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PAPER

Development and Evaluation of the WepMEt Platform for Enhancing a Medical Equipment Management in Hospitals

Nutdanai Singkhleewon[1], Arthorn Sanpanich[2](✉), Teerawit Asawasilpakul[1], Kanlaya Thanasin[1], Amonrat Khambun[1]

[1]Faculty of Science and Technology, Bansomdejchaopraya Rajabhat University, Bangkok, Thailand

[2]Institute of Molecular Biosciences, Mahidol University, Nakhon Pathom, Thailand

arthorn.san@mahidol.ac.th

ABSTRACT

Medical equipment management by using computerized systems is a key success of medical equipment maintenance and repair in hospitals. This system, which is installed in the biomedical engineering department, mostly provides an important management function for equipment registration, repair maintenance, and spare part administration. This study presents the development and evaluation of the WepMEt second version platform for managing medical equipment in hospitals across Thailand. The study focused on an improvement and expanding functionality in five key modules: equipment registration, preventive maintenance, repair, spare parts management, and equipment pooling modules, utilizing a rapid prototyping development method. Feedback information from 15 hospitals and primary criticism from five experts in medical equipment management were intently incorporated to improve an original version. Then, the post-development system was assessed in an intensive hands-on training workshop by 23 users from 16 hospitals, both nurses and biomedical engineers, and also the expert, in order to evaluate a satisfaction comment. The results show that our new WepMEt platform was highly accepted, with an average score of 4.73 and 4.75 for the expert team and all users, respectively. Most summarized comments clearly demonstrate effectiveness in comprehensively meeting the user needs, improving management efficiency significantly, and also reducing workload in hospitals. Our future work will be focused on AI technology to facilitate a modernized hospital by integrating administrative decision-making models for equipment maintenance management, enhancing the smart user interface, and incorporating an IoT and cloud computing technology to support real-time equipment tracking.

KEYWORDS

medical equipment management system, WepMEt program set, preventive and corrective maintenance, hospital information technology system

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1 INTRODUCTION

In the modernized hospital, medical equipment management plays an important role in delivering effective healthcare services, especially international standard compliance, which is an important scheme in the hospital administration. Hospital infrastructure management, such as medical personnel, supporting facilities, and particularly healthcare equipment, is mainly invested, operated, and evaluated efficiently. In the case of medical equipment, management elements commonly depend on the equipment lifecycle in hospitals as technology assessment, budgeting planning, equipment acquisition and installation, using and safety control, maintenance, and repairing until decommissioning and replacement. Those processes always concern data recording-reporting, guideline-regulation control, and resource management monitoring, which are mostly supported and enhanced by a computerized maintenance management system. CMMS is generally installed in the biomedical engineering department and used by nurses and BMEs according to their responsible duties. However, as complex technology changes, safety and service quality are more required by patients and also the public sector in order to guarantee potential problem prevention and quality management. Then, within the last decade, CMMS was developed and increasing performance continuously by many reports. For instance, C. Corciovă et al. [1] and A. K. Abdul Jawwa [2] presented approaches for developing the life cycle of medical devices, from planning and procurement to maintenance, with a focus on utilizing technology for systematic risk analysis and quality control of equipment.

Consequently, information technology has been integrated into medical device management systems, leading to the development of efficient medical equipment management technologies. M. Fuaddi et al. [3] developed a web-based medical equipment maintenance management system to track maintenance and calibration activities in hospitals. J. Li et al. [4] developed a maintenance and quality control system for medical equipment using data integration technology, which enhances the accuracy and efficiency of equipment maintenance, enabling real-time tracking and early detection of potential issues. M. I. Waly et al. [5] evaluated the services of clinical engineering departments in Riyadh hospitals and recommended the development of standardized manuals and continuous specialized training for the engineering staff. Lin Yao et al. [6] developed a “Medical equipment comprehensive management system based on cloud” using cloud computing technology, focusing on equipment management through dynamic scheduling with advanced algorithms such as particle swarm optimization (PSO) and chicken swarm optimization (CSO). Experimental results showed that this system is highly efficient in managing data and operates quickly, even in scenarios with a large number of simultaneous users. S. Xayalath et al. [7] developed a “Computerized maintenance management system (CMMS)” at Luang Prabang royal hospital, Laos, designed with Visual Studio and MySQL, enabling web-based access for rapid and efficient medical equipment maintenance. J. S. Jothiraj et al. [8] developed a web-based medical equipment database management system, which has been implemented in multiple hospitals, significantly improving the efficiency of medical equipment management. H. Sritart et al. [9] developed a web-based information system for medical laboratories (ME/CMM information system), designed to enhance data management efficiency and simplify operations using database and web applications, which significantly reduces the workload of staff and increases the efficiency of managing equipment and consumables. M. Pinho, et al. [10] devised a decision-making model for equipment maintenance management within the Hospital da Luz Lisboa network, and Q. Hidalgo et al. [11] developed an equipment management system using MySQL databases and

QR codes. These systems have been evaluated and further developed to meet the demands of medical equipment management in hospitals.

Based on a survey of essential needs of users, both nurses and biomedical engineers, the first version of the WepMEt platform was developed in Thailand in 2015. It aimed to support the management of medical equipment in provincial and regional hospitals, which has various requirements according to a different hospital context and healthcare servicing policy. These concepts are intently realized during platform development and a feature application module designing process in order to differ from the others [7, 8, 11]. The platform was developed based on a web-based application concept by using MySQL Server and PHP version 4.1; then it can operate both internally and externally. The WepMEt program set consists of two main parts, as shown in Figure 1 [12–14]. Part 1 is a medical equipment management part. It consists of six modules (module no. 1–6) as a 1) medical equipment registration module, 2) spare parts module, 3) repairing module, 4) preventive maintenance and calibration module, 5) pooling module, and 6) summary-reporting module. Part 2, a system management part, consists of four modules (modules no. 7–10): 7) a backup module, 8) a web board module, 9) a back-office module, and 10) an importing module. The first platform was charitably distributed and effectively implemented in many hospitals all over the country since 2016. However, among the success of our original platform, some limitations have occasionally been reported [15], such as a shortage of IT personnel in hospitals, requests for user training, and more linkage between each module. Furthermore, technology change and more complicated needs, such as hospital standard requirements in the healthcare servicing sector, are unavoidable influences on improving the medical equipment management system.

For those reasons described above, after five years of distribution, a new version of the WepMEt platform is re-developed thoughtfully to improve and respond to all suggestions. Firstly, first version platform experienced users from 15 hospitals and five experts in regional and provincial hospitals all over the country are selected to gather a comment by questionnaire method and in-depth interview. Significant comments from those users are summarized in detail to clarify the corrective topics or required additional features and used as a main criterion in this development. Then, a new program set in the WepMEt second version is designed and developed using the rapid prototyping-based method, which not only reduces the development time but also obtains a concise topic to improve. After the development is complete, 16 new hospitals that never used the WepMEt system before are recruited to participate in the orientated introduction and intensive hand-on training program of the WepMEt new version, and then satisfaction scores and comments are analyzed and reported finally.

2 METHODS

The methodology in this study was conducted in the following three steps:

Step 1: Identify the Improvement Topics and Additional Functions: In this step, we selected a sample of 20 hospitals, consisting of regional and province hospitals, using a random sampling technique. The selection criteria ensured that the hospitals had consistently used the WepMEt system for all modules for at least two consecutive years and had a bed capacity ranging between 50 and 300 beds. The selected hospitals were divided into two groups: 15 hospitals were chosen to provide feedback via a structured questionnaire, while the remaining five hospitals, classified as expert users, participated in in-depth interviews. The expert users were defined as biomedical engineering (BME)

staff who had been responsible for managing the WepMEt platform in their respective hospitals for a minimum of five years.

1. Questionnaire method. Questions in the questionnaire were meticulously designed and synthesized from issues and comments gathered during the five-year period of the WepMEt 1st version's usage (2017–2021). The questionnaire comprised 55 items across five main modules: registration, spare parts, repairing, maintenance-calibration, and pooling. Each question offered three response options: strongly agree, strongly disagree, and not sure. The reliability of the questionnaire was tested using Cronbach's alpha coefficient, yielding a value of 0.950, indicating high reliability. The questionnaires were mailed to the selected hospitals with clear instructions, and responses were collected and analyzed for further development.
2. In-depth interview method. In addition to the questionnaire, open-ended questions were used during the in-depth interviews to allow participants to freely discuss their needs and challenges with the WepMEt first version. The interview questions were based on the same 55 items used in the questionnaire. All interviews were audio-recorded and transcribed for qualitative data analysis.
3. Data analysis. The important criteria for evaluating the questionnaire scores are that only the item that voted "Strongly agree" higher than 75% by all users will be considered for further development of the platform function.

Step 2: Design and development of the 2nd version of the WepMEt platform

1. Development process. Our study team developed the new WepMEt platform using the rapid prototyping method, which allowed for a shorter development time compared to conventional techniques. This approach was particularly suitable for program development based on an existing version. The summarized data from Table 2 was used as input for this development process. During this step, five expert users were periodically invited to participate in the development process. These experts provided online panel feedback on each GUI (graphical user interface) and program output screen, ensuring that the design met user requirements.
2. Technical implementation. The platform was developed using PHP version 7.3, JavaScript, and MySQL Database version 8.0.17, along with responsive web design techniques to ensure adaptability across various devices and screen resolutions. The development and testing processes were conducted using tools such as Adobe Dreamweaver (a PHP editor) and an emulator tool.

Step 3: Satisfaction of the developed system

1. User groups. To evaluate satisfaction with the second version of the WepMEt platform, we established two user groups: Group A, the expert group, and Group B, the new user group. Group A consisted of five expert users who had participated in the development process. These experts were provided with the complete version of the platform, which was installed on a cloud system, along with a user manual. They were given a one-month trial period to comprehensively assess the platform. After the trial, their satisfaction was evaluated, and adjustments to the platform were made based on the feedback received.

   Group B included 23 new users from 16 hospitals across the country who had never used WepMEt version one before. These users, comprising Biomedical Engineering (BME) staff, nurses, executives, and other personnel, were invited to attend an intensive two-day hands-on workshop organized by the research team. The workshop was designed to train them in the use of the second version of WepMEt. All participants were requested

to remain engaged until the workshop was completed, after which their satisfaction was evaluated.

2. Satisfaction survey. The satisfaction survey form consisted of 24 questions that addressed key areas such as required functions in modern hospitals, user-friendliness, standard compliance, and data security. The survey was designed using a Likert scale, with scores ranging from one (very dissatisfied) to five (very satisfied). The reliability of the survey form was tested using Cronbach's alpha coefficient, which yielded a value of 0.950, indicating high reliability.
3. Data analysis. The satisfaction data from both groups were analyzed to summarize and compare the overall satisfaction levels between the expert group and the new user group. The results of this comparison are shown in Table 3.

3 RESULTS

The results of this study are presented as follows:

3.1 Results of identifying the improvement topic or required additional function

The characteristics of the old user from 20 sampling hospitals are shown in Table 1, and the summarized improvement topic and additional required functions are shown in Table 2.

Table 1. The characteristics of old user from 20 hospital in step 1

Items	Number (%)
Hospital type: 100–150 beds : 150–300 beds : > 300 beds	5 (25%) 10 (50%) 5 (25%)
Job position : head of department/center : BME staff	5 (25%) 15 (75%)
Working experience: 5–10 years	20 (100%)

Table 2. The summarized improvement topic and additional required function

Module/Item	Frequency (%)
Medical Equipment Registration module	
1. Show specific information alert that there is a duplicated with the previous information that has already been registered, such as equipment number, ID code, serial no., sales contract no.	100
2. Added QR code and can be used together with barcode	100
3. Adjust the ID code to 20 digits.	80
4. Automatic refresh of data in registration fields when basic data is added.	100
5. Added Clone item function in to registration part for register new equipment that have similar information	100
6. Enhancements were made to the display system of the medical equipment list, including lifespan color bars and the addition of a link to view repair history.	100

(Continued)

Table 2. The summarized improvement topic and additional required function *(Continued)*

Module/Item	Frequency (%)
Spare parts module	
7. No changes required	100
Repairing module	
8. Adjusted to be able to edit or delete items sent for repair. When there is an error in recording information.	90
9. Add buttons and function for external repairs by outsource company	100
10. Added End Repair button from progress report menu.	100
11. Display a yellow bar when the repair task is over 7 days, and a purple bar when over 15 days, and a red bar when over 30 days.	100
Preventive maintenance – Calibration module	
12. Added function for creation of IPM pass stickers.	100
13. Can be display a list of equipment in IPM planning before plan creation is finalized.	100
14. Equipment types or items, can be deleted from the plan before the plan ends. Except that if results are recorded, they cannot be deleted.	100
15. Add dashboard for summarized IPM results	100
16. Add Clone planning function for create a new PM plan	100
Pooling module	
17. Add a dashboard for show the sufficiency of borrowing-return statistics.	100
18. Adjustable to lend more than 1 device at a time.	100
19. Add link to see list of borrowing equipment	80

The results of identifying additional issues and needs in Section 3.1 reveal the main problems experienced by existing users in the first generation of the WepMEt system, which has led to the development of new functionalities in the second generation that address this. So, the researchers developed functions for solving the problem from the 1st version of WepMEt, such as creating IPM stickers, QR code generators, and displaying equipment status in color bars based on the life of the equipment.

3.2 Results of design and development of the second version of the WepMEt platform

The second WepMEt platform retains the core structure of the first version and includes two main sections: the medical equipment management section with six main modules as 1) a medical equipment registration module; 2) a spare parts module; 3) a repairing module; 4) a preventive maintenance and calibration module; 5) a pooling module; and 6) a summary-reporting module, and the system management section with three modules as a data backup module, a back-office module and an importing module, (see Figure 1). The significant enhancements have been introduced in this version, including:

1. The removal of the underutilized web board module.
2. The addition of a data migration function within the importing module, enabling users to seamlessly transfer data from WepMEt version one to version two without losing any accumulated management data.

3. The implementation of an automated backup reminder function, which prompts users to perform data backups every seven days, thereby reducing the risk of data loss due to virus attacks, such as those caused by the WannaCry virus, or hardware failures of the main computer.
4. The use of responsive web design technology in this platform enables efficient response to display on various smart devices.
5. The installation of an ORG ID in the database facilitates, the development of a cloud-based system that can aggregate data from WepMEt across various hospitals for big data processing.

Fig. 1. First page of 2nd version WepMEt platform

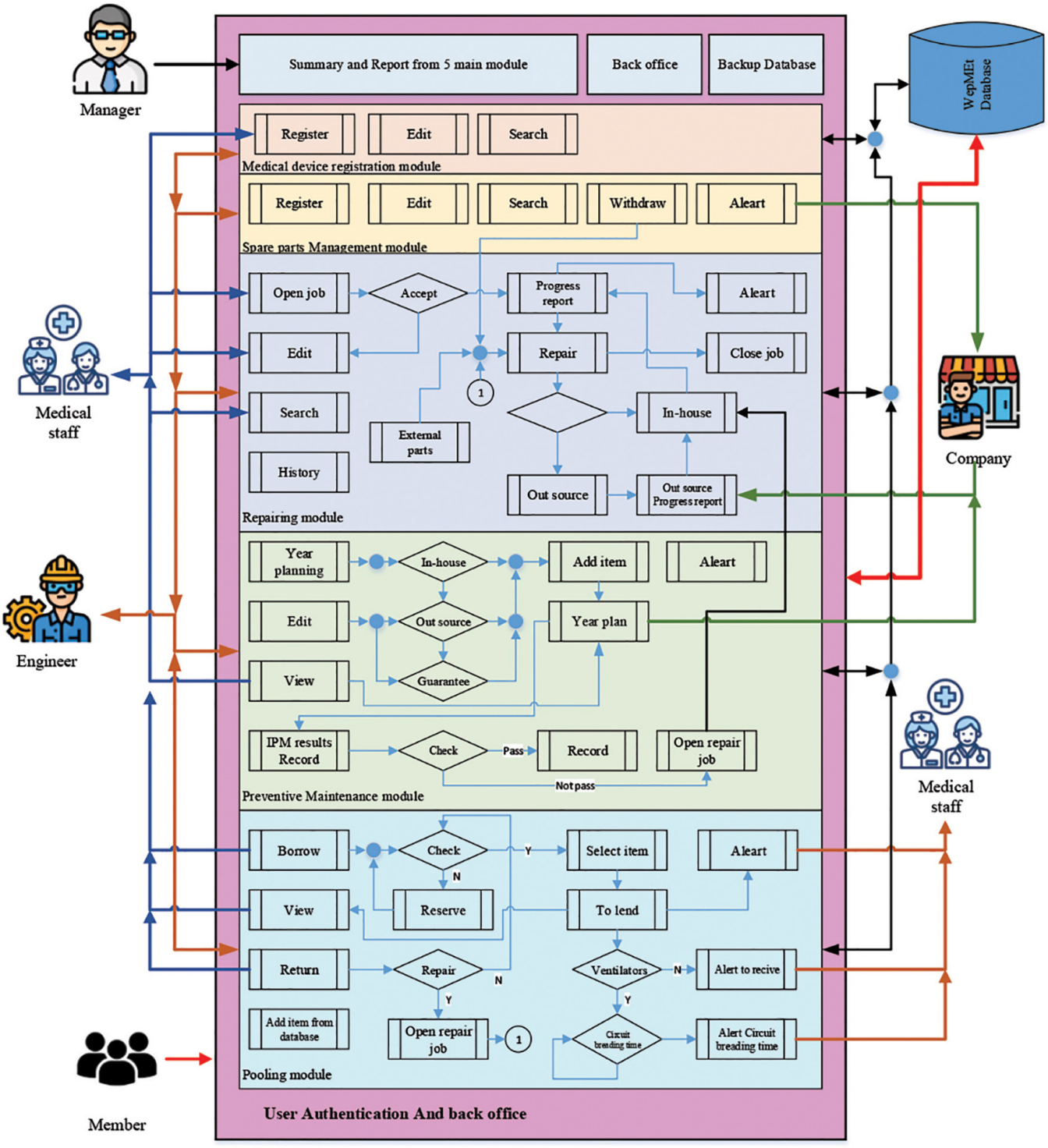


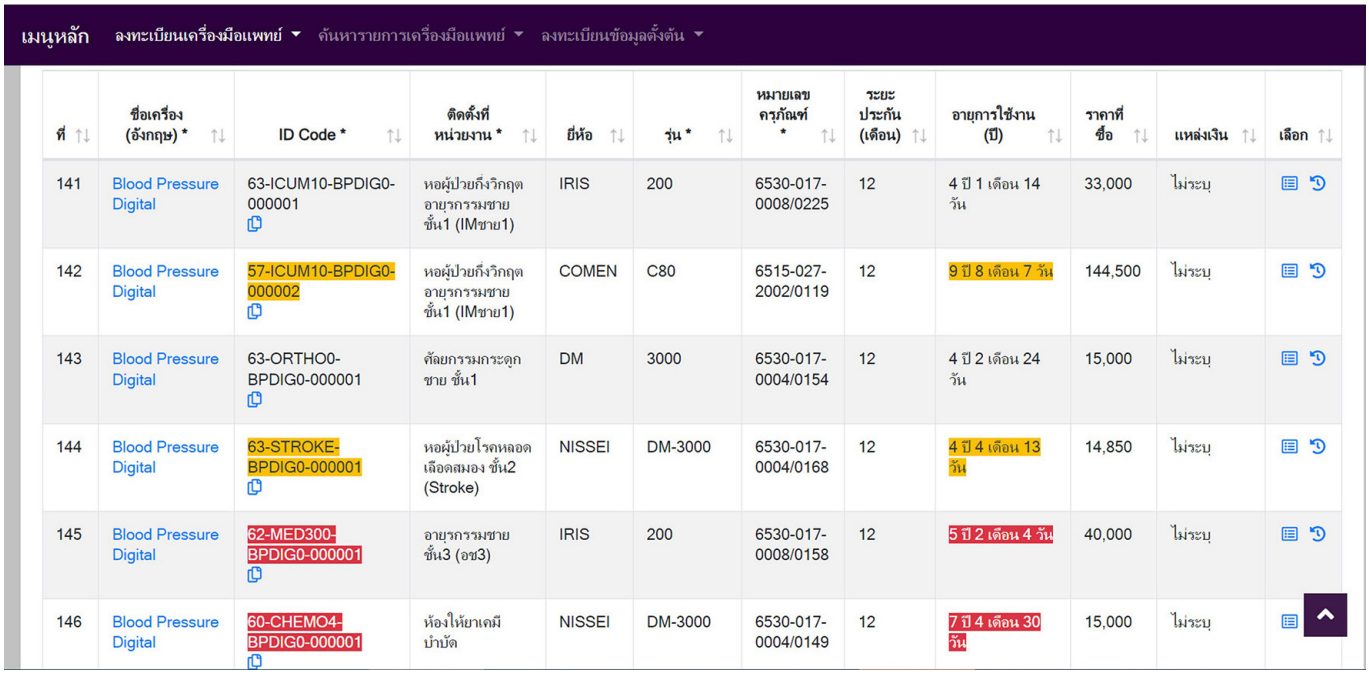
Fig. 2. Flow diagram of 2nd version WepMEt platform. [Adapted from 14]

The 2nd WepMEt platform is designed to enhance coordination between internal and external hospital users through a customizable role-based access control system, ensuring data security and process accuracy. Figure 2 shows the work process of WepMEt. The cores module is the medical equipment registration module, which integrates with other modules, such as the spare parts module for inventory

management, the repair module for managing equipment repairs, and the maintenance module for planning and monitoring preventive activities. The pooling module improves operational flexibility, while backup data management and back-office administration ensure effective system governance and data integrity. Figure 4 illustrates these components and their interactions.

Medical equipment registration module. The medical equipment registration module is the center of this plateform; it is managing all medical equipment within the hospital that is registerred on the plateform. Key improvements in this module include:

1. Cloning function: This feature reduces the time to register a new medical equipment item in the database by up to 30%, as users are no longer required to enter data in every field in the register form, thereby increasing the efficiency of the registration process.
2. QR code generation: QR codes are suitable for supporting 20-digit ID codes more effectively than barcodes and enhance the accuracy and quality of scanning, enabling efficient access to detailed information about medical equipment.
3. Automatic data refresh in registration fields: When basic data is added, the registration fields are automatically refreshed, allowing users to continue entering information without interruption, thereby improving workflow efficiency.
4. Color-coded equipment age indicator: This feature allows users to easily monitor the lifespan of medical equipment, aiding in decision-making regarding equipment procurement or decommissioning (see Figure 3).

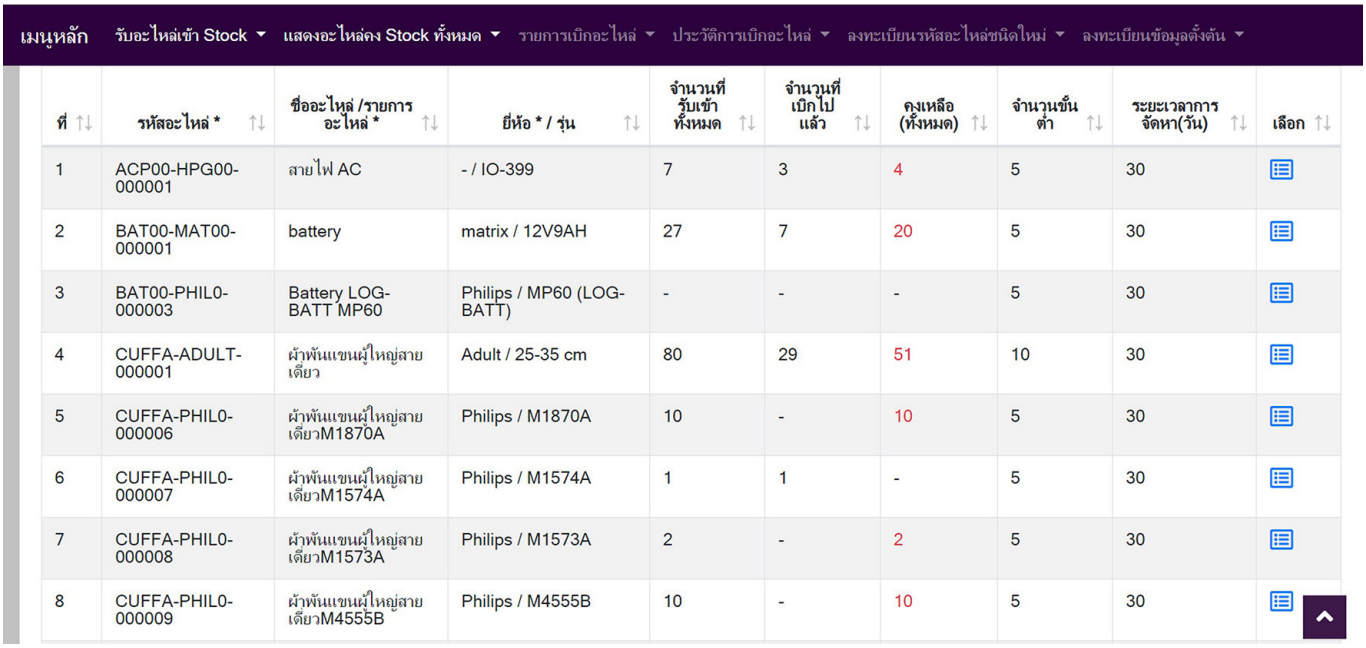


ที่	ชื่อเครื่อง (อังกฤษ) *	ID Code *	ติดตั้งที่หน่วยงาน *	ยี่ห้อ	รุ่น *	หมายเลขครุภัณฑ์ *	ระยะประกัน (เดือน)	อายุการใช้งาน (ปี)	ราคาที่ซื้อ	แหล่งเงิน	เลือก
141	Blood Pressure Digital	63-ICUM10-BPDIG0-000001	หอผู้ป่วยกึ่งวิกฤตอายุรกรรมชาย ชั้น1 (IMชาย1)	IRIS	200	6530-017-0008/0225	12	4 ปี 1 เดือน 14 วัน	33,000	ไม่ระบุ	
142	Blood Pressure Digital	57-ICUM10-BPDIG0-000002	หอผู้ป่วยกึ่งวิกฤตอายุรกรรมชาย ชั้น1 (IMชาย1)	COMEN	C80	6515-027-2002/0119	12	9 ปี 8 เดือน 7 วัน	144,500	ไม่ระบุ	
143	Blood Pressure Digital	63-ORTHO0-BPDIG0-000001	ศัลยกรรมกระดูกชาย ชั้น1	DM	3000	6530-017-0004/0154	12	4 ปี 2 เดือน 24 วัน	15,000	ไม่ระบุ	
144	Blood Pressure Digital	63-STROKE-BPDIG0-000001	หอผู้ป่วยโรคหลอดเลือดสมอง ชั้น2 (Stroke)	NISSEI	DM-3000	6530-017-0004/0168	12	4 ปี 4 เดือน 13 วัน	14,850	ไม่ระบุ	
145	Blood Pressure Digital	62-MED300-BPDIG0-000001	อายุรกรรมชาย ชั้น3 (อช3)	IRIS	200	6530-017-0008/0158	12	5 ปี 2 เดือน 4 วัน	40,000	ไม่ระบุ	
146	Blood Pressure Digital	60-CHEMO4-BPDIG0-000001	ห้องให้ยาเคมีบำบัด	NISSEI	DM-3000	6530-017-0004/0149	12	7 ปี 4 เดือน 30 วัน	15,000	ไม่ระบุ	

Fig. 3. Medical equipment list display screen with status color bar

The spare parts module. The spare parts module (see Figure 4) is designed to manage the inventory of spare parts used for the maintenance of medical equipment in hospitals. It includes functions for receiving spare parts into the warehouse,

distributing parts, displaying inventory values, and alerting when the stock level is low. In this version, although there are no suggestions for improvement from users in this module, researchers have improved the user interface and adjusted the menus to increase ease of use, making this module more convenient and efficient to use.

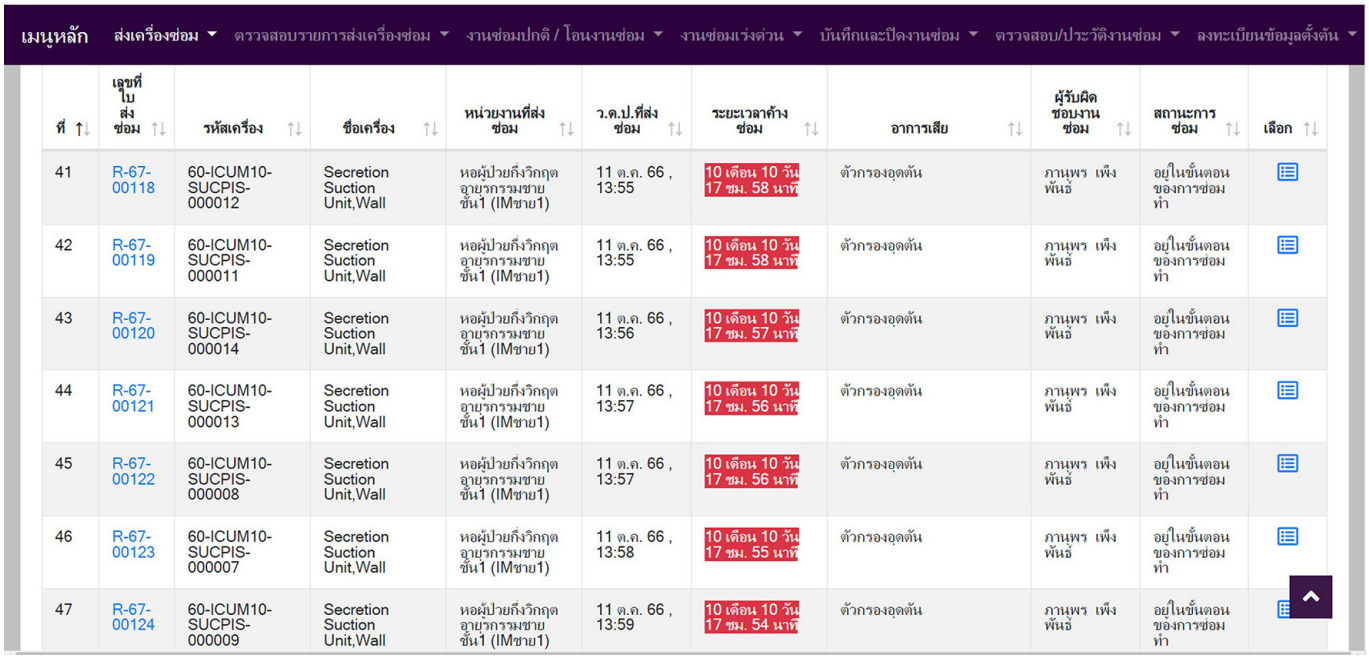


ที่	รหัสอะไหล่ *	ชื่ออะไหล่ /รายการอะไหล่ *	ยี่ห้อ * / รุ่น	จำนวนที่รับเข้าทั้งหมด	จำนวนที่เบิกไปแล้ว	คงเหลือ (ทั้งหมด)	จำนวนขั้นต่ำ	ระยะเวลาการจัดหา(วัน)	เลือก
1	ACP00-HPG00-000001	สายไฟ AC	- / IO-399	7	3	4	5	30	
2	BAT00-MAT00-000001	battery	matrix / 12V9AH	27	7	20	5	30	
3	BAT00-PHIL0-000003	Battery LOG-BATT MP60	Philips / MP60 (LOG-BATT)	-	-	-	5	30	
4	CUFFA-ADULT-000001	ผ้าพันแขนผู้ใหญ่สายเดียว	Adult / 25-35 cm	80	29	51	10	30	
5	CUFFA-PHIL0-000006	ผ้าพันแขนผู้ใหญ่สายเดียวM1870A	Philips / M1870A	10	-	10	5	30	
6	CUFFA-PHIL0-000007	ผ้าพันแขนผู้ใหญ่สายเดียวM1574A	Philips / M1574A	1	1	-	5	30	
7	CUFFA-PHIL0-000008	ผ้าพันแขนผู้ใหญ่สายเดียวM1573A	Philips / M1573A	2	-	2	5	30	
8	CUFFA-PHIL0-000009	ผ้าพันแขนผู้ใหญ่สายเดียวM4555B	Philips / M4555B	10	-	10	5	30	

Fig. 4. Spare parts inventory display screen

The repairing module. The Repairing module is designed to support the maintenance and repair of medical equipment. All equipment must be recorded in the Registration module before it can be sent for repair. During the testing phase, 133 repair tasks were initiated, with 119 tasks completed and 24 tasks still in progress. No errors were detected throughout the process. Notifications for repair requests, task assignments, and completion are consistently displayed on the computer screen. The key improvements in this module are as follows:

1. The added repair close button significantly reduces the confusion for technicians in closing repair jobs found in WepMEt 1st version.
2. The added external repairs button for outsourcing companies reduces the confusion for technicians found in WepMEt 1st version.
3. Automatic technician assignment. This function reduces the waiting time for technician selection by the administrative department by at least 30 minutes, even when notifications are displayed on the computer screen. It also ensures an even distribution of workload among technicians, thereby improving the efficiency of the repair management process.
4. Color-coded repair status indicator (see Figure 5). This feature motivates technicians to complete repairs more quickly and allows department heads to monitor the repair status of medical equipment promptly.



ที่	เลขที่ใบส่งซ่อม	รหัสเครื่อง	ชื่อเครื่อง	หน่วยงานที่ส่งซ่อม	ว.ด.ป.ที่ส่งซ่อม	ระยะเวลาค้างซ่อม	อาการเสีย	ผู้รับผิดชอบงานซ่อม	สถานะการซ่อม	เลือก
41	R-67-00118	60-ICUM10-SUCPIS-000012	Secretion Suction Unit,Wall	หอผู้ป่วยกึ่งวิกฤตอายุรกรรมชาย ชั้น1 (IMชาย1)	11 ต.ค. 66 , 13:55	10 เดือน 10 วัน 17 ชม. 58 นาที	ตัวกรองอุดตัน	ภานุพร เพ็งพันธ์	อยู่ในขั้นตอนของการซ่อมทำ	
42	R-67-00119	60-ICUM10-SUCPIS-000011	Secretion Suction Unit,Wall	หอผู้ป่วยกึ่งวิกฤตอายุรกรรมชาย ชั้น1 (IMชาย1)	11 ต.ค. 66 , 13:55	10 เดือน 10 วัน 17 ชม. 58 นาที	ตัวกรองอุดตัน	ภานุพร เพ็งพันธ์	อยู่ในขั้นตอนของการซ่อมทำ	
43	R-67-00120	60-ICUM10-SUCPIS-000014	Secretion Suction Unit,Wall	หอผู้ป่วยกึ่งวิกฤตอายุรกรรมชาย ชั้น1 (IMชาย1)	11 ต.ค. 66 , 13:56	10 เดือน 10 วัน 17 ชม. 57 นาที	ตัวกรองอุดตัน	ภานุพร เพ็งพันธ์	อยู่ในขั้นตอนของการซ่อมทำ	
44	R-67-00121	60-ICUM10-SUCPIS-000013	Secretion Suction Unit,Wall	หอผู้ป่วยกึ่งวิกฤตอายุรกรรมชาย ชั้น1 (IMชาย1)	11 ต.ค. 66 , 13:57	10 เดือน 10 วัน 17 ชม. 56 นาที	ตัวกรองอุดตัน	ภานุพร เพ็งพันธ์	อยู่ในขั้นตอนของการซ่อมทำ	
45	R-67-00122	60-ICUM10-SUCPIS-000008	Secretion Suction Unit,Wall	หอผู้ป่วยกึ่งวิกฤตอายุรกรรมชาย ชั้น1 (IMชาย1)	11 ต.ค. 66 , 13:57	10 เดือน 10 วัน 17 ชม. 56 นาที	ตัวกรองอุดตัน	ภานุพร เพ็งพันธ์	อยู่ในขั้นตอนของการซ่อมทำ	
46	R-67-00123	60-ICUM10-SUCPIS-000007	Secretion Suction Unit,Wall	หอผู้ป่วยกึ่งวิกฤตอายุรกรรมชาย ชั้น1 (IMชาย1)	11 ต.ค. 66 , 13:58	10 เดือน 10 วัน 17 ชม. 55 นาที	ตัวกรองอุดตัน	ภานุพร เพ็งพันธ์	อยู่ในขั้นตอนของการซ่อมทำ	
47	R-67-00124	60-ICUM10-SUCPIS-000009	Secretion Suction Unit,Wall	หอผู้ป่วยกึ่งวิกฤตอายุรกรรมชาย ชั้น1 (IMชาย1)	11 ต.ค. 66 , 13:59	10 เดือน 10 วัน 17 ชม. 54 นาที	ตัวกรองอุดตัน	ภานุพร เพ็งพันธ์	อยู่ในขั้นตอนของการซ่อมทำ	

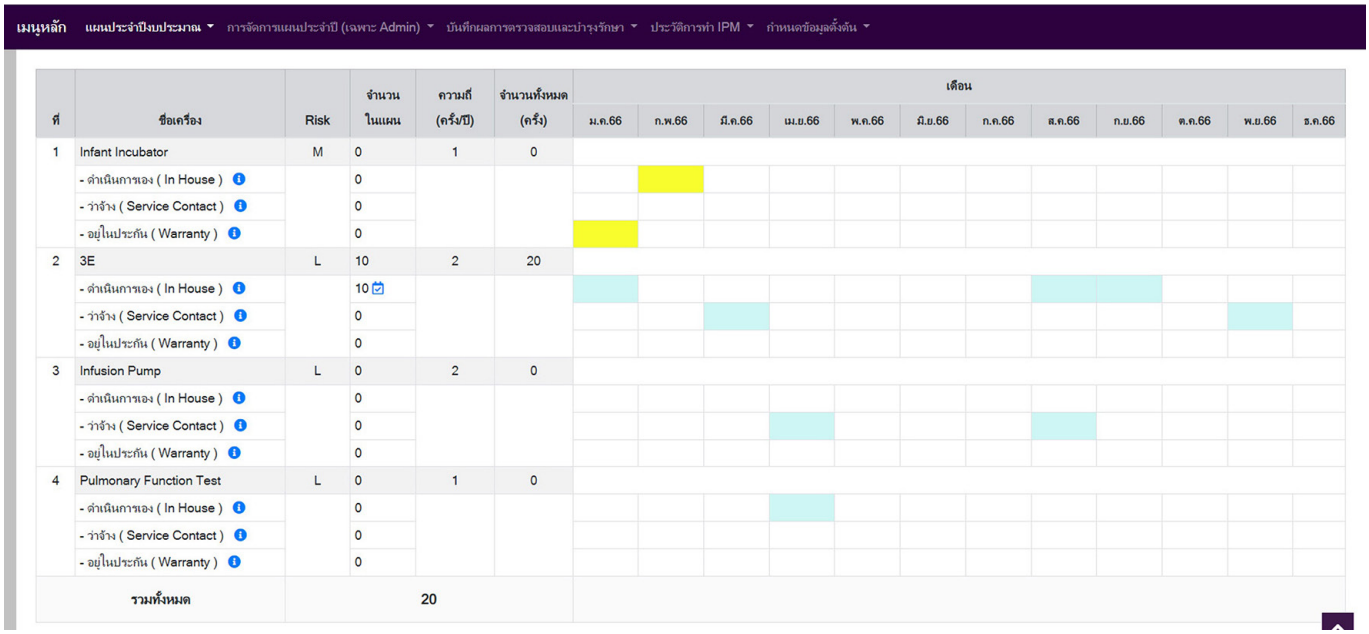
Fig. 5. Repair report display screen

The maintenance-calibration module. The maintenance and calibration module (IPM module) are designed to help users to create preventive maintenance plans for medical equipment in hospitals. Other nursing departments can effectively monitor preventive maintenance schedules. The creation of maintenance plans is divided into three categories as 1) In-house plan: Conducted by hospital staff, 2) Outsourced plan: Performed by an external company, and 3) Warranty plan: Provided by the manufacturer or service company (see Figure 6).

This module has undergone several enhancements to improve performance and user-friendliness, including:

1. IPM pass sticker. It is a new feature that helps users to create stickers to indicate that equipment has maintenance, which is crucial for confirming that maintenance activities have been completed.
2. Device linking in the IPM plan. Users can view a list of devices included in the IPM plan before finalizing it, facilitating more accurate and convenient management.
3. Equipment deletion from the plan. Users can delete equipment types or specific items from the maintenance plan before results are recorded. Once the results are saved, deletion is not permitted, ensuring data integrity.
4. IPM summary dashboard. A new dashboard has been added to summarize preventive maintenance results, providing users with a clear overview of maintenance activities and outcomes.
5. Clone planning function. This feature allows users to quickly create a new PM plan for the following year by duplicating the existing plan.

This module is tested by recording maintenance plans for 22 equipment groups and 140 items, hiring plans for 92 equipment categories and 801 items, and warranty plans for 18 equipment categories and 38 items. No errors were identified during the testing process.



ที่	ชื่อเครื่อง	Risk	จำนวนในแผน	ความถี่ (ครั้ง/ปี)	จำนวนทั้งหมด (ครั้ง)	เดือน											
						ม.ค.66	ก.พ.66	มี.ค.66	เม.ย.66	พ.ค.66	มิ.ย.66	ก.ค.66	ส.ค.66	ก.ย.66	ต.ค.66	พ.ย.66	ธ.ค.66
1	Infant Incubator	M	0	1	0												
	- ดำเนินการเอง (In House)		0														
	- ว่าจ้าง (Service Contact)		0														
	- อยู่ในประกัน (Warranty)		0														
2	3E	L	10	2	20												
	- ดำเนินการเอง (In House)		10														
	- ว่าจ้าง (Service Contact)		0														
	- อยู่ในประกัน (Warranty)		0														
3	Infusion Pump	L	0	2	0												
	- ดำเนินการเอง (In House)		0														
	- ว่าจ้าง (Service Contact)		0														
	- อยู่ในประกัน (Warranty)		0														
4	Pulmonary Function Test	L	0	1	0												
	- ดำเนินการเอง (In House)		0														
	- ว่าจ้าง (Service Contact)		0														
	- อยู่ในประกัน (Warranty)		0														
	รวมทั้งหมด		20														

Fig. 6. Year plan for preventive maintenance

The pooling module. This module is designed to support the medical equipment management centers in hospitals, especially for high-priced medical equipment that is not regularly used in each nursing department, such as ventilators, infusion pumps, and syringe pumps. This system allows the sharing of equipment between departments or wards by borrowing and returning it to the medical equipment center when it is finished. It is effective to reduce the need to purchase new equipment within the hospital. In addition, the location of medical equipment can be checked from the borrowing request sent through the system. If any equipment is found to be damaged, the repair process will be automatically forwarded to the repair module.Several enhancements have been made to this module to improve its performance and ease of use, including:

1. Dashboard for borrowing – return statistics (see Figure 7). This dashboard allows users to effectively assess the sufficiency of medical equipment and the demand for usage.
2. Multi-device lending capability. Ti is the flexibility of medical equipment management lending.
3. Dashboard link for viewing borrowed equipment. The addition of a link from the dashboard to view the list of currently borrowed equipment increases transparency and ease of tracking.

The functionality of this module was tested by importing three categories of equipment, including 30 infusion pumps, 10 ventilators, and two mobile ventilators. No errors were found during the testing process, demonstrating the module's reliability and effectiveness of the pooling module.

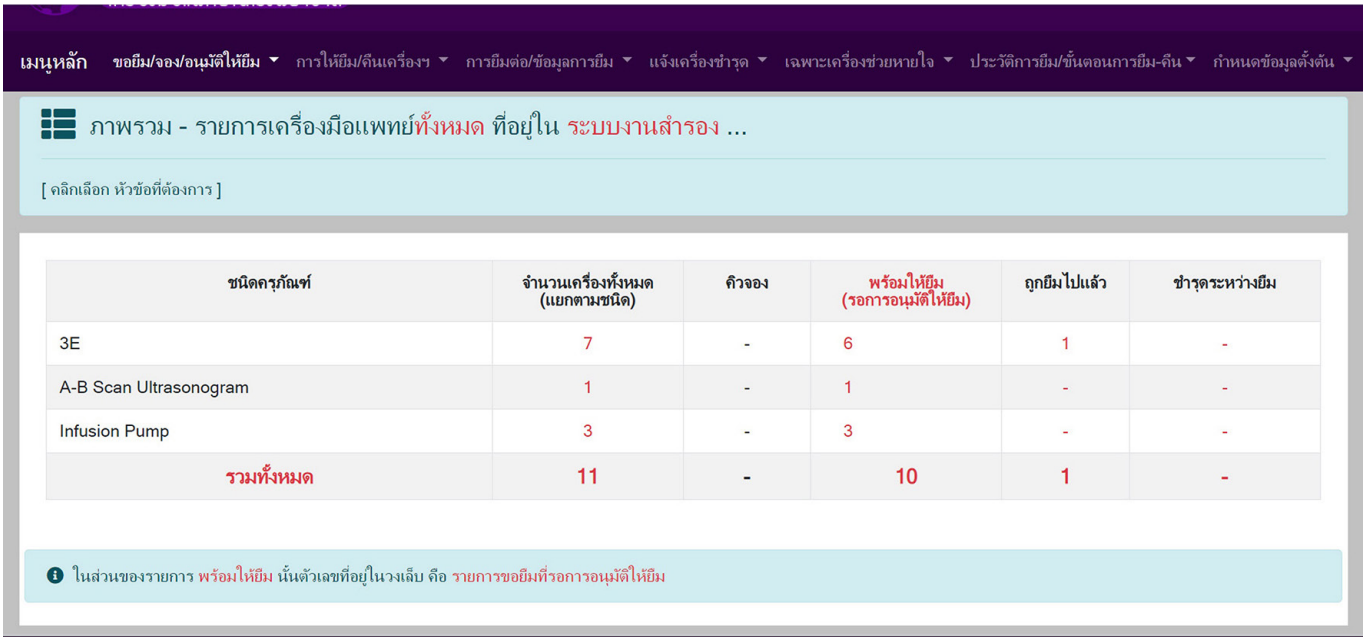


Fig. 7. System overview display screen

3.3 Result of satisfaction of the developed system

The characteristic of new users (23 persons) from 16 hospitals is shown in Table 3. Table 4 shows the satisfaction score compared between Group A–the five expert users–and Group B–new users.

Table 3. The characteristics of new user from 16 hospital (23 persons) in step 3

Items	Number (%)
Hospital type: 100–150 beds : 150–300 beds : > 300 beds	8 (50%) 5 (31%) 3 (19%)
Job position: BME staff : nurse : executive	8 (50%) 7 (44%) 1 (6%)
Working experience: 6–10 years : > 10 years	12 (75%) 4 (25%)

Table 4. The evaluation of satisfaction

Item	Experts ($\bar{x}$(SD))	New User ($\bar{x}$(SD))	$\bar{x}$
1. Alignment with intended objectives	4.60 (0.51)	4.57 (0.52)	4.59
2. Responsiveness of medical equipment data display to user needs	4.67 (0.48)	4.71 (0.47)	4.69
3. Clarity and accessibility of data presentation	4.70 (0.46)	4.71 (0.47)	4.71
4. Responsiveness of spare parts data display to user needs	4.72 (0.46)	4.71 (0.47)	4.72
5. The database is up-to-date and current.	5.00 (0.00)	5.00 (0.00)	5.00

(Continued)

Table 4. The evaluation of satisfaction *(Continued)*

Item	Experts ($\bar{x}$(SD))	New User ($\bar{x}$(SD))	$\bar{X}$
6. Completeness of information in summary reports	4.73 (0.46)	4.71 (0.47)	4.72
7. System efficiency for usability	4.81 (0.40)	4.86 (0.41)	4.84
8. Enhanced operational efficiency	4.62 (0.80)	4.71 (0.47)	4.67
9. Compliance with hospital quality assurance systems	4.75 (0.46)	4.71 (0.47)	4.73
10. Expedited equipment data search or summarization	4.75 (0.46)	4.71 (0.47)	4.73
11. Compliance with hospital quality assurance systems	4.75 (0.46)	4.71 (0.47)	4.73
12. Expedited equipment data search or summarization	4.75 (0.46)	4.71 (0.47)	4.73
13. Enhanced convenience and speed of user tasks	4.81 (0.40)	4.86 (0.41)	4.84
14. User-friendly and convenient screen layout	4.52 (0.81)	4.57 (0.81)	4.55
15. Clear meaning conveyed through command buttons or menu items	4.62 (0.50)	4.57 (0.50)	4.60
16. Ease of understanding in notification messages	4.62 (0.80)	4.71 (0.47)	4.67
17. Suitability for user interaction	4.70 (0.46)	4.71 (0.47)	4.71
18. Appropriateness and meaningfulness of colors used	4.52 (0.81)	4.57 (0.81)	4.55
19. Value of information presented	4.81 (0.40)	4.86 (0.40)	4.84
20. Suitability of component placement on screen	4.69 (0.46)	4.71 (0.47)	4.70
21. Data access security	4.81 (0.40)	4.86 (0.38)	4.84
22. Facilitated task tracking	4.81 (0.40)	4.86 (0.38)	4.84
23. System speed in processing	4.81 (0.40)	4.86 (0.38)	4.84
24. System reliability	4.81 (0.40)	4.86 (0.38)	4.84
25. Alignment with actual system operations	4.74 (0.46)	4.71 (0.47)	4.73
26. Data failure prevention in system	4.71 (0.41)	4.71 (0.47)	4.71
Average	**4.73 (0.46)**	**4.75 (0.48)**	**4.74**

From Table 4, it is found that the satisfaction average score of the experts group and the new user group is 4.73 and 4.75, respectively. All items obtain a satisfaction score higher than 4.51. The topic with the highest score (5.00) is the no. 5 database is up-to-date and current. The second highest (4.74) is no. 7, 11, 19, 20, 21. The lowest score (4.55) is no. 16–appropriateness and meaningfulness of colors used. We also compared the satisfaction score between the expert and new user and found that there is no statistically significant difference between the two groups at the 0.01 significance level as shown in Table 5.

Table 5. The T-test comparison results

	n	Mean	Variance	t	df	Sig
Training	23	4.75	0.01	2.65	24	0.01
Expert	5	4.73	0.01			

4 DISCUSSION

This study demonstrates significant success in the development of the 2nd version of the WepMEt platform for managing medical equipment in hospitals. The development not only enhances management efficiency and data tracking but also comprehensively meets user needs and provides a significant advantage over several previous studies.

Compared to the development of other medical equipment management systems, such as the work of Corciovă [1] and Abdul Jawwad [2], which focused on developing the lifecycle of medical equipment from planning to maintenance, our WepMEt offers a powerful support for tracking equipment maintenance status and providing the expiration alerts. This improvement enhances the accuracy of maintenance planning and management. The additional function to include registration, repairs, and spare parts management reflects WepMEt's efficient capability in equipment management along the equipment life cycle compared to existing systems.

Furthermore, the development by Al-Asmari [4], which utilized data integration technology to enhance accuracy and maintenance efficiency, has also been effectively implemented in WepMEt through a real-time tracking of repairs and maintenance status. This function reduces workload and improves equipment management efficiency. Additionally, WepMEt has adopted the development by Waly [5], which proposed the creation of standard manuals and ongoing training for clinical engineering staff by providing user manuals and training for new users, making our system easier to use. Yao's research [6], which developed a cloud-based medical equipment management system, is also comparable to WepMEt. Although WepMEt is not a cloud-based system, it supports the internet function and multi-user access, ensuring seamless connectivity and functionality. Similarly, the development of CMMS by Xayalath [7] demonstrates WepMEt's ability to extend its function to include equipment borrowing and returning, thereby increasing management flexibility and usability.

While WepMEt has advanced in data management and integration functions, it still lacks a decision-making model for maintenance management, which is a key feature in Pinho's research [10]. Future development of WepMEt should focus on integrating decision-making models and IoT technology to enhance the efficiency of medical equipment management in hospitals.

Considering the satisfaction evaluation of the WepMEt platform, assessed by five experts who had used WepMEt platform first version and 23 trainees who had never used the platform, the platform received significantly high satisfaction levels from both groups, with average scores of 4.73 and 4.75, respectively. This indicates that the platform effectively meets user needs in various aspects. Compared to Corciovă [1] and Abdul Jawwad [2], which did not emphasize user satisfaction assessment, our high satisfaction scores from actual users demonstrate a program design that focuses on real user needs. Additionally, the highest satisfaction score in the "Database is current and up-to-date" item at 5.00 indicates emphasizing data integration to enhance accuracy and efficiency maintenance. In the context of Xayalath [7], which focused on ease of use and data accessibility, WepMEt also gets high scores in "Ease of use" and "System speed" reflecting the platform's ability to enhance management flexibility and usability. However, some colors using in order to indicate a notification event, as shown in item 16, still need to be slightly adjusted in the near future.

Contrast to the other works, our second version of the WepMEt platform first integrates the equipment pooling function in CMMS. This originality not only promotes resource sharing between clinical wards in strategic management policy in modern

hospitals but also enhances equipment status monitoring of borrowed or returned equipment effectively. Another initial innovation of our platform is a data linkage function in the importing module, which is designed to support equipment data transfer processes between the other CMMS and our platform. This novelty reduces BME's working load in data importing tasks and minimizes errors from the user, obviously.

5 CONCLUSION

In this study, we present the development of the second version of the WepMEt platform, which was comprehensively designed and improved in order to respond to user needs and medical equipment management requirements in modern hospitals. Comments from the experts and the experienced users are systematically gathered and thoroughly analyzed, then used as initiative information in the rapid prototype development process. Our final platform is functionally assessed by new users who attend the intensive WepMEt user training course. The evaluation shows a very high satisfaction score in the modernized database management. In terms of originality, the pooling module for medical equipment sharing and data transfer supporting functions between two different databases is first introduced in CMMS by our research team.

However, there are still some applications that are able to integrate into our system in order to serve the user needs, especially the decision-making models for preventive maintenance planning adjustment or the connection system for IoT technology in modern equipment to enhance equipment tracking. These challenges will be our further development in the near future.

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8 AUTHORS

Nutdanai Singkhleewon is an Associate Professor at Bansomdejchaopraya Rajabhat. University, Bangkok, Thailand and also a Deputy Dean of Graduate School, with areas of expertise being Medical Equipment Management Information System, Technology Management, Electronic Technology (E-mail: nutdanai.si@bsru.ac.th).

Arthorn Sanpanich is an Assistant Professor in Biomedical Instrumentation at Institute of Molecular Biosciences, Mahidol University. His areas of expertise include Biomedical Equipment Technology, Medical Image Processing and Medical Equipment Management Information System (E-mail: arthorn.san@mahidol.ac.th).

Teerawit Asawasilpakul is an Assistant Professor at Bansomdejchaopraya Rajabhat. University, Bangkok, Thailand. He works in the Computer Electronic Technology program, Faculty of Science and Technology. His areas of expertise include Robotic, Electronic Technology, Digital Electronics, and Automatic Systems (E-mail: teerawit.as@bsru.ac.th).

Kanlaya Thanasin is an Assistant Professor at Bansomdejchaopraya Rajabhat. University, Bangkok, Thailand. She works in the Computer Electronic Technology program, Faculty of Science and Technology. Her areas of expertise include Physic, Electronic Technology, Sensor Technology (E-mail: kanlaya.th@bsru.ac.th).

Amonrat Khambun is an Assistant Professor Doctor at Bansomdejchaopraya Rajabhat. University, Bangkok, Thailand. Dr. Amonrat works in the Health Technology program, Faculty of Science and Technology and areas of expertise include Physic, Nano Technology, Sensor Technology, Health Science (E-mail: amonrat.kh@bsru.ac.th).