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Occupational health and safety measurement equipment management system integrated with QR code and LINE API Communication

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ABSTRACT

The management of occupational health and safety measurement equipment in educational institutions often faces challenges related to borrowing and returning records, calibration tracking, and access to equipment information, resulting in inefficient management. This research and development study aimed to develop an integrated web-based occupational health and safety measurement equipment management system combining QR Code-based equipment identification, equipment lifecycle management, and LINE Messaging API communication, and to evaluate system quality, user satisfaction, and factors associated user acceptance. The participants consisted of three groups: three personnel involved in equipment management, three information technology experts, and thirty system users. The research instruments included a semi-structured interview form, a system quality evaluation form, and a user satisfaction questionnaire. Data were analyzed using frequency, percentage, mean, standard deviation, Pearson's correlation coefficient, and multiple linear regression analysis. The developed system consisted of eight main modules covering user management, equipment information management, borrowing and returning, calibration, maintenance, QR code management, LINE notification, and administrative reporting. The overall system quality evaluated by experts was at the highest level (mean = 4.88, SD = 0.20), and overall user satisfaction was also at the highest level (mean = 4.85, SD = 0.33). System usability showed a strong positive correlation with user acceptance ($r = 0.81$, $p < 0.01$). Moreover, system usability, interface design, and system reliability and security jointly explained 72.0% of the variance in user acceptance. These findings indicate that the developed system-achieved high levels of perceived quality and user acceptance, while providing an integrated digital approach to equipment identification, lifecycle management, user communication, and learning support for occupational health and safety measurement equipment in higher education.

Keywords: Equipment management system, Occupational health and safety, QR code, LINE Messaging API, Information system

INTRODUCTION

The management of occupational health and safety (OHS) measurement equipment in educational institutions is essential for ensuring measurement accuracy and supporting effective teaching and practical training. Institutions offering occupational health and safety programs are also required to comply with relevant national regulations. In Thailand, the 2025 Notification of the Department of Labour Protection and Welfare [1] requires higher education institutions offering occupational health and safety programs to provide standardized industrial hygiene measurement equipment to support teaching and professional training. Such equipment includes instruments for measuring illumination, noise, heat, and chemical hazards.

Previous studies have demonstrated that digital asset management systems integrating QR code technology and centralized databases can improve equipment identification, reduce human error, facilitate real-time information access, and enhance asset management efficiency [2-4]. However, these studies have primarily focused on general asset tracking, laboratory inventory, or equipment identification. Limited attention has been paid to integrated systems specifically designed for occupational health and safety measurement equipment, which require not only equipment identification and loan records but also calibration tracking, maintenance management, access to instructional resources, and timely communication

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with users. Furthermore, the integration of QR code-based equipment information with real-time communication through the LINE Messaging API has received limited attention in this specific educational and occupational health context.

To address this gap, this study developed an integrated web-based Occupational Health and Safety Measurement Equipment Management System that combines QR code-based equipment identification, borrowing and return management, calibration and maintenance tracking, instructional resources, administrative reporting, and LINE Messaging API notifications within a single platform. The principal contribution of the proposed system is therefore the integration of equipment lifecycle management, user communication, and learning support functions specifically for OHS measurement equipment in a higher education setting. The study aimed to (1) develop the integrated OHS measurement equipment management system based on identified user requirements, (2) evaluate its system quality and user satisfaction, and (3) examine the relationships between system usability, user interface design, system reliability and security, and user acceptance. In the analytical component of the study, system usability, user interface design, and system reliability and security were treated as explanatory variables, while user acceptance was treated as the outcome variable. Their relationships were examined to determine which system-related factors were associated with greater acceptance of the developed system.

MATERIALS AND METHODS

Research design

This study employed a Research and Development (R&D) approach to develop and evaluate a web-based Occupational Health and Safety (OHS) Measurement Equipment Management System integrating QR code technology and the LINE Messaging API. The study comprised four phases: (1) needs assessment through interviews with end users, (2) system design and development based on the identified requirements, (3) system testing and refinement, and (4) evaluation of system quality, user satisfaction, and user acceptance.

Participants

Participants were divided into three groups according to their roles in the system development and evaluation process. The first group comprised three occupational health and safety practitioners selected by purposive sampling to identify operational problems, user requirements, and essential system functions. The second group consisted of three computer science/information technology experts selected by purposive sampling. Eligible experts were required to hold at least a master's degree in computer science, information technology, or a related field and to have at least five years of teaching experience at the university level. These experts evaluated the quality of the developed system. The third group consisted of 30 fourth-year students enrolled in the Occupational Health and Safety program who were selected by purposive sampling. These students were undertaking professional practice during the semester in which data were collected and used the developed system in actual practice before evaluating user satisfaction and system acceptance.

The end-user sample size was determined by the availability of eligible fourth-year students who were undertaking professional practice during the study period and were able to use the developed system in actual practice. Accordingly, the end-user evaluation should be considered an initial implementation assessment within a specific educational setting rather than a population-level evaluation.

Research instruments

Four research instruments were employed. The first was a semi-structured interview guide used to identify existing problems and user requirements for equipment management. Interview data were analyzed using content analysis and served as the basis for system development.

The second instrument was the web-based Occupational Health and Safety Measurement Equipment Management System, which was developed using the Laravel Framework with PHP, HTML5, CSS3, JavaScript, and MySQL. The system integrated QR code technology and the LINE Messaging API and comprised eight functional modules user management, equipment management, equipment borrowing and return management, maintenance management, calibration management, QR code identification, notification services, and administrative reporting.

The third instrument was a system quality evaluation form completed by three information technology experts. The fourth instrument was a user satisfaction and system acceptance questionnaire completed by 30 end users after system implementation. Both instruments employed a five-point Likert scale, and mean scores were interpreted according to Sullivan and Artino [5]. The content validity of the evaluation instruments was assessed using the Index of Item–Objective Congruence (IOC), with item-level IOC values ranging from 0.67 to 1.00. The internal consistency reliability of the satisfaction questionnaire was assessed using Cronbach's alpha, yielding a coefficient of 0.87, indicating good internal consistency.

System design and development

The system was developed following the principles of User-Centered System Development [6]. Requirements identified during the needs assessment

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were used to define system functions and architecture. The application was designed as a client–server web application with a centralized MySQL database and developed using the Laravel Framework [7]. The system incorporated role-based access control and consisted of eight integrated modules supporting equipment management, equipment borrowing and return transactions, calibration, maintenance, QR code identification, LINE Messaging API notifications, and administrative reporting. Functional testing was conducted before the system was evaluated by experts and implemented for end-user testing.

Data collection

Data collection was conducted sequentially. Following the needs assessment, the system was developed and underwent functional testing. The revised system was subsequently evaluated by three information technology experts. After incorporating their recommendations, the system was implemented with 30 end users, who performed routine equipment management tasks before completing the user satisfaction and system acceptance questionnaire.

Data analysis

Qualitative interview data were analyzed using content analysis. Quantitative data were analyzed using descriptive statistics, including frequency, percentage, mean, and standard deviation. Pearson's correlation analysis was used to examine the relationships between system usability, user interface design, system reliability and security, and user acceptance. Multiple linear regression analysis was subsequently performed with user acceptance as the dependent variable and system usability, user interface design, and system reliability and security as predictor variables. Before multiple linear regression analysis, multicollinearity among the predictor variables was assessed using tolerance and the variance inflation factor (VIF). Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

User requirements for the occupational health and safety measurement equipment management system

The interviews identified several limitations in the existing equipment management process, including difficulties in tracking borrowing and return status, calibration schedules, equipment utilization, and maintenance records. All participants recommended that the developed system should include online borrowing and return management, QR code identification, LINE notifications, calibration tracking, and maintenance management, while two participants additionally suggested incorporating instructional videos (Table 1).

System design and development outcomes

The developed system was implemented as a web-based application integrating QR code technology and the LINE Messaging API. It comprised eight functional modules supporting user management, equipment management, borrowing and return transactions, calibration, maintenance, QR code identification, notification services, and administrative reporting (Table 2).

Table 1 User requirements identified from interviews with occupational health and safety experts.

Required System Function	Frequency (n = 3)	Percentage (%)
Online borrowing and returning system	3	100.0
QR code-based equipment identification	3	100.0
LINE notification system	3	100.0
Calibration management	3	100.0
Maintenance request management	3	100.0
Video tutorial repository	2	66.7

Table 2 Functional modules of the developed system.

Module	**Function**
User Management	Manages user information and access permissions
Equipment Management	Manages equipment information
Borrowing and Returning	Manages equipment borrowing and return transactions
Maintenance Management	Manages equipment maintenance activities
Calibration Management	Manages equipment calibration records and schedules
QR code Management	Identifies equipment and provides access to equipment information
LINE Notification	Sends notifications regarding system status and activities
Dashboard and Reporting	Generates administrative summaries and reports

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In addition to the eight modules, the system generated a unique QR code for each item of equipment. Scanning the QR code enabled users to access equipment details, instructional videos, borrowing and return histories, and calibration status in real time. The system also delivered automated LINE Messaging API notifications related to borrowing, returns, maintenance activities, and upcoming calibration schedules.

System architecture

Figure 1 illustrates the information flow within the client–server architecture of the developed system. User requests generated through the web application are processed by the application server and recorded in the centralized MySQL database. QR codes function as access points linking individual equipment items to their corresponding records in the database. After the relevant database transactions are completed, the system sends notification requests to the LINE Messaging API for events such as borrowing approval, equipment return, maintenance activities, and calibration reminders. In this architecture, the database serves as the primary source of transaction records, whereas the LINE Messaging API functions as a communication channel rather than as the primary transaction-processing component. If the LINE Messaging API or network connection is temporarily unavailable, the core equipment-management transaction remains recorded in the centralized database and is not dependent on successful notification delivery. Thus, temporary notification failure does not alter the recorded transaction status.

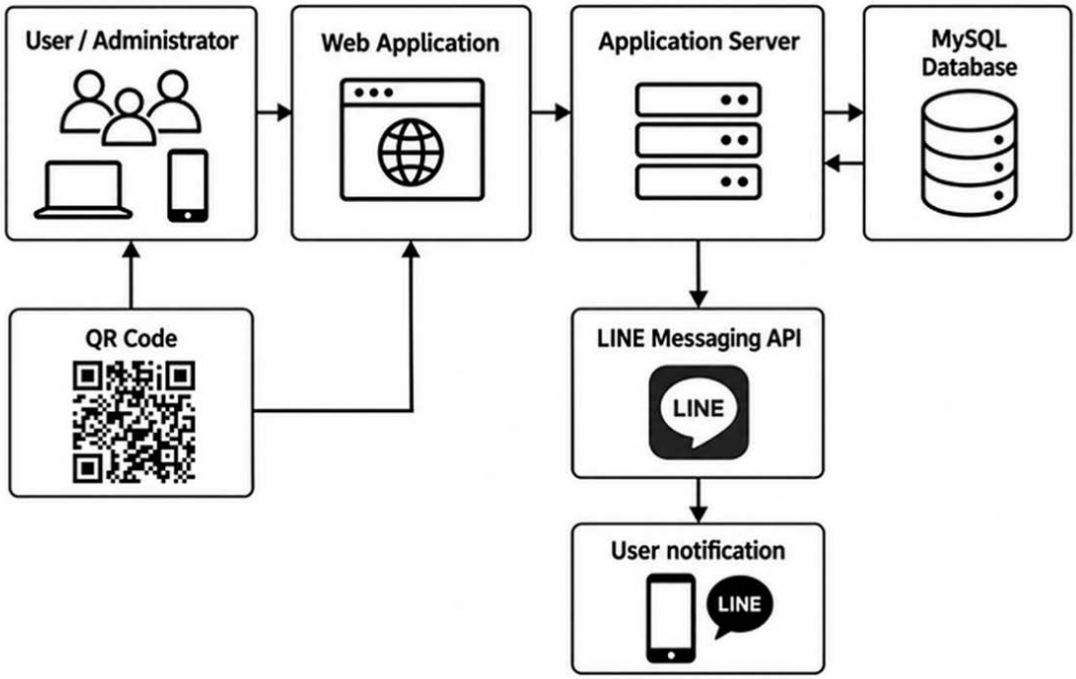


Figure 1 System architecture and information flow.

The current implementation was designed for routine use within a single educational setting. System performance under under high concurrent user loads, including processing speed and data-transmission latency, was not formally evaluated in this study. These aspects, together with dedicated security monitoring, should be examined in future large-scale deployments.

System functions and user roles

Figure 2 presents the Use Case Diagram illustrating the interactions among system administrators, equipment administrators, and general users. Access privileges were assigned according to user roles to ensure secure and efficient system operation.

Database design

Figure 3 illustrates the relational database structure developed to support equipment information, borrowing and return transactions, calibration, maintenance, and user management.

To maintain data integrity, each equipment item was assigned an operational status in the database. Before a new transaction was recorded, the system verified the equipment status to prevent conflicting transactions. For example, equipment already recorded as borrowed could not be borrowed again until it had been returned, while equipment undergoing maintenance or calibration was not available for borrowing. Related transaction records were linked to the equipment record through the database structure, allowing borrowing, return, maintenance, and calibration activities to be traced consistently for each item.

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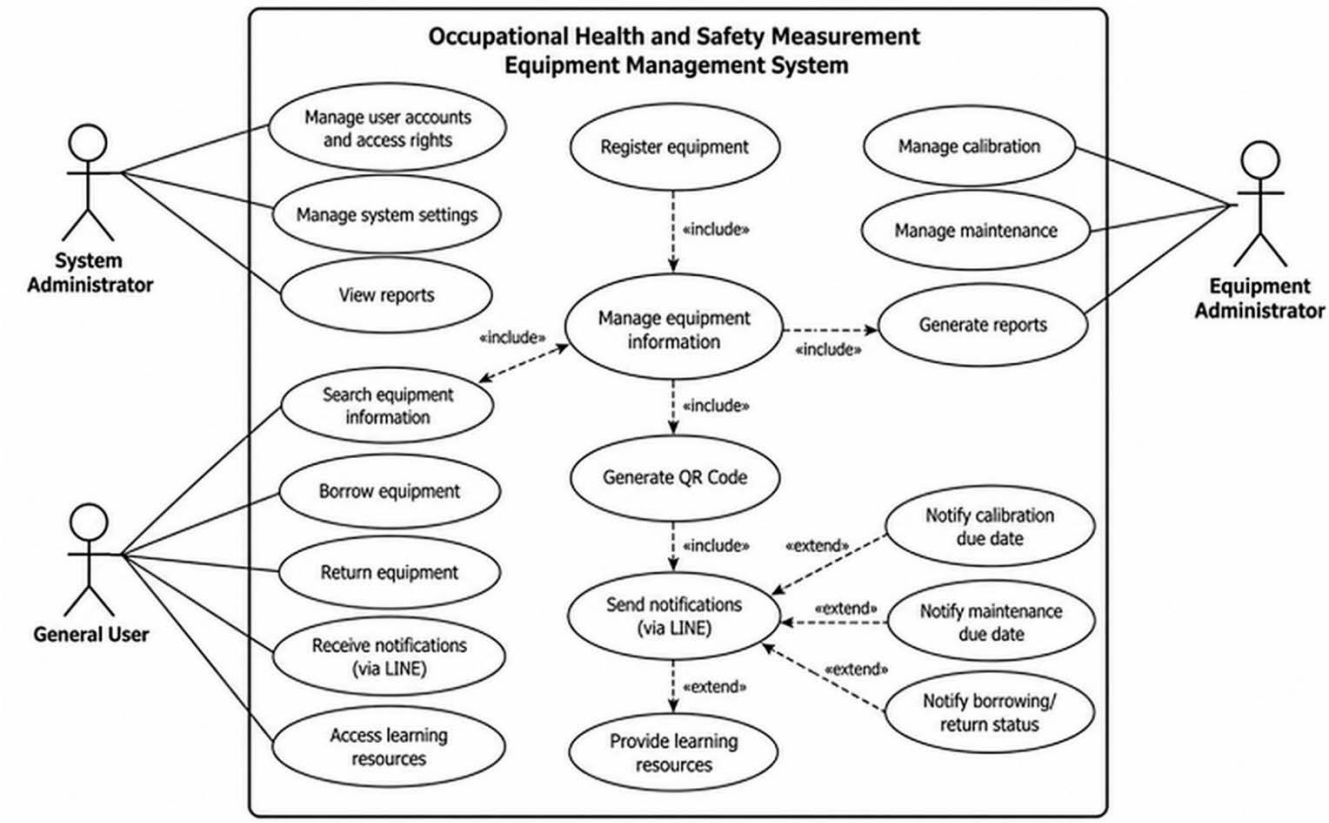


Figure 2 Use case diagram of the developed system.

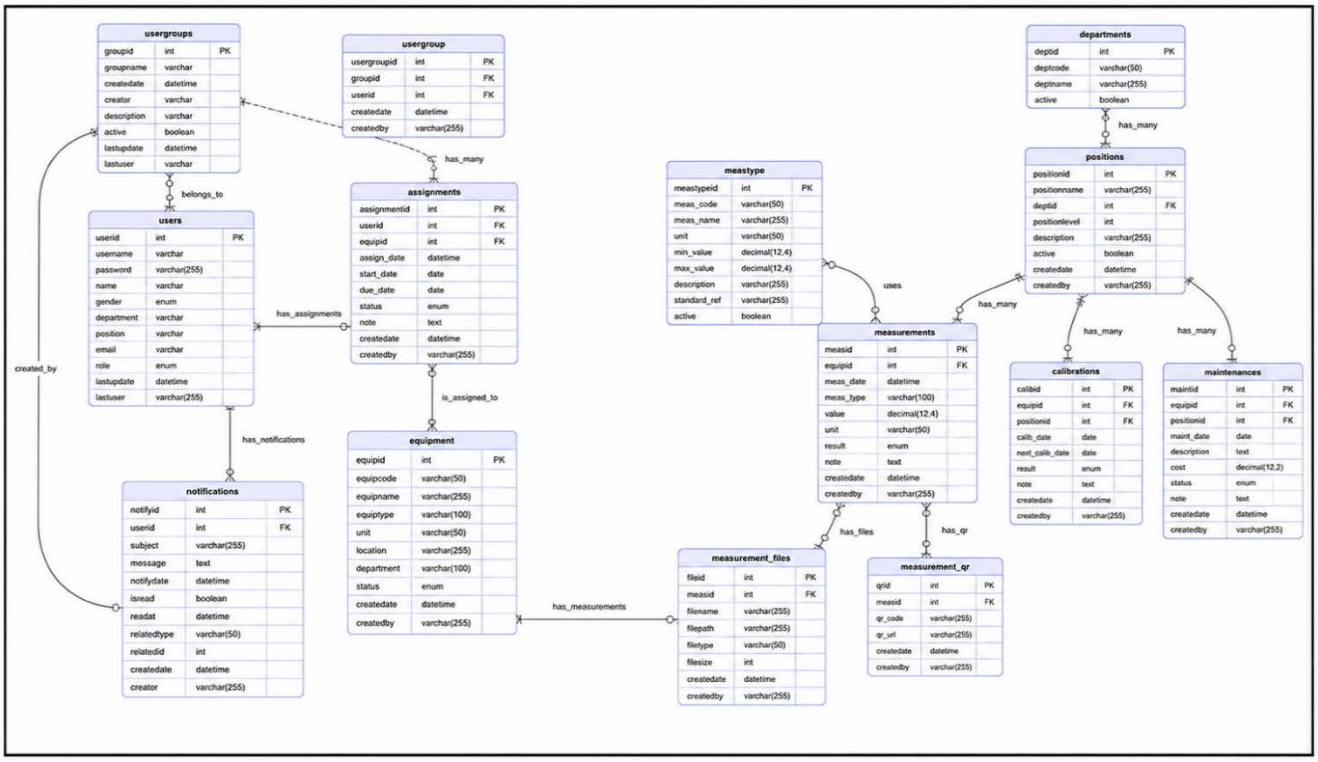


Figure 3 Entity relationship diagram.

Real-time equipment monitoring and data management

A real-time administrative dashboard was developed to support equipment monitoring and centralized data management. The dashboard displayed summary information on the total number of equipment items, current equipment status, borrowing and return transactions, and pending activities requiring administrative action. This functionality enabled administrators to monitor the overall status of equipment in real time, as shown in Figure 4.

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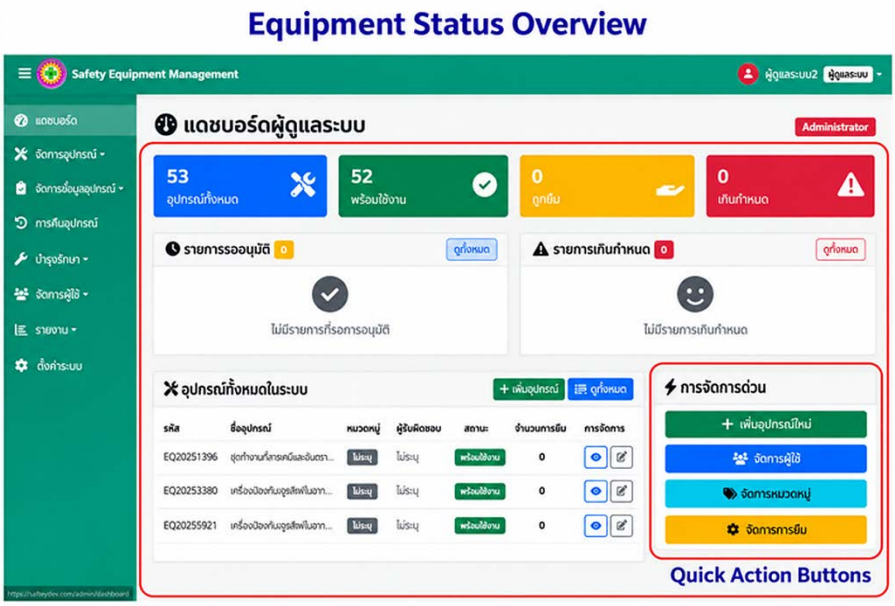


Figure 4 Real-time administrative dashboard.

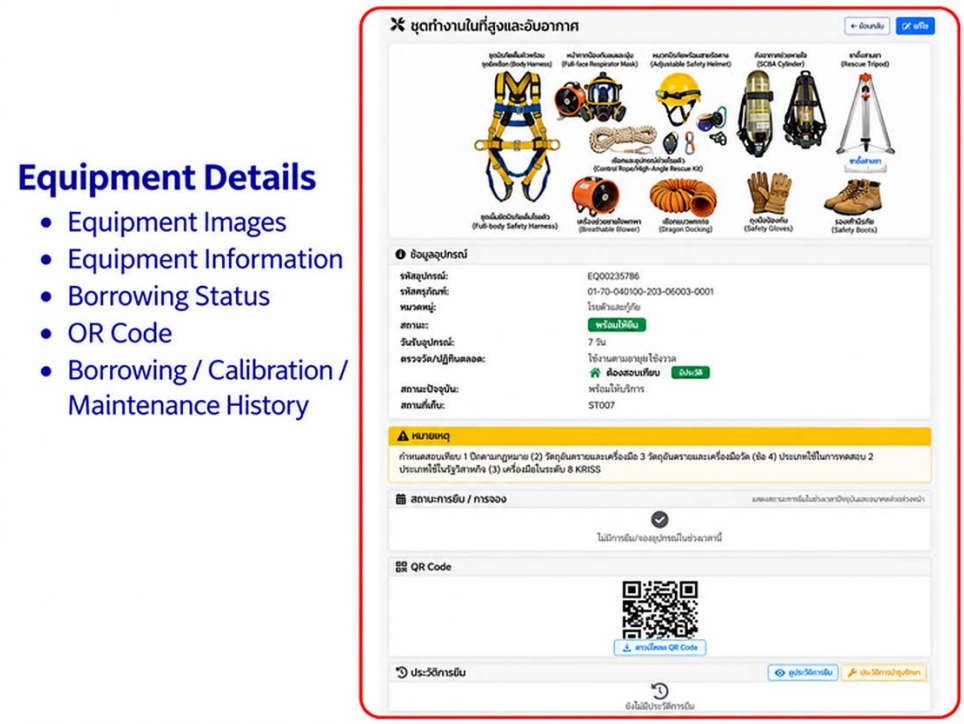


Figure 5 Equipment information page linked to the QR code.

QR code-based equipment information retrieval

The system provided a dedicated equipment details page integrated with QR code technology to facilitate rapid and accurate access to equipment information. By scanning the QR code assigned to each equipment item, users could immediately retrieve basic equipment information, borrowing and return records, calibration records, and instructional materials or user guides. This feature improved the efficiency of information retrieval and equipment-status monitoring by reducing the need for manual searches and paper-based records, as illustrated in Figure 5.

Equipment borrowing and return management

A dedicated interface was developed for equipment administrators to manage borrowing and return requests through the web application. The interface was integrated with the LINE Messaging API to support real-time communication between users and equipment administrators.

The system enabled administrators to review requests, approve transactions, monitor borrowing status, and manage equipment use through mobile devices. The borrowing management interface and notification function are presented in Figure 6.

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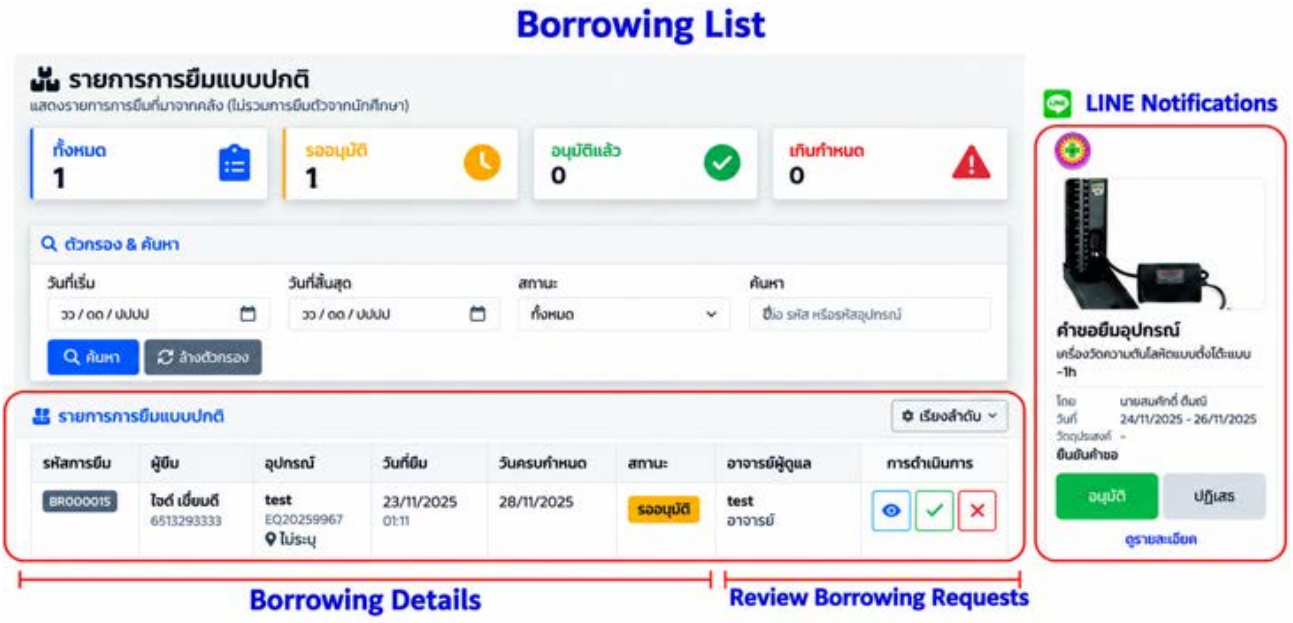


Figure 6 Equipment borrowing interface and LINE messaging API notification.

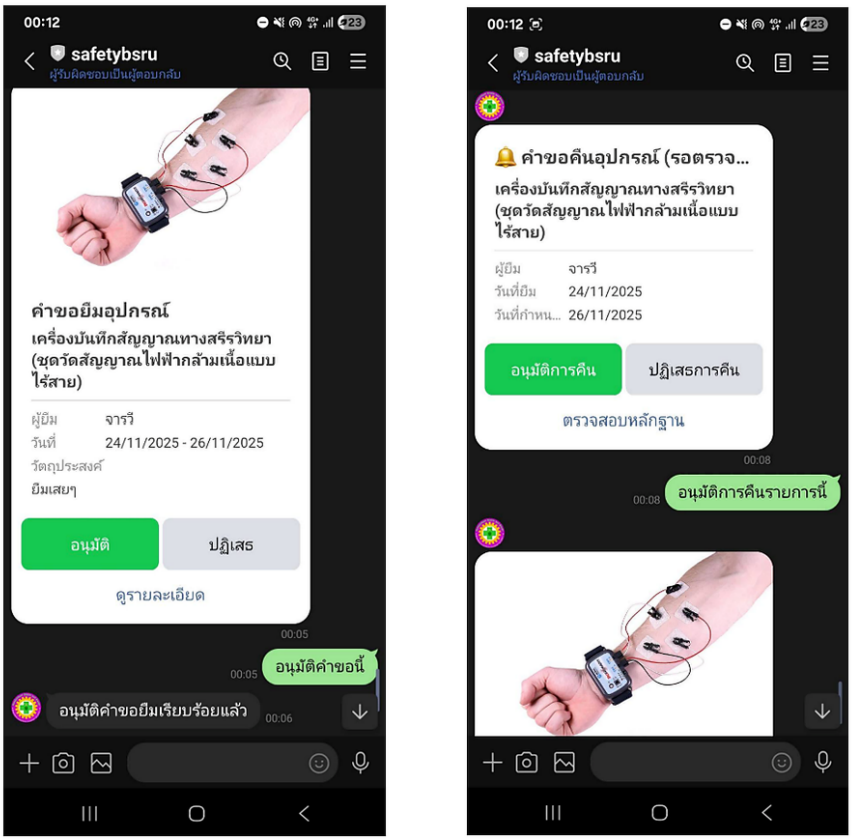


Figure 7 Examples of approval and equipment return notifications delivered through the LINE Messaging API.

Communication and notifications through the LINE messaging API

The system integrated the web application with the LINE Messaging API to provide real-time communication and automated notifications related to borrowing and return activities. Users received notifications concerning request approval, borrowing status, equipment returns, maintenance activities, and calibration schedules through their smartphones.

This functionality allowed users to monitor requests and respond to relevant activities more conveniently and promptly. Examples of approval and return notifications are presented in Figure 7.

Expert evaluation of system quality

Overall system quality was rated at the highest level (Mean = 4.88, SD = 0.20). System reliability received the highest score, followed by system functionality, usability, and system security (Table 3).

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User satisfaction

Overall user satisfaction was rated at the highest level (Mean = 4.85, SD = 0.33). System security and reliability received the highest score, followed by system acceptance, system usability, and user interface design (Table 4).

Table 3 Expert evaluation of system quality (n = 3).

Evaluation Dimension	Mean	SD	Level
System functionality	4.88	0.19	Highest
Usability	4.86	0.23	Highest
System reliability	4.92	0.17	Highest
System security	4.85	0.22	Highest
Overall	4.88	0.20	Highest

Table 4 User satisfaction with the developed system (n = 30).

Evaluation Dimension	Mean	SD	Level
System usability	4.80	0.39	Highest
User interface design	4.77	0.42	Highest
System security and reliability	4.92	0.22	Highest
System acceptance	4.90	0.29	Highest
Overall	4.85	0.33	Highest

Comparison of equipment management performance between the conventional and developed systems

Compared with the conventional system, the developed system provided additional digital functions, including online data management, QR code-based equipment identification, automated notifications, and real-time equipment monitoring (Table 5). These functional differences indicate potential operational advantages; however, task completion time, information retrieval time, recording errors, and administrative workload were not quantitatively measured in this study.

Relationships between factors and user acceptance

Pearson's correlation analysis indicated that system usability showed the strongest positive correlation with user acceptance ($r = 0.81$, $p < 0.01$), followed by system reliability and security and user interface design (Table 6).

Factors associated with acceptance

Multiple linear regression analysis revealed that system usability, user interface design, and system reliability and security jointly explained 72.0% of the variance in user acceptance. Among these variables, system usability showed the strongest association with user acceptance. (Table 7).

Table 5 Comparison between the conventional system and the developed system.

Feature	Conventional System	Developed System
Data recording	Paper-based records	Online database
Equipment status monitoring	Manual checking	Real-time monitoring
Calibration tracking	Paper documents	Automatic notification
Borrowing and return notification	None	LINE Messaging API
Equipment operation guidance	Printed manual	QR code and instructional videos
Report generation	Manual preparation	Automatic reporting

Table 6 Relationships between factors associated with user acceptance (n = 30).

Variable	1	2	3	4
1. System Usability	1.00			
2. User Interface Design	0.68**	1.00		
3. System Reliability and Security	0.72**	0.64**	1.00	
4. User Acceptance	0.81**	0.74**	0.78**	1.00

Note: *p<0.05; **p<0.01

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Table 7 Multiple linear regression analysis of factors associated with user acceptance (n = 30).

Predictor	B	β	t	*p*-value	Tolerance	VIF
Constant	0.87	-	2.41	0.017*	-	-
System Usability	0.41	0.43	6.84	<0.001**	0.400	2.50
User Interface Design	0.19	0.21	3.76	<0.001**	0.491	2.04
System Reliability and Security	0.32	0.35	5.28	<0.001**	0.440	2.28

Note: Dependent Variable = User Acceptance; *p<0.05; **p<0.01

The present study developed and evaluated an Occupational Health and Safety (OHS) Measurement Equipment Management System integrating QR code technology and the LINE Messaging API to improve equipment management in higher education institutions. The findings demonstrated that the developed system successfully addressed users' operational requirements through eight integrated modules supporting equipment registration, borrowing and return management, calibration, maintenance, notification services, and administrative reporting. The needs assessment further confirmed that online borrowing and return management, QR code-based equipment identification, calibration tracking, maintenance management, and LINE notifications were considered essential functions. These findings suggest that conventional paper-based equipment management no longer adequately supports current operational requirements. The successful implementation of the system may be attributed to a User-Centered System Development approach, which aligns system functions with practical user needs [6, 8]. Similar improvements have been reported for digital asset management systems that enhance equipment traceability, reduce manual errors, and improve operational efficiency [2,4,9]. Compared with these previous studies, the present system extends beyond basic asset identification and inventory management by integrating borrowing and return management, calibration and maintenance tracking, instructional resources, and communication via LINE within a single platform specifically designed for OHS measurement equipment.

Expert evaluation demonstrated that the developed system achieved the highest level of overall quality, while end users also reported the highest level of satisfaction. These findings may be explained by the implementation of a client–server architecture with centralized database management, role-based access control, and real-time communication through the LINE Messaging API, all of which contributed to improved system reliability, functionality, and security. According to the DeLone and McLean Information Systems Success Model, system quality represents one of the most important determinants of successful information system implementation [10]. The present findings are consistent with previous studies showing that system quality and reliability positively influence user satisfaction and information system success [11,12]. Likewise, the high level of user satisfaction observed in this study is consistent with Srisutam et al. [13], who demonstrated that integrating digital communication technologies into occupational health applications improves accessibility and user experience. However, unlike the application reported by Srisutam et al. [13], the present study applied communication via LINE specifically to equipment-management activities, including borrowing, returning, maintenance, and calibration notifications.

The system introduced several functions that may support more efficient equipment management, including centralized data management, QR code-based information access, automated LINE notifications, and real-time status monitoring. Similar advantages of digital asset management systems have been reported in previous studies [2, 4, 9], while the use of QR code technology for asset identification and equipment management is consistent with previous reports in educational and organizational settings [17]. However, the present study did not directly quantify operational efficiency using measures such as task completion time, information retrieval time, error rates, or administrative workload. Therefore, these practical benefits should be interpreted as potential advantages of the system architecture rather than as experimentally demonstrated improvements in efficiency. Correlation and regression analyses further showed that system usability had the strongest association with user acceptance, followed by system reliability and security and user interface design. Together, these factors explained 72.0% of the variance in user acceptance. These findings are consistent with the Technology Acceptance Model [14,15] and the DeLone and McLean Information Systems Success Model [10,16], which emphasize the importance of perceived usability and system quality in technology acceptance and information system success.

From a practical perspective, the developed system offers an efficient digital solution for managing occupational health and safety measurement equipment in higher education institutions. Beyond improving equipment traceability and reducing administrative workload, the system facilitates timely calibration

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management, supports maintenance planning, and enhances learning through QR code-linked instructional resources. Owing to its modular architecture, the proposed system could also be adapted for managing laboratory equipment in other academic disciplines or organizations requiring standardized equipment control.

A key strength of this study is the development of an integrated equipment management system that combines web-based technology, QR code identification, and communication via the LINE Messaging API into a single platform. The study also evaluated system quality, user satisfaction, and user acceptance, providing a multidimensional assessment of the developed system. However, several limitations should be acknowledged. First, the study was conducted at a single higher education institution with a relatively small end-user sample (n = 30), which may limit the generalizability of the findings. Accordingly, the correlation and multiple regression results should be interpreted as exploratory and should be confirmed in larger and more diverse samples. Second, system quality was evaluated by only three information technology experts; therefore, future studies should involve a larger and more diverse expert panel. Third, operational effectiveness was not directly assessed using objective before-and-after indicators such as task completion time, information retrieval time, recording errors, or administrative workload. Finally, long-term technical performance, scalability, and cybersecurity were not evaluated. Future studies should validate the system across multiple institutions and incorporate objective performance indicators and long-term technical evaluations.

CONCLUSIONS

This study developed an Occupational Health and Safety Measurement Equipment Management System integrating QR code technology and the LINE Messaging API. The system supported equipment registration, borrowing and returning, calibration, maintenance, notifications, and administrative reporting. Expert-rated system quality and end-user satisfaction were both at the highest level. System usability showed the strongest positive association with user acceptance, while system usability, user interface design, and system reliability and security jointly explained 72.0% of the variance in user acceptance.

The system provides an integrated digital platform for managing occupational health and safety measurement equipment and offers potential benefits for equipment traceability, centralized information access, and user communication. However, objective improvements in operational efficiency were not directly quantified in this study. Future research should evaluate the system in larger and more diverse user groups, across multiple institutions, and include objective performance indicators, long-term technical performance, scalability, and cybersecurity.

DECLARATION OF AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the authors used generative artificial intelligence tools solely to improve grammar, language clarity, and readability. The authors subsequently reviewed and revised all AI-assisted content and take full responsibility for the accuracy, integrity, and final content of the manuscript.

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