การพัฒนาโปรแกรมสารสนเทศที่ใช้บริหารยาคงคลัง โรงพยาบาลพุทธโสธร
Development of the Information Technology System for Drug Inventory Management, Buddhasothorn Hospital

นิพนธ์ต้นฉบับ

Original Article

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บทคัดย่อ

วัตถุประสงค์: เพื่อพัฒนาและประเมินผลโปรแกรมสารสนเทศผ่านโทรศัพท์มือถือเพื่อบริหารยาคงคลังของโรงพยาบาลพุทธโสธร (Inventory-Buddhasothorn Hospital; INV-BSH) ในการลดอุบัติการณ์ยาขาดคลังและยาหมดอายุในคลัง **วิธีการศึกษา:** ใช้รูปแบบวิจัยและพัฒนา ศึกษารายการยาในคลัง 737 รายการในช่วงก่อนพัฒนาโปรแกรม (2562) และระยะพัฒนาที่ 1 - 4 (2563 - 2566) พัฒนาโปรแกรม INV-BSH โดยทบทวนวรรณกรรมและประยุกต์เครื่องมือสารสนเทศ ปรับปรุงตามปัญหาที่พบในแต่ละระยะ นับอุบัติการณ์ยาขาดคลังและยาหมดอายุแต่ละระยะเทียบกับเกณฑ์ คือ ยาขาดคลังโดยรวมไม่เกิน 2% ยาจำเป็นขาดคลัง 0% และยาหมดอายุไม่เกิน 1% จากข้อมูลโปรแกรม HOSxP และ INV-BSH **ผลการศึกษา:** ยา 737 รายการแบ่งเป็น 3 กลุ่ม ได้แก่ vital, essential และ non-essential (136, 438 และ 163 รายการตามลำดับ) ระยะที่ 1 - 4 ประยุกต์ใช้ AppSheet เชื่อมกับ Google Sheet เพื่อเข้าถึงข้อมูลยาในคลังผ่านโทรศัพท์เคลื่อนที่ กำหนดเวลาให้ระบบปรับปรุงข้อมูลให้เป็นปัจจุบันและส่งข้อมูลไป Cloud อัตโนมัติ ค้นหารายการยาได้เร็วและแม่นยำโดยใช้รหัสชื่อสามัญ Generic Product Use (GPU) ร่วมกับการสแกน QR code ที่ชั้นเก็บยา ระบบแจ้งเตือนยาช่วยชีวิตถึงจุดสั่งซื้อผ่าน Line Notify แสดงวันหมดอายุแบบปฏิทินและตาราง พบว่ายาขาดคลังลดลงจาก 16/15 ครั้ง/รายการ (2.04% ของรายการยาทั้งหมด) ช่วงก่อนพัฒนา เป็น 11/11, 7/7, 6/6 และ 1/1 ครั้ง/รายการ (หรือ 1.49%, 0.95%, 0.81% และ 0.14%) ในระยะที่ 1 - 4 ตามลำดับ ยาจำเป็นขาดคลังลดจาก 2 รายการเป็น 2, 1, 0 และ 0 รายการ ตามลำดับซึ่งผ่านเกณฑ์ ส่วนยาหมดอายุลดลงจาก 20/20 ครั้ง/รายการ (2.71%) เป็น 8/8 ครั้ง/รายการ (1.49%) ในระยะ 1 แต่เพิ่มเป็น 23/23 ครั้ง/รายการ (3.12%) ในระยะ 2 และลดลงเป็น 19/19 และ 9/9 ครั้ง/รายการ (2.58% และ 1.22%) ในระยะ 3 และ 4 ซึ่งไม่ผ่านเกณฑ์ **สรุป:** โปรแกรม INV-BSH ลดอุบัติการณ์ยาจำเป็นขาดคลังและยาหมดอายุของโรงพยาบาลพุทธโสธร ควรพัฒนาและประเมินผลโปรแกรมอย่างต่อเนื่อง

คำสำคัญ: โปรแกรมสารสนเทศ; บริหารยาคงคลัง; ยาขาดคลัง; ยาจำเป็นขาดคลัง; ยาหมดอายุในคลัง; INV-BSH

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Abstract

Objective: To develop and evaluate the Inventory-Buddhasothorn Hospital (INV-BSH) mobile phone program for drug inventory controls to reduce incidents of short supply and expiration. **Method:** In this research and development, inventory status of 737 drug items in pre-development phase (2019) to development phases 1 – 4 (2020 – 2023). INV-BSH was developed based on literature review and applied information technology. The program was improved based on problems found in each phase. In each phase, incidents of short supply and expired drugs from HOSxP and INV-BSH were tallied and compared with passing criteria, i.e., short supply of < 2% for all drugs and 0% for essential drugs, and expired drugs < 1%). **Results:** Of the 737 items, there were 136, 438 and 163 items of vital, essential and non-essential drugs, respectively. In phases 1 – 4, AppSheet was connected with Goo Sheet for data access through mobile phone application. Automatic Data update time and upload to Cloud was pre-set. Searching drug items was rapid and precise using Generic Product Use (GPU) for scanning QR code on the shelf. Automatic warning for reordering life-saving drugs was sent through Line Notify. Expiration date was shown in calendar and table forms. Incidents of short supply of all drugs decreased from 16/15 times/items (2.04%) in pre-development to 11/11, 7/7, 6/6 and 1/1 times/items (i.e., 1.49%, 0.95%, 0.81% and 0.14%) in phases 1 – 4, respectively. For essential drugs, short supply decreased from 2 items to 2, 1, 0 and 0 items, respectively which passed the criteria. Expired drugs decreased from 20/20 times/items (2.71%) to 8/8 times/items (1.49%) in phase 1 but increased to 23/23 times/items (3.12%) in phase 2 and decreased to 19/19 and 9/9 times/items (2.58% and 1.22%) in phases 3 and 4, respectively, which did not pass the criteria. **Conclusion:** INV-BSH program reduced incidents of short supply and expired drugs in Buddhasothorn Hospital. The program should be continuously improved and evaluated.

Keywords: information technology; drug inventory control; short supply; short supply of essential drugs; expired drugs; INV-BSH

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Introduction

Effective drug inventory management is crucial for the hospital's success. At present, drug inventory management must meet standards set by the Healthcare Accreditation Institute (Public Organization) regarding process to prevent short supply especially vital and essential drugs, and adequate inventory management.[1] In addition, standards of the Hospital Pharmacy Association (Thailand) indicate proper distribution and control of drug by means of regular inspection and monitoring for drug quality, expired drugs, and deteriorated medicine.[2] Unfortunately, specific procedures for

quality assurance on drug inventory have not been detailed. Pharmacists responsible for the inventory management should design all detailed process according to the hospital context.

Computer-based information system has been widely used for the inventory management in many hospitals in Thailand. A study of software program development for sub-stock inventory management for HIV clinic using Google Application revealed that time for inventory management was effectively reduced.[3] The software program INVC was developed by Chiangrai Prachanukraoh Hospital using Microsoft Access as a user interface to aide purchase decision making and inventory management.[4] Google Application however has a limited coverage of drug list. In addition, INVC has not fully connected to certain hospital information system (HIS) such as HOSxP version 4, therefore, dispensing data could not be linked and a real-time, up-to-date inventory level could not be obtained. Most inventory software programs are installed in desktop computers with local area network (LAN). Recently, more drug inventory management software programs have been installed in mobile phone as mobile application which offers constant data updating, convenience for use, less time for inspecting and reporting, and convenient access to the database.[6,7] The development of the web application also allows the work on desktop and mobile phone through web browser.[5] A study on web application for drug inventory management showed that the application was accepted with the highest satisfaction in easiness, pleasant visual design, speed, correctness, and data safety.[8]

Buddhasothorn Hospital is a tertiary-care facility with 650 beds, responsible for managing 737 – 890 drugs items. In the fiscal years of 2019 – 2023, indicators of effective drug inventory management were set including short supply of not more than 2% for all drugs and 0% for vital drugs, and not more than 1% of expired drugs for all drugs. BMS Inventory software program is used to manage the inventory. BMS Inventory is a module of the hospital information system (HIS) with the proprietary name of HOSxP (version 4.0) developed by Bangkok Medical Software (BMS). BMS Inventory provides purchasing, inventory control, and report through LAN of the hospital. However, BMS Inventory cannot monitor real-time inventory off-service time since the warehouse is closed and the desktop computer there is also turned off. BMS Inventory also lacks the convenient tools for auditing the inventory, and warning system such as minimum stock of vital drugs and near-expired drugs. In 2018 and 2019, incidents of 28/27 and 16/15 time/item (i.e., 3.66% and 2.04%), respectively, of short supply of all drugs, 5/8 and 2/2 time/item (1.09% and 0.27%), respectively, of short supply of vital drugs, and 10/10 and 20/20 time/item (1.35% and 2.70%), respectively, of expired drugs. There have been under-performance indicators of the inventory management according to the set indicators of short supply of not more than 2% for all drugs and 0% for vital drugs, and not more than 1% of expired drugs for all drugs. Therefore, there has been room for improvement in drug inventory management of Buddhasothorn Hospital using information technology.

This present study aimed to develop and evaluate the information technology for drug inventory management of Buddhasothorn Hospital to lessen the incidents of short supply and drug expiration. The researcher developed the program named Inventory-Buddhasothorn Hospital (INV-BSH) which incorporated information technology as a mobile phone application. INV-BSH was connected with the LAN-based BMS Inventory program which was a module of the program HOSxP version 4.0 which runs on personal computers (PCs). To compensate for a drawback of BMS Inventory, INV-BSH offered more convenient access to the drug inventory database and fast inventory status audit. The system also provided a reliable warning on inventory status so planning for purchasing could be done effectively and ultimately the short supply and drug expiration could be reduced to the set targets.

The researcher had been developing the INV-BSH program continuously from the fiscal year of 2020 to 2023. Information technology had been applied to solve problems in each of the four phases. In each phase, outcomes were evaluated including incidents of short supply of all drugs and vital drugs, and expired drugs compared with the set targets. The trend of achieving the targets could be used for further improvement in drug inventory management.

Methods

This research and development project was approved by the Ethics Committee for Human Study of Buddhasothorn Hospital (approval number: BSH-IRB 031/2566). All 737 drug items were studied in the 4 phases of development and evaluation which were detailed as follows.

In the pre-development (i.e., preparation phase) in 2019, the researcher audited the inventory of all drug items and categorized each item as either vital, essential, or non-

essential. The concepts of information technology and drug inventory management were studied for application.

The first to fourth phases of development and evaluation (i.e., fiscal years of 2020 – 2023) consisted of three steps. Firstly, the researcher performed situational analysis using gap analysis, before and after the implementation of the developed system, in each of the four phases. Relevant literature was consulted for problem solutions. Secondly, the researcher developed and improved the software program INV-BSH based on problems found in the trial in the previous phase. Thirdly, the evaluation of the program comparing numbers of incidents of short supply and expired drugs of preparation phase with phases 1 – 4. The researcher followed standard operating procedure (SOP) in collecting drug inventory data. This SOP has been updated annually.

Data were from BMS Inventory database which was module of HOSxP version 4.0. Data included drug items, numbers of drug items, inventory level of each item, short supply compared with rate of use, and number of expired drugs at the audit date. The incidents of short supply of all drugs and vital drugs and expired drugs of items in the inventory were compared with the set targets of not more than 2% of all drugs, 0% of vital drugs, and not more than 1% of all drugs, respectively. Incidents from each phase were calculated as number of drug items with short supply divided by number of all drug items, number of vital drug items with short supply divided by number of all vital drug items, and number of expired drug items divided by number of all drug items, all multiplied by 100, in each fiscal year. During the study period, the total number of drugs items was 737.

Results

Development and specifications of the INV-BSH drug inventory management software program

Development of the INV-BSH software program

Details of problems and problem solutions from preparation and the four phases of development are as follows (Table 1).

Preparation phase (pre-development) (fiscal year 2019)

The hospital used the software program Inventory (INV) which was a module of the Hospital Information System (HIS). Drug inventory data were presented in Excel® file in the desktop computer that was in the physical location of the drug warehouse, no other options were available for data viewing.

Phase 1 (fiscal year 2020)

A total of 737 drug items were categorized to three groups of vital, essential and non-essential drugs (136, 468 and 163 items, respectively). The hospital started using the software program BMS Inventory which was a module of HOSxP (version 4). Drug items were coded and drug inventory data were exported to Excel® database and uploaded to Google Sheet.[9] Mobile application was developed to connect with Google Sheet so the inventory could be audited remotely. The warning system alerting the use on drugs with a small volume of use such as antidote was installed; however, the automatic warning did not function. The data had to be uploaded to the Cloud for the mobile phone to retrieve and be viewed. Such drawbacks were placed for improved in the next phase.

Phase 2 (fiscal year 2021)

Automatic data updating system was set up using the Microsoft (MS) Access.[10] Once the computer server restarts, the data were updated automatically by the Start-Up of the Windows system.[11] The updated data were then automatically uploaded to Google Sheet. Unfortunately, the automatic data update could operate only when restarting the computer. Therefore, data in the mobile phone application was not updated if the computer was not restarted. The updated data were presented in the desktop based BMS Inventory program. Therefore, in the next phase, the mobile phone application was subject to have automatic data update comparable to the BMS Inventory.

Phase 3 (fiscal year 2022)

The data update was made every hour using Navicat®[9] which allows connecting simultaneously to various query software programs (e.g., MySQL, Redis, PostgreSQL, SQL Server, Oracle, MariaDB, SQLite, and MongoDB. This capability allowed mobile phone to login and retrieve the daily updated data. In addition, the mobile phone could scan the barcode of each of all drug items on the shelf instead of searching the drug item in the computer's BMS Inventory program. Therefore, inventory check was fast and convenient. However, certain problems remained. When searching for drug items with less than four digits codes, several drug items with shared codes, not a specific drug item, were shown.

Another problem was the Internet connection between desktop-based inventory database and Google Drive was not stable. Therefore, in the next 4th phase, it was aimed at identifying drug item inventory status rapidly, correctly and precisely, retrieving the most up-to-date inventory information through mobile phone, and stabilizing the database system.

Phase 4 (fiscal year 2023)

The database was more frequently updated at every hour. Data were queried using QR code instead of barcode. Generic drug names were used (as guided by the Generic Product Use (GPU)[12] for a more accurate searching. The expiration date of each drug item was displayed in advance in the form of calendar and table. Warning for nearly expired drug items and items with minimum stock volume[13,14] was set and shown through Line Notify.[15] Performance of each individual worker (e.g., in- and out-inventory control, shelfing and distribution control) was collected and summarized automatically. The use of Dropbox instead of Google Drive allowed for a more stable Internet connection.

Table 1 Process and outcomes of development of INV-BSH at each phase.

Phase (fiscal year)	Development process	Outcomes	Problems
Pre-development (2019)	- The existing HIS inventory system was used.		- Inventory status was identified only on desktop computer in the warehouse.
Phase 1 (2020)	- BMS Inventory program was used to retrieve and export inventory data in Excel format. The data were further uploaded to Google Sheet connecting with mobile phone application.	- The workers were able to access data on Google Sheet through mobile phone. Inventory status and drugs with small prescription volume such as antidotes were identified.	- The system was operated manually in data processing. The uploading to Cloud was done with the desktop computer in the warehouse.
Phase 2 (2021)	- Data were retrieval using MS Access and uploaded Google Sheet automatically once the desktop computer was started. - Mobile application was developed using Appsheet with more functions than Google Sheet.	- It was more convenient to retrieve inventory data through mobile phone application. The data were updated at the last start of the desktop computer in the warehouse. - Searching drug item data through Appsheet program was easy and convenient.	- The inventory status in mobile phone was not real-time data unlike those in the desktop computer.
Phase 3 (2022)	- Navicat program was used to retrieve the inventory data automatically with a automatically pre-set daily data update. - Barcode on the shelf was used for drug item searching instead of typing the item codes into the desktop computer or the mobile phone.	-Inventory status shown on mobile phone application was more up to date, if not the real-time one. - The workers were convenient in searching drug items using barcode on the shelf.	- The use of barcode based on drug item codes in HOSxP resulted in imprecise outputs. For drug items with less than 4-digit codes, more than one item was shown. - Google Drive was not stable.
Phase 4 (2023)	- QR Code was used instead of barcode and drug codes of GPU instead of those of BMS Inventory program. - Expiratory dates were presented in advance in forms of calendar and table. - Performance and workloads of each worker were automatically summarized. - Dropbox was used instead of Google Drive.	- With QR codes, searching for specific drug items were more precise. - Data of items approaching expiration could be used for management. - Performance could be summarized for each worker. - The INV-BSH program was more stable.	- Data were processed by Navicat program and uploaded to Dropbox to be retrieved by INV-BSH application on mobile phone. This data synchronization between the database and INV-BSH was done hourly. Inventory status discrepancy between the actual shelf volume and the one shown in the mobile phone application was highly limited.

Table 2 Features of INV-BSH program in development phases 1 – 4.

Program features	Phase of development			
	1	2	3	4
Tools for application development	Google Sheet	Appsheet	Appsheet	Appsheet
Cloud for data storage	Google Drive	Google Drive	Google Drive	Dropbox
Inventory data retrieval	MS Access automatically retrieved data from desktop computer every time the computer started (with the Start Up function of Windows). The data were uploaded to Cloud system.	MS Access automatically retrieved data from desktop computer every time the computer started (with the Start Up function of Windows). The data were uploaded to Cloud system.	Navicat program automatically retrieved data from the desktop computer. The data were uploaded to Cloud system at 5 pm daily.	Navicat program automatically retrieved data from the desktop computer with pre-set time, and automatically uploaded the data to Cloud.
Data update	Inventory data were updated only at the start of the desktop computer. Therefore, the data were not real-time ones. The data in the system were not up to date like the actual volume on the shelf.	The inventory status data were not real-time. Data discrepancy existed.	Data were automatically updated every day.	Data were automatically updated every hour. Data shown in mobile phone application were highly close to real-time ones.
Drug item codes for searching	Barcode was used to search drug items with 1- to 5-digit codes.	Barcode was used to search drug items with 1- to 5-digit codes.	Barcode was used to search drug items with 1- to 5-digit codes.	QR code was used to search drug items using standard codes of GPU. With 6- to7-digit codes, search results were more precise.
Warning system for reorder of life-saving drugs.	No. Only warning for a prescription of drugs with a low prescription rate.	No. Only warning for a prescription of drugs with a low prescription rate.	Warning system for essential drugs when reaching reorder point and drugs approaching expiration date through Line Notify.	Warning system for essential drugs when reaching reorder point and drugs approaching expiration date through Line Notify.
Expiration date inspection	No	No	No	Expiration date was presented in the form of calendar and table.

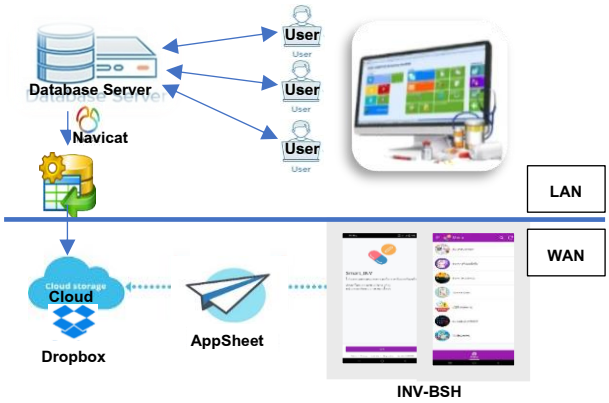

Figure 1 Connection between BMS Inventory and INV-BSH programs.

The features of INV-BSH program

The INV-BSH program was designed to query drug items as automatically scheduled and upload the data into Dropbox folders for INV-BSH mobile phone application to access. Dropbox is an online database server, which allows sharing data among assigned users through remote connection of Wide Area Network (WAN). Appsheet program was used to develop the mobile application for remote inventory control (Figure 1).[19,20]

In summary, features of INV-BSH from development phase 1 to 4 compared with those before the development could be summarized with certain aspects (Table 2). For example, at pre-development, the drug inventory data could be viewed at the desktop computer in the warehouse (Table 1). In phase 1, data were queried and exported to MS Excel format and uploaded onto Google Drive for the user to view through the Internet via Google Sheet on the worker's mobile phone or desktop computer. In phase 2, the INV-BSH application was developed using AppSheet for mobile phone viewing. In phase 3, Navicat instead of MS Access was used for data retrieval. Queried data were uploaded to Cloud at automatically pre-set time of 5 pm daily. In phase 4, the inventory data for viewing were updated every hour instead of every day as in phase 3. In Cloud storage, Dropbox was used instead of Google Drive. For drug code references, GPU codes accompanied with QR code were used for a faster and more precise searching.

The features and workflow of INV-BSH at the end of phase 4 are shown in Figures 1 and 2. The program retrieved and processed the inventory information with 7 features searching drug items to identify 1) inventory level and rate of use, 2) reorder point, 3) items in waiting list, 4) expiratory date calendar 5) lot number with expiratory date, 6) performance of individuals workers on inventory control, shelfing, and distribution, and 7) randomly counting the inventory. The program also notified expiratory date of the items to mobile phone through Line Notify (Figure 2).

The performance evaluation of INV-BSH program

The INV-BSH program was evaluated based on the inventory control before the program development (up to the fiscal year of 2019) and phases 1 – 4 of the development (fiscal years of 2020 – 2023) (Table 3).

Incidents of short supply decreased from 16/15 incidents/items before the INV-BSH development (2019) to 11/11, 7/7, 6/6 and 1/1 times/items at phases 1 – 4 (i.e., 2020 – 2023), respectively (Table 3). Regarding the 3 drug categories, 2, 10, 3 times of vital, essential and non-essential drugs were found, respectively in 2019; while the number of short supply incidents for vital, essential and non-essential drugs decreased over time, with finally 0, 0, and 1 time in 2023.

Incidents of expired items decreased from 20/20 times/items before the INV-BSH development (2019) to 8/8 times/items before the development (2020); however, the incidents increased to 23/23 in 2021 but decreased to 19/19 and 9/9 in 2022 and 2023, respectively (Table 3).

Based on the criteria of less than 2% and 0% for short supply of all drug items and essential drug items, respectively, and 0% for expired items, the improvement was found. Specifically, the short supply of all items decreased from 2.04% in 2019 to a passing level of 1.49%, 0.95%, 0.81% and 0.14% in 2020 to 2023, respectively. For the essential drug items with a passing criterion of 0% short supply, the short supply was at 0.41% in 2019 and decreased 0.27% and 0.14% in 2020 and 2021, respectively. The short supply of essential drug items reached 0% in 2022 and 2023. For the expired items with the 0% passing criterion, the incidents decreased from 2.71% in 2019 to 1.49% in 2020. The incidents fluctuated with 3.12%, 2.58% and 1.22% from 2021 to 2023 which did not pass the criterion of 0% (Table 3).

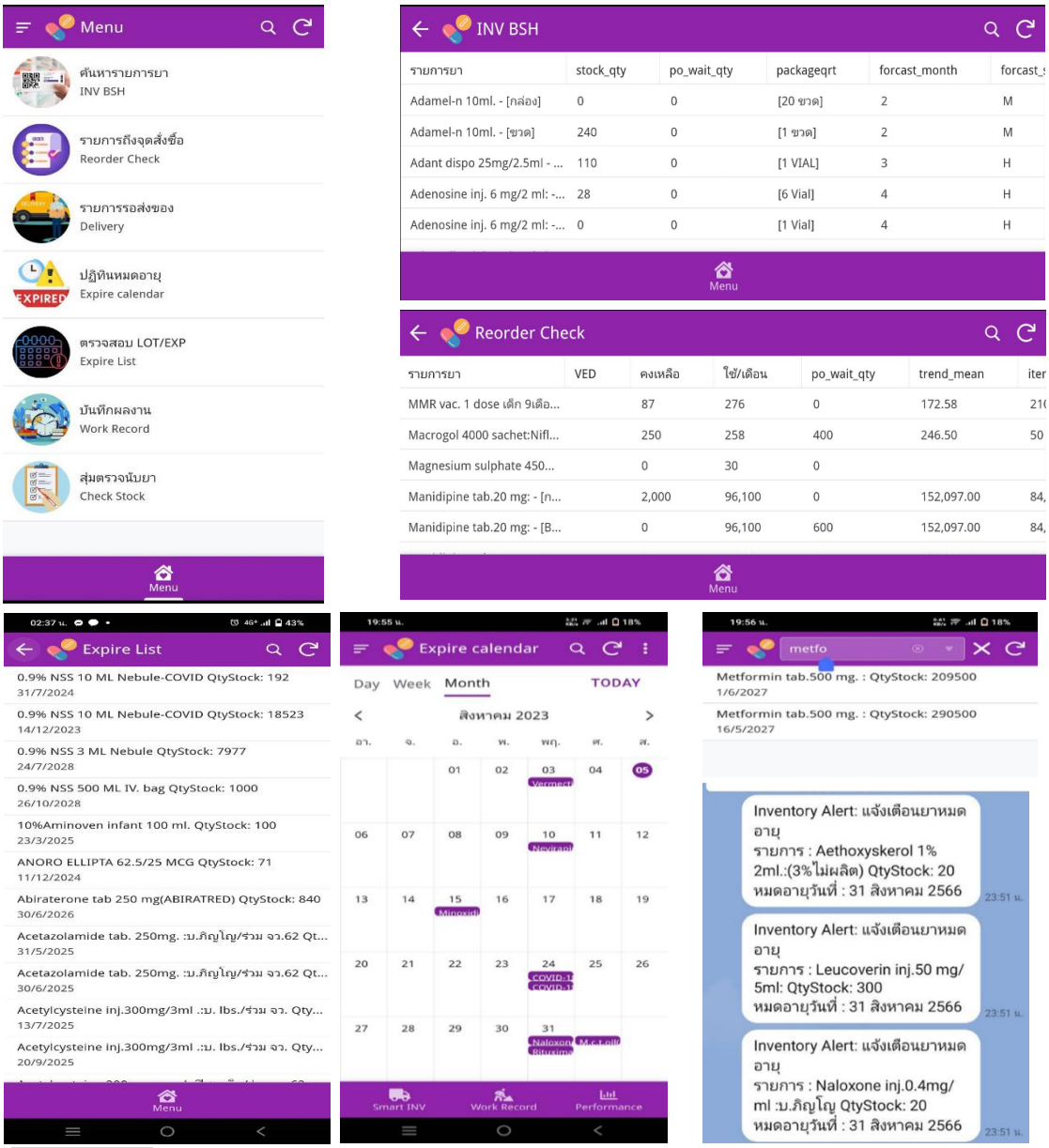

Figure 2 Features of INV-BSH program.

Table 3 Incidents of short supply and expired drugs by development phases.

	Development phase (fiscal year)				
	Pre-development (2019)	1 (2020)	2 (2021)	3 (2022)	4 (2023)
Incidents of short supply by drug categories					
Vital drugs	2	2	1	0	0
Essential drugs	10	6	4	4	0
Non-essential drugs	3	3	2	2	1
Item total	15	11	7	6	1
Time total	16	11	7	6	1
Incidents of expired drug items by drug categories					
Vital drugs	4	0	3	2	1
Essential drugs	6	5	12	9	5
Non-essential drugs	10	3	8	8	3
Item total	20	8	23	19	9
Incidents of short supply of all and essential drug items and expired drug items					
Short supply of all drugs	2.04	1.49	0.95	0.81	0.14
Short supply of essential drugs	0.41	0.27	0.14	0	0
Expired drugs	2.71	1.49	3.12	2.58	1.22

For specific items, drugs in all categories were found with short supply and expired items (Table 4). However, in phases 3 and 4, there were no short supply of vital drugs. For expired items, most were life-saving drugs, e.g., adenosine inj 6 mg/2 mL and diphenhydramine 5% inj), and antidotes (e.g., methylene blue inj and antivenom serum for Malayan Krait snake (Bungarus candidus).

Discussion and Conclusion

The INV-BSH could identify the up-to-date inventory level, reorder point, expiratory date through mobile phone. The program could also summarize the workload of each inventory worker. Overtime, the INV-BSH alleviated short supply

Table 4 Example of short supply and expired drugs by development phase.

Development phase (fiscal year)	Drug items with short supply	Expired drug items
Pre-development (2019)	Vital drugs: *Human normal immunoglobulin 5% w/v* Essential drugs: *Clofazimine cap100 mg, Yakaelom (Thai traditional powder)* Non-essential drugs: *Glycerosteril soln. 500 m, IInfloran cap*	Vital drugs: *Diphenhydramine 5% inj, Methylene blue inj 50 mg/5 ml* Essential drugs: *Quinine inj 600 mg/2 ml* Non-essential drugs: *Aethoxyskerol 1%, Docusate ear drops*
Phase 1 (2020)	Vital drugs: *Sodium nitrite inj 3%* Essential drugs: *Letrozole 2.5 mg tab* Non-essential drugs: Hyaluronate sodium 25 mg/2.5 ml	Vital drugs: - Essential drugs: *Quinine inj.600 mg/2 ml* Non-essential drugs: *Pentaglobin 10 ml*
Phase 2 (2021)	Vital drugs: *Adenosine inj. 6 mg/2 ml* Essential drugs: *Labeterlol inj 100 mg/20 ml, ยาหอมอินทจักร์* Non-essential drugs: *Sorafenib tab 200 mg*	Vital drugs: *Diphenhydramine 5% inj* Essential drugs: *Clotrimazole 1% ear drop* Non-essential drugs: *Aflibercept 40 mg/1 ml inj*
Phase 3 (2022)	Vital drugs: - Essential drugs: *Pazopanib tab.200 mg, Hematotonic cap* Non-essential drugs: *Glycerosteril soln 500 ml, Infloran cap*	Vital drugs: *Adenosine inj 6 mg/2 mL, Diphenhydramine 5% inj* Essential drugs: *Hematotonic cap 500 mg* Non-essential drugs: *Everolimus 10 mg tab*
Phase 4 (2023)	Vital drugs: - Essential drugs: - Non-essential drugs: *Nivolumab 100 mg/10 mL*	Vital drugs: *Antivenom serum for Malayan Krait snake (Bungarus candidus)* Essential drugs: *Dimercaprol inj 100 mg/2 ml* Non-essential drugs: *Dapagliflozin 10 mg tab*

incidents and expired drug items continuously from phases 1 to 4 of the program development.

The INV-BSH program was aimed at correcting the shortcomings of the existing BMS Inventory program. With the BMS Inventory program, the inventory level could be determined from the HOSxP database in desktop computer only during working hours, with no warning system which could lead to short supply and expiration beyond the acceptable criteria. The use of mobile phone application with INV-BSH program to retrieve up-to-date inventory information from HOSxP database equipped with the warning system and the link with the inventory indicators would allow for a real-time inventory status and subsequent precise and timely reorder and prevention of expired drugs.

In the development process, problems remained partly because the information technique the researcher (the program developer) used did not allow for solving certain problems within a single round of development. At the early phases of development, the researcher focused on major problems of the INV-BSH program. The researcher learned more to choose more effective information technique for the next phase of development.

The incidents of short supply and expiration had decreased continuously over time from pre-development to INV-BSH development phases 1 to 4. In phase 1, retrieving inventory information had been improved from the HOSxP desktop computer-restricted access to mobile phone remote access to the database served by the Google Sheet program. The warning system was also placed for drugs with a small volume of use such as antidotes. With all these features, inventory status could be identified on- and off-site at all time. Such advantages resulted in decreased incidents of short supply and expiration from 2.04% and 2.71%, respectively in pre-development phase to 1.49% and 1.49%, respectively in phase 1.

Certain studies were done to improve effectiveness of inventory control tools. A study in Thailand developed Google Sheets from Microsoft Excel for reducing short supply and time needed to check expiration date of drug inventory of Ramathibodichakrinaruebodin Hospital.[21] A study in Thailand applied the concept of LEAN to improve prescription refill system of the primary care network in Chainat province.[22] Using Google Sheet as a bill of lading, the system reduced resource waste relating to prescription refill and improved efficiency of workers at the sub-district health promoting hospitals in Chainat province. At the National Children Health Institute of Thailand, a mobile phone application to control sub-stock inventory of HIV clinic.3 The application helped reduce working hours from 583.3, 615.0 and 637.5 minutes per month in the 3 months before the experiment to 29.7, 32.3 and 37.5 minutes/month in the 3-month experiment. This less time meant more efficient inventory control and resulted in high satisfaction among the workers. Barcode also reduced the time in sub-stock drug inventory control of the workers.[23,24] However, the program developed in the study still needed manual input of inventory data to achieve an up-to-date information.[24]

To solve all the problems mentioned, the INV-BSH program was modified to be able to update the data automatically in phase 2. With the use of the Startup function of Microsoft Windows, the inventory data were updated at the start of the desktop computer. The data were transferred from the desktop computer to mobile phone application. The data were updated more timely than those in phase 1 and helped plan the reorder more precisely. Short supply of all drug items and essential drugs decreased from 1.49% and 0.27%, respectively, in phase 1 to 0.95% and 0.14%, respectively in phase 2, the expiration rate increased from 1.49% in phase 1 to 3.12% in phase 2. These expired items were those with a

low prescription volume including diphenhydramine 5% injection. With Covid-19 pandemic, the hospital admitted fewer emergency cases of patients and the use of these life-saving drugs was even less. This circumstance was also found in other hospitals in Thailand.[25] These drug items could not be returned to the drug distributor companies. In addition, aflibercept injection which was a sample drug for ophthalmologists was not prescribed during Covid-19 and could not be returned to the company. Such a drop of prescribing rate of these drugs resulted in a higher expiration rate. The timely updating inventory status and warning system for expiration were thus of a great concern for the developer.

In phase 3, INV-BSH program updated the inventory status everyday regardless of computer on-off status. The inventory information was close to the present number that that in phase 2. Reorder point for essential drugs and expiration-approaching items was reminded through LINE Notify.[15] The workers could reorder drug items with a proper volume in a timely fashion. During phase 3, Covid-19 pandemic subsided and prescription rates of most drug items gradually returned to the usual ones. The incidents of short supply of all items and essential items decreased to 0.81% and 0%, respectively, which were at passing levels of less than 2% and 0%, respectively. However, the expiration rate was at 2.58% which did not pass the criterion of 0%. These expired items included life-saving drugs such as adenosine inj 6 mg/2 mL, diphenhydramine 5% inj, Thai traditional drugs, and sample drugs.

Searching drug items using barcode and the codes created by HOSxP since pre-development phase caused certain problems when scanned by mobile phone application. Drug items with code number of less than 4 digits were pulled out unintentionally in addition to the desired one. For example, to find drugs with a code of 11, items with codes of 11, 111, 1111, and 11111 were also selected and shown. This made the user repeat the search to screen for specific items. With this imprecision in searching, methods with more precision were created in phase 4. QR code instead of barcode was used and drug item codes based on Generic Product Use (GPU) replaced existing codes generated by HOSxP. Faster and more precise searching was a result where only one item was precisely identified and shown on the mobile phone application.[5]

In this present study, it was found that short supply of all drug items decreased from 0.81 % in phase 3, 0.14% in phase 4 and to a passing level (a criterion of less than 1%). For expired items, the incidents decreased from 2.58% in phase 3 to 1.22% in phase 4, even though it did not pass the criterion of less than 1%. Like what found in pre-development phase, certain expired items included antidotes such as antivenom serum for Malayan Krait snake (Bungarus candidus) and dimercaprol injection. These drugs were with small, unpredictable prescription volume. These drugs are needed for life saving and could not be exchanged for a newer lot with the distributors.[16] Another example was dapagliflozin 10 mg tablet, an endocrinological drug which could not be exchanged with the distributor either. More innovative means must be invented to solve this problem on these certain groups of drugs to reduce unnecessary expiration.

For the performance of the inventory workers, in phase 4, the INV-BSH collected the work by scanning barcode on the invoice for received products and dispensed products from the warehouse. The workloads of each worker were summarized and could be used for more effective human resource administration. In the future, more sophisticate workload summarization could be done by barcode scanning standard GS1 codes on the drug product package before shelfing.[17]

After phase 4 development, the INV-BSH program had certain features that could be compared with other inventory control programs. For example, the M Stock is a web-based application for administering inventory of drugs and medical supplies.[8] With no need for installation, this web-based application cold be operated through desktop computer, mobile phone and tablet. With satisfaction among users, the application still lacks a warning system for items closing to short supply or expiration. In addition, INVC and INVS are the two programs developed by the Drug Information Technology workforce of the Ministry of Public Health and the Hospital Pharmacist Special Interest Group, respectively. Both programs have been widely used in a large number of public hospitals. These two programs offer purchasing and inventory control. The INV-BSH program shares certain features with these two programs such as mobile phone application, an hourly automatic inventory data update, and warning system through Line Notify. For the INV-BSH, there is room for advanced function development such as documentation system, purchasing report, and time used for each step of inventory control system.

Since the INVC and INVS programs have not been able to connect with the main service program of our hospital (i.e., HOSxP Version 4.0), the developer thus developed the INV-BSH to directly connect with the existing inventory database that was connected with the HOSxP. The development has been done continuously from phase 1 to 4 to reduce the incidents of short supply and expiration of drug items as mandated by the policy of Buddhasothorn Hospital.

The INV-BSH has certain limitations. To prevent data breach through mobile phone application, the INV-BSH could not directly connect to the database of HOSxP. The INV-BSH thus uploaded the data to Cloud. Allowing the mobile phone application to access the data on Cloud caused discrepancy of inventory status in the real-time HOSxP database and the one shown on the mobile phone application. In the future, a direct connection or access to the HOSxP database by mobile phone application should be developed. Another way to overcome such discrepancy could be the use of slave server which could allow for a transfer of more real-time data and a pre-set condition of warning system.

This present study could suffer certain limitations. The outcomes of incidents of short supply and expiration of drug items could be biased. The incidents could be influenced by factors other than the INV-BSH program. For example, the Covid-19 pandemic could affect prescribing and use of a lot of drug items and their inventory status. The outcome measures could be different from what should be. In addition, improvement in purchasing such as the use of economic order quantity (EOQ) could help reduce the short supply of drug items. Lastly, there could be some missing in date of short supply and expiration because of the retrospective nature of data collection such as incomplete records in the HOSxP system.

In conclusion, the INV-BSH developed could in part help reduce short supply of drug inventory both all items and essential throughout development phases 1 to 4 to the passing level. The incidents of expired drug items decreased in phase 1 but rebounded in phase 2; the decrease was continuously found in phases 3 and 4 but did not reach the passing level. Most expired drugs were antidotes and drug samples for specialists. The INV-BSH application program could be used for drug inventory control in other hospitals with context comparable with Buddhasothorn Hospital such as the use of HOSxP program for the service. The program could also be applied for sub-stock inventory control of any dispensary unit. The program should be further improved and tested continuously to attain the optimal performance for effective drug inventory control.

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