RML++: Development of Calibration Management System for Regional Metrology Laboratory Dost-Calabarzon, Philippines

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Abstract: The Regional Metrology Laboratory is the lone government institution that provides calibration services in Region IV-A or in CALABARZON. RML's objective is to guarantee the safety and fair trade of both local and international markets by calibrating measuring devices and instruments used by industry and the general public. RML is also ISO/IEC 17025 certified, demonstrating that its calibration services meet the international standard for testing and calibration laboratories. However, the complexity of the preparation of calibration certificates with the increasing number of clienteles becomes the bottleneck and cause of delay in the release of certificates. RML ++ is a system which is a management software solution that optimizes the processing of documentary requirements, from the receipt of customers' measuring devices and instruments to the issuance of calibration certificates. The system was developed using the Model-Driven Architecture (MDA) that is built on the principle of abstraction, modelling reuse, and patterns to help understand standard referencing and all the mathematical calculations of the three (3) calibration certificates namely the Single Range Electronic Balance, Thermohygrometer, and Test Weights. RML ++ was able to reduce the processing time of the calibration certificates from encoding to releasing with a systematic process of the mathematical calculation of uncertainty and selection of standards.

Keywords: Calibration management system, single range electronic balance, thermohygrometer, test weights

1. Introduction

By virtue of the Republic Act No. 9236 also known as National Metrology Act of 2003, the Regional Metrology Laboratory (RML) formerly known as Regional Metrology Center (RMC) was established in 2003. A joint venture of DOST- CALABARZON as the servicing unit and the Laguna State Polytechnic University as co-implementor. RML aims to calibrate measuring devices and instruments utilized by industry and by the public to ensure the safety and fair trade to both local and international markets. In fact, RML became the leading institution that provides calibration services in the region for several years and continues to provide accurate and reliable measurements to its customers. RML is also ISO/IEC 17025 accredited that proves and conforms that its calibration services are complying to the international standard for testing and calibration laboratories [1].

The citizen's charter of RML indicates the turnaround time of the calibration process, it indicates the

specific time of the delivery of services to customers. The calibration process begins with the preparation of formal quotation, acceptance of technical service requests, and the releasing of calibration results. On time issuance of calibration certificates is important to ensure customer satisfaction. With the increasing numbers of customers and limited numbers of workforce, RML personnel face challenges in the preparation of Calibration Certificates due to the implementation of the manual system. Under the current process, Microsoft Excel is used as the main platform for the computation and preparation certificates. The raw data from the calibration results is written on the worksheet and then manually transferred to the calibration certificates in excel format. Accuracy, reliability, and precision of the certificates could be compromised as the current process could be error prone. The release of calibration certificates should be released within the span of 8 days however, because of the underlying situation it could take more days.

Process streamlining with the application of an information system is very important. The system will be designed and tailored to RML processes and transactions. It will give the opportunity for the RML personnel to increase their productivity in terms of the number of customers they can accommodate. Moreover, the system will speed up the release of customers' calibration certificates, and the assurance of data accuracy and precision adjustment in the calibration process is guaranteed [2].

As part of their commitment to continual improvement and to give their customers an added value of satisfaction, RML ++ or the Development of Calibration Management System for Regional Metrology Laboratory DOST-CALABARZON is conducted. RML ++ is a management software solution that will streamline the processing of documentary requirements from receiving of measuring devices and instruments of customers to the releasing of the calibration certificates that focus on three calibration certificates these are Single Range Electronic Balance, Thermohygrometer, and Test Weights. The system will provide a platform for data input of customer's information, instrument details, calibration procedures, calibration results and certificates. The system includes data management of RML processes, data bank for easy retrieval of documents, printing of calibration certificates and generation of reports. RML ++ provides management solutions in handling their documents efficiently, with data accuracy, and on time release of calibration certificates. Thus, the system can be used as a tool to increase and support RML personnel productivity because of streamlined processes at the same time providing better services to customers [3].

2. Related Literature

Most of the testing and calibration laboratories in recent years have adopted information management systems to strengthen the information construction. There are benefits of having a Calibration Management System (CMS) as stated, it can provide guarantee of improving refined management level of measuring and testing by standardizing business processes. Moreover, implementation of CMS improves the management of risk specific processes and increases the reliability results in paper documents. RML having ISO/IEC-17025 accreditation ensures customers with a technically competent laboratory that has a quality management system by providing the best services and maintaining records efficiently [4, 5].

Project (Monitoring and Evaluation Information System) MEIS is a type of Management Information System (MIS) to demonstrate accountability and promote organizational learning for the benefit of future projects [6], which also act as a real-time platform that synchronizes various users that interact with it [7].

MIS and MEIS are integrated and upgraded as e-governance systems in the Philippines' local government to deliver more accessible and efficient services to the communities [8]. LeMTrac, eBPLS, eBPS, RPATs, PoPS and the IIDS are the e-governance systems funded by DOST-PCIEERD to LGUs as initiation to transform local government services into a one-stop web portal solution.

Legislative Management and Tracking System (LeMTrac) is a computer legislative management system implemented in the Local Government Unit of Nabua and Bula in Camarines Sur to give solution to the

identified problems in the existing process of the legislative management of the LGU such as difficulty in document management, delayed processing time, and the inability to track the status of a document [9]. E-Building Permit and Licensing System (eBPLS) is a web-based system aimed to convert the conventional paper-based process into a faster and easy way using eBPLS in the renewal and application of business license and permit in the fifth District of Camarines Sur. The system will provide electronic generation of permits, electronic checking and processing of documents and provide online forms and account for easy tracking of business application permits [10]. Interoperable ID system Solution for e-Government Systems (IDS) enhanced the citizen-centric services' portfolio [11], Point of Payment Systems (PoPS) serves as the central unit in the Finance Department that manages and accepts transactions of payment from taxes, fees and those charges collected by the LGUs [12]. The Electronic Building Permit System (eBPS) permits the citizen to track the inspections' schedule, permit requests' progress, to print certifications by themselves, attach e-plans and requirements and receive corrections. Real Property Assessment and Tax Management Systems (RPATs) automates transactions of real property (collection liquidation, assessment, and appraisal) and the users or public can print and access Declaration of real Property Value (DRPV) and view auction for delinquent real property [12–14].

The abovementioned management information systems are implemented in the Municipality of Nabua and Bula in Camarines Sur, which serves as a one-stop web portal accessible to the Municipality staff and citizens with function restriction based on the user distinction.

Regional Offices of Department of Science and Technologies (DOST ROs) developed management information systems in effort to centralized and manage projects by DOST such as DARIUS I, FIRST, SMIS, eProMIS, DPMIS and DATOS and is accessible to the different DOST Regional offices nationwide.

DARIUS I (Data Analytics-Ready Info Unified Systems), which harmonized the project information system of the DOST Regional Offices. Local servers hosted by the DOST ROs automatically upload project information to the DARIUS central server which then stores and consolidates the data that is accessible in the DARIUS DOST central system. It improves operational management, helps in decision making by enhancing data gathering, standardization, monitoring and sharing practices [15].

Fast and Interactive Processing of Requests for Science and Technology (FIRST) is an information system developed and implemented by DOST 6, which records, processes, and tracks customer requests. This can complement IMPRESSION in fully document activities prior to project proposal approval. Scholarship Management Information System (SMIS) is an in-house system developed by DOST 9, which stores information on DOST-SEI scholars and relevant information used for monitoring. DOST CARAGA is developing the productivity measurement system of the DOST ROs called Electronic Productivity Management Information System (eProMIS). DOST Central Office, through the DOST-PCMD is implementing the DOST Project Monitoring Information System (DPMIS) developed by DOST ITD that gathers data from R&D Councils and Institutes of DOST which has an existing related database in which IMPRESSION can upload its projects database and/or download its contents to be included in the Central IMPRESSION platform [16]. DOST ASTI has a Project called Remote Sensing and Data Science (DATOS) Help De]. Otherect, which capitalizes on the current advancements of computing technology and applies it in the fields of Geographic Information Systems (GIS), Remote Sensing (RS), Artificial Intelligence (AI) and Data Science to provide maps and other information for Disaster Risk Reduction applications.Other developed online services platforms led by DOST ROs which will be integrated to IMPRESSION are DOST 2's oneSTore, DOST 6's OneExpert, DOST 9's OneLab, DOST CALABARZON's WATCH and GeoRisk Philippines' Hazard Hunter [16–18].

3. Methodology

The modified software development cycle in the process of developing the software was adopted. The phases are requirement analysis, system analysis, system development, testing and debugging, deployment and system maintenance as shown in Fig. 1.

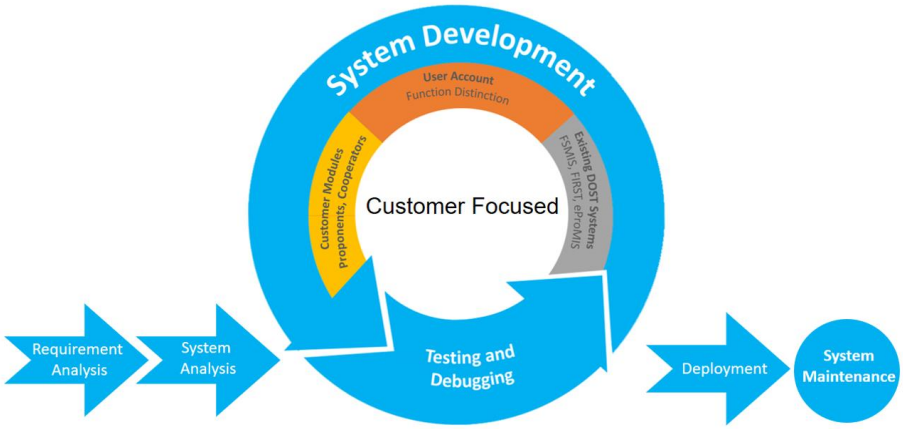

Fig. 1. System development methodology.

Requirement Specification: A Group discussion with RML and LSPU-CCS team was conducted to ascertain the requirement on the preparation of a calibration certificate. It involves data gathering, hardware and software specification. In data gathering, all the forms used in calibration were collected to the RML together with a stand-up meeting to discuss all the requirements in evaluating an equipment and the process in issuing a certificate. Table 1 shows the hardware specification in developing the calibration system.

Table 1. Hardware specification for the development

Hardware Specification	
Central Processing Unit (CPU)	i5 @ 1.5GHz 10th Gen
Random Access Memory (RAM)	4 Gigabyte
Hard Disk Drive (HDD)	500 Gigabyte
System Type	64-bit Operating System

Likewise, Table 2 shows all the software needed to develop the calibration system. In this table, there are three main software identified to deliver the project considering the user requirements as discussed during the requirements specification.

Table 2. Software specification for the development

Hardware Specification	
React Native Framework	V 0.63.4
Visual Studio Code (VS Code)	v1.54.1
Node JS	v 12.18.2

3.1. System Analysis

Systems analysis was conducted to fully refine the process flows, database structures, user interfaces, and other relevant information systems considerations. In this phase, the top-view and other architectural of the calibration system was used as guideline for developing the project. The use of different logical

designs such as data flow diagram, use case diagram and functional decomposition diagram help for the analysis of the business process of RML transactions.

The system architecture illustrates the interconnection of system modules of RML++ system, as shown in Fig. 2. RML++ includes five (5) main modules such as Account Management Module, Calibration Management Module, Report Generation Module, and Dashboard Module as essential components of the project.

3.2. Account Management Module

The user account management allows different users to access their accounts in the system at different access levels. The primary users are the RML personnel and customers that are able to create, edit and save user account information. Accounts created by the user have restrictions on functions and features based on user needs.

The Calibration Management module is part of the system that streamline the calibration process for the receiving of instruments, evaluation, the calibration of instruments, encoding of the results of the calibration, verification / validation and printing and releasing of calibration certification.

The Report Generation Module allows the users to generate reports based on the historical data of the system.

The System Dashboard Module provides user information based on simple data analytics of the laboratory services, Summary of the provided services, and data visualization to provide users with infographics.

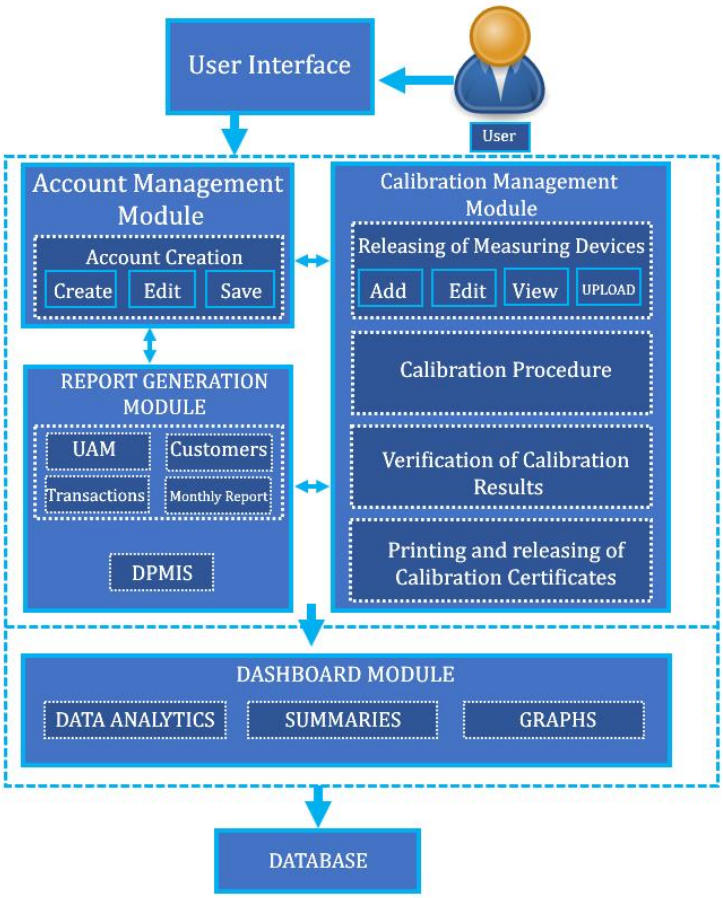

Fig. 2. RML++ system architecture.

3.3. System Development

Model-Driven Architecture (MDA) was used that is built on the principle of abstraction, modelling reuse, and patterns to provide the project with an additional tool to help understand and develop the system. MDA provides a framework to identify and classify all the system development work being done in the project (see Fig. 3).

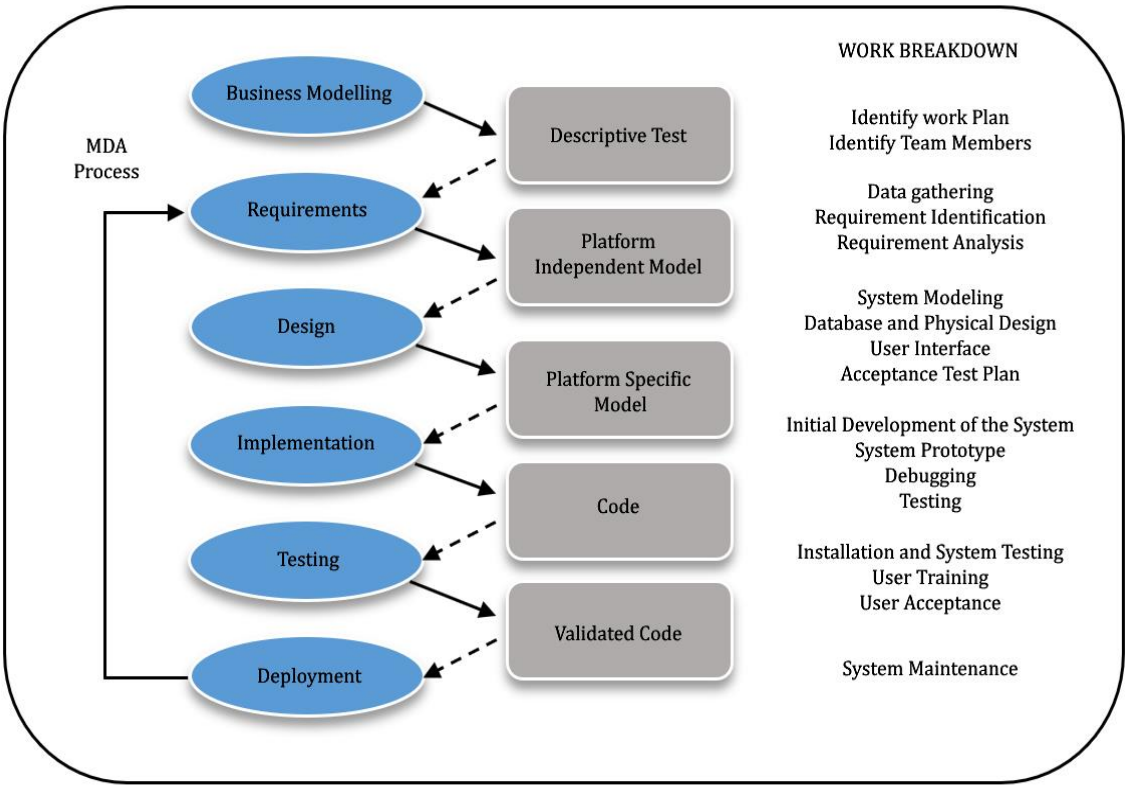

Fig. 3. Software development method and model-driven architecture.

The process of creating software is represented in the diagram. Processes and adaptive, iterative processes can both use the paradigm. In predictive processes, the development team compiles all the specifications, creates a thorough design, and then codes the complete system. The flow is repeated multiple times across various iterations in adaptive techniques.

3.4. System Development

Represents the written materials that outline the demands of the user. Typically, these documents include of notes, rough drawings, outlines, and other disorganized descriptions of the procedures and user actions.

3.5. Platform-Independent Model (PIM)

These are models based on the organization structure that is built independently.

3.6. Platform-Specific Model (PSM)

It details the computer information platform and implementation specifics.

The adoption of Model View Controllers (MVC) Framework was integrated in system development most specially in the coding and design phase. It gives the program developers and the users' direct interaction with the system development. The framework includes Model that represent the business logic or operation to be performed. The View that represents the content using design interface and the Controllers, that facilitate user interaction, work with the model and determine the view selection to render. A

documentation of these frameworks details the activities conducted during the development of the system.

Upon identification of the user requirements and analysis of the process flow, system development will follow. With careful consideration the parameters identified by RML personnel will be given high priority. These are,

1. Calibration officer will directly encode raw data or results in the system installed in a tablet or mobile phone. Eliminating worksheets in a paper form.

2. The system immediately generates a calibration report in a pdf form after encoding. Uncertainty of measurements, corrections, date conducted, person who conducted the calibration, place and other details of the calibration done are automatically reflected on the report.

3. An admin or the Laboratory Head will verify the accuracy of the report generated. He or she will approve/disapprove the release of the calibration certificate.

4. A Calibration Certificate ready for release can be an electronic copy or can be printed.

3.7. Testing and Debugging

Testing and debugging were performed throughout the system development. This includes comparison on the conventional preparation of certificates and the newly developed system (see Fig. 4).

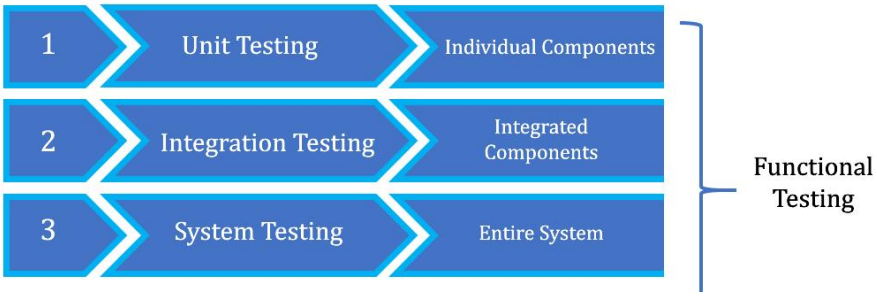

Fig. 4. Software testing.

Software testing involves unit, integration and system testing, which is a combination of functional and non-functional testing. The testing consists of a series of test cases to ensure that the developed system is working properly.

3.8. Deployment

RML ++ deployment uses client/server architecture as shown in Fig. 5.

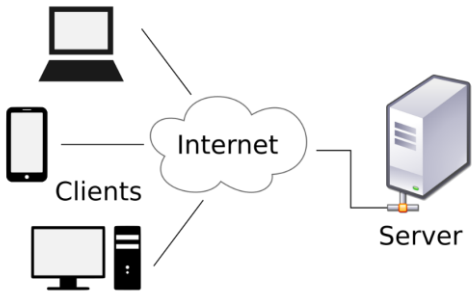

Fig. 5. Client/Server architecture.

The implementation of the system employs a client server paradigm. The server hosts the developed system connected to the internet, the main function of the server is to supply the needed information of RML personnel and their customers. The system was designed in a multiplatform that runs in mobile devices, laptop, or tablet to give users the capability to access and perform business transactions outside

RML offices.

Before the system is deployed for utilization, it will be subjected to live testing. In this case, the system was installed, configured, and hosted to LSPU servers. All components, features and system functionality were tested and should be passed based on the expected outcome. After the live testing, the system was installed and configured to a dedicated server, the minimum hardware and software specifications for the server and thin client are presented in Table 3.

Table 3. Client/server specifications

	Hardware Specifications		
		Web Server	**Dedicated Server**
Server Specifications	Max # of users	1-500	1-500
	Operating System	Window 10 Professional	Linux OS
	Database Engine	SQL Standard	SQL Standard
	Memory	8GB	16 GB RDIMM DR 2666 MT/s running at 2400 MT/s
	CPU	Intel i5 or i7 Quad-Core Processor	1x HPE ML110 Gen10 Intel Xeon-Silver 4110 (2.1GHz/8-core/85W)
	Hard Drives	SATA, SAS, SSD Drives	SATA, SAS, SSD Drives
	Free Space	8 TB	12 TB
Client Specifications	Operating System	Window 10 Professional 64 bit	
	Memory	8GB	
	CPU	Intel i3	
	Hard Drives	SATA, SAS, SSD Drives	
	Free Space	500 GB min	
Network Specifications	Network Speed	1000 mbps	
	Connection	1000 mbps switch	
	Cabling	Category 5e or 6 Cable	

3.9. System Evaluation

In user acceptability testing, the technology acceptance model or TAM was utilized in the project. TAM is a theory of information systems that describes how consumers accept and use technology. The endpoint where humans employ technology is the actual system utilization. An element that motivates people to use technology is their behavioral intention. The survey questionnaire was designed to determine the acceptability of the system based on user's perceived usefulness, ease of use and user satisfaction. The instrument used a Five (5) point scale 5 Strongly Agee, 4 Agree, 3 Undecided, 2 Disagree, 1 Strongly Disagree.

4. Results and Discussion

RML ++ system was evaluated using the Technology Acceptance Model (TAM) to determine the acceptability of the system. The system development process is systematically evaluated to ensure the accuracy of the mathematical calculation and interpretation of the instrument standards.

4.1. Technology Acceptance Model (TAM)

Table 4 shows the results of the system evaluation based on the perceived usefulness, perceived ease of use and user satisfaction of the system.

For the statements, RML ++ was able to reduce the processing time of the calibration certificates from encoding to releasing; the system provides a systematic process of the mathematical calculation of uncertainty and selection of standards; RML ++ provides management solutions in handling documents efficiently, with data accuracy, and on-time release of calibration certificates; The system can be used as a tool to increase and supports RML personnel to increase office productivity because of a streamlined

process obtained a weighted mean of 5 interpreted as strongly agree. While for the statement, the system provides a platform for multiple user accessibility and reliability obtained a weighted mean of 4.6 interpreted as strongly agree. With a weighted mean of 4.92 the system was accepted based on perceived usefulness by the users (see Table 5).

Table 4. Evaluation results based on perceived usefulness.

	Perceived of Usefulness	Mean
1.	RML ++ was able to reduce the processing time of the calibration certificates from encoding to releasing.	**5**
2.	The system provides a systematic process of the mathematical calculation of uncertainty and selection of standards.	**5**
3.	The system provides a platform for multiple user accessibility and reliability.	**4.6**
4.	RML ++ provides management solutions in handling documents efficiently, with data accuracy, and on-time release of calibration certificates.	**5**
5.	The system is flexible to accommodate changes in the certificate contents such as in client information, remarks, logo, and assigning of calibration officer and verifier.	**5**

Table 5. Evaluation results based on perceived ease of use

	Perceived of Ease of Use	Mean
1.	User-interface enables pleasing and satisfying interaction for the user.	**5**
2.	The software/system has attributes that make it easy to operate and control.	**5**
3.	System modules provide visual information from the encoding of calibration data to the printing of calibration certificates.	**5**
4.	The calibration data were stored in the database for easy retrieval and generation of reports.	**4.6**
5.	The system is flexible to accommodate changes in the certificate contents such as in client information, remarks, logo, and assigning of calibration officer and verifier.	**5**

For the statements, User-interface enables pleasing and satisfying interaction for the user; the software/system has attributes that make it easy to operate and control; System modules provide visual information from the encoding of calibration data to the printing of calibration certificates; The system is flexible to accommodate changes in the certificate contents such as in client information, remarks, logo, and assigning of calibration officer and verifier obtained a weighted mean of 5 interpreted as strongly agree. With a weighted mean of 4.92 the system was accepted based on perceived ease of use by the users (see Table 6).

Table 6. Evaluation Results Based on Perceived Ease of Use.

	User Satisfaction	Mean
1.	The set of system functions covers all the specified tasks and user objectives	**5**
2.	The system provides the correct results with the needed degree of precision.	**5**
3.	The system will speed up the release of customers' calibration certificates with an assurance of data accuracy and precision adjustment in the calibration process is guaranteed.	**5**
4.	The system is acceptable in terms of the desired output in the calculation of the calibration certificates and generation of reports.	**5**
5.	The system is recommended for implementation.	**5**

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For user satisfaction a weighted mean of 5 was obtained. A grand mean of 4.97 was computed, interpreted as strongly agree indicates an overwhelming acceptance of the system by the RML personnel.

4.2. Testing and Validation of the Platform-Based Calibration Data Exchange and Management Processes

The testing and validation of the calibration certificates are presented in the platform-based data exchange and managements processes. The functionality and technological readiness were evaluated as follows: 2 = pass, usable as is; 1 = pass, usable but improvable; 0 = fail [18] (see Tables 7–9).

Table 7. Single Range Electronic Balance Process.

Single Range Electronic Balance		
System Features	**Functional Readiness**	**Technological Readiness**
Balance Worksheet	**1**	**2**
Computation of Average	**2**	**2**
Temperature and Humidity	**2**	**2**
Automatic Computation of Eccentricity	**2**	**1**
Linearity Test	**2**	**1**
Standard Test Point Selection Modal	**2**	**1**
Display of MPE, uncertainty of Selection Standard	**2**	**1**
Repeatability Test	**2**	**2**
Repeatability Test	**1**	**2**
Adding / Updating Standards	**1**	**2**

Table 8. Thermohygrometer process

Thermohygrometer		
System Features	**Functional Readiness**	**Technological Readiness**
Thermohygrometer Balance Worksheet	**1**	**2**
Standard and Chamber Selection	**2**	**2**
Selection of Theymohygrometer Standard	**2**	**2**
	2	**1**
Input of Measurement Data	**2**	**2**
Printing of Certificates	**2**	**2**
Adding / Updating Standards	**2**	**2**

Table 9. Test weight

Thermohygrometer		
System Features	**Functional Readiness**	**Technological Readiness**
Test Weight Calibration Worksheet	**2**	**2**
Standard Selection	**2**	**2**
Generation of data	**2**	**2**
Standard Table	**2**	**2**
PAB Table	**2**	**2**
MPE	**2**	**2**
Alloy Table		
Sensitivity Test Table	**2**	**2**
Printing of Certificates	**2**	**2**

Adding / Updating Standards	2	2

The system functionalities of the calibration certificates printed output are validated using the data comparison of the manual data as test data compare to the required input and output data. All system process for Single Range Electronic Balance, Thermohygrometer, and Test Weights calibration certificates conformed with the functional and technological readiness.

4.3. System Features

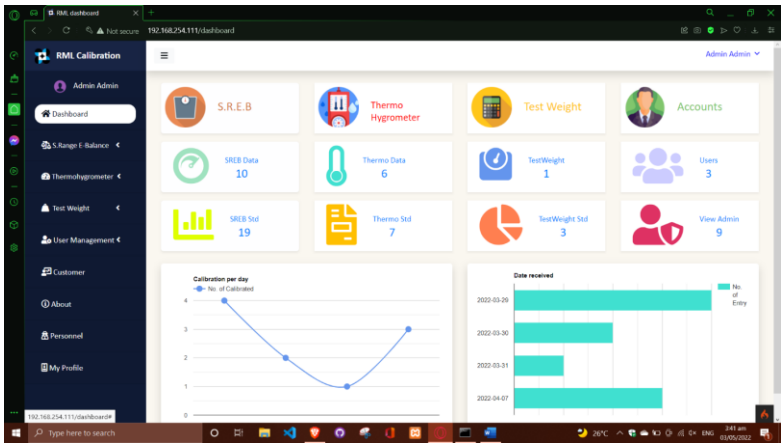

Fig. 6. System dashboard.

The dashboard shows the system link or access to the different components of the system. The left panel in dark grey contains the link for the administrator, the module for the Single Range Electronic Balance, Thermohygrometer, and Test Weights, User Account Management, Calendar, About, and My Profile. A graphical display with links for these modules was shown also in the dashboard (see Figs. 6–7).

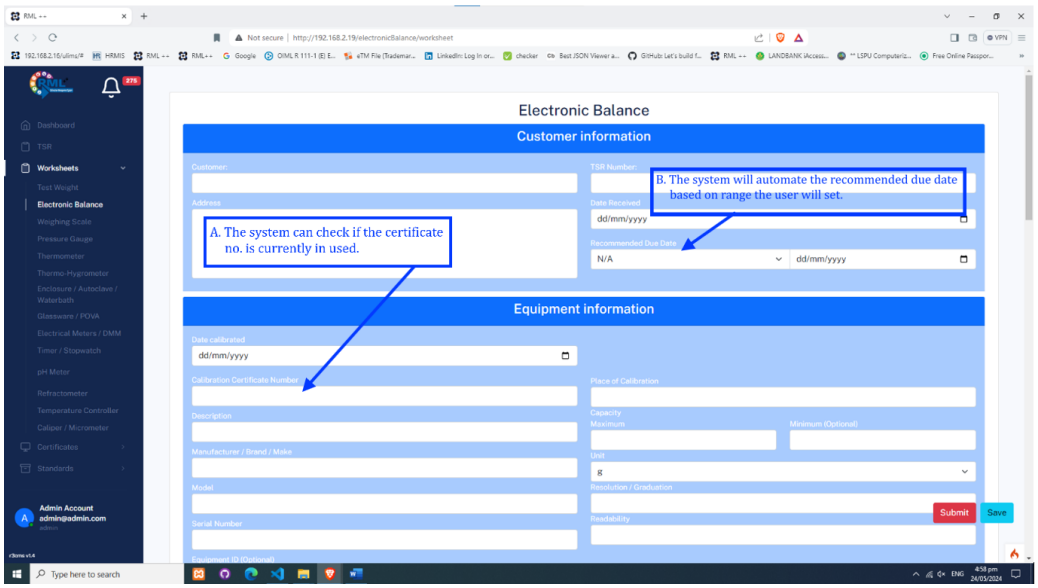

Fig. 7. Single range electronic balance worksheet.

The encoding of data for the Single Range Electronic Balance certificates starts with the checking of certificate number. In a color-coded scheme, the system checks the availability of the certificate number, a red color indicates that the certificate number was already used. The expiration of the certificate is also included in this module ranging from 6 months, 1 year or 2 years validity (see Fig. 8).

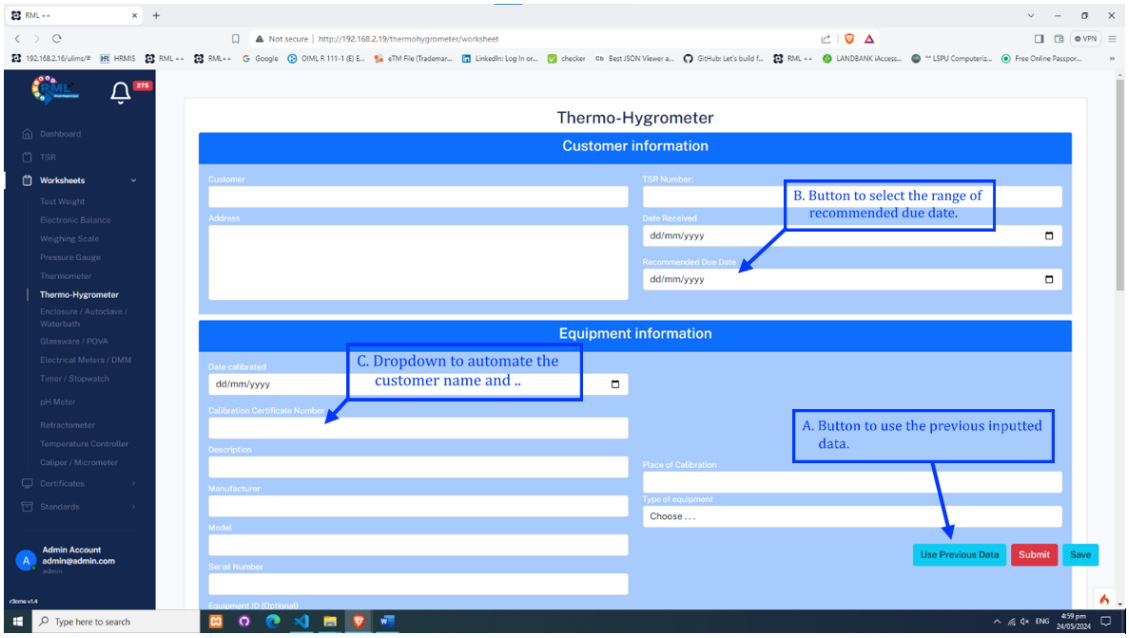

Fig. 8. Thermohygrometer calibration worksheet.

The Thermohygrometer is used to determine the temperature and humidity of the environment. It is used in laboratories, food industry, pharmaceutical manufacturing, and pharmacy. The thermohygrometer calibration module will require basic information of the specific instruments. A unique certificate number will be assigned per instrument. The system implements a color-coded scheme to detect duplication, when there is a duplicate certificate number a color red and an error message will be displayed. The previous data button will show the historical data for selection of the user if needed. The user can set the range of the date of recommended due date from 6 months, 1 year or 2 years, it will automatically calculate and display at the recommended due date text box. The Customer textbox will drop down all the saved data of the customer. It will auto fill the Customer Name and address textbox (see Fig. 9).

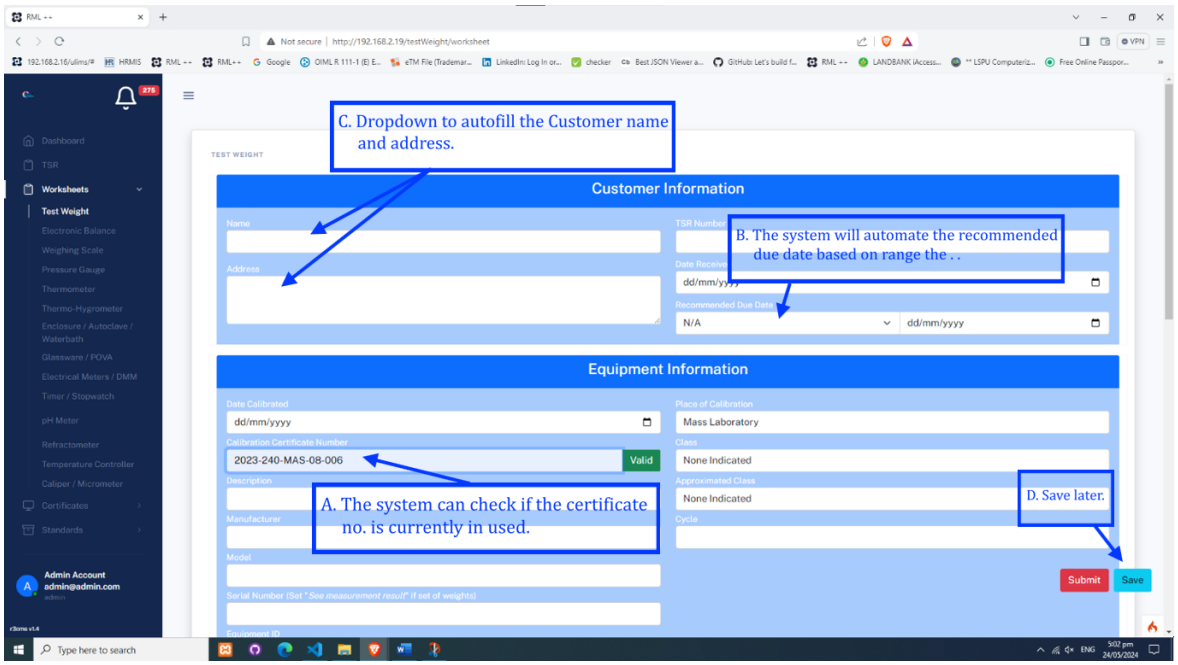

Fig. 9. Test weight calibration worksheet.

Test weights for scales, also known as precision weights, are used to calibrate weight scale systems of varying degrees of accuracy, based on their intended usage and needs. In order to calibrate weight scale systems, certified test weights or precision weights should be utilized. It is critical to verify that the test weights are calibrated and accurate in order to obtain reliable calibration results.

The system can check if the inputted Certificate No. is currently in use. The user can set the recommended due date range to 6 months, 1 year, or 2 years. The recommended due date will automatically display based on the date calibrated. The customer dropdown will autofill the customer's name and address. The Save Later button will save the current inputted data of the user for later use.

5. Conclusions

The Regional Metrology Laboratory is the only government entity in Region IV-A or CALABARZON that provides calibration services. By calibrating measuring devices and instruments used by business and the general public, RML aims to ensure the safety and fair trade of both local and international markets. RML's calibration services are also ISO/IEC 17025 accredited, indicating that they satisfy the international standard for testing and calibration laboratories. However, as the number of clients grows, the difficulty of preparing calibration certificates becomes a bottleneck and causes delays in the issuance of certificates. A system for data management is an effective and efficient tool to innovate the procedural preparation of the calibration certificates.

The project RML++ is a development of a calibration management system using the modified system development life cycle with the adaptation of model driven architecture and model view controller framework. To provide the project with an additional tool to better understand and develop the system, the principles of abstraction, modeling reuse, and patterns were implemented. The technical scope of the project is the three (3) calibration certificates the Single Range Electronic Balance, Thermohygrometer, and Test Weight. The process of calibration of instruments in the manual system is very complex because of the standard referencing and all the mathematical calculations. RML ++ is a management software solution that automates the processing of documenting requirements, from the receipt of clients' measuring devices and instruments to the release of calibration certificates. Customers' information, instrument specifics, calibration methods, calibration results, and certifications will all be input into the system. The system incorporates RML process data management, a data bank for quick document retrieval, calibration certificate printing, and report generating.

The system received a weighted mean of 4.92 for perceived utility and simplicity of use by the users. A weighted average of 5 was calculated for user satisfaction. The grand mean of 4.97, interpreted as highly approve, indicating that the RML workers have overwhelmingly accepted the system. And based on the analysis of the processing time, from 8 days in the manual system it was reduced to 5 working days from the preparation until the releasing of the calibration certificates.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

This paper was made possible through the help of Engr. Rogerson A. Esmeria who provided the data of RML processes, system analysis, the calibration process, and requirements. Dr. Jefferson L. Lerios wrote the paper and served as the co-project leader of RML ++ and Associate Professor Joel M. Bawica as the Project Leader; all authors had approved the final version.

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