COMPARISON OF THE EFFECTIVENESS OF AUTOMATED VERSUS MANUAL DISPENSING SYSTEMS AT SIRIRAJ HOSPITAL

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การเปรียบเทียบประสิทธิผลของการใช้ระบบการจ่ายยาโดยใช้เครื่องจ่ายยาอัตโนมัติกับการใช้แรงงานคน ณ โรงพยาบาลศิริราช

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ประภาพร นพรัตยาภรณ์ : การเปรียบเทียบประสิทธิผลของการใช้ระบบการจ่ายยาโดยใช้เครื่องจ่ายยาอัตโนมัติกับการใช้แรงงานคน ณ โรงพยาบาลศิริราช (COMPARISON OF THE EFFECTIVENESS OF AUTOMATED VERSUS MANUAL DISPENSING SYSTEMS AT SIRIRAJ HOSPITAL) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ภญ. ดร. รุ่งเพ็ชร สกุลบำรุงศิลป์, หน้า.

เครื่องจ่ายยาอัตโนมัติได้ถูกนำมาใช้ในห้องยา 1 ใน 4 ห้องยาของงานเภสัชกรรมผู้ป่วยใน โรงพยาบาลศิริราช นำร่องในหอผู้ป่วยหอแรก ในเดือนกุมภาพันธ์ 2555 และหอที่สอง ในเดือนพฤศจิกายน 2555 การศึกษานี้ทำการประเมินระบบการจ่ายยาผู้ป่วยในโดยเครื่องจ่ายยาอัตโนมัติ เพื่อวางแผนขยายการใช้งานไปยังทุกหอผู้ป่วย โดยมีวัตถุประสงค์เพื่อเปรียบเทียบความคลาดเคลื่อนทางยาและระยะเวลา ซึ่งแสดงในรูปของจำนวนกำลังคนที่ต้องการสำหรับการทำงานในระบบการจ่ายยา โดยใช้เครื่องจ่ายยาอัตโนมัติ และระบบเดิมที่ใช้แรงงานคน รวมทั้งเปรียบเทียบต้นทุนต่อใบสั่งยาผู้ป่วยใน และต้นทุนทางตรงที่คาดว่าจะเกิดขึ้นในระยะเวลา 10 ปี หากมีการขยายการใช้เครื่องจ่ายยาอัตโนมัติครอบคลุมงานผู้ป่วยในทุกหอผู้ป่วย โดยระบบการจ่ายยาด้วยเครื่องจ่ายยาอัตโนมัติเป็นการใช้เครื่องควบคู่กับแรงงานคนเนื่องจากเครื่องรองรับเฉพาะการจัดยาเม็ด นอกจากนั้นยังเปรียบเทียบรูปแบบการจ่ายยาด้วยเครื่องจ่ายยาอัตโนมัติ 3 รูปแบบ ได้แก่ 1. การจ่ายยาตามขั้นตอนเดิมและเภสัชกรทำหน้าที่คืนยาเข้าเครื่องจ่ายยาอัตโนมัติ 2. ลดขั้นตอนการตรวจสอบและคืนยาโดยเภสัชกรผ่านเครื่องจ่ายยาอัตโนมัติ 3. ลดขั้นตอนการตรวจสอบยาและไม่รับคืนยาที่จ่ายผ่านเครื่องจ่ายยาอัตโนมัติ ผลการศึกษาพบว่ารูปแบบที่ 1 ใช้จำนวนเภสัชกร 81 คน รูปแบบที่ 2 และ 3 เท่ากันคือ 70 คน และรูปแบบที่ 1 ใช้ผู้ช่วยเภสัชกร 114 คน รูปแบบที่ 2 ใช้ 116 คน แบบที่ 3 ใช้ 113 คน รูปแบบที่ 1 มีต้นทุนต่อใบสั่งยา 64.07 บาท รูปแบบที่ 2 และ 3 เท่ากับ 60.83 และ 60.34 บาท ตามลำดับ และต้นทุนการดำเนินการในระยะเวลา 10 ปี รูปแบบที่ 1 สูงที่สุดที่ 687,128,835 บาท รูปแบบที่ 2 และ 3 เท่ากับ 641,784,802 และ 636,170,946 บาท ตามลำดับ เมื่อทำการวิเคราะห์โดยเพิ่มการใช้เครื่องจ่ายยาอัตโนมัติให้ครอบคลุมจำนวนใบสั่งยามากขึ้นร่วมกับการปรับระบบการทำงาน จะสามารถลดจำนวนผู้ช่วยเภสัชกร ต้นทุนต่อใบสั่งยา และต้นทุนในการดำเนินการในระยะเวลา 10 ปี ได้ เช่น การดำเนินงานโดยรูปแบบที่ 3 และครอบคลุมจำนวนใบสั่งยาร้อยละ 75 ของจำนวนใบสั่งยาทั้งหมด จะใช้เภสัชกร 70 คน ผู้ช่วยเภสัชกร 71 คน ต้นทุนต่อใบสั่งยา 53.95 บาท และต้นทุนการดำเนินการในระยะเวลา 10 ปี 567,819,915 บาท ซึ่งเมื่อเปรียบเทียบกับระบบการจ่ายยาโดยการใช้แรงงานคนทั้งหมด ที่ใช้เภสัชกร 47 คน ผู้ช่วยเภสัชกร 133 คน มีต้นทุนต่อใบสั่งยา 55.59 บาท และต้นทุนการดำเนินการในระยะเวลา 10 ปี 569,436,486 บาท จะเห็นได้ว่าระบบการจ่ายยาโดยใช้เครื่องจ่ายยาอัตโนมัติสามารถลดภาระงานของผู้ช่วยเภสัชกร แต่เพิ่มภาระงานของเภสัชกร อย่างไรก็ตามในภาพรวมสามารถเพิ่มคุณภาพการดูแลผู้ป่วย ลดความคลาดเคลื่อนทางยาในขั้นตอนการจัด จ่าย และการบริหารยา ในเบื้องต้นคาดว่าหากขยายการใช้งานไปยังหอผู้ป่วยต่างๆ จะลดความคลาดเคลื่อนทางยาได้ 906 ครั้งต่อปี รวมทั้งลดต้นทุนในการดำเนินการต่างๆ ได้ จึงสรุปได้ว่าการนำเทคโนโลยีเครื่องจ่ายยาอัตโนมัติเข้ามาใช้สามารถเพิ่มประสิทธิภาพของระบบการทำงาน รวมทั้งการดูแลผู้ป่วย แต่ทั้งนี้ควรมีการใช้เทคโนโลยีนั้นอย่างมีประสิทธิภาพและเต็มศักยภาพ

ภาควิชา เภสัชศาสตร์สังคมและบริหาร ลายมือชื่อนิสิต .....

สาขาวิชา เภสัชศาสตร์สังคมและบริหาร ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

ปีการศึกษา 2557

5576352333 : MAJOR SOCIAL AND ADMINISTRATIVE PHARMACY
KEYWORDS: AUTOMATED DISPENSING MACHINE, AUTOMATED DISPENSING SYSTEM, MEDICATION ERROR, FULL TIME EQUIVALENT, UNIT COST, COST OF INVESTMENT, SURVEY, DISPENSING SYSTEM, RETURNED DRUG SYSTEM, STOCK MANAGEMENT, ACCEPTANCE

PRAPAPORN NOPARATAYAPORN: COMPARISON OF THE EFFECTIVENESS OF AUTOMATED VERSUS MANUAL DISPENSING SYSTEMS AT SIRIRAJ HOSPITAL. ADVISOR: ASST. PROF. RUNGPETCH SAKULBUMRUNGSIL, Ph.D., pp.

Automated dispensing machine (ADM) was implemented in 1 of 4 inpatient pharmacy units at Siriraj Hospital to dispense medicines to inpatient ward. The first ward was automated dispensed in February 2012 and the second ward in November 2012. This research evaluated the recent situation of ADM implementation to further plan for all inpatients. The purpose of this study was to compare medication errors and workload, between automated and manual dispensing systems. Unit cost per prescription and the estimated net cost of investment over a 10-year period, when ADM has been thoroughly implemented throughout the hospital were also calculated. In this study we compared 3 models of ADM system. ADM model 1 was the current implemented system, which added the prescription verifying process into the manual dispensing procedures with a pharmacist in charge of checking and monitoring the returned drugs back in ADM. The dispensing procedure of ADM model 2 skipped the last checking process by pharmacist with pharmacy technician in charge of checking ADM drug and filling returned drug back to ADM. ADM model 3 had similar dispensing process to ADM model 2 but dispensed drug by ADM was not allowed to return. The study found that ADM model 1 needed 81 pharmacists while model 2 and 3 needed 70. ADM model 1 needed 114 pharmacy technicians while model 2 and 3 needed 116 and 113 respectively. Unit cost of ADM model 1 was 64.07 baht/prescription with 60.83 and 60.34 baht for model 2 and 3 respectively. Cost of investment over 10-years was 687,128,835 baht for model 1 with 641,784,802 and 636,170,946 baht for model 2 and 3 respectively. When we covered more prescriptions by ADM with less work process, the number of pharmacy technicians, unit costs, and cost of investment could decrease. The sensitivity analysis showed that when 75% of prescriptions were dispensed by ADM model 3, we needed 70 pharmacists and 71 pharmacy technicians with unit cost of 53.95 and 567,819,915 baht for cost of investment over 10 years. When compared with manual system, 47 pharmacists and 133 pharmacy technicians were required with unit cost of 55.59, and cost of investment over 10 years at 569,436,486 baht. The study present that ADM system could decrease pharmacy technicians but increased pharmacists was due to adding the verifying process, which was not performed under the manual system. This would improve the quality of patient care. The study estimated about 906 medication errors per year in preparation, dispensing, and administration could be prevented from the ADM. In conclusion, ADM system could increase the efficiency of drug distribution system and improve quality of patient’s care while the improved efficient working system should be implemented.

Department: Social and Administrative Pharmacy Student's Signature .....
Field of Study: Social and Administrative Pharmacy Advisor's Signature .....
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CHAPTER I

INTRODUCTION

Rational and Background

In hospitals, adequate methods of drug distribution are the important part to assist the pharmacist in preparing drug control procedures for all medication-related activities. This responsibility is under the pharmacy service (1). This simply functional service extends throughout the hospital and organizational structures are essential to support the successful treatment. Nowadays work process of medication distribution in pharmacy unit comprises of multiple steps and personnel involved which cause the medication errors and adverse events (2). Medication distribution in the part of pharmacy unit work process starts from the prescription is sent to pharmacy unit. Pharmacist screens prescription by reviewing the appropriate use of medicine such as indication, dose, route, drug allergies, and drug interaction. Pharmacy technician records the order into computer system and prepares the medicines. Pharmacist checks and dispenses medicine to ward where the medicine will be kept in a patient-specific drawer. Finally, medication is administered by nurse. During to these steps medication errors have occurred. Most medication errors of Siriraj Hospital which are reported by health professionals are medication error type B (medication error type B indicates that a medication error occurred, but the error did not reach the patient following the criteria of National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) Index). Although a study by Bates et al found that only five in five hundred and thirty medication errors lead to adverse drug events which affect the patients' safety (3). It is our goal to minimize the

patient risk and improve patient care. Many interventions and technologies have been developed to support the system and prevent errors in each step of medication distribution system such as medication error reporting program (4), information technologies (5), computerized physician order entry (CPOE) (6-10), automatic dispensing machine (ADM) (2, 11, 12) and barcode verification for dispensing step (13), electronic medication administration records (eMARs) and barcode system for administration step (2). ADMs are widely used in many countries such as the United States (14), Canada (2) and also in the private hospitals in Thailand such as Bumrungrad Hospital, Synphaet Hospital, and Vejthani Hospital. ADM implementation may be used as pharmacy-based (centralized) or ward-based (decentralized) whichever is appropriate for each setting for example medical-surgical patient care units in Canada implemented ward-based (decentralized) ADM can decrease the medication errors and save cost (2). Pharmacy-based (centralized) at Bumrungrad (the large private hospital in Thailand) found that an ADM can save labor cost, training costs, and inventory costs and avoid medication filling error costs in Bumrungrad Hospital (15).

At Siriraj Hospital, the electronic prescribing was developed and planned to implement in 2014 for reducing errors. Since February 2012, a pharmacy-based (centralized) ADM; Yuyama YS-TR-406FDS-II, has been implemented for inpatients at Siriraj Hospital for improving the limitation of manual dispensing system in safety; dispensing and administration error, time consumption from multi steps in distribution process, personnel involved, and cost. The 10^{th} floor South Assadang ward (medication ward) was the first ward for implementation in February 2012 and expanded to the 10^{th} floor North Assadang ward in November 2012. Medication

which is prepared by ADM is dispensed to patients in unit doses in which one unit dose contains all types of drug in each meal, so this is easier than the manual system and may decrease the administration error when compared with the manual system.

Nowadays only two wards use ADM in drug preparation process; ADM system. In this study about 220 types of tablet are prepared by ADM whereas other dosage forms are prepared by pharmacy technician. The other wards in which all dosage forms of drug are prepared by pharmacy technician is called manual dispensing system (Manual system). Many questions need to be raised and answered before thorough hospital implementation about the effectiveness of automated dispensing system such as the efficacy of ADM to reduce medication errors, workforce planning, operational cost of dispensing system, and cost of investment when hospital implementation is complete. The ADM system has errors, because ADM cannot cover all types of drugs. Only tablet dosage form is prepared by ADM whereas other dosage forms (i.e. injection, solution, and the external used medicine) is still prepared manually. Moreover work process and role of pharmacist and pharmacy technician have changed after ADM implementation in the process of dispensing medication, returned drug process, and stock management. The work process in ADM system is nearly similar to manual system, but a pharmacist is more involved in some steps. Work flow of dispensing process of both systems which start by prescribing by physician, dispensing by pharmacy unit, and finally medication is administered by nurse have been shown as the following and summarized as table 1.

Steps of dispensing process in manual and automated dispensing system:

Manual dispensing system (Manual system)

1. Prescription screening by pharmacist for the appropriate use of medication such as indication, dose, route, drug allergies, and drug interaction.
2. Record medication order and generate the label by pharmacy technician with HIS computer system.
3. Label zip-locked bags and prepare all types of medication (tablet, injection, solution, external used drug, etcetera) by pharmacy technician.
4. Check and dispense by pharmacist.

Automated dispensing system (ADM system)

1. Prescription screening by pharmacist for the appropriate use of medication such as indication, dose, route, drug allergies, and drug interaction.
2. Record medication order and generate the label by pharmacy technician with HIS computer system.
3. Prescription verification such as review the new order with the patient medication profile from the program (Pharmanager program) of ADM system and transfers the data to ADM for preparation. The process is managed by pharmacist.
4. 220 types of tablet are prepared by ADM while others are still prepared by pharmacy technician. For ADM drug, the step of labeling on zip-locked bag by pharmacy technician is skipped because the label will be printed automatically on the unit dose package, although pharmacy technician is still required to separate the individual patients' strip of packaged medication after preparation by ADM and matching ADM drug with manual drug and prescription.

5. Check and dispense by pharmacist.

Table 1 Summary of medication dispensing process

Process	Manual system	ADM system
Screen	R.Ph	R.Ph
Record	Ph.Tech	Ph.Tech
Verify	-	R.Ph
Sticker	Ph.Tech	-
Preparation	Ph.Tech	ADM
Check	R.Ph	R.Ph

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

Most steps of dispensing process such as prescribing, screening, recording, and checking are similar in both systems while the step of verify is added in ADM in order to connect the data between HIS computer system which is the computer program for medication recording and the program of ADM.

ADM system may be faster and safer in preparation step, although in the part of medication checking requires more time and effort, because medication checking from unit dose package is more difficult than medication which is packed in manufacturers' original pack and separated in zip-locked bag in manual system. It seems that medication checking from unit dose package will increase the pharmacist workload in ADM system.

The work flow of medications return process changed when ADM system was implemented as the following and summarized as table 2.

Manual dispensing system (Manual system)

1. Check returned drug from ward by pharmacy technician.
2. Record data in computer system by pharmacy technician.

3. Pharmacy technician checks receipt of returned drug.
4. Place the returned drugs back in inventory by pharmacy technician.

Automated dispensing system (ADM system)

1. Check returned drug from ward by pharmacy technician.
2. Record data in computer system by pharmacy technician.
3. Check the receipt of returned drug by pharmacy technician.
4. Place the returned drugs back in inventory by pharmacist or pharmacy technician.

Table 2 Summary of medication returned process

Process	Manual system	ADM system
Check returned drug	Ph.Tech	Ph.Tech
Record	Ph.Tech	Ph.Tech
Check receipt	Ph.Tech	Ph.Tech
Storage	Ph.Tech	R.Ph

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

In the manual system pharmacy technician has the role to place drug on the shelf whereas in the ADM system both pharmacy technician and pharmacist are involved in returning drug.

Process of stock management covers the step of filling drug on shelf or ADM and checking stock. Step of filling drug for dispensing on shelf or ADM is different in both systems. Drug preparation step for removal of tablet from manufacturers' original pack before filling to ADM is added in ADM system. The part of checking stock, in ADM system has a program to support stock management as table 3 so spending less time than manual system.

Table 3 Summary of stock management

Process	Manual system	ADM system
Filling shelf	Ph.Tech	Ph.Tech
Filling ADM	-	R.Ph & Ph.Tech
Checking stock	R.Ph & Ph.Tech	R.Ph & Ph.Tech

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

As mentioned above the alternative systems contain both advantages and disadvantages. Changing the work process in ADM is believed to increase the system capacity. Moreover implementing ADM throughout the hospital needs intensive investment. Under the budget constraint situation, the new system needs to prove its values in terms of effectiveness as well as the magnitude of the impact on the hospital budget.

Research objectives

1. To compare the effectiveness between automated and manual dispensing systems
2. To estimate the cost of investment of implementing Automated Dispensing Machine (ADM), and
3. To survey the acceptance of pharmacists and pharmacy technicians on the new dispensing system

Expected Benefits

The results of this study will be used to design and support new dispensing system and decision making of ADM implementation at Siriraj Hospital. The ADM is expected to increase efficiency of pharmacy dispensing process and could directly and indirectly improve the quality of patient care in the hospital.

CHAPTER II

LITERATURE REVIEW

Drug distribution and Control

Drug distribution and control are the roles of hospital pharmacist (16) especially drug dispensing so the efficient drug-dispensing system is crucial to assure the patients safety and treatment achievement goals. There are four types of drug-dispensing system in hospital (17).

1) Collective system or traditional system

Collective system is the oldest system which nurses have the major role for patients' drug-use process including transcribing prescriptions, inventory management, preparing, and drug administration while the responsibility of pharmacy department is drug dispensing forward-stock. The advantages of this system are prompt drugs to use in ward and lower use of human resources and materials of pharmacy department. The disadvantages are the financial burden, the high rate of medication errors, inappropriate drug use, and inefficient stock control which lead to the high drug expenditure.

2) Individualized system

Individual system is the system in which the pharmacists are more involved. After doctor orders medication for patients, nurse transcribes prescription or directly sends the copy of doctor order sheet to pharmacists or indirectly send the doctor order sheet by fax, or computerized prescription etcetera. Then drug is dispensed to each patient by pharmacy service and administered to patients by nurse, so this system still has medication errors with the lower rate than collective system. This system can

reduce inappropriate drug use and stock in wards, but increases human resources and consumption materials from pharmacy department. Moreover the unused drugs which return from ward are lower in this system.

3) Mixed system

Mixed system is combination between collective system and individualized system. Adoption of the mix system may different in each setting. For example, specific wards (emergency, endoscopy) are supported by collective system while others are supported by both individualized system and collective system. The common use and life-saving drugs are ward stock and others are dispensed under the doctor's orders by pharmacist. Many disadvantages from collective system still persist in this system, but in the lower rate when compared with the collective system.

4) Unit dose system

Unit dose system was developed in 1960 for medication errors reduction, drug expenditure reduction, and patients care improvement. This system is widely used in the United States for inpatients (18). Drug is dispensed in unit dose package which contains the particular dose for each patient and ready to administer (19). The advantages are medication errors reduction, inventory cost reduction, patient care improvement at ward thus this system is so interesting to implement in the hospital. Jansooksee C et al, (20) studied about unit dose system improvement in Thailand such as medication error, spending time on drug related activities by nurse, satisfaction, and cost. The implementation of unit dose system at a community hospital provided many advantages over the traditional system such as medication error prevention, transcribing error, administration error, and ward stocking errors which were statistically significant reduced from 5% to 1.9%, 4.7% to 0.9%, and 7.1% to 4.1%,

respectively. Preparation and dispensing errors were not significantly different while dispensing errors reduced from 2.3% to 1.2% whereas preparation increased from 3% to 4.2%. The proportions of spending time on drug related activities by nurse were not increased significantly whereas the spending time by pharmacy department in part of packaging and checking drug was increased. Nurses' time for stock management was decreased significantly while spending time for patients' education was increased more than traditional system. Pharmacy and nursing department liked unit dose system because it could overcome the obstruction such as the medication error and nurse has more time for patient care. Total direct cost (per month or per patient per day) in pharmacy department with unit dose system was higher than traditional system at 4,340.92 baht per month or 0.168 baht per patient per day, with a decrease in nursing departments of 6,359.80 baht per month or 0.537 baht per patient per day. Thus the overall cost was a saving in unit dose system by 2,605 baht per month or 0.369 baht per patient per day. The unit dose system may be different in each setting which depends on the specific needs, resource, and characteristics of the setting. The unit dose system consist of four elements; 1) medication is contained in and administered from the unit dose package, 2) medication is dispensed in ready to administer packets, 3) most medication is dispensed not for more than 24 hours, 4) each patient's medication profile is reviewed by the pharmacist before dispensing (1).

As the above unit dose system is the good medication distribution system which can reduce medication errors, nurse's spending time on drug related activities, and inventory cost with increased worker satisfaction, and cost saving. Moreover the standard guideline (16) recommends the role of hospital pharmacist in medication distribution and control so that the inpatients' drugs should be distributed in daily

dose with single-unit packages which are prompt and ready for use without manipulation before administration. All of this action can improve patient safety and collaborate with multidisciplinary hospital staff to develop policies or procedures and monitoring to prevent the medication errors (16). However a disadvantage is the increased workload of pharmacy, the burden of finance for the extra pharmacy staff and ADM investment.

Medication errors

Definition of Medication Errors from the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) is “any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer. Such events may be related to professional practice, health care products, procedures, and systems, including prescribing, order communication, product labeling, packaging, and nomenclature, compounding, dispensing, distribution, administration, education; monitoring; and use”.

There are many criteria to classify medication error (21) such as Hartwig et al, (22) that classifies medication error depending on the severity level as 7 levels (Level 0 to Level7), to classify based on probability and severity scale analogous to those which are used in ADR reporting program (23, 24). NCC MERP index criteria were widely used to evaluate classification of medication errors and in use at Siriraj Hospital (25, 26). NCC MERP index classifies an error according to the severity of the outcome as follows (27).

Category A: Circumstances or events that have the capacity to cause error.

Category B: An error occurred, but the error did not reach the patient (An "error of omission" does reach the patient).

Category C: An error occurred that reached the patient, but did not cause patient harm.

Category D: An error occurred that reached the patient and required monitoring to confirm that it resulted in no harm to the patient and/or required intervention to preclude harm.

Category E: An error occurred that may have contributed to or resulted in temporary harm to the patient and required intervention.

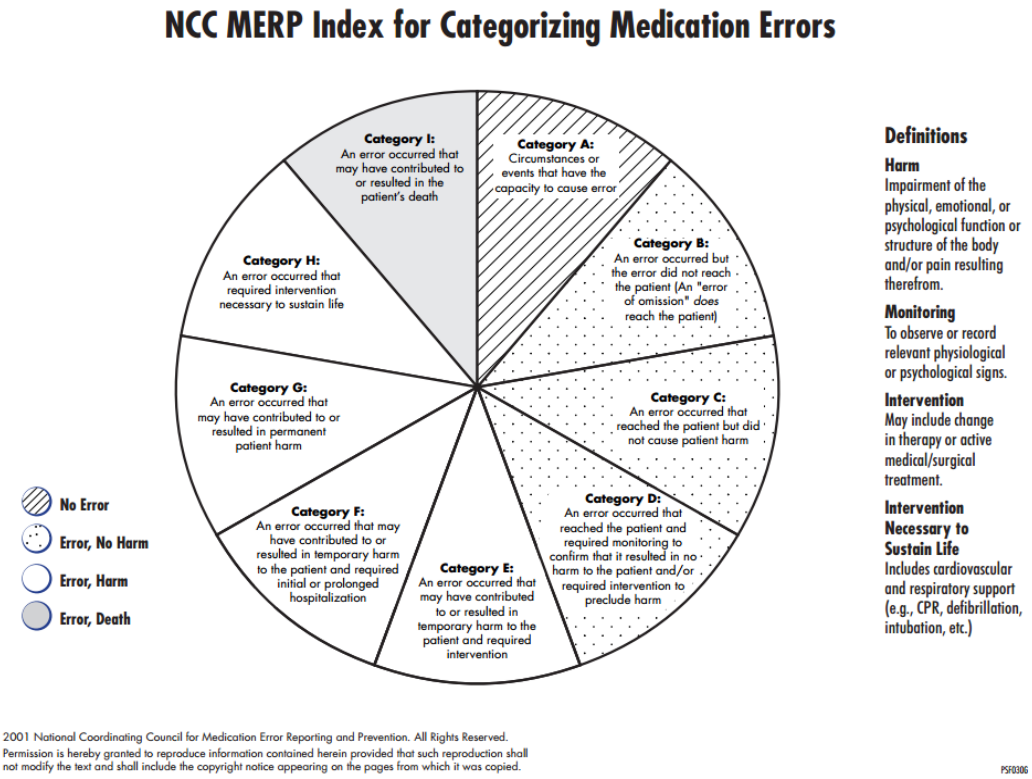
Category F: An error occurred that may have contributed to or resulted in temporary harm to the patient and required initial or prolonged hospitalization.

Category G: An error occurred that may have contributed to or resulted in permanent patient harm.

Category H: An error occurred that required intervention necessary to sustain life.

Category I: An error occurred that may have contributed to or resulted in the patient's death.

Figure 1 NCC MERP Index for Categorizing Medication Errors



Medication errors are the common cause of morbidity and mortality such as prolonged hospital stay as shown in previous studies (5, 28) and increase cost of hospital stay (29). From systematic review the causes and factors associated with medication errors in hospital included lack of training or experience, fatigue, stress, high workload (30), different day of the week, drug items per prescription, and inadequate communication between healthcare professionals (31). The error of dispensing may be associated with the communication failure, work overload, work environment, problem about drug package label, and the out-of-date drug information (17).

Many defensive measurements such as the renovated medication safety system, electronic-medication administration record, training new physicians and nurses were adopted in the hospital for medication error reduction (32). NCC MERP

recommends that medication error should be reported as soon as possible. For the good quality of data and health care an organization should develop a system to collect and also analyze and report at the time a medication error occurs. Rajavithi Hospital improved the electronic system for collection of the data instead of the manual system which would increase the complete data of medication error (33). After development, the analyzed medication errors data are reported in time and feedback provided to stakeholders for reviewing of the service to the needs of administrators of the hospital (33).

Many methods to collect data of dispensing error have been shown in table 4 (34). From a review of the literature, which covers studies from UK, US, and other countries (34), methods have been implemented such as incident form, observation, de-identified patient, case-note review, simulation, surveys, interview, and focus group. Most studies collected the dispensing errors' data by incident forms which were reported by staff on the standardized form. Further data came from observation and from previous studies (35, 36) which revealed that observational method can significantly detect more errors. The observation method in which the error data is recorded by the researcher observation is highly sensitive while incident form method may underestimate the incidence of error. The presence of observer may influence staff's performance, which is the Hawthorne effect. Moreover the difference of observer's accuracy may influence the recorded data. From the limitation of the observational method and the advantages of incident form method such as the low cost and can be used in routine monitoring so incident form method is most commonly used to investigate the incidence of dispensing error.

Table 4 Description, strengths, and limitation of the methods to detect dispensing error

Method	Description	Strengths	Limitations
Incident form	The errors reported by staff on standard form (self-report)	Can use in routine No fear to report because anonymous	Under report
Observation	The errors reported by observer or recheck accuracy of drug independently	Highly sensitive	Presence of observer may effect to staff performance (Hawthorne effect) Detection depends on observer
De-identified patients	Medicine was dispensed to de-identified patient and rechecked by researcher	Reflects the accuracy of the incidence	Expensive and time- consuming Finding may be influenced by the setting in study
Case-note review	Trained researcher screens and reports the error in patients' case notes	More information of errors	Detection may depend on the observers skill Expensive and time consuming

Method	Description	Strengths	Limitations
Simulation	Two researchers check medicine which is dispensed with the artificial error and report	Used for research and training program for pharmacy and nursing staff	Artificial errors and the environment in study may not reflect the real situation
Surveys	The surveys were sent to pharmacy staff for information about cause of error	Have the large sample in short time	Highly subjective opinion Low response rate, Loss of data from non-respondents
Interviews	The staff who are involved in the error were interviewed within 24-48 hours after error incurred	Can inspect the cause and situation of error	Staff may not fully report detail of the error Highly subjective and depends on memory
Focus groups	Group discussion with staff	Can inspect the causes and find the methods to reduce error	Does not directly concern with actual error

To report the incidence of dispensing errors, from a review of the literature (34) in community and hospital pharmacy most studies from forty-five studies calculate the incident ratio by the numerator is the total number of errors (each prescription may contain one or more errors) and the denominator is the number of medication items dispensed in the same period and in the same setting.

Automated dispensing machine

ADM are widely used in many countries such as the United States (14), Canada (2) and also in the private hospitals in Thailand such as Bumrungrad Hospital, Synphaet Hospital, and Vejthani Hospital. ADM can provide the important characteristics of safe medication distribution system such as security, accessibility, and inventory control (11). ADM implementation may be used as pharmacy-based (centralized) or ward-based (decentralized) whichever is appropriate for each setting. For example ward-based (decentralized) ADMs in medical-surgical patient care units in Canada revealed that after an ADM was implemented, medication errors and also costs decreased. (2). Another example is the pharmacy-based (centralized) ADM at Bumrungrad Hospital (a large private hospital in Thailand) found that an automated system can save labor cost, training costs, and inventory costs and avoid medication filling error costs (15). ADM is used to control narcotics, expensive drugs, and other drugs.

Objectives of ADM usage (37)

- To improve patient care such as accuracy, accessibility, and timeliness
- To decrease medication errors
- To manage resources and improve medication distribution system
- Increase patient satisfaction with the quality and delivery of care

- Resource management for development of medication distribution system
- Billing accuracy when dispensing or for returned drug

The organization should consider the following for ADM implementation (37)

- Practice standards are necessary for safety, accuracy, timeliness, and costs.
- There are many different staffs involved in this implementation such as pharmacist, pharmacy technician, and nurse so the supporting and preparation system should be considered.
- The effective training especially for pharmacy unit who have the responsibility for safe use, development, and maintenance of ADM.
- Computer system should be developed for complete management and integration with the traditional system and comfort for staff.

Types of ADM (38, 39)

- Pharmacy-based original-pack dispensers

This ADM has pharmacy labeling and stock control software. Medication is stored in the machine. When labeling is generated, the data from labeling software is transmitted to picking device for selection from specific shelves of drug. After that these drugs will be transferred to delivery stations via conveyor belt or chute. Some of these have the labeling device which adds the dispensing label before transferring to delivery station. Previous study reveals that pharmacy-based original-pack dispensers reduce rate of dispensing near-miss (39, 40) and increase the median dispensary workload (items/person/hour) significantly (39).

- Repackaging systems

Medication will be removed from manufacturers' original pack before dispensing medication in unit dose pack or blister card. The medicines are stored in the cassettes which are calibrated by the vendor for specificity of each medicine. Some of these increase compliance by each unit dose contains the medication required in a particular time of day (41). This system reduces medication errors (42, 43) and time which is spent by pharmacy technician (42).

- Ward-based automated dispensers

This system comprises of drug cabinets and/or drug trolleys and there is drawer which is controlled by computer system. After staff record patient's details in computer system, the drawer opens. Selected drugs which are stored in patient-specific or product-specific drawers are dispensed in manufacturers' original packs or unit dose (41, 44).

Ward-based automated dispensers decrease medication administration errors significantly (45, 46), although in a study by Barker KN et al,(45) there was no significant difference in nursing workload. Ray MD et al, (47) revealed that this system reduces time which is spent by f pharmacists to resolve drug distribution problems and mean waiting time for new medicines.

The Benefits of ADM (2, 11)

- Medication error

One of the important objectives of ADM use is to decrease medication errors especially for dispensing errors. There are widely in both pharmacy-based and ward-based ADM settings. From previous studies, the implementation of pharmacy-based

ADM in many large (42, 48, 49) and general hospitals (50-53) and ward-based ADM in large hospitals (47, 54-56) can reduce dispensing errors.

Although ADMs provide security in some part of medication distribution, incidence of errors occur in other parts which are created by ADM system (57-59), such as an error in override function which is the program for patient drug profile management. Many researches about the impact of ADM on medication safety are not clear because of flaws in methodology (2, 60), such as the period of study was too short (51-53); no mention about the comparator in the study (51, 52); data collected by non-experienced staff (52), and variation of methodology for medication errors detection effect to number of medication errors (35, 36) which could not be checked from the reported method (48). Many comments have been made about the lack of evidence of ADMs alone to improve medication safety (60). Combining with other technologies includes CPOE, barcode, and electronic charting system will promote a safer system.

- Working time

Pharmacy unit

From previous studies, many studies revealed that ADMs reduce dispensing time of pharmacist and pharmacy technician (56, 61-63) in the process of preparation and checking. From this advantage, pharmacist has more time for the higher value-added activities such as patient care-related activities (63) and pharmacy technician can be assigned to more important pharmacy activities such as automation specialist. The reduced time may be different according to the designed work process as in the study at 650-bed tertiary-care medical center. The time of medication preparation by pharmacy technician was significantly decreased in automated system whereas the

reduction of pharmacist time was not significantly changed since pharmacist had to cut the strip-packaged drugs into individual doses of patients when they checked the medications. Furthermore the overall time of automated system in this study was higher (42). To implement ward based also increased working time in some settings (64).

Nurse

Moreover, reduced time spent in pharmacy unit is means reduced time in nurses' involvement in drug related activities (56, 65). However, the pilot studies in a surgical intensive care unit and a medicine unit of university hospital revealed that there is no significantly reduction of medication related activities by nurse (63).

- Operational cost

The operational cost may cover many types of cost such as labor cost, inventory cost, the cost of drug storage and the cost of expired drug. A financial analysis showed that ADMs can save cost due to the decrease of personnel time which is converted into full-time equivalent (FTE) (56). ADM implementation in a 12-bed cardiovascular intensive care unit of a French teaching hospital reduced cost of drug storage and the cost of expired drugs (65). However, at a 650-bed tertiary-care medical center the drug costs to implement ADM were higher when compared with the traditional system because of a need to purchase bulk drug suitable for use in ADMs (42).

Work flow when ADM is implemented

The work flow differs when ADM implementation is different in each setting. For example the work flow at a private hospital (15) in Thailand after implementation of a pharmacy-based (centralized) ADM for inpatients since 2008, the prescriptions

are sent to pharmacy unit after scanning by nurse. A pharmacist records list of drugs and another pharmacist verifies this list. This is a process in which a pharmacist checks the new order with a patient's drug profile in the system before dispensing. After verification, the list of drugs were filled by pharmacy technician and ADM. Dispensed drugs from ADM are sent directly to ward without re-check, whereas the drug which is filled by manual will be re-checked by a trained pharmacy technician. Drugs which are dispensed from ADM are dispensed for 1 day in unit doses and attached together by a plastic ring with label attached with patient information.

ADM in Siriraj Hospital: Yuyama YS-TR-406FDS-II

Yuyama YS-TR-406FDS-II contains four hundred and six medication cassettes and special tray for special tablets. Each cassette has RFID chips which record information about the medication for recognition of the cassette position in ADM, so whenever a cassette is replaced in incorrect position a light alarm is activated. Each cassette is calibrated to specify the medication contained for dispensing accuracy. To access or change patient data in the computer system of our ADM is assigned for the authorized personnel. Computer system in automated dispensing system is useful in processing patient medication order and managing inventory. Moreover the program can report packaging activity and tracking lot numbers and expired dates of medicine.

Everyday physicians do their rounds and order drugs in the morning. These new medication orders are sent to pharmacy unit and reviewed by pharmacist. After that the new medication order is prepared and sent to ward and this order which has been approved will be link to the patient's medication profile. At about 11 a.m. pharmacists review all patient medication profiles from the Pharmanager program

(computer system of our ADM) and the medicines will be automatically dispensed as unit doses by our ADM which covers medicines for evening to the afternoon of the next day. Before our ADM dispenses medicines a pharmacy technician and pharmacist will refill medications to the ADM according to the list which is calculated from our ADM computer system.

The process of filling medicines into our ADM consists of 1) removing medicine from the manufacturers' original pack and 2) filling medicine into the cassettes which are calibrated for specific medications to optimize dispensing accuracy and to reduce the risk of cross-contamination and tablet miscount. Each drug cassette has the radio-frequency identification (RFID) chip used for automatic recognition of the cassette position, regardless of where the cassette is located. RFID chips and barcode system are used to ensure accuracy in the process of medication filling. In the process of drug filling into ADM, the data of *lot number and* expired date is required to our ADM's system from identification information assigned to a particular quantity from the manufacturer. The rate of ADM for filling the medicine in the package/pouch is up to 1 filled/labeled pouch per second. The unit dose is dispensed for 1 day use in which all medications for each meal are contained in single unit packages or single labeled pouches and ready-to-administer. Our ADM has the ability to print the medication name, expiration date, dispensed date, time of administration, patient's name, and ward on the package/pouch. Moreover our ADM can generate barcode or QR code which contains all medication information on the pouch. In case of more than one type of medicine in one package/pouch, the shortest expiration date of any contained medicine is selected to print on the pouch. A list of all unit doses for each patient is dispensed as a strip. At the end of each strip the

names of all medicines which a patient receives followed by any allergies a patient has about these medicines are printed. Only an unopened medication package/pouch can be reused when returned from ward to the pharmacy.

Cost analysis (66, 67)

In general we analyze cost by 2 methods such as standard or conventional and activity-based costing (ABC), Standard cost is the simple method which can provide enough information and activity-based costing is to accumulate cost in each process of productivity.

Standard or conventional method

There are five steps to analyze unit cost:

1) To identify cost center and grouping
2) Direct cost determination
3) Indirect cost determination
4) Full cost calculation
5) Unit cost calculation

1) To identify cost center and grouping

System analysis is carried out to identify a cost center and categorize it into non-revenue producing cost center (NRPCC), revenue producing cost center (RPCC), and patient service (PS). Non-revenue producing cost center (NRPCC) is the cost center which has the responsibility to support other cost centers. This cost center does not charge to patients directly. Revenue producing cost center (RPCC) is the cost center which provides service and charges to patient. Patient service (PS) is the cost center which provides service to patients directly.

2) Direct cost determination

Process to determinate direct cost:

- Identify perspective which is important and which impacts to the result of the analysis. To identify and assign cost which will be accumulated depend on perspective.
- Specify time horizon which is mostly calculated for 1 fiscal year.
- Identify cost which is calculated from items such as labor cost, material cost, and capital cost. Labor cost includes all benefits such as salary, wage, and fringe benefits. Material cost includes all materials which are used to utilize in a cost center. Capital cost includes items such as cost of building, durable goods and equipment which are calculated in terms of depreciation cost.
- Accumulate all direct costs in each cost center.

3) Indirect cost determination

To allocate the cost from NRPCC and RPCC to PS by many methods such as direct allocation method, step down allocation method, double distribution method, and simultaneous equation method.

4) Full cost calculation

Total cost in cost center is combined from direct and indirect cost.

5) Unit cost calculation

In a cost center with one service or many services which are homogeneous, cost products can calculate unit cost by the average method. In a cost center with several services costs are calculated by many methods for unit cost such as micro-costing, ratio of costs to charges, and relative value unit.

CHAPTER III

METHODOLOGY

This study was divided into three parts according to the objectives. The first part was the comparison of the effectiveness between automated and manual dispensing systems. The second part was to estimate the investment cost of implementing automated dispensing machine (ADM) thoroughly throughout the hospital and the last was to survey the acceptance of pharmacists and pharmacy technicians on the new dispensing system.

Setting

We performed the research in the inpatient department at Siriraj Hospital, a 2,100-bed university hospital. Each year more than one million prescriptions were dispensed via four pharmacy units. At pharmacy unit, all types of drugs were prepared manually and limited the quantities dispensed such as injection was limited to supply for not more than 3 days, other dosage forms were limited supply for not more than 7 days except saline solution and medical supplies which were supplied in full as the order. Since February 2012 ADM was implemented in one pharmacy unit at 100th Year Somdech Phrasrinakarinth Building in the first ward; 10th floor of South Assadang ward, and expanded to the second ward; 10th floor of North Assadang ward, in November 2012**.** Recently ADM has supported for tablets which cover about 220 types of tablets and cover about 22.83% of all prescriptions. The 10th floor of South Assadang and 10th floor of North Assadang were pilot wards for which drugs supported by ADM would be dispensed for 1 day tablets while the other medicines

would be dispensed for the usual quantities as mentioned above. The number of dispensed and returned prescriptions increased 25.22% and 3.7%, respectively in pilot wards after ADM implementation. Nowadays ADM is still implemented only in two wards. This study has compared two types of drug distribution system as follows.

1. Manual dispensing system (Manual system)

   In this system all dosage forms of drug were prepared by pharmacy technician.

2. Automated dispensing system (ADM system)

   In this system tablets were prepared by ADM whereas other dosage forms were prepared by pharmacy technician in the recently applied ADM system covering 220 types of tablets and covering about 22.83% of all prescriptions.

Part I: To compare the effectiveness between automated and manual dispensing systems

The effectiveness of this study was compared by medication errors, working time of pharmacist and pharmacy technician, and operational cost of dispensing system.

1. Medication error

At Siriraj Hospital medication error was identified and classified in nine classes of severity (A - I) according to the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) (27). Medication errors were detected and reported by health professionals at pharmacy unit and wards by self-reporting in standard forms. Medication errors could occur in any working process such as prescribing, recording, preparation, dispensing, and administration. Each medication item could contain several errors i.e. wrong patient, wrong drug, wrong strength, wrong dosage form, wrong quantity, and wrong dose. Each error

would be counted and recorded for analysis. Preparation, dispensing, and administration errors would be observed for the study effectiveness of ADM.

Preparation error was defined as the error which occurred in the process of preparation and was detected before medication left pharmacy unit.

Dispensing error was the error which was detected after the medication left pharmacy unit and before administration to patient.

Administration error was the error which occurred in process of medication administration.

Data collection

Medication errors were collected by pharmacists and nurses' self-reporting in routine reports. The incident of medication errors between November 2012 and October 2013 in inpatient pharmacy unit were recorded and classified by type of medication error (A-I) was supported by the Statistics Unit of Pharmacy Department and Risk Management Division Siriraj Hospital. The data were analyzed and shown as the representation of the medication errors in manual system. After ADM implementation, the error from 220 types of tablets which were prepared by ADM could decrease.

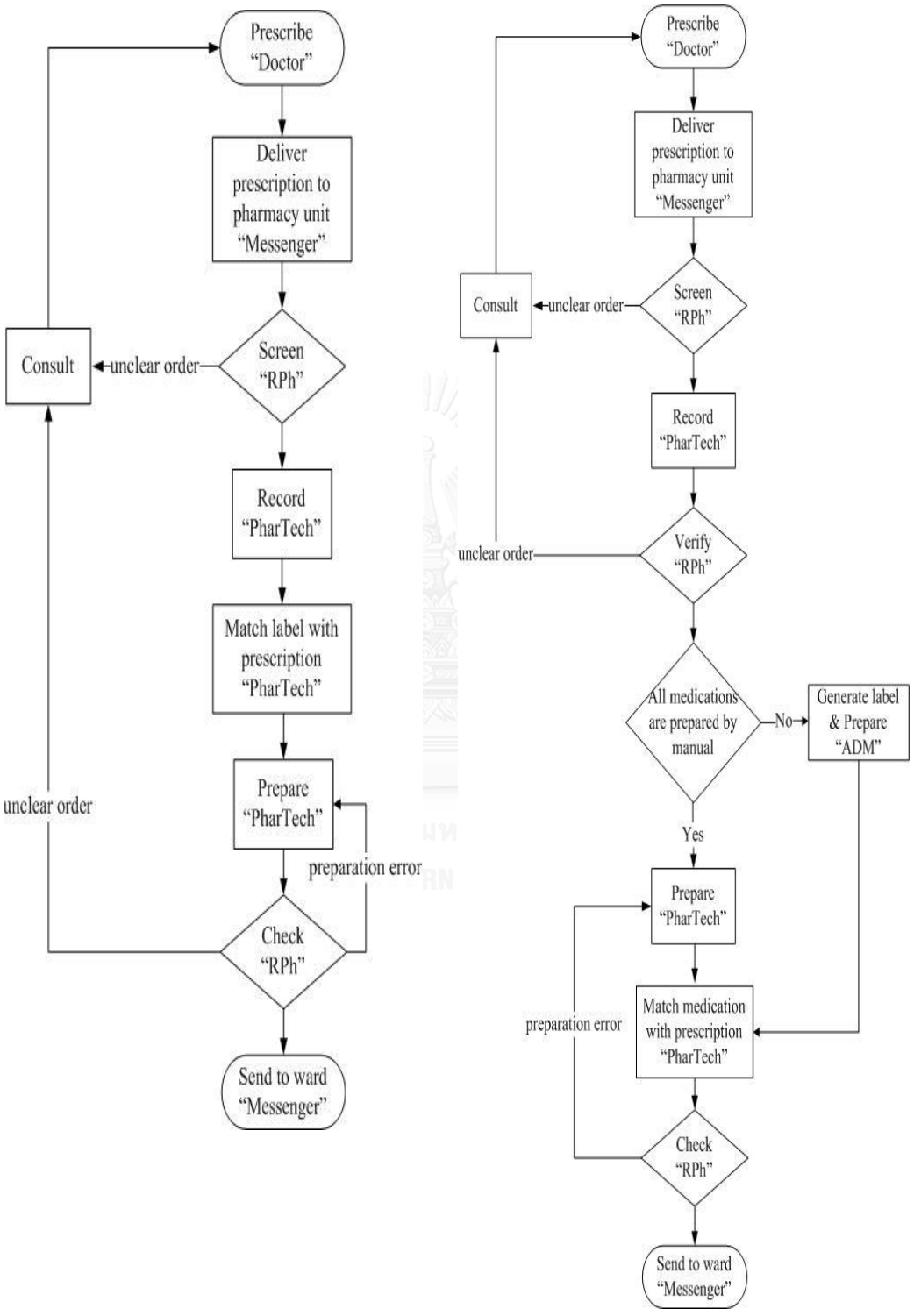
Data analysis

The efficacy of both systems was compared for the occurred medication error in each step of work process and type of medication error. We estimated that the number of medication errors from 220 types of tablets in manual system which could become zero when ADM had been implemented.

2. Working time

The study estimated the working time of pharmacist and pharmacy technician by full-time-equivalent (FTE) which was the time spent in work process. The data of time spent in each work process and number of prescriptions in manual and ADM system were analyzed. To collect time in work process by self-reporting, all activities were analyzed and the time of processing recorded via recording forms whereas the expert opinion was obtained in some processes which were unable to directly record. Before collecting data, all staff such as pharmacists (RPh) and pharmacy technicians (Ph.Tech) were informed and clarified about the data collection. The activities were different in manual and ADM system such as dispensing process (figure 2), returned drug process (figure 3), and stock management. Dispensing process consisted of screen, record, verify, labeling sticker, preparation, and check. Returned drug process consisted of check returned drug, record, check receipt, and place returned drug to shelf/ADM. Stock management covered time of filling shelf and ADM and checking stock. The work process in ADM system is mostly similar to manual system, but a pharmacist is more involved in some steps.

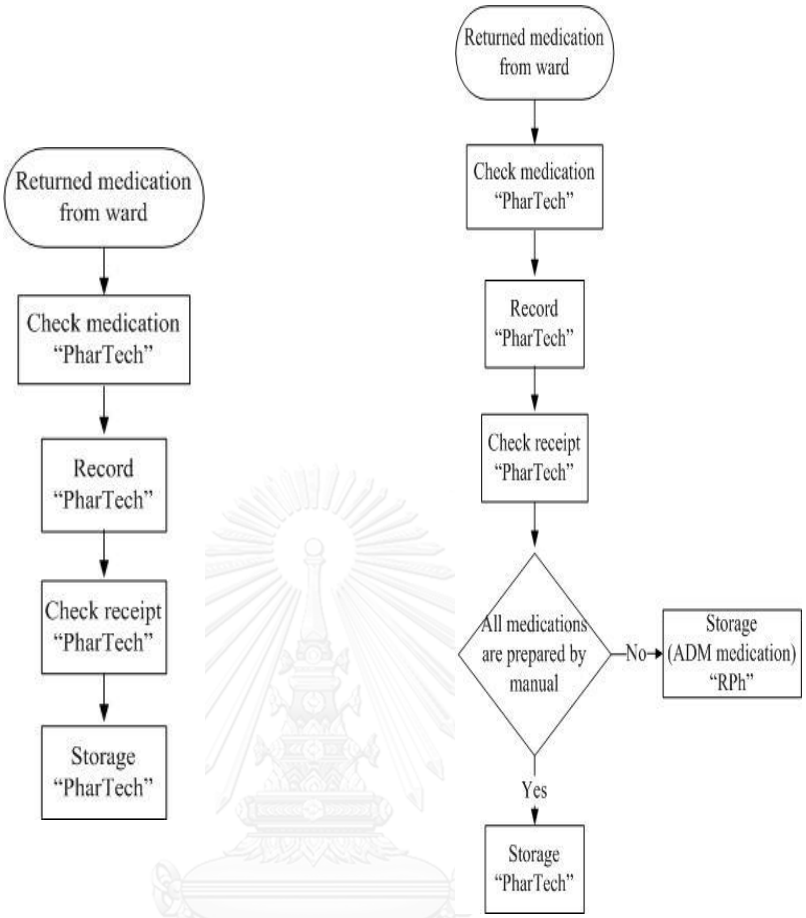
Figure 2 Dispensing process: Manual and ADM system



Dispensing process: Manual system

Dispensing process: ADM system

Figure 3 Returned drug process: Manual and ADM system



Returned drug process: Manual system

Returned drug process: ADM system

In this study we also designed new workflow of ADM system in dispensing and returning process using ADM model 2 and ADM model 3, which required less working process. All models such as manual, ADM model 1, ADM model 2, and ADM model 3 were analyzed and compared used FTE.

Dispensing process:

Manual system: Prescription was screened by pharmacist. Pharmacy technician recorded medication order, labeled zip-locked bags, and prepared drug. Pharmacist checked and dispensed drug to ward.

ADM model 1 (present): Prescription is screened by pharmacist and recorded by pharmacy technician. Pharmacist verifies the prescription and transfers data to ADM for preparation. ADM filled drug in unit dose package and labeling is printed automatically. Pharmacist checks and dispenses drug.

ADM model 2: The steps of working in this model were less than ADM model 1. There was no step of checking drug by pharmacist however pharmacy technician checked for the consistency of dispensed unit dose.

ADM model 3: Similar to ADM model 2

Table 5 Dispensing process in each model

Dispensing process	**Manual system**	**ADM system**		
		Model 1	**Model 2**	**Model 3**
Screen	R.Ph	R.Ph	R.Ph	R.Ph
Record	Ph.Tech	Ph.Tech	Ph.Tech	Ph.Tech
Verify*	-	R.Ph	R.Ph	R.Ph
Sticker*	Ph.Tech	-	-	-
Preparation*	Ph.Tech	ADM	ADM**	ADM**
Check*	R.Ph	R.Ph	(Ph.Tech)**	(Ph.Tech)**

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician
* Different step in ADM system
**Preparation and checking are the continuous process conducted by pharmacy technician

Returned drug process:

Manual system: All the return process was managed by pharmacy technician such as check returned drug from ward, record, check receipt of returned drug, and place returned drug back to inventory.

ADM model 1 (present): Steps of checking returned drug from ward, record, and check receipt of returned drug are managed by pharmacy technician in which pharmacist is more involved in step of filling the returned drug back to ADM.

ADM model 2: The step of work in this model was similar with ADM model 1 while filling returned drug back to ADM was the responsibility of pharmacy technician instead of pharmacist.

ADM model 3: Dispensed drug which was prepared by ADM was not allowed to return so there was no step in this model.

Table 6 Returned process in each model

Returned process	**Manual system**	**ADM system**		
		Model 1	**Model 2**	**Model 3**
Check returned drug*	Ph.Tech	Ph.Tech	Ph.Tech	-
Record*	Ph.Tech	Ph.Tech	Ph.Tech	-
Check receipt*	Ph.Tech	Ph.Tech	Ph.Tech	-
Storage*	Ph.Tech	R.Ph	Ph.Tech	-

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician
* Different step in ADM system

Stock management:

Manual system: Stock management covered time of checking stock by pharmacist and pharmacy technician, and filling shelf for dispensing.

ADM model 1 (present), ADM model 2, ADM model 3: The process of checking stock and filling shelf in ADM system are similar with manual system while pharmacist and pharmacy technician are more involved in the process of filling drug to ADM.

Table 7 Stock management in each model

Stock management	Manual system	ADM system		
		Model 1	Model 2	Model 3
Checking stock	R.Ph & Ph.Tech	R.Ph & Ph.Tech	R.Ph & Ph.Tech	R.Ph & Ph.Tech
Filling shelf	Ph.Tech	Ph.Tech	Ph.Tech	Ph.Tech
Filling ADM*	-	R.Ph & Ph.Tech	R.Ph & Ph.Tech	R.Ph & Ph.Tech

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician
* Different step in ADM system

Data collection

Time of start and finish in each work process was recorded by pharmacist and pharmacy technician. Data was collected in October 2012 in the pharmacy unit at 100th Year Somdech Phrasrinakarinth building in which ADM had been implemented. Time spent of ADM system was represented by the 10th floor of South Assadang ward and manual system was represented by the other wards which were not implemented with ADM.

Data analysis

We compared working time between the models when complete implementation in the hospital by FTE. All time spent in work process was calculated to hours per year and divided by working time of one person per year (7 hour per day and 230 days per year which were used in practice at Siriraj Hospital) as the formula.

$$\frac{\text{Total time spent (hr/year)}}{\text{Working time (hr/man/year)}}$$

Sensitivity analysis

Sensitivity analysis was used to find out the model which resulted in the lower FTE of staff. Four models; manual, ADM model 1, ADM model 2, and ADM model 3, which were different in work process and proportion of prescription covered by ADM were compared.

3. Operational cost of dispensing system

Operational cost was calculated in terms of unit cost by standard or conventional method. Cost data and method supported by unit cost division and numbers of prescription data were from a business intelligence program, in the pharmacy department. For inpatient service section, some data such as labor cost of medical staff, medical material cost, capital cost, and number of staff were reanalyzed according to workload and resource which was needed in system operation while the other data in this unit and other units were from unit cost division. This research studied unit cost per prescription in inpatient service section compared between four models; manual, ADM model 1, ADM model 2, and ADM model 3 based on cost data in fiscal year 2014. The process of unit cost calculation comprised of:

1) To identify cost center and grouping

There were 9 cost centers in pharmacy department which were classified into groups of non-revenue producing cost center (NRPCC) and patient service (PS). Non-revenue producing cost center (NRPCC) included central office, central administration, academic, data development, and purchasing. Patient service (PS)

included aseptic pharmaceutical product, general pharmaceutical product, inpatient service, and outpatient service.

2) Direct cost determination

Calculate direct cost of inpatient service in perspective of provider covered labor cost, medical material cost, capital cost, and other costs.

Labor cost was defined as labor cost of medical staff and labor cost of supporting staff which covered salary, professional cost, and fringe benefits. Medical staffs were pharmacists, pharmacy technician, and scientists. Supporting staff were administrative officers and general staff. Inpatient service section, labor cost of pharmacist and pharmacy technician were calculated from full-time equivalent (FTE) of staff multiplied by salary and fringe benefits.

Medical material cost for inpatient service section included zip-locked bags, stickers for drug labeling, plastic bags, and unit dose bags for drugs from ADM. The numbers of used materials were multiplied by cost per unit and converted into material cost per prescription.

Capital cost was depreciation cost of equipment which included cost of hardware (computer, printer), and ADM which were calculated by straight line method with useful life 5 years as the formula.

$$\frac{\text{Acquisition cost (baht)}}{\text{Estimated useful life (year)}}$$

Other costs were such as cost of computer gadget, conference, book or journal.

All direct costs were accumulated in each cost center.

3) Indirect cost determination

Cost allocated from NRPCC to PS. In this research we studied unit cost per prescription of inpatient service. NRPCC were central office, central administration, academic, data development, and purchasing. Direct cost of NRPCC was allocated to be the indirect cost of PS.

First allocation from purchasing, direct cost of purchasing cost center was allocated to inpatient service section by percentage of drug expenditure.

Second allocation from central office, central administration, academic, and data development was allocated to inpatient service section by percentage of staff.

4) Full cost calculation

Full cost or total cost of inpatient service section was calculated from summation of direct costs and indirect costs.

5) Unit cost calculation

To calculate unit cost per prescription, the total cost of inpatient service section was divided by the number of prescriptions.

At Siriraj Hospital indirect costs from other cost center outside pharmacy department were also allocated to inpatient service section which added 10% to the calculated unit cost.

Sensitivity analysis

Sensitivity analysis was generated to find out the model which resulted in the lower cost per prescription. Four models; manual, ADM model 1, ADM model 2, and ADM model 3, which were different in work process and proportion of prescription covered by ADM were compared.

Part II: To estimate the cost of investment of implementing automated dispensing machine

The cost of investment was estimated as the related cost which will incur when ADM has been thoroughly implemented throughout the hospital. The net cost of investment of manual, ADM model 1, ADM model 2, and ADM model 3 were analyzed for 10-year period in perspective of hospital. The direct cost was calculated such as labor costs of pharmacist, pharmacy technician, supporting staff, and nurse, capital costs, material costs, maintenance costs, and other costs as shown in table 8. All costs were for 2014 in baht and adjusted with 3% discount rate for the future value to present value.

Labor cost

Labor cost of pharmacist and pharmacy technician were calculated from full-time equivalent (FTE) of staff multiplied by salary and fringe benefits. FTE of staff was converted from the data of time spent in each work process which was directly recorded at pharmacy unit and concluded from expert opinion when data were unable to be directly recorded. Data of salary and fringe benefits were obtained from human resource unit. For labor cost of supporting staff, we assumed that it was equal in all systems. Labor cost of nurse was also included in ADM system, because unit dose medication from ADM system could decrease administration time. We estimated that in every year all staff's salaries increased 5% (general rate of increase in salary was between 3-7%).

Material cost

Material cost included zip-locked bags, sticker for drug labeling, plastic bag, and unit dose bag for drug from ADM. The number of materials used was multiplied by cost per unit and converted into material cost per prescription.

Automated dispensing machine and maintenance cost

We assumed ADM lifetime to be 10 years. For the first four years of implementation the support and maintenance were free and after that to maintain an ADM was 60,000 baht per year.

Capital costs and other costs

We estimated that these costs were equal in all systems. Capital cost included cost of hardware (computer, printer) which used in pharmacy unit for inpatient service. The other cost included computer gadgets, conferences, and books. Data of costs were supported by unit cost division.

Sensitivity analysis

Sensitivity analysis was generated to find out the model which resulted in the lower net cost. Four models; manual, ADM model 1, ADM model 2, and ADM model 3, which were different in work process and number of prescriptions which were covered by ADM were compared.

Table 8 Direct costs used in cost of investment analysis

Direct cost	Manual system	ADM system
Labor cost of pharmacist	✓	✓
Labor cost of pharmacy technician	✓	✓
Labor cost of supporting staff	✓	✓
Capital cost	✓	✓
Material cost	✓	✓
Other costs	✓	✓
Automated dispensing machine (ADM)		✓
Cost of maintenance (ADM)		✓
Labor cost of nurse (cost saving)		✓

Part III: To survey the acceptance of pharmacists and pharmacy technicians on the new dispensing system

As mentioned above, the work flow in all work processes of ADM system was mostly similar to manual dispensing system whereas pharmacist was more involved in some steps. To revise and redesign the work process may be necessary in the next step, so in the last part of this study we surveyed the acceptance of pharmacists and pharmacy technicians who have the experience of using the ADM in the new dispensing and returned drug process (Appendix A). The questionnaire was anonymous and self-administered /overall result presentation.

The first part of the questionnaire was biological data. The second part of the questionnaire was the questions about the acceptance of the new dispensing and returned drug process.

Steps of dispensing process in ADM and new ADM system:

ADM system

1. Prescription screening by the first pharmacist for the appropriate use of medication.
2. To record medication order by pharmacy technician with HIS computer system.
3. The first pharmacist verifies prescription with Pharmanager program and transfers the data to ADM for preparation.
4. Tablet is prepared by ADM.
5. Checking and dispensing by the second pharmacist.

New ADM system

1. To screen, record, and verify a prescription by the first pharmacist.
2. Tablet is prepared by ADM.
3. Send to ward.

Table 9 Dispensing process in ADM and new ADM system

Dispensing process	**ADM system**	**New ADM system**
Screen	1st R.Ph	1st R.Ph
Record	Ph.Tech	
Verify	1st R.Ph	
Preparation	ADM	ADM
Check	2nd R.Ph	-

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

The new dispensing system had less working process and number of staff when compare with the current process. The new returned drug process was the same

process although the staff involved staff was different. A pharmacy technician was involved in the process of filling returned drug to the ADM instead of a pharmacist.

Steps of returned drug process in ADM and new ADM system:

ADM system

1. Pharmacy technician checks the returned medicine from ward.
2. Pharmacy technician records data in computer system.
3. Check the receipt of returned drug by pharmacy technician.
4. Fill the returned drugs to ADM by pharmacist.

New ADM system

1. Pharmacy technician checks the returned medicine from ward.
2. Pharmacy technician records data in computer system.
3. Check the receipt of returned drug by pharmacy technician.
4. Fill the returned drugs to ADM by pharmacy technician.

Table 10 Returned drug process in ADM and new ADM system

Returned drug process	ADM system	New ADM system
Check medicine	Ph.Tech	Ph.Tech
Record	Ph.Tech	Ph.Tech
Check receipt	Ph.Tech	Ph.Tech
Storage	R.Ph	Ph.Tech

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

Respondents were asked to indicate the agreement and reason that they agreed or disagreed with the new process. However respondents were invited to offer suggestions if they had any other recommended work process. The suggestions from the questionnaire were used for working process improvement and led to the

appropriate model of working process. We expected that the automated medication machine could increase efficiency of pharmacy dispensing process and would directly and indirectly improve the quality of patient care in the hospital.

CHAPTER IV

RESULTS AND DISCUSSION

We performed the research in the inpatient department at Siriraj Hospital, which is a 2,100-bed university hospital. 110 wards for inpatient service are spread in 15 buildings and were supported by four pharmacy units. Each year more than one million prescriptions are dispensed. Staff in pharmacy unit who have responsibility for inpatient service comprises of 64 pharmacists, 67 pharmacy technicians, and 16 supporting staff. In the past all type of drugs were prepared manually until February 2012, when a pharmacy-based (centralized) automated dispensing machine (ADM); Yuyama YS-TR-406FDS-II, was implemented for inpatients in one pharmacy unit at 100th Year Somdech Phrasrinakarinth Building. The 10th floor South Assadang ward (medication ward) was the first ward for implementation in February 2012 and expanded to the 10th floor North Assadang ward in November 2012.

For ADM system, medication is removed from manufacturers' original pack before dispensing medication in unit dose pack in which one unit dose contains all types of drug for each meal and ready-to-administer, so this may decrease the administration error and time. The capacity of this ADM can contain four hundred and six medication cassettes for tablets and special tray for special tablets. However recently, this ADM has covered about 220 types of tablets and covered about 22.83% of all prescription in pilot wards so other drugs have still been prepared by pharmacy technicians.

Before hospital implementation throughout the effectiveness of automated dispensing system needs evaluation such as the efficacy of ADM to reduce medication errors, workforce, operational cost of dispensing system, and cost of investment which will be needed to be raised for planning.

Part I: To compare the effectiveness between automated and manual dispensing systems

1. **Medication errors**

The incidence of medication errors between November 2012 and October 2013 in the inpatient pharmacy unit was evaluated. 1,150,550 prescriptions were dispensed. The reduction in each type of the medication error according to the severity of the outcome, if we implement ADM system has been shown in table 11.

Table 11 Number of medication errors according to the severity level in work process

Work process	All items	ADM items	
		Manual system	ADM system
Preparation	2,131	864	0
Dispensing	189	24	
	Category B	23	0
	Category C	1	0
Administration	182	18	
	Category C	11	0
	Category D	6	0
	Category F	1	0

All preparation errors were 2,131 and only 864 errors were the items which were covered by ADM. 24 errors from 189 errors in process of dispensing and 18 errors from 182 errors in process of administration were from the items which were covered by ADM. When ADM has been completely implemented, we estimated that the error from 220 types of tablets which were prepared by ADM could decrease to zero so for 1 year 864 preparation errors, 24 dispensing errors, and 18 administration errors could be prevented. Totally about 906 medication errors could be prevented when complete ADM has been implemented.

ADM could prevent preparation errors. About dispensing error, there were several root causes of medication errors such as recording and preparation whereas ADM could prevent errors only in step of preparation. The number of administration errors in this study was revealed and analyzed only the record which has enough detail and could be identified as the error could be prevented by ADM whereas most of administration errors especially type A and B were reported with not much detail.

Recently we estimated that 906 medication errors could be prevented when ADM has been completely implemented. Although the capacity of ADM could contain four hundred and six medication cassettes for tablets, recently this ADM has just been used for 220 types of tablets. To increase items covered by ADM for example if we prepared all tablets by ADM, 1,210 preparation errors, 42 dispensing errors, and 24 administration errors could be prevented. Moreover about 868 administration errors type B may be prevented by ADM such as the error from wrong drug, wrong quantity, no labeling of name of patient, drug name, and dose in process of drug administration.

2. Working time

The time of work process was collected in the pharmacy unit at 100th Year Somdech Phrasrinakarinth pharmacy unit in October 2012. The representative of ADM system was the 10th floor of South Assadang ward and the others were representative of manual system.

The process between manual and ADM system were mostly similar. In the ADM system a pharmacist was more involved in the step of verification, filling drug to ADM, and placing returned drug into ADM. A pharmacy technician was more involved in the step of filling drug to ADM and reduced in step of labeling sticker on zip-locked bags and prepared medication. Tables 12, 13, and 14 show the process in each model. Manual system was the system in which all drugs were prepared by pharmacy technician. ADM model 1 was the recently implemented system. ADM model 2 and ADM model 3 were the new systems which we designed with less working steps of ADM system in dispensing and returned drug process.

Table 12 Summary of dispensing process in each model

Dispensing process	Manual system	ADM system		
		Model 1	Model 2	Model 3
Screen	R.Ph	R.Ph	R.Ph	R.Ph
Record	Ph.Tech	Ph.Tech	Ph.Tech	Ph.Tech
Verify*	-	R.Ph	R.Ph	R.Ph
Sticker*	Ph.Tech	-	-	-
Preparation*	Ph.Tech	ADM	ADM**	ADM**
Check*	R.Ph	R.Ph	(Ph.Tech)**	(Ph.Tech)**

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician
* Different step between manual and ADM system
**Preparation and checking are the continuous process conducted by pharmacy technician

Table 13 Summary of returned drug process in each model

Return process	Manual system	ADM system		
		Model 1	Model 2	Model 3
Check returned drug*	Ph.Tech	Ph.Tech	Ph.Tech	-
Record*	Ph.Tech	Ph.Tech	Ph.Tech	-
Check receipt*	Ph.Tech	Ph.Tech	Ph.Tech	-
Storage*	Ph.Tech	R.Ph	Ph.Tech	-

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician
* Different step between manual and ADM system

Table 14 Summary of stock management in each model

Stock management	Manual system	ADM system		
		Model 1	Model 2	Model 3
Checking stock	R.Ph & Ph.Tech	R.Ph & Ph.Tech	R.Ph & Ph.Tech	R.Ph & Ph.Tech
Filling shelf	Ph.Tech	Ph.Tech	Ph.Tech	Ph.Tech
Filling ADM*	-	R.Ph & Ph.Tech	R.Ph & Ph.Tech	R.Ph & Ph.Tech

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician
* Different step between manual and ADM system

From the pilot wards; the 10th floor of North Assadang ward and the 10th floor of South Assadang ward, revealed that after implementation of ADM system, the number of dispensed prescriptions increased about 25.22% and number of returned prescription increased about 3.7% which was based on the number of present prescriptions. In the fiscal year 2014, the number of dispensed prescription was 1,307,520 and the number of returned prescriptions was 132,199. The estimated number of prescriptions per year when ADM has been completely implemented in this hospital was 1,637,277 dispensed prescriptions and 137,090 returned prescriptions. Nowadays in this ADM system, the ADM covered 220 types of tablets and covered about 22.83% of all prescriptions. The data of wards which used ADM system comprised of two type of prescriptions such as the prescription which was prepared by ADM (ADM prescription) and the prescription which was prepared by pharmacy technician (manual prescription). Calculation of FTE of manual, ADM model 1, ADM model 2, and ADM model 3 has been shown in tables 15, 16, 17, and 18.

Table 15 Time spent of all work processes in manual system

Dispensing process (manual prescription)				**Time spent per year**	
Manual system	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Screen	R.Ph	42	1,637,277	68,765,615	0
Record	Ph.Tech	78	1,637,277	0	127,707,570
Verify**	R.Ph	0	0	0	0
Sticker*	Ph.Tech	60	1,637,277	0	98,236,593
Prepare*	Ph.Tech	287	1,637,277	0	469,898,368
Check*	R.Ph	119	1,637,277	194,835,909	0
Total dispensing process (hr)				73,222.65 hr	193,289.59 hr
Returned drug process (manual prescription)				**Time spent per year**	
Manual system	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Check returned drug*	Ph.Tech	61	137,090	0	8,362,512
Record*	Ph.Tech	51	137,090	0	6,991,609
Check receipt*	Ph.Tech	38	137,090	0	5,209,434
Place returned drug to shelf	Ph.Tech	7,200	365 days	0	2,628,000
Total returned drug process (hr)				0.00 hr	6,442.10 hr
Stock management process				**Time spent per year**	
Manual system	Role	Time (sec/Rx)	Quantity (day)	R.Ph (sec)	Ph.Tech (sec)
Checking stock	Ph.Tech	72,000	365	0	26,280,000
Checking stock	R.Ph	21,600	365	7,884,000	0
Filling shelf	Ph.Tech	64,800	365	0	23,652,000
Filling ADM**	Ph.Tech	0	0	0	0
Filling ADM**	R.Ph	0	0	0	0
Total stock management process (hr)				2,190.00 hr	13,870.00 hr
Total time spent in all processes (hr)				75,412.65 hr	213,601.69 hr
Total time spent in all processes (FTE)				**46.84 FTE**	**132.67 FTE**

Total 1,637,277 dispensed and 137,090 returned prescriptions
R.Ph = Pharmacist, Ph.Tech = Pharmacy technician
* Different step in ADM system, ** This step was not in the process

Table 16 Time spent of all work processes in ADM model 1

Dispensing process (ADM prescription)				**Time spent per year**	
ADM model 1	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Screen	R.Ph	180	373,790	67,282,242	0
Record	Ph.Tech	65	373,790	0	24,296,365
Verify*	R.Ph	67	373,790	25,043,946	0
Sticker**	Ph.Tech	0	0	0	0
Prepare*	Ph.Tech	51	373,790	0	19,063,302
Check*	R.Ph	138	373,790	51,583,052	0
Dispensing process (manual prescription)				**Time spent per year**	
ADM model 1	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Screen	R.Ph	49	1,263,486	61,910,829	0
Record	Ph.Tech	78	1,263,486	0	98,551,932
Verify	R.Ph	58	1,263,486	73,282,206	0
Sticker	Ph.Tech	60	1,263,486	0	75,809,179
Prepare	Ph.Tech	283	1,263,486	0	357,566,625
Check	R.Ph	136	1,263,486	171,834,138	0
Total dispensing process (hr)				125,260.11 hr	159,802.06 hr
Returned drug process (ADM prescription)				**Time spent per year**	
ADM model 1	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Check returned drug*	Ph.Tech	73	31,298	0	2,284,734
Record*	Ph.Tech	54	31,298	0	1,690,077
Check receipt*	Ph.Tech	36	31,298	0	1,126,718
Place returned drug to ADM*	R.Ph	933,900	12 months	11,206,800	0

Returned drug process (manual prescription)				**Time spent per year**	
ADM model 1	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Check returned drug	Ph.Tech	61	105,793	0	6,453,351
Record	Ph.Tech	47	105,793	0	4,972,254
Check receipt	Ph.Tech	32	105,793	0	3,385,364
Place returned drug to shelf	Ph.Tech	5,556	365 days	0	2,028,028
Total returned drug process (hr)				3,113.00 hr	6,094.59 hr
Stock management process				**Time spent per year**	
ADM model 1	Role	Time (sec)	Quantity (day)	R.Ph (sec)	Ph.Tech (sec)
Checking stock	Ph.Tech	55,562	365	0	20,280,276
Checking stock	R.Ph	16,669	365	6,084,083	0
Filling shelf	Ph.Tech	50,006	365	0	18,252,248
Filling ADM*	Ph.Tech	67,987	365	0	24,815,255
Filling ADM*	R.Ph	1,368	365	499,320	0
Total stock management process (hr)				1,828.72 hr	17,596.61 hr
Total time spent in all processes (hr)				130,201.84 hr	183,493.25 hr
Total time spent in all processes (FTE)				**80.87 FTE**	**113.97 FTE**

Total 1,637,277 dispensed and 137,090 returned prescriptions (covered by ADM 22.83%)
R.Ph = Pharmacist, Ph.Tech = Pharmacy technician
* Different step in ADM system, ** This step was not in the process

Table 17 Time spent of all work processes in ADM model 2

Dispensing process (ADM prescription)				**Time spent per year**	
ADM model 2	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Screen	R.Ph	180	373,790	67,282,242	0
Record	Ph.Tech	65	373,790	0	24,296,365
Verify*	R.Ph	67	373,790	25,043,946	0
Sticker**	Ph.Tech	0	0	0	0
Prepare*	Ph.Tech	51	373,790	0	19,063,302
Check**	R.Ph	0	373,790	0	0
Dispensing process (manual prescription)				**Time spent per year**	
ADM model 2	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Screen	R.Ph	49	1,263,486	61,910,829	0
Record	Ph.Tech	78	1,263,486	0	98,551,932
Verify	R.Ph	58	1,263,486	73,282,206	0
Sticker	Ph.Tech	60	1,263,486	0	75,809,179
Prepare	Ph.Tech	283	1,263,486	0	357,566,625
Check	R.Ph	136	1,263,486	171,834,138	0
Total dispensing process (hr)				110,931.49 hr	159,802.06 hr
Returned drug process (ADM prescription)				**Time spent per year**	
ADM model 2	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Check returned drug*	Ph.Tech	73	31,298	0	2,284,734
Record*	Ph.Tech	54	31,298	0	1,690,077
Check receipt*	Ph.Tech	36	31,298	0	1,126,718
Place returned drug to ADM*	Ph.Tech	933,900	12 months	0	11,206,800

Returned drug process (manual prescription)				**Time spent per year**	
ADM model 2	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Check returned drug	Ph.Tech	61	105,793	0	6,453,351
Record	Ph.Tech	47	105,793	0	4,972,254
Check receipt	Ph.Tech	32	105,793	0	3,385,364
Place returned drug to shelf	Ph.Tech	5,556	365 days	0	2,028,028
Total returned drug process (hr)				0.00 hr	9,207.59 hr
Stock management process				**Time spent per year**	
ADM model 2	Role	Time (sec)	Quantity (day)	R.Ph (sec)	Ph.Tech (sec)
Checking stock	Ph.Tech	55,562	365	0	20,280,276
Checking stock	R.Ph	16,669	365	6,084,083	0
Filling shelf	Ph.Tech	50,006	365	0	18,252,248
Filling ADM	Ph.Tech	67,987	365	0	24,815,255
Filling ADM	R.Ph	1,368	365	499,320	0
Total stock management process (hr)				1,828.72 hr	17,596.61 hr
Total time spent in all processes (hr)				112,760.21 hr	186,606.25 hr
Total time spent in all processes (FTE)				**70.04 FTE**	**115.90 FTE**

Total 1,637,277 dispensed and 137,090 returned prescriptions (covered by ADM 22.83%)
R.Ph = Pharmacist, Ph.Tech = Pharmacy technician
* Different step in ADM system, ** This step was not in the process

Table 18 Time spent of all work processes in ADM model 3

Dispensing process (ADM prescription)				**Time spent per year**	
ADM model 3	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Screen	R.Ph	180	373,790	67,282,242	0
Record	Ph.Tech	65	373,790	0	24,296,365
Verify*	R.Ph	67	373,790	25,043,946	0
Sticker**	Ph.Tech	0	0	0	0
Prepare*	Ph.Tech	51	373,790	0	19,063,302
Check**	R.Ph	0	373,790	0	0
Dispensing process (manual prescription)				**Time spent per year**	
ADM model 3	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Screen	R.Ph	49	1,263,486	61,910,829	0
Record	Ph.Tech	78	1,263,486	0	98,551,932
Verify	R.Ph	58	1,263,486	73,282,206	0
Sticker	Ph.Tech	60	1,263,486	0	75,809,179
Prepare	Ph.Tech	283	1,263,486	0	357,566,625
Check	R.Ph	136	1,263,486	171,834,138	0
Total dispensing process (hr)				110,931.49 hr	159,802.06 hr
Returned drug process (ADM prescription)				**Time spent per year**	
ADM model 3	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Check returned drug**	Ph.Tech	73	0	0	0
Record**	Ph.Tech	54	0	0	0
Check receipt**	Ph.Tech	36	0	0	0
Place returned drug to ADM**	R.Ph	933,900	0	0	0

Returned drug process (manual prescription)				**Time spent per year**	
ADM model 3	Role	Time (sec/Rx)	Quantity (prescription)	R.Ph (sec)	Ph.Tech (sec)
Check returned drug	Ph.Tech	61	105,793	0	6,453,351
Record	Ph.Tech	47	105,793	0	4,972,254
Check receipt	Ph.Tech	32	105,793	0	3,385,364
Place returned drug to shelf	Ph.Tech	5,556	365 days	0	2,028,028
Total returned drug process (hr)				0.00 hr	4,677.50 hr
Stock management process				**Time spent per year**	
ADM model 3	Role	Time (sec/Rx)	Quantity (day)	R.Ph (sec)	Ph.Tech (sec)
Checking stock	Ph.Tech	55,562	365	0	20,280,276
Checking stock	R.Ph	16,669	365	6,084,083	0
Filling shelf	Ph.Tech	50,006	365	0	18,252,248
Filling ADM*	Ph.Tech	67,987	365	0	24,815,255
Filling ADM*	R.Ph	1,368	365	499,320	0
Total stock management process (hr)				1,828.72 hr	17,596.61 hr
Total time spent in all processes (hr)				112,760.21 hr	182,076.16 hr
Total time spent in all processes (FTE)				**70.04 FTE**	**113.09 FTE**

Total 1,637,277 dispensed and 137,090 returned prescriptions (covered by ADM 22.83%)
R.Ph = Pharmacist, Ph.Tech = Pharmacy technician
* Different step in ADM system, ** This step was not in the process

Table 19 Summary time spent by pharmacist in all work processes

Work process	**Pharmacist (FTE)**			
	Manual	**ADM model 1**	**ADM Model 2**	**ADM Model 3**
Dispensing	45.48	77.80	68.90	68.90
Returned drug	0	1.93	0	0
Stock management	1.36	1.14	1.14	1.14
Total	**46.84**	**80.87**	**70.04**	**70.04**

Total 1,637,277 dispensed and 137,090 returned prescriptions (covered by ADM 22.83%)

Table 20 Summary time spent by pharmacy technician in all work processes

Work process	Pharmacy technician (FTE)			
	Manual	**ADM model 1**	**ADM Model 2**	**ADM Model 3**
Dispensing	120.06	99.26	99.26	99.26
Returned drug	4.00	3.79	5.72	2.91
Stock management	8.61	10.93	10.93	10.93
Total	**132.67**	**113.97**	**115.90**	**113.09**

Total 1,637,277 dispensed and 137,090 returned prescriptions (covered by ADM 22.83%)

As tables 19, 20 in manual system show, it took 46.84 FTE of pharmacist and 132.67 FTE of pharmacy technician for supporting 1,637,277 dispensed prescriptions and 137,090 returned prescriptions. ADM model 1 took 80.87 FTE of pharmacist and 113.97 FTE of pharmacy technician. ADM model 2 took 70.04 FTE of pharmacist and 115.90 FTE of pharmacy technician. Also, ADM model 3 required lowest staff 70.04 FTE of pharmacist and 113.09 FTE of pharmacy technician.

Total time used in dispensing process was 9.77 minutes per prescription in manual system. In ADM model 1 system, each ADM prescription took 8.35 minutes per prescription. In ADM model 2 and ADM model 3, the ADM prescription involved less process and took 6.05 minutes per prescription as shown in tables 15, 16, 17, and 18.

Manual system has been shown in table 15. The step which used most time was preparation step (287 seconds per prescription) which was replaced by ADM in ADM system. Step of preparation by ADM took less time (51 seconds per prescription) and still needed pharmacy technician to separate the individual patients' strip of packaged medication after preparation by ADM, match ADM drug with

prescription, and check for the consistency of dispensed unit dose. The step of sticker labeling on zip-locked bag in manual system was skipped in ADM prescription.

In the ADM system has been shown in table 16. The step which used most time was screening step in which the pharmacist reviewed the appropriate use of medicine in ADM prescription, and took 180 seconds per prescription, which was longer than manual system, which took 42 seconds per prescription. The step of verification was needed in ADM system. The checking step of ADM prescription in ADM model 1 system (138 seconds per prescription) took more time than manual system (119 seconds per prescription). We found that if we skipped the step of checking drug as in ADM models 2 and 3 the FTE of pharmacist in dispensing process reduced from 77.80 FTE to 68.90 FTE as shown in table 19.

From the study has been shown tables 19, 20. In dispensing process, ADM system increased the workload of pharmacist while it decreased workload of pharmacy technician. The role of pharmacist changed after ADM implementation. Pharmacist spent more time in three steps; verification which was the additional step, screening and checking which were the basic steps, but took more time when compared with manual system. Checking step increased workload which may not give the benefit because ADM was high accuracy. This step could be skipped to reduce FTE as in ADM models 2 and ADM model 3 however pharmacy technician checked for the consistency of dispensed unit dose. The step of screening in ADM system took more time than manual system because it involved more activity. In the screening step of manual and ADM system, pharmacist reviewed the appropriate use of medication in a prescription such as indication, dose, route, drug allergies, and drug interaction.

Moreover in the screening step in ADM, the new prescription would be checked with patient drug profile which used the computer program in ADM system. In ADM system pharmacist had to calculate the quantity of dispensed drug for one day dose covered or decrease medication list in treatment in computer system. These processes were not managed by pharmacist in manual system, so the time of screening step in ADM system was longer than manual system. Verification in ADM system was the step of drug information linkage between HIS program in which drug information was recorded by pharmacy technician and Pharmanager program which was the program of ADM. Also in this step Pharmanager program could detect the inappropriate use of drug such as drug interaction, or drug duplicate. The verification step in ADM system covered time of data linkage, overall drug review, and generated one day dose prescription. Although the step of screening and verification in ADM system increased workload of pharmacist, the system could improve the quality of patient care.

For time spent in returned drug process, we found that check returned drug time in ADM prescription at 73 seconds per prescription was longer than the manual system at 61 seconds per prescription while the other steps were mostly in working time. The average of total time spent in returned drug process which covered time to check returned drug, record, and check receipt of manual system was 2.5 minutes per prescription and 2.72 minutes per prescription in returned drug process of ADM prescription. More pharmacists were involved in returned drug process of ADM system in step of placing returned drug to ADM which was about 8.53 hours per day if ADM system was implemented to all 110 wards.

To decrease workload of pharmacist in step of place return drug to ADM, ADM model 2 pharmacy technician has this responsibility instead of pharmacist. Also in order to decrease workload of pharmacist and pharmacy technician, ADM model 3 has no receiving the returned medicine which was prepared by ADM so there was no step of place return drug to ADM. Because of less work process, ADM model 3 used the lowest FTE of pharmacy technician and did not involve pharmacist in returned drug process as shown in tables 19, 20. Moreover to reduce workload, there was no receiving the returned medicine which could decrease the probability to cause medication error which may occur in this step.

The time for stock management process covered filling drug and checking stock. In ADM system, time for filling shelf by pharmacy technician decreased from 64,800 seconds (manual system) to 50,006 seconds per day. However the time for filling 220 types of tablets to ADM increased more workload to both of pharmacy technician and pharmacist. Before filling drugs to ADM, the list and quantity of drugs in ADM would be printed out from the system. Pharmacist managed the list and quantity of drugs which would be filled in ADM and rechecked before filling to ADM. Drugs have to be removed from their original package before filling to ADM by pharmacy technician and this step took more time when compared with the step of filling drug to shelf in manual system. Each day 67,987 seconds of pharmacy technician and 1,368 seconds of pharmacist were used for filling drugs to ADM. In step of checking stock, less time was consumed in ADM system because ADM program could report quantity of drug, expiration date, and lot number which was useful in stock management.

Nowadays ADM system supports for tablets which covers about 220 types of tablets and covers about 22.83% of all prescription (1,637,277 prescriptions per year). Staff will be needed when ADM is implemented throughout the hospital as shown in tables 19, 20. Although to decrease step of work in ADM system could reduce FTE of pharmacy technician, more pharmacists were required. On the other hand, we varied the proportion of prescription covered by ADM to find out the model which resulted in the lower FTE of staff as shown in table 21.

Table 21 Sensitivity analysis: work process and proportion of prescriptions covered by ADM

ADM: Manual prescription	Pharmacist (FTE)				Pharmacy technician (FTE)			
	Manual	ADM model 1	ADM model 2	ADM model 3	Manual	ADM model 1	ADM model 2	ADM model 3
0:100	46.84				132.67			
22.83:77.17		80.87	70.04	70.04		113.97	115.90	113.09
25:75		81.90	70.04	70.04		112.32	114.44	111.36
50:50		93.80	70.08	70.08		93.34	97.58	91.41
55:45		96.18	70.08	70.08		89.54	94.20	87.42
60:40		98.56	70.09	70.09		85.75	90.83	83.44
75:25		105.70	70.11	70.11		74.36	80.71	71.47
100:0		117.60	70.15	70.15		55.38	63.85	51.52

The number of prescriptions covered by ADM varied from 22.83% (present system) to 100%. All work processes and proportions of prescriptions covered by ADM required more pharmacists while they decreased pharmacy technicians when compared with manual system (46.84 FTE of pharmacist, 132.67 FTE of pharmacy technician).

From previous studies, many revealed that ADM reduced dispensing time of pharmacist and pharmacy technician (56, 61-63) in the process of preparation and checking. The reduced time may be different according to the designed work process

as in the study at 650-bed tertiary-care medical center. The time of medication preparation by pharmacy technician was significantly decreased in automated system whereas the reduction of pharmacist time was not significantly changed since pharmacist had to cut the strip-packaged drugs into individual doses of patients when they checked the medications. Furthermore the overall time of automated system in this study was higher (42).

In this study we found that the present system was ADM model 1, which ADM covered 22.83% of prescriptions and required pharmacist 80.87 FTE and pharmacy technician 113.97 FTE. This system needed more pharmacists especially in dispensing process; screening and verification steps, whereas pharmacy technician's FTE decreased in step of preparation. To decrease workload of staff it is necessary to change work process and/or cover more prescription by ADM.

3. Operational cost of dispensing system

Operational cost of dispensing system was calculated in terms of unit cost which compared cost (baht) per inpatient prescription of manual, ADM model 1, ADM model 2, and ADM model 3. We estimated the number of prescriptions was 1,637,277 prescriptions. Nine cost centers were classified into non-revenue producing cost center (NRPCC) which included central office, central administration, academic, data development, and purchasing and patient service (PS) which included aseptic pharmaceutical product, general pharmaceutical product, inpatient service, and outpatient service. In this study we found cost in every cost center were equal in four models excepted inpatient service. Most of cost data were supported by unit cost

division. For inpatient service section, data of number of staff, labor cost of medical staff, medical material cost, and capital cost were reanalyzed according to workload and resource which were needed in system operation.

For the inpatient service section, the number of all staff which comprised of pharmacist, pharmacy technician, and supporting staff in each model has been shown in table 22. Pharmacist and pharmacy technician were classified into group of medical staff and the numbers of staff were analyzed from the study in part of working time. For supporting staff in this study we assumed that the number was equal in all models. To calculate labor cost of pharmacist and pharmacy technician, the number of staff was be multiplied by salary and fringe benefits. Data of salary and fringe benefits were obtained from human resource unit. The average salary and fringe benefit of pharmacist were 26,506.94 and 8,150.12 baht per month, respectively. The average salary and fringe benefit of pharmacy technician were 14,794.21 and 430.61 baht per month, respectively.

Table 22 Number of staff in all work processes

FTE	Manual	ADM model 1	ADM model 2	ADM model 3
Pharmacist	46.84	80.87	70.04	70.04
Pharmacy technician	132.67	113.97	115.90	113.09
Supporting staff	16	16	16	16
All staff	**196**	**211**	**202**	**199**

To analyze medical material cost for inpatient service section, the numbers of prescriptions were multiplied by material cost per prescription. Material cost in manual system which included zip-locked bags, stickers for drug labeling, and plastic bags was 3.53 baht per prescription. In ADM system comprised of two types of

prescription which were the prescription which was prepared by ADM (ADM prescription) and the prescription which was prepared by pharmacy technician (manual prescription). Material cost of ADM prescription which included unit dose bags for drugs from ADM was 4.46 baht per prescription and material cost of manual prescription which included zip-locked bags, stickers for drug labeling, and plastic bags was 2.55 baht per prescription.

Capital cost was depreciation cost of equipment which was used in inpatient service section and analyzed in terms of cost per year by straight line method with useful life 5 years. Cost of hardware (computer, printer) in manual system was 64,984.31 baht per year which also occurred in ADM system. Moreover ADM system included cost of ADM. The cost of ADM was 8,018,440 baht or 1,603,688 baht per year when analyzed by straight line method.

The calculation of unit cost of manual system has been shown in tables 23, 24. The direct cost of inpatient service section was 53,422,488.61 baht. Indirect cost from purchasing section was allocated with the percentage of drug expenditure. The percentage of inpatient drug expenditure was 12.66% of all drug expenditure. Therefore, 2,397,595.59 baht which was 12.66% of direct cost in purchasing section was allocated to inpatient service section. Indirect cost from others NRPCC (included central office, central administration, academic, data development) was allocated to aseptic pharmaceutical product, general pharmaceutical product, outpatient service, and inpatient service by the percentage of staff. The percentage of inpatient staff (196 persons) was equal to 42.36% of all staff in PS centers. 26,922,725.45 baht which was 42.36% of direct cost in others NRPCC was allocated to inpatient. The total cost of manual system which included direct and indirect costs was 82,742,809.65 baht per

year. Unit cost was calculated after plus 10% which was indirect cost from supporting unit outside pharmacy department. Unit cost of inpatient prescription in manual system was 55.59 baht.

Table 23 Non-revenue producing cost center (NRPCC)

Cost	**Non-revenue producing cost center (NRPCC)**				
	Central office	Central administration	Academic	Data development	Purchasing
Labor cost of medical staff	41,004,982.05	648,754.80	6,910,005.32	1,906,334.93	11,357,143.25
Labor cost of supporting staff	2,740,367.33	2,805,164.77	328,776.00	1,464,372.84	7,120,285.09
Medical material cost	417,554.05	-	86,058.04	-	2,686.11
Capital cost	803,838.85	-	102,858.64	-	46,858.67
Other cost	4,165,778.01	12,249.13	64,471.43	90,341.12	410,194.53
Total direct cost	49,132,520.31	3,466,168.71	7,492,169.43	3,461,048.89	18,937,167.65

Table 24 Patient service (PS) in manual system

Cost	Patient service (PS)			
	Aseptic pharmaceutical product	General pharmaceutical product	Outpatient service	**Inpatient service***
Labor cost of medical staff *	1,811,112.63	1,336,411.53	48,541,333.09	**43,718,970.93**
Labor cost of supporting staff	865,900.13	4,947,230.85	2,711,660.84	3,158,926.68
Medical material cost*	1,634,510.13	10,126,260.83	33,669.48	**5,779,937.84**
Capital cost*	1,136,444.84	328,378.75	236,557.67	**64,984.31**
Other cost	1,074,392.15	202,105.69	896,030.57	699,668.85
Total direct cost	6,522,359.88	16,940,387.65	52,419,251.65	53,422,488.61
Indirect cost: First allocation from purchasing to Outpatient and Inpatient service				
According to drug expenditure (baht)			4,371,813,824.27	633,743,212.00
Indirect cost from purchasing				2,397,595.59
Indirect cost: Second allocation from NRPCC to Aseptic pharmaceutical product, General pharmaceutical product, Outpatient service, Inpatient service				
According to number of staff (person)*	33	63	170	**196**
Indirect cost from others NRPCC				26,922,725.45
Total cost (Direct cost+Indirect cost)				82,742,809.65
Number of inpatient prescriptions				1,637,277
Unit cost				50.54
Plus 10% for indirect cost				5.05
Unit cost plus 10%				**55.59**

* Different cost data

For ADM model 1, the direct cost of inpatient service section was 64,866,725.66 baht. The indirect cost of 2,397,595.59 baht was allocated from purchasing section. Also indirect cost from others NRPCC was 28,100,292.31 baht. The total cost of ADM system was 95,364,613.56 baht per year. The unit cost was 64.07 baht. The calculation of unit cost of ADM model 1 has been shown in tables 23, 25.

Table 25 Patient service (PS) in ADM model 1

Cost	**Patient service (PS)**			
	Aseptic pharmaceutical product	General pharmaceutical product	Outpatient service	**Inpatient service***
Labor cost of medical staff *	1,811,112.63	1,336,411.53	48,541,333.09	**54,455,146.44**
Labor cost of supporting staff	865,900.13	4,947,230.85	2,711,660.84	3,158,926.68
Medical material cost*	1,634,510.13	10,126,260.83	33,669.48	**4,884,311.38**
Capital cost*	1,136,444.84	328,378.75	236,557.67	**1,668,672.31**
Other cost	1,074,392.15	202,105.69	896,030.57	699,668.85
Total direct cost	6,522,359.88	16,940,387.65	52,419,251.65	64,866,725.66
Indirect cost: First allocation from purchasing to Outpatient and Inpatient service				
According to drug expenditure (baht)			4,371,813,824.27	633,743,212.00
Indirect cost from purchasing				2,397,595.59
Indirect cost: Second allocation from NRPCC to Aseptic pharmaceutical product, General pharmaceutical product, Outpatient service, Inpatient service				
According to number of staff (person)*	33	63	170	**211**
Indirect cost from others NRPCC				28,100,292.31
Total cost (Direct cost+Indirect cost)				95,364,613.56
Number of inpatient prescriptions				1,637,277
Unit cost				58.25
Plus 10% for indirect cost				5.82
Unit cost plus 10%				**64.07**

ADM covered 22.83% of 1,637,277 prescriptions
* Different cost data

For ADM model 2, the direct cost of inpatient service section was 60,714,571.75 baht. The indirect cost of 2,397,595.59 baht was allocated from purchasing section. Also indirect cost from others NRPCC was 27,426,039.52 baht. The total cost of ADM system was 90,538,206.86 baht per year. The unit cost was 60.83 baht. The calculation of unit cost of ADM model 2 has been shown in tables 23, 26.

Table 26 Patient service (PS) in ADM model 2

Cost	**Patient service (PS)**			
	Aseptic pharmaceutical product	General pharmaceutical product	Outpatient service	**Inpatient service***
Labor cost of medical staff*	1,811,112.63	1,336,411.53	48,541,333.09	**50,302,992.53**
Labor cost of supporting staff	865,900.13	4,947,230.85	2,711,660.84	3,158,926.68
Medical material cost*	1,634,510.13	10,126,260.83	33,669.48	**4,884,311.38**
Capital cost*	1,136,444.84	328,378.75	236,557.67	**1,668,672.31**
Other cost	1,074,392.15	202,105.69	896,030.57	699,668.85
Total direct cost	6,522,359.88	16,940,387.65	52,419,251.65	60,714,571.75
Indirect cost: First allocation from purchasing to Outpatient and Inpatient service				
According to drug expenditure (baht)			4,371,813,824.27	633,743,212.00
Indirect cost from purchasing				2,397,595.59
Indirect cost: Second allocation from NRPCC to Aseptic pharmaceutical product, General pharmaceutical product, Outpatient service, Inpatient service				
According to number of staff (person)*	33	63	170	**202**
Indirect cost from others NRPCC				27,426,039.52
Total cost (Direct cost+Indirect cost)				90,538,206.86
Number of inpatient prescriptions				1,637,277
Unit cost				55.30
Plus 10% for indirect cost				5.53
Unit cost plus 10%				**60.83**

ADM covered 22.83% of 1,637,277 prescriptions
* Different cost data

For ADM model 3, the direct cost of inpatient service section was 60,200,510.83 baht. The indirect cost of 2,397,595.59 baht was allocated from purchasing section. Also indirect cost from others NRPCC was 27,207,501.63 baht. The total cost of ADM system was 89,805,608.05 baht per year. The unit cost was 60.34 baht. The calculation of unit cost of ADM model 3 has been shown in tables 23, 27.

Table 27 Patient service (PS) in ADM model 3

Cost	**Patient service (PS)**			
	Aseptic pharmaceutical product	General pharmaceutical product	Outpatient service	**Inpatient service***
Labor cost of medical staff*	1,811,112.63	1,336,411.53	48,541,333.09	**49,788,931.61**
Labor cost of supporting staff	865,900.13	4,947,230.85	2,711,660.84	3,158,926.68
Medical material cost*	1,634,510.13	10,126,260.83	33,669.48	**4,884,311.38**
Capital cost*	1,136,444.84	328,378.75	236,557.67	**1,668,672.31**
Other cost	1,074,392.15	202,105.69	896,030.57	699,668.85
Total direct cost	6,522,359.88	16,940,387.65	52,419,251.65	60,200,510.83
Indirect cost: First allocation from purchasing to Outpatient and Inpatient service				
According to drug expenditure (baht)			4,371,813,824.27	633,743,212.00
Indirect cost from purchasing				2,397,595.59
Indirect cost: Second allocation from NRPCC to Aseptic pharmaceutical product, General pharmaceutical product, Outpatient service, Inpatient service				
According to number of staff (person)*	33	63	170	**199**
Indirect cost from others NRPCC				27,207,501.63
Total cost (Direct cost+Indirect cost)				89,805,608.05
Number of inpatient prescriptions				1,637,277
Unit cost				54.85
Plus 10% for indirect cost				5.49
Unit cost plus 10%				**60.34**

ADM covered 22.83% of 1,637,277 prescriptions
* Different cost data

From four models, the manual system was the lowest cost at 82,742,809.65 baht per year and unit cost was 55.59 baht per prescription. In the study we also varied the proportion of prescriptions covered by ADM to find out the model which resulted in the lower cost per year and unit cost as shown in table 28.

We found that when we implemented ADM model 3 which covered 75% of all prescriptions by ADM, the cost per year was 89,805,608 and the unit cost was 53.95 baht per prescription which was a cost saving when compared with manual system.

Table 28 Sensitivity analysis: work process and proportion of prescriptions covered by ADM

ADM:Manual prescription	Total cost (baht/year)				Unit cost (baht/prescription)			
	Manual	ADM model 1	ADM model 2	ADM model 3	Manual	ADM model 1	ADM model 2	ADM model 3
00:100	82,742,810				55.59			
22.83:77.17		95,364,614	90,538,207	89,805,608		64.07	60.83	60.34
25:75		95,515,313	90,226,886	89,423,009		64.17	60.62	60.08
50:50		97,242,826	86,587,235	84,939,002		65.33	58.17	57.07
55:45		97,578,061	85,825,310	83,997,896		65.56	57.66	56.43
60:40		97,929,273	85,102,520	83,103,477		65.79	57.18	55.83
75:25		98,953,912	82,842,126	80,301,050		66.48	55.66	**53.95**
100:00		100,647,803	78,978,761	75,486,374		67.62	**53.06**	**50.72**

Total cost including direct and indirect cost for 1,637,277 dispensed prescriptions

Part II: To estimate the cost of investment of implementing automated dispensing machine

The estimated net cost when ADM has been thoroughly implemented throughout the hospital was analyzed for a 10-year period. The direct cost of manual, ADM model 1, ADM model 2, and ADM model 3 were calculated which comprised of labor costs of pharmacist (R.Ph), pharmacy technician (Ph.Tech), and supporting staff, capital costs, material costs, maintenance costs, and other costs as shown in tables 29, 30, 31, 32. The cost data in this part in the initial year related with the direct cost of inpatient service section when we analyzed unit cost per prescription. The labor costs of pharmacist and pharmacy technician were calculated from the full-time equivalent (FTE) of staff from the study in part of working time multiplied by salary and fringe benefits. For the labor cost of supporting staff, we assumed that it was equal in all systems. For the 10-year period of study, we estimated that in every year all staff salaries increased 5%. For capital costs and other costs, we estimated that these costs were equal in all systems. In ADM system, the cost of ADM occurred 8,018,440 baht in the initial year for which we assumed the ADM lifetime to be 10 years. For the first four years of implementation the support and maintenance were free and after that to maintain an ADM was 60,000 baht per year. Material costs in manual and ADM systems were different which depended on the number of materials; zip-locked bags, stickers for drug labeling, plastic bags, and unit dose bags which were used in each system. All direct costs were accumulated for annual costs and adjusted with 3% discount rate for the future value to present value (year 2014).

The estimated net cost of manual system and ADM model 1 (present system) were 569,436,486 and 687,128,835 baht, respectively. The net cost of ADM model 1

(present system) was higher than manual system at 117,692,349 baht. More activities were involved by pharmacist in ADM system so labor cost of pharmacist was higher whereas labor cost of pharmacy technician was lower from time saving in preparation step. After redesign of the new model with less work process, for ADM model 2 and ADM model 3, the estimated net costs were lower when compared with ADM system. The estimated net cost of ADM model 2 and ADM model 3 were 641,784,802 and 636,170,946 baht, respectively. The difference of cost of investment between manual and others system in the 10-year period has been shown in table 33. Although there is less work process in ADM system, the estimated net cost of ADM model 2 and ADM model 3 were higher when compared with manual system.

Table 29 10-year cost of investment for manual system

Manual system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
R.Ph*	19,480,105	20,454,111	21,476,816	22,550,657	23,678,190	24,862,099	26,105,204	27,410,465	28,780,988	30,220,037	
Ph.Tech*	24,238,865	25,450,809	26,723,349	28,059,517	29,462,493	30,935,617	32,482,398	34,106,518	35,811,844	37,602,436	
Supporting staff	3,158,927	3,316,873	3,482,717	3,656,853	3,839,695	4,031,680	4,233,264	4,444,927	4,667,173	4,900,532	
Capital cost	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	
Material cost*	5,779,938	5,779,938	5,779,938	5,779,938	5,779,938	5,779,938	5,779,938	5,779,938	5,779,938	5,779,938	
Other cost	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	
Annual costs	53,422,489	55,766,383	58,227,473	60,811,617	63,524,969	66,373,987	69,365,457	72,506,501	75,804,596	79,267,596	655,071,068
Discounting factor	1	0.97	0.94	0.92	0.89	0.86	0.84	0.81	0.79	0.77	
PV of annual costs	53,422,489	54,142,120	54,884,978	55,651,244	56,441,112	57,254,785	58,092,478	58,954,420	59,840,848	60,752,012	**569,436,486**

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

* Different cost data

Table 30 10-year cost of investment for ADM model 1

ADM model 1	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
R.Ph*	33,632,894	35,314,539	37,080,266	38,934,279	40,880,993	42,925,043	45,071,295	47,324,860	49,691,103	52,175,658	
Ph.Tech*	20,822,252	21,863,365	22,956,533	24,104,360	25,309,578	26,575,057	27,903,809	29,299,000	30,763,950	32,302,147	
Supporting staff	3,158,927	3,316,873	3,482,717	3,656,852	3,839,695	4,031,680	4,233,264	4,444,927	4,667,173	4,900,532	
Capital cost	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	
ADM*	8,018,440	0	0	0	0	0	0	0	0	0	
Maintenance (ADM)*	0	0	0	0	60,000	60,000	60,000	60,000	60,000	60,000	
Material cost*	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	
Other cost	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	
Annual costs	71,281,478	66,143,741	69,168,480	72,344,456	75,739,231	79,240,744	82,917,333	86,777,751	90,831,191	95,087,302	789,531,706
Discounting factor	1	0.97	0.94	0.92	0.89	0.86	0.84	0.81	0.79	0.77	
PV of annual costs	71,281,478	64,217,225	65,197,926	66,205,425	67,293,325	68,353,762	69,441,961	70,558,253	71,702,981	72,876,499	**687,128,835**

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

* Different cost data

Table 31 10-year cost of investment for ADM model 2

ADM model 2	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
R.Ph*	29,127,487	30,583,861	32,113,054	33,718,707	35,404,642	37,174,874	39,033,618	40,985,299	43,034,564	45,186,292	
Ph.Tech*	21,175,506	22,234,281	23,345,995	24,513,295	25,738,960	27,025,908	28,377,203	29,796,063	31,285,866	32,850,160	
Supporting staff	3,158,927	3,316,873	3,482,717	3,656,852	3,839,695	4,031,680	4,233,264	4,444,927	4,667,173	4,900,532	
Capital cost	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	
ADM*	8,018,440	0	0	0	0	0	0	0	0	0	
Maintenance (ADM)*	0	0	0	0	60,000	60,000	60,000	60,000	60,000	60,000	
Material cost*	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	
Other cost	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	
Annual costs	67,129,324	61,783,980	64,590,730	67,537,819	70,692,261	73,941,426	77,353,049	80,935,254	84,696,568	88,645,948	737,306,360
Discounting factor	1	0.97	0.94	0.92	0.89	0.86	0.84	0.81	0.79	0.77	
PV of annual costs	67,129,324	59,984,446	60,882,958	61,806,672	62,809,159	63,782,524	64,781,961	65,807,768	66,860,253	67,939,738	**641,784,802**

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

* Different cost data

Table 32 10-year cost of investment for ADM model 3

ADM model 3	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
R.Ph*	29,127,487	30,583,861	32,113,054	33,718,707	35,404,642	37,174,874	39,033,618	40,985,299	43,034,564	45,186,292	
Ph.Tech*	20,661,445	21,694,517	22,779,243	23,918,205	25,114,115	26,369,821	27,688,312	29,072,728	30,526,364	32,052,683	
Supporting staff	3,158,927	3,316,873	3,482,717	3,656,852	3,839,695	4,031,680	4,233,264	4,444,927	4,667,173	4,900,532	
Capital cost	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	
ADM*	8,018,440	0	0	0	0	0	0	0	0	0	
Maintenance (ADM)*	0	0	0	0	60,000	60,000	60,000	60,000	60,000	60,000	
Material cost*	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	
Other cost	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	
Annual costs	66,615,263	61,244,216	64,023,978	66,942,729	70,067,417	73,285,340	76,664,159	80,211,918	83,937,066	87,848,471	730,840,557
Discounting factor	1	0.97	0.94	0.92	0.89	0.86	0.84	0.81	0.79	0.77	
PV of annual costs	66,615,263	59,460,404	60,348,740	61,262,080	62,253,993	63,216,578	64,205,026	65,219,630	66,260,695	67,328,538	**636,170,946**

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

* Different cost data

Table 33 Difference of cost of investment between manual and others system in 10-year period

Difference	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
Manual vs. ADM model 1	- 17,858,989	- 10,377,358	- 10,941,007	- 11,532,839	- 12,214,262	- 12,866,756	- 13,551,876	- 14,271,251	- 15,026,594	- 15,819,706	- 134,460,637
Manual vs. ADM model 2	- 13,706,835	- 6,017,596	- 6,363,257	- 6,726,202	- 7,167,293	- 7,567,439	- 7,987,592	- 8,428,753	- 8,891,972	- 9,378,352	- 82,235,292
Manual vs. ADM model 3	- 13,192,774	- 5,477,832	- 5,796,505	- 6,131,112	- 6,542,449	- 6,911,352	- 7,298,701	- 7,705,418	- 8,132,470	- 8,580,875	- 75,769,488
Discounting factor	1	0.97	0.94	0.92	0.89	0.86	0.84	0.81	0.79	0.77	
PV of Manual vs. ADM model 1	- 17,858,989	- 10,075,105	- 10,312,948	- 10,554,181	- 10,852,214	- 11,098,977	- 11,349,482	- 11,603,833	- 11,862,132	- 12,124,487	**- 117,692,349**
PV of Manual vs. ADM model 2	- 13,706,835	- 5,842,326	- 5,997,980	- 6,155,427	- 6,368,047	- 6,527,739	- 6,689,483	- 6,853,348	- 7,019,405	- 7,187,726	**- 72,348,316**
PV of Manual vs. ADM model 3	- 13,192,774	- 5,318,284	- 5,463,762	- 5,610,836	- 5,812,881	- 5,961,793	- 6,112,547	- 6,265,210	- 6,419,847	- 6,576,526	**- 66,734,460**

PV = Present value

Recently ADM system covered 220 types of tablets and ADM was not used all the time in a day in preparation, so ADM covered only 22.83% of all prescriptions. For sensitivity analysis and finding out the model which resulted in the lower net cost, we varied the number of prescriptions which were covered by ADM as shown in table 34. We found that when we implemented ADM model 3 which covered 75% of all prescriptions by ADM, in 10 years we could save cost 1,616,571 baht.

Table 34 Sensitivity analysis: work process and proportion of prescriptions covered by ADM

ADM:Manual prescription	Present value of cost (baht/10 years)				Present value of net benefit between manual and other systems (baht/10 years)		
	Manual	ADM model 1	ADM model 2	ADM model 3	ADM model 1	ADM model 2	ADM model 3
00:100	569,436,486						
22.83:77.17		687,128,835	641,784,802	636,170,946	- 117,692,349	- 72,348,316	- 66,734,460
25:75		689,129,354	639,475,355	633,327,900	- 119,692,868	- 70,038,869	- 63,891,414
50:50		712,176,817	612,868,818	600,573,907	- 142,740,331	- 43,432,332	- 31,137,421
55:45		716,786,309	607,547,510	594,023,109	- 147,349,823	- 38,111,025	- 24,586,623
60:40		721,395,801	602,226,203	587,472,310	- 151,959,316	- 32,789,717	- 18,035,824
75:25		735,224,279	586,262,281	567,819,915	- 165,787,793	- 16,825,795	**1,616,571**
100:00		758,271,741	559,655,744	535,065,922	- 188,835,255	9,780,742	**34,370,563**

Only direct cost for 1,637,277 dispensed prescriptions per year in 10-year period

However the unpublished data from pilot ward, when ADM system was implemented which covered 22.83% of prescriptions, drugs which were dispensed in the form of unit doses could save administration time of nurse about 30 minutes per ward per day or save cost of nurse for administration 10,331,510 baht/year. If we included labor cost saving of nurse as the benefit of ADM system, in 10-year period with recently acquired ADM system was higher than manual system at 4,866,010 baht as shown in table 35. We also varied the number of prescriptions which were covered by ADM and estimated that the administration time could save up to 60 minutes per ward per day when ADM covered 50% or more of prescription or save 20,663,020.09 baht per year for labor cost of nurse.

To calculate labor cost saving of nurse, FTE of nurse for administration time was multiplied by salary and fringe benefits. For example, in recently acquired ADM system two nurses who have responsibility in drug administration could save time 30 minutes per day per ward. Therefore, when we implemented to all 110 wards, 24.94 FTE would be saved. Moreover we estimated that the administration time could save up to 60 minutes per ward per day when ADM covered 50% or more of prescriptions. To implement to all 110 wards, 49.88 FTE would be saved. Salary and fringe benefits of nurse per month were 34,524 baht, so the cost saving from nursing in ADM system were 10,331,510 and 20,663,020.09 baht per year for 24.94 and 49.88 FTE, respectively. From table 36 when cost savings of nursing were included, we found that in 10 years we could save cost 40,478,022 baht when we implemented ADM model 2 which covered 22.83% of all prescriptions by ADM. Moreover when we implemented ADM model 3 which covered 75% of all prescriptions by ADM, in 10 years we could save cost 227,269,249 baht.

Some costs were not included in this study such as cost saving from medication errors, so actual saving cost of ADM system could be higher. The cost for pre-implementation which may occur when fully implemented included staff training, and temporary loss of productivity which were not analyzed in this study.

Table 35 10-year cost of investment for ADM model 1 (including cost saving from nurse)

ADM model 1	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
R.Ph*	33,632,894	35,314,539	37,080,266	38,934,279	40,880,993	42,925,043	45,071,295	47,324,860	49,691,103	52,175,658	
Ph.Tech*	20,822,252	21,863,365	22,956,533	24,104,360	25,309,578	26,575,057	27,903,809	29,299,000	30,763,950	32,302,147	
Supporting staff	3,158,927	3,316,873	3,482,717	3,656,852	3,839,695	4,031,680	4,233,264	4,444,927	4,667,173	4,900,532	
Capital cost	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	64,984	
ADM*	8,018,440	0	0	0	0	0	0	0	0	0	
Maintenance (ADM)*	0	0	0	0	60,000	60,000	60,000	60,000	60,000	60,000	
Material cost*	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	4,884,311	
Other cost	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	699,669	
Nurse (cost saving)*	-10,331,510	-10,848,086	-11,390,490	-11,960,014	-12,558,015	-13,185,916	-13,845,212	-14,537,472	-15,264,346	-16,027,563	
Annual costs	60,949,968	55,295,656	57,777,990	60,384,442	63,181,215	66,054,828	69,072,121	72,240,279	75,566,845	79,059,739	659,583,083
Discounting factor	1	0.97	0.94	0.92	0.89	0.86	0.84	0.81	0.79	0.77	
PV of annual costs	60,949,968	53,685,103	54,461,297	55,260,318	56,135,692	56,979,475	57,846,814	58,737,958	59,653,165	60,592,707	574,302,496
Manual vs. ADM	-7,527,479	470,728	449,483	427,176	343,753	319,159	293,336	266,222	237,751	207,858	- 4,512,014
PV of Manual vs. ADM	-7,527,479	457,017	423,681	390,926	305,420	275,310	245,664	216,462	187,683	159,305	**- 4,866,010**

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician, PV = Present value

* Different cost data

Table 36 Sensitivity analysis: work process and proportion of prescriptions covered by ADM (including cost saving from nurse)

ADM:Manual prescription	Present value of cost (baht/10 years)				Present value of net benefit between manual and other systems (baht/10 years)		
	Manual	ADM model 1	ADM model 2	ADM model 3	ADM model 1	ADM model 2	ADM model 3
00:100	569,436,486						
22.83:77.17		574,302,496	528,958,464	523,344,607	- 4,866,010	**40,478,022**	**46,091,879**
25:75		576,303,015	526,649,016	520,501,561	- 6,866,530	**42,787,470**	**48,934,925**
50:50		486,524,139	387,216,140	374,921,230	**82,912,347**	**182,220,346**	**194,515,256**
55:45		491,133,631	381,894,833	368,370,431	**78,302,854**	**187,541,653**	**201,066,055**
60:40		495,743,124	376,573,525	361,819,633	**73,693,362**	**192,862,960**	**207,616,853**
75:25		509,571,601	360,609,603	342,167,237	**59,864,885**	**208,826,883**	**227,269,249**
100:00		532,619,063	334,003,066	309,413,245	**36,817,422**	**235,433,420**	**260,023,241**

Only direct cost for 1,637,277 dispensed prescriptions/year in 10-year period

ADM covered <50% of prescription could save cost of nurse for administration 10,331,510 baht per year

ADM covered ≥50% of prescription could save cost of nurse for administration 20,663,020 baht per year

Part III: To survey the acceptance of pharmacists and pharmacy technicians on the new dispensing system

We surveyed the acceptance on the new dispensing and returned drug process in September 2014 to 25 pharmacists and 9 pharmacy technicians who have the experience of the automated dispensing machine usage. The new dispensing system had less working process and number of staff when compared with the current process as shown in table 37. The new returned drug process was the same process although the staff involved was different. A pharmacy technician was involved in the process of filling returned drug to the ADM instead of a pharmacist as shown in table 38.

Table 37 Dispensing process in ADM and new ADM system

Dispensing process	ADM system	New ADM system
Screen	1st R.Ph	1st R.Ph
Record	Ph.Tech	
Verify	1st R.Ph	
Preparation	ADM	ADM
Check	2nd R.Ph	-

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

Table 38 Returned drug process in ADM and new ADM system

Returned drug process	ADM system	New ADM system
Check returned drug	Ph.Tech	Ph.Tech
Record	Ph.Tech	Ph.Tech
Check receipt	Ph.Tech	Ph.Tech
Storage	R.Ph	Ph.Tech

R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

For the dispensing process, 47.06% of all respondents agreed with the new dispensing process and most of these respondents agreed that the new dispensing process reduced process work and time spent. 52.94% of all respondents disagreed with the new dispensing process as shown in table 39. The reason for new dispensing process disagreement were classified by 2 points such as 1) non confidence in the ADM working; the cracked tablet in the unit dose and the incorrect quantity of drug in unit dose, 2) the perception about the double check process by individual pharmacist. However the occurrence of errors of ADM could be solved such as using the bigger size of unit dose package and changing some spares of ADM.

For the returned drug process, 41.18% of all respondents agreed with the new returned drug process and most of these respondents agreed that the new returned process reduced pharmacist workload and time spent. However, most of all respondents (44.12%) disagreed with the new return process because of the non-confidence of the matching cassette and the returned drug when the pharmacist technician was on duty. All of 44.12% respondents who disagreed were pharmacists while all of pharmacy technicians agreed for the new returned drug process. The interesting point from this survey is 20% of pharmacists who offer the new option such as not receiving the returned drug for reuse has been shown in table 39. The reason of no reuse were the quality of care, patient safety, medication error prevention (the error from process of returned drug into the ADM), decreasing workload of pharmacists, and they think that ADM system could reduce the volume of returned drugs.

Table 39 The acceptance on the new dispensing and new returned system

	Pharmacist (%)	**Pharmacy technician (%)**	**All staff (%)**
N	25	9	34
Gender			
Male	4 (16)	1 (11.11)	5 (14.71)
Female	21 (84)	8 (88.89)	29 (85.29)
Age (years)	28.7	36.1	30.7
Experience (years)	5.2	9.7	6.4
Dispensing process			
Agree	7 (28)	9 (100)	16 (47.06)
Disagree	18 (72)	0 (0)	18 (52.94)
Return process			
Agree	5 (20)	9 (100)	14 (41.18)
Disagree	15 (60)	0 (0)	15 (44.12)
Other	5 (20)	0 (0)	5 (14.70)

To implement the effective ADM system, the effective use of ADM should be communicated before implementation of the new technology into the old traditional work process and the research about the efficacy of ADM such as the error reduction, and the ADM benefits should be announced to all staff. However, the surveillance of ADM after implementation should be done to enhance the confidence of new technology use.

CHAPTER V

CONCLUSION

Conclusion

To implement ADM system could promote pharmacist in professional standard activity which dispenses drugs in the most ready-to-administer form that minimizes opportunities for distribution and administration errors (16). The benefits of ADM in terms of improving the quality of patient care and supporting information management was from ADM's computer system which could help the pharmacist access patient's drug profile, remind the data of drug allergy and drug interaction, and stock management program which informed the drug expiration date and can track lot numbers of drugs which were dispensed. In ADM system, pharmacist was more involved in patient care activity.

Dispensed drug in unit dose by ADM was higher accuracy when compared with manual system. From the study in 1 year, 2,502 medication errors occurred in manual system in step of preparation, dispensing, and administration. Nowadays ADM covers 220 types of tablets, and we estimated that about 906 medication errors from 1,150,550 dispensed prescriptions could be prevented when ADM has been completely implemented. Moreover if we prepared all types of tablets by ADM, 1,276 medication errors from tablets per year could be reduced. From the study we found that medication errors were caused from many factors in many steps, so ADM was not the only tool for medication error elimination. Many interventions and technologies have been developed to support the system and prevent errors in each step of medication distribution system such as information technologies (5),

computerized physician order entry (CPOE) (6-10), automatic dispensing machine (ADM) (2, 11, 12), and barcode verification for dispensing step (13), electronic medication administration records (eMARs) and barcode system for administration step (2). To increase efficiency of ADM system, other technologies such as barcode system in step of dispensing and administration may be considered because ADM can generate barcode or QR code which contains all medication information on unit dose packages.

In all models of ADM system, workload of pharmacist obviously increased especially from dispensing process; step of screening and verification. In ADM system, pharmacist was more involved in many steps which did not exist in manual system before such as verification, filling dispensed and returned drug to ADM. Moreover, the step of screening and checking in ADM system has more activity when compared with manual system. In our recent system ADM covered 22.83% of all prescriptions, and FTE of pharmacist in manual, ADM model 1, ADM model 2, and ADM model 3 were 46.84, 80.87, 70.04, and 70.04, respectively. Workload of pharmacy technician decreased in all models of ADM system especially in step of preparation. FTE of pharmacy technician in manual, ADM model 1, ADM model 2, and ADM model 3 were 132.67, 113.97, 115.90, and 113.09, respectively. To reduce some steps of work process in ADM model 2 and ADM model 3 such as checking drug, filling returned drugs back to ADM, and no returned drugs process for ADM prescription could decreased workload of staff. Increasing the proportion of prescriptions covered by ADM will save the workload of pharmacy technicians. Moreover, we expect that continuous work process in ADM system could reduce turnaround time in dispensing process when compared with manual system. From

unpublished data in a pilot ward, administration time and opportunities in administration error decrease when nurse administers drugs in unit dose package. By decreasing administration time, nurses have more time for providing care to patients.

Unit cost per prescription of manual, ADM model 1, ADM model 2, and ADM model 3 which were analyzed by direct and indirect cost were 55.59, 64.07, 60.83, and 60.34 baht per prescription, respectively. Unit cost was lower when work process was reduced and more covered prescription by ADM. We found that when we implemented ADM model 3 which covered 75% of all prescriptions by ADM, the unit cost was 53.95 baht per prescription. The lower work process and more prescriptions covered could save cost when compared with manual system.

The estimated net cost of investment for 10 years in manual, ADM model 1, ADM model 2, and ADM model 3 were 569,436,486, 687,128,835, 641,784,802, and 636,170,946 baht, respectively. To reduce work process and cover more prescriptions could save cost when compared with manual system. We found that when we implemented ADM model 3 which covered 75% of all prescriptions by ADM, in 10 years we could save cost 1,616,571 baht when compared with manual system.

Initially, from the study we found that if we implement ADM model 3 which covered 75% of all prescriptions by ADM, we will save 1,616,571 baht in 10 years and unit cost was 53.95 baht per prescription which was lower when compare with manual system (55.59 baht). Also we need pharmacist 70.11 FTE and pharmacy technician 71.47 FTE for system operation (in manual system used pharmacist 46.84 FTE and pharmacy technician 132.67 FTE). The minimum estimated medication errors which occurred in preparation, dispensing, and administration, and could be prevented were 906 errors per year when ADM has been thoroughly implemented

throughout the hospital. Therefore, ADM system was the interesting system if we redesign work system which has lower steps in work process and covered more prescriptions because the system could reduce medication errors, unit cost per prescription, and cost of investment in 10 years.

However drugs which were dispensed in the form of unit doses could save administration time of nurses. When we included labor cost saving of nurses as the benefit of ADM system, ADM model 1 which covered 22.83% of all prescriptions system (present system) was higher than manual system at 4,866,010 baht in 10-year period. When we implemented ADM model 2, we could save cost 40,478,022 baht. Also, if we implemented ADM model 3 which covered 75% of all prescriptions by ADM, we could save cost 277,269,249 baht when compared with manual system.

From this study we found that ADM system decreased workload of pharmacy technician and nurse while it increased workload of pharmacist. However the process in ADM system could increase efficiency of drug distribution system which could directly and indirectly improve the quality of patient care in the hospital and could decrease cost of operation when compared with manual system.

Limitations of the study

Medication error

To evaluate the effectiveness of ADM in reducing medication errors, these should be compared between before and after ADM implementation at the implemented pharmacy unit/ward. However, at Siriraj hospital only two pilot wards implemented ADM system which covered 220 types of tablets and not all time of day used ADM in preparation. Moreover staff in pharmacy unit changed between inpatient and outpatient 15 pharmacy units every 3-6 months, so in different time

periods meant different staff which could affect the incidence of medication errors. From these factors the effectiveness of ADM in reducing medication errors was not obvious when we compared between before and after ADM implementation.

In the real situation we found that preparation error by ADM occurred such as the cracked tablet in the unit dose, and the incorrect quantity of drug in unit dose. These errors occurred about 1-2 errors per month when implemented in 2 wards. However after we consulted with ADM's company and the other hospitals which used the same ADM we found that these ADM errors which occurred could be solved such as using the bigger size of unit dose package and changing some spares of ADM. Therefore in this study about the effectiveness on medication errors we estimated that the number of medication errors from 220 types of tablets which were prepared by ADM could decrease to zero.

From previous study, many researches about the impact of ADM on medication safety were not clear because of flaws in methodology (2, 61), such as the period of study was too short (51-53); no mention about the comparator in the study (51, 52); data collected by non-experienced staff (52), and variation of methodology for medication errors detection affected to number of medication errors (35, 36) which could not be checked from the reported method (48). Many comments have been made about the lack of evidence of ADMs alone to improve medication safety (61). Combined with other technologies including CPOE, barcode, and electronic charting system will promote a safer system.

Working time

Data was collected since October 2012. However these steps in 2012 were still similar with the steps which have recently been used in pharmacy unit. The

estimation of the number of prescriptions, workload of pharmacist and pharmacy technician after expansion of the ADM system implementation to all wards was derived from a pilot of ADM implementation in the 10th floor of South Assadang ward and the 10th floor of North Assadang ward. Both wards are the medication wards in which the working time and number of prescriptions may be higher than other wards which have less type of drugs use such as ophthalmology ward and gynecology ward. Nowadays ADM has just been used for 220 types of tablets whereas the capacity of ADM could contain four hundred and six medication cassettes for tablets. When we increased the type of tablets to full capacity of ADM, the workload of pharmacist and pharmacy technician could decrease. Therefore in a real situation when completely implemented the FTE used may be less than the result from this study.

In the study part of sensitivity analysis, we mentioned about the proportion of prescriptions covered by ADM was 100%. However in the real situation ADM which covered only tablet drugs may not cover all prescriptions.

Operational cost of dispensing system and Cost of investment

To analyze unit cost and cost of investment (in initial year) some cost data and number of prescriptions in fiscal year 2014 which were supported by unit cost division and business intelligence program were data which covered 9 months. To calculate in term of cost per year in this study we estimated data to 12 months. To analyze cost of investment, some costs were not included in this study such as cost saving from medication errors, so actual saving cost of ADM system could be higher. The cost for pre-implementation which may occur when fully implemented included

staff training, and temporary loss of productivity which were not analyzed in this study.

Future research recommendation

For outpatient service especially in chronic disease, elderly patients who have to take many drugs in one day, drug compliance is essential for clinical outcome. To dispense drugs in unit dose packages which are ready-to-administer packages could minimize opportunities for distribution and administration error and promote patient's compliance. To apply ADM for outpatient service may be the option to increase patient's compliance and clinical outcome. Further study about the effectiveness of ADM for outpatient service may be done in order to improve quality of care.

Policy recommendations

1. Nowadays work process in ADM system is nearly similar to manual system. Some steps of work process may not be needed in ADM system such as checking drug which was prepared by ADM because the accuracy of ADM was higher than human and the errors could be zero. Therefore the new dispensing system which had less working process should be implemented in order to increase the efficiency of ADM system in workload reduction. However pharmacy technician may check for the consistency of dispensed unit dose.

2. In returned drug system, dispensed drug which was prepared by ADM should not be allowed to return. The reason of no return were the quality of care, patient safety, medication error prevention (the error from process of returned medicine into the ADM), and decreasing workload of staff.

3. To dispense drug in unit dose package which was ready-to-administer form and minimized opportunities for distribution and administration errors was the role of

pharmacist in professional standard activity. Administration time of nurse decreased when drugs were administered in unit dose packages, so nurses have more time to give patients' care. The process in ADM system could increase efficiency of drug distribution system which could directly and indirectly improve the quality of patient care in the hospital and ADM system could decrease workload of pharmacy technician and cost of operation. From these benefits, ADM system should be promoted and be used in full capacity such as increasing type of tablets in ADM, extended service time and number of prescription which are prepared by ADM.

4. To increase efficiency of ADM system, other technologies such as barcode system in step of dispensing and administration may be considered because ADM can generate barcode or QR code which contains all medication information on unit dose package.

5. ADM system needs more pharmacists whereas it requires less pharmacy technicians, so workforce management should be planned and the effective training for staffs who involved in ADM implementation such as pharmacist, pharmacy technician, and nurse staffs should be considered before ADM implementation.

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APPENDICES

Appendix A

Questionnaire

แบบสอบถามความคิดเห็นที่มีต่อระบบการทำงานด้วยเครื่องจ่ายยาอัตโนมัติ ห้องยาพระศรีฯ

โปรดตอบแบบสอบถามที่เป็นข้อมูลของท่านและตรงกับความคิดเห็นของท่านมากที่สุด เพื่อนำข้อมูลมาใช้ในการพัฒนาระบบการทำงานของห้องยาต่อไป

1. **ข้อมูลทั่วไป**

   เพศ ☐ ชาย ☐ หญิง

   ตำแหน่ง ☐ **เภสัชกร**

   ☐ **ผู้ช่วยเภสัชกร** หน้าที่รับผิดชอบ (ตอบได้มากกว่า 1 ข้อ)

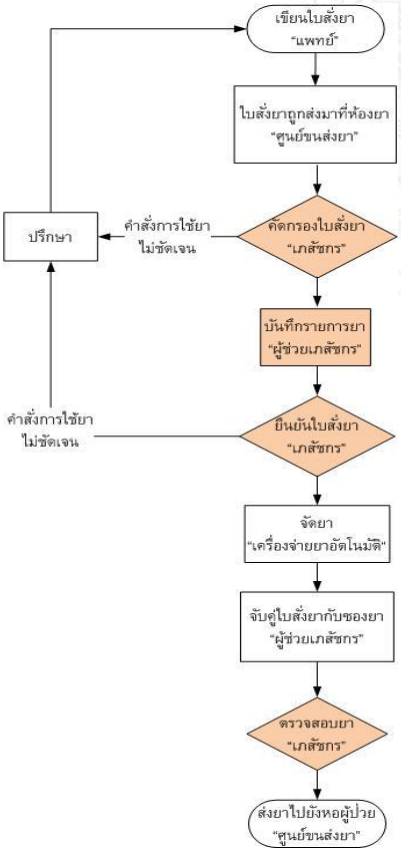
   ☐ บันทึกข้อมูลจ่าย/คืนยา ☐ จัดยา

   ☐ ตรวจสอบยาคืน/ใบแจ้งรายการยาคืน ☐ อื่นๆ.....

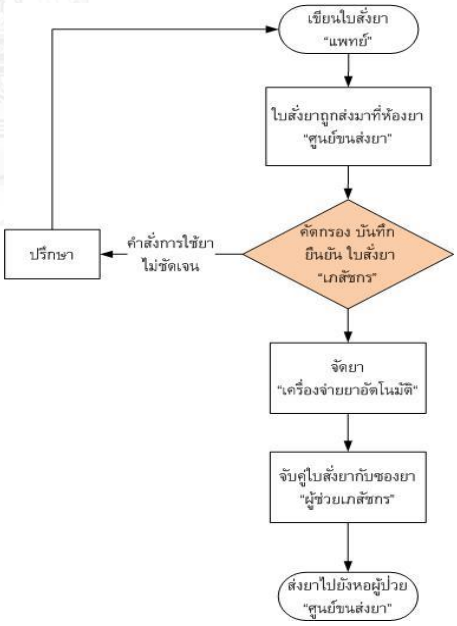
   อายุ ..... ปี

   ประสบการณ์การทำงานในห้องยา ..... ปี

2. **จากภาพเป็นขั้นตอนการทำงานในปัจจุบัน และขั้นตอนการทำงานแบบใหม่ของการจ่ายยาด้วยเครื่องจ่ายยาอัตโนมัติ (หอผู้ป่วยอัษฎางค์ 10 เหนือ และ10 ใต้)**



รูปที่ 2.1 ขั้นตอนการทำงานใน<u>ปัจจุบัน</u>ในการ



รูปที่ 2.2 ขั้นตอนการทำงานแบบ<u>ใหม่</u>ในการจ่าย

จากรูปที่ 2.1 ขั้นตอนการจ่ายยาในปัจจุบัน และรูปที่ 2.2 ขั้นตอนการทำงานแบบใหม่ ขั้นตอนที่มีการแรเงาคือขั้นตอนที่มีการเปลี่ยนแปลงขั้นตอนการทำงาน
ท่านมีความคิดเห็นต่อขั้นตอนการทำงาน<u>แบบใหม่</u>ในการจ่ายยาให้กับผู้ป่วย ในภาพรวมอย่างไร

☐ เหมาะสมดีแล้ว เนื่องจาก.....

.....

.....

☐ ไม่เหมาะสม เนื่องจาก.....

.....

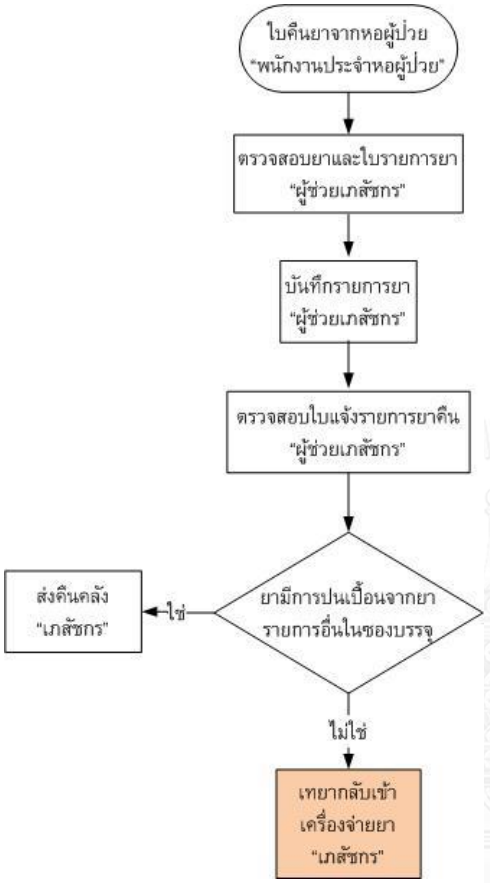
.....

ข้อเสนอแนะ หากท่านคิดเห็นว่ามีขั้นตอนการทำงานรูปแบบอื่นที่อาจจะมีความเหมาะสมมากกว่าระบบที่ยกตัวอย่าง.....

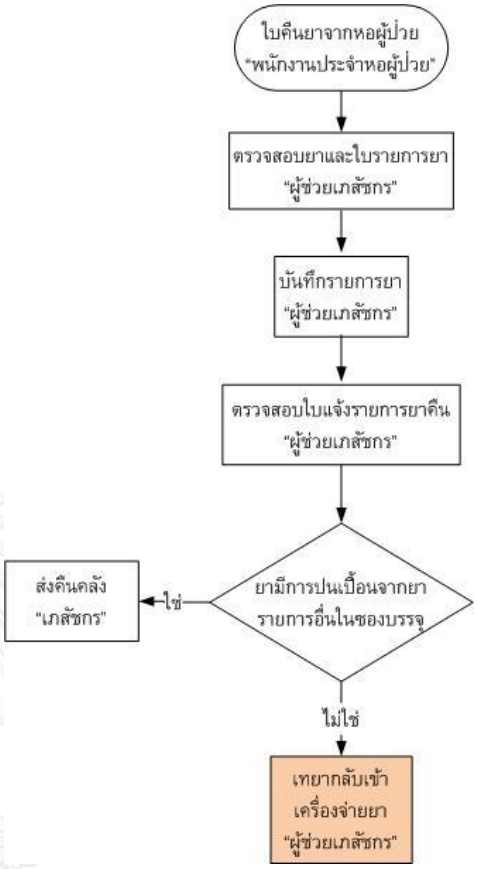
.....

.....

3. จากภาพเป็นขั้นตอนการทำงานในปัจจุบัน และขั้นตอนการทำงานแบบใหม่ของการคืนยาที่จัดด้วยเครื่องจ่ายยาอัตโนมัติ (ยา unit dose หอผู้ป่วยอัษฎางค์ 10 เหนือ และ10 ใต้)



รูปที่ 3.1 ขั้นตอนการคืนยา<u>ปัจจุบัน</u>



รูปที่ 3.2 ขั้นตอนการคืนยาแบบ<u>ใหม่</u>

จากรูปที่ 3.1 ขั้นตอนการคืนยาในปัจจุบัน และรูปที่ 3.2 ขั้นตอนการคืนยาแบบใหม่ ขั้นตอนที่มีการแรเงาคือขั้นตอนที่มีการเปลี่ยนแปลงขั้นตอนการทำงาน

ท่านมีความคิดเห็นต่อขั้นตอนการทำงาน<u>แบบใหม่</u>ในการคืนยาให้กับผู้ป่วย ในภาพรวมอย่างไร

☐ เหมาะสมดีแล้ว เนื่องจาก.....

.....

.....

☐ ไม่เหมาะสม เนื่องจาก.....

.....

ข้อเสนอแนะ หากท่านคิดเห็นว่ามีขั้นตอนการทำงานรูปแบบอื่นที่อาจจะมีความเหมาะสมมากกว่าระบบที่ยกตัวอย่าง.....

.....

.....

ข้อเสนอแนะอื่นๆ

.....

.....

*** ขอขอบพระคุณทุกท่านที่กรุณาให้ความร่วมมือในการตอบแบบสอบถาม ***

Appendix B

Additional results

Table 40 Cost of inpatient service section when ADM system covered 25% of all prescriptions

Cost	Inpatient service*		
	ADM model 1	ADM model 2	ADM model 3
Labor cost of medical staff *	**54,583,693.00**	**50,036,875.31**	**49,473,952.70**
Labor cost of supporting staff	3,158,926.68	3,158,926.68	3,158,926.68
Medical material cost*	**4,952,226.95**	**4,952,226.95**	**4,952,226.95**
Capital cost*	**1,668,672.31**	**1,668,672.31**	**1,668,672.31**
Other cost	699,668.85	699,668.85	699,668.85
Total direct cost	65,063,187.79	60,516,370.10	59,953,447.50
Indirect cost: First allocation from purchasing to Outpatient and Inpatient service			
According to drug expenditure (baht)	633,743,212.00	633,743,212.00	633,743,212.00
Indirect cost from purchasing	2,397,595.59	2,397,595.59	2,397,595.59
Indirect cost: Second allocation from NRPCC to Aseptic pharmaceutical product, General pharmaceutical product, Outpatient service, Inpatient service			
According to number of staff (person)*	**210**	**200**	**197**
Indirect cost from others NRPCC	28,054,529.14	27,312,920.37	27,071,965.80
Total cost (Direct cost+Indirect cost)	95,515,312.52	90,226,886.06	89,423,008.88
Number of inpatient prescriptions	1,637,277.00	1,637,277.00	1,637,277.00
Unit cost	58.34	55.11	54.62
Plus 10% for indirect cost	5.83	5.51	5.46
Unit cost plus 10%	**64.17**	**60.62**	**60.08**

Total 1,637,277 prescriptions

* Different cost data

Table 41 Cost of inpatient service section when ADM system covered 50% of all prescriptions

Cost	Inpatient service*		
	ADM model 1	ADM model 2	ADM model 3
Labor cost of medical staff *	**56,064,644.11**	**46,971,008.74**	**45,845,163.52**
Labor cost of supporting staff	3,158,926.68	3,158,926.68	3,158,926.68
Medical material cost*	**5,734,664.37**	**5,734,664.37**	**5,734,664.37**
Capital cost*	**1,668,672.31**	**1,668,672.31**	**1,668,672.31**
Other cost	699,668.85	699,668.85	699,668.85
Total direct cost	67,326,576.32	58,232,940.94	57,107,095.73
Indirect cost: First allocation from purchasing to Outpatient and Inpatient service			
According to drug expenditure (baht)	633,743,212.00	633,743,212.00	633,743,212.00
Indirect cost from purchasing	2,397,595.59	2,397,595.59	2,397,595.59
Indirect cost: Second allocation from NRPCC to Aseptic pharmaceutical product, General pharmaceutical product, Outpatient service, Inpatient service			
According to number of staff (person)*	**203**	**184**	**177**
Indirect cost from others NRPCC	27,518,653.79	25,956,698.84	25,434,311.09
Total cost (Direct cost+Indirect cost)	97,242,825.70	86,587,235.37	84,939,002.41
Number of inpatient prescriptions	1,637,277.00	1,637,277.00	1,637,277.00
Unit cost	59.39	52.88	51.88
Plus 10% for indirect cost	5.94	5.29	5.19
Unit cost plus 10%	**65.33**	**58.17**	**57.07**

Total 1,637,277 prescriptions

* Different cost data

Table 42 Cost of inpatient service section when ADM system covered 55% of all prescriptions

Cost	Inpatient service*		
	ADM model 1	ADM model 2	ADM model 3
Labor cost of medical staff *	**56,360,834.33**	**46,357,835.42**	**45,119,405.69**
Labor cost of supporting staff	3,158,926.68	3,158,926.68	3,158,926.68
Medical material cost*	**5,891,151.85**	**5,891,151.85**	**5,891,151.85**
Capital cost*	**1,668,672.31**	**1,668,672.31**	**1,668,672.31**
Other cost	699,668.85	699,668.85	699,668.85
Total direct cost	67,779,254.02	57,776,255.11	56,537,825.38
Indirect cost: First allocation from purchasing to Outpatient and Inpatient service			
According to drug expenditure (baht)	633,743,212.00	633,743,212.00	633,743,212.00
Indirect cost from purchasing	2,397,595.59	2,397,595.59	2,397,595.59
Indirect cost: Second allocation from NRPCC to Aseptic pharmaceutical product, General pharmaceutical product, Outpatient service, Inpatient service			
According to number of staff (person)*	**202**	**180**	**173**
Indirect cost from others NRPCC	27,401,210.98	25,651,459.02	25,062,474.63
Total cost (Direct cost+Indirect cost)	97,578,060.59	85,825,309.72	83,997,895.59
Number of inpatient prescriptions	1,637,277.00	1,637,277.00	1,637,277.00
Unit cost	59.60	52.42	51.30
Plus 10% for indirect cost	5.96	5.24	5.13
Unit cost plus 10%	**65.56**	**57.66**	**56.43**

Total 1,637,277 prescriptions

* Different cost data

Table 43 Cost of inpatient service section when ADM system covered 60% of all prescriptions

Cost	Inpatient service*		
	ADM model 1	ADM model 2	ADM model 3
Labor cost of medical staff *	**56,657,024.55**	**45,744,662.11**	**44,393,647.85**
Labor cost of supporting staff	3,158,926.68	3,158,926.68	3,158,926.68
Medical material cost*	**6,047,639.34**	**6,047,639.34**	**6,047,639.34**
Capital cost*	**1,668,672.31**	**1,668,672.31**	**1,668,672.31**
Other cost	699,668.85	699,668.85	699,668.85
Total direct cost	68,231,931.73	57,319,569.28	55,968,555.03
Indirect cost: First allocation from purchasing to Outpatient and Inpatient service			
According to drug expenditure (baht)	633,743,212.00	633,743,212.00	633,743,212.00
Indirect cost from purchasing	2,397,595.59	2,397,595.59	2,397,595.59
Indirect cost: Second allocation from NRPCC to Aseptic pharmaceutical product, General pharmaceutical product, Outpatient service, Inpatient service			
According to number of staff (person)*	**200**	**177**	**170**
Indirect cost from others NRPCC	27,299,745.91	25,385,355.06	24,737,326.64
Total cost (Direct cost+Indirect cost)	97,929,273.23	85,102,519.93	83,103,477.25
Number of inpatient prescriptions	1,637,277.00	1,637,277.00	1,637,277.00
Unit cost	59.81	51.98	50.76
Plus 10% for indirect cost	5.98	5.20	5.08
Unit cost plus 10%	**65.79**	**57.18**	**55.83**

Total 1,637,277 prescriptions

* Different cost data

Table 44 Cost of inpatient service section when ADM system covered 75% of all prescriptions

Cost	Inpatient service*		
	ADM model 1	ADM model 2	ADM model 3
Labor cost of medical staff *	**57,545,595.22**	**43,905,142.16**	**42,216,374.34**
Labor cost of supporting staff	3,158,926.68	3,158,926.68	3,158,926.68
Medical material cost*	**6,517,101.79**	**6,517,101.79**	**6,517,101.79**
Capital cost*	**1,668,672.31**	**1,668,672.31**	**1,668,672.31**
Other cost	699,668.85	699,668.85	699,668.85
Total direct cost	69,589,964.85	55,949,511.79	54,260,743.97
Indirect cost: First allocation from purchasing to Outpatient and Inpatient service			
According to drug expenditure (baht)	633,743,212.00	633,743,212.00	633,743,212.00
Indirect cost from purchasing	2,397,595.59	2,397,595.59	2,397,595.59
Indirect cost: Second allocation from NRPCC to Aseptic pharmaceutical product, General pharmaceutical product, Outpatient service, Inpatient service			
According to number of staff (person)*	**196**	**167**	**158**
Indirect cost from others NRPCC	26,966,351.09	24,495,019.12	23,642,710.53
Total cost (Direct cost+Indirect cost)	98,953,911.53	82,842,126.49	80,301,050.08
Number of inpatient prescriptions	1,637,277.00	1,637,277.00	1,637,277.00
Unit cost	60.44	50.60	49.05
Plus 10% for indirect cost	6.04	5.06	4.90
Unit cost plus 10%	**66.48**	**55.66**	**53.95**

Total 1,637,277 prescriptions

* Different cost data

Table 45 Cost of inpatient service section when ADM system covered 100% of all prescriptions

Cost	Inpatient service*		
	ADM model 1	ADM model 2	ADM model 3
Labor cost of medical staff *	**59,026,546.33**	**40,839,275.59**	**38,587,585.16**
Labor cost of supporting staff	3,158,926.68	3,158,926.68	3,158,926.68
Medical material cost*	**7,299,539.20**	**7,299,539.20**	**7,299,539.20**
Capital cost*	**1,668,672.31**	**1,668,672.31**	**1,668,672.31**
Other cost	699,668.85	699,668.85	699,668.85
Total direct cost	71,853,353.38	53,666,082.63	51,414,392.20
Indirect cost: First allocation from purchasing to Outpatient and Inpatient service			
According to drug expenditure (baht)	633,743,212.00	633,743,212.00	633,743,212.00
Indirect cost from purchasing	2,397,595.59	2,397,595.59	2,397,595.59
Indirect cost: Second allocation from NRPCC to Aseptic pharmaceutical product, General pharmaceutical product, Outpatient service, Inpatient service			
According to number of staff (person)*	**189**	**150**	**138**
Indirect cost from others NRPCC	26,396,853.92	22,915,083.16	21,674,386.24
Total cost (Direct cost+Indirect cost)	100,647,802.88	78,978,761.37	75,486,374.03
Number of inpatient prescriptions	1,637,277.00	1,637,277.00	1,637,277.00
Unit cost	61.47	48.24	46.10
Plus 10% for indirect cost	6.15	4.82	4.61
Unit cost plus 10%	**67.62**	**53.06**	**50.72**

Total 1,637,277 prescriptions

* Different cost data

Table 46 10-year cost of investment when ADM system covered 25% of all prescriptions

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	71,477,940	66,346,631	69,378,118	72,561,180	75,963,395	79,472,721	83,157,513	87,026,545	91,089,028	95,354,635	791,827,706
PV of annual costs	71,477,940	64,414,205	65,395,530	66,403,759	67,492,493	68,553,867	69,643,108	70,760,545	71,906,520	73,081,388	689,129,354
ADM model 2											
Annual costs	66,931,122	61,572,472	64,365,252	67,297,670	70,436,710	73,669,701	77,064,342	80,628,716	84,371,307	88,301,029	734,638,322
PV of annual costs	66,931,122	59,779,099	60,670,423	61,586,902	62,582,104	63,548,132	64,540,174	65,558,524	66,603,489	67,675,386	639,475,355
ADM model 3											
Annual costs	66,368,199	60,981,403	63,744,630	66,646,017	69,752,474	72,951,254	76,309,972	79,836,627	83,539,614	87,427,751	727,557,942
PV of annual costs	66,368,199	59,205,246	60,085,427	60,990,547	61,974,170	62,928,392	63,908,400	64,914,484	65,946,943	67,006,091	633,327,900

Discount rate 3%

Table 47 **10-year cost of investment when ADM system covered 50% of all prescriptions**

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	73,741,328	68,684,067	71,793,304	75,058,004	78,545,938	82,145,269	85,924,567	89,892,829	94,059,505	98,434,514	818,279,324
PV of annual costs	73,741,328	66,683,560	67,672,075	68,688,706	69,787,049	70,859,231	71,960,472	73,091,096	74,251,441	75,441,859	712,176,817
ADM model 2											
Annual costs	64,647,693	59,135,750	61,767,571	64,530,984	67,492,567	70,539,230	73,738,225	77,097,171	80,624,064	84,327,301	703,900,556
PV of annual costs	64,647,693	57,413,349	58,221,860	59,054,992	59,966,272	60,847,759	61,754,603	62,687,055	63,645,380	64,629,854	612,868,818
ADM model 3											
Annual costs	63,521,848	57,953,612	60,526,327	63,227,677	66,124,095	69,102,334	72,229,485	75,512,994	78,960,677	82,580,745	689,739,796
PV of annual costs	63,521,848	56,265,643	57,051,868	57,862,282	58,750,402	59,608,281	60,491,057	61,398,974	62,332,288	63,291,265	600,573,907

Discount rate 3%

Table 48 10-year cost of investment when ADM system covered 55% of all prescriptions

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	74,194,006	69,151,554	72,276,342	75,557,368	79,062,447	82,679,779	86,477,977	90,466,086	94,653,600	99,050,490	823,569,648
PV of annual costs	74,194,006	67,137,431	68,127,384	69,145,695	70,245,960	71,320,303	72,423,945	73,557,206	74,720,426	75,913,953	716,786,309
ADM model 2											
Annual costs	64,191,007	58,648,405	61,248,035	63,977,647	66,903,739	69,913,136	73,073,002	76,390,862	79,874,615	83,532,555	697,753,003
PV of annual costs	64,191,007	56,940,199	57,732,147	58,548,610	59,443,105	60,307,685	61,197,489	62,112,761	63,053,758	64,020,748	607,547,510
ADM model 3											
Annual costs	62,952,577	57,348,054	59,882,666	62,544,010	65,398,420	68,332,550	71,413,388	74,648,267	78,044,890	81,611,344	682,176,166
PV of annual costs	62,952,577	55,677,722	56,445,156	57,236,629	58,105,649	58,944,258	59,807,588	60,695,872	61,609,357	62,548,300	594,023,109

Discount rate 3%

Table 49 10-year cost of investment when ADM system covered 60% of all prescriptions

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	74,646,684	69,619,041	72,759,379	76,056,733	79,578,955	83,214,288	87,031,388	91,039,343	95,247,695	99,666,465	828,859,971
PV of annual costs	74,646,684	67,591,302	68,582,693	69,602,685	70,704,871	71,781,376	72,887,417	74,023,317	75,189,410	76,386,047	721,395,801
ADM model 2											
Annual costs	63,734,321	58,161,061	60,728,499	63,424,309	66,314,910	69,287,041	72,407,779	75,684,553	79,125,166	82,737,810	691,605,449
PV of annual costs	63,734,321	56,467,049	57,242,435	58,042,228	58,919,939	59,767,610	60,640,375	61,538,468	62,462,137	63,411,642	602,226,203
ADM model 3											
Annual costs	62,383,307	56,742,496	59,239,006	61,860,342	64,672,744	67,562,767	70,597,290	73,783,540	77,129,103	80,641,943	674,612,537
PV of annual costs	62,383,307	55,089,802	55,838,445	56,610,976	57,460,895	58,280,236	59,124,119	59,992,770	60,886,426	61,805,335	587,472,310

Discount rate 3%

Table 50 10-year cost of investment when ADM system covered 75% of all prescriptions

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	76,004,717	71,021,503	74,208,490	77,554,827	81,128,481	84,817,817	88,691,620	92,759,113	97,029,981	101,514,393	844,730,942
PV of annual costs	76,004,717	68,952,915	69,948,619	70,973,653	72,081,604	73,164,594	74,277,836	75,421,648	76,596,363	77,802,329	735,224,279
ADM model 2											
Annual costs	62,364,264	56,699,027	59,169,891	61,764,298	64,548,425	67,408,758	70,412,108	73,565,626	76,876,820	80,353,573	673,162,790
PV of annual costs	62,364,264	55,047,599	55,773,297	56,523,082	57,350,439	58,147,387	58,969,032	59,815,586	60,687,271	61,584,323	586,262,281
ADM model 3											
Annual costs	60,675,496	54,925,821	57,308,024	59,809,338	62,495,717	65,253,415	68,148,998	71,189,360	74,381,740	77,733,740	651,921,649
PV of annual costs	60,675,496	53,326,040	54,018,309	54,734,017	55,526,635	56,288,169	57,073,713	57,883,464	58,717,633	59,576,439	567,819,915

Discount rate 3%

Table 51 10-year cost of investment when ADM system covered 100% of all prescriptions

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	78,268,105	73,358,939	76,623,676	80,051,651	83,711,023	87,490,365	91,458,674	95,625,398	100,000,458	104,594,271	871,182,560
PV of annual costs	78,268,105	71,222,271	72,225,164	73,258,600	74,376,160	75,469,957	76,595,199	77,752,199	78,941,285	80,162,800	758,271,741
ADM model 2											
Annual costs	60,080,835	54,262,305	56,572,210	58,997,611	61,604,282	64,278,287	67,085,991	70,034,081	73,129,576	76,379,845	642,425,023
PV of annual costs	60,080,835	52,681,849	53,324,734	53,991,172	54,734,607	55,447,015	56,183,462	56,944,117	57,729,162	58,538,791	559,655,744
ADM model 3											
Annual costs	57,829,144	51,898,030	54,089,722	56,390,998	58,867,338	61,404,496	64,068,511	66,865,727	69,802,804	72,886,734	614,103,503
PV of annual costs	57,829,144	50,386,437	50,984,750	51,605,752	52,302,868	52,968,057	53,656,369	54,367,955	55,102,978	55,861,613	535,065,922

Discount rate 3%

Table 52 10-year cost of investment when ADM system covered 25% of all prescriptions (including cost saving from nurse)

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	61,146,430	55,498,545	57,987,628	60,601,166	63,405,380	66,286,805	69,312,301	72,489,073	75,824,682	79,327,072	661,879,083
PV of annual costs	61,146,430	53,882,083	54,658,901	55,458,652	56,334,859	57,179,580	58,047,961	58,940,250	59,856,704	60,797,595	576,303,015
ADM model 2											
Annual costs	56,599,612	50,724,387	52,974,762	55,337,656	57,878,695	60,483,786	63,219,131	66,091,243	69,106,962	72,273,466	604,689,699
PV of annual costs	56,599,612	49,246,977	49,933,794	50,641,794	51,424,471	52,173,845	52,945,027	53,738,229	54,553,674	55,391,593	526,649,016
ADM model 3											
Annual costs	56,036,689	50,133,318	52,354,140	54,686,003	57,194,459	59,765,338	62,464,761	65,299,155	68,275,269	71,400,188	597,609,319
PV of annual costs	56,036,689	48,673,124	49,348,798	50,045,439	50,816,536	51,554,105	52,313,254	53,094,188	53,897,127	54,722,299	520,501,561

Discount rate 3%

Table 53 10-year cost of investment when ADM system covered 50% of all prescriptions (including cost saving from nurse)

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	53,078,308	46,987,896	49,012,325	51,137,975	53,429,908	55,773,437	58,234,143	60,817,885	63,530,813	66,379,388	558,382,078
PV of annual costs	53,078,308	45,619,316	46,198,817	46,798,491	47,471,781	48,110,657	48,770,178	49,450,506	50,151,811	50,874,274	486,524,139
ADM model 2											
Annual costs	43,984,673	37,439,579	38,986,592	40,610,955	42,376,537	44,167,398	46,047,802	48,022,227	50,095,372	52,272,175	444,003,310
PV of annual costs	43,984,673	36,349,105	36,748,602	37,164,777	37,651,005	38,099,186	38,564,309	39,046,465	39,545,749	40,062,269	387,216,140
ADM model 3											
Annual costs	42,858,828	36,257,441	37,745,347	39,307,649	41,008,065	42,730,503	44,539,062	46,438,049	48,431,986	50,525,619	429,842,549
PV of annual costs	42,858,828	35,201,399	35,578,610	35,972,067	36,435,135	36,859,707	37,300,763	37,758,384	38,232,657	38,723,680	374,921,230

Discount rate 3%

Table 54 10-year cost of investment when ADM system covered 55% of all prescriptions (including cost saving from nurse)

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	53,530,986	47,455,383	49,495,362	51,637,340	53,946,416	56,307,947	58,787,554	61,391,142	64,124,908	66,995,364	563,672,402
PV of annual costs	53,530,986	46,073,187	46,654,126	47,255,481	47,930,692	48,571,730	49,233,651	49,916,616	50,620,795	51,346,368	491,133,631
ADM model 2											
Annual costs	43,527,987	36,952,234	38,467,056	40,057,618	41,787,709	43,541,304	45,382,579	47,315,918	49,345,923	51,477,429	437,855,756
PV of annual costs	43,527,987	35,875,955	36,258,889	36,658,395	37,127,838	37,559,111	38,007,195	38,472,171	38,954,127	39,453,163	381,894,833
ADM model 3											
Annual costs	42,289,557	35,651,883	37,101,687	38,623,981	40,282,390	41,960,719	43,722,965	45,573,323	47,516,198	49,556,218	422,278,920
PV of annual costs	42,289,557	34,613,479	34,971,898	35,346,414	35,790,381	36,195,685	36,617,295	37,055,282	37,509,726	37,980,715	368,370,431

Discount rate 3%

Table 55 10-year cost of investment when ADM system covered 60% of all prescriptions (including cost saving from nurse)

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	53,983,664	47,922,870	49,978,399	52,136,704	54,462,925	56,842,457	59,340,965	61,964,398	64,719,004	67,611,339	568,962,725
PV of annual costs	53,983,664	46,527,058	47,109,435	47,712,470	48,389,603	49,032,802	49,697,124	50,382,726	51,089,779	51,818,462	495,743,124
ADM model 2											
Annual costs	43,071,301	36,464,890	37,947,519	39,504,281	41,198,880	42,915,210	44,717,355	46,609,609	48,596,474	50,682,684	431,708,203
PV of annual costs	43,071,301	35,402,805	35,769,177	36,152,013	36,604,671	37,019,037	37,450,081	37,897,877	38,362,506	38,844,057	376,573,525
ADM model 3											
Annual costs	41,720,287	35,046,325	36,458,026	37,940,313	39,556,714	41,190,935	42,906,867	44,708,596	46,600,411	48,586,817	414,715,291
PV of annual costs	41,720,287	34,025,558	34,365,186	34,720,761	35,145,628	35,531,662	35,933,826	36,352,180	36,786,795	37,237,750	361,819,633

Discount rate 3%

Table 56 10-year cost of investment when ADM system covered 75% of all prescriptions (including cost saving from nurse)

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	55,341,697	49,325,332	51,427,511	53,634,798	56,012,451	58,445,985	61,001,197	63,684,169	66,501,290	69,459,267	584,833,696
PV of annual costs	55,341,697	47,888,672	48,475,361	49,083,438	49,766,337	50,416,020	51,087,542	51,781,057	52,496,732	53,234,744	509,571,601
ADM model 2											
Annual costs	41,701,244	35,002,856	36,388,911	37,844,269	39,432,395	41,036,927	42,721,685	44,490,682	46,348,128	48,298,447	413,265,543
PV of annual costs	41,701,244	33,983,355	34,300,039	34,632,867	35,035,172	35,398,813	35,778,739	36,174,996	36,587,640	37,016,738	360,609,603
ADM model 3											
Annual costs	40,012,476	33,229,650	34,527,045	35,889,309	37,379,687	38,881,583	40,458,575	42,114,416	43,853,049	45,678,614	392,024,403
PV of annual costs	40,012,476	32,261,796	32,545,051	32,843,802	33,211,368	33,539,595	33,883,420	34,242,874	34,618,002	35,008,854	342,167,237

Discount rate 3%

Table 57 10-year cost of investment when ADM system covered 100% of all prescriptions (including cost saving from nurse)

ADM system	Initial cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
ADM model 1											
Annual costs	57,605,085	51,662,768	53,842,697	56,131,622	58,594,993	61,118,533	63,768,251	66,550,453	69,471,766	72,539,145	611,285,314
PV of annual costs	57,605,085	50,158,027	50,751,906	51,368,386	52,060,893	52,721,384	53,404,906	54,111,609	54,841,654	55,595,215	532,619,063
ADM model 2											
Annual costs	39,417,815	32,566,134	33,791,231	35,077,583	36,488,252	37,906,455	39,395,568	40,959,137	42,600,884	44,324,719	382,527,777
PV of annual costs	39,417,815	31,617,605	31,851,476	32,100,957	32,419,339	32,698,441	32,993,168	33,303,527	33,629,531	33,971,206	334,003,066
ADM model 3											
Annual costs	37,166,124	30,201,859	31,308,742	32,470,969	33,751,308	35,032,664	36,378,088	37,790,783	39,274,112	40,831,608	354,206,257
PV of annual costs	37,166,124	29,322,193	29,511,492	29,715,537	29,987,600	30,219,484	30,466,076	30,727,364	31,003,347	31,294,028	309,413,245

Discount rate 3%

VITA

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