]. Figures 2. shows an overview of the duty structures in EMTs and Figures 3. illustrates the data storage and management system. When equipment is received along with its certificate, the owner stores the certificate and related data in electronic form in the EMTs. Authorized users can then log in to search for the equipment data within the system.

The key benefits of this system include easier document retrieval, improved data privacy, and enhanced security.

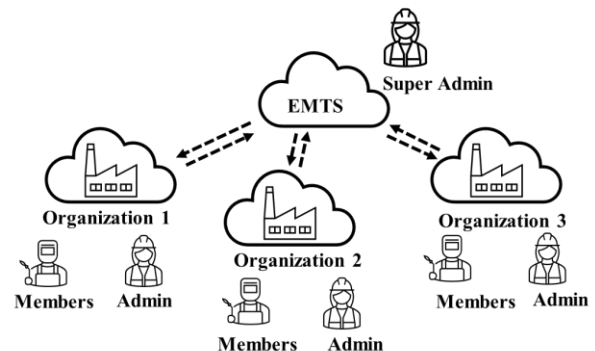


Figure 2. Diagrams of the duty structures in EMTs system

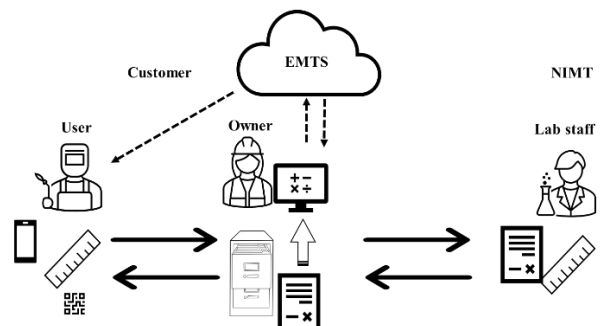


Figure 3. illustrates the data storage and management system – EMTs

5. Policy Changes and Interagency Coordination

National policies are often difficult to predict and cannot be directly changed [11]. However, NIMT can prepare for

digital transformation by improving its internal structures and processes to effectively support these changes. By fostering cooperation both within the organization and with external partners, leveraging modern technologies, and continuously monitoring progress, NIMT can strengthen its readiness and enhance the efficiency of its calibration services at the international level.

IV. CONCLUSION

The digitalization of calibration workflows at the National Institute of Metrology Thailand (NIMT) represents a significant advancement in aligning national metrology practices with international standards. By implementing systems such as the EMTs, OCR technologies, and DCC. NIMT has improved data accuracy, reduced processing time, and enhanced transparency across its services. These developments address key challenges, including legacy system integration, infrastructure limitations, regulatory compliance, and workforce digital readiness. The planned introduction of a digital system to support audit and quality management processes further reinforces NIMT's commitment to continuous improvement and ISO/IEC 17025 compliance. This transformation has not only increased operational efficiency but also fostered a culture of innovation and collaboration within the organization. Staff have gained essential digital skills, and interdepartmental coordination has improved, enabling more responsive and reliable calibration services. NIMT's experience illustrates that successful digital transformation requires strategic planning, cross-functional engagement, and sustained effort. It provides a practical model for other metrology institutes seeking to modernize their systems in response to evolving technological and industrial demands.

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