The Research and Development of Sterilize Device Management Information System with RFID Technology and Supply Chain Management for Central Sterile Services Department (CSSD) in Hospital

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Abstract—This The purposes of this research were to: 1) develop the sterile medical device management information system and 2) to evaluate the efficiency of the sterile medical device management information system for hospital CSSD with RFID and supply chain concept. The sample group consisted of 5 experts selected by purposive sampling method. The research instruments were the structured interview, questionnaire, sterile medical device management information system and efficiency evaluation form. The statistics used for data analysis were mean and S.D. The research findings indicated that the sterile medical device management information system works through web browser could be displayed according to the Responsive Web Design principles consisting of 2 modules, registration system module and sterile medical device warehouse system module. The result of efficiency evaluation by 5 experts was at high level (avergave = 4.13 S.D. = 0.59).

Keywords-Central sterile services department information system; Central sterile services department; RFID technology; Supply chain management

I. INTRODUCTION

It had been found that a large number of patients used public health facility in Thailand each year. According to the National Statistic Office of Thailand, there were as many as 12,445,264 patients in 2012 [1]. And, according to the Accident Data Center of Thailand, the number of patients who were injured and faced disabilities due to accidents in 2020 was 946,435 [2]. Due to the high number of patients, the need to use sterilized medical devices in patients' treatment also increases which deems necessary that they should be sufficiently and appropriately provided and are always ready-to-use. This is more essential for reused medical devices where they must go through disinfection process before they can be reused to eliminate all bacteria which can cause severe diseases [3]. Preparation of sterilized medical devices in hospitals is managed by the central sterile services departments which act as the main department in collecting used medical devices for disinfection process before distributing them back to other departments in the hospital to be used to treat patients.

Sterilized devices management information system for the central sterile services department in the hospital appropriately assists with management of sterilized medical devices. The first approach focuses on the fact that there is a large amount of patients to use sterilized medical devices which require management and inspection throughout the disinfection process and to assure that they are sufficiently provided. From the study, it was found that there are many expired unused sterilized medical devices according to the hospital. Several departments withdraw the devices as spares for emergencies but never use them until expired which cause extreme economic loss each year. The second approach focuses on the control of the disinfection process. As the central sterile services department is the unit that collects reused medical devices for disinfection process before using them to treat patients, it is at high risk if the disinfection process is not complete or not thorough as that can cause infections, other illness, or side effects when used with patients.

With the stated rationales, the researchers developed the sterilize devices management information system for the central sterile services department using RFID technology and supply chain management to regulate the disinfection process to international standard and to assure quality in the disinfection process. Also, the system links

the database of central sterile services departments across the country to create big data for future analysis and management on a national level.

II. OBJECTIVES

1. To develop sterilized devices management information system for the central sterile services departments in hospitals using RFID technology and supply chain management
2. To evaluate the efficiency of sterilized devices management information system for the central sterile services departments in hospitals using RFID technology and supply chain management

III. BACKGROUND

This research had studied theories, concepts and principles of central sterile services department (CSSD) in hospital and RFID Technology for healthcare applications. Also, big data concepts principles and supply chain implementation which had studied from books, documents and research both in the country and abroad. This background were used as a conceptual framework for the development of information systems for sterilize device management information system with RFID technology and supply chain management for central sterile services department in hospital.

IV. METHOD

This research was developmental research using the following methods;

A. Population and sample

Population and sample were ten experts and five dignitaries in information system with experience in sterilized medical devices management using purposive sampling method.

B. Research instruments

Research instruments were as follows: 1) Structured interview questionnaire that has been approved for validity and suitability of interview items with IOC (Index of Item Objective Congruence) ranging from 0.50 - 1.00; 2) Sterilized devices management information system for the central sterile services departments in hospitals using RFID technology and supply chain management; 3) Evaluation criteria model to evaluate the efficiency of sterilized devices management information system for the central sterile services departments in hospitals using RFID technology and supply chain management with IOC (Index of Item Objective Congruence) ranging from 0.50 - 1.00

C. Methodology

The main method could be divided into four stages as follows; 1) Researchers met with dignitaries in sterilized medical devices management, users of sterilized devices management information system of the central sterile services department, and other related personnel to analyze requirements in developing hospitals and to set a path for the development of sterilized devices management information system. 2) Researchers presented specification draft for the sterilized devices management information system for the central sterile services department to the panel of dignitaries to help in analyzing and planning of the information system. 3) Researchers analyzed and designed data flow diagram of sterilized devices management information system of the central sterile services with Use Case Diagram, Class Diagram, Work Flow, and ER- Diagram.

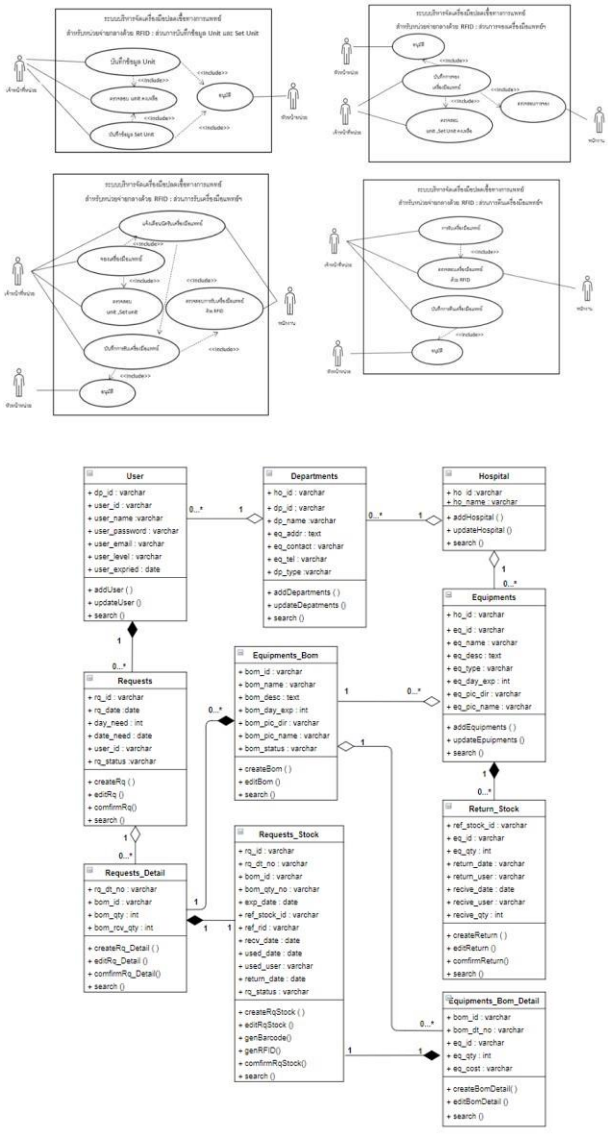

Figure 1. Use Case Diagram and Class Diagram of the information system

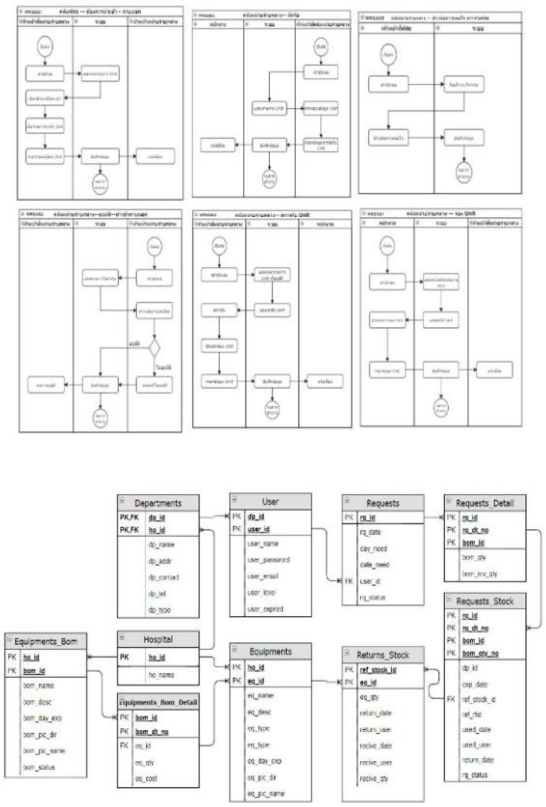

Figure 2. Work flow and ER-Diagram of the information system

4) Researchers developed the information system using System Development Life Cycle (SDLC), with procedures as follows; 4.1) Researchers studied problems in the sterilized devices management, the requirements for the system, and essential data directly from experts and related personnel; 4.2) Researchers designed and developed a prototype of the information system, which was separated into modules where each module worked according to the previously-designed procedure. The module was then taken to study and critiqued for further adjustment to be able to be applied to the real existing system before it was taken into programming and testing on the integrated system; 4.3) Researchers held a meeting with panel of experts to critique each module of the prototype of the information system before re-adjustment; 4.4) Researchers test the information system according to the users' requirements and experts evaluated the efficiency of same. 5) Mean and standard deviation was used in data analysis using evaluation criteria model to evaluate the information system using Likert Scale with rating scales as follows: Score of 5 with average between 4.51 - 5.00 equaled to Excellent. Score of 4 with average between 3.51 - 4.50 equaled to Good. Score of 3 with average between 2.51 - 3.50 equaled to Fair. Score of 2 with average between 1.51 - 2.50 equaled to Acceptable. Score of 1 with average between 1.00 - 1.50 equaled to Poor.

V. RESULTS

The results of the sterilized devices management information system for central sterile services departments using RFID technology and supply chain management could be separated into two parts as follows:

A. The development of the sterilized devices management information system

The development of the sterilized devices management information system for central sterile services departments using RFID technology and supply chain management provided information system through web browser in the form of web application where data was displayed on smartphones or tablets. This was developed by using the Responsive Web Design approach through PHP language which was also used in developing MySQL for database management and through Bootstrap for instruction sets to develop user interface resulting in two modules, as follows:

Module 1 was the registration module for sterilized medical devices whose precursor data on medical devices can be added, deleted, and edited. The module was able to search and display lists and photos of medical devices, as well as automatically or manually set ID codes for the medical devices which can then be generated to QR code. The module also supported RFID which also enable users to search the database using same. In addition, the module displayed analytics on the sterilized medical devices and enables users to export data in Microsoft excel format.

Module 2 was the warehouse system which was able to monitor the process of receiving, dispensing and recording of sterilized medical devices, prepare new sets of same, import and record data from Microsoft excel files, and print out barcode labels. The system were also able to display daily, monthly, and annual inventory of the sterilized medical devices and those below minimum stock. Moreover, the system was linked to Web Met maintenance system and can generate QR code to label on spare devices.

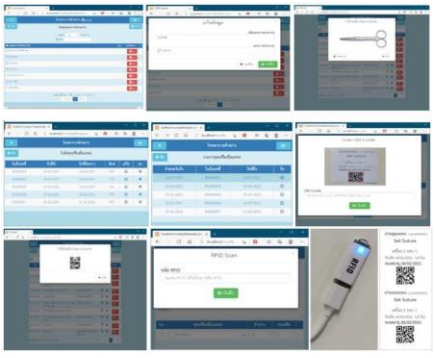

Figure 3. Sample of a screen of the information system on a web browser used with RFID and QR Code

Figure 4. Sample of a screen of the information system on a web browser used with RFID and QR Code

B. *The result of efficiency evaluation of the information system*

The result of efficiency evaluation of the information system by five experts in information system and sterilized medical devices management was shown in Table 1.

C. *Figures and Tables*

1) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they were cited in the text. Use the abbreviation "Fig. 1", even at the beginning of a sentence.

TABLE I. THE RESULTS OF EFFICIENCY EVALUATION OF THE STERILIZED DEVICES MANAGEMENT INFORMATION SYSTEM OF CENTRAL STERILE SERVICES DEPARTMENT USING RFID TECHNOLOGY AND SUPPLY CHAIN MANAGEMENT

Evaluation Items	$\bar{x}$	S.D.	Efficiency
1. Functional Requirement			
1.1 The system is able to add, delete, edit data relating to registration.	4.00	0.00	Good
1.2 The system is able to show search results of sterilized devices.	4.00	0.00	Good
1.3 The system is able to add, delete, edit photos of medical devices.	4.20	0.84	Good
1.4 The system is able to set ID codes for each device, automatically and manually.	4.40	0.89	Good
1.5 The system is able to generate QR code for the sterilized medical devices.	4.00	0.00	Good
1.6 The system is able to print bar code to label the sterilized medical devices.	4.00	0.00	Good
1.7 The system is able to read QR code using QR code reader.	4.00	0.00	Good
1.8 The system is able to record RFID code and enable search using RFID.	4.00	0.71	Good
1.9 The system is able to export data in Microsoft excel format.	4.40	0.55	Good
1.10 The system is able to display analysis reports of data on sterilized medical devices.	4.00	0.71	Good
1.11 The system is able to receive sterilized medical devices into the warehouse.	4.60	0.55	Good
1.12 The system is able to record or import data from Microsoft excel files on sterilized medical devices.	3.80	0.45	Good
1.13 The system is able to dispense sterilized medical devices and print labels for same.	4.20	0.84	Good
1.14 The system is able to display inventory of sterilized medical devices.	4.00	0.71	Good
1.15 The system is able to summarize daily, month, and annually received and dispensed	4.80	0.45	Good
1.16 The system is able to display records on received and dispensed sterilized medical devices.	3.80	0.45	Good
1.17 The system is able to link to Web Met maintenance system.	3.80	0.45	Good
1.18 The system is able to report on the sterilized medical devices that are lower than minimum level.	4.00	0.71	Good
Total average	**4.11**	**0.57**	**Good**
2. Function			
2.1 Validity in the process of addition, deletion, and edition of data	4.20	0.45	Good
2.2 Validity in search results	4.60	0.55	Good
2.3 Validity in generating reports	4.00	0.00	Good
2.4 Validity in generating	4.00	0.45	Good
Total average	**4.15**	**0.49**	**Good**
3. Usability			
3.1 The system is suitable, convenient, and easy to use.	4.40	0.55	Good
3.2 The data record form is suitable and easy to use.	4.20	0.45	Good
3.3 The processing of data in each stage is swift.	4.00	0.00	Good
3.4 Data search and generating list	4.40	0.55	Good
3.5 Font, size, and color of data are	4.00	0.00	Good
3.6 Printing of data reports is easy	4.20	0.45	Good
Total average	**4.20**	**0.41**	**Good**
4. Security			
4.1 Verification of accessibility to each level is suitable.	4.40	0.55	Good
4.2 The system separates user menu for each level of user	4.20	0.45	Good
4.3 The overall security of database is suitable.	4.40	0.55	Good
Total average	**4.33**	**0.49**	**Good**
5. User Interface Design			
5.1 Suitability of user interface design	4.00	0.00	Good
5.2 Suitability of data recording and editing design	4.60	0.55	Good
5.3 Suitability of data search	4.00	0.71	Good

Evaluation Items	$\bar{x}$	S.D.	Efficiency
5.4 Suitability of generating and printing reports	4.00	0.00	Good
Total average	**4.15**	**0.49**	**Good**
6. Overview of the Information System			
6.1 The information system is convenient and is easy to use.	3.80	0.45	Good
6.2 The information system processes data and summarizes swiftly with accuracy.	4.40	0.89	Good
6.3 The information system conforms with users' requirements.	4.00	0.00	Good
6.4 The information system facilitates in data preparation.	4.20	0.45	Good
6.5 Using QR code in the information system is convenient and suitable.	4.20	0.45	Good
6.6 Using RFID in the information system is convenient and suitable.	4.40	0.55	Good
6.7 The language used in the information system is clear and easy to understand.	4.00	0.71	Good
6.8 The font, size, and color used in the information system are suitable.	3.80	0.45	Good
6.9 The information system can be applied to the existing system.	4.20	0.89	Good
Total average	**4.15**	**0.53**	**Good**
Total average of all aspects	**4.13**	**0.59**	**Good**

According to the evaluation of the information system by five experts in table 1, it was found that all six aspects received a score in the "Good" range (x = 4.13 S.D. = 0.59). After evaluating each aspect separately, it was found that the information system matches users' requirements with efficiency score and score was also in the "Good" range (x = 4.11 S.D. = 0.57), which was the similar for the Function aspect (x= 4.15 S.D. = 0.49), the Usability aspect (x = 4.20 S.D. = 0.41), Security aspect (x = 4.33 S.D. = 0.49), User Interface Design (x = 4.15 S.D. = 0.49), and the Overview (x = 4.15 S.D. = 0.53) that were all in the "Good" score range. This can be interpreted that the efficiency score of all aspects passes the evaluation criteria and that the system could be applied to the existing system. The evaluation and suggestions relating to the information system can be concluded as follows: 1) The design of user interface is simple and clear, and the user menu is easy to use; 2) Data search and generating of reports are clear and legible. Search results were completed and accurated; 3) Setting different levels of accessibility makes the system secured.

VI. DISCUSSIONS

A. Users' requirements

Through research of users' requirements, it was found that executives and related personnel prefer using information system that helps to improve the work of the central sterile services department as it deals with management of data in the department. According to [4], information system collects and store data from various sources with principles in order to process that data and reduce operation cost. It was also able to check detail in the management of sterilized medical devices. For the analyzed and designed, researchers studied the existing system along with users' requirements and problems in small, medium, and large-scale hospitals in order to match to their exact needs. The collected data were then analyzed for strengths and weaknesses and was used for the design of the information system. Developed an information system for completion report of in-patient medical record, analysis of strengths and weaknesses of the system affected the development of the system. On the system development, researchers used the System Development Life Cycle [5]. Also, software development must follow every step in the system development life cycle. Similarly, developing an information system with presentation of user interface design, procedure, database system, and design of other related features were beneficiated in checked its validity, suitability, and possibility to be developed into a prototype. The information system was developed as web application on web browser that can be displayed on smartphones or tablets using Responsive Web Design approach to make the system easy to use [6-8]. Responsive Web Design approach allows users to use various tools and is convenient as the trend in using mobile devices to display data was constantly increasing, whereas the use of RFID increases the efficiency of the system [9].

B. The efficiency of the information system

The efficiency of the information system had the score in "Good" range which showed that the efficiency of every aspect of the system had the score in "Good" range, passed the criteria and could be applied to the existing system. This was due to researchers proceeding in every step according to the principles and theory of developing an information system starts from the study of existing problems in the management to sterilized medical devices in small-, medium-, and large-scale hospitals and analyzing them before designing the system according to the requirements [10-12]. Also, the system used standard supply chain management with RFID or QR code. Moreover, the researched and developed RFID to improve the efficiency of supply chain of sterilized medical devices to be more convenient, more swift, more accurate; to reduce operation cost and increase efficiency in treatment of patients [13-14]. When each aspect was evaluated separately, the designing of the information system to conform with users' requirements was also in the score range of "Good". The development of an information system for medical devices in operating rooms, it was found that the work process of the system was accurated and matched the requirements. The system was able to add, delete, edit, and search for data on medical devices making preparation of the medical

devices more convenience. Moreover, the system could either automatically or manually set ID code for each device, printed out barcodes, generated QR code to label the medical devices, and was also able to read same. In addition, the system supports database search using RFID, was able to export files in Microsoft excel format, and displayed analytics. Also, the system was able to receive and dispense sterilized medical devices and printed labels for same, as well as showing the inventory. Furthermore, the system was able to generate daily, monthly, and annual summary reports of receiving-dispensing of sterilized medical devices, display dispensing records. Likewise, it was also able to link to Web Met maintenance system and report when a device's inventory was below the minimum level. As for the function aspect, the efficiency was also in the score range of "Good" due the ability of the system to add, delete, edit, search, generate reports, and summarize accurate data which developed an information system for medical devices in operating rooms. The usability aspect also had efficiency in the score range of "Good" because the information system was suitable and easy to use. It was also swift in processing data on the convenience in using the system. The security aspect had efficiency in the score range of "Good" as verification of accessibility separates users into levels and restricts access to the database according to the verification, as well as setting username and password for each user. The user interface design aspect also had efficiency in the score range of "Good". The information system was designed to have user interface where users can design how to record and edit data, search data, generate report, and print. As for the overview of the information system, the efficiency was also in the score range of "Good" as it was convenient and was easy to use. Also, it was able to process data at a swift speed and was accurate and uses QR code and RFID. The language was easily legible and the font, size, and color were suitable. Overall, the system was able to be used with the existing system. It could be concluded that the sterilized devices management information system for central sterile services departments in hospitals using RFID technology and supply chain management was efficient and could be applied to the existing systems in hospitals.

VII. SUGGESTIONS

A. Suggestions for general use

1. Limitation of this research was that the related data were kept in various forms resulting in the unorganized data prior to using the information system which cause delay when the system is actually used.

2. Network capacity should be tested prior to the execution of the system to avoid experiencing some users being out

B. Suggestions for further research

1. Researchers should explore more in-depth detail of the system and expand the framework to every hospital.

2. Researchers should construct a large database of sterilized medical devices to support big data in management at the national level.

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